tomorrow

EXPERIENCING TECHNOLOGY WITH SCHAEFFLER

Issue 1 · 2015

SCHAEFFLER

» ***Ingenious people begin great works, industrious people complete them***

Leonardo da Vinci

DEAR **READER,**

Have you been mobile yet today – on a bike, train, plane, bus or in your car? If so, then welcome to the world of Schaeffler! More than likely, one of the vehicles you use is equipped with products of the Schaeffler Group. While many of these components may be very small, they do play a key role in any application. Some of our innovations have even been in use for decades. But we'd like future generations to continue to benefit from our know-how. That's why, today, we're already working on 'Mobility for Tomorrow.'

Mobility is a basic need – for all of us – like eating, sleeping and breathing. Mobility in all its facets is the focal topic of the Schaeffler technology compendium you're holding in your hands.

Mobility is part of our lives. It's shaped by many factors and is equally diverse. While in western industrialized countries traveling by air has become almost as common as riding a taxicab, many people in other parts of the world may still be envying their neighbor for a rickety bicycle that's financially out of reach for them.

While this may be true for the moment, in so-called threshold and third world countries prosperity and the urge to acquire (automotive) mobility are moving forward in step, implying global challenges of mammoth proportions. The number of commercial vehicles and passenger cars around the world will have doubled from 750 million in 2010 to 1.5 billion in 2030, according to the United Nations. The situation in the rail, marine and aviation sectors is similar. But where do the raw materials and the energy required to produce and power all these vehicles come from?

One key to answering this question is 'efficiency,' one of Schaeffler's core competencies. And as a globally active technology group, we're also present with our development and production sites, as well as tailored solutions, in the locations that will pose the greatest challenges: in Asia and in South America. Be it start-stop systems, variable valve timing or cylinder deactivation for internal combustion engines, drive system solutions for e-mobility such as eDifferential and eWheelDrive or other hidden masters of efficiency: on the following pages you'll find a wealth of information showing that the mobility of the future has long begun at Schaeffler – not only in the automotive sector.

For in the major cities, as well as in networks of global centers and in the field of energy generation new concepts and solutions are needed. Moving people and freight both have to become more efficient by preventing traffic jams, reducing dead mileage, making public transportation networks more efficient and optimizing the utilization of transport areas – to name just four key topics. Schaeffler's portfolio, in addition to components and systems for automotive powertrains, ranges from products for high-speed trains, innovative solutions for the aviation sector through to rolling bearings for solar energy and windfarms.

Mobility has been and will continue to be an exciting topic – also as reading material. On this note, I wish you an equally enjoyable and informative tour of the following 112 pages.

Klaus Rosenfeld
Chief Executive Officer

global

Different countries –
different mobility needs

in motion

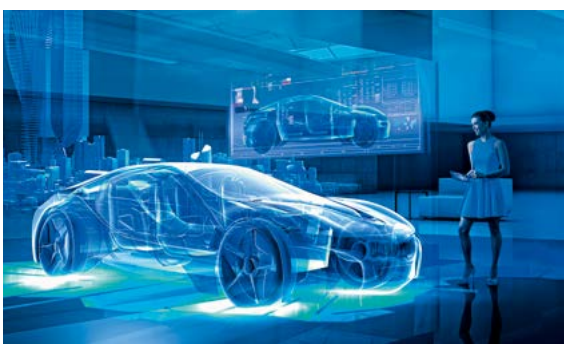
Mobility in the course of time

here and now

A tour of our mobile life

mobility tomorrow

How we move around in the future



» *Even the longest journey begins with the first step* Laotse

global

Different countries –
different mobility needs

MOBILE **IMBALANCE**

With 872 vehicles per 1,000 inhabitants Brunei is the world's best motorized country. Coming in last is Sudan with 3 vehicles per 1,000 inhabitants. The Indian subcontinent has a lot of catching up to do in terms of mobility as well. The ratio there is 18 motor vehicles per 1,000 inhabitants. For comparison, it is 647 in North America, 160 in South America, 563 in Europe, 317 in Russia, 539 in Japan and South Korea, 79 in China and 713 on the Australian continent.

Source: Int. Organization of Motor Vehicle Manufacturers (as of 2012)

THREE-WHEELING THROUGH THE SUBCONTINENT

Taxi, van or family car – the tuk-tuk is India's rolling all-purpose answer to everything. Intrepid tourists even go rallying with the daredevil trike.

by Sonja Schmidt


FOR HIRE
AP9v
2310
FIVE STAR

1,300 €

is the price of a new **basic model tuk-tuk**. The average annual income is 1,022 Euro.

80%

of Indians **rent their auto-rickshaws** in order to bypass the registration regulations.

Source: indiagovernance.gov.in

1.5 million

motorized rickshaws are on India's roads – and **growing by 15% every year.** India has 75% of the world's tuk-tuks.

Sources: globalfootprints.org, embarqindia.org

It's pouring with rain. Deep ruts in the cracked asphalt turn into gushing rivers. Scootering along at full speed, the muddy monsoon waters mercilessly soak the trousers up to the waist. A door for protection? Seat belts? Nope. What's the point? Negotiating India's nightmarish streets in a rickety tuk-tuk is no place for wimps. Dirt, smog, honking tangles of metal chaos are just as much a part of the adventure through this land of contrasts as the cattle grazing peacefully at the roadside.

Tuk-tuk owners are used to the pandemonium. With stoic composure they squeeze their three-wheelers into the tiniest gaps, stick to the bumper of the guy in front and are unfazed when a battered truck barrels towards them on the other side of the road. Whatever happens, just don't stop. True to the motto "You brake, you lose," these daredevil drivers don't stop tooting until the path is clear. In a 13-million megacity like Mumbai, whose streets are filled daily with 150,000 screaming auto-rickshaws as they're called in India, the noise is almost unbearable. Still, the Indians are not prepared to give up their favorite mode of transport. It's as much a part of the cityscape as the Beetle once was in Germany.

