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1. Introduction

Rubber is an unsaturated organic compound made of carbon and hydrogen. Historically, rubber is thought to have been in use 3,000 to 4,000 years ago by the Mayan and Aztec peoples of Central and South America for tools, footwear, and balls for religious observances. Natural rubber, or latex, is collected from the natural plant *Hevea brasiliensis,* native to South America but now grown widely and primarily on plantations in Asia and Africa. The Mesoamericans recognised latex for its toughness, resilience, and ability to stretch when heated, especially when mixed with the juice from the morning glory plant vine, making the mixture less brittle and more flexible. The morning glory plant held spiritual significance for the Mayans as well.

By the turn of the 18th century, rolled sheets of natural rubber were making their way to Europe where it was met with fascination and wonderment. Wheelwrights immediately began forging bands of iron and steel, compressing them around wheels, and then attaching the imported latex strips. In 1791, an Englishman by the name of Samuel Peal discovered a means to waterproof cloth by mixing natural rubber with turpentine. An English inventor and scientist, Joseph Priestly, used a small dose of it to rub off pencil marks on paper, thus the name rubber was born. By 1820, a Scottish chemist named Charles MacIntosh created a way to use the product to bond two pieces of fabric, making a waterproof cloak called the "mackintosh." Thomas Hancock, another English inventor, developed a machine that took scraps of rubber, making it reusable for many purposes.

Throughout the early 19th Century, rubber was used to treat clothes and footwear to make them water-resistant. In 1845, pneumatic carriage tyres were invented. And in 1876, an Englishman by the name of Sir Henry Wickham collected some 70,000 *Hevea brasiliensis* seeds in Brazil and transported them to the East Indes where he started rubber plantations.

But 37 years before that, in 1839, an American inventor and hardware store merchant by the name of Charles Goodyear, created the process of vulcanization whereby a mixture of rubber, lead, and sulphur was accidentally dropped onto a hot stove, or so the story goes. For a decade before that, Goodyear (1800-1860) had done experiments on natural rubber and other compounds in order to make the substance less sticky and better for practical use. By heating sulphur or other curatives or accelerants, the polymer of natural latex was modified by forming crosslinks between individual polymer chains. Vulcanization, named for the Roman god Vulcan, made a durable yet stable substance. The product was resistant to water and chemical interactions and did not conduct electricity, so it was suited for a variety of end uses.

By 1844, Goodyear's discovery was sufficiently perfected that he applied for and received Patent No. 3363 from the US Patent Office for the vulcanization process. But in England in 1843, Thomas Hancock, then working for Charles MacIntosh and Co., applied for a patent on the same process with the British government and that was granted a year later. But Hancock's patent was challenged in court by Stephen Moulton, an agent of Goodyear's who in 1842 had shared samples of the American's vulcanized rubber product with Hancock. After several trials that culminated with one in 1855, Moulton, then the owner of

a rubber factory in Wiltshire specialising in rubber suspension systems for railroad carriages, lost when chemists said it was not possible to tell how vulcanized rubber was made by simply studying the American samples. Thus, Hancock won the British patent and Goodyear was blocked, denying him vast royalties from both Hancock and Moulton. (In the US, the Goodyear Tire & Rubber Co. was founded in 1898 by Frank Seiberling, well after Goodyear's death with no connection but in name only.)

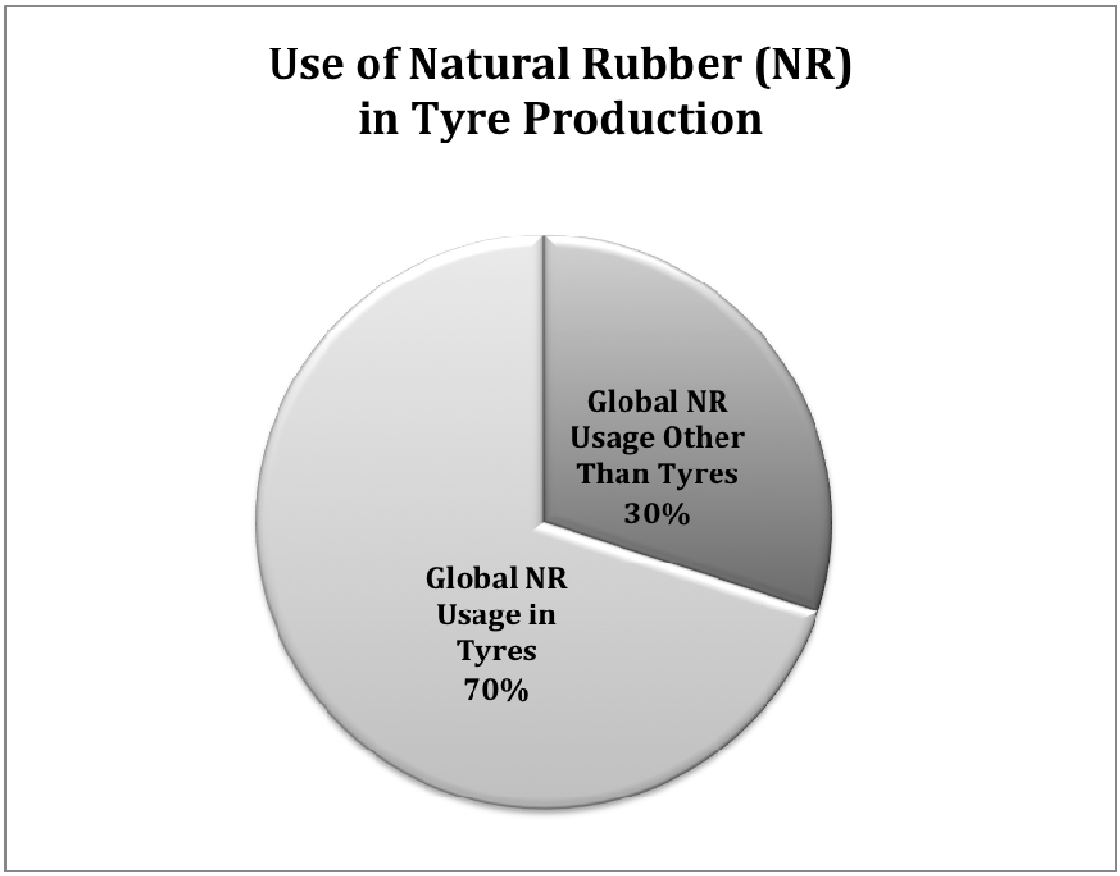
By the late 19th century, the pneumatic, or air-inflated tyre business was flourishing in both the early automobile industry and in agriculture and related machinery. From John Boyd Dunlop developing a pneumatic tyre for greater cushioning that consisted of vulcanized rubber and a canvas tube with a valve to Charles Kingston Welsh and William Erskine Bartlett's refinements in vulcanized pneumatic tyres, advancements came rapidly.

During World War II, with natural rubber supplies cut short by geo-political fighting, western companies quickly and out of necessity began developing synthetic rubber, a material derived mainly from petroleum or other fossil fuels that is shaped into materials containing copolymers, or polymers consisting of more than one monomer. When the war ended, a return to natural rubber was prevalent but by the 1960s, synthetic rubber sales equalled that of natural rubber as a raw material for tyres.

Also following the war, in 1948, Michelin first introduced steel-belted radial tyres, so named because the ply cords radiate at a 90-degree angle from the wheel rim and the casing is strengthened by a belt of steel fabric that runs around the circumference to stabilize the tyre. Meanwhile, bias-ply constructed tyres were also in use, in which plies are run diagonally from one bead to the other of the tyre. One ply is set on a bias in one direction with succeeding plies set alternately in opposing directions that cross each other.

Today, tyres have classifications according to the respective requirements of different vehicle types and operating conditions. The essential data, tyre dimensions, load ratings, specified inflation pressures, and authorised speeds, are standardised for the convenience of interchangeable and common across all vehicle categories.

While tyre products remain the predominate product of the rubber industry, there are tens of thousands of other products that depend on natural or synthetic rubber. A mere sampling of those products includes tubes, hoses, pipes, belts, sound-proof insulation, gaskets, seals, cables, clothing, footwear, and latex gloves.



