Standards and labelling programme for passenger car tyres

April 2018

An initiative supported by

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that support renewable energy, energy efficiency and sustainable transport solutions.

List of abbreviations

ATMA	Automotive Tyre Manufacturers' Association
BIS	Bureau of Indian Standards
◦ C	degrees Celcius
GHG	Greenhouse Gas
HDV	Heavy Duty Vehicle
ICAT	International Centre for Automotive Technology
IRMRA	Indian Rubber Manufacturers' Research Association
ISO	International Standards Organisation
kN	kiloNewtons
LL	Lower limit
m	metre
N	Newtons
NATRAX	National Automotive Test Tracks
PwC	PricewaterhouseCoopers Private Limited
R117.02	UNECE Regulation 117 - 02 series
RR	Rolling Resistance
RRC	Rolling Resistance Coefficient
S&L	Standards & labelling
SSEF	Shakti Sustainable Energy Foundation
TED7	Transport Engineering Division committee 7
TTT	Tyre Test Trailer
UL	Upper limit
UNECE	United Nations Economic Commission for Europe

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1. Introduction

Amidst the growing concerns of rising global temperatures, instances of extreme weather, and climate change, recent times have seen governments of several countries take initiatives to introduce efficiency in their net energy use. These initiatives attempt to promote efficient use of energy (or fuel) across all sectors, including Transport and Power.

For countries such as India, where the fiscal deficit comprises mostly of petroleum imports, introduction of policies to improve efficiency in the transport sector (termed as "fuel efficiency") has an added advantage – reduction in import burden on the fiscal budget. Given the frequent and unpredictable volatility in petroleum prices, any relative reduction in fuel use reduces the country's vulnerability on price changes and supports its mandate of energy security.

1.1. Mandate for fuel efficiency in India

In light of these advantages, the government of India has introduced/is planning to introduce several initiatives in the transport sector with an aim to reduce the emissions intensity of vehicles and improve fuel efficiency. These initiatives target an entire automobile segment as a whole, rather than impose requirements on specific vehicular components such as engines/transmission.

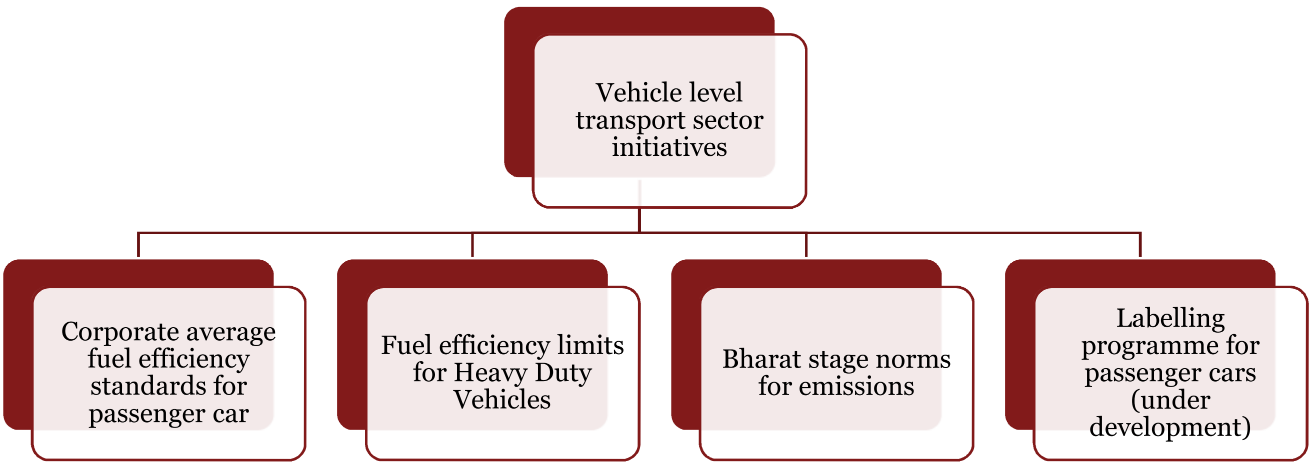


Figure 1: Vehicle level transport sector initiatives

Over the last 6 years, the Government has taken several steps to promote electric mobility, including the launch of FAME pilot scheme. Through its landmark "FAME India" initiative, end users are provided a substantial subsidy for the purchase of electric and hybrid vehicles. The Central Government has also declared its target to have only electric vehicles on Indian roads by 2030.

The following table shows a few initiatives of the government of India in the alternate fuel /fuel efficiency space in recent years:

Table 1: Initiatives by Government of India in alternate fuel /efficiency space

Event	Timeline	Key Highlights
National Mission of Electric Mobility (NMEM)	Mar-2011	• **Introduction of NMEM** by govt. to promote EM through development and adoption of EVs • Approval to set up **NCEM** and **NBEM** • Agreement to form **NAB** to provide technical advisory support

National Electric Mobility Mission Plan 2020 (NEMMP 2020)	Jan-2013	• Launch of NEMMP to achieve the following by 2020: o **~7M sales** of EVs o **~13,000 - 14,000 Cr.** savings in fuel o **~1.3% - 1.5%** reduction in CO2 emissions o Generate ~60K-65K additional jobs • Facilitate **demand and supply side incentives to** promote capabilities across EVs ecosystem
Faster Adoption & Mfg. of (Hybrid &) Electric Vehicles (FAME)	Apr-2015	• Launch of FAME India pilot phase: o Envisaged budget of **795 crores across 2 yrs**. o Allocation of **incentives by technology/benefit** o Eligible vehicle categories – **2W, 3W**, **4W, LCV, HCV and Retrofit** o Restricted to major metros, capitals, Smart Cities, north-eastern cities
FAME India Pilot Phase	Apr-2015 to Dec-2016	• Key actions/outcomes realized around: o Investments and **manufacturing capability** established o **Fuel savings** o Environmental impact and **reduction in CO2** emissions o (Direct) **employment generation** o **Adherence** of Phased Implementation
100% Electric Mobility by 2030	April 2017	• Incentivizing consumers to purchase electric vehicles with a target to have a 100% electric car fleet

Given these wide range of initiatives, the Indian automotive sector is set to undergo a vehicular efficiency revolution of sorts when these policies come into force. However, these policies are likely to put pressure on the automotive industry, especially vehicle manufacturers, who will need to improve the overall efficiency of their vehicle fleets.

As the efficiency in a motor vehicle with respect to fuel consumption is subject to several design parameters such as engine and transmission technologies, vehicle aerodynamics etc. options available to manufacturers, advances in component-level efficiency will contribute to reducing fuel consumption in the coming decade. Some of the key technology options which are proven and being implemented are:

- Turbo charging and intercooling
- Friction reduction oils and materials development
- Development of DI-stratified charge or lean burn engine
- Downsizing or down-speeding of engines
- Variable valve timing (VVT) and valve lift
- Improved thermal management
- Aerodynamic drag reduction
- Integrated starter generator (ISG)
- Selectively switching off cylinders based on duty cycle
- Development of higher injection pressure CRDI technology
- Development and adaptation of six-speed transmission
- Automatic transmissions or CVT with electronic control/management
- Dual clutch transmission (DCT)
- Weight reduction
- Tyre rolling resistance reduction

The above mentioned technology options provide significant fuel efficiency potential, however, some of these options also require longer lead time for larger implementation as the cost also becomes a controlling factor. Some of the simple ones as first priority, which are quicker to introduce are:

- Stop – Start systems (penetration in Indian market is increasing)
- Low rolling resistance tyres (tyre manufactures have such tyres)

Tyres as a component has been identified to have huge potential for improving fuel efficiency of vehicles, and is the focus of this study.

1.2. Tyres as an option for achieving fuel efficiency

***"Tyres, on account of their rolling resistance, account for approximately 20–30% of the vehicular fuel consumption.*"** [1]

Rolling resistance is a measure of the energy dissipated as heat because of rolling of the tyre. A reduction of the RR of tyres would therefore contribute significantly to the fuel efficiency thrust of the road transport sector and consequently to reduction of GHG emissions intensity. Having identified this potential, governments of several countries have implemented policy measures seeking to promote manufacturers to manufacture and consumers to purchase fuel efficient tyres.

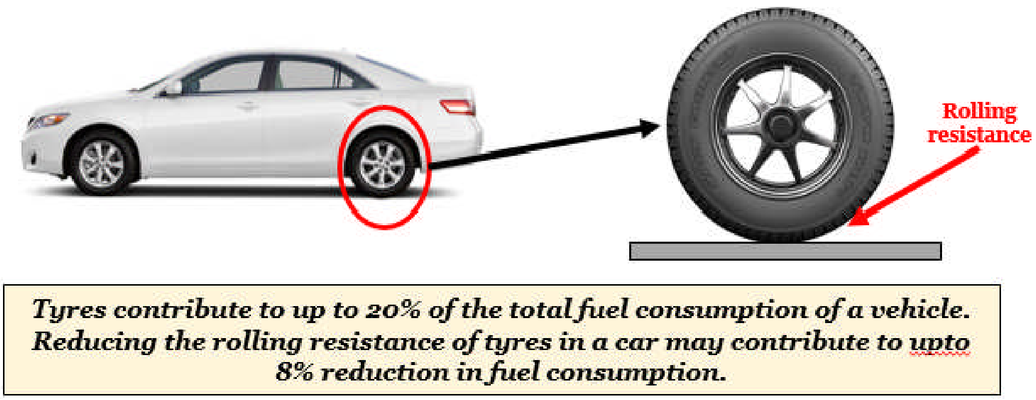


Figure 2: Illustration[2]

The EU has passed Regulation 1222/2009 making it mandatory for tyres to be accompanied with appropriate labels as specified in the regulation. The South Korea and Japan have set in place labelling programmes for tyres. The label design is still under consideration in the US. A brief on these programs are described in Appendix C.

All these abovementioned programs have been based on the limits proposed in the EU, through the regulation UN ECE Regulation No. 117, or UNECE R117. The regulation, first passed in 2005, introduced requirements on the maximum rolling sound emissions of tyres. In 2006, the 01 series amendments[3] to UN ECE R117 added requirements on the minimum wet grip performance of passenger car tyres (C1 tyres). In 2011, the 02 series amendments[4] to UN ECE R117 added requirements on the maximum RR of tyres and increased the stringency of the maximum rolling sound emissions requirements.[5] The maximum RR limits were introduced with separate limit values specified for class C1 tyres (passenger car tyres), class C2 tyres (light commercial vehicle tyres) and class C3 tyres (truck and bus tyres).

[1] Source: The European Commission, Impact Assessment Study on Possible Energy Labelling of Tyres, March 2016
[2] Source: The European Commission, Impact Assessment Study on Possible Energy Labelling of Tyres, March 2016
[3] The 01 series amendments refer to the amendments made to UNECE R117 in 2006
[4] The 02 series amendments refer to the amendments made to UNECE R117 in 2011
[5] http://www.interregs.com/articles/spotlight/new-ece-requirements-on-tyre-noise-and-rolling-resistance-published-000110 (Accessed on 28 July 2016)

Wet grip refers to the safety performance of tyres – it defines the ability of a tyre to brake on a wet road. The wet grip of a tyre is judged by calculating its wet grip index (G).

1.3. Existing regulations for tyres in India

Since 2010, all pneumatic tyres manufactured and sold in India are required comply with the specifications mentioned in the standards mentioned in Table 2 and must be type approved by testing laboratories.

Table 2: Applicable tyre standards in India

Standard	Description	Tyre segment
IS 15627: 2005	Automotive vehicles: Pneumatic tyres for two and three wheeled motor vehicles—specification	Two-/three-wheelers
IS 15633: 2005	Automotive vehicles: Pneumatic tyres for passenger car vehicles—diagonal and radial ply—specification	Passenger cars
IS 15636: 2012	Automotive vehicles: Pneumatic tyres for commercial vehicles—diagonal and radial ply—specification	LCV and HDV

The standards mentioned above specify requirements related to safety, durability and dimensions for tyres in India. However, **these standards do not specify requirements for performance parameters such as rolling resistance, wet grip, external noise, internal noise, braking performance**, etc.

Developments towards introduction of RR and wet grip requirements in India

The **TED 7 committee** of TEDC in BIS, which is responsible for composition of standards of automotive tyres, tubes and rims, began discussing on drafting standards for RR and wet grip for tyres in India in 2014. The list of key stakeholders in India which are working for development in tyre space is provided in **Appendix A.** Despite relentless efforts of the committee members and various stakeholders, presence of several important issues, including test data for tyres for Indian conditions and aligned test facilities has slowed down the progress of development of standards in India.

Specifically, as per a 2016 study[6], the process of developing standards for RR & wet grip faced limitations such as: (i) Limited infrastructure for testing of rolling resistance and wet grip in India; (ii) Variation in RRC value obtained by different machines; and (iii) Unavailability of data on the Indian tyre market.

However, since then, most of these barriers have already been addressed to some extent, specifically,

- Test infrastructure for determination of tyre RRC as per ISO 28580 is available with IRMRA, and the tyre test trailer for determination of wet grip is available with ICAT.
- Officials from IRMRA have informed that they have begun the alignment process required by ISO 28580 with laboratories in Europe, and this process is underway and shall be completed soon. This implies that the issue of variation in RRC value will be addressed.
- Since test infrastructure is now available in India, generation of data on the Indian tyre market will not prove to be an extravagant task.

Therefore, data on the Indian market, which was a major constraint in India, can now be generated in third party test agencies. This could facilitate development of standards for tyre RRC and wet grip performance in the country.

[6] Source: "Framework for S&L of tyres in India", study by SSEF, September 2016

Next steps to support stakeholders for development of standards in India

The next major step towards development of standards for tyres is to generate data on the Indian tyre market. The most convenient way forward is to conduct tests for rolling resistance and wet grip for randomly selected samples from the passenger car segment through the test facilities available with agencies in India.

Once data is generated for the passenger car segment, the TED 7 committee /stakeholders can start working towards arriving at benchmark values for RRC and wet grip coefficients in the passenger car tyre market.

1.4. Description of this assignment

This assignment essentially builds on the findings of the study conducted by SSEF in 2016, which focuses on "Roadmap for standards & labelling program for vehicular tyres in India", and intends to assess and identify suitable policy options to improve fuel efficiency through tyres, so that the overall potential identified in the previous study can be realized. It is intended that the findings and outcomes of this assignment will support the government and other key stakeholders to undertake an appropriate way forward for the tyre industry and automotive sector in general.

Towards this objective, the proposed project is intended to generate requisite test data for key parameters needed to assessment of tyre performance. The test data along with a market-trend analysis and review of international best practices, will be used to assess the steps required to perform benchmarking of passenger car tyres' RR and wet grip performance in India. The findings will be shared with the relevant government stakeholders for further pursuit in this initiative.

The project is focused on passenger cars tyres for which the full vehicle standards are at an advanced stage of implementation.

1.5. Scope of work

This study targets to capture market as well technical information with respect to tyres in order to design an energy efficiency program for tyres in India. The following activities are included in the scope of work for this study:

1. Review of market structure for passenger car tyres in India.
2. Identify a representative sample size of various passenger car tyres to be tested, in consultation with BIS-TED 7, IRMRA and ICAT.
3. Test the tyre samples for rolling resistance and wet grip in the testing facilities at IRMRA and ICAT respectively.
4. Compare the performance of Indian tyres with reference to UNECE R117.
5. Develop recommendations for the benchmark standards for rolling resistance and wet grip of tyres in India.

2. Approach for this study

This section describes the approach adopted to achieve the outputs mentioned under the scope of work. Its overall outline is shown below in Figure 3:

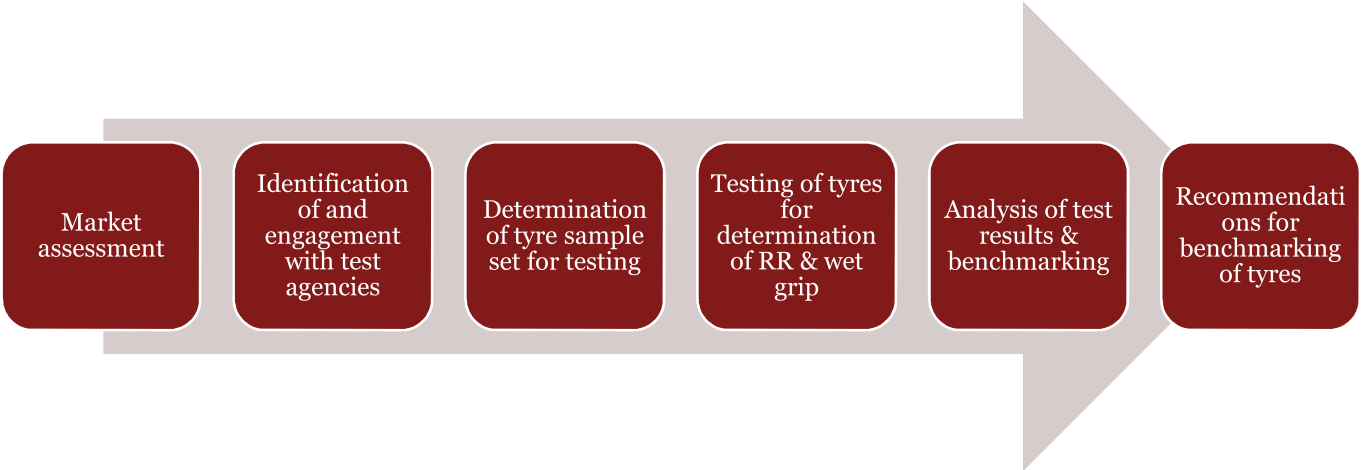


Figure 3: Outline of approach adopted by the project team

2.1. Market assessment

The approach for market analysis involved conducting three mutually exclusive and exhaustive activities: review of existing reports on the Indian tyre market, interaction with key stakeholders at all levels (retailers, manufacturers, test agencies, industry associations such as ATMA, SIAM etc.), and conducting independent assessment of tyres available in the market.

The market assessment of passenger car tyres brought out several insights about the Indian tyre market, such as:

- Working of the industry and key stakeholders
- Major revenue sources, imports and exports
- Market segmentation
- Key product categories and types
- Technical assessment of applicable test standards
- Major players and segmentation

The detailed nature of the market assessment was imperative for the sampling exercise conducted in subsequent sections.

2.2. Identification and engagement with test agencies

Test agencies such as IRMRA, and ICAT which have the facilities to test rolling resistance performance and wet grip performance of passenger car tyres respectively can play a key role in design and implementation of benchmarks /standards for tyres. The test agencies were engaged for testing of representative sample of passenger car tyres.

2.3. Determination of tyre sample set for testing

This exercise focused on selection of an appropriate sample tyre set for performance testing. Insights from the market assessment exercise were used to identify an appropriate tyre sample set. In addition, data on all major passenger car tyre models sold in the market was accumulated, and sample tyres were selected on this basis. The sample tyre set was shared with test agencies for their inputs, post which the final sample set was selected.

The selected sample set was then tested for RR and wet grip performance at the designated testing agencies, and the results would be deemed representative of the market *to a reasonable extent*.

2.4. Testing of passenger car tyres for RR and wet grip performance

Two sets of tyre samples were purchased for the testing exercise – one for RR testing and one for wet grip. The tyre samples were purchased through the official dealer network in cities where the testing would take place and transported to the lab's premises.

Testing for determination of RR was performed at IRMRA's premises in Thane, as per the test procedure mentioned in UNECE R117.02 and/or ISO 28580. Testing for determination of wet grip was performed in Indore at NARTRAX's facilities by ICAT. The test procedure followed was as mentioned in UNECE R117.02 - trailer method. ICAT arranged for transportation of trailer and SRTT tyres to Indore.

2.5. Analysis of test results and performance benchmarking

The RR and wet grip test results were analysed using standard techniques such as regression analysis to identify the existing situation of the Indian market in terms of RR & wet grip, investigate the relationships among various tyre parameters, and assess the benchmark values of RRC and wet grip index for the Indian market.

The findings of this analysis will be shared with BEE, BIS, MoRTH, Shakti Foundation and key industry stakeholders.

2.6. Final recommendations

A set of recommendations were identified on the basis of the results of the analysis conducted in the previous stage. Each option was assessed on the basis of its merits, advantages of adoption, and key challenges likely to be faced. Finally, a set of next actions was proposed.

3. The tyre industry in India

The market analysis presented in this chapter is a quantitative and qualitative assessment of the tyre market in India. It looks into the size of the market both in terms of volume and value, various revenue segments and buying patterns, major players including manufacturers, etc. Moreover, it analyses the supply chain structure of the market. The passenger car tyre segments are discussed in detail in later part of this chapter.

3.1. Techniques for data collection

Information captured in this chapter has been collated through multiple techniques:

- Desk research and analysis based on information published in major reports.
- Discussion with key stakeholders, including manufacturers, industry associations and retailers

3.2. Classification of tyres

Tyres can be classified on the basis of the following parameters:

- **Based on application**: Passenger car tyres, LCV tyres, HDV tyres, two-wheeler tyres, three-wheeler tyres, tractor tyres, etc.
- **Based on type of construction**: Bias ply construction or radial construction
- **Based on carcass material**
- **Based on pattern design**

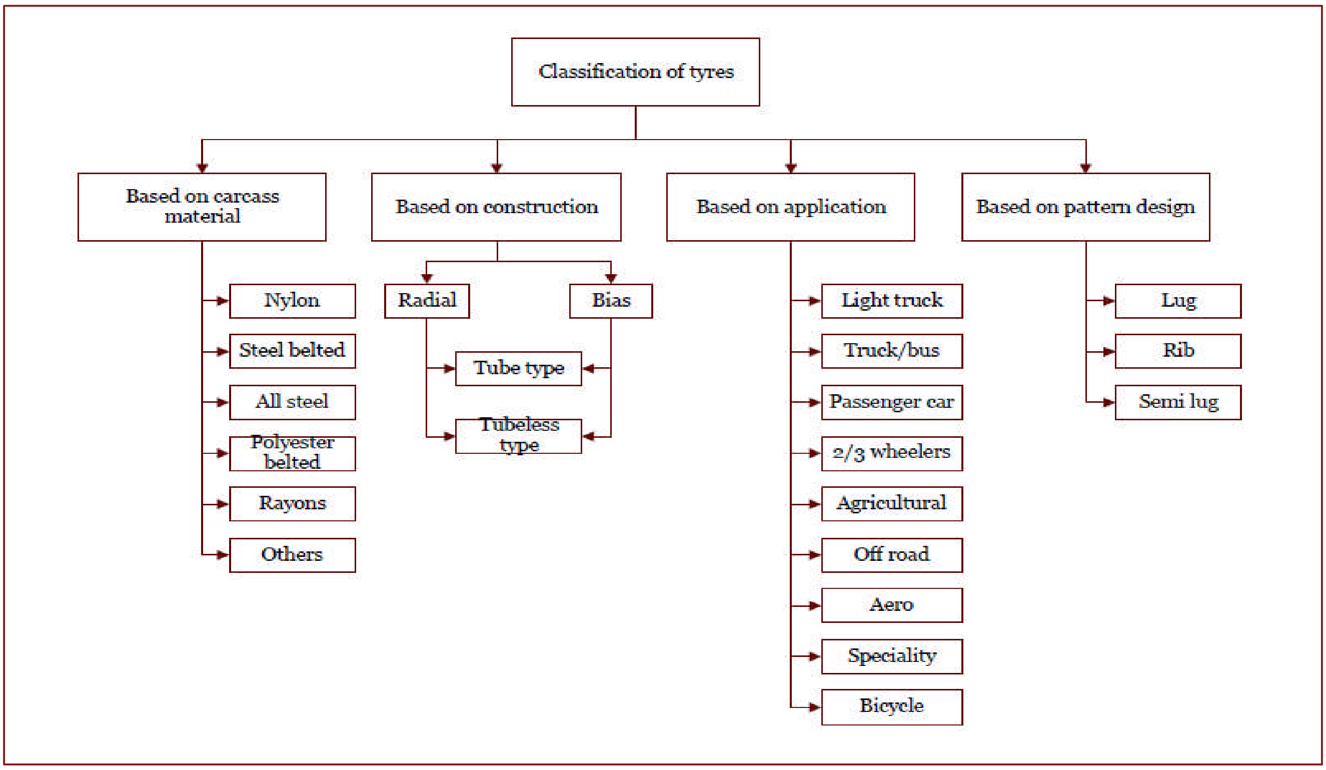


Figure 4: Classification of tyres (Know your tyre, 2016)

3.2.1.1. Classification based on application

Tyres are most commonly classified on the basis of the type of vehicles for which they are designed. In this classification, tyres are divided into passenger car tyres, LCV tyres, HDV tyres, two-/three-wheeler tyres, tractor tyres and OTR tyres.

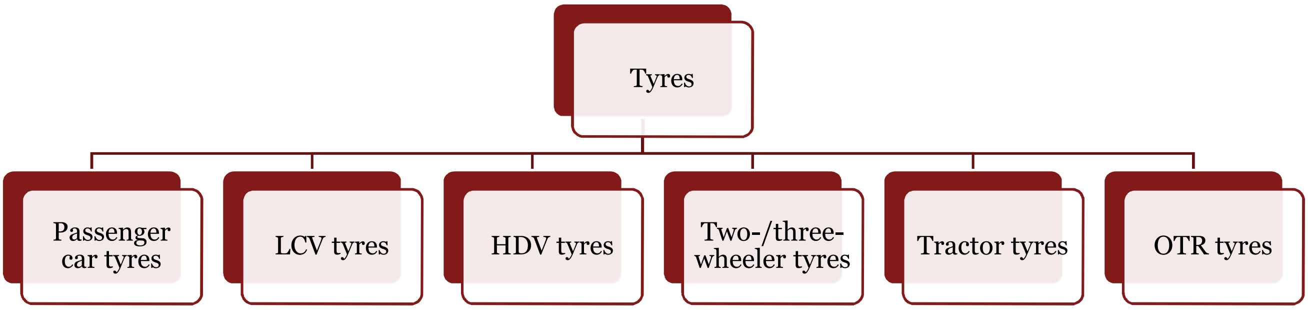


Figure 5: Classification of tyres based on application

All the above-mentioned vehicle categories are defined on the basis of the methodology mentioned in AIS-053: automotive tyre–types-terminology.

3.2.1.2. Classification based on type of construction

Tyres can be classified on the type of construction, i.e. bias tyres and radial tyres. These tyres are further segregated into tube and tubeless types.