The tooting doesn't stop until the path is clear

Even for tourists it's hard to avoid using the six horsepower city mobiles – the descendants of Italy's Piaggio Ape from the post-war years. There are undoubtedly more comfortable ways to travel, but none cheaper. At ten cents per kilometer, visitors can be chauffeured around India's cities in a tuk-tuk taxi – although unsuspecting sightseers are often charged three times that

ASIA TAKES OFF **ON TWO WHEELS**

No other vehicle category is growing as rapidly as motorised bikes.

Worldwide, the number of motorized two-wheelers (motorbikes, mopeds, scooters, trikes etc), according to a 2013 survey conducted by the World Health Organisation WHO has increased from 200 million in the year 2002 to 455 million in 2010. Particularly impressive is Asia's share in this development. Almost 80 percent of all motorbikes are registered on the continent, predominantly in South East Asia.

Vietnam (358 motorbikes per 1,000 inhabitants), Malaysia (332), Indonesia and Thailand (251 each) are the countries with highest density of motorbikes in the world. When it comes to the total number of overall registrations, China holds the lead (110 m) ahead of India (82 m), Indonesia (60 m) and Vietnam (31 m). In Vietnam, motorbikes make up 96 percent of all vehicles. In Cambodia, Indonesia, Myanmar, the Maldives and Laos the percentage is over 80, with 72 percent in India and 61 in Thailand.

One of the main reasons for success of the motorbike market in these countries is that, unlike the car, a motorized bike is reasonably affordable. In India, a low-budget Honda (110 cc, 8.25 hp, 86 km/h) costs around 530 Euro, the basic model of the leading automobile marque Maruti Suzuki is at least ten times that amount. And unlike Western nations, a motorbike in these regions is not for leisure but the main mode of transportation – when necessary with a trailer on a hook or carrying the entire family or a stack of chicken coops.

The large number of vehicles, frequent use, at times chaotic safety standards and not least a lack of discipline in wearing helmets is mirrored in the devastating number of fatalities on the road. In direct correlation to the market share, 80 percent of the 300,000 fatal motorbike accidents each year occur in Asia.

And the environmental impact caused by the two-wheeled hordes is not insignificant either. In this regard, Schaeffler is taking countermeasures with efficiency-enhancing developments. More about this from page 68.

Nimble city runabout, tractor or heavy load transporter – particularly in Asia, mopeds, scooters and bikes are the inexpensive all-general answer to urban mobility

RICKSHAW CHALLENGE

The classic *Starting at 1,125 Euro, set off across the country in a tuk-tuk for seven, nine or 14 days. Included in the price is technical support by mechanics along the route.*

rickshawchallenge.com

RICKSHAW RUN

For fun-lovers *Three route options each over 3,500 kilometers for around 1,000 Euro per team, with an epic finish-line party at the end.*

theadventurists.com/rickshaw-run

amount. With his passengers aboard, the driver maneuvers his rickshaw with its "tuk-tukking" two-stroke engine through the traffic. Rarely, however, do passengers get the thrill of experiencing its 50 km/h top speed – the clogged city traffic on the subcontinent makes this almost impossible.

Those keen to explore India as a free independent traveler will sooner or later have a go themselves. Numerous events make this possible – for example the "Rickshaw Challenge," one of the nation's best known tuk-tuk rallies. Five times a year, up to 25 two-person teams meet in Panaji, Mumbai, Chennai or Trivandrum to rattle around the countryside in their brightly colored auto-rickshaws. Adrenaline junkies come from all over the world to take part. Ironically, not many locals are chomping at the bit to tackle long distances at the wheel of a tuk-tuk. But one thing is certain: such a road trip is an intense experience.

WITH 2.55 MILLION

new car registrations, India is the sixth largest automobile market in the world. Analysts from J.D. Power predict an increase to 11 million car registrations by the year 2020, pushing India to the number three spot in the world. Indian car buyers currently prefer small, inexpensive cars. Very few of the leading four automobile manufacturers are able to satisfy this demand, hence the market share is only 5%. Hyundai is the only global player with a double-digit market share of 10%. The top-seller is the Indian Suzuki subsidiary Maruti which, depending on the vehicle segment, has a market share of 48%.

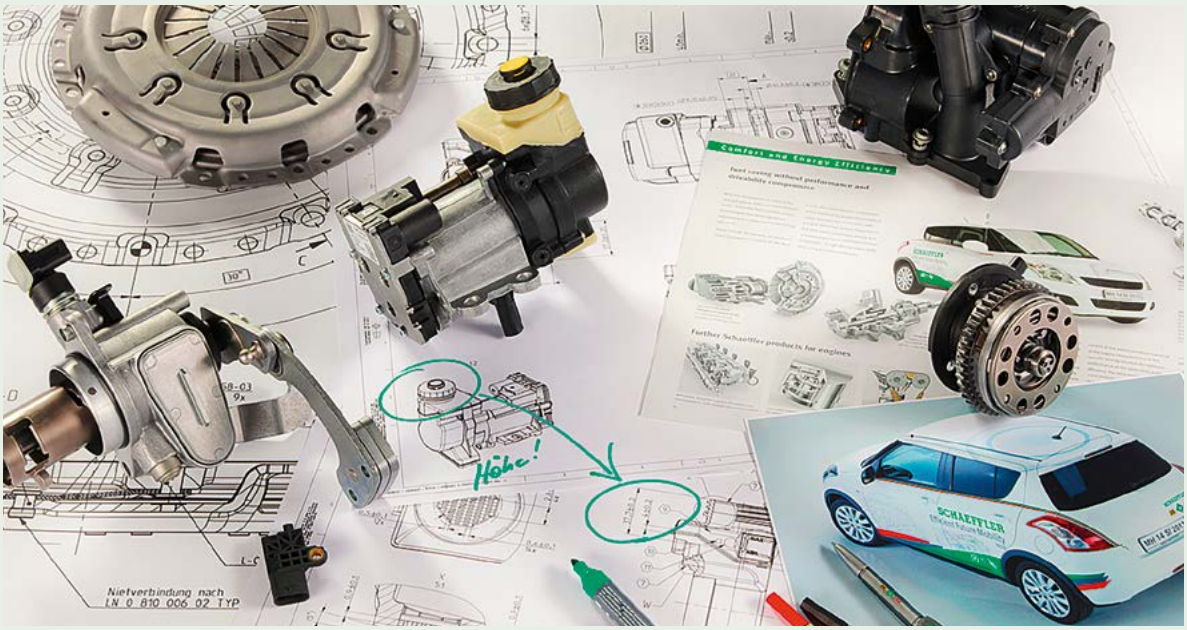
Sources: Credit Suisse, The Financialist, OICA