2. Natural Rubber

Natural rubber, also known as Caoutchouc or Pará rubber, consists of polymers of the organic compound isoprene that are obtained from the milky secretion, or latex, of various plants, most notably *Hevea brasiliensis.* To soften rubber so that compounding elements can be added, the natural substance's long polymer chains are partially broken by mastication, a mechanical chewing process discovered by Thomas Hancock in 1820 that breaks down the polymer chains and lowers their molecular weight so that further processing can be done. Those processes, mixing, calendaring, extrusion, are done whereby chemical substances are compounded with the rubber, thus readying the material for the cross-linking of polymer chains. This commercial processing of natural rubber is used widely in many applications and processes, either alone or in combination with other materials. It has a large stretch ratio, high resilience, and is extremely waterproof.

Besides the five nations listed in the chart below, there are five other countries that are the major producers of natural rubber: Cambodia, China, Papua New Guinea, Philippines, and Sri Lanka. These countries today account for 93% of global natural rubber production, and 57% of the global demand for

natural rubber. Natural rubber is less and less cultivated in its native continent, South and Central America, because of a fungal disease called South American Leaf blight caused by the ascomycete *Microcycyclus ulei,* as well as other natural predators of the rubber tree.

In Southeast Asia, such factors as soil and climate, competition with other crops like palm oil, and availability of labour at harvest time are just a few of the elements hampering natural rubber and positioning synthetic rubbers ahead of natural latex. For example, of late, heavy rain in Malaysia and a dry winter in Indonesia have affected production.

Natural rubber accounts for 60% of the raw material costs for the tyre industry. In heavy-duty truck and aircraft tyres, that figure is higher since natural rubber use in those tyres is much higher than the average 70% used in automobile tyres. The natural rubber market now stands at its weakest price point since 2010, brought on in part by high inventories and irregular supply to China, a fact that has made the Chinese government reduce natural rubber import tariffs.

TOP 5 NATURAL RUBBER PRODUCING COUNTRIES

RANK	COUNTRY	2010 (METRIC TONNES)	% CHANGE vs. 2004
1	Thailand	3,166,910	5.296
2	Indonesia	2,921,872	41.439
3	Malaysia	1,072,400	-8.24
4	India	819,000	9.249
5	Vietnam	659,600	57.422

It is estimated that global natural rubber production will only increase 3.2% per year between now and 2015. China is the world's largest natural rubber importer, with shipments of natural rubber growing. Bearish forecasts on crude oil adversely affects demand and pricing of natural rubber, since synthetic rubber as an alternative to natural rubber becomes more cost effective. The world's 3 largest natural rubber producers, Thailand, Indonesia, and Malaysia, moved to cut output late in 2012 in order to boost prices. But that effort did not succeed and those countries, along with India, are studying subsidies on rubber exports, while imposing import controls on rubber products and natural rubber, something tyre manufacturers are fiercely opposing.

Natural rubber and synthetic rubber are substitutes for each other as the basic material in the production of tyres and other rubber composites. The pricing of the 2 tends to move in tandem, thus deep concern early in 2013 with natural rubber prices dropping steeply and synthetic prices teetering close to a high mark. Market volatility exists on both sides and synthetic rubber makers currently are in a stand-by mode, waiting to see which way raw material pricing will go.

3. Synthetic Rubber

The manufacture of synthetic rubber lies basically in the petrochemicals industry. The more than 20 major classifications of synthetic rubber are defined as substances similar to natural rubber in properties, only artificially produced by the polymerization of unsaturated hydrocarbons from two petroleum by-products, styrene and butadiene. Styrene is obtained from ethylene and benzene, while butadiene is obtained from ethylene and butylene. Synthetic rubber is classified as an artificial elastomer, meaning it can be deformed without sustaining damage, and having the ability to be returned to its original shape after being stretched.

The earliest synthetic rubbers were the styrene-butadiene copolymers, SBR and Buna S, whose properties are closest to natural rubber. SBR, the most commonly used synthetic rubber that accounts for 45% of global consumption, is derived from the two monomers, styrene and butadiene. The mixture of these two monomers is polymerised by two basically different processes, solution (S-SBR) or an emulsion (E-SBR) process. S-SBR is produced by an anionic polymerization. Polymerization is initiated by alkyl lithium compounds with water excluded. E-SBR is a synthetic polymer made via free radical cold emulsion copolymerization of styrene and butadiene monomers in a chemical reaction. The reactive process involves combining the 2 monomers in water with an emulsion system and molecular weight modifiers.

Tyre manufacturing is the single largest application segment for SBR and consumes over 75% of the SBR produced globally. The footwear and construction industry rank second and third, and SBR is also in many polymer modifications and adhesives. It is prominent in the making of gaskets, belts, hoses, brake and clutch pads, matting, floor and window framing as well as in caulking compounds, floor tiles, sponges, shoe soles, and other uses. Its demand is assessed in terms of end-user segments, price, and both regional and global competition.

Global E-SBR pricing between 2012 and 2013 has dropped, due in part to Asian's spot market and ample supply and lower than anticipated demands. The Asia-Pacific region is both the highest producer and highest consumer of SBR, and is expected to drive the market in the future due to its robust demand. Asia has been on the receiving end of excess E-SBR supply from Europe mainly due to the downswing in the Euro automobile industry. The feedstock butadiene, a compound of 4 chemicals each with 4 carbon atoms manufactured in the olefins process, comprises 70% of SBR and is the most expensive component. Pricing of butadiene directly affects the pricing mechanism of SBR.

There are several other synthetic rubber classifications, including ethylene-propylene-diene monomer (EPDM), the third largest segment in the overall global market for synthetic rubber that is primarily used in the automotive components sector, and in hose, electrical insulation, and other applications; Buna S, name derived from butadiene and sodium (NA), a nitrile elastomer that offers good resistance to abrasion, low gas permeability, and high dielectric strength; basic urethane elastomers that are used in elasticized materials; and silicone rubbers, which provide tensile strength and retain flexible resilience over wide temperature ranges, and are used in wire and cable insulation.

But the major synthetic rubber is SBR, which more and more has replaced natural rubber in a majority of applications. It is made inside a highly fragmented marketplace and with a high level of integration. The major producers are Lanxess, Sinopec, China National Petroleum Corp., Synthos, Asahi Kasei, Versalis, Dow Chemicals, ExxonMobil Chemicals, DSM Elastomers, and DuPont Performance Elastomers. Some of the leading tyremakers operate their own SBR production plants in order to assure supply and control costs. Bridgestone and Goodyear Tire & Rubber are 2 such examples.

The SBR market over the next several years will shift dramatically towards production of S-SBR from E-SBR, due mainly to new labelling guidelines on tyres that can only be met by the use of S-SBR. This is because S-SBR is an essential component of tyre tread that gives an automobile better grip and low-rolling resistance, a key factor in higher fuel economy. Lanxess, the German company that is the leading producer of SBR, is currently shifting production from E-SBR to S-SBR in its Brazilian plants, and is constructing an S-SBR plant on Jurong Island, Singapore. There is currently a global oversupply of SBR that is restricting growth in all synthetic rubber markets.

TYRE SALES: TOTAL MARKET SHARE

RANK	COMPANY	% MKT SHARE
1	Bridgestone Corp.	16.2
2	Group Michelin	15.5
3	Goodyear Tire & Rubber	12.4
4	Continental AG	5.1
5	Pirelli	4.4
6	Sumitomo	3.7
7	Yokohama	3.1
8	Hankook	3
9	Cooper Tire	2.2
10	Cheng Shin / Maxxis Intl.	2.2
11	Hanghou Zhongce	1.9
12	Others	30.3

4. Multinational Companies in Tyre-making

After years of intense price wars, consolidation, and the inevitable job losses, the global tyre industry has become highly concentrated. From a value of US$80 billion in 2004, the industry plummeted to less than half that amount 4 years later. The world's three largest tyremakers – Bridgestone, Michelin and Goodyear – collectively control 58% of the global tyre market and that has been the case over the past half-decade. In 2012, the three, along with their subsidiaries and joint venture stakes, accounted for US$76 billion in sales, or 40% of estimated global tyre sales. As the Big 3 have grown and increased their geographical reach through acquisitions and joint ventures , so too has their global market share increased, from 55% in 1999 to 58% today. These 3 companies generate at least 75% of their total turnover from the manufacture of tyres.