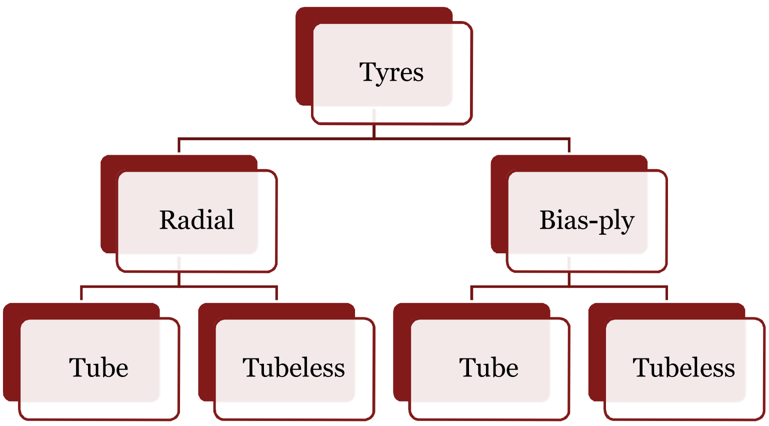


Figure 6: Classification of tyres based on type of construction

Bias-ply tyres

Bias-ply (or cross-ply) tyre construction utilises body ply cords that extend diagonally from bead to bead, usually at angles in the range of 30 to 40 degrees, with successive plies laid at opposing angles forming a crisscross pattern to which the tread is applied. The design allows the entire tire body to flex easily, providing the main advantage of this construction, a smooth ride on rough surfaces.[7] The design is such that the tyre is more stable at higher loads than radial tyres. However, bias tyres have the following disadvantages: **increased RR**, **less control and traction at higher speeds**.

Traditionally, the Indian market has been dominated by bias-ply tyres because of its lower initial cost and its load-bearing capacity.

[7] http://cocomponents.com/dealer/powersports-industry/bias-ply-radial-explained/

Radial tyres

Radial tire construction utilises body ply cords extending from the beads and across the tread so that the cords are laid at approximately right angles to the centreline of the tread, and parallel to each other, as well as stabiliser belts directly beneath the tread. The belts may be cord or steel. The advantages of this construction include longer tread life, better steering control, and lower RR. Disadvantages of the radial tire include a harder ride at low speeds on rough roads and in the context of off-roading, decreased 'self-cleaning' ability and lower grip ability at low speeds.[8]

The uptake of radial tyres in India has been slow, especially in the HDV and LCV segments. This could be attributed to several factors: tendency of consumers to overload vehicles, poor condition of Indian roads, non-compatibility of radial tyres with older vehicles, unwillingness of consumers to switch to radial tyres, etc.

However, the passenger car segment has been completely radialised since 2015.[9] Table below[10] shows the radialisation level in various vehicle segments in India.

Table 3: Market penetration of radial tyres

Vehicle segments	2001–02	2007–08	2015–16
Passenger cars	70%	97%	100%
LCVs	10%	15%	20%
HDVs	2%	9%	30%

3.3. Market structure

The tyre industry in India is highly organised and dominated by few major players as a result of the capital intensive nature and competitiveness of the industry. As per ATMA's website, there are 39 tyre companies registered in India. Various industry reports suggest that the top 4 companies command over 80% of the market share by revenues.

Table 4: Tyre industry in India[11]

Key figures (illustrative)	
Number of tyre companies	39
Number of tyre plants	60
ATMA member companies	11
Tyre plants of ATMA members in India	32
Industry turnover (FY 2014-15)	INR 50,000 crores (USD 8.5 billion)
Tyre exports from India (FY 2014-15)	INR 10,500 crores (USD 1.7 billion)

3.3.1. Tyre market end users

The tyre industry has two major end user segments in the domestic market – the Original Equipment Manufacturer (OEM) segment and the replacement segment. Consumption patterns of both replacement market and OEMs play a central role in setting the tyre demand in the country.

[8] http://cocomponents.com/dealer/powersports-industry/bias-ply-radial-explained/
[9] Based on interactions with stakeholders
[10] Based on interactions with stakeholders
[11] Source: ATMA website, http://atmaindia.org/overview, accessed on 5 December 2017

The OEM segment comprises of automobile manufacturers who purchase tyres from tyre manufacturers in bulk quantities for their vehicles. The replacement market segment comprises of end customers who replace old tyres of their vehicles. It is generally operated through a dealer network and company-owned outlets.

The industry also derives considerable revenues from exports. Indian tyre manufacturers export tyres to more than 100 countries, which include the US, the EU, UAE etc. The exports for FY 2014-15 stood at INR 10,500 crores.[12]

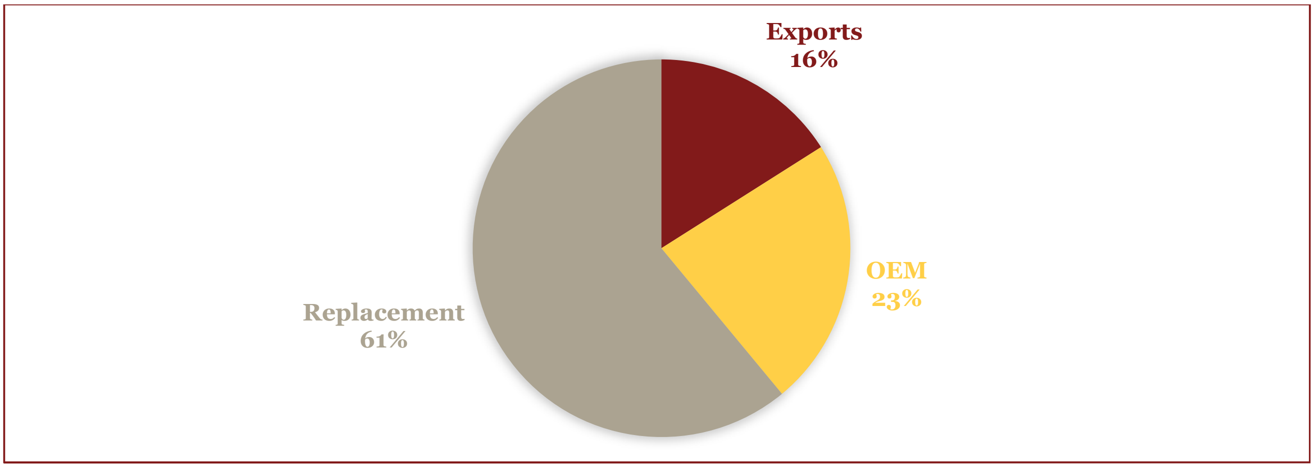


Figure 7: Segmental break-up of turnover for FY 2011 (Sushil Finance, 2012)

3.3.2. Tyre production

Tyre production has been growing at a consistent pace for the past few years. Tyre production reached around 1520 lakh units for FY 2015–16. Figure 8 shows the annual production of different categories of tyres over the years. Figure 9 displays the annual production of different categories of tyres for FY 2014–15.

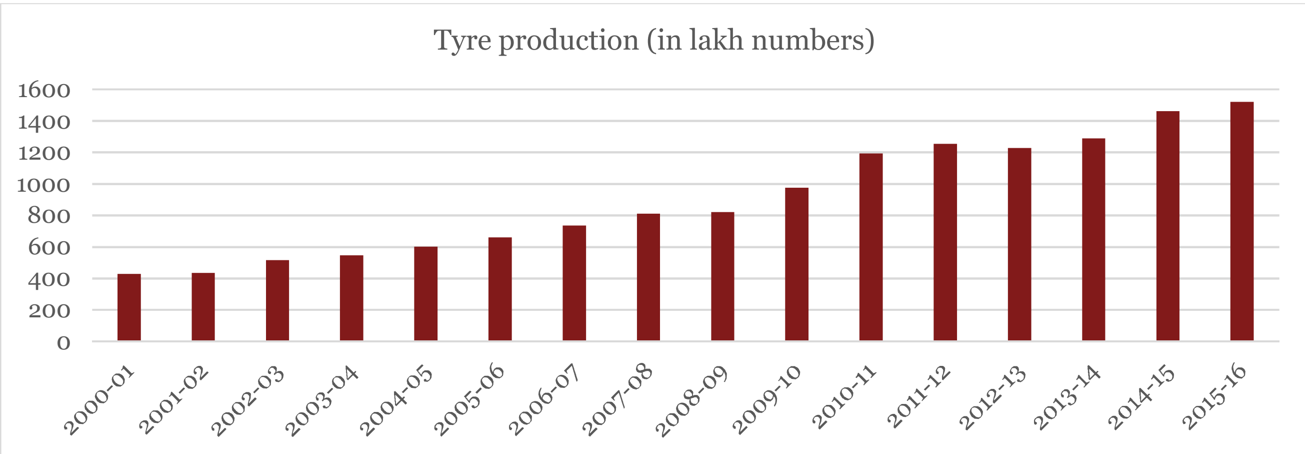


Figure 8: Tyre production in India (ATMA India, 2016)

[12] Source: ATMA website, http://atmaindia.org/overview, accessed on 5 December 2017

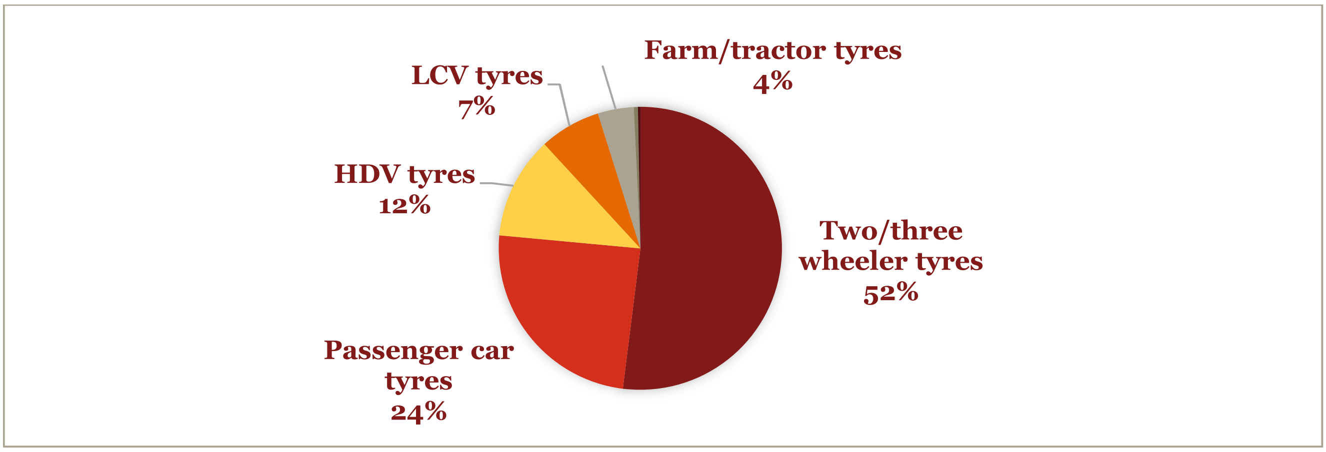


Figure 9: Segmental break-up of tyre production for FY 2014–15 (ATMA India, 2016)

From these figures, it can be concluded that in terms of numbers the share of tyres for two-wheelers is highest followed by tyres for passenger vehicles and then HDVs.

In volume terms, tyre production grew by CAGR of 5% during FY 2012-16 to reach 150.7 million units and annually it grew by 3% in FY 2016, with highest demand comprising from two & three wheeler which account for about 52% of tyre produced by segment.

3.3.3. Major players in the Indian tyre market

The tyre industry comprises 11 key players registered with ATMA. These members includes, Apollo Tyres Ltd., Birla Tyres, Ceat Ltd., Bridgestone India Pvt. Ltd., Continental India Ltd., Goodyear India Ltd., JK Tyre & Industries Ltd., Michelin India Pvt. Ltd., MRF Ltd., TVS Srichakra Ltd., and Yokohama India. As per ATMA, these companies account for almost 90% plus of total industry size in value terms. Industry players in organized segment have presence in the Trucks, Buses, Car, and Two wheeler segments while unorganized segment mostly caters to the bi-cycle industry.

3.4. Assessment of the passenger car tyre market

The overall structure, segmentation and exports of the Indian tyre industry as a whole is shown in the previous chapter. However, for selecting appropriate tyre samples for testing for RR and wet grip, detailed ***specification-wise data on the passenger car tyre market*** was collected.

A comprehensive secondary research was conducted for the major players in Indian tyre industry. The following information was captured for passenger car tyres sold by each manufacturer from their official websites: Tyre models, Tyre specifications, and Key features of the tyre. A data of 694 tyre types in the passenger car tyre segment was collated. A snapshot of the database is shown in the figure below:

Manufacturer	Tyre model	TT/TL	Section width	Aspect ratio	Construction	Rim diameter	Load index	Speed rating	Key feature
MRF tyres	SLM	TL	185		R	14			Enhanced mileage and traction
MRF tyres	SLM		185	85	R	16			Enhanced mileage and traction
MRF tyres	VTM	TL	175	70	R	13			Long life
MRF tyres	WANDERER AT		215	75	R	15			Durability
MRF tyres	WANDERER AT		235	75	R	15			Durability

Figure 10: Snapshot of data collected

Using this data, the following insights[13] conclusions about the Indian passenger car market were drawn.

3.4.1. Prevalent sizes in the market

Like the overall tyre industry, the passenger car tyre segment is also closely linked with the passenger car market in India. The research conducted under the project and inputs from stakeholders reveal that the passenger car market in India is dominated by tyres of low rim sizes, such as 12", 13" and 14" etc., as opposed to the market in EU, where rim sizes 15" and above are prevalent.

Tyres sold in the market are marked with a specific code /configuration that describes the tyre's size, construction type, load index and speed limit rating. The code is in the following format:

$$(section\ width\ in\ mm)/(aspect\ ratio)\ (construction\ type)(rim\ diameter\ in\ inches)$$

Data collected from seven major tyre manufacturers in India suggests that the total number of tyre configurations in the passenger car market are approximately 118 of which majority lies in the tyres with lower rim diameter.

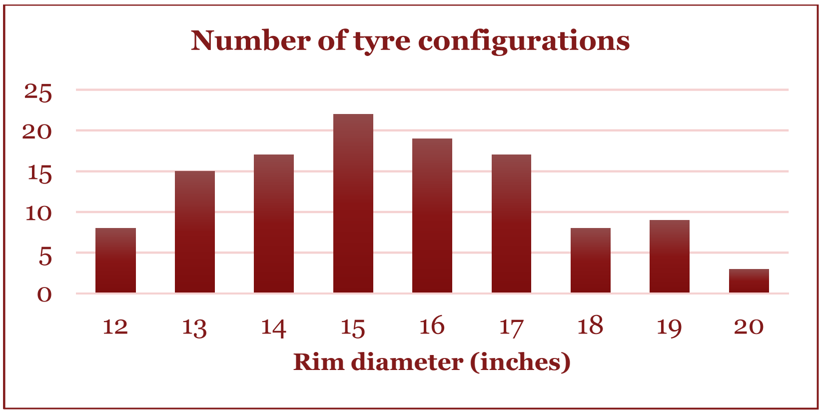


Figure 11: Number of tyre configurations[14]

The seven tyre manufacturers together provide several tyre types to cater to the demand for these tyre configurations. As the case with tyre configurations, **the number of tyre types are maximum for the lower rim diameter such as upto 15".**

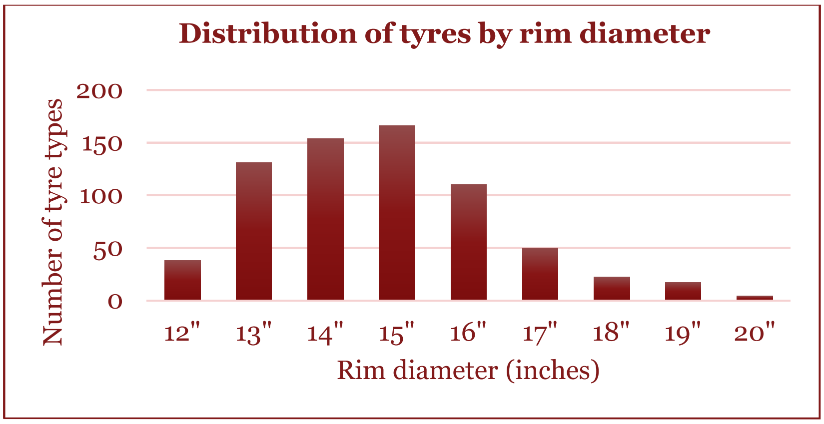


Figure 12: Distribution of tyre types by rim diameter

This indicates that the passenger car tyre market is dominated by tyres of lower rim sizes, while the majority of the market (in terms of types and configuration) lies between rim sizes 12" and 15". Tyres of higher rim diameters

[13] Based on data of 694 tyre types
[14] Source: PwC research

18", 19" & 20" are for high end luxury cars such as BMW, Mercedes etc., and therefore represent a small segment of the market.

3.4.2. Tyre branding

A tyre's characteristics are influenced by factors such as tread pattern and tyre material. These factors are common for a specific brand of tyres sold by a manufacturer. For example, the tyre brand XX YYY refers to a type of tyre material and tread pattern, regardless of tyre size. Tyre manufacturers specify the characteristics of a tyre brand in its advertisements and brochures. These characteristics include:

- Fuel efficiency or low rolling resistance or fuel saving
- High wet grip or wet braking performance
- High mileage
- Other characteristics such as durability, high load carrying capacity etc.

A tyre brand may have multiple characteristics. The following Venn diagram describes the distribution of characteristics across 694 tyres for which the data was collected.

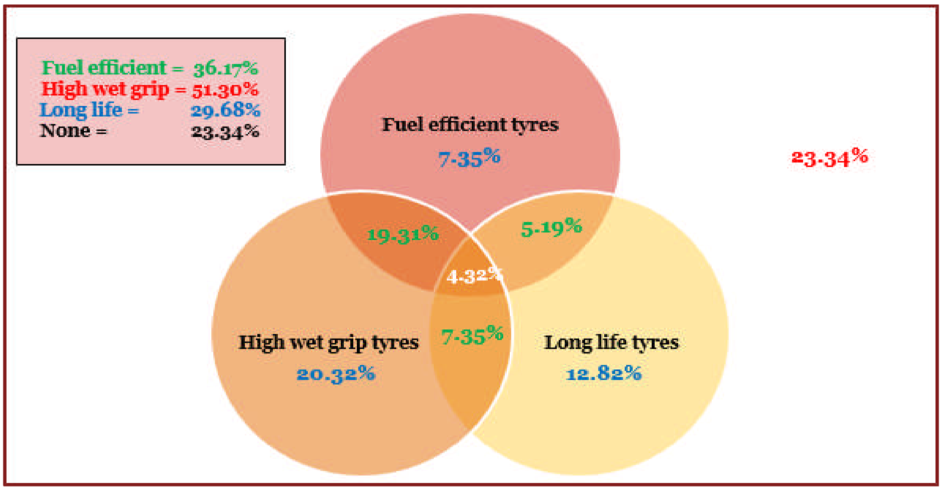


Figure 13: Distribution of tyre types by performance (as advertised by manufacturers)

About 35% of all tyre types sold by these manufacturers are claimed to be fuel efficient by these manufacturers. This represents the penetration of fuel efficient tyres in the Indian market. Also, these fuel efficient[15] tyre models seem to be available for tyres across all rim diameters.

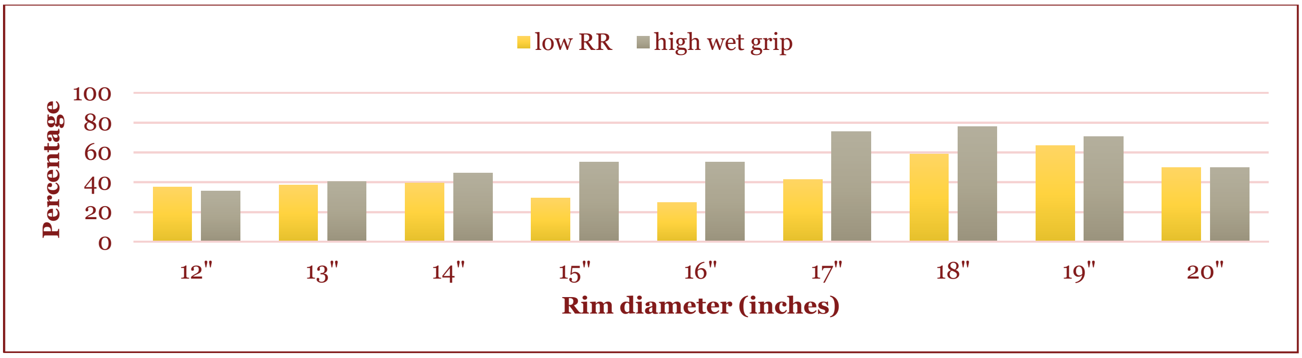


Figure 14: Proportion of fuel efficient and high wet grip tyres

[15] Here, fuel efficient tyres refer to those tyres whose RRC values are considerably lower than that of other tyres in the Indian market

3.4.3. Unorganized market

Although the majority of the passenger car tyre market is comprised of established players, a small but significant portion of the market is captured by imported unorganised market tyres, which are being fed through cash-driven unorganised channels. These tyres are available in smaller rim sizes such as 12", 13", 14" and 15", and typically cost half that of an average tyre of similar size. Interaction with tyre dealers and an independent market survey suggest that these tyres are preferred only by owners of commercial passenger car vehicles. These tyres are purchased at specific locations through unorganised channels.

3.5. Assessment of the HDV tyre market in India

Like the data for passenger car tyres, the information for HDV tyres sold by key manufacturers from their official websites was also captured. This includes data on Tyre models, Tyre specifications, and Key features of the tyre. The data collected suggests that there are fewer varieties of tyre configurations for the HDV tyre market than there are for the passenger car tyre market. Almost 63% of the tyres in the list corresponded to the rim diameter code 20. This indicates that the majority of the market corresponds to tyres of this size. Other prevalent sizes were 22.5", 16" and 24".

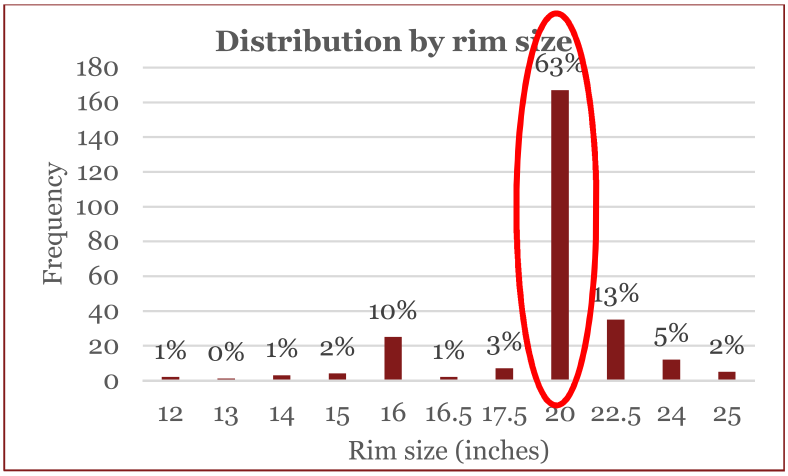


Figure 15: HDV tyre size distribution

As opposed to the passenger car tyre market which is almost completely radialised, the HDV tyre market comprises of a significant portion of bias tyres. In the data collected, the percentage of bias tyres reached almost 51%.

3.5.1. Tyre branding

For the manufacturers included in this analysis, the tyres sold are marketed as one or more of the following – fuel efficient, high mileage/long life, increased retreadability, high load carrying capacity and others. It was found that manufacturers focused more on tyre life (in terms of mileage and retreadability) than other factors. **This indicates that life of the tyre is one of the most important features for end users of HDV tyres**.

Table 5: HDV tyre branding summary[16]

Parameter	Percentage of tyres
Fuel efficiency	8%

[16] Source: PwC research

High mileage[17]	48%
Increased retreadability	36%
High load carrying capacity	16%
Wet grip	4%

Also, only 8% of the tyres available in the Indian market are claimed to be fuel efficient. This indicates that fuel efficiency may not be a key purchasing criteria for consumers of HDV tyres.

3.5.2. Retreading of worn-out tyres

Due to high initial cost of tyres, consumers generally prefer to retread worn-out/damaged tyres instead of purchasing new ones. **This is especially true for the LCV and HDV segments**. The cost of retreading a tyre is about 20–30% of the cost of a new tyre.

In the retreading process, the worn-out tread in the tyre is removed and the body of the tyre is replaced with a new tread called casing. Retreading of a tyre extends its life by 60% of the overall life of a new tyre. **The tyre can be retreaded about two to three times during its life cycle**. Therefore, on an average, a LCV and HDV tyre lasts for about 100,000 km instead of the designated 50,000 km.

India's retreading industry is estimated to be worth more than US$ 1 billion (INR 5,000 crore annually).[18] To cater to this demand, there are roughly 20,000 retreaders in India scattered in the organised and unorganised sector.

[17] Here, high mileage refers to those tyres with high life in terms of kilometers
[18] Source: http://www.retreadingbusiness.com/latest-news/posts/2017/february/indian-tyre-retreading-association-established/, accessed on 20 June 2017

4. Test procedures for determination of tyre RR and wet grip

4.1. Test procedures followed globally

The UN ECE Regulation No. 117 (R117), originally published in 2005, introduced requirements on the maximum rolling sound emissions of tyres. In 2006, the 01 series amendments to UNECE R117 added requirements on the minimum wet grip performance of passenger car tyres (C1 tyres). In 2011, the 02 series amendments to UN ECE R117 added requirements on the maximum RR of tyres and increased the stringency of the maximum rolling sound emissions requirements.[19]

The test procedures for determining RRC of tyres are based on ISO 28580. The maximum RRC limits are introduced in a two-stage process with separate limit values specified for class C1 tyres, class C2 tyres and class C3 tyres.[20]

The test procedures for determining wet grip of tyres are described in UNECE R117 regulation itself.

Table 6: Applicable testing standards for RR and wet grip

Tyre type	**Rolling resistance**		**Wet grip**	
	Type approval	**Labelling**	**Type approval**	**Labelling**
C1	UNECE R117.02 (**ISO 28580,** w/o point 10)	UN ECE R117.02 + **EC Alignment procedure** (Reg. 1235/2011)	**UNECE R117.02**	**Reg. 1222/2009 Annex V**
C2			NA-[21]	ISO 15222:2011 EU Reg. 1235/2011
C3				

The test procedures for determination of RRC and wet grip index specified in UNECE R117 are deemed appropriate and the test results obtained are widely accepted.

4.1.1. Overview of test protocol for determination of RRC[22]

ISO 28580 specifies methods for measuring rolling resistance, under controlled laboratory conditions, for new pneumatic tyres designed primarily for use on passenger cars, trucks and buses. Tyres intended for temporary use only are not included under this standard.

The standard also includes a method for correlating measurement results to allow **inter-laboratory comparisons.**

Prescribed test methods

There are four alternative test methods described in the standard. **Any of the four methods can be used to determine the RR value of the tyre**, and hence the choice of method is left to the testing laboratory.

[19] http://www.interregs.com/articles/spotlight/new-ece-requirements-on-tyre-noise-and-rolling-resistance-published-000110 (Accessed on 28 July 2016)
[20] C1 tyres refer to passenger car tyres, C2 to LCV tyres, and C3 to HDV tyres
[21] No requirement
[22] Disclaimer: The description provided in this chapter for Test procedure for determination of rolling resistance coefficient has been mentioned by taking reference from authorized copy of Standards. The Standards were purchased by the project team.