Cars, motorcycles, rickshaws, tongas, pedestrians and bicycles – India's road traffic is a colorful mobility mix

Before foreigners throw themselves into the potentially chaotic traffic and the equally as tumultuous roads, it is important to first become familiar with the machine: How do you steer a three-wheeler? How does the gear shift work? And what was that about driving on the left? For two full days before setting off it's about learning, learning, learning. Loaded up with all the necessary beginner's tips, the adventurers are unleashed into the melee of the metropolis. But don't get too cocky. The organizer's website states very clearly: "A tuk-tuk didn't score particularly high in crash tests." But it did get best marks for the most creative design. If you want to travel in true Indian style, then before setting out, the tuk-tuk has to be suitably "pimped." Liberal splashes of color, a couple of kitschy curtains for the windshield, plastic flowers for the mirrors – and the mousy chassis is transformed into a gaudy objet d'art à la Bollywood. Teams dress up too – as James Bond, Hippies, Bonny and Clyde or Gandhi. Anything goes as long as it's fun and attracts a lot of attention.

When all the preparations are done the journey can begin. Especially popular is the Mumbai Express: A rally over 1,900 kilometers from Mumbai in the west heading east to Chennai, past holy rivers, temples, elephants, and spice traders of the Maharashtra, Goa, Karnataka and Tamil Nadu regions. Driving time: two weeks – provided everyone finds the destination. A navigation device or a detailed map on paper? No such thing. After all, no one wants to quarantine themselves in a tuk-tuk, they're there to experience the country and the people first hand. And there's no better way to do this than to get lost. Those who don't lose their way in the maze of narrow alleys at least once a day are missing out on the real India.

Eight to ten hours of driving every day is the only way for competitors to get the task done with a little time for breaks. The temperature has reached over 30 degrees – and it's only breakfast time. After a few minutes, the sweat-soaked bodies are pasted to the plastic seats like the characteristic sticker on the back stating "Please horn!" Despite the humidity and wavering concentration, it's impossible to doze at the wheel of a trishaw. "Bike, cow, kid!" screams the co-driver every second. Faced with dozens of mud puddles and pot holes, it's a small miracle that drivers aren't constantly biting their own tongues – the second skill of driving a rickshaw after keeping calm. The ultimate winner is the one who dares the most – and the one who has the most bruises at the end of the day.



NEW IDEAS FOR INDIA

Motorbike, tuk-tuk or even a car – with wealth increasing (half a billion Indians will join the middle class by 2025) the growing desire among millions of Indians is to own their own vehicle. In addition to individual mobility, public transport and freight carriage on the streets, train and air transport are gaining in importance – with the associated burdens on resources and the environment. The Schaeffler brands FAG, INA and LuK, which have had a presence on the subcontinent for half a century, are helping to counteract the growing energy demands with efficient drive solutions.

The Hamburg Institute of International Economics anticipates that the number of cars in India alone will triple by the year 2030 to around 65 million units. Similar growth rates are expected in the two-wheeler and freight transport segments. Given these figures, every drop of fuel and every gram of exhaust emission that can be saved per vehicle counts. Taking the example of the concept vehicle "Future Mobility India," based on India's market leader Maruti Suzuki Swift, Schaeffler demonstrates that the CO_2 emissions can be slashed by ten percent over comparable production vehicles through using proven and cost-effective technologies from Schaeffler's current production portfolio (e.g. thermal management, variable camshaft, electronic clutch).

Schaeffler India is also working on a concept for reducing fuel consumption and emissions in motorcycles. New, low-friction bearings for engines and wheels are important steps towards low-friction chain-drive and valve train systems. "With our manufacturing and development expertise, we can supply our customers in the automotive industry with cutting-edge technology for engines, gearboxes and chassis," says Dharmesh Arora, CEO of Schaeffler India.

With a broad range of bearing solutions, systems and services, Schaeffler has also become an important partner to other crucial industries in India, including heavy industry, machine tools, wind energy and rail transport.

Dharmesh Arora,
CEO Schaeffler India

SCHAEFFLER IN INDIA

— *Schaeffler has been represented in India since 1962.*

— *After China and Korea, India is the Schaeffler Group's third largest market in Asia.*

— *23 percent of Schaeffler products worldwide are sold to Asia. By 2015 this sales figure should reach 25 percent.*

— *In three factories and 13 branches, 2,300 employees manufacture and sell products of the LuK, INA and FAG brands.*

WHEN IN **ROME...**

For almost the last two decades, the Australian professional race driver Mark Webber has travelled the globe. He knows from experience that negotiating his way around the streets of the world can be as challenging as on a race track.

by Torben Schröder

Rumour has it that professional race drivers only sit at the wheel of their race cars or in the back seat of a chauffeur-driven luxury limo: wrong. Mark Webber is the best contradiction of this. Like you and me, he is not too proud to throw himself into the everyday traffic chaos – no matter where in the world it is. His private wheels: a Porsche 911 Turbo S.