The next block of major tyremakers includes Pirelli, Continental AG – with only partial focus on tyres – and the Asian producers Sumitomo, Yokohama, Hankook, Cheng Shin/Maxxis International, and Hangzhou Zhongce, a Chinese-based tyremaker that is 50% state-run in partnership with Zhongce Investment of Hong Kong. Together, this block of major tyremakers control about 25% of global tyre sales. Some 70 other companies have a 17% stake. More and more, those 70 are finding niches in tyre manufacturing, specialising in aircraft, agricultural tyres, or heavy-duty tyres, or even tyres for motorcycles and bicycles.

The integration of the tyre industry is an important factor in today's production cycle. Goodyear has 75/25 joint venture with Sumitomo in operations in North America and Europe for production of Dunlop tyres, while Sumitomo controls 80% of P.T. Sumi Rubber of Indonesia. Bridgestone derives hefty revenues from its 34% BRISA stake in Turkey, as well as a 16% stake in Nokian of Finland. The world's biggest tyremaker, Bridgestone, still derives 21% of its sales from Asia where it operates 11 tyre plants and has some 20 diversified rubber product operations. Michelin holds a 10% stake in Hankook, as well as a 10% stake in P.T. Gajah Tunggal, the world's 26th largest tyremaker, which also sees GITI Tire Pte. Ltd. of Singapore holding a 49.8% share. Mitsubishi Corp. recently increased its stake in Toyo Tire & Rubber Co to nearly 6% with a US$25 million cash infusion. In general, all of the majors with joint ventures or operating arrangements with other producers derive excellent financial results from industry integration.

In 2012, overall growth in tyre markets occurred and most of the largest tyremakers reported double-digit revenue growth despite lacklustre unit sales. This was due to higher wholesale pricing, thus increased margins, and lower raw material costs in 2012. The top 10 tyremakers represent US$125 billion, or two-thirds of the global marketplace.

Of the 75 largest tyre companies, 24 are based in China, 10 in India, 9 in Europe, 5 in Taiwan, 4 in both Japan and the US, and 3 each in Russia and Korea. The growth of Chinese companies has been phenomenal, giving solid proof that Asia is now the centre of the rubber and tyre universe. Several of these Chinese producer such as Hangzhou Zhongce, Shandong Linglong, Double Coin Holdings, Guizhou Tire, Shandong Luhe have expanded to not only build plants inside China, but also to market tyres

aggressively throughout Southeast Asian. Many are producing tyres for specialty niches, tailored to the needs of construction, mining, agriculture, or even motorcycle or bicycle tyres.

The tyre sector in Korea is made up of 6 publicly-listed companies with a combined market capitalisation of US$4.8 billion. The three largest, Hankook, Kumho, and Nexen, have a world presence with Hankook developing a European market, and all three with plants in China. The Taiwanese company Maxxis International, with Cheng Shin as its parent, operates a 10-year-old all-purpose tyre plant in Thailand, and recently began operations in 2 greenfield plants in China, its 6th and 7th factories there. Nearly 53% of the Taiwanese company's revenues are generated from heavy-duty truck and off-the-road (OTR) tyres. Yokohama of Japan has plants between 5- and 7-years-old in Thailand and Vietnam, and it operates 2 plants in China, one a 5-year-old facility.

25 LARGEST GLOBAL TYRE PRODUCERS

RANK	COMPANY	COUNTRY	2012 SALES (USD MILLIONS)	2011 SALES (USD MILLIONS)	EMPLOYEES
1	Bridgestone Corp.	Japan	28,500	28,450	143,124
2	Group Michelin	France	27,474	27,414	108,300
3	Goodyear Tire & Rubber Co.	United States	20,500	20,490	73,000
4	Continental AG	Germany	(Tyre NA)	10,645	170,000
5	Pirelli	Italy	8,380	7,802	36,349
6	Sumitomo	Japan	7,523	7,413	22,320
7	Yokohama	Japan	6,022	6,028	19,272
8	Hankook	Korea	6,300	5,744	14,000
9	Cheng Shin / Maxxis Intl.	Taiwan	NA	4,268	24,350
10	Hangzhou Zhongce Rubber	China	NA	4,263	6,000
11	Cooper Tire	United States	4,200	3,927	12,890
12	Kumho Tire Co.	Korea	NA	3,522	4,949
13	Toyo Tire	Japan	NA / FY 31March	3,065	9,523
14	GITI Tire	Singapore	2,910	2,894	NA
15	Triangle Group	China	NA	2,527	2,800
16	Apollo Tyres	India	NA / FY 31March	2,527	16,000
17	MRF Ltd.	India	NA / FY 31March	2,352	14,960
18	Nokian Tyres	Finland	2,026	1,825	4,155
19	Shandwg Linglong Rubber	China	NA	1,604	5,834
20	Aeolus Tyre	China	NA	1,586	7,624
21	Double Coin Holdings	China	NA	1,559	2,338
22	JK Tyre & Industries	India	N/A FY 31March	1,550	5,340
23	Nexen Tire	Korea	1,752	1,472	3,118
24	Xingyuan Tyre	China	NA	1,357	5,000
25	Qingdao Doublestar	China	NA	1,312	9,654

The fastest rising companies for capital spending are Nexen Tire of Korea, Nokian of Finland, and Shandong Linglong of China, while those committed to expenditures of the highest numbers over the next few years include Bridgestone (US$2.6 billion), Yokohama (US$1.75 billion), Pirelli (US$1.12 billion), and Michelin (US$1 billion). Bridgestone has hinted that about one-third of its capital expenditures for 2011-15 will be directed toward China, India, and Brazil.

RECENT CAPITAL SPENDING (TYRES)

RANK	COMPANY	2011 (USD MILLIONS)	% CHANGE vs. 2009	% of SALES
1	Bridgestone Corp.	1,118.30	1.8	6.7
2	Group Michelin	1,457.00	63.7	6.1
3	Goodyear Tire & Rubber	944.00	26.5	5.0
4	Hankook	812.80	157.1	16.2
5	Continental AG	603.30	90.7	6.3
6	Pirelli	536.40	-23.9	8.5
7	Cheng Shin / Maxxis Intl.	480.40	-39.0	14.3
8	Sumitomo	352.70	3.2	6.0
9	Toyo Tire	298.90	149.0	12.0
10	Yokohama	287.80	42.7	4.8
11	MRF Ltd.	142.40	104.7	8.1
12	Cooper Tire	119.70	50.9	3.3
13	JK Tyre & Industries	116.80	9.7	9.0
14	Kumho Tire	103.00	9.4	4.4
15	Nexen Tire	101.20	NA	8.4

Source: Rubber & Plastics News

Most of the major tyremakers offer a multi-brand assortment of tyres to the consumer. For instance, Bridgestone offers Bridgestone at the premium end, Firestone in the mid-range, Dayton at the budget end. Michelin sells its premium brand under its name, while it sells several mid-range brands including BFGoodrich, Kléber, and Uniroyal, and budget tyres called Tigar, Kormoran, Riken, Taurus, and Warrior. Continental AG has the Conti name on premium brands, with a host of secondary brands such as Semperit, Uniroyal, Barum, Sime, and General Tires.

5. Industrial Rubber & Mechanical Rubber Goods

Industrial rubber, or general rubber goods are primarily used in the automobile industry, but are also used in the construction, mechanical, bioscience, and other industries. Industrial and mechanical rubber products are found in aerospace, construction, mining, forestry, household appliances, and computer and office equipment.

Industrial rubber will post strong advances through 2015, and it is expected to reach US$88.5 billion by then. But industrial rubber will not overtake tyres as the largest segment in rubber. It will be bolstered greatly by a strengthened outlook for overall manufacturing. Rubber demand for industrial applications like sealing and vibration controls in automobiles will grow, and this in part will make the growth spurt for industrial rubber greater than tyres through to 2015. However, rubber products face strong competition from thermoplastic elastomers and the innovative range of plastics.