Force method

- The reaction force measured or converted at the tyre spindle

Torque method

- The torque input measured at the test drum

Deceleration method

- The measurement of deceleration of the test drum and tyre assembly

Power method

- The measurement of the power input to the test drum

Figure 16: Methods for determination of rolling resistance as per ISO 28580

Alignment procedure as per ISO 28580

ISO 28580 describes the procedure to be followed to align measurement results and allow direct inter-laboratory comparisons. However, UNECE R117 has not incorporated this procedure in type approval requirements.

This machine alignment procedure requires two predetermined alignment tyres used by the candidate laboratory operating the machine. These tyres are used to align candidate machine(s) by comparing the measured C_r results to those obtained on a reference machine. An alignment formula is then established and shall be used to translate the results obtained on the candidate machine into aligned results.

The laboratory operating the reference machine shall measure each alignment tyre three times, and provide **the mean value and standard deviation established from the three measurements for each tyre**

↓

The candidate machine shall measure each alignment tyre three times, with a measurement standard deviation within limits defined as per the standard

↓

The correlation shall be performed by the candidate laboratory and shall be a linear regression technique

Figure 17: Alignment procedure

4.1.2. Overview of test protocol for determination of wet grip index

The Regulation UNECE R117.02 applies to new pneumatic tyres of Classes C1, C2 and C3 with regard to their sound emissions, rolling resistance and to adhesion performance on wet surfaces (wet adhesion). The test procedure for determination of wet grip index is described in the Regulation.

Test methods (for wet grip)

There are two alternative test methods described in the standard. Either method can be used to determine the value of wet grip index, or hence the choice of method is left to the testing laboratory.

Vehicle method

- This method involves testing a set of tyres mounted on an ***instrumented passenger car***

Trailer method

- This method uses a trailer towed by a vehicle or a tyre test vehicle equipped with test tyres

Table 7: Comparison between vehicle method and trailer method

	Vehicle method	Trailer method
Principle	• The deceleration performance of C1 tyres during braking is measured using an instrumented passenger car.	• The measurements are conducted on test tyres mounted on a trailer towed by a vehicle (tow vehicle)
Comparison parameter	• Average deceleration between 80 km/hr and 20 km/hr • Comparison with SRTT*	• Peak break force coefficient at 65 km/hr • Comparison with SRTT
Number of candidate tyres required	• 3 sets of 4 tyres each	• 1 tyre
Number of reference tyres needed	• 1 set of 4 tyres each	• 1 tyre

4.2. Availability of testing infrastructure in India

At present, a working test facility for **RR is available with IRMRA and that for wet grip is available with ICAT**. Testing for wet grip can also be performed by other testing agencies as per the vehicle method mentioned in UN ECE R117. The tracks available at VRDE Pune, NATRAX Indore and tracks in Chennai where testing of wet braking is done can be used for wet grip testing. The findings are summarized in the following table.

Table 8: Availability of testing facilities for RR & wet grip in India

Parameter to be determined	Test procedure	Infrastructure required	Availability	Test procedure adopted
Rolling resistance	ISO 28580 w/o alignment	RR test apparatus	IRMRA, Pune	Torque method
Wet grip		Tyre Test Trailer	ICAT, Manesar	Trailer method

	UNECE R117 – trailer method	Test tracks	VRDE, Ahmednagar	-
			NATRAX, Indore	
			GARC, Chennai	
	UNECE R117 – instrumented passenger car method	Test tracks	VRDE, Ahmednagar	-
			GARC, Chennai	

Note: ICAT's TTT is suitable for testing of passenger car tyres up to rim size between 14" to 17". Therefore, wet grip testing as per UNECE R117.02's trailer method is not available for HDV tyres and few passenger car tyres of rim diameters which are much smaller and those above 18" (testing of some of the tyres in 17" category is also difficult and hence entire range of 17" tyres cannot be tested with the existing TTT machine available with ICAT).

4.3. Conclusion & next actions

Though the stakeholders in India are putting their best efforts in developing standards for RR and wet grip for tyres in India, progress on this front has been limited mostly on account of constraints on availability of data on RR and Wet Grip performance of tyres in the Indian market.

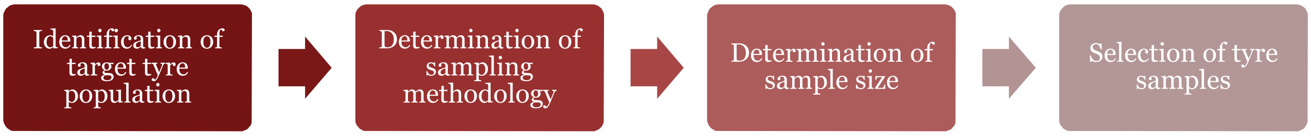
The primary reason for limited data was unavailability of adequate testing facilities in the country at the time. However, recent studies and research have established that testing facilities for these parameters are available in India, at IRMRA for RRC and at ICAT for wet grip index respectively. Therefore, data on these parameters can be generated through testing tyre samples, effectively addressing the barrier of unavailability of data.

This study intends to generate data on these parameters by selecting tyre samples from the Indian market and testing them in these test facilities. However, because the TTT in ICAT can only load passenger car tyres[23], this study will focus only on passenger car tyres.

[23] Of rim diameter upto 17"

5. Selection of tyre samples for RR and wet grip testing

The approach followed for selection of the tyre sample set for testing for determination of RRC and Wet Grip Index is described in this section. An outline of the approach adopted is shown in the following steps.



5.1. Identification of target population

In statistics, the population (or the sample space) is defined as the set of all elements with the characteristic that needs to be understood. Population sampling is the process of taking a subset of subjects that is representative of the entire population.

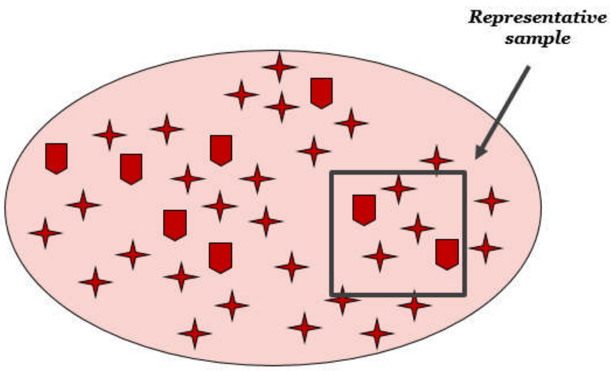


Figure 18: Illustration - population sampling

This study aims to understand the prevalent values of RRC and wet grip index of passenger car tyres sold in India. Therefore, for the scope of this study, **the term population refers to the all passenger car tyre models sold in the Indian market**. Tyres which are type approved for use in passenger cars are included in the population. Tyres of the same brand (Eg. Michelin Energy XM2) but different tyre size designations are considered different elements. Tyres of the same brand and tyre size designations are considered one element.

A sample set representative of the target population is selected and tested for determination of values of RRC and wet grip indices. Based on the values obtained for the sample set, the average values of these parameters for tyres in the Indian market can be estimated.

5.2. Determination of sampling methodology

The principle of **stratified sampling has been adopted** for selection of tyre samples. In stratified sampling, the entire population is divided into a certain number of more homogeneous groups (or "strata") on the basis of parameters which affect the value of the characteristic to be determined.

RRC is considered the primary characteristic of interest in the sampling exercise. Once the tyre samples for RR testing is finalised, similar tyres shall be selected and tested for wet grip index as well. This is to ensure that the relationship between the two parameters are understood and reasonable conclusions are drawn on the basis of the data obtained by testing of tyre samples.

Identification of parameters influencing RRC

The rolling resistance coefficient (or "RRC") of a tyre is defined as the ratio of the rolling resistance force exhibited by the tyre, in N, adjusted to 2 m drum and 25° C, to 80% of its rated load carrying capacity, in kN[24]. In mathematical terms,

$$\text{RRC} = \frac{\text{Rolling Resistance force}}{\text{80\% of Rated Load}}$$

Therefore, from the above equation, two parameters influence the value of RRC obtained for a tyre – **tyre rolling resistance** (RR) and **the rated load**. In turn, the RR value of a tyre depends on several factors, such as tread pattern, tyre material, tyre construction, section width etc. The rated load highly depends on tyre size, and is specified by the tyre's load index.

As per our understanding of the market and based on our discussions with key stakeholders from the Indian tyre industry, we expect the following factors to influence the value of a tyre's RRC.

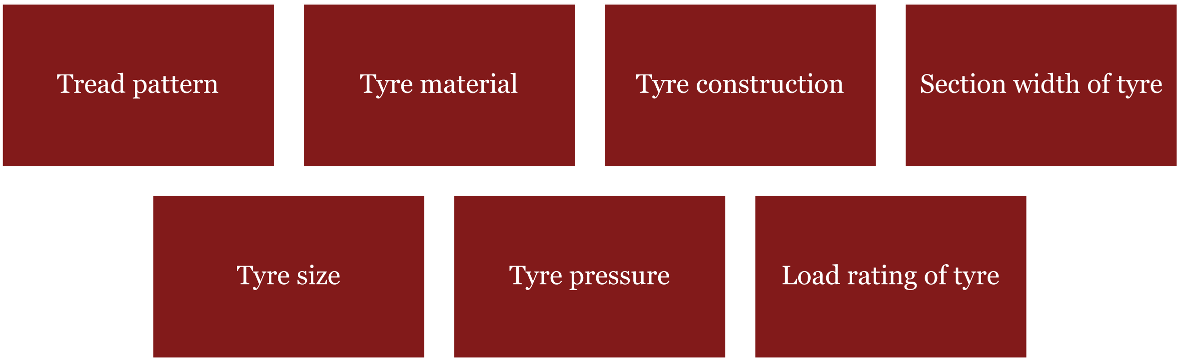


Figure 19: Factors influencing RRC

Of the factors that influence a tyre's RR, section width seems the most quantifiable parameter which can be used to differentiate different tyres within a specific diameter category. Therefore, **section width is selected as one of the parameters for defining strata for sampling**.

Two factors have a considerable impact on the rated load – tyre size (indicated by rim diameter) and load index. Although both these factors are equally quantifiable and information on both factors is accessible, **rim diameter is selected as one of the parameters for defining strata for sampling,** because rim diameter is more widely used and generally more "acceptable" parameter for tyre size than load index.

Forming strata for sampling

Rim diameter and section width are used to define strata for sampling. The following figure provides a glimpse of the distribution of section widths to rim diameters for various passenger car tyres used in the Indian market. The dots in the diagram represent a particular section width - rim diameter configuration present in the Indian passenger car tyre market.

[24] ISO 28580

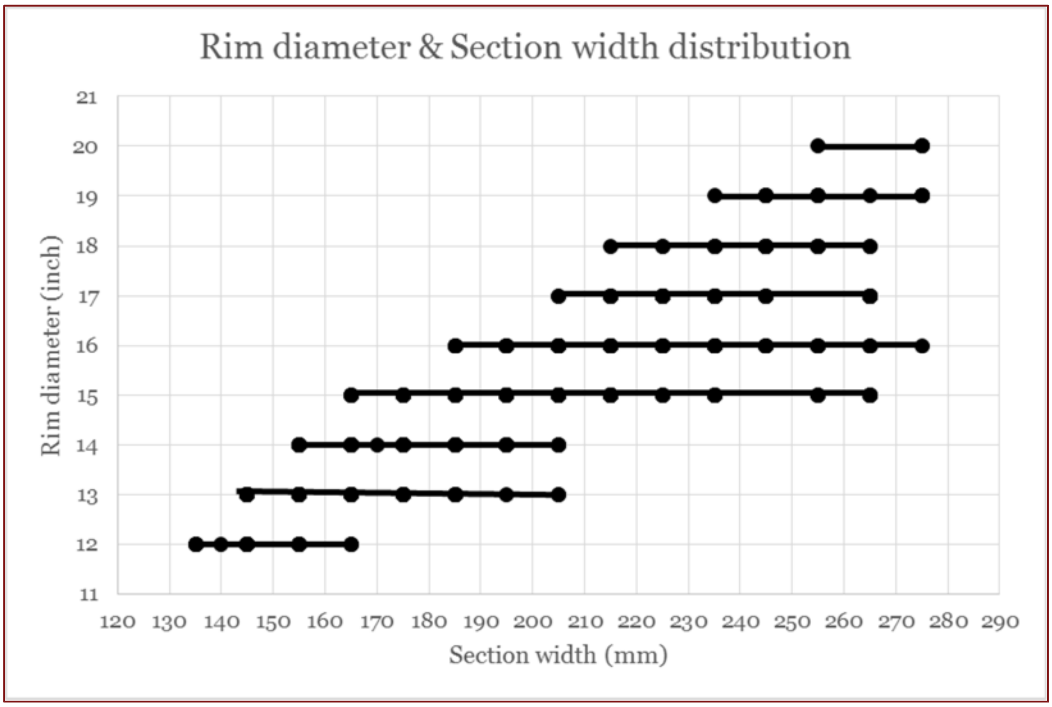


Figure 20: Section width vs rim diameter[25]

The figure indicates that there are approximately 60 different configurations of rim diameters and section widths available in the Indian passenger car tyre market.

5.3. Determination of sample size

The sample size is defined as the number of representative samples selected from the entire population. It is selected such that the properties of the sample set **sufficiently** represent those of the population. The approach followed for determination of sample size is described:

- As discussed in the previous sub-section, two parameters were considered to assess **the value of a tyre's RRC – its section width and its rim diameter**, among other factors. These parameters form the basis for selection of tyre samples.

- The underlying principle used to determine the sample size is based on the assumption that the strata defined by rim diameter and section width are homogeneous in nature, i.e. the variation in RRC is nearly equal in all strata. The variation in RRC within each strata can be explained by intrinsic factors such as tread pattern, tyre material etc.

- As shown in Figure 20, there are multiple tyres for each rim diameter value. The sample set has been selected such that the samples are spread out over the range of rim diameter-section width configurations, and **it represents that majority of the market**.

On this basis, tyres of rim sizes 12" to 17" only are included in the sample set.

The following table summarises information from Figure 20, and presents the minimum, median and maximum section width for each rim diameter segment. The sample size has been selected on the basis of this table.

[25] Source: PwC analysis

Table 9: Section width details (passenger car tyres)

Rim diameter (inches)	Lowest section width (mm)	Median section width (mm)	Highest section width (mm)
12	135	145	165
13	145	155	205
14	155	175	205
15	165	205	265
16	185	215	275
17	205	225	265

The sample size is selected on the basis of the sample selection methodology. Samples that must be included in the sample set are first identified, and the appropriate sample size is then determined on that basis. The sample selection methodology and the corresponding sample size is described in the following table.

Table 10: Sample selection methodology (passenger car tyres)

S. No.	Selection criteria	No. of samples
1.	There is considerable distribution in the values of section widths within each rim diameter segment. To capture this distribution of section width, **tyres with section widths approximately equal to the minimum, median and maximum section widths within each rim diameter segment are to be included in the sample set**. Since tyres of six specific rim diameters i.e. 12" to 17" are considered for sampling, the total number of samples identified is 18 (3 samples in each diameter)	18
2.	**Rim diameter segments 15" and 16" comprise of a large range of section width values**. This may or may not lead to a variation of RRC values within this segment, and therefore to assess this **an additional tyre from each of these segments is to be included in the sample set**.	2
3.	Tyres from the **rim diameter segments – 13", 14", 15', and 16" – are most prevalent in the Indian market**. To account for this, an **additional tyre from each of these segments** is to be included in the sample set.	4
	Total	24

The main sample set therefore comprises of 24 tyres. However, these tyres only represents the majority of the market and therefore those tyres which are not prevalent in market, but might be relevant to this study are excluded from this sample set.

To account for the "outliers", such as imported tyres, tyres from the unorganised market, tyres not prevalent etc., an additional 6 tyres is included in the sample set. **Therefore, in summary, a total of 30 tyres are proposed to be included in the tyre sample set, with 6 outliers.** This way, **outlier tyres were given about 20% of the total sample set**.

Distribution of the main sample set is summarised in the following table.

Table 11: Distribution of sample set[26]

Rim diameter	Min. section width	Median section width	Max. section width	Additional tyre for large range	Prevalence in the market	Total
12”	1	1	1			3
13”	1	1	1		1	4
14”	1	1	1		1	4
15”	1	1	1	1	1	5
16”	1	1	1	1	1	5
17”	1	1	1			3
Total						**24**

Selection of outlier tyre samples

The outlier tyre samples were selected such that tyres not prevalent in the Indian market are selected for testing. These comprised mostly of tyres of higher sizes imported through the organized channels, and those sold through unorganized channels in the market. The distribution is shown below:

- Two tyres of sizes 13”, one of 14”, and one of 15” from the unorganized market
- Two imported tyres of sizes 14” and 17”

5.4. Selection of tyre samples for RR testing

Once the sample set is defined the next stage is selection of tyres. Two factors were prioritised while selecting the tyres i.e. tyre make/brand and popularity in the market for that particular tyre size. The tyre samples have been selected such that a representative sample comprising of a mix of “make of tyres” as well as those tyres which are popular in a specific segment gets selected.

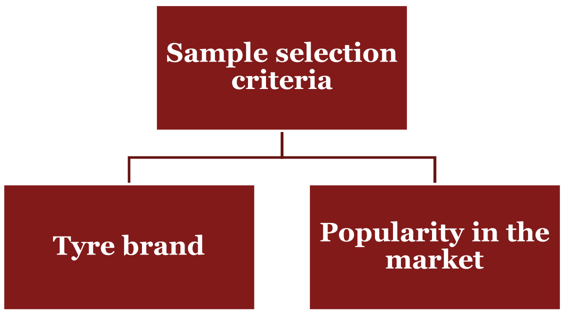


Figure 21: Sample selection criteria

In sum, the tyre samples have been selected such that adequate variation in both of the above-mentioned factors is ensured in the final sample set. The final sample set is detailed in sub-section 5.6.

5.5. Selection of tyre samples for wet grip testing

UNECE R117.02 and the European tyre labelling regulation (Reg. 1222/2009) requires tyres to be tested for both RR and wet grip. While maximum permissible values for RRC are aimed at improving the overall fuel efficiency

[26] This distribution does not account for the 6 outlier tyre samples

of tyres, minimum thresholds on wet grip index (G) ensure that improvements in fuel efficiency are not at the cost of tyre safety.

For this reason, **the sample set selected for RR testing shall also be tested for wet grip** to understand the underlying dynamics between a tyre's RRC and its wet grip index, and the factors influencing this relationship. This understanding will be crucial during development of benchmark standards.

In an ideal scenario, the wet grip indices of all 30 tyres in the entire sample set should be determined through wet grip testing. However, due to budgetary constraints for this study and the estimated wet grip testing costs, the number of tyres to be tested for wet grip is limited to 18.

To select the 18 tyres for wet grip testing, an approach similar to that for RR testing has been adopted. The approach adopted to arrive at 18 tyres is described below:

- As pointed out in section 4.2, the TTT in ICAT is suitable for testing of tyres of rims upto 17". The team's discussion with ICAT also brought out that not all tyres of rim size 17" can be tested in the TTT. **Therefore, only tyres of rim sizes 12" to 16" in the sample set are included for wet grip testing**.
- The two imported tyres in the sample set are already equipped with the EU label, which indicates the wet grip class of the tyres. Since the information on wet grip performance is available through the EU label and there is no such calibration requirements, there is no specific requirement for testing these tyres for wet grip. **Therefore, these two imported tyres in the sample set are excluded from wet grip testing**.
- **Of the four tyres from the unorganized market, two are selected for wet grip testing**. As the four unorganised market tyres are of two brands, one tyre from each brand has been selected.
- Application of the above criteria brings the overall sample size down to 23. From this set, 18 tyres are selected such that the final sample set comprises of rim diameters and brand prevalent in the Indian market.

The final sample set for wet grip testing is shown in sub-section 5.7.

5.6. Final sample set for RR testing[27]

The final list of tyre samples along with their tyre size configurations[28] are shown in the following table.

Table 12: Sample set for RR testing

Rim	12"	13"	14"	15"	16"	17"
1	**Ceat Milaze TL** 135/70 R12	**MRF ZVTS** 145/70 R13	**Pirelli** 185/65 R14	**Yokohama E400** 195/60 R15	**Goodyear** 205/60 R16	**Continental TL** 265/65 R17
2	**Apollo** 155/70 R12	**Bridgestone** 165/65 R13	**JK Tyres Tornado TL** 165/80 R14	**Bridgestone** 175/60 R15	**Apollo** 255/65 R16	**Good Year** 215/55 R17
3	**MRF ZLX R** 145/80 R12	**JK Tyres** 185/70 R13	**MRF ZLO** 185/70 R14	**Continental AT** 255/70 R15	**Falken Azenis** 205/60 R16	**Pirelli** 235/65 R17
4		**Michelin** 145/80 R13	**Apollo Amazer 4G Life TL** 155/65 R14	**Apollo AXL/TT** 165/80 R15	**Bridgestone** 215/65 R16	**Bridgestone TL** 235/65 R17
5		**Torque** 155/80 R13	**Goodyear Duraplus** 165/80 R14	**Michelin Energy XM2 TL** 205/65 R15	**CEAT** 195/55 R16	
6		**Torque** 165/65 R13	**Sunfull** 165/80 R14	**Sunfull** 195/60 R15		

[27] Cells highlighted in green represent imported tyre brands. Those highlighted in pink are brands sold through unorganized channels
[28] Basic tyre terminology is described in Appendix B

Snapshot of selected sample set for RR testing

An overall snapshot of the selected tyre sample set is illustrated in this sub-section. The tyre brands highlighted in the following table belong to the outlier section. Brands highlighted in green represent imported tyre brands. Those highlighted in pink are brands sold through unorganized channels.

S. No.	Brand	No. of tyres
1	Ceat	2
2	MRF	3
3	Yokohama	1
4	Goodyear	3
5	Continental	2
6	Bridgestone	4
7	JK Tyres	2
8	Michelin	2
9	Pirelli	2
10	Torque	2
11	Apollo	4
12	Sunfull	2
13	Falken	1

A total of 13 different tyre brands are included in the sample set.

S. No.	Rim diameter	No. of tyres
1	12"	3
2	13"	6
3	14"	6
4	15"	6
5	16"	5
6	17"	4

Majority of sample tyres are from rim diameters 13" to 15"

There is adequate representation from each rim diameter segment

5.7. Final sample set for wet grip testing[29]

The final list of tyre samples along with their tyre size configurations[30] are shown in the following table.

Table 13: Sample set for Wet Grip Testing

Rim	12"	13"	14"	15"	16"	17"
1		**MRF ZVTS** 145/70 R13			**Goodyear** 205/60 R16	
2	**Apollo** 155/70 R12	**Bridgestone** 165/65 R13	**JK Tyres Tornado TL** 165/80 R14	**Bridgestone** 175/60 R15	**Apollo** 255/65 R16	
3	**MRF ZLX R** 145/80 R12	**JK Tyres** 185/70 R13	**MRF ZLO** 185/70 R14	**Continental AT** 255/70 R15		
4		**Michelin** 145/80 R13	**Apollo Amazer 4G Life TL** 155/65 R14			
5		**Torque** 155/80 R13	**Goodyear Duraplus** 165/80 R14	**Michelin Energy XM2 TL** 205/65 R15	**CEAT** 195/55 R16	
6				**Sunfull** 195/60 R15		

[29] Cells highlighted in the table represent outliers
[30] Basic tyre terminology is described in Appendix B

Snapshot of selected sample set for wet grip testing

An overall snapshot of the selected tyre sample set is illustrated in this sub-section. The tyre brands highlighted in the following table belong to the outlier section. Brands highlighted in pink are brands sold through unorganized channels.

S. No.	Brand	No. of tyres
1	MRF	3
2	Goodyear	2
3	Continental	1
4	Bridgestone	2
5	JK Tyres	2
6	Michelin	2
7	Torque	1
8	Apollo	3
9	Sunfull	1

A total of 9 different tyre brands are included in the sample set.

S. No.	Rim diameter	No. of tyres
1	12”	2
2	13”	5
3	14”	4
4	15”	4
5	16”	3
6	17”	-

Majority of sample tyres are from rim diameters 13” to 15”

There is adequate representation from each rim diameter segment except 17”

6. Testing of sample tyres for RRC

This section illustrates the project team's efforts in procurement of tyre samples, and describes the RR testing process at IRMRA.

6.1. Overall RR testing plan

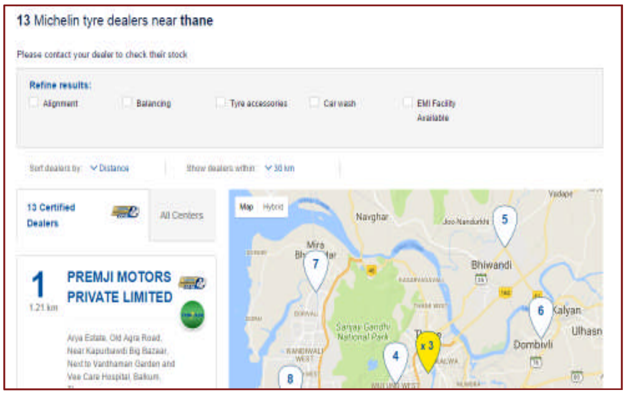
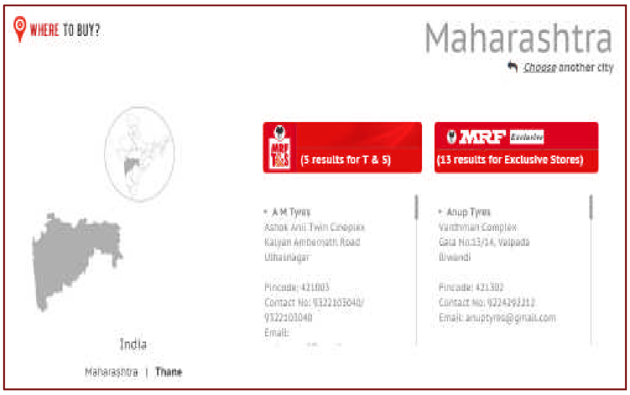
The overall plan for testing of tyre samples for RR involved procurement of tyre samples from **authorized dealers** in the open market and delivery of these samples to IRMRA's premises for testing.

Because IRMRA's testing facilities are located in Thane, Maharashtra, it was decided that tyres would be procured from authorized local dealers to avoid transportation time and costs. Two members from the project team travelled to Thane, from 15th May 2017 to 19th May 2017, to procure tyre samples and witness RR testing at IRMRA's premises.

6.2. Procurement of tyre samples

Procurement of tyre samples from authorized dealers was one of the most critical tasks for the RR testing exercise. To this end, the project team had identified few dealers in Thane and Mumbai for all tyre brands from the organized sector through the respective manufacturers' official websites.[31] The illustrative snapshots of the websites are provided in the following table.