Webber's motoring roots stretch back to his homeland of Australia. In 1990, at the age of 14, he kick-started his motor racing career at the wheel of a kart. At 16, he obtained his driver's license for public roads and afterwards – like many teenagers all over the world – there was no holding him back. "I hooned over paddocks with my mates, and inevitably we got into sticky situations. But I did it all without any major incidents. That was pretty much how I learned to drive a car in Australia," says the now 38-year-old. "As a rule, you shouldn't mix racing and driving on public roads, of course."

Australia – big country with many rules and precious little public transport

Webber's first car: a Toyota Corona scrap heap that cost him 500 Australian dollars. But it was good enough for cruising through the traffic of Australia. "The infrastructure is not so bad. All the arterial and coastal roads are paved and in good condition. There are lots of long, straight roads. Driving is not particularly exciting. Except in our largest cities, like Sydney. It's madness there." Webber's tip for anyone heading out on Australian roads: "Stick to the regulations." In very few other countries has he encountered such strict adherence to and close monitoring of the rules. "There are loads of speed cameras set up, especially in the cities. Illegal parking and speed offenses are penalized with high fines." And that is a memory Webber will not forget: In Australia it's not unusual for speed limits to vary between 40 and 110 km/h within a few kilometers. Not uncommon for a huge, flat country: The car is by far the most important mode of transport in Australia. "It's not like in Europe with its extensive public transport system or cycle paths," said Webber.

In 1996, Webber moved to Great Britain to further his motor racing career. Via various feeder series he made the leap in 2002 to become a regular Formula 1 driver where his best results were third place at three world championship rounds. The great world journey began, and continued after his switch at the end of 2013 into the World Endurance Championship (see box at the right) as a Porsche works driver. Since then, Webber has visited countless countries – and encountered countless interpretations of mobility.

Up to speed on the fly: Mark Webber prepares for his next racing commitment by studying the Schaeffler Fact Sheet on his iPad

Take London for example: In stark contrast to Australia, Webber found he could quite happily do without a car in the capital of his new home, thanks to the city's exceptional public transport network. Even in densely populated Japan, cars can be left at home: "There is no other country where I feel safer on foot."

India, however, is a completely different story. No matter how one gets about there, it's always dangerous. "Are there any rules? I've never seen such chaotic traffic. It's not uncommon to have cars coming at you on the wrong side of the road. Luckily I always had a driver. They seem to know how to deal with it." Webber also tells of encounters with elephants and free roaming dogs in India, with plenty of the latter crossing his path in Brazil, as well. In Malaysia it's wild monkeys you have to watch out for, "which make driving a car there a rather interesting exercise," said Webber matter-of-factly. It's not surprising: growing up in Australia he has come face to face with a large variety of wildlife.

Habit, as Webber has discovered over the years, is definitely a good driving instructor, and he recalls his first year in Europe. After the hot temperatures of Australia, he experienced is first exposure to the vagaries of winter at the wheel of his old Fiesta 1.1: from scraping ice from the windshield to ignition problems and driving on ice and snow. "Completely unfamiliar for me, but when I arrived in Switzerland, for example, the people there take the situation completely in their stride."

Something else he noticed in Switzerland and its neighbours Austria and Germany was how clean and well maintained the cars were there. Real status symbols. Not at all like in southern Europe or poorer regions such as Africa or India where cars are simply a means of getting from A to B.

As a motor racing globetrotter, Webber is constantly confronted with switching from the right to the left-hand side of the road. And here as well, practice makes perfect: "I've been doing it now for quite a number of years, so it's no big deal for me. But if you're not used to it, you should take extra care for the first kilometers in order to familiarize yourself with the unaccustomed conditions."

To make road transport safe and smooth for everyone there is one thing that is essential, no matter what country: tolerance. Webber notices this particularly when he's out on his racing bike. While cyclists are often regarded as rolling traffic barriers by some motorists around the world, in France and Italy they are treated as equals on the road: "Possibly it's because professional cycle races are very popular in these two countries," speculates Webber.

But one thing is certain: In contrast to the race track, on the road it's all about driving with and not against each other. It's a guideline that should apply the world over.

MISSION LE MANS

Campaigning the Hybrid car 919, Porsche announced its return *to the highest vehicle class in long distance racing after 16 years – including the 24 Hours of Le Mans. And there again as support: Schaeffler. In the seventies, the automobile supplier used Porsche's Le Mans winning 917 as a development mule for valve train components, which would eventually be incorporated into the production line and lay the foundation for the extensive portfolio of fuel-saving components at Schaeffler. At Le Mans since 2014, energy efficiency has been more important than ever before. "The parallels between motorsport and series production make the World Endurance Championship WEC and the cooperation with Porsche an ideal platform for Schaeffler," says Prof. Peter Gutzmer, Board Member for Technology at Schaeffler. Since the 2014 season, Porsche has fielded the 919 hybrid sports car in the WEC races around the globe, with one of them piloted by ex-F1 driver Mark Webber. A V4-turbocharged petrol engine putting out 370 kW (500 hp) drives the rear axle, with a circa 185 kW (250 hp) e-motor at the front axle.*

Racing around the world: the Porsche Hybrid 919 sports car

CLICHE – YES OR NO?