Global rubber consumption is forecast to rise 4.3% annually through to 2015 to 30 million metric tonnes. Rubber demand overall will be stimulated by a pickup in tyre and rubber components growth in an automobile industry that in most parts of the world is beginning to rebound from weak postings from 2005-2010. Because tyres represent by far the largest market for rubber – over two-thirds of all rubber demand in 2010 – growth in output of motor vehicles, as well as more automobiles in use, greatly impacts rubber consumption each year. The modern automobile is likely to have some 300 components made out of rubber.

Growth in automotive aftermarkets is largely determined by the replacement cycle of vehicles. Over the past 5 years with cut-backs and pull-backs the norm, today's aftermarkets are positioned to be the biggest beneficiary of the tough economic times. Due to consumer tendencies to retain vehicles longer, thus requiring continued maintenance, this ratio translates to greater demand for aftermarket service and mechanical parts.

The Asia-Pacific region constitutes the largest as well as the fastest growing market for industrial rubber products. A major portion of global auto production is located in Asia, which gives a significant boost to demand for rubber-based products. This market is forecast to flaunt a Compound Annual Growth Rate (CAGR), or year-over-year growth rate of an investment, of more than 6.6% annually over the next few years,

Among segments in aftermarkets, mechanical products including tyres represent the highest revenues but aftermarket electronic products will grow the fastest. Mechanical rubber products such as wiper blades, vibration control products, body seals, and a host of other miscellaneous products will witness increased demand with a rebounding automobile industry. Another category is hose and belting, which accounts for 28% of the industrial rubber market.

Industrial and mechanical rubber is highly fragmented with some 4,100 companies competing in an innovation-driven marketplace. Continental AG's ContiTech and Bridgestone are among the handful of leading producers, and others are Hutchinson S.A., Freudenberg Group, Trelleborg A.B., NOK Inc., Tokai

Rubber industries, Tomkins PLC, Cooper Standard Automotive, Bando Chemical, Delphi, Eaton, and Federal-Mogul Corp. A major recent development in the fragmented business is a joint venture between the German firm Freudenberg and the Swedish firm Trelleborg AVS to create Trelleborg Vibracoustic, an enterprise that will handle development, production, and sale of anti-vibration products worldwide that will combine the German company's vibration control products with Trelleborg AVS's strong global marketing presence in automotive products.

6. Tyres

The global tyre industry is expected to record close to 5% yearly growth in volume demand through 2015, to reach almost 3.5 billion units in use. Some 1 billion units are made each year and that figure will increase in the near future with growth in the developing world. The entire industry is expected to experience close to 7% yearly growth in revenue, to reach US$220 billion in 2015. Beginning fully this year, 2013, the world's tyre market will recover from a five-year period of mostly negative growth and declining revenues brought on by the world's economic recession that started in 2007. Given its connection to the automotive sector – one of the worst affected industries of the downturn and one still facing dire straits in Europe – the global tyre market ran flat in volume sales in both Original Equipment Manufacturing (OEM) and replacement markets starting in 2008-2009.

Plant closures, capacity idling, and job layoffs reduced the demand for tyres, and this was felt in OEM markets the most. Off-the-road (OTR) vehicle tyres also felt the pressure, particularly with the collapse of the construction industry. Volume of tyre sales to the OEM segment plunged a massive 12.7% globally during the worst of the downturn, while replacement tyre sales fell by only 1.85% in 2009. Reduced output of new automobiles meant higher spending on maintaining older vehicles, which cushioned the blow considerably for the replacement market. This recorded decline, however, was the result of a reduced number of vehicle miles driven which reduced the need for replacement tyres.

The market for both OEM and replacements started to bounce back in 2010. About three-quarters of tyre shipments for the auto industry are for replacement tyres, with one-quarter for new vehicles. Margins on replacements are typically higher than for OEM, since automakers receive discounts for buying in high volumes. Most automakers dual-source tyre supplies for every model, thus spreading their total purchase of tyres between three or four tyre manufacturers. The type of tyre specified by an automaker differs markedly from one region to another due to the different vehicle mix sold in each market, as well as different driving habits. Where tyres are more difficult to make, such as specialty or high-performance tyres, prices remain high and the product offering is dominated by the premium manufacturers. To increase margins, those tyremakers are moving that production from developed markets to emerging markets, particularly in Central and Eastern Europe.

GLOBAL SALES (TYRE) PER EMPLOYEE

RANK	COMPANY	USD
1	Nokian Tyres	419,862
2	Toyo Tire	397,657
3	Titan International	367,333
4	Nexen Tire	338,035
5	Yokohama	324,880
6	Hankook	316,181
7	Sumitomo	309,469
8	Goodyear Tire & Rubber	261,556
9	Cooper Tire	260,583
10	Bridgestone Corp.	233,018
11	Continental AG	270,964
12	Kumho Tire Co.	229,449
13	Group Michelin	224,260
14	Pirelli	218,968
15	Apollo Tyres Ltd.	149,354
16	Cheng Shin / Maxxis Intl.	135,678

Source: Rubber & Plastic News
Figures: August 2011

Economic stimulus packages extended by some governments brought recovery in automobile manufacturing, thus boosting demand in the OEM market. The strong demand for replacement tyres now and the increasing sale of passenger and commercial vehicles in developing countries is driving new growth. As well, economic recovery will benefit movement of freight and commercial activity and this will boost demand for heavy-truck and aircraft tyres.

The global tyre market is forecast to reach an estimated US$187 billion in 2017, with a CAGR of 4%. Despite consolidation and whopping market shares held by a handful of the leading tyre producers, competition in the global tyre industry is fierce, with a combination of macro elements like vehicle sales, government regulations, and environmental factors impacting market specifics significantly.

In 2012, the rubber and tyre industry fully recovered, thanks largely to raw material costs that abated following a steep increase in year 2011. Revenue growth in 2012 came despite zero growth in unit sales

and with auto sales remaining flat in most parts of the world, but opposite that was continuation of higher wholesale selling prices and an uptick in the replacement market that was beginning to take hold.

Major economic challenges of the entire industry reside in volatile raw material prices, higher dependency on suppliers in the OEM markets, and in after-markets, especially in the fiercely competitive tyre and equipment replacement segment. Meeting new legal requirements on labelling, adopting sustainable practices, and a green environment are also major challenges, and the rubber industry is only now starting to recognise green as an elucidating factor in growth.

Since the 1980s, the global automobile tyre industry has become highly consolidated. North America has traditionally dominated the market with approximately 30% of the global total, but that trend is now shifting toward Asia.

7. Tyre & Rubber, Region-by-Region

7.1. Asia-Pacific

The APAC region is anticipated to realize the strongest growth in rubber consumption between now and 2017, reflecting the strength in China but also in India, Korea, Thailand, Vietnam and other nations. Asia-Pacific is the biggest regional market in terms of growth, with CAGR of 7.2% in OEM and 5.2% in replacement markets. In terms of volume, some estimates say the region will account for upwards of 90% of total growth through 2015. The Asia-Pacific region is by far the largest market for rubber, with 60% of global rubber demand in 2010. Companies with primary or a majority of operations in Asia are benefitting from lower cost raw materials and increased sales volume. Motorcycle and bicycle tyres are also a major driver in Asia. Despite a slowing down of Chinese GDP growth, China is still expected to produce between 16 and 18 million automobiles annually over the next few years, and tyre demand will continue to be buoyant particularly in the replacement market. Most of the major tyremakers have opened operations in China, and the economic outlook for the rubber industry in Asia is particularly bright. A host of Chinese-based companies such as Hangzhou Zhongce, Aeolus Tyre, Triangle Group, the Huyai Group's Double Coin Holdings, Shandong Linglong, Jiangshu Tongyong, Shanxi Suanxi and some 35 others are growing rapidly and are now among the top 75 global tyre producers. Combined, they operate over 100 tyre factories in China. All but 3 of China's 43 major tyremakers posted profits in 2011.

The rubber market in China accounted for nearly one-third of global rubber demand over the past two years, and will continue to post the highest gains among nations through to 2015, with nearly 65% of world tyre output volume gains forecast to then. Chinese tyremakers combined now account for 18% of the market, a rise from 5% in 2000. Behind the US, China ranks as the world's second highest in sales of motor vehicles and between 2004 and 2012, China has become the largest tyre exporting country in the world, shipping 35% of its inventories to other nations.