Table 14: Official websites - dealer locator

Michelin[32]	MRF[33]
	

The team visited the shortlisted dealers to purchase the tyre samples. Most of the tyre samples were readily available with the respective dealers. For tyres not available or not in stock, the dealers were requested to procure them at a day's notice. Tyres once purchased were transported to IRMRA's premises at day's end. Overall, the procurement exercise was completed in approximately 2 ½ days. The following table summarizes the list of dealers from where the tyres have been procured.

[31] Dealers of unorganized market tyres could not be identified in this manner. They were located with the help of local persons, including cab drivers and other dealers.
[32] Source: http://dealer-locator.michelin.in/IN/en/tyres/MAHARASHTRA/thane, accessed on 14 July 2017
[33] Source: http://www.mrftyres.com/, accessed on 14 July 2017

Table 15: List of dealers

S. No.	Dealer name	Tyre brand	Size
1	Bombay Tyres	MRF ZVTS	145/70 R13
		MRF ZLX R	145/80 R12
2	Mayur Tyres	Continental TL	265/65 R17
		Bridgestone TL	235/65 R17
3	Samarth Tyres	Falken Azenis	205/60 R16
4	Satyam Tyres	Apollo Amazer 4G Life TL	155/65 R14
		Apollo AXL/TT	165/80 R15
		Apollo	155/70 R12
5	Supreme Tyres	Ceat Milaze TL	135/70 R12
		Yokohama E400	195/60 R15
		Goodyear	205/60 R16
		JK Tyres Tornado TL	165/80 R14
		Goodyear DP	165/80 R14
		Michelin Energy XM2 TL	205/65 R15
6	Supreme Tyres	Pirelli	185/65 R14
		Pirelli	235/65 R17
7	Satyam Tyres	Apollo Apterra	255/65 R16
8	Supreme Tyres	Bridgestone	165/65 R13
		JK	185/70 R13
		Michelin	145/80 R13
		Bridgestone	175/60 R15
		Bridgestone	215/65 R16
		CEAT	195/55 R16
		Good Year	215/55 R17
9	Mayur Tyres	Continental AT	255/70 R15
10	Ruby Tyres	MRF ZLO	185/70 R14
11	Supreme Tyres	Torque	155/80 R13
		Torque	165/65 R13
		Sunfull	165/80 R14
		Sunfull	195/60 R15

6.3. RR performance testing at IRMRA's premises

The tyre samples, after delivery to IRMRA, were segregated into 6 different lots of 5 tyres each. Tyres from one lot were tested at one go, and each lot was tested separately. **The test procedure followed was as per ISO**

28580, and the results of testing were delivered lot-wise. The project team witnessed the testing of "LOT 1" first-hand.

Following is the proposed sequence for testing of tyres:

LOT 1		
1	Ceat Milaze TL	135/70 R12
2	MRF ZVTS	145/70 R13
3	Yokohama E400	195/60 R15
4	Goodyear	205/60 R16
5	Continental TL	265/65 R17

LOT 2		
6	Bridgestone	165/65 R13
7	JK	185/70 R13
8	Michelin	145/80 R13
9	Pirelli	185/65 R14
10	JK Tyres Tornado TL	165/80 R14

LOT 3		
11	Torque	155/80 R13
12	Torque	165/65 R13
13	MRF ZLO	185/70 R14
14	Apollo Amazer 4G Life TL	155/65 R14
15	Goodyear DP	165/80 R14

LOT 4		
16	Sunfull	165/80 R14
17	Bridgestone	175/60 R15
18	Continental AT	265/70 R15
19	Apollo AXL/TT	165/80 R15
20	Michelin Energy XM2 TL	205/65 R15

LOT 5		
21	Sunfull	195/60 R15
22	Apollo	255/65 R16
23	Falken Azenis	205/60 R16
24	Bridgestone	215/65 R16
25	CEAT	195/55 R16

LOT 6		
26	Apollo	155/70 R12
27	MRF ZLX R	145/80 R12
28	Good Year	215/55 R17
29	Pirelli	235/65 R17
30	Bridgestone TL	235/65 R17

Figure 22: Segregation of sample set into 6 lots

The first lot of tyres was tested between 17th May 2017 to 19th May 2017, and the subsequent lots were tested in following weeks.

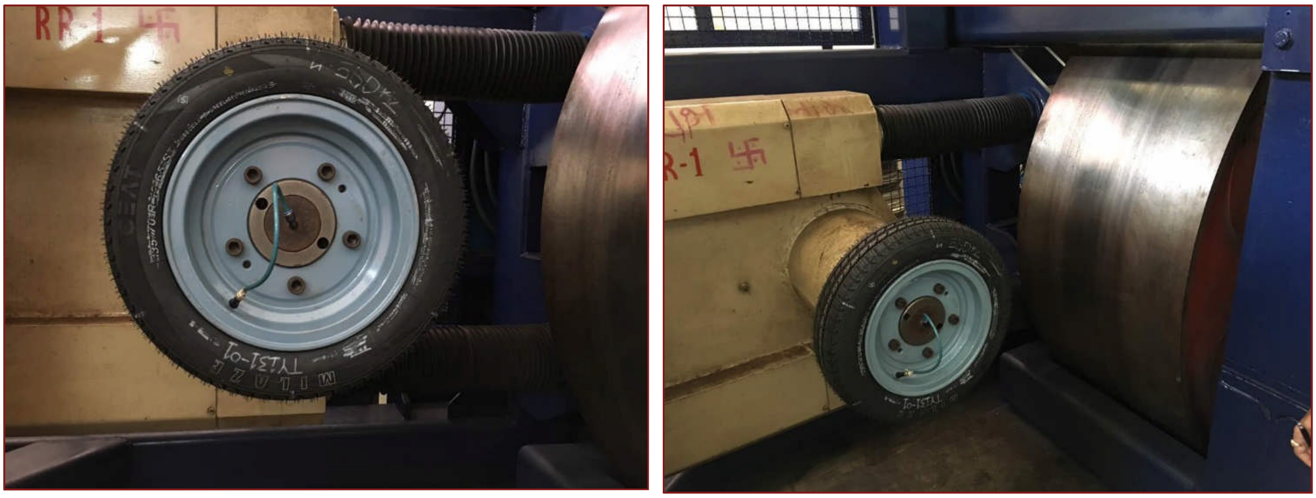


Figure 23: Photos - RR testing at IRMRA

<u>Note</u>: The RRC results reported by IRMRA are not aligned with the Network of Reference Laboratories in Europe. The aligned RRC results will be reported once the correlation equation for the machine in IRMRA is established. The tentative completion time for alignment is December 2017.

6.4. RRC test results

The sample tyres were coded to maintain confidentiality of the test results. The approach followed for coding is described below.

- All 13 tyre brands included in the sample set were first assigned an alphabet at random (For example, "M")
- Each sample tyre corresponding to a brand was assigned a number at random (For example, "M1")
- The rim diameter for each tyre sample was appended to arrive the code for the tyre (For example, "M1 – 4")

The test results for the tyre sample set is shown below.

Table 16: RRC test results (masked)

S. No.	Sample tyre code	RRC (unaligned)	S. No.	Sample tyre code	RRC (unaligned)	S. No.	Sample tyre code	RRC (unaligned)
1	H1 - 12	13.52	11	B2 - 14	11.96	21	M2 - 15	11.36
2	F4 - 12	11.23	12	E2 - 14	11.89	22	A1 - 16	9.79
3	E3 - 12	12.25	13	F1 - 14	14.27	23	F3 - 16	10.61
4	E1 - 13	14.61	14	A2 - 14	13.18	24	L1 - 16	12.18
5	K1 - 13	12.59	15	M1 - 14	11.09	25	K3 - 16	10.16
6	B1 - 13	13.65	16	J1 - 15	10.09	26	H2 - 16	12.01
7	D1 - 13	11.61	17	K2 - 15	11.35	27	C1 - 17	8.22
8	G1 - 13	12.39	18	C2 - 15	12.49	28	A3 - 17	7.93
9	G2 - 13	11.17	19	F2 - 15	11.85	29	I2 - 17	9.08
10	I1 - 14	11.04	20	D2 - 15	8.77	30	K4 - 17	10.18

7. Testing of sample tyres for wet grip

This section illustrates the project team's efforts in procurement of tyre samples, and describes the wet grip testing conducted by ICAT at NATRAX's premises in Indore.

7.1. Overall wet grip testing plan

The overall plan for testing of tyre samples for wet grip involved procurement of tyre samples from **authorized dealers** in the open market and delivery of these samples to the testing premises for testing. NATRAX's premises in Indore was selected as the test site to perform wet grip testing. Therefore, it was decided that tyres would be procured from authorized **local** dealers to avoid transportation time and other related costs. Two members from the project team travelled to Indore to procure tyre samples and witness wet grip testing in Indore. The testing occurred from 13th December 2017 to 22th December 2017,

7.2. Procurement of tyre samples

The project team had identified few dealers in Indore for all tyre brands for included in the sample set for wet grip testing from the organized sector through the respective manufacturers' official websites.[34] The team visited the shortlisted dealers to purchase the tyre samples. Most of the tyre samples were readily available with the respective dealers.

For tyres not available or not in stock, the dealers were requested to procure them at a day's notice. Tyres once purchased were transported to NATRAX's premises at day's end. Overall, the procurement exercise was completed in approximately 2 ½ days. The following table summarizes the list of dealers from where the tyres have been procured.

Table 17: List of dealers

S. No.	Dealer name	Tyre brand	Size
1	Shreeram Tyres	Apollo	155/65 R14
		Michelin	205/65 R15
		Apollo	255/65 R16
2	Go Wheels	Bridgestone S322	165/65 R13
		Bridgestone B250	175/60 R15
		Goodyear Assurance	205/60 R16
		Goodyear Assurance Duraplus	165/80 R14
3	Shreeram Automobiles	Ceat Milaze	135/70 R12
		MRF ZLX	145/80 R12
		MRF ZVTS	145/70 R13
		Michelin XM2	145/80 R13

34 Dealers of unorganized market tyres could not be identified in this manner. They were located with the help of local persons, including cab drivers and other dealers.

		JK Tornado	165/80 R14
4	Harikripa Tyres	MRF ZLO	185/70 R14

Note: The remaining five tyres from the sample set were not available with most major vendors in Indore. The team had two options; either to change the sample set and procure tyre with different configuration or to stick with the sample set and get the tyres from other location which was the preferred option. Therefore, the tyres which were procured for RR testing were used. From the sample set of RR testing, those tyres were selected which were not available in Indore and these were shipped from IRMRA's premises in Thane to NATRAX Indore for wet grip testing.

7.3. Wet grip performance testing at NATRAX

The testing of passenger car tyres for determination of wet grip index 'G' was done as per the procedure mentioned in UNECE R117.02 (and its amendments). The testing was performed by M/s ICAT. The details of instrumentation used for the testing is shared below:

- Tyre Traction Trailer (TTT-995-2) was transported from M/s ICAT's premise in Manesar to the test site
- The test site selected was NATRAX (Indore).
- Standard Reference Test Tyres (SRTT) as per the specifications defined under UNECE R117
- Measurement instruments such as tyre pressure gauge, L350, ambient temperature sensor, road surface temperature sensor and other necessary accessories & tools.

The team from M/s ICAT performed the entire testing as per the procedures defined in UNECE R117.02 and its amendments.

Some of the observations and points considered during the testing:

Reference tyres: The latest amendment of UNECER117.02 recommends the use of SRTT of diameter 16". However, the earlier version of this standard recommended SRTT of diameter 14".

The tyre market in India is different than that of Europe in terms of the tyre size. In India majority of the tyre market stands within the diameter 13" to 15" however in EU the majority is beyond 15" diameter. During the testing, the team initially planned to perform the testing of sample tyres specifically of diameter 12" to 14" with both SRTT 16" and SRTT 14". This was planned only to assess the difference of results between the testing through two reference tyres. The testing of sample tyres of 15" and 16" was planned with SRTT 16" as per the standard.

To begin with, testing of smaller tyres was initiated using SRTT 14". However, for smaller tyres there were serious concerns observed in using the trailer method. Due to constraints in testing of smaller diameter tyres somehow the team managed one round of testing that is with SRTT 14". It was not feasible to test the tyres again with SRTT 16" because of the limitations of test equipment.

Therefore, the wet grip values for five tyres from the sample set (of rim sizes 12" and 13") were determined using SRTT 14" reference tyres instead of SRTT 16" which is required as per the Revision 4 of UNECE R117.02. The remaining 13 tyres within the sample set were tested and referenced with SRTT 16" as per Revision 4 of UNECER117.02.

Testing of smaller size tyres (12" and 13"): One of the key observations was limitation in using the trailer-method for wet grip measurement of smaller size tyres. These are summarized below:

- **Non compatibility in load requirement:** One of the sample tyre of 12" diameter couldn't be tested due to lower load requirement. For trailer method, it is important to maintain the load on test tyre as prescribed in the standard, which is 75% of the maximum load defined for the tyre. For some of the lower size tyres the maximum load defined is lesser than the dead weight of trailer itself due to which it is not possible to test such tyres.

- **Non compatibility of test apparatus:**

  The water nozzle is mounted on the trailer such that it could spray the water at a defined angle on the test tyre during the wet grip testing. For the smaller size tyres it was observed that the water nozzle was touching the road surface after mounting the test tyre on the trailer. Hence, it was not feasible to test the smaller size tyres specifically of diameter 12" and 13". The only possibility of testing the tyres was to unhinge the water nozzle from its defined place and manually mount it in a manner such that the nozzle doesn't touch the road surface and is also able to spray the water in a defined angle.

  The team tried and managed the testing of tyres by manually mounting the water nozzle. However, this setting required complete alterations every time the sample tyre changed. For example, while testing a set of 12" test tyre, the SRTT 14" was tested first (as the water nozzle should be as per original condition). Then two sample tyres of 12" diameter (which required the water nozzle to be manually mounted) and then again SRTT 14" were tested. With each change, copious amounts of time was invested in preparing the apparatus to be ready for testing which included complete calibration of TTT after each change of tyre. Because of these limitations it wasn't feasible to test the smaller tyres two times i.e. with both SRTT 14" and SRTT 16".

7.4. Wet grip test results

The sample tyres were coded to maintain confidentiality of the test results. The coding of tyres was done by ICAT during testing. **The test results for the tyre sample set is shown below.**

Table 18: Wet grip test results (masked)

S. No.	Sample tyre code	G	S. No.	Sample tyre code	G
1	T1	1.00	10	T10	1.26
2	T2	1.10	11	T11	1.43
3	T3	1.20	12	T12	1.19
4	T4	1.20	13	T13	1.06
5	T5	1.27	14	T14	1.12
6	T6	1.22	15	T15	1.39
7	T7	1.13	16	T16	1.24
8	T8	1.24	17	T17	1.18
9	T9	1.25	18	T18	1.27

Note: Cells highlighted in Table 18 represent those tyres whose wet grip index values were measured w.r.t. SRTT14" instead of SRTT16". All of the values have been used for further analysis presented in this report.

8. Analysis of test results

The results of RR and wet grip testing of the tyre sample set are described in previous two chapters respectively. **This chapter explores the relationships exhibited by RRC and wet grip with other key tyre parameters and draws key insights which are crucial for conducting the benchmarking exercise** and standard setting. This is done in chapter 9.

8.1. Approach adopted

The test results obtained by testing of the tyre sample set for RRC and wet grip have been analysed through widely accepted statistical techniques benchmarking studies involving development of MEPS and labelling programs.

Scatterplots and linear regression techniques have been employed to examine the relationships that RRC & wet grip exhibit with each other, and with other key parameters such as rim diameter, section width etc. A tyre price analysis has also been conducted to understand the price premium consumers must pay to purchase fuel efficient tyres.

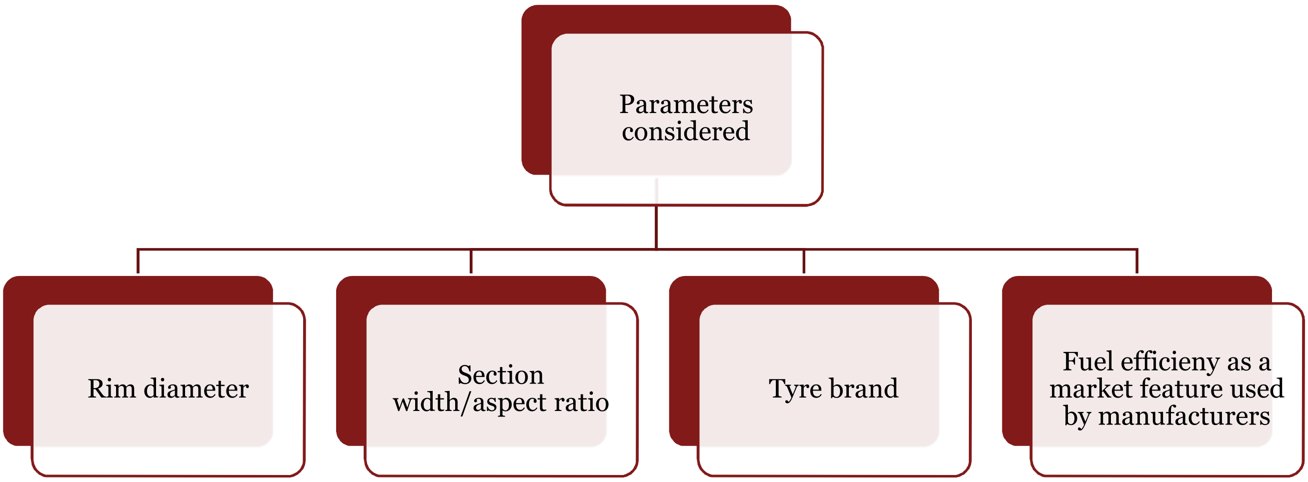


Figure 24: Parameters considered for analysis

The key terminology used for the analysis are described in **Appendix B**.

8.2. Analysis of RRC data

8.2.1. Overall RRC results and comparison with EU requirements

The existing position of the Indian passenger car tyre market relative to that of Europe is assessed in this sub-section. The existing regulations relating to tyre fuel efficiency applicable in the EU are described below. Comparison of RRC test results with those regulations is conducted in the subsequent sub-section.

Fuel efficiency regulations for tyres in the EU

There are two major regulations involving fuel efficiency of tyres sold in the EU – UNECE R117.02 and Reg. 1222/2009. UNECE R117.02 introduces maximum threshold values for RRC, and 1222/2009 introduces a mandatory labelling program for fuel efficiency of tyres, based on UNECE R117.02.

UNECE R117 was first introduced in 2005, which introduced requirements on the maximum rolling sound emissions of tyres. In 2006, the 01 series amendments to UN ECE R117 added requirements on the minimum wet grip performance of passenger car tyres (C1 tyres). In 2011, the 02 series amendments to UN ECE R117 added requirements on the maximum RR of tyres and increased the stringency of the maximum rolling sound emissions requirements.

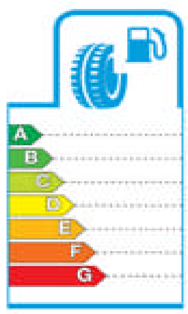
As per the 02 series amendments (UNECE R112.02), the maximum allowable RRC value for C1 tyres was 12 N/kN from November 2012 (stage 1 requirements). Since November 2016, the maximum allowable RRC value for C1 tyres is 10.5 N/kN (stage 2 requirements).

Table 19: Norms in EU for RR

	Stage 1 requirements	Stage 2 requirements
Applicability	1 November 2012	1 November 2016
Max. RRC value (Unaligned)	12 N/kN	10.5 N/kN
Applicable test procedure	ISO 28580 w/o point 10	

The threshold values of 12 N/kN and 10.5 N/kN were chosen to ensure that the regulation covers the majority of the European passenger car tyre market, which comprises of tyres of rim diameters 15" and above.

Regulation 1222/2009 establishes a mandatory labelling scheme for tyres sold in the EU. The label is based on 3 parameters – RRC, wet grip index, and noise. The labelling criteria are based on the limits prescribed in UNECE R117.02. Tyres marked as G do not conform to the stage 1 requirements, and those marked as F do not conform to the stage 2 requirements.



Fuel efficiency grade for C1 tyres	Range of RRC values (N/kN) Aligned.
A	up to 6.5
B	6.6 to 7.7
C	7.8 to 9
E	9.1 to 10.5
F	10.6 to 12
G	greater than 12

EU label requires aligned RRC values

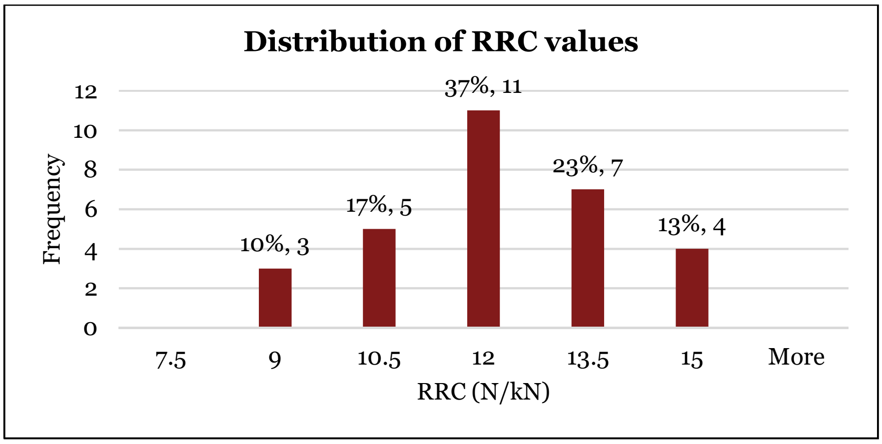
Fails with Stage 1 requirements

Fails with Stage 2 requirements

For the EU tyre labelling regulation, the fuel efficiency rating of a tyre is defined using its aligned RRC value. The aligned RRC value is calculated by applying a correction formula to the unaligned RRC value obtained through RR testing.

Distribution of RRC values

The distribution of RRC values of the sample set is illustrated through the following histogram. For plotting the histogram, the range of intervals (bin range) was chosen as *7.5 to 9 N/kN*, *9 to 10.5 N/kN*, *10.5 to 12 N/kN* and so on. This way, the bin ranges coincide with threshold values for RRC of C1 tyres established in UNECE R117.02, i.e. **12 N/kN for stage 1 requirements**[35] **and 10.5 N/kN for stage 2 requirements**[36].



Range (N/kN)	No. of tyres
7.5	-
9	3
10.5	5
12	11
13.5	7
15	4
More	-

Key observations:

The following observations were made from the above histogram:

- 64% of sample tyres meet the **stage 1 requirements**
- 27% of sample tyres meet the **stage 2 requirements**
- 37% of sample tyres have RRC values between 10.5 N/kN and 12 N/kN.

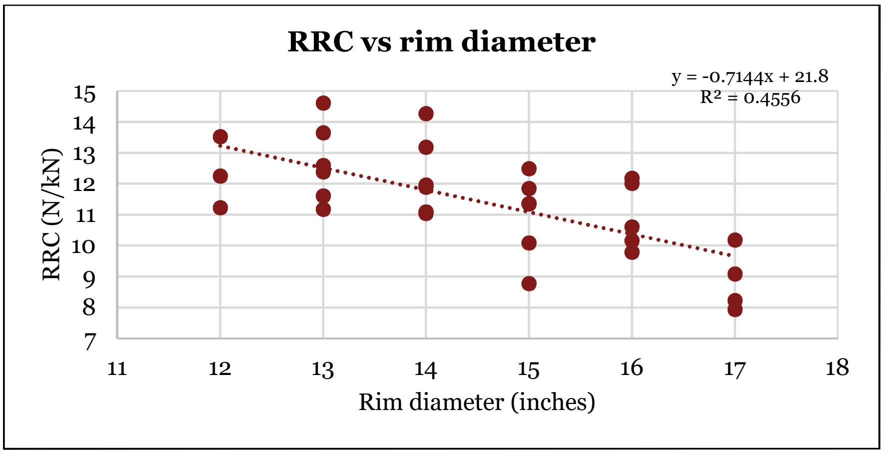
The above results indicate that more than **one-third of tyre samples fail to meet the stage 1 requirements.** Almost **three-fourth tyre samples fail the meet the stage 2 requirements**, which have been in place since November 2016. This implies that **there may be scope for improvement in RRC value in the Indian market.** However, a direct comparison of the Indian tyre market cannot be made with EU because European tyre market mostly comprises of size 15" and above and hence the values of RRC is in-general is lower there.

Also, the above representation requires further analysis into the relationships exhibited by RRC with other tyre parameters such as rim diameter, section width, tyre brand, impact of price etc. This is done in subsequent sections in this chapter.

[35] "Stage 1 requirements" refers to the RRC requirements set in UNECE R117.02 stage 1 for C1 tyres
[36] "Stage 2 requirements" refers to the RRC requirements set in UNECE R117.02 stage 2 for C1 tyres

8.2.2. Relationship between RRC & rim diameter

The RRC values obtained for the tyre sample set were plotted against the tyre's rim diameter values. The following scatter plot was obtained.



Regression results	
R-square	0.4556
Coefficient (rim diameter)	-0.7144
p-value	0.000043

S. No.	Observations
1	There is a downward sloping trend in RRC with increasing rim diameter. The regression results indicate that on average, **every 1 inch increase in rim diameter results in a decrease of 0.7144 N/kN in RRC.**
2	There is significant variation in RRC values within each rim diameter segment (approximately 26%). This indicates that **several parameters other than rim diameter influence the value of RRC**. Also, **there may be significant improvement potential in RRC for passenger car tyres**.
3	The RRC values for tyres of rim diameters 12 – 14 inches tend to be **significantly higher** than for tyres of rim diameters 15 – 17 inches.

The above results indicate that tyres with lower rim diameters tend to have higher values of RRC. This phenomenon has two major implications in the policy development process:

- Because the majority of the Indian passenger car tyre market comprises of tyres of smaller rim sizes, the Indian market on average, comprises of tyres with higher RRC values.[37]
- A single threshold value/regulation defined on RRC will likely impact tyres of rim sizes 12" to 14" first as they tend to have higher RRC values.

Consistency of results obtained from RRC-rim diameter analysis

A key result from the above analysis is that tyres with higher rim diameters tend to exhibit lower RRC values. This result is expected after examining the threshold values for RRC in UNECE R117.02 for passenger car tyres, LCV and HDV tyres.