Italians drive like lunatics*– do you agree? Well, it's true. At least according to a survey by the French research institute, Ipsos. Here are the front-runners of each category:*

SWEDISH
Responsible

ITALIANS
Hooligans

GERMANS
Ranters

SPANIARDS
Honkers

BRITS
Speedsters

GALACTIC GEOLO

Place of action: Mars. Since August 2012 the research vehicle ‘Curiosity’ has probed the rocks, atmosphere and the radiation on the red planet. Also on board: Schaeffler technology. An extraterrestrial achievement.

by Volker Paulun and Tom Teßmer

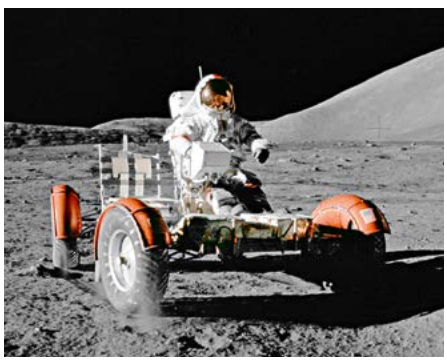
GIST

MISSION MILESTONES

November 2011 *At Cape Canaveral on 26.11 at 15:02 coordinated world time (UTC) the US mission 'Mars Science Laboratory' (MSL) is launched into orbit in a Centaur upper stage-Atlas V(541) rocket. After eight months in space, the Mars rover Curiosity lands on 06.08.2012 in Gale Crater. The signal requires 13:48 minutes for the 248 million km between Mars and Earth.*

September 2012 *Curiosity discovers the remains of a riverbed dried up for several billions of years. The form and size of the eroded pebbles allow Geologists to suggest the river's flow velocity (0.9 m/s) and depth (10 cm to max. 1 m).*

March 2013 *Primitive life forms could have existed on Mars. The analysis of a sample indicates that the rocks in the examined regions contain sulphur, nitrogen, hydrogen, oxygen, phosphorus and carbon. These elements are regarded as the basic components of life.*

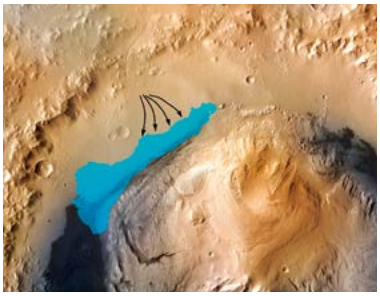


Man is not only mobile on Mars, but in fact also on the Moon – at a leisurely pace. The record is 18 km/h, set in 1972 by Eugene Cernan with the 'Lunar Roving Vehicle'. Strangely: Cernan set another speed record, which remains intact to this day, with his fellow astronauts in 1969. This was, however, in the high-speed domain: the Apollo 10 Command Module reached 39,897 km/h on its trip back to Earth. Never before and never after were humans so fast.

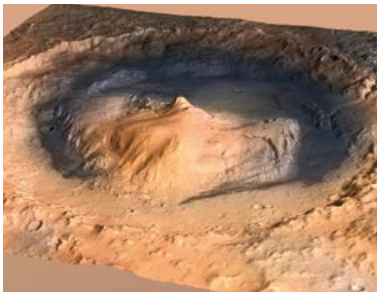
Space, the final frontier. Star date 2015. The mobility adventure of the Mars rover Curiosity started more than two years ago. 248 million kilometers from Earth, the unmanned high-tech vehicle probes planetary corners of Mars, where no man has gone before, at a sedate 0.10 km/h. With its thirst for knowledge, Curiosity completely justifies its name. A crucial factor for the success of the Mars fact-finding mission is the stability of the technology. Just as a car not running on Earth is of little value, in space it is of virtually no value whatsoever. In Curiosity's case, the financial loss of an irreparable defect would be in the area of ten digits. All the same, the NASA estimates the total project cost to be 2.5 billion Dollars. The 3.1-meter long Mars rover, which weighs 900 kilos is by far the heaviest manmade object ever to roam the Mars surface, would have to wait for an eternity for a breakdown service. With a signal transmission duration of 14 minutes, the same applies for remote maintenance.

It is all the more important that every sequence of functions down to the smallest link quite literally withstand the extraterrestrial demands without a hiccup. Otherwise, a fate similar to that which struck its four luckless predecessors threatens Curiosity as well: although Spirit lived for five years and thus longer than expected, in this time, however, it completed a mere eight kilometers on Mars. Its suffering began with a hobbled front wheel; the ailing vehicle then got bogged down in a dune before finally throwing in the towel due to a flat battery. The worst: the scientific harvest was just as weak as the distance travelled due to the poorly selected operational area. The appropriate soundtrack for this mission: 'Money for nothing' by Dire Straits.

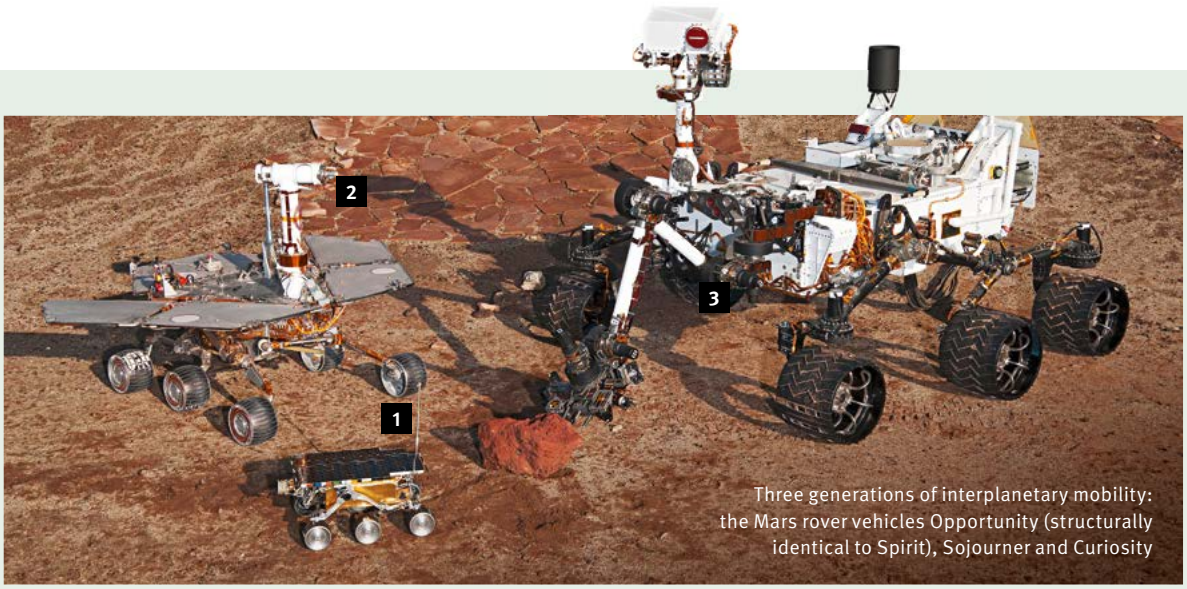
September 2013 *Curiosity finds traces of methane. The gas can be evidence of biological activities. However, the percentage of methane in the Mars atmosphere is six times less than anticipated.*