Because of proximity to raw materials and chemical resources, huge tyre demand, and advantages in energy and labour, transnational companies are rapidly increasing their investments in China and

elsewhere in the Asia-Pacific region. And Chinese-based tyre manufacturers have carved out a bigger domestic market share for themselves. In foreign direct investment, Michelin has invested US$1.5 billion in a new heavy equipment tyre factory in Liaoning province, Goodyear last year brought a new plant on-line in Pulandian, Dalian, Pirelli is investing US$200 million into its Qingdao, Shandong, plant, while Korean-based Hankook in 2011 opened its 3rd tyre plant in China. Yokohama, meanwhile, is partnering with a Chinese company to make heavy industry tires in Shandong province, hoping to control 10% of that world market, while the Japanese tyremakers – Bridgestone, Yokohama, Sumitomo, and Toyo – are also expanding investment and production in China.

Aside from investment inside China, a number of big Chinese tyre producers, including Hangzhou Zhonce, Shandong Linglong, Sailun Tyre, and Shandong Ao Gerui, are closing in on finalising capitalisation projects in Thailand, Indonesia, and Vietnam in order to circumvent international trade barriers enacted against tyre products made in China.

If there's been a blip to Chinese tyre-making, it's that Toyota, Nissan, and Honda have all taken recent downtime in factories to match drop-offs in sales. That is because throughout 2012, Chinese consumers have tended to avoid buying Japanese brands because of the territorial dispute in the East China Sea. Consumer spending on Japanese passenger cars has dropped nearly 60% in China of late.

Tyre production in India is expected to reach new zeniths with a projected 191 million units to be produced by 2016. Between now and 2015, India's tyre market will grow at a CAGR of 12%. The boom in automobile sales in recent years, proximity of raw materials, as well as growth in motorcycles makes India one of the fastest growing tyre and rubber markets in the world. Expected high growth in radial tyres for Indian and export commercial vehicle markets will also give strength to India's global standing in the tyre industry. Companies such as Apollo Tyres, MRF Ltd, JK Tyre, and Birla Tyres Ltd. do better in the aftermarket, making and distributing replacement tyres that offer margins relatively better than OEM.

The growing demand has caused a shortage in available tyre manufacturing capacity inside India and both Michelin and Bridgestone have major capitalisation projects underway there. Michelin will go on-line this year with a US$742.8 million heavy-duty radial truck tyre plant near Chennai, while Bridgestone opened a US$539 million plant in Pune, Maharashtra province, that is currently making radial tyres for passenger cars but will expand later this year to make heavy-duty truck and bus tyres. This is Bridgestone's second plant in India and the other is the 16-year-old Kheda plant in Madhya Pradesh province. Continental AG is investing US$71 million this year in its newly-acquired, 39-year-old factory in Modipuran, Upper Pradesh province, where it makes auto, truck, and bus tyres. Among India-based companies, Apollo Tyres is investing US$55 million in developing off-the-road (OTR) and heavy equipment tyres at an existing plant in Kerala province, while Alliance Group of Mumbai, the world's 48th largest tyre company, has World Bank/International Finance Corp. backing for another tyre factory in India. The Indian tyre market has also seen the emergence of tubeless tyres in recent years and the ebb and flow of raw material markets, especially natural rubber, will chart this business segment.

The Japanese rubber and tyre industry has been arguably the most dominate on global markets. Besides the major tyremakers such Bridgestone, Yokohama, and Sumitomo and their rubber products supply businesses, Japan is home to a great number of other enterprises focusing on rubber products for the

automotive supply markets. The Tokyo Rubber Exchange is a major centre of world global trade. Tyre exports from Japan's more than 20 factories reach across the world and specifically, tyre imports to the US rose from US$1.39 billion in 2008 to US$1.74 billion in 2011. A number of capitalisation projects are occurring in Thailand, Indonesia, and Vietnam and that will increase the stakes those nations have in the rubber industry.

7.2. North America

Despite massive consolidation in the US tyre market over the past decades, the large American market has recovered lost ground, judging from major capitalisation projects underway by multinational companies. Some US$2.75 billion in new investment is at hand for tyre manufacturing in the US and nearly US$2 billion of that is targeted for greenfield projects. North America ranks just below the Asia-Pacific region in planned tyre spending this year and next, with several companies charting tyre expansion projects in Asia totalling US$2.9 billion. In the US, due to driving habits and population demographics, production and distribution of tyres will grow marginally in the years to come following the great global downturn of 2007-2009 brought on primarily by an American debt and mortgage crisis.

Combined annual revenue of US tyre and rubber producers is approximately US$15 billion. US tyre shipments are projected to increase by 2% in 2013 over 2012, an increase of 6 million units to 290 million total units. An increase in original equipment (OE) shipments will offset a decrease in replacement shipments in 2013, an indication of the slightly upward tick to automobile production and sales. The highest revenue-producing products in the US are tyres for passenger cars (45%), truck and bus (30%), and agriculture and industrial equipment next. The biggest tyremakers operating in the US – Goodyear, Bridgestone, Michelin, Cooper – also make rubber products for numerous US consumer and industrial uses, as do 100 other chemical and manufacturing companies that lead the market.

Tyre production in the US from 2011 to 2012 remained unchanged at about 284 million units, as a slight increase in original equipment (OE) shipments offset a decrease in replacement shipments, an anomaly. The lack of much expected growth in the US can primarily be attributed to continued economic stagnation. There are an estimated 697 workplaces in the US engaged in the rubber manufacturing of such things as pneumatic casings, inner tubes, and solid and cushion tyres for vehicles, farm equipment, airplanes, and many other uses, so the North American rubber products industry is large and diverse.

In preceding years, the economic bottom of the great recession, an overall decrease in tyre production followed steep declines in replacement market shipments, despite price increases (12.1% for passenger tyres) in the OEM markets. For the first time in the US passenger tyre market, imports exceeded American production by 126 million units to 123.2 million. Individually, passenger tyre production declined by 6.1%, light truck production by 2.4%, and medium and heavy truck tyres by 7%.

But the landscape looks to change in the near future, as stated above, mainly due to the combined investments of three major companies operating in the US – Bridgestone, Continental, and Michelin. Bridgestone has set out with a plan to build a new off-road (OTR) tyre factory near its Aiken, South

Carolina, car and light-truck tyre plant, with inclusion of expansion of that existing plant at a total sum of US$1.2 billion. The Japanese company is also investing in existing plants in the state of Iowa, Illinois, and Tennessee. Continental AG is staking out a 3-year project to build a greenfield plant in Sumter, South Carolina, for manufacture of auto and light-truck tyres, and is expanding a large, existing plant in Mount Vernon, Illinois, with a capitalisation project of US$129 million to increase commercial vehicle tyre production. And Michelin is studying a greenfield OTR tyre plant for Starr, South Carolina, as well as expanding existing heavy equipment and OTR, as well as auto and light-truck capacity at a plant in Lexington, South Carolina. Total spending could exceed US$750 million.

7.3. Europe

As the rest of the world sees either modest or a bit better upturns to their economies, Europe has tumbled into a steady recession and the automobile industry is a showcase for that. Credit restrictions due to austerity measures put in place by debt-ridden governments, lack of consumer confidence, and capital constraints have stymied growth. The single economy has faced steep declines in car sales and in new car registrations. It is estimated that 25% of automobile dealers in Europe are under extreme financial pressure.

Yet, Europe remains an important market for the tyre industry, accounting for 30% of the global tyre market share. With three of the major multinational companies based in Europe – Michelin, Pirelli, and Continental AG – it remains a centre of research and development, but a transfer tendency of production and assets has occurred, particularly to Eastern and Central Europe. Even though in 2010 European tyre production recovered with a 26% growth from the previous year, it was still -11.7% down from 2007 levels. A lingering debt crisis across the one economy has meant further rationalising and stagnation in most tyre markets.