Tyre category	RRC limit for Stage 1	RRC limit for Stage 2
C1 (passenger car tyres)	12.0	10.5
C2 (LCV tyres)	10.5	9.0

[37] The average value of RRC for tyres of rims 13", 14" and 15" was found to be 11.964 N/kN

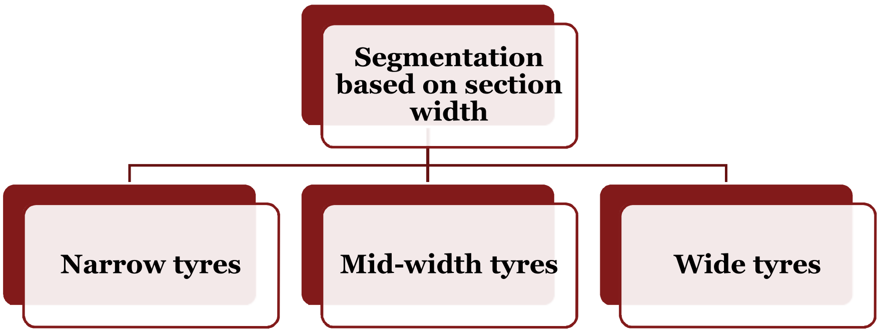
C3 (HDV tyres)	8.0	6.5

The lower RRC limits for C2 and C3 type tyres indicate that tyres of these categories exhibit lower RRC values than those of C1 category. This fact is also mentioned in **"A Handbook for the Rolling Resistance of Pneumatic Tyres" by Clark and Dodge, University of Michigan in 1979,** where it was found that while larger tyres exhibit higher rolling resistance force, the higher load factors given their higher rim diameters pull the overall RRC value low.

8.2.3. Relationship between RRC & section width/aspect ratio

It was found that section width is highly correlated with rim diameter – tyres of higher rim diameter tend to have higher section widths. Therefore, probing into the effects of section width on the value of RRC required an indirect approach, due to multicollinearity.

To circumvent this issue, the tyres were segregated into three categories – "Narrow" tyres, "Mid" width tyres, and "Wide" tyres on the basis of their section widths and rim diameters.



Segment	Brief description
"Narrow"	Tyres whose section widths are less than the "lower limit" defined for the rim diameter segment.
"Mid"	Tyres whose section widths lie between the "lower limit" and the "higher limit" defined for the rim diameter segment.
"Wide"	Tyres whose section widths are more than the "higher limit" defined for the rim diameter segment.

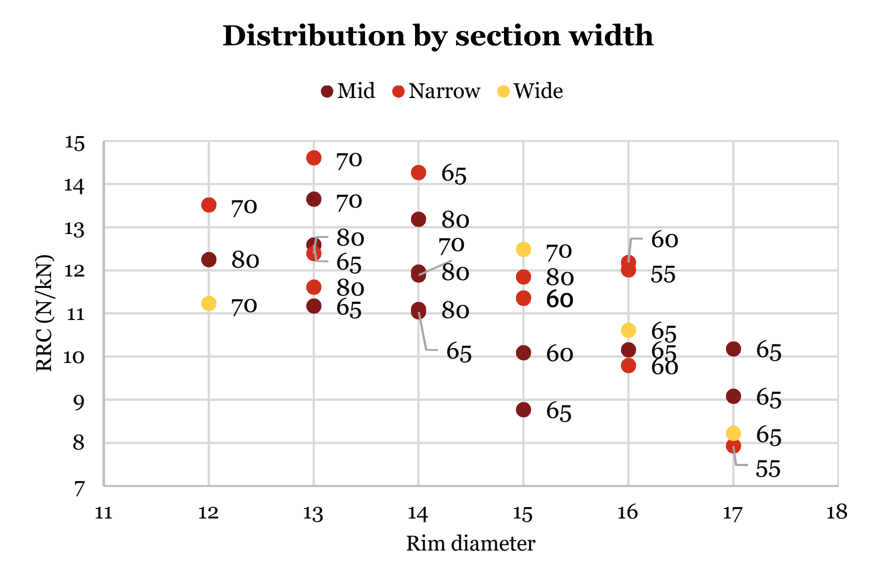
The "lower limit" and the "upper limit" for each rim diameter segment are defined in the following table.[38]

Rim diameter	Min. section width	Max. section width	Lower Limit	Upper Limit
inches	mm	mm	mm	mm
12	135	165	145	145
13	145	205	165	185
14	155	205	165	185
15	165	265	190	230

[38] The values of "lower limit" and "upper limit" are equal for the 12" rim diameter segment, because the range of section widths for that rim diameter segment is very small (30 mm).

16	185	275	210	250
17	205	265	220	240

The scatter diagram between the RRC values and the rim diameter was modified to indicate the tyre segment each sample tyre belonged to. The aspect ratio corresponding to each data point is also indicated in the diagram.



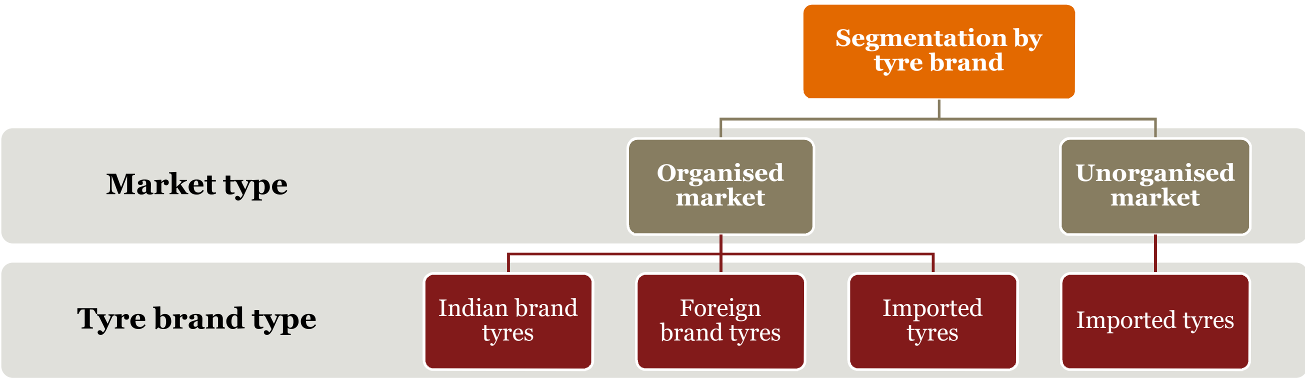
Regression results	
Adjusted R-square	0.4663
Rim diameter	-0.71163
Narrow (dummy)	0.9943
Mid (dummy)	0.1662

S. No.	Observations
1	Tyres belonging to the "Narrow" segment tend to have higher RRC values than those belonging to the "Mid" segment. The regression results suggest that, **on average, "Narrow" tyres have higher RRC values, by 0.828 N/kN, than "Mid" tyres**.
2	No significant conclusions can be made for "Wide" tyres on the basis of only 4 observations. However, **the regression results suggest that "Wide" tyres have the lowest RRC values on average, after controlling for rim diameter**.
3	The corresponding **aspect ratios of the tyres seem to be randomly distributed** across all rim diameter segments.

Mostly, this analysis is only a broad level assessment of tyres with varied widths in a particular diameter. The above results to some extent indicate that "Narrow" tyres have higher RRC values than "Mid" tyres. The results also indicate that "Wide" tyres tend to have the lowest RRC values among the three categories. Also, aspect ratio seems to have minimal bearing on the tyre RRC values.

8.2.4. Relationship between RRC & tyre brand

The analyses conducted in this subsection probe into the relationship between RRC and tyre brand. For this analysis, the tyre sample set has been segmented on the basis of tyre brand, as shown in the following figure. The definitions of these segments are provided in the table below the figure.

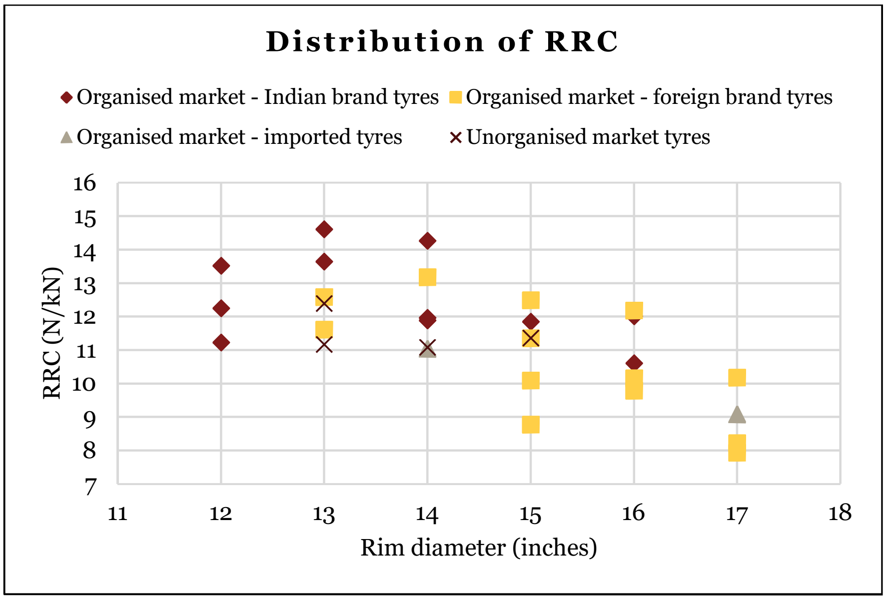


Segment	Definition
Organised market – Indian brand	Tyres sold by manufacturers predominantly based in India. This segment includes tyres of manufacturers such as Apollo tyres, MRF tyres etc.
Organised market – foreign brand	Tyres sold by manufacturers that are either subsidiaries to Global brands, or are aligned with established foreign manufacturers. This segment includes tyres of manufacturers such as Michelin. Some of the tyres in this segment are specifically designed for sale in India.
Organised market – imported	Tyres that are imported from other countries through organised channels. Tyres in this segment are not specifically designed for sale in India. This segment includes tyres of manufacturers such as Pirelli.
Unorganised market – also imported tyres	This segment includes tyres which are sold through unorganised channels. These tyres are characterised by unusually low prices.

The tyre sample set was segregated on the basis of the above-mentioned criteria. The distribution of the sample set is described in the following table.

Rim diameter	Organised - Indian brand	Organised - Foreign brand	Organised - Imported	Unorganised
12”	3	-	-	-
13”	2	2	-	2
14”	3	1	1	1
15”	1	4	-	1
16”	2	3	-	-
17”	-	3	1	-
Total	**11**	**13**	**2**	**4**

The scatter plot between RRC and rim diameter was modified to reveal information on the brand segment that each data point belongs to.



Regression results	
Adjusted R-square	0.4955
Rim diameter	-0.5891
Indian brand	1.0099

The range of RRC values of samples tyres for each brand segment and for each rim diameter segment were calculated and summarized.[39]

Rim diameter	Organised - Indian brand	Organised - Foreign brand	Organised - Imported	Unorganised
12”	11.23 - 13.52	-	-	-
13”	13.65 - 14.61	11.61 - 12.59	-	11.17 - 12.39
14”	11.89 - 14.27	13.18	11.04	11.09
15”	11.85	8.77 - 12.49	-	11.36
16”	10.61 - 12.01	9.79 - 12.18	-	-
17”	-	7.93 - 10.18	9.08	-

S. No.	Observation
1.	Tyres from the organised market – Indian brand segment tend to have higher RRC values, by 1 N/kN on average, than tyres from other segments
2.	There is no significant difference in RRC values of tyres belonging to the other three tyre segments

The above results indicate that Indian brand tyres exhibit slightly higher values of RRC than other tyres in the market. However, this may also be due to the fact that foreign brand tyres are generally with larger rim diameters. The above analysis presents the situation based on the 30 samples selected for the study.

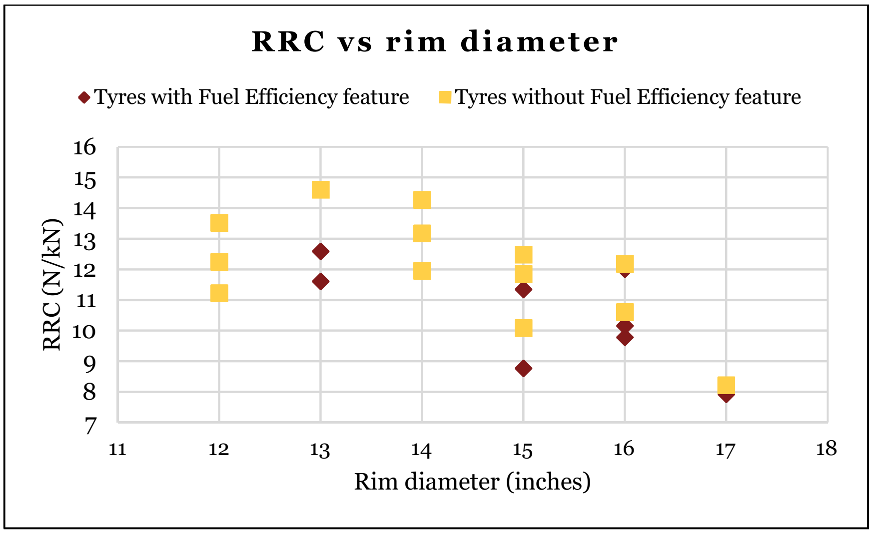
[39] The colours in the cells were obtained through conditional formatting. Higher values are marked in red, while lower values are marked in green.

8.2.5. *Assessment of the "fuel efficiency" feature in tyres*[40]

Tyre manufacturers specify the characteristics of a tyre brand in its advertisements and brochures. These characteristics include fuel efficiency, high wet grip, wet braking performance, high mileage etc.

The analysis shown in this subsection assessed whether there is a significant difference in RRC values between tyres branded as fuel efficient and those that are not. For this assessment[41], **tyres in the sample set were segregated into two segments – tyres with the fuel efficiency feature, and tyres without the fuel efficiency feature**.

The scatter plot between RRC and rim diameter was modified to reveal information on the segment that each data point belongs to.



Regression results	
Rim diameter coefficient	**-0.6603**
Fuel Efficiency (dummy) coefficient	**-0.9187**

The modified scatter plot reveals that **tyres branded as fuel efficient had lower RRC values within almost all rim diameter segments**. *This indicates that the technology for manufacturing fuel efficient tyres may already be available with tyre manufacturers in India.*

Performing regression analysis on the data suggests that **tyres with fuel efficiency feature tend to have, on average, a lower value of RRC by 0.9187 N/kN, than tyres without the feature**.

[40] As declared by tyre manufacturers
[41] Only 21 tyres were considered for this assessment

8.3. Analysis of wet grip data

8.3.1. Overall wet grip results and comparison with EU requirements

Wet grip regulations for tyres in the EU

The **regulation UNECE R117 has set minimum standards for wet grip that must be met** by all tyres that come under the scope of the Regulation. The test methods for measuring the three parameters have been specified in the annexures of the Regulation.

Table 20 shows the minimum value of G that ***tyres of category C1*** must maintain as per the regulation.

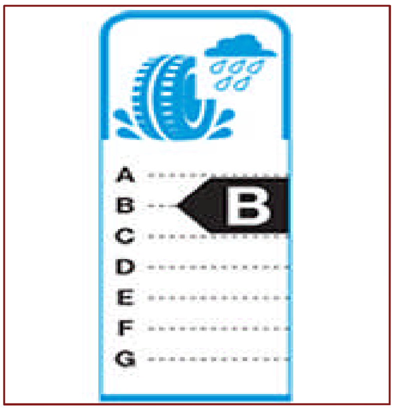
Table 20: Minimum value of G

Tyre category	G
Snow tyre with speed symbol indicating permissible speed ≤ 160 km/hr	0.9
Snow tyre with speed symbol indicating a maximum permissible speed > 160 km/hr	1.0
Normal (regular use) tyre	1.1

In addition, the EU tyre labelling regulation has defined a grading scheme for wet grip index for C1, C2 and C3 tyres. This is illustrated in the following table.

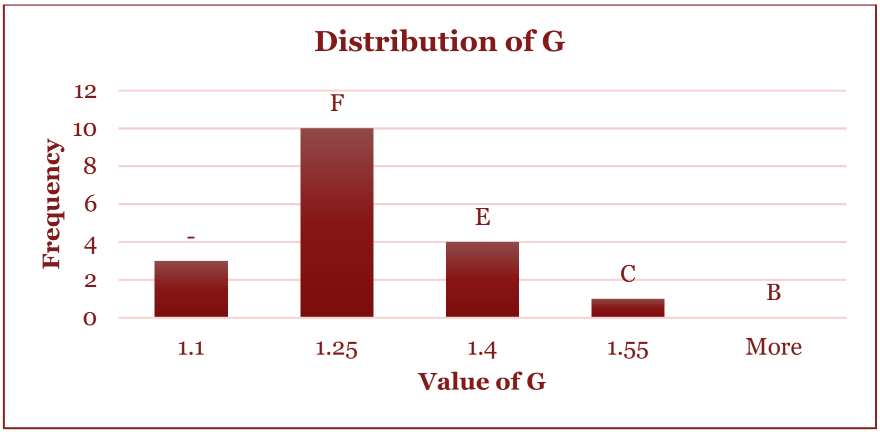
Table 21: The EU wet grip grading using wet grip index (G)

Class	PCR (C1)	LTR (C2)	TBR (C3)
A	1.55 ≤ G	1.40 ≤ G	1.25 ≤ G
B	1.40 ≤ G ≤ 1.54	1.25 ≤ G ≤ 1.39	1.10 ≤ G ≤ 1.24
C	1.25 ≤ G ≤ 1.39	1.10 ≤ G ≤ 1.24	0.95 ≤ G ≤ 1.09
D			0.80 ≤ G ≤ 0.94
E	1.10 ≤ G ≤ 1.24	0.95 ≤ G ≤ 1.09	0.65 ≤ G ≤ 0.79
F	G ≤ 1.09	G ≤ 0.94	G ≤ 0.64



Distribution of wet grip index values

The distribution of wet grip values of the sample set is illustrated through the following histogram. For plotting the histogram, the range of intervals (bin range) was chosen *as 0 – 1.10, 1.10 – 1.25, 1.25 – 1.40, 1.40 – 1.55, and 1.55 & above*. This way, the bin ranges coincide with threshold values for wet grip index of C1 tyres established in UNECE R117.02 and the EU labelling program, with the limit value for G defined at 1.10.



Range (N/kN)	No. of tyres
1.1	3
1.25	10
1.4	4
1.55	1
More	0

Key observations:

The following observations were made from the above histogram:

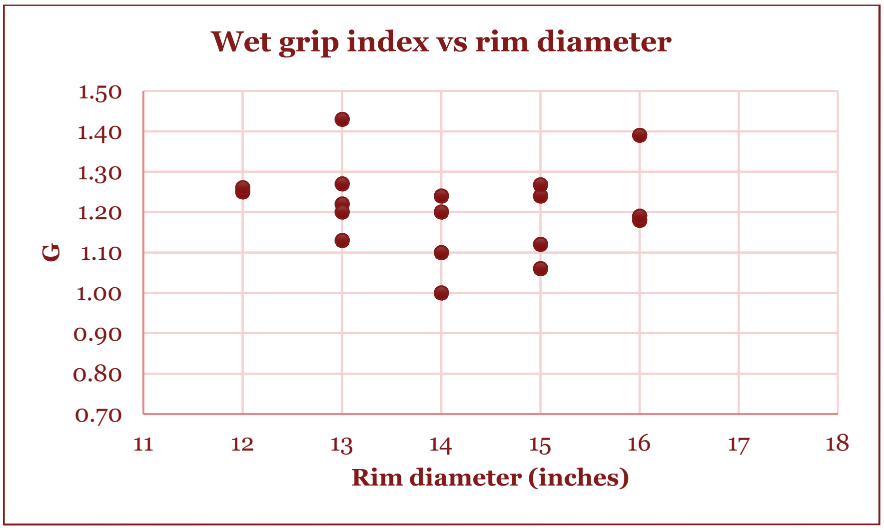
- 83% of sample tyres meet the **wet grip requirements of UNECE R117.02**
- **Most sample tyres (56%) just meet the requirements** and are rated E

The above results indicate that **most tyre samples (87%) meet the limit of 1.10 defined in UNECE R117.02.** However, **78% of sample tyres have wet grip index values between 1.1 and 1.4**. Only 1 sample tyre would qualify for a rating B for wet grip. **No sample tyre would receive a rating of A**.

This implies that while most of the Indian market meets the minimum requirements of UNECE R117, **there may be scope for improvement in wet grip value in the Indian market.**

8.3.2. Relationship between wet grip index & rim diameter

The wet grip values obtained for the tyre sample set were plotted against the tyre's rim diameter values. The following scatter plot was obtained.



Regression results	
R-square	0.01347
Adjusted R-square	-0.04818
Coefficient (rim diameter)	-0.00936
p-value	0.64644

S. No.	Observations
1	The values of G seem to be randomly distributed w.r.t. rim size. Also, the value of R-square and p-value suggest that the relationship between G and rim diameter is negligible.
2	There is significant variation in wet grip values within each rim diameter segment

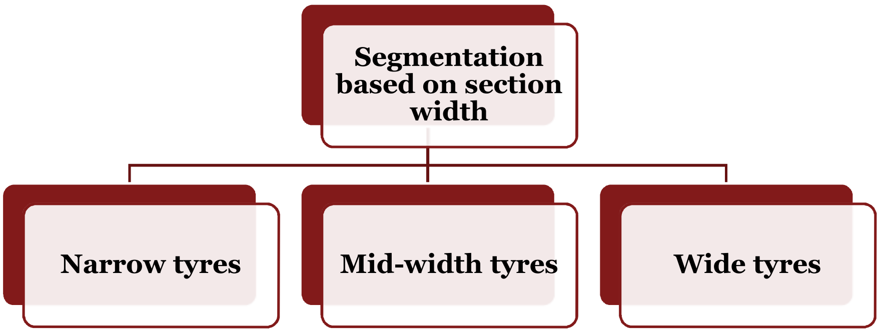
The above results **indicate that the wet grip index values of tyres do not depend on their rim sizes**. This phenomenon has two major implications in the policy development process:

- A common baseline for wet grip index across the entire passenger car market is appropriate
- There is no requirement to consider effects of rim diameter in consequent analyses

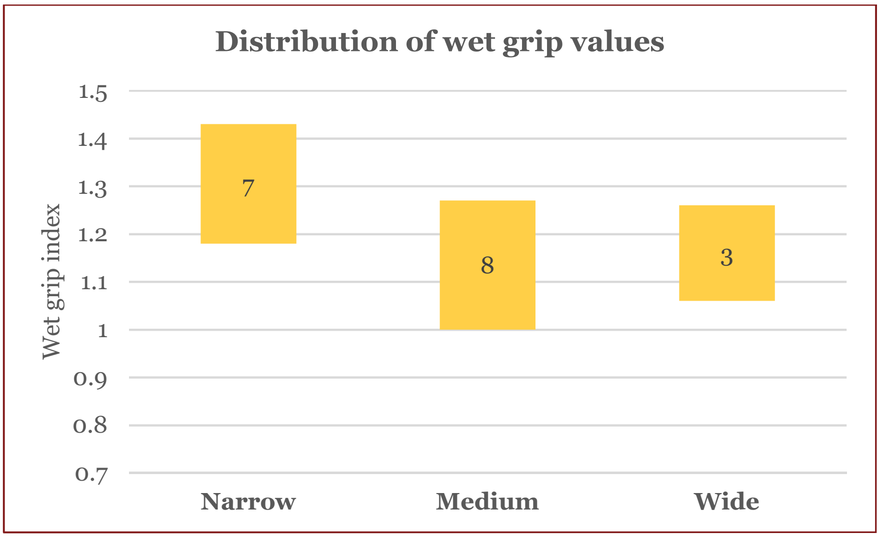
8.3.3. Relationship between wet grip index & section width

It was found that section width is highly correlated with rim diameter – tyres of higher rim diameter tend to have higher section widths. Therefore, probing into the effects of section width on the value of wet grip index required an indirect approach, due to multicollinearity.

To circumvent this issue, the tyres were segregated into three categories – “Narrow” tyres, “Mid” width tyres, and “Wide” tyres on the basis of their section widths and rim diameters, just as in the case of RRC.



The following scatter diagram was constructed to probe into the relationship between G and section width. The box shows the range of wet grip index for each segment of tyre, and the number in the box shows the number of samples within the segment.



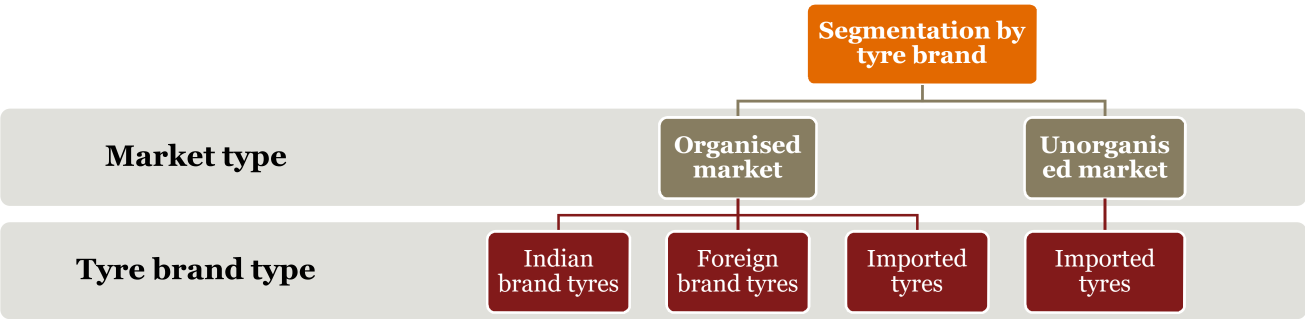
Regression results	
Adjusted R-square	0.10848
Narrow (dummy)	0.09884
Mid (dummy)	-0.01043

S. No.	Observations
1	Tyres belonging to the “Narrow” segment tend to have slightly higher wet grip values than those belonging to the “Mid” and “Wide” segments. The regression results suggest that, **on average, “Narrow” tyres have higher G values, by 0.09884, than “Wide” tyres**.
2	No significant conclusions can be made for “Wide” tyres on the basis of only 3 observations.

Mostly, this analysis is only a broad level assessment of tyres with varied widths. The above results to some extent indicate that “Narrow” tyres have higher G values than “Wide” tyres. However, given the low value of adjusted R-square and the small sample size involved, **the results are not statistically significant**.