December 2013 *While examining primeval water, Curiosity discovered a wide range of essential elements. Once again, there is evidence that microorganisms could have lived in the freshwater lake around 3.5 billion years ago.*



September 2014 *After a little less than two years Curiosity has reached its main destination, Mount Sharp. From this point, the rover is supposed to slowly work its way up the mountain while consistently collecting new samples in the process. The objective is to sample a sequence of strata in order to gain additional findings about the geological history of the mountain.*



Three generations of interplanetary mobility: the Mars rover vehicles Opportunity (structurally identical to Spirit), Sojourner and Curiosity

CURIOSITY AND ITS ANCESTORS – **GENERATIONS COMPARED**

	1 Sojourner	2 Opportunity/Spirit	3 Curiosity
Year of launch	1996	2003	2011
Mass (kg)	10.6	174	900
Scientific instruments	4	5	10
Max speed (cm/s)	1	5	4
Data (MB/day)	max. 3.5	6–25	19–31
Computing power (MIPS)	0.1	20	400
RAM (MB)	0.5	128	256
Schaeffler parts on-board	–	High-precision bearings	High-precision bearings

MARS AND THE EARTH IN COMPARISON

228,000,000 km	***Average distance from the sun***	*150,000,000 km*
6,792 km	***Diameter***	*12,742 km*
687 days	***Length of year (in Earth days)***	*365 days*
3.72 m/s	***Gravitational force at equator***	*9.78 m/s*
–63 °C	***Average temperature***	*15 °C*
approx. 22 km	***Highest peak (Volcano Olympus Mons v Mt. Everest)***	*8.848 km*
approx. 7 km	***Deepest canyon (Valles Marineris canyon system v Mariana Trench)***	*11.034 km*
2 moons	***Phobos and Deimos (Greek for fear and dread)***	*1 moon*

Curiosity on the other hand functions flawlessly so far – with the exception of a few insignificant teething problems. Since August 2012, the galactic geologist covered almost 5.2 kilometers at crawling speed. Admittedly, fast is something different. However, the agile rover can pirouette through 360 degrees on the spot and it masters the art of autonomous driving – a mobility issue that may also play an ever more important role on Earth in the future. Curiosity is also en vogue in terms of drive technology: each of its six wheels is powered by a dedicated DC motor. Its all-wheel drive and wheel diameter of 51 centimeters make Curiosity into a real 'monster truck': it can scale obstacles of up to 75 centimeters. Energy source for all equipment and the 2.9 kW/4 hp e-motor is a radioisotope thermoelectric generator, which converts 2,000 Watts of thermal energy gained through radioactive decay into 110 W of electric power. The power supply's low efficiency of just six percent, which is also due to the icy temperatures of minus 50 degrees Celsius on Mars, is offset by its robustness: the tiny power plant functions without moving parts.

In addition to the drill and excavator, the brush is also one of Curiosity's truly terrestrial tools

The enormous Gale Crater is viewed as the stony Mars encyclopaedia

The Mars rover's mobility is for a specific purpose. It should roam across Mars and collect information. Its domain: the Gale Crater where it was deployed. With a diameter of 154 kilometers and an extra biblical age of almost four billion years, the trough is regarded as the stony encyclopaedia of Mars. The exploratory rover may well be able to satisfy its curiosity here. A pair of extremities help in its task: a mast equipped with a variety of cameras, navigation aids and measuring instruments as well as a near two-meter long multifunctional arm, in which various equipment is housed. A drilling system, an excavator shovel, a brush and a sieve with different collecting trays form the tool unit for ground analysis. The Schaeffler subsidiary Barden provides type 36HX320 and S200HDL high-precision bearings to further guarantee the flexibility of these important 'limbs' on the rover. Compact design, lowest possible weight, lowest

friction, highest precision and greatest possible reliability enjoy priority. The components are custom-made to suit the extreme demands on Mars and resist minus 90 degrees Celsius or sandstorms with top speeds of up to 140 km/h. For the design and manufacture of such components, Barden and Schaeffler can rely on a long extraterrestrial track record (see also info box on this and previous page).