European automobile manufacturing is now producing at only 60% capacity, with major automakers such as GM, Ford, and PSA Citroën either shutting or announcing shutdowns and causing economic distress in such places as Antwerp and Genk, Belgium, Bochum, Germany, Southampton and Dagenham, UK, and Aulnay, France. In turn, tyre factories of Continental AG in Clairoix, France, and Hanover, Germany have been shut, or in the case of Bridgestone at Modugno, Italy, near Bari, a tyre factory will be shut in the near future. In Amiens, in northern France, a 3-year-long battle over jobs and social responsibility typifies the breakdown that has occurred in European manufacturing. The dispute pits French unions and their government with foreign multinational companies over the critical issue of investment behaviour and social conduct. A Goodyear Tire & Rubber closure in Amiens, and then aborted resale of the agricultural tyre end of the big twin complex has seen a deeply contentious divide between a state's industrial sovereignty and global capital.

One market that is a bright spot in the European tyre is in winter tyre opportunities and the value growth it brings to established markets. As well, top European tyremakers and others are investing in premium tyre manufacturing in order to gain high selling points with the public and wider profit margins.

China is the major importer of tyres to Europe, followed by Japan, Korea, Turkey, US, Russia, and Thailand. China, Japan, and Korea account for 65% of the global import total in passenger car and light-truck tyres. India is source for the largest agricultural and heavy-duty truck imports of tyre units to Europe.

Turkey is one of the few exceptions in Europe dispelling overall negative growth numbers. Because of its location, Turkey is one of the world's biggest markets for commercial tyres. In 2011, Bridgestone Europe sold its Turkish Bandag operations to BRISA, the joint venture of Bridgestone and Sabanci Holdings for US$3.6 million, adding weight to Bridgestone's Anatolian holdings. Bridgestone's revenues are enhanced now by its 43% stake in BRISA Bridgestone Sabanci, which holds a 30% tyre market stake in Turkey and a company currently investing US$200 million in expanding a plant in Izmit to meet higher demand. Goodyear and Pirelli also operate profitable plants in Turkey, as do two local industrial groups.

7.4. Central/Eastern Europe

Over the past decade, multinational tyre companies made Central Europe an investment utopia, shifting production and expanding factories at a rapid rate, and that trend is starting now in Eastern Europe as well. With free market exports and the number of automobiles rapidly increasing on Central and Eastern European roads, production demand for tyres has multiplied, stunting the effects of a global downturn that stands in sharp contrast to the rest of Europe.

In Hungary, Bridgestone and Hankook – both with 5-year-old tyre plants running at full capacity – now have major expansion plans underway, and Michelin completed a US$66 million project last year at its Nyiregyhaza plant that increased production of premium and high-performance tyres. Through the midway point of 2012, Michelin Hungaria Abroncsgyarto posted profits 78% higher than the same period in 2011 and total sales revenue was up 10%. Bridgestone of Japan has announced a 4-year spending plan at Tatabanya of US$346.4 million that will boost tyre production of premium and high-performance tyres three-fold. The expansion will create 500 new jobs. Hankook of Korea, which has seen egregious labour rights abuses at its plant in Recalmas, has seen tyre production increase from 5 million units in 2008 to 12 million last year, and is now investing US$11.2 million in added rubber compounding capacity that will be operational in the second half of 2013. Apollo Tyre of India also has a plant in Hungary.

Similarly, in Romania, Pirelli, which opened a factory in Slatina in 2005, is commencing on its second expansion in 3 years, a US$136 million one that will lift the making of premium tyres from 10 million to 13 million by 2017 and increase employment from 3,000 to 3,500 workers. Continental AG also is spending US$26.5 million to put a research and development center at its Timisoara tyre plant, a move that will provide 2,000 jobs inside 3 of Conti's automotive businesses. In Slovenia, the Goodyear Tire & Rubber Co. owned Goodyear Dunlop Sava Tire plant in Kranj saw a US$13.4 million investment last year to increase passenger car tyre production aimed at the Central European market.

The only Central European-based tyre manufacturer is Mitas A.S. of the Czech Republic, owned by CGS Holding and ranked as the world's 42nd largest tyre company. Last year Mitas opened a farm and equipment tyre plant in the US state of Iowa. The company operates three other tyre plants in the Czech Republic and one in Serbia, and primarily makes agriculture, construction equipment, and motorcycle tyres.

Recently, Goodyear invested US$100 million in an existing plant in Debica, Poland, while Bridgestone in the same country moved to expand its 4-year-old plant at Stargard, Szczecinski, with a US$150 million capital infusion to boost truck and bus tyre production by 56% late this year. In Serbia, US-based Copper Tire will spend US$67 million to add capacity to a plant it bought last year in Kruševac and Michelin has announced a US$227 million expansion of its Tigar Tyres plant in Pirot, Serbia. In the Ukraine, the tyre market grew by 12% in 2012, with domestic tyre production controlled by 4 regional companies there.

In Russia, where Nokian, Michelin, Pirelli, and Yokohama are the major tyre producers with manufacturing facilities, the market showed decent growth from 2011 to 2012 that was directly proportional to auto sales in the country. The period 2012 to 2017, however, is expected to witness phenomenal growth in both tyre production and sales. Nokian of Finland, which has just under one-third of its sales coming from Russia and the CIS states, has set its sights on gaining an even stronger foothold in Russia. Pirelli, which has a joint venture at 2 plants with state-owned Russian Technologies, is investing US$276 million to enhance rubber compounding development at the Voronezh factory in order to produce high-performance tyres. In addition, Pirelli has signed an agreement with Russian oil and gas producer Rosneft to sell its tyres at Rosneft's vast network of petrol stations. And Yokohama, which opened a US$165 million auto and light-truck tyre plant in Lipetsk in May 2012, will hit its initial targeted capacity of 1.4 million units in mid-2013, and is poised for further investment in that facility.

7.5. Africa/Middle East

Despite being the smallest region in rubber consumption, Africa and the Middle East will realise the highest growth of any region due to areas of fast-paced economic development and rising levels of income. With capitalisation projects under way totalling over US$1.5 billion, the region has become more and more important as the crossroads of global goods and capital. GDP growth in many Middle Eastern and African nations far exceeds that of older economies. For example, Saudi Arabia's tyre market continues on a steady path of growth due to rising rates of automobile ownership, increasing GDP, and a thriving used-car market. With that, a trio of Arab investment houses have committed US$240 million to build an auto and light-truck tyre plant in Yanbu, Saudi Arabia.

Besides tyre imports from Turkey, the Middle East is massively served by imports from India. Apollo tyres, in fact opened a major shipping terminal in Dubai that will serve 14 countries and the Indian company says 30% of its export revenues are derived from the Middle East. In Africa, Pirelli operates a truck and bus tyre plant in Egypt, Michelin has two tyre factories in Tunisia and one in Algeria, which

makes truck and bus tyres in the city of Hussein Dey. In South Africa, Bridgestone and Apollo Tyres each operate two tyre factories, while Goodyear and Continental AG operate one each. Continental is investing US$13.5 million this year in a new rubber mixing line in Port Elizabeth that will increase its industrial and off-the-road (OTR) tyre production. Apollo of India also operates a Dunlop plant in Zimbabwe.

7.6. Latin America

The region is considered a growth area for major tyremakers and for rubber products in general. Brazil, backed by high government investment in infrastructure, a growing logistics market, strong domestic demand, and a heightened agricultural machine market, will see the manufacture of rubber products increase in the coming years. South America's biggest economy will see nearly double-digit truck manufacture growth over the next 3 years. And coupled with this is that Brazil, a major exporter of automobiles dating to 2008, will see a continued surge in domestic sales of autos. Argentina, backed again by a mature automotive industry and developed tyre-making operations in place, will also see substantial growth.

Among the foreign investments include big holdings by Goodyear Tire & Rubber in several countries, Bridgestone in Argentina, Brazil, Venezuela, Costa Rica, Pirelli in Argentina, Brazil, and Venezuela, and Michelin in Brazil and Colombia. A company moving fast into South America is US-based Titan International, with its global strategy to gain a greater share of the farm tyre market in South America and elsewhere. Titan, the world's 27th largest tyremaker, operates an existing factory in São Paulo and in 2011 purchased all of Goodyear Tire & Rubber's farm tyre capacity in Latin America.