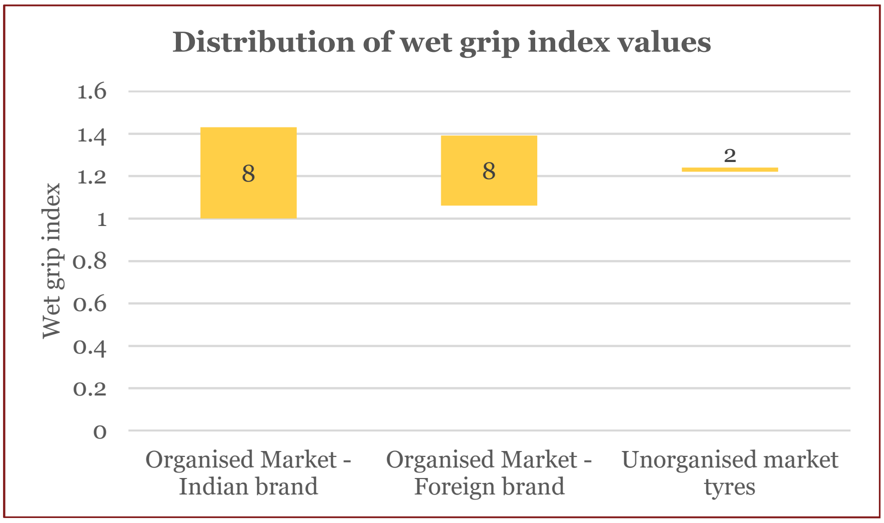
8.3.4. Relationship between wet grip index & tyre brand

The analyses conducted in this subsection probe into the relationship between RRC and tyre brand. For this analysis, the tyre sample set has been segmented on the basis of tyre brand, as shown in the following figure. The definitions of these segments are provided in the table below the figure.



Segment	Definition
Organised market – Indian brand	Tyres sold by manufacturers predominantly based in India. This segment includes tyres of manufacturers such as Apollo tyres, MRF tyres etc.
Organised market – foreign brand	Tyres sold by manufacturers that are either subsidiaries to Global brands, or are aligned with established foreign manufacturers. This segment includes tyres of manufacturers such as Michelin. Some of the tyres in this segment are specifically designed for sale in India.
Organised market – imported	Tyres that are imported from other countries through organised channels. Tyres in this segment are not specifically designed for sale in India. This segment includes tyres of manufacturers such as Pirelli.
Unorganised market – also imported tyres	This segment includes tyres which are sold through unorganised channels. These tyres are characterised by unusually low prices.

The tyre sample set was segregated on the basis of the above-mentioned criteria. The following scatter diagram was constructed to probe into the relationship between G and make. The box shows the range of wet grip index for each segment of tyre, and the number in the box shows the number of samples within the segment.

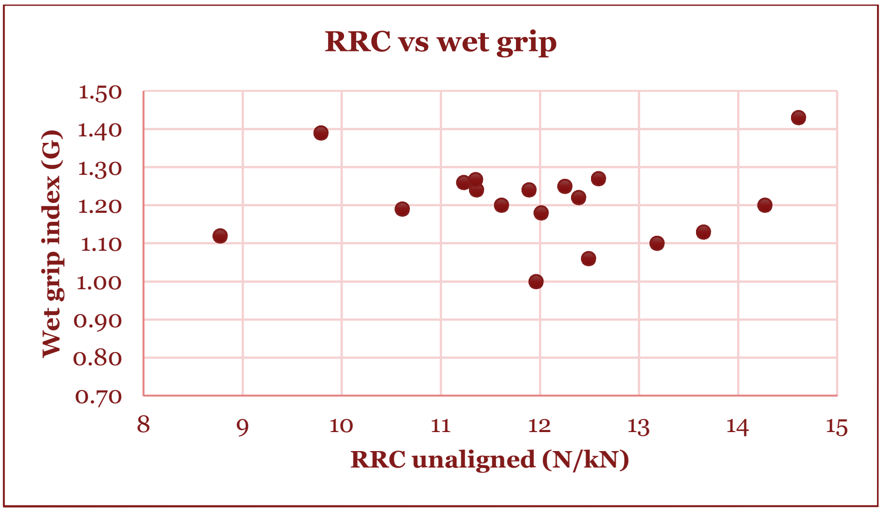


Regression results	
Adjusted R-square	-0.19091
Rim diameter	-0.5891
Indian brand	1.0099

Mostly, this analysis is only a broad level assessment of tyres with different brands. The above results to some extent indicate that values of G do not depend on brand type. However, **given the low value of adjusted R-square and the small sample size involved, the results are not statistically significant**.

8.4. Relationship between RRC and wet grip index

The relationship between RRC and wet grip values is investigated in this section. To this end, a scatter diagram between the RRC values and wet grip values for 18 tyres was plotted. In addition, a single variable linear regression was performed to further investigate any relationships between the two variables. The results are shown below.



Regression results	
R-square	0.00149
p-value	0.87919
Coefficient (RRC)	0.00280

S. No.	Observation
1.	No particular pattern is observed between RRC and wet grip index values
2.	The R-square value of the linear regression is 0.00149. This implies that the linear regression fails to explain the variation in values of wet grip index.
3.	The value of the RRC coefficient is 0.00280 and the p-value is 0.87919. This implies that the results of the regression are not statistically significant. Also, even if it were, the coefficient is nearly zero, implying independence of wet grip index on RRC values.

From the above observations, we can conclude with relative certainty that **wet grip index value of a tyre does not depend on its RRC value**. This has two important implications from a policy perspective:

- Consumers have the option of purchasing tyres with lower RRC values without compromising on wet grip performance.
- If an appropriate policy option is set in motion, the overall fuel efficiency of the passenger car tyre market in India can be improved without compromising on safety.

8.5. Summary & key findings

The RRC and wet grip index test results have brought out crucial insights into the relationships exhibited by these parameters with each other and with other tyre parameters. These insights are extremely relevant in the benchmarking process, and identifying appropriate policy options for moving forward with the fuel efficiency mandate.

The following major conclusions were made from examination of test results:

1. Because tyres of smaller rim sizes exhibit higher RRC values, introduction of threshold values for RRC would have a higher impact on tyres of smaller rim sizes. Incidentally, the Indian passenger car tyre market is dominated by lower rim sizes contrary to that of EU or other developed economies where the tyre sizes are generally higher. The results of RRC values for the sample set indicates that considering the EU stage 1 or 2 norms for India would not be practical if it is considered for the entire market. There can be a few options which needs further investigation:

    - Should a threshold value which is different from the one defined in the EU be adopted in India, given different market conditions.

    - Should there be two threshold value for RRC i.e. one threshold value for tyre size 12" to 14" and other value for 15" and above.

    - Should the value be based on the test results obtained from tyre size 12" to 14" only because higher sizes of tyres will mostly meet the RRC standards defined for lower tyre sizes

    These options are further discussed in the next chapter.

2. The significant variation of RRC values within a rim diameter segment implies that atleast few fuel efficient tyre options are already available in the Indian market. Incidentally, tyres marketed as "Fuel Efficient" in the Indian market exhibited lower values of RRC.

3. The value of a tyre's wet grip index does not vary with its rim diameter, its section width, its RRC or any other parameter. Also most of the tyre samples complied with the threshold limit value of 1.10 defined in UNECE R117.02. Therefore, a single threshold value for wet grip index across all rim sizes is appropriate. The selection of a threshold value is discussed in the next chapter.

4. As there is very little correlation between RRC and wet grip index, consumers have the option of purchasing tyres with lower RRC values without compromising on wet grip performance. This indicates that a policy option such as fuel efficiency labelling can positively impact the Indian market.

9. Benchmarking of RR & wet grip performance

The objective of the benchmarking process is to understand and evaluate the current position of the Indian tyre market in relation to a defined baseline value, and to identify appropriate policy options to achieve performance improvement.

However, prior to defining the benchmarking process for India, firstly the benchmarking processes adopted by standard & labelling programs in other countries has been studied. The countries with established labelling programs are shared below. The details on the programs and their implementation are provided in Appendix C of this report.

The EU	Japan	South Korea

It was found that all of the above programs are aligned with the limits specified in the limits specified in UNECE R-117, which sets the benchmark value for tyre RRC 12 N/kN in stage 1, and 10.5 N/kN in stage 2, for tyres of all rim diameters.

However, the approach may not be the most appropriate for India, since the predominant sizes in the European market is 15" and above, where as in India, majority of tyres range from 12" to 14". So, while the common benchmark value of 12 N/kN applies to tyres of all rim diameters in the EU, effectively the common benchmark impacts tyres of higher rim diameters due to the fact that market in EU and other developed countries is dominated by passenger cars of higher weight segment, features, luxury etc. and such vehicles usually comprise of tyres of diameter 15" and above.

In India, tyres of this rim size, as seen from the data, already have lower RRC values and most qualify for the stage 1 limit of EU. However, tyres of rim diameters 12" to 14", given their lower sizes and consequently higher RRC values may find it difficult to qualify for this benchmark.

This implies that if a common benchmark value for all tyre sizes is adopted in India, the requirements will be more stringent on tyres of lower rim diameters, which form the majority in India, than on higher rim diameters. To circumvent this issue, two more approaches for benchmarking, other than the common benchmark approach adopted in the EU, are assessed on a case-wise basis. The three cases identified are described next.

Case 1 - common benchmark approach

- Defining a standalone value of RRC applicable to the entire population of passenger car tyres.
- This is the most common approach for defining the benchmark of RRC and is inline with that of EU where all tyres irrespective of rim size and aspect ratio gets compared with a standalone value of RRC.

Case 2 - grouped benchmark approach

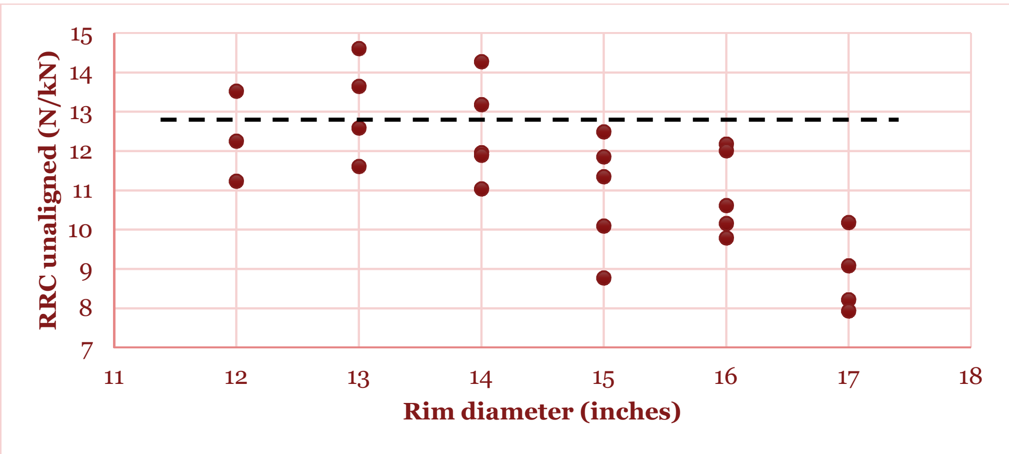
- Defining two benchmark values of RRC - one for tyres of lower rim diameters (12" to 14") and one for higher rim diameters (15" and above).
- With this approach, a slightly linient benchmark value is defined for the former, to compensate for the effect low rim diameters has in increased value of RRC.

Case 3 - benchmarking using a dummy variable

- Defining a benchmark value using a dummy variable (derived from RRC and rim diameter) which neutralises the effect of rim diameter on RRC.
- This approach describes a single benchmark for tyres of all rim diameters, but as the benchmark is based on another parameter, the effect of relationship between rim diameter on RRC is effectively neutralised.

Case 1: common benchmark approach

Through the common benchmark approach, benchmarking of fuel efficiency performance of tyres is based solely on the unaligned[42] value of RRC of passenger car tyres, regardless of their rim diameters. The overall impact of the benchmark on the tyre market is depicted graphically in the following figure.



The resultant benchmark value will be common for tyres of all rim diameters. All tyres falling north of the benchmark exhibit a performance below that of the benchmark, and would fail to comply with a standard. The figure shows that with a common benchmark approach, tyres with smaller rims are more likely to fall below the benchmark value than those with larger rims.

Therefore, **standards based solely on RRC is likely to impact tyres of smaller rims more, which incidentally makes up majority of the Indian market**.

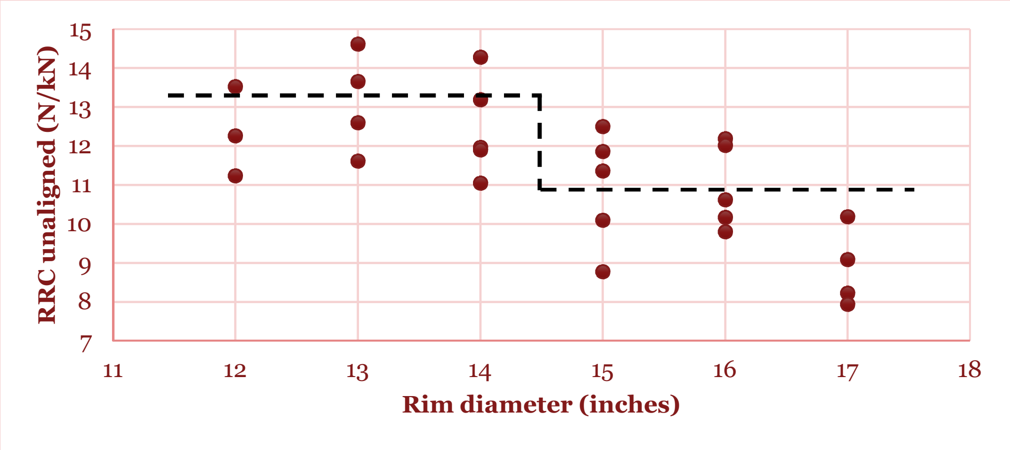
[42] RRC unaligned is the value of RRC obtained through testing of tyres. These values have not been aligned with reference labs because IRMRA's lab alignment process is still underway.

Case 2: grouped benchmark approach

To circumvent the issue of higher impact on tyres with lower rim diameters in the common benchmark approach, separate benchmark RRC values are defined for tyres of lower rim diameters and tyres of higher rim diameters, hence the grouped benchmark approach. Here, two groups are defined on the basis of the analysis discussed in previous chapter, and are shown below.

- Group 1 – tyres of lower rim diameters, i.e. 12” to 14”
- Group 2 – tyres of higher rim diameters, i.e. 15” and above

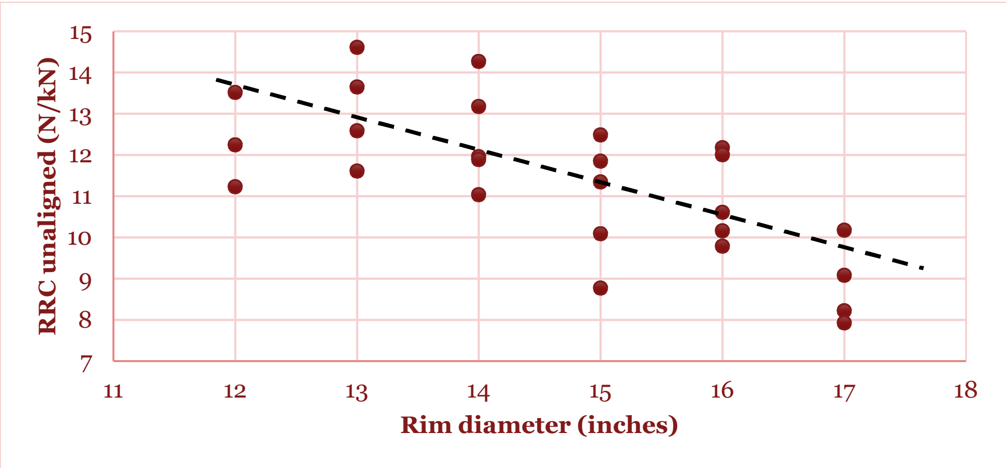
The overall impact of this approach on the tyre market is depicted graphically in the following figure.



All tyres falling above the benchmark line exhibit a performance below that of the benchmark, and would fail to comply with a standard. The figure shows that with the grouped benchmark approach, the overall impact of the benchmark is equally distributed between the two tyre groups.

Case 3: benchmarking using a dummy variable

Another approach to circumvent the issue of higher impact on tyres with lower rim diameters in the common benchmark approach is described here. This approach is essentially an expansion of the grouped approach, but instead of defining different benchmark RRC values for different groups, benchmarks are defined on a dummy variable, which removes the net impact of rim diameter from RRC. The dummy variable is chosen such that the effect of the relationship between rim diameter and RRC is effectively neutralized. The overall impact of the benchmark on the tyre market is depicted graphically in the following figure.



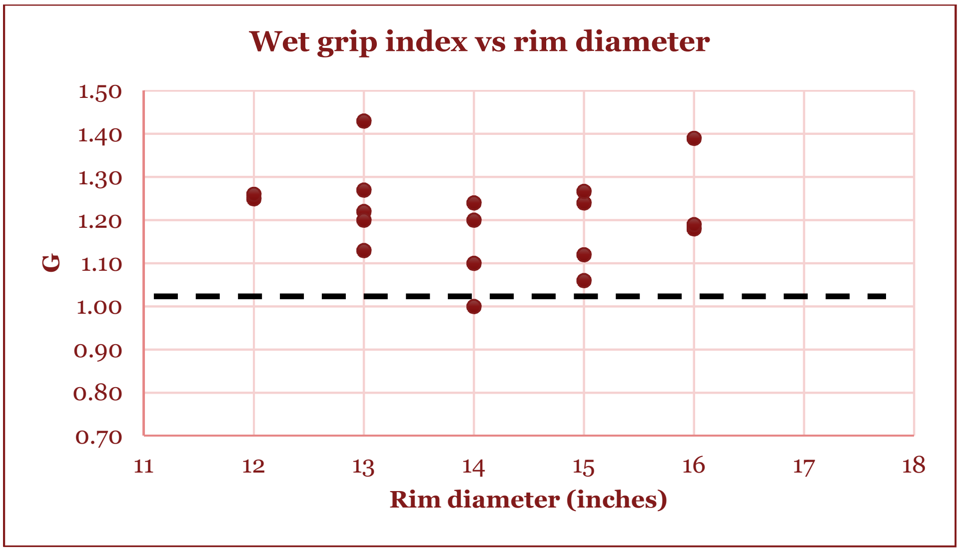
All tyres falling north-east of the benchmark line exhibit a performance below that of the benchmark, and would fail to comply with a standard. The figure shows that with this approach, tyres of all rim sizes are equally impacted by the benchmark, unlike in the common benchmark approach.

It is important to note that the dummy variable is simply used to determine where the benchmark lies, and has no physical significance. The determination of the line equation that describes the benchmark line in this case is shown in the **Appendix E.**

Assessment matrix for the 3 approaches

	Case 1	Case 2	Case 3
Approach	Common benchmarking approach	Grouped benchmarking approach	Benchmarking on the basis of dummy variable
Characteristics of benchmark	One benchmark for all tyres	Two separate benchmarks: • One for low rim sizes (12” to 14”) • One for high rim sizes (15”+)	One benchmark for all tyres
Benchmarking parameter	RRC unaligned	RRC unaligned	RRC vs rim diameter line (derived using dummy variable)
Stringency on low rim sizes	High	Distributed	Distributed
Stringency on high rim sizes	Low		
Fuel saving potential	High	Medium	Medium
Relative ease of implementation	Easy	Easy	Difficult

Approach for benchmarking of wet grip index



The approach for benchmarking of wet grip performance of tyres in the Indian market is more straightforward since the value of a tyre's wet grip index does not vary significantly with other parameters. Therefore, a single threshold value across the entire passenger car tyre market, as done in the EU, is most appropriate.

A threshold value will likely impact the market as shown in the following figure. All tyres lying below the threshold value (indicated by the black dashed line) will fall below the limit.

The European Case study: Assessment of the impact of the EU tyre labelling regulation

The EC passed the Regulation 1222/2009 with a goal to improve the safety, the economic and environmental efficiency of road transport by promoting fuel-efficient and safe tyres with low noise levels. The label specifications are aligned with the standards specified in UN ECE R-117, and were made mandatory from 2012.

A review study conducted on the tyre labelling regulation conducted in March 2016 suggests that the regulation "***has been able to transform the market in a positive direction from 2013 to 2015, although the positive tendency is less obvious for external rolling noise than for fuel efficiency and wet grip.***"[43]

The study purchased market data from two major EU tyre databases – TOL[44] (Germany) and VACO[45] (Holland) and supplemented with information from industry associations to create a tyre stock model for use in scenario calculations. Analysis of the market data shows that the Tyre Labelling Regulation has driven an increased R&D and technology innovation effort, resulting in increased wet grip performance of tyres, as well as optimisation of fuel efficiency leading to decreased fuel consumption.

Predicted C1 RRC value (fast pace)	Corresponding FE class	Actual C1 RRC value (avg. of TOL & VACO)	Corresponding FE class
10.52	E	9.27	E

The comparison showed that the observed RRC values in 2015 is lower for C1 tyres than predicted, though they still fall into labelling class E. However, the assessment concluded that the lower rolling resistance in 2015 is not due to faster changes in 2013-2015, but due to a lower starting point in 2013, than anticipated in the EPEC impact assessment.

But, the report also suggested that **rolling resistance change rates are likely to increase during the coming years if the implementation is continuously supported.**

Surveys were also prepared and conducted as a part of the study to assess the tyre buying behaviour of the end-users, the end-user awareness of the Tyre Labelling Scheme, and the need for further information on the label.[46] The C1 end-user survey showed that around half of the private car owners in the surveyed countries are aware of the tyre label, and that most (64 %) have medium confidence in the labelling scheme.

The findings of the report show that appropriate policy measures for tyres cab be successful in improving RR performance of tyres without deteriorating their wet grip performance.

[43] "Review study on the Regulation (EC) No 1222/2009 on the labelling of tyres", March 2016
[44] Tyres online and Energy GmbH
[45] Dutch Tyre and Wheel Trade Association
[46] The surveys were highly focused towards C1 tyres

9.1. Determination of benchmark values for RRC & wet grip index

The appropriate benchmarking methodology for RR and wet grip is determined in the previous section. This section describes the methodology used to arrive at possible benchmark values of RRC and wet grip index.

9.1.1. Benchmark value of tyre RRC

Benchmark values for a particular parameter are defined on the basis of percentiles, and used to generate a baseline to facilitate policy development. This analysis has been done using the results for the sample tyres tested for RRC and G values.

For the three approaches for benchmarking of RRC values discussed in the previous section, appropriate benchmark values can be set on the basis of the following tables. Each table below describes the various percentile values corresponding to the benchmarking approaches described in the previous sections. For example, in Table 22, if the benchmark is set at 10.09 N/kN, only 20% of the tyre within the sample set would meet the benchmark.

Table 22: Benchmark values based on the common baseline approach

Percentile	RRC unaligned. (N/kN)
20%	10.09
40%	11.23
50%	11.73
60%	11.96
80%	12.59

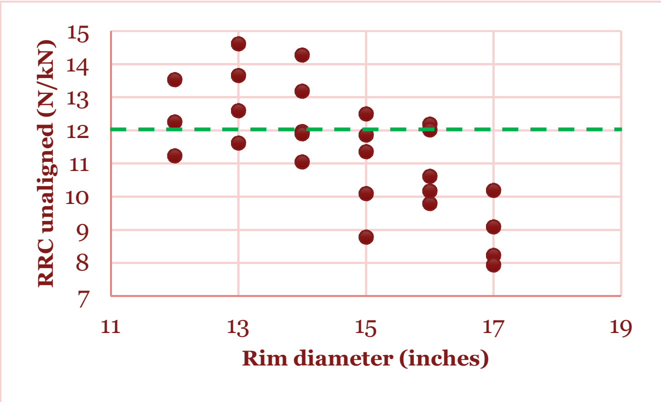


Table 23: Benchmark values based on the grouped baseline approach

Rim diameter 12" to 14"		Rim diameter 15" and above	
Percentile	**RRC unaligned**	**Percentile**	**RRC unaligned**
20%	11.67	**20%**	8.96
40%	12.08	**40%**	10.10
50%	12.42	**50%**	10.17
60%	12.94	**60%**	10.52
80%	13.62	**80%**	11.91

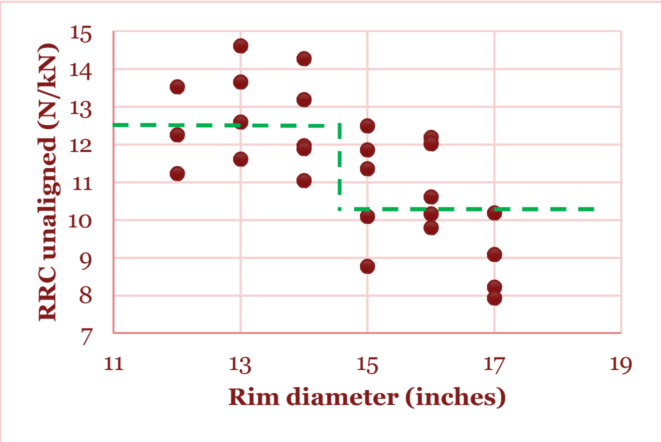
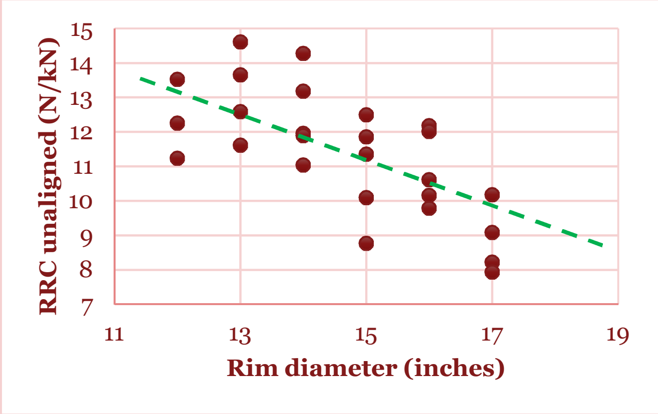


Table 24: Benchmarking on the basis of a dummy variable (see Appendix E)

Percentile	Value of dummy variable	Value of intercept
20%	10.09	21.4855
40%	10.92	22.3152
50%	11.17	22.5608
60%	11.35	22.7455
80%	12.42	23.8158

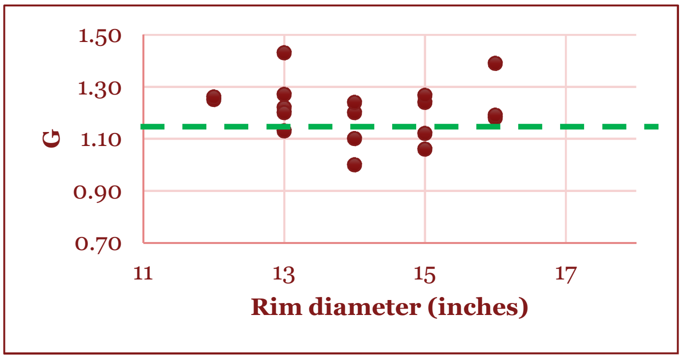


9.1.2. Benchmark value of wet grip index

The benchmark value for wet grip index can be determined by adopting an approach similar to that used for RRC benchmarking. The percentile values for wet grip index are mentioned below:

Table 25: Benchmark values for wet grip index

Percentile	Wet grip index (g)
20%	1.26
40%	1.24
50%	1.21
60%	1.20
80%	1.12



Alternatively, the limit value of 1.10 applicable in the EU can also be adopted. It is estimated that approximately 88% of the market will be above the threshold value.