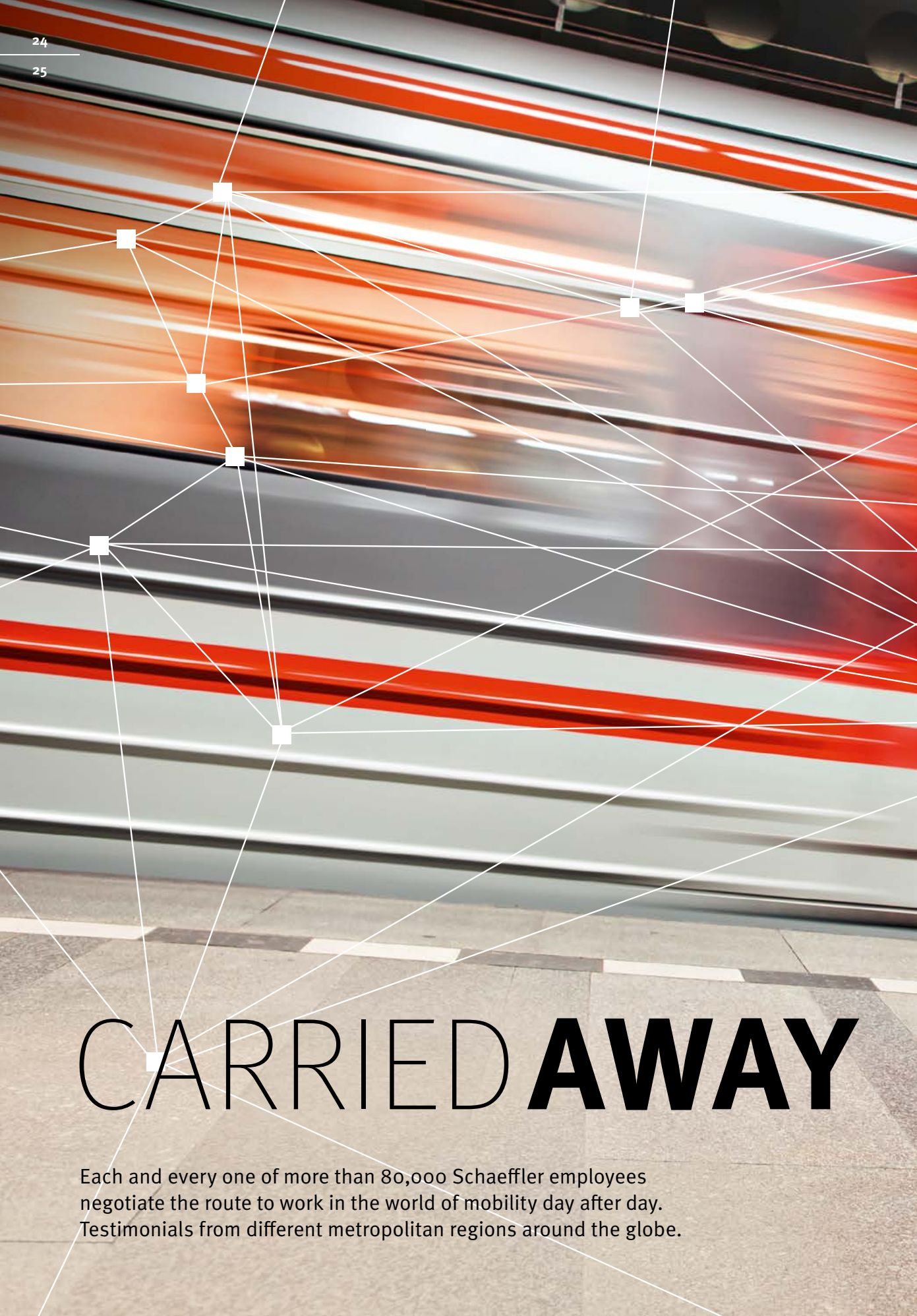
Opportunity's estimated lifespan has grown from 90 days to ten years

Its creators are hoping that Curiosity will be able to continue its exploratory mission far beyond the stated minimum goal of two years. Their confidence is based on the unstoppable Mars rover Opportunity. Unlike Spirit, which failed early, its twin Opportunity also equipped with Schaeffler bearings appears indestructible. The estimated lifespan of 90 days has now grown to ten years during which the rover rolls across Mars and transmits scientific data to Earth. In July 2014, Opportunity set a new distance record of about 40 kilometers for space vehicles, which the Soviet lunar vehicle Lunochod 2 had held since 1973.

In 2020, NASA aims to send the next rover to Mars. The Curiosity successor should have seven research instruments on board, which should facilitate "unprecedented, previously unseen scientific investigations" announced NASA, and include an UV laser and a device to produce oxygen. Extremely likely then that Curiosity is still mobile on Mars at this time.

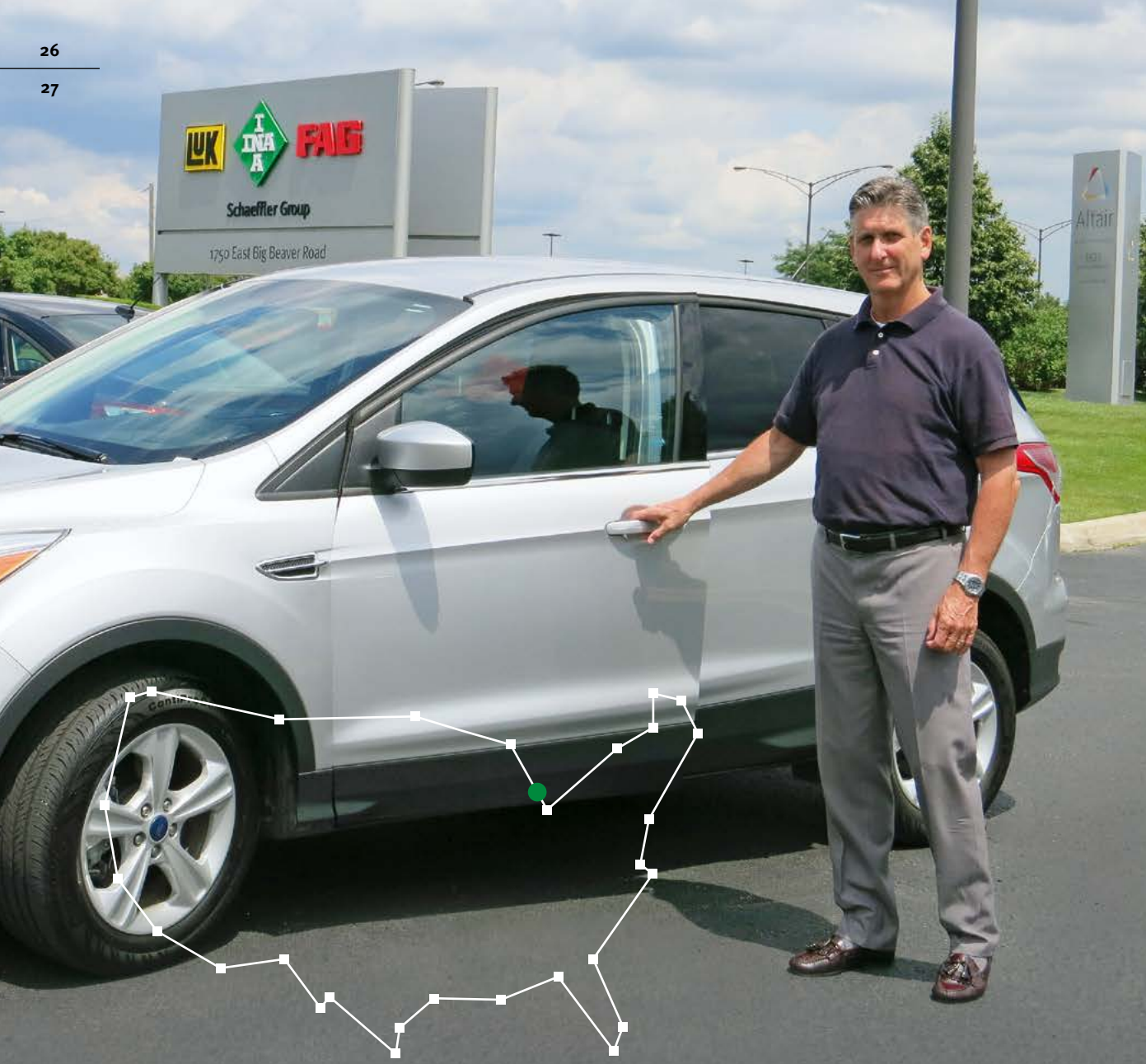
DID YOU KNOW THAT ...