With total tyre investment for the region set at US$2 billion, Latin America stands behind Asia-Pacific as the second largest expected growth region in the world. Pirelli is investing US$500 million over several years in a truck tyre plant near Merlo, Argentina, and is spending US$190 million to expand capacity by 57% at a passenger automobile tyre factory in Silao, Mexico. The Italian company also recently announced US$100 million in Brazil and other Latin American projects for production of off-the-road (OTF) and agricultural tyres. Goodyear is running with a US$500 million investment to upgrade its plant in Santiago, Chile, a facility that makes high-value passenger tyres.

And Brazil is expected to witness a boom in overall rubber products over the next 4 years with stadium and infrastructure construction for the 2014 FIFA World Cup and the 2016 Summer Olympics.

8. Tyre Labelling

Oncoming tyre labelling regulations is right now touching all facets of internal corporate culture, from research and development, manufacturing processes, supply chain control, testing, and both internal and external communications. Compliance with tyre labelling is forcing commitments to greater levels of capital and even higher levels of human resource development in order to adopt new business

perspectives and organisational needs. Tyre labelling is already having a profound effect on the European tyre market as it means vast strides of improvement and optimisation across an entire value chain to meet new criteria aimed at an enlightened buying public, specifically on cost, quality, and safety. Formal tyre labelling is said to give the consuming public an informed view on what they are purchasing.

In coming years, as more nations adopt tyre labelling, the trend to meet fuel efficiency, eliminate certain chemicals in manufacturing processes, and improve safety through better handling will be the driving force in global tyre production. Tyre labelling, to be sure, will compress profit margins on the whole due to the costs associated with labelling, and how the major and mid-size tyremakers will respond is uncertain. Overall compliance across the industry has also become a challenge that still must be met.

New labelling legislation in Europe took effect on November, 1, 2012, this time mandating tyre retailers to display the new label on all replacement tyres. It is the first time an enforcement mechanism for tyre labelling has come to Europe. Fuel efficiency by low-rolling resistance, chemical content, safety (a tyre's wet grip), and noise emissions are now categorised using a 7-grade ranking scale, similar to new automobile CO2 emissions or appliance efficiency labels. For new model automobiles, all cars sold in Europe must be equipped with a Tire Pressure Monitoring System (TPMS), with even tighter specifications that will be defined by the UNECE Vehicle Regulations (Regulation No. 64). From November 1, 2014, all passenger cars sold must have a TPMS. The US has a Department of Transportation TPMS regulation on vehicles and it is studying one for heavy-duty trucks. Korea's Ministry of Land, Transport, and Maritime issued regulations in 2010 that take effect for new car labelling this year, and for all existing models in 2014. Japan is expected to adopt the EU legislation approximately one year after EU implementation. The Japan Automobile Tyre Manufacturers' Association introduced a voluntary tyre labelling system in 2010. Australia, Brazil, Russia, Indonesia, Malaysia, the Philippines, Turkey, and Israel are on the cusp of issuing new labelling rules that will place greater pressure on tyre design and development.

There is pitched debate now inside the industry on compliance, as well as who will profit most from labelling, the premium-brand tyremaker or budget and mid-range tyres. To be certain, the automatic winners in tyre labelling will be providers of high-tech materials such as polymers, silica, silanes, and processing equipment for monitoring. Industry speculation is labelling will help the economy brand tyremakers increase their presence in developed markets because the consumer will look at both price and label, and then choose price when the labels are the same. But that also brings into question the issue of compliance, with some premium-brand tyremakers complaining that tests determining standards are uneven from country to country. The European Tyre and Rubber Manufacturers' Association (ETRMA) has set up a working group across all member states with the responsibility to share experience with the enforcement process. It has also produced documents which outline practical steps covering implementation, intended for the non-expert eyes of EU officials charged with monitoring and enforcing the directive.

To meet the TPMS labelling requirement, TPMS technology has evolved to where it is used even inside run-flat tyres and emergency spares. TPMS regulation does go back to 2005 and the global market scale

for systems reached nearly 18 million units in 2011, an increase of 13% from the preceding year. The US market accounts for 50% of the global total and was one of the earliest to develop regulation. There are some 200 million TPMS sensors on the road today and 35% of them will be nearing the end of their useful battery lives. It is estimated that 9 million systems will need replacement over the next 2 years, so strict regulatory systems for TPMS is at hand. The sizeable growth of TPMS has seen some 200 TPMS manufacturers rise alone in China, a nation accounting for just 10% of the TPMS global total and one where the installation rate is only 8% on all vehicles. Schrader Electronics is the leading global production supplier, holding a market share of 33%, followed by Continental AG with a 25% share. Other producers include Bendix, Eaton Corp., Dana, TRW, Federal-Mogul, Meritor, and Tiremetric LLC.

There are two main forms of TPMS systems on the market today, indirect and direct. Indirect TPMS systems use algorithms to interpret signals in the brake system and they use wheel speed sensors to detect pressure loss when a tyre is damaged or malfunctions. Direct systems are those that have separate radio sensors with long-life battery power built into the tyre which detect deflation and then transmit that to the driver by a radio frequency signal.

Tyre companies will use their TPMS ratings to tout fuel economy, longer tyre wear, fewer crashes due to blow-outs, and less hydroplaning. Because the dynamics of the pneumatic tyre is based on inflation pressure, key factors like braking, lateral stability, and wear require inflation pressures to be adjusted by weather, road, or sudden or unseen instability. And the common consensus is that total dioxide emissions could be reduced by several million tonnes annually by strict adherence of regulations. But compliance and universal acceptance across a broad range of tyre manufacturing in the world will be the challenge.

9. ‘Greening’ of an Industry?

There is at present an undeterred emphasis by tyremakers to market sustainable innovations in their new product development and this is a major barometer that drives optimism in the global tyre market. A common catch-word in today’s rubber industry lexicon is “green tyres,” defined as using materials, especially elastomers that are derived from sustainable bio-materials. The global market for “green tyres” is forecast to reach US$70.6 billion by 2017, a 56% growth from the 2012 level of US$44.8 billion, with the largest segment of this market to come in the manufacture of low-rolling resistance tyres. Green tyres will climb from 28% of the current global tyre supply to 35% by 2017, but much of that percentage then will still contain the use of non-sustainable filler technology over improved synthetic elastomers. To gauge the evolution to completely sustainable inner liner materials, Bridgestone has set a goal of cradle to grave sustainability by the year 2050.

Europe has been and will remain the dominate market for “green tyres” over the next several years, but its leading percentage will shrink from 56% to 44% as other regions catch up. The Asia-Pacific market is second in use of energy-conscious tyres, and will see its global numbers increase from 24% to 31% between now and 2017. The North American share of the market will increase from 14% to 17%, while the South American share will increase from 3% to 4%.

The rubber industry is devoting vast resources and has created a thickly interwoven sub-industry of suppliers and providers who concentrate on front-end technological achievements. For instance, Michelin is using oleic – one of the 4 prime sunflower oils – in formulation of its passenger car tyre production, claiming it gives the tyre a better edge in wet and snowy weather, while Goodyear claims that rubber compounds made with soybean oil blend more easily with silica in the tyre-building process. Yokohama in North America is experimenting with the oil extracted from an orange peel, several companies besides Goodyear are including the use of soybean oil to cut back on petroleum-based oils, and others are using the desert shrub quayule (*Parthenium argentatum*), which contains hypoallergenic properties that is suitable in rubber-making as a latex substitute for medical products and devices. One company, Apollo Tyres in Vredestein, Netherlands, is using a dandelion species native to Uzbekistan and Kazakhstan (*Taraxacum Kok-saghyz* or TKS) in tyre construction. It is estimated by the industry that use of soybean oil in tyres, for instance, can potentially increase tread life by up to 10% and reduce a tyremaker's dependence on oil by up to 32 million litres annually.

Precision work on things such as tyre connections to catalyst systems, fuel economy, or spare tyres dominate spending and too little is devoted to waste, disposal, and proper reuse of rubber. It is estimated that less than 10% of waste rubber is reused in any kind of new product. Vast stockpiles of discarded tyres take up space in Europe and North America. Accumulation in North America is estimated to be 6 billion, while in Europe that number is 3 billion. The rubber recycling process is labour-intensive and prone to rabid market swings, including raw material price fluctuations and overall demand for recycled rubber. Due to technological advancements, the combination of material and energy recovery has increased from 31% to 78% over the past 15 years, while retreading has decreased over those years from 12% to 8%.