10. Recommendations and next actions

A policy is a course of action proposed by an organisation or an individual to bring about a desired change. In this chapter, an appropriate policy option is identified to improve the overall fuel efficiency of the Indian passenger car tyre market without compromising on other aspects including safety.

10.1. Appropriate policy option for achieving improvement in RRC & wet grip index

As discussed in earlier section, several benchmarking and policy options are available for stakeholders to achieve an improvement in tyre RRC and consequently, fuel efficiency. The underlying objective for policy development is "**minimizing the value of RRC in tyres, but without downgrading the overall wet grip/safety performance**". To bring about this objective, three options were identified, as shown in the following table.

Table 26: Possible policy options

	Policy for RRC	Policy for wet grip
Option 1	Labelling	Labelling
Option 2	MEPS	Minimum threshold value
Option 3	Labelling	Minimum threshold value

Based on our understanding of the subject matter and past experience in tyre labelling, we believe that improvement in tyre RR and improvement in tyre wet grip should go simultaneously, and therefore the policy option must be such that manufacturers are prohibited from downgrading wet grip performance in order to improve fuel efficiency.

10.2. Case for standard & labelling program for passenger car tyres

The standard & labelling program is one such policy which is globally accepted and has proved a cost effective solution to drive fuel efficiency in the transport sector.

Given that fuel efficient options are already available in the Indian passenger car market and wet grip index values are independent of RRC values, consumers have the option to upgrade to fuel efficient tyres without compromising on the safety aspect. This implies sales of fuel efficient tyres may increase if consumers are able to make a more informed choice during purchase of tyres (in the replacement market). This presents a case of labelling of fuel efficiency of passenger car tyres.

To improve fuel efficiency, we propose a comparative labelling program for tyre RRC. The tyre industry is already under pressure from OEMs to improve the fuel efficiency (and thereby reduce RRC) of their tyres, on the backdrop of the fuel efficiency policies such as CAFE norms and the upcoming passenger car S&L programme. The comparative labelling program's objective for tyres will be to impact the replacement market, where consumers have a choice to purchase fuel efficient tyres. This will lead to a consumer-driven push for fuel efficiency, and complement the ongoing fuel efficiency programs in India.

However, it must also be ensured that a consumer driven push for tyres with high fuel efficiency does not result in introduction of tyres with poor wet grip performance in the future. This presents a case for a threshold limit value for wet grip index of passenger car tyres.

For wet grip index, the limiting value we propose is equal to the lowest performing tyre in the market. This is because it might prove costly for the manufacturers to improve both RR & wet grip simultaneously, and hence might result in an increase in prices. Also, at present, many manufacturers may not have the technology to do so. This may cause a market disruption in the short term, which is not healthy for the industry as a whole. Instead, manufacturers should be afforded time to develop their technology in the next 5-10 years, during which the limit for wet grip should get more stringent.

10.3. Evaluating the readiness for defining S&L programme for passenger car tyres

The standards and labelling programme broadly require seven major steps for implementation as shared below:

- Undertake detailed market analysis
- Define the reference standard /test procedure for tyres
- Evaluating the infrastructure for testing of tyres
- Generate energy /fuel performance data
- Develop Minimum Energy Performance Standard /labelling framework
- Develop Monitoring Verification & Enforcement (MV&E) protocols
- Launch of S&L programme
- Training & capacity building of stakeholders

Table 27: Readiness for defining S&L programme for passenger car tyres

Activity	Readiness				Status
	Not started	Beginning	Intermediate	Advanced	
Detailed market analysis				√	Market assessment of the Indian passenger car tyres provides considerable information to proceed for next steps
Define the reference standard /test procedure for tyres			√		The TED7 committee in BIS has prepared a draft test procedure based on UNECE R117.02
Infrastructure for testing of tyres		√			Though RR and Wet Grip testing is possible in India however the capacity is limited at present. Specifically for wet grip testing there are limitation in existing infrastructure. There is a need for creating more infrastructure in the country before proceeding for the labelling programme
Generate performance data		√			The TED7 committee has formed a working group to collect RRC and wet grip index data of all tyres in the Indian market for analysis purpose. Further, the data and analysis provided in this report shall support the stakeholders for

					deliberations towards defining the standards
Development of standards for RRC and wet grip index		√			The work towards setting the minimum requirement for RRC and Wet Grip is underway. However, the work towards defining the labelling framework has not started yet. Once BIS defines the minimum requirement thereafter BEE shall initiate deliberations amongst the stakeholders for labelling band /type etc.
MV&E protocols	√				Discussion on MV&E protocols shall be initiated once BEE formulates the technical committee
Launch of S&L program	√				-
Training and capacity building	√				-

Initiation of the standards and labelling programme for tyres require formulation of a technical committee by Bureau of Energy Efficiency followed by a detailed deliberation on setting norms for the label.

Deciding on the test procedure is critical step in developing Standards and Labelling program. In the present context, there is no nationalized standard & test procedure for determination of RRC and wet grip index of passenger car tyres in India. The test procedure needs to be developed / adopted based on internationally accepted methods so that it can facilitate international trade and competitiveness in local markets.

The basic requirements for the programme such as availability of testing infrastructure is not a limitation but the existing capacity is very limited. Further, the testing infrastructure for wet grip has a few limitations. This require a support from the stakeholders including OEMs to discuss and come out with an assessment of how the present infrastructure can be used for developing the policy options.

As discussed in the earlier section, the data presented in this report shall support the ongoing initiatives of stakeholders for setting the minimum requirement of RR and wet grip performance for passenger car tyres however the stakeholders might need more data to be able to conclude this. Once the minimum requirement is defined, BEE can initiate the process of developing the labelling framework.

11. Suggestions for development of labelling programme, compliance & enforcement and covering other tyres under the domain of programme

11.1. Establishing a labelling framework – illustrative approach

This section provides an outline of the approach that could be followed for establishing a labelling framework for RRC and wet grip index of tyres. The proposal for grading of tyre RRC and minimum threshold for wet grip index, as discussed in earlier chapter, is built upon in this section. For grading RRC, benchmarking approach 2, that is separate limits for tyres of rim diameters 12” to 14”, and 15” & above are proposed in this section. The flow of this section is as shown below:

Establish baseline value for RRC → Establish labelling framework for RRC → Establish baseline value for wet grip index

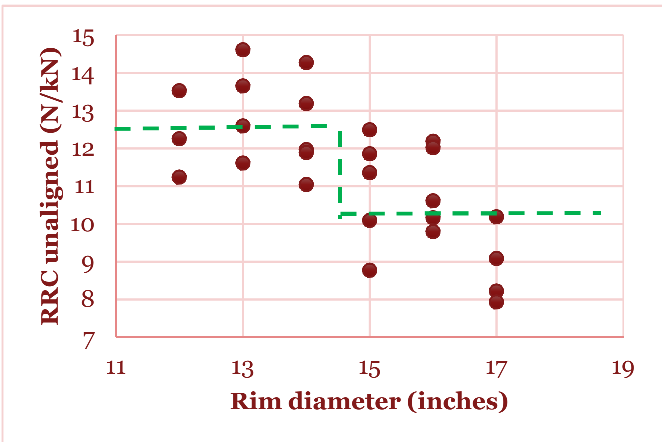
Establish baseline value for tyre RRC

The purpose of this section is to identify that value of RRC (unaligned) which would be the baseline for the proposed labelling program. Only tyres having RRC lower than the baseline would be eligible for the labelling program. As and when the labelling program is made mandatory, sale of tyres with RRC over the baseline values will be prohibited.

Chapter 9 discusses the grouped benchmark approach in detail: two separate benchmarks are established for tyres of rim diameters 12” to 14”, and for 15” and above. All tyres falling above the benchmark line exhibit a performance below that of the benchmark, and would fail to comply with a standard. The overall impact of the benchmark is equally distributed depending upon the two groups of tyre sizes.

Chapter 9 also discussed the possible benchmark values for tyre RRC using the grouped benchmark approach. The relevant section is replicated below.

Rim diameter 12” to 14”		Rim diameter 15” and above	
Percentile	**RRC unaligned**	**Percentile**	**RRC unaligned**
20%	11.67	**20%**	8.96
40%	12.08	**40%**	10.10
50%	**12.42**	**50%**	**10.17**
60%	12.94	**60%**	10.52
80%	13.62	**80%**	11.91



To identify the appropriate baseline values based on the above data, any one of the following approaches may be followed[47]:

a) **Allow only the top 60%ile RRC values for the program from each group** – Effectively, this approach limits the program to the top 60% tyres from each group. With this approach, the baseline value for 12” to 14” group would be 12.94 N/kN, and that for the 15” & above group would be 10.52 N/kN. *Incidentally, the latter value is very close to the stage 1 limit value of 12 N/kN prescribed by UNECE R117.02.*

b) **Set the baseline such that all tyres qualify for the labelling program** – This approach sets the baseline at the highest possible value of tyre RRC. This allows all tyres to qualify for the labelling program, and let the labelling program’s dynamics (and consumer awareness) shift the market towards fuel efficient products. Over time (generally 2 years), the baseline value can be made more stringent. However, with this approach, the objective of introduction as well as promotion of most efficient tyres in the market gets defeated in the beginning unless the programme is made more stringent.

c) **Set the baseline equal to limit value for stage 2 of UNECE R117.02 for group 2, and atleast 60 percentile value for group 1** – In this approach, the baseline for group 2 is set at 12 N/kN for the labelling programme. This is because as tyres of rim diameters 15” and above match the sizes available in the EU market, the limits mentioned in UNECE R117.02 are appropriate. For the smaller tyre group, the value corresponding value to 60%ile that is 12.94 N/kN could be considered so that it provides certain flexibility to the tyre manufacturers for RRC qualification and simultaneously keeps the stringency level to some extent so that efficient tyres could be identified and marked accordingly.

Establish labelling framework for tyre RRC

Once the benchmark values for tyre RRC are defined, the next step is to establish a labelling framework, based on which the value of star rating a particular tyre will receive. The star-labelling framework of BEE comprises of bands from 1-star (least efficient) to 5-star (most efficient), which provides the end user the power to make an informed choice based on fuel efficiency. **A sample labelling framework for tyre RRC is illustrated below based on option (c) discussed above**:

Table 28: Template for labelling framework table for RRC

Star rating	Value of RRC	
	Rim diameter 12” to 14”	Rim diameter 15” and above
1-star (baseline)	*a4* < RRC ≤ *a5*	*b4* < RRC ≤ *b5*
2-star	*a3* < RRC ≤ *a4*	*b3* < RRC ≤ *b4*
3-star	*a2* < RRC ≤ *a3*	*b2* < RRC ≤ *b3*
4-star	*a1* < RRC ≤ a2	*b1* < RRC ≤ *b2*
5-star (most efficient)	RRC ≤ *a1*	RRC ≤ *b1*

Illustrative

As per option (c), the baseline values for tyre RRC have been proposed at 12 N/kN for tyres with rim diameters 15” and above, and 12.94 N/kN for rim diameters 12” to 14”, the maximum value of tyre RRC for 1 star would be equal to the baseline values.

47 The points /approaches below provides the information based on impact of each of the option on the available sample set of tyres which have tested for RRC.

The approach for determining the values of labelling framework is shown below:

- For tyres with rim diameters 15" and above, the proposal shall be to align the rating table with the values in the EU tyre labelling program for C1 tyres (Regulation 1222/2009).
- For tyres with rim diameters 12" to 14", we propose that one of the following approaches be adopted:
  - o The baseline value of RRC for 5-star, the most efficient tyre is fixed at the technologically possible lowest achievable value of RRC in India, without deteriorating the wet grip performance. This value shall be identified by deliberation with major industry players and test laboratories in India. The limits for other star ratings can be determined by adopting a step approach.
  - o Alternatively, the star bands can be defined such that there is a certain percentage improvement in RRC or fuel efficiency for each improvement in star rating. While this is a more subjective approach, this is simpler and its adoption of this approach may be discussed with stakeholders. In case of tyres with 15" and above, the labelling framework is proposed as per the EU programme. For the smaller tyres group, it is proposed to consider the percentage improvement approximately in-line with that of EU programme.

An illustrative framework taking the former option is shown below.

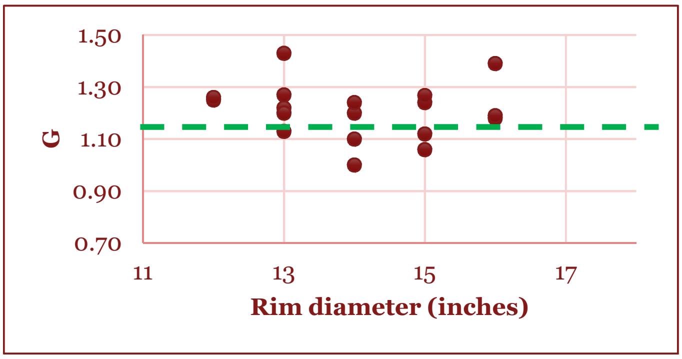
Table 29: Illustrative labelling framework table for RRC

Star rating	Illustrative value of RRC unaligned (N/kN)	
	Rim diameter 12" to 14"	Rim diameter 15" and above
1-star (baseline)	11.3 ≤ RRC ≤ 12.9	10.6 ≤ RRC ≤ 12.0
2-star	9.9 ≤ RRC ≤ 11.2	9.1 ≤ RRC ≤ 10.5
3-star	8.6 ≤ RRC ≤ 9.8	7.8 ≤ RRC ≤ 9.0
4-star	7.5 ≤ RRC ≤ 8.5	6.6 ≤ RRC ≤ 7.7
5-star (most efficient)	RRC ≤ 7.4	RRC ≤ 6.5

Establish baseline value for wet grip index

The benchmark value for wet grip index can be determined by adopting an approach similar to that used for RRC benchmarking. The percentile values for wet grip index are mentioned below:

Percentile	Wet grip index (g)
20%	1.26
40%	1.24
50%	1.21
60%	1.20
80%	1.12



Alternatively, the limit value of 1.10 applicable in the EU can also be adopted. It is estimated that approximately 88% of the tyres set (from the sample considered) will be above the threshold value. The stakeholders may consider this for deliberations.

Although **the proposal is to define a threshold value for wet grip index,** a labelling framework for wet grip index can also be developed. Possible approaches include:

- **Adoption of labelling framework as per the EU label (Reg. 1222/2009)** – as the values of wet grip index obtained are observed to be at par with those in the European Standard. An illustrative table for wet grip index is shown below:

Star rating	Illustrative Value of wet grip index (G)
1-star (least efficient)	G < 1.1
2-star	1.1 ≤ G ≤ 1.24
3-star	1.25 ≤ G ≤ 1.39
4-star	1.40 ≤ G ≤ 1.54
5-star (most efficient)	1.55 ≤ G

- Alternatively, the star bands can be defined such that **there is a 10% or 15% improvement in wet grip index for each improvement in star rating**.

Though there are multiple approaches and proposals presented in this section towards the development of a standards and labelling framework for passenger car tyres, however applicability of most of these thoughts can be assessed once the benchmark values for RRC and Wet Grip Index is finalized by the stakeholders within the TED7 committee of BIS. Therefore, as discussed in the previous chapter it is important to first establish the benchmark values, address the capacity building requirements and in parallel work on the approaches discussed here which shall facilitate in development of the standards and labelling programme.

11.2. Compliance and enforcement mechanism for the S&L program

The compliance and enforcement is an integral part for the successful implementation of the standards and labelling scheme of BEE. The Energy Conservation Act 2001 along with Amendments empowers BEE and its State designated Agencies to implement energy efficiency schemes and undertake measures to assess compliance of standards formulated by BEE. The relevant sections related with formulation, compliance and enforcement of standards by BEE under the EC Act 2001 are section 14, 15, 17, 18, 26 and 27.

Also, tyres are under the mandatory marking scheme of BIS, the national standards body in India under the aegis of the Ministry of Consumer Affairs, Food and Public Distribution. One of the major functions of BIS is to conduct measures to establish compliance of products and its manufacturing process as per the standard. To support the activities of product certification, BIS has a chain of eight to ten laboratories. In certain cases where it is economically not feasible to develop test facilities in BIS laboratories, the services of outside approved laboratories are availed of (for example in case of tyres, the services from laboratories such as ARAI, CIRT, VRDE, ICAT, etc. are availed of). Most of the labs are NABL accredited. BIS also operates a scheme for recognising labs

A brief about both the methodologies is shared next.

11.2.1. Check testing process followed by BEE[48]

As per the process under standards and labelling scheme of BEE, the compliance is evaluated through check and testing methodology. For example, in case of tyres, the testing shall be conducted to check whether the performance of the tyres is as described by the label approved by BEE. This involves procurement of tyre samples and performing verification testing in independent NABL accredited laboratories or the laboratories earmarked under the CMVR 1989. BEE has been regularly performing check testing of labelled products through an Independent Agency for Monitoring and Verification (IAME). IAME has been hired by BEE for supporting scrutiny of applications for star label and for supporting BEE in check testing.

The methodology allows BEE to:

- ✓ Randomized procurement of samples (tyre models) from the market (for which the BEE's label has been awarded)
- ✓ Transportation of samples from different cities in India to respective test facilities
- ✓ 1st check testing of the tyre models
- ✓ 2nd check testing of the failed tyre models in 1st check testing

The testing is carried out as per the test protocol defined by BEE for the S&L program.

In case of non-conformance, the EC Act, 2001, mandates that state commissions impose penalties on manufacturers whose products are found to be non-compliant with the provisions of the Act. The State Designated Agencies of the BEE have the legal mandate to file cases with respective State Electricity Regulatory Commissions in case a manufacturer is found to be non-compliant. The penalties imposed on defaulters can be recovered as if it were an arrear of land revenue.

11.2.2. Inspection process followed by BIS[49]

A manufacturer is granted permission to use the BIS mark on a product only after BIS has ensured that the product can be manufactured as per the relevant Indian Standard. Capability of the manufacturer is checked by conducting a preliminary factory evaluation w.r.t. raw materials, manufacturing process, quality check, etc. Samples are tested in the factory to bring out any deficiencies in the entire process. Simultaneously, **samples are also drawn for testing in independent laboratories for assessing conformation to the relevant standard.** Also, prior to grant of license, **the manufacturer must agree to the Scheme for Testing and Inspection (STI).**

STI

STI is a document that lays down system for checks and controls to be exercised by the firm in ensuring quality of the product during various stages of production of the article. Reference to BIS website.

[48] Source of information: BEE's website and discussion with officials of BEE
[49] Source of information: The explanation of inspection process followed by BIS is based on the information sourced from BIS website

The process of grant of license is shown:

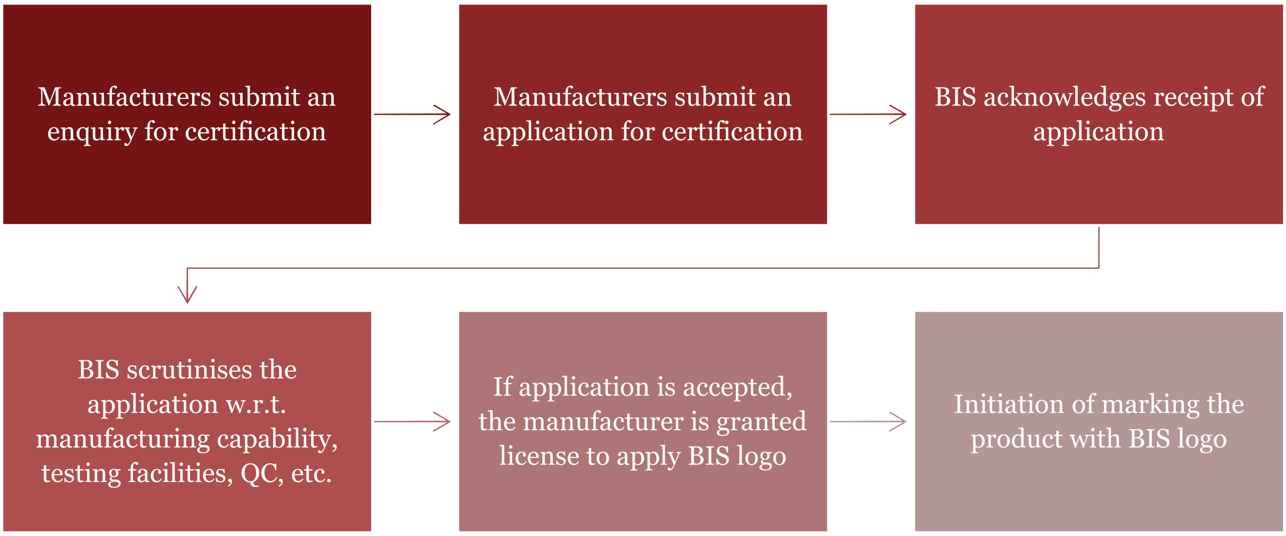


Figure 25: Steps for grant of license under BIS

To ensure that products that are marked with the BIS mark, comply with the corresponding standards, BIS conducts random factory inspections and testing of samples acquired from the assembly line, warehouse and/or authorised dealers.

However, the BIS logo just certifies that a product is compliant with the relevant standard. Therefore, BIS only performs check testing of samples collected from the assembly line, warehouse and/or the market place. If the sample is found to be non-compliant with the provisions of the Indian Standard, the stop marking procedure is initiated. It is ensured that until the product complies with the provisions of the standard, marking does not re-initiated. To ensure that quality of the product is maintained, each Branch Office has to visit factories coming under its purview at least twice in a year.

BIS conducts four types of inspections over the year: surveillance visits, supervisory visits, internal audits and special visits.

Table 30: Inspection visits by BIS for compliance and enforcement process

Surveillance visits	**Supervisory visits**
After initiation of marking by the licensee, visits are paid to the licensee's factory to keep a check on operation of STI, and for the procurement of samples from the factory. ***BIS is required to arrange a minimum of two visits of a licensee unit in a year***. The gap between two successive visits does not exceed 6 months.	The Head of the Certification Department pays periodic surprise visits to the licensees by rotation, especially for products under mandatory certification, new products brought under certification, and licensees whose performance is inconsistent to ensure that the procedures are strictly followed both by the licensees and the technical auditors. ***The head must carry out at least two supervisory visits in a month.***
Internal audits	**Special visits**
In order to ensure uniform implementation of certification system, annual audits of Branch and Regional offices are conducted.	Special visits are conducted to address specific situations that arise

Inspection procedure

Prior to proceeding for inspections, the technical auditors of BIS are required to study the relevant standards and all aspects to be inspected during the visit. Once thoroughly acquainted with background information and requirements, the officers visit the factory. The following tasks are performed during the factory visit:

- Inspect the factory thoroughly with respect to raw materials, storage, manufacturing process, the controls exercised at intermediate stages of production; and examine the results of incoming inspection and/or test certificates of raw material or bought out components or sub-assemblies.
- Check availability of relevant standards, STI, etc., and examine the various test procedures that are being followed.
- Check records of production, laboratory testing, calibration of instruments, wherever necessary, for ascertaining compliance to the provisions of scheme of testing and inspection.
- Check if there is any change regarding the manufacturing machinery and test equipment declared in the pro forma.
- Check and report hygienic conditions maintained in the premises, wherever applicable.
- Sign records indicating the date of visit and record observations about any improvements needed in maintaining the records.
- ***Draw samples of the material with the Standard Mark*** and ***test it in the factory*** for the important requirements of the specification. The test results obtained should be compared with the results recorded by the licensee.
- ***Another sample with the Standard Mark, preferably of different type/size/grade/lot/control unit, is drawn for independent testing***. One sample properly sealed and labelled is also left with the licensee as counter sample.
- The technical auditors also note down the test results of the particular control unit from which samples are drawn as recorded by the licensee. The technical auditors invariably ensure that at the time of drawing of the sample the particular type/grade/size/brand/variety of the sample drawn is the one which is included in the standard and for which the licence has been granted; and check that the varieties/grades/sizes, etc., not included in the licence are not marked by the licensee.
- Where conformity of raw materials is specified, samples of raw materials may be drawn by rotation during surveillance visits.
- See that the quantity of the sample is adequate for testing the requirements for which it is desired to be tested.
- Check whether the licensee has taken all the actions asked for during the previous inspections.
- Ensure that samples drawn during previous visits and left with the firm, if any, have been dispatched to the desired laboratory.
- Discuss any recent failure of samples and corrective actions taken.
- Discuss manufacturing, testing and other technical problems to find solutions.

- Discuss details of improvements made in management/process/quality control with specific reference to the improvements required on the non-conformities observed during surveillance visits and testing of samples. This should be specifically reported in evaluation reports.
- After completing the inspection, the technical auditor immediately reports to the group leader his conclusions regarding the operation of the licence, particularly if the operation is not satisfactory.

Enforcement actions

The actions to be taken by dealing officer/group leader/director/head of Branch during operation of licence include:

- Giving a notice to the licensee for lapses observed and advising him to take necessary action to remove these lapses, and thereafter following up to ensure that actions are taken by the licensee well in time
- Advising the licensee to stop marking if STI is not being operated satisfactorily
- Permitting resumption of marking if the operation is found to be satisfactory after approval by the Head of MD/BO concerned
- Ensuring forwarding of the samples to the laboratory for testing
- Making arrangements for acquiring market samples and seeking consumers' views
- Carrying out investigations in case of failure of samples
- Informing licensees of any amendments to the scheme of testing and inspection, marking fee, operational procedures, etc.
- Informing technical departments regarding any gaps that are noticed during the inspection
- Suggesting modifications in specification requirements on the basis of the analysis of data collected from licensee
- Processing of notice of cancellation of licence under the act
- Investigation of complaints received

11.2.3. Takeaways

The procedure explained above for compliance and enforcement under BEE and BIS is the standard methodology applied by these organisations for the products under the labelling programs of BEE and marking of BIS respectively. For the passanger car tyres the compliance procedures of BIS are already applicable.

Once the standards and labelling programme for passenger car tyres is introduced, the programme may adopt the standard compliance and check testing methodology of BEE or can introduce ways to align the compliance measures with the ongoing compliance process of BIS in the interest of meeting the intended objectives of compliance verification.

The overall process shall be finalized through consultative deliberations amongst the key stakeholders including the tyre industry association and key manufactures.

11.3. Key actions for developing an S&L programme for the commercial vehicle tyre types

Since the passenger car tyre market in India has been unregulated in terms of RRC, the labelling programme for tyres is bound to provide the necessary push for the passenger car tyre market to move towards fuel efficient tyres. This in turn will result in avoidance of use of petroleum and related GHG emissions from the sector in coming years. However, the existing proposal only focuses on the passenger car tyre segment, without considering the LCV and HDV segments, where there is tremendous potential for fuel efficiency. This is because these segments are not yet radialised completely and therefore are not ready for a labelling programme.

However, once the benchmarks for RRC & Wet Grip index are defined, the standards & labelling programme for passenger car tyres is developed and is implemented in the country, the TED7 committee and BEE can focus on expanding the programme to tyres of other categories, such as LCV and HDV tyres. This is especially important, since these vehicle segments are meant for commercial use, and therefore labelling programs if adopted may offer even higher fuel savings than for passenger car segments.