Rubber recycling begins with shredding. After the steel and fibres are removed and grinding occurs, the resulting powder is processed to delink the sulphur molecules from the rubber molecules, allowing the formation of new cross-linkages. Then, either a water/oil process is used, or a modified oil process to rebuild the chemical structure through a lengthy heat and pressure regimen that is followed by extensive mechanical post-procession. Most reclaimed rubber is unsuitable for many modern uses, including tyres, and that must change. Resources and human skills are needed to ensure that the industry meets the future knowing full sustainability is at hand. But the large labour and capital costs associated with rubber reclamation make it undesirable for companies that concentrate on balance sheets and shareholder returns.

RESEARCH & DEVELOPMENT SPENDING

RANK	COMPANY	USD (MILLIONS)	% of SALES
1	Continental AG	1,921.1	5.6
2	Bridgestone Corp.	968.90	3.0
3	Group Michelin	721.90	3.0
4	Goodyear Tire & Rubber	342.00	1.8
5	Sumitomo	212.90	3.1
6	Pirelli	198.30	3.1
7	Hankook	175.20	3.5
8	Yokahama	147.10	2.5
9	Toyo Tire	87.20	2.7
10	Cheng Shin / Maxxis Intl.	50.70	1.5
11	Kumho Tire Co.	48.70	0.2
12	Cooper Tire	39.70	1.2
13	Nexen Tire	18.90	1.6
14	Nokian Tyres	16.80	1.2
15	Apollo Tyres Ltd.	9.00	0.5

Source: Rubber and Plastics News

10. Research and Development

The capital-intensive nature of today's rubber industry, combined with fluctuating raw material prices, places Research and Development (R&D) endeavours squarely in the middle of conflicting corporate culture values. The conflict is generally over budgets and project development, and hot debate exists today inside the industry over supplier relationships and how such relationships should be structured. Current tyre technology is linked intricately to auto chassis engineering, so the major tyremakers need qualified and experienced R&D staff to build links directly with the primary company's engineering teams.

But that is not the norm and major tyremakers have become both a slave and victim to contract employers. Clusters of specialised suppliers are forming partnerships to work together on product design and development for the major companies. The ultimate burden is reflected in the financial ledger when outsource costs soar and competition is removed from the marketplace. And because engineering departments in most major tyremakers are overworked and understaffed – with fast-paced technical advancements taking hold – tyremakers have become dependent on consortiums of raw material and

machine supply contractors combining with specialised service vendors to take the lead on product development.

Tyre development is increasingly taking place inside the virtual world of a computer. Historically, tyre development and design occurred through multiple iterations. Design, test and then refine the design, using real tyres on real vehicles several times over was the standard methodology. Now, hundreds of iterations are done through powerful computers and highly-sophisticated modelling software. Also, a major part of development is converting rubber characteristics into equations to better improve the properties of synthetic rubber.

Research over the past decade has centred on creating and improving the design and specifications of tyre products to meet automakers' needs, with an emphasis on durability and fuel economy. With every move to improve durability, traction, cornering, shock absorption, even ease of mounting, tyre technology has made vast strides. The design of tyres with greater width and lower height gives vehicles greater contact with the road, lowering the centre of gravity, thus giving greater fuel economy.

There are several factors that have shaped the global tyre market over the past 20 years. The popularity of sport utility vehicles, minivans and crossover vehicles has steadily increased, making tyre manufacturers redesign their products. The increasing segmentation of the automobile market has directly led to a more complex tyre market, with tyremakers focused on ways to improve tyre dimensions, weight, rolling resistance, wear and abrasion resistance, noise and most importantly, fuel efficiency. Growing environmental awareness and advances in tyre technology are more and more playing a defining role in tyre development. With automakers feeling social and legislative pressure to produce more fuel-efficient cars, technological advances are quickly coming to the marketplace that find auto companies eliminating the spare tyre as excess weight and economising by supplying a tyre sealant and tyre-inflating pack, thus spotlighting a company's technical development capabilities. There are two basic types of sealants, one that is manufactured into the tyre in the event of a puncture, the other supplied in a kit to be used following a puncture. In the first, tyre design incorporates a polymer material which liquefies and then hardens around a puncture. In the latter, the sealant and compressed air are injected through the tyre valve but the result is dependent on only small punctures over short distances.

Tyre blow-outs cannot be permanently repaired by using an inflator kit. Perhaps then the most dramatic innovation in tyre technology over the past 20 years has been the development of the run-flat tyre. The industry is overall in a second-generation period in design and development, with several major tyremakers offering various units on passenger vehicles. Bridgestone even offers the product in the European and Japanese replacement markets. Run-flat tyres are specifically constructed to enable them to be driven on in the event of loss of air pressure. It allows a motorist to either drive home or to a repair ship to fix the tyre. Run-flat tyres allow a motorist with a puncture to drive an automobile up to 200 kilometres at 80 kph before repair is needed.

Several factors are increasing the demand slightly for run-flat tyres, including safety, the need to make vehicles lighter to reduce CO2 emissions and simple environmental sustainability. There are 2 types of basic run-flat systems: a reinforced tyre sidewall that enables the sidewall to support a vehicle's weight;

and a rubber clip-on tyre rim, basically a clip that prevents the rim from cutting into the tyre with sudden air pressure loss. Automobiles fitted with run-flat tyres have no need for a fifth tyre as a spare, even the "limited use" or compact spare tyre, from the beginning to the end of a vehicle's life. Automobiles fitted with run-flat tyres are growing disproportionately from Europe and other parts of the world than in the US. In 2005, run-flat tyres accounted for less than 1% of replacement tyres in the US and that figure today hovers at that 1%. A Michelin study in 2008 found that only 3% of drivers polled worldwide want run-flat tyres. There are only a handful of volume manufacturers offering them as standard fittings and then only on select models. BMW is the largest fitter of run-flats as original equipment (OE) and others that use them as optional fitment include Ford, Ferrari, Maserati, Mercedes-Benz, Toyota, Lexis, Mazda, Volvo, Volkswagen, Audi, and Nissan. On the other hand, American Honda Motor Co. in 2008 announced that its 2009 Honda Odyssey Touring and Acura RL were its last models available with run-flat tyres, and with Honda no longer using run-flats.

In the automobile industry, precision vehicle grip and handling behaviour ultimately depends on the physics and mechanics of the four tyre contacts with the road or surface. The same can be said for other areas of auto manufacturing; precision rubber engineering is essential to maximum performance. The four tyre points of an automobile contribute up to 10% of its total spring rate, so comfort, economy, internal and external noise, and other factors are dependent on precise engineering.

With more and more electric vehicles coming to the marketplace, R&D departments face keen challenges. It is one more example of technology outpacing human resources in that companies constantly chop at labour costs, stifling productivity, staffing, and technological innovation. With this backdrop, two major challenges face tyremaking R&D staffs in electric automobile production. The first involves rolling resistance. The current limit on the range and performance of an electric vehicle is the amount of energy that can be stored in the batteries. Batteries are heavy. Technicians are working on tyres with reduced rolling resistance, not unlike R&D for fuel-injected vehicles, but with range per unit of battery storage that is vastly improved. Also, because batteries are heavy, evolving R&D designs have to include tyres that can carry heavier loads.

The great leap of technological advancement in synthetic rubber manufacturing has brought further and overall challenges to tyremakers. Spending trends on R&D in the tyre industry tend highest for the world's largest tyre producers, although not necessarily in order of sales and revenues. In latest figures dated to September 2011, Continental AG topped R&D spending at US$1.9 billion, a figure based on total corporate R&D spending that reflects the German company's evolution as a total auto parts supplier. Continental's tyre division spending made up US$215 million of the total. Conti's total was followed by Bridgestone at US$968.9 million, a 0.7% reduction from 2009, and Group Michelin at US$721.9 million, 7.7% higher than in 2009. Fourth in R&D spending was Goodyear Tire and Rubber Co. at US$342 million, 1.5% higher than in 2009, followed by Sumitomo at US$212.9 million. Pirelli, Hankook, Yokohama, Toyo Tire, and Cheng Shia/Maxxis International round out the top ten in R&D spending.

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