However, issues such as lack of availability of testing infrastructure for wet grip index for LCV and HDV tyres remains a key challenge in generation of data. Without this, development of benchmark values and labelling framework for tyres of these categories will be challenging.

Therefore, the following illustrative steps are proposed for expansion of the labelling programme for passenger car tyres to LCV and HDV tyres:

Step1: Introduction of programme for passenger car tyres

- Development and implementation of S&L programme for passenger car tyre
- Introduction of compliance and enforcement protocols for the S&L program for passenger car. Assessment of impact of the S&L programme

Step 2: Infrastructure augmentation and setting benchmarks for other tyres

- Capacity augmentation of test facilities for LCV and HDV tyres
- Testing and generation of test data for LCV and HDV tyres OR collection of requisite data from tyre manufacturers (if available)
- Setting of benchmarks by TED7 committee for the RRC and Wet Grip Index

Step 3: Review of impact of programme for passenger car tyres

- Review of learning from the labelling programme for passenger car tyres in terms of number of tyres models covered under the programme, market acceptability, implementation of all stages under the programme, etc.
- Impact assessment in terms of approximate fuel savings (as per the methodology to be defined by BEE)

Step 4: Expansion of labelling programme for other tyre categories

- Develop a labelling framework for LCV and HDV tyres based on data generated
- Introduction of programme in consensus with stakeholders
- Support the programme with various market transformation strategies

Figure 26: Illustrative steps proposed for expansion of the labelling programme for passenger car tyres to LCV and HDV tyres

Appendix A. - List of stakeholders

Type		Stakeholders
Industry association/consumer association	1.	SIAM
	2.	ATMA
Key manufacturers /brands in Indian market for passenger car tyres	3.	Apollo
	4.	Birla
	5.	Bridgestone
	6.	Ceat
	7.	Continental
	8.	Goodyear
	9.	JK Tyres
	10.	Michelin
	11.	MRF
	12.	TVS tyres
	13.	Yokohama
Testing laboratories	14.	IRMRA, Thane
	15.	ICAT, Manesar
	16.	ARAI, Pune
	17.	CIRT, Pune
	18.	VRDE, Pune
Regulatory bodies	19.	BIS
	20.	BEE
	21.	MoRTH
Distribution channels	22.	Retailers
	23.	Car showrooms
	24.	Online tyre dealers such as Flipkart, Amazon etc.
	25.	Cardekho

Appendix B. - Basic tyre terminology

Basic parameters

Tyres sold in the market are marked with a specific code that describes the tyre's size, construction type, load index and speed limit rating. The code is in the following format:

$$(\textit{section width in mm})/(\textit{aspect ratio})\ (\textit{construction type})(\textit{rim diameter in inches})$$

Load index and speed rating of the tyres are marked separately. A brief description on these parameters is provided in Table 31.

Table 31: Tyre parameters

Parameter	Description
Section width	The distance between one sidewall of the tyre to the other is defined as the section width. It is expressed in millimetres (mm).
Aspect ratio	The aspect ratio is defined as the ratio between the nominal section height of the tyre to its nominal section width. It is expressed as a percentage.
Construction type	The road performance of a tyre depends heavily on the type of construction. Broadly, tyres are of 2 types: • **Bias ply tyres (B):** In this type of structure, the ply cords extend diagonally from bead to bead at an angle of less than 90° (generally 40-55°) with the centreline of the tread. Bias ply tyres offer better traction and superior driving experience but have higher rolling resistance. • **Radial tyres (R):** In this type of structure, the ply cords extend perpendicular to the centreline of the tread. Radial tyres offer low resistance loss but are considerably costlier (about 40%).
Rim diameter	The diameter of the rim on which the tyre is to be mounted is defined as the rim diameter. It is expressed in inches.
Load index	The load index is the tyre size's assigned number value used for comparison of load carrying capabilities. The higher the load index, the higher the load carrying capacity[50]. 89 = 580 kg 88 = 560 kg 87 = 545 kg 86 = 530 kg 85 = 515 kg
Speed rating	Speed rating is a measure of the speed bearing capacity of the tyre. It generally is denoted as a letter. S = 180 km/hr T = 190 km/hr U = 200 km/hr V = 240 km/hr H = 210 km/hr

[50] http://www.tyrerack.com/tyres/tyretech/techpage.jsp?techid=35

Performance parameters

Along with the general parameters mentioned in the previous sub-section, the performance of a tyre is assessed using rolling resistance for fuel efficiency, wet grip for safety and noise for comfort. A brief description of these parameters is provided next.

Rolling Resistance (RR)[51]

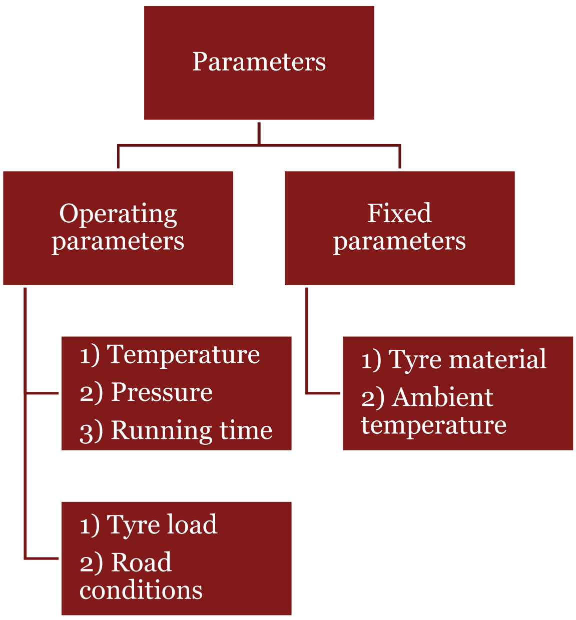
Rolling resistance is a measure of the rolling loss in the tyre. Rolling loss is calculated using rolling resistance coefficient (RRC), which is defined as:

$$RRC = \frac{rolling\ resistance\ force\ (N)}{load\ on\ the\ tyre\ (kN)}$$

Fuel efficiency of a tyre mainly depends on the energy lost during operation. The rolling loss in a tyre is made up of mainly 3 components: *frictional force* between the tyre tread and the surface, *windage loss* and *hysteresis loss*. During normal operation of a tyre, hysteresis loss is the dominant factor influencing fuel efficiency as it is the main component of rolling loss.

The rolling loss is dependent on multiple factors:

- **Temperature of the tyre**: As the temperature of the tyre increases, the rolling loss decreases. As the tyres roll, their temperature increases and hence rolling loss decreases. In general, the rolling loss can decrease by upto a third of its initial value.
- **Tyre pressure**: As the tyre pressure increases, the rolling loss decreases. As the tyres roll, their temperatures increase and cause the air inside the tyres to heat up. This in turn increases the tyre pressure and reduces the rolling loss.
- **Tyre load**: The rolling loss is dependent on the loading of the tyre. Increased load on the tyre increases the rolling loss.
- **Ambient temperature**: The equilibrium temperature of the tyre and therefore the rolling loss directly depends on the ambient temperature.
- **Tyre material**: This is one of the most important factors for determining the rolling loss in a tyre.
- **Running time:** As running time increases, the rolling loss of the tyre decreases.



- **Road conditions**: Road conditions directly affect the frictional force between the tyre and the surface. A smooth surface is better for driving and has a lower rolling loss.

Among the parameters presented above, only tyre material and tyre load remain constant during operation. Ambient temperature and road conditions depend on the geography and type of use. Tyre speed, temperature and pressure are dynamic parameters and vary continuously during operation.

[51] (Clark & Dodge)

All these factors are different for each vehicle segment. For example, a truck used for transportation of goods from Delhi to Andhra Pradesh go through many different road conditions, from highways to inner roads. Even the ambient temperature varies significantly during the journey. Our understanding suggests that there are a lot of variables involved, identifying which of these parameters has the greatest impact on RRC in Indian conditions is very important. Only then standards that specify conditions for testing can be made.

Wet Grip

Wet grip refers to the safety performance of tyres – it defines the ability of a tyre to brake on a wet road. The wet grip of a tyre is judged by calculating its wet grip index (G). During measurement, the wet grip braking performance of the candidate tyre is compared to the wet grip braking performance of the reference tyre on a vehicle travelling straight ahead on a wet, paved surface.

Wet grip is measured with one of the following methods:

- **Instrumented passenger car method**: The testing method covers a procedure for measuring the deceleration performance of C1 tyres during braking, using an instrumented passenger car equipped with an Antilock Braking System (ABS). Starting with a defined initial speed, the brakes are applied hard enough on four wheels at the same time to activate the ABS. The average deceleration is calculated between two pre-defined speeds.
- **Trailer method**: The measurements are conducted on test tyres mounted on a trailer towed by a vehicle or on a tyre test vehicle. The brake in the test position is applied firmly until sufficient braking torque is generated to produce the maximum braking force that will occur prior to wheel lockup at a test speed of 65 km/h.

The wet grip index also depends on many factors such as material of the tyre, frictional force between the tyre and the surface, road conditions, tyre pressure, load etc. It should be noted that lowering the value of RRC has a negative impact on wet grip and can therefore impact safety. Therefore, setting standards for wet grip is as important as setting standards for RR.

Noise[52]

The main source of road noise in the EU is the tyre-to-road surface interaction. It is an important indicator of driving comfort experienced by the driver.

Tyre noise is caused by multiple factors. One is the sound of the tread contacting the road. Another is the sound of air being compressed inside the tread grooves. Different tread styles and tread compounds cause different levels of noise, and as the tread wears down, the level and type of noise change.

Treads designed for heavier loads or off-road grip often are louder than treads designed for smooth rides. Grand Touring tyres and others with asymmetric treads are usually the quietest, while high-performance directional treads are generally louder.

[52] http://tyres.about.com/od/understanding_tyres/a/Tyre-Noise.htm

Appendix C. - Labelling programs in other countries

The UN ECE Regulation No. 117, originally published in 2005, introduced requirements on the maximum rolling sound emissions of tyres sold in the EU.

Prior to 2006, UNECE R117 only established limitations on maximum rolling sound emissions. However, in 2006, the 01 series amendments to UN ECE R117 added requirements on the minimum wet grip performance of passenger car tyres (C1 tyres).

In 2011, the 02 series amendments to UN ECE R117 added requirements on the maximum RR of tyres and increased the stringency of the maximum rolling sound emissions requirements.[53] The maximum RR limits are introduced in a two-stage process with separate limit values specified for class C1 tyres (passenger car tyres), class C2 tyres (light commercial vehicle tyres) and class C3 tyres (truck and bus tyres).

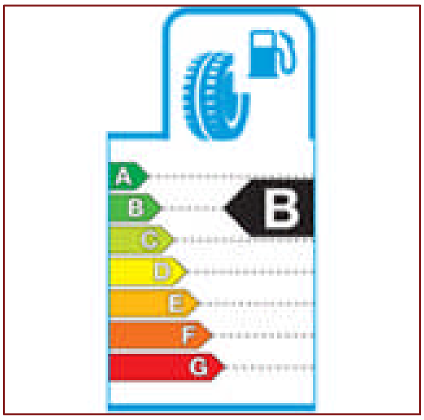
Timelines for compliance with limits for rolling resistance are shown in Table 32.

Table 32: Deadlines for compliance with rolling resistance limits[54]

Tyre class	Stage 1		Stage 2	
	Type approval	Implementation	Type approval	Implementation
C1	1 November 2012	1 November 2014	1 November 2016	1 November 2018
C2	1 November 2012	1 November 2014	1 November 2016	1 November 2018
C3	1 November 2012	1 November 2016	1 November 2016	1 November 2020

Several countries have set tyre labelling programs in place to raise consumer awareness and promote fuel efficiency in the tyre industry. These countries include the EU member countries, South Korea and Japan. The programme in the US is yet to be finalized. All these programs are aligned with the limits specified in the limits specified in UN ECE R-117.

Tyre labelling program in the EU



The EC passed the Regulation 1222/2009 with a goal to improve the safety, the economic and environmental efficiency of road transport by promoting fuel-efficient and safe tyres with low noise levels. The label specifications are aligned with the standards specified in UN ECE R-117.

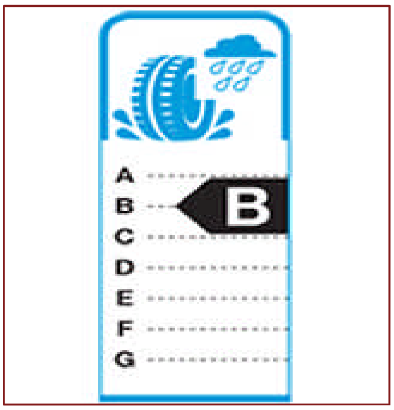
The scope of the regulation is the same as that of UN ECE R-117. The rules apply to all tyres produced on 1 July 1 2012 or later.

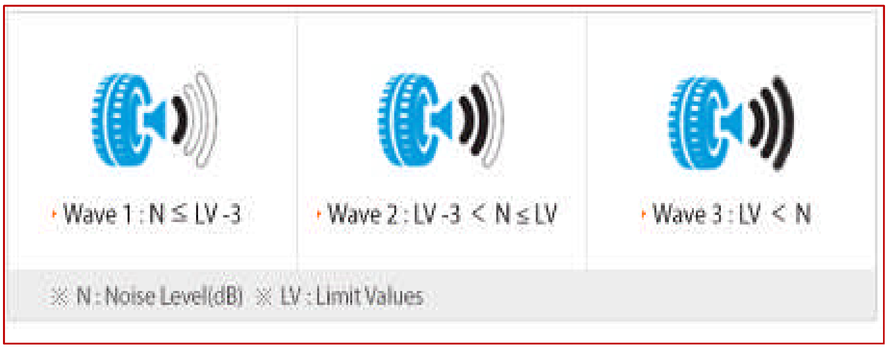
The fuel efficiency is indicated using grades between A to G—A indicating the best performance and G worst. Tyres with grade G[55] would fail to comply with UN ECE R-117.

53 http://www.interregs.com/articles/spotlight/new-ece-requirements-on-tyre-noise-and-rolling-resistance-published-000110 (Accessed on 28 July 2016)
54 http://www.etrma.org/tyres/type-approval-requirements/requirements-detailed (accessed on 31 July 2016)
55 For C1 and C2 tyres

Just as with fuel efficiency, wet grip of a tyre is indicated with the help of grades from A to F, A indicating the best performance and F the worst. Tyres with grade G would fail to comply with UN ECE R-117.

The exterior noise levels are measured in dBs and are indicated using three figures. The noise dB level is also mentioned in the label. More black bars mean that the tyres create more road noise.





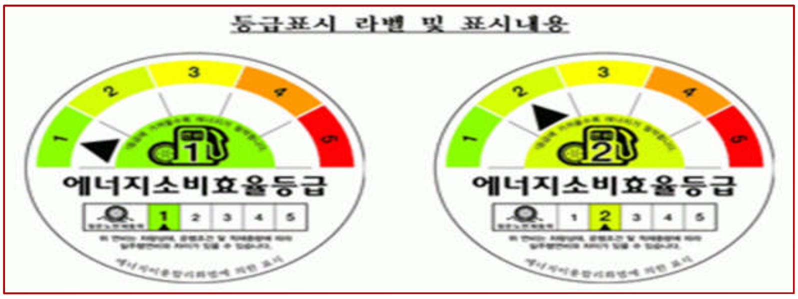
Tyre labelling programme in Japan

In January 2010, Japanese manufacturers began to implement a voluntary passenger vehicle summer tyre efficiency and safety labelling programme.[56]

It should be noted that those tyres graded 'C' in fuel efficiency do not pass the specifications of UN ECE R-117.

Tyre labelling programme in South Korea

The tyre-labelling programme is one of the eco-friendly efforts made in South Korea. A voluntary tyre-labelling programme for passenger cars was enacted on November 2011. In November 2012, the programme was made compulsory. The label has a grading system for two parameters—RRC and wet grip. A sample label[57] is shown below:



[56] Tyre Express, 2010
[57] http://images.rezulteo-tyres.co.uk/news/tyre_label_korea_uk_vl.gif

Tyre labelling programme in the US

The Energy Independence and Security Act, 2007, requires that the NHTSA finalise a national tyre fuel efficiency consumer information programme to educate consumers about automotive replacement tyres' effects on fuel consumption, safety and durability. In this context, NHTSA finalised a rule on 23 March 2010 that adopts ISO 28580:2009(E) as the RR testing procedure (U.S. NHTSA, 2010, p. 13). However, NHTSA did not finalise a proposed rating, labelling, and consumer education programme for efficiency, safety and durability. As of now, there is no system in place for labelling of tyres in the US.

It is expected that the labels will contain information on the following parameters:

- Fuel efficiency (measured using RRC)
- Safety (measured by wet traction)
- Durability

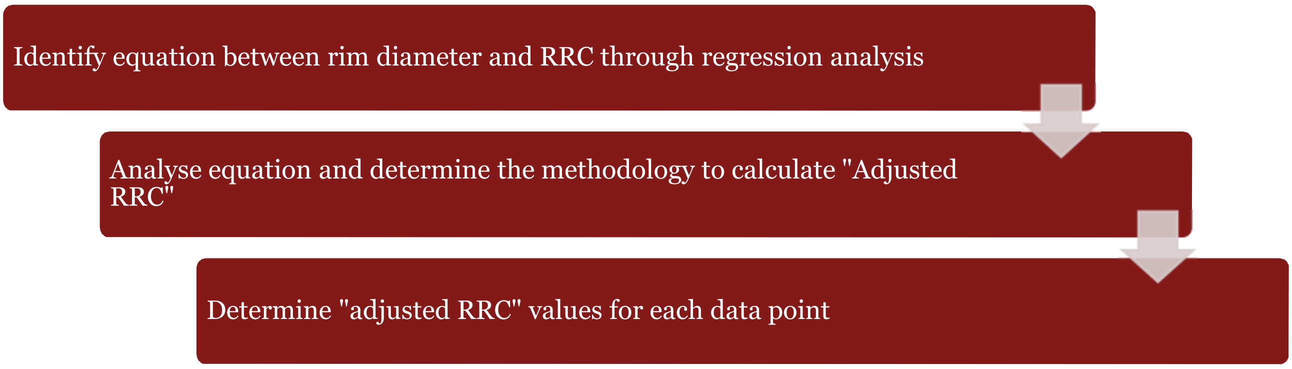
Appendix D. - Glossary for Chapter 9

Term	Definition
Histogram	A histogram is a graphical representation of the distribution of numerical data. It consists of rectangles whose area is proportional to the frequency of a variable and whose width is equal to the class interval.
Bin range	The range of intervals the entire range of values is distributed into. The bins are usually specified as consecutive, non-overlapping intervals of a variable.
Frequency	The number of data points falling into to each bin.
Regression	Regression analysis is a statistical process for estimating the relationships among variables. It helps understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed. Linear regression analysis has been performed to examine relationships among RRC, rim diameter, section widths etc.
Dummy variable	A dummy variable is a numerical variable used in regression analysis to represent subgroups of the sample in your study. It can take a value of either "0" or "1". Dummy variables were assigned to qualitative parameters such as tyre brand to facilitate regression analysis.
R-square	The R-square value is an indicator to assess the "fit" of the regression model. The higher the R-square, the better the fit. The R-square ranges from 0 to 1.
Adjusted R-square	The adjusted R-squared is a modified version of R-squared that has been adjusted for the number of predictors in the model. The adjusted R-squared increases only if the new term improves the model more than would be expected by chance.
95% confidence interval	A 95% confidence interval of "a" to "b" indicates that the probability of the population average lying between "a" and "b" is 95%.
p-value	A small p-value (typically ≤ 0.05) indicates strong evidence against the null hypothesis, and hence the null hypothesis can be rejected.
Regression coefficient	The slope of a line obtained using linear least squares fitting is called the regression coefficient. A coefficient of "a" implies that for a unit increase in the independent variable, the dependent variable increases by "a". This concept is used for establishing relations between RRC and rim diameter, brand, price etc.

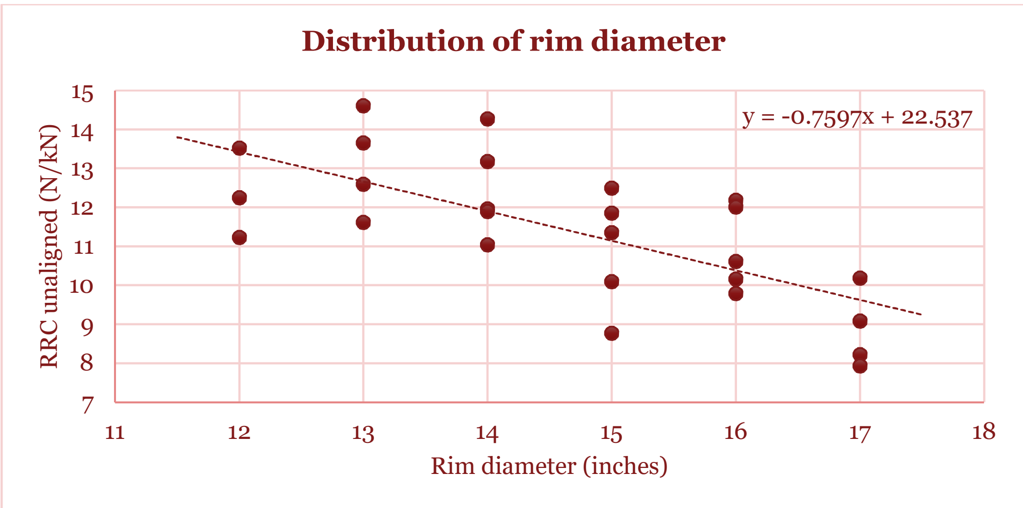
Appendix E. - Benchmarking of RRC performance on the basis of dummy variable

This section describes the process used to determine the locus of the benchmark line for RRC as per Case 3: benchmarking using a dummy variable.

The dummy variable to be used for benchmarking should account for the relationship between RRC and rim diameter, and adjust the value of RRC such that the net effect of rim diameter on RRC is neutralized. Although there are several approach to define the dummy variable, the following approach was deemed appropriate. The term "Adjusted RRC" refers to the dummy variable in this section.



The equation between RRC and rim diameter is determined by conducting a single variable regression analysis of the data set[58]. The equation representing the regression line describes the relationship between the two variables.



The regression line is described by the equation

$$y = -0.7597x + 22.537,$$

where y represents RRC unaligned (test values), and

[58] The data set refers to the sample set for RR testing excluding Chinese tyres

x represents rim diameter

As the regression line is the "best fit" line for representing the relationship between rim diameter and RRC for the above data set, the benchmark line will be parallel to the regression line.

Therefore, the benchmark line has the same slope as that of the regression line but a different intercept, and therefore is of the form:

$$y_1 = -0.7597x_1 + c$$

where c = the value of the Y-axis intercept of the benchmark line, and is determined with the help of the dummy variable, adjusted RRC.

Benchmarking of tyres is conducted on the basis of adjusted RRC, which essentially "adjusts" the RRC values of different tyres so that the effect of rim diameter is neutralized. For simplicity, the value of adjusted RRC for a tyre with rim diameter x is "***the value of RRC had the tyre's rim diameter been equal to 15 inches***". The concept is illustrated below for further clarity:

For unbiased comparison of the RRC values among tyres Y1 (with RRC *y1* and rim diameter *x1),* Y2 (with RRC *y2* and rim diameter *x2),* and Y3 (with RRC *y3* and rim diameter *x3),* the RRC values must be adjusted for rim diameter. To arrive at an adjusted RRC value for a tyre of a particular rim diameter, a base rim diameter must first be chosen. Since absolute values of adjusted RRC are not used, the choice of base rim diameter has no real significance.

For simplicity, the value of base rim diameter has been chosen as 15". The methodology for adjusting the RRC value of tyre Y1 is described below.

If y represents the adjusted RRC value for the tyre T1 with RRC *y1* and rim diameter *x1,*

$$y_1 = -0.7597x_1 + 22.537$$

$$y = -0.7597 \times 15 + 22.537$$

Solving for y, we arrive at: $y = y_1 - 0.7597 \times (15 - x_1)$. The adjusted RRC values for all tyres in the sample set are determined through the above equation.

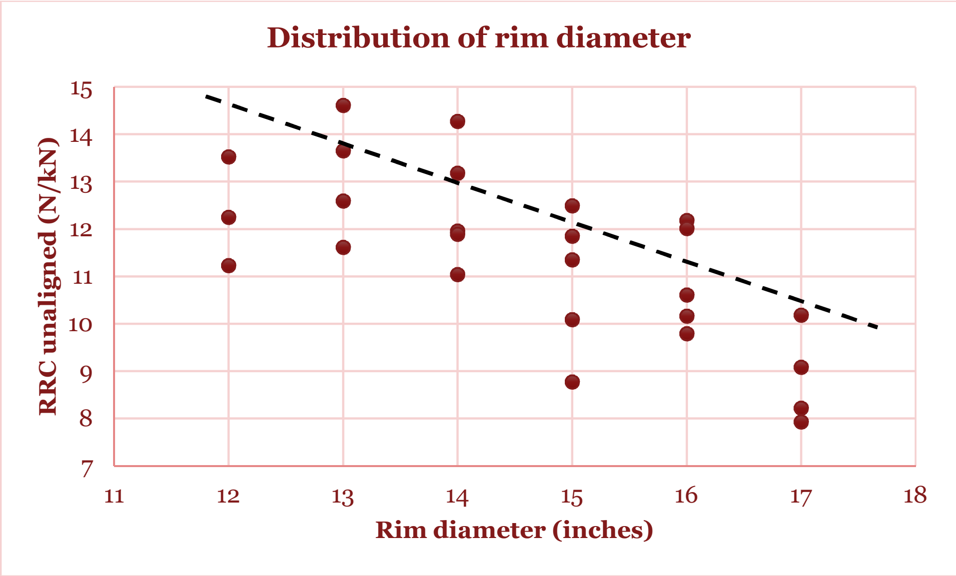
Benchmarking is conducted using the adjusted RRC values, as shown in the previous section, and is replicated below.

Percentile	Value of dummy variable
50%	11.17
60%	11.35
70%	11.77
80%	12.42
90%	12.85
100%	13.51

An appropriate benchmark value for adjusted RRC is chosen, and the value of intercept c is determined. If the value of benchmark adjusted RRC is "B", then the coordinates (15,B) is fed into the benchmark equation to calculate *c*.

For instance, if the benchmark is chosen at 80%ile, then the benchmark adjusted RRC value is 12.42. Therefore, the coordinates (15,12.42) are fed into the equation: $y = -0.7597x + c$, to arrive at *c* = 23.8155.

Therefore, the benchmark equation becomes, $y = -0.7597x + 23.8155$. **Graphically, all tyres lying to the north of the benchmark line fail to meet the benchmark.**



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