... Schaeffler products also blast off in rockets? *FAG Aerospace equipped the NASA rocket Delta IV Heavy, which was launched into space from Cape Canaveral on 29 June 2012, with high-precision angular contact ball bearings. The components withstand the high rotational speeds and temperatures generated by the rocket engines. A glance at the datasheet reveals exactly which forces are exerted here: the liquid hydrogen powered power plant develops a total thrust of 9,400 kilonewtons or, in other words, around 8.15 million horsepower. The special steel Cronidur 30 and ceramic rolling elements proved to be the ideal combination to ensure smooth operation of the bearing. Until the program was cancelled, the Space Shuttle also escaped the Earth's gravitational pull with FAG roller bearings in the turbo pumps. The same applies for the Ariane rockets used by the European Space Agency ESA.*



CARRIED **AWAY**

Each and every one of more than 80,000 Schaeffler employees negotiate the route to work in the world of mobility day after day. Testimonials from different metropolitan regions around the globe.



“NO WIDESPREAD CYCLE PATH NETWORK, HARDLY ANY PUBLIC TRANSPORT”

Richard Neilson (56), Birmingham/Michigan, USA
Schaeffler employee since 1989

Position *Marketing Manager*
Distance to work *15 km (duration 20 min)*
Form of transport to work *Private car*
Vehicles available in household
2 cars, bicycles
Annual expenditure for mobility
5,000–7,000 US Dollar (approx. 3,650–5,100 Euro)

“In my spare time I like to go walking and cycling. When the weather is good I would also like to ride my bike to work, but there aren’t any decent cycle paths on the way to Schaeffler. Public transportation is also very sparse. So, I climb into my Ford Escape every morning at 07:30 and drive from my hometown Birmingham, a suburb of Detroit with 20,000 inhabitants, to Schaeffler in neighbouring Troy. As the roads are quite full during the rush hour, I need around 15 to 20 minutes for the few kilometers. To avoid the traffic jams on the freeway I deliberately take the minor roads. In general, the roads in and around Detroit are not congested, but they are busy. This is also related to the meagre selection of public transport services. Cinema, shopping, visiting the doctor – without a car you are completely up the creek.”

M-1 RAIL

is the name of a streetcar project, which is mainly privately financed, started in 2013 in Detroit. It will connect the city district around Woodward Avenue (125,000 jobs, 275,000 residents) to the existing sparse public transport network currently comprised of trains and express bus routes. Additionally, the Michigan Department of Transport plans to equip Detroit with one of the world's most modern transport systems, in which busses, trains, motorists and cyclists as well as pedestrians are perfectly networked with one another. This modern transport system should also help to make Detroit more attractive again.

The 'big three' of the US automobile industry (Ford, GM and Chrysler) once made Detroit wealthy and into the fourth biggest city in the USA. The mechanisation of jobs and a shrinking market share led to a massive loss of jobs, which was not compensated for locally. The consequence: Detroit has lost over 60% of its once 1.9 million inhabitants over the last 60 years. 35% of the urban area is now deserted.

SCHAEFFLER IN NORTH AMERICA

Schaeffler has 13 facilities *in the USA and Canada. In addition to pure distribution centers, there are also manufacturing plants and development centers for bearings and engine components. Schaeffler is an important supplier to the aerospace industry through its trio FAG Aerospace, Winsted Precision Ball and Barden. With the concept vehicle 'Efficient Future Mobility North America', Schaeffler demonstrates by using selected products how the consumption limits imposed for 2020 can also be met on an SUV, which is so popular in America.*

5,456,428

inhabitants live in the **Detroit metropolitan area,** which is the third largest in the Great Lakes region behind Chicago and Toronto.

50%

of Michigan's economic power is **generated through exports.** A good infrastructure is therefore essential for the state to survive.

July 2013

saw Detroit become the **first US metropolis to announce bankruptcy.** Today, many young start-ups inject fresh tax dollars into the empty coffers of the former 'Motor City'.

FACTS USA

Inhabitants *316.1 m (3rd place worldwide)*

Urbanisation *82.9% (51st place)*

Life expectancy *♂ 76 (35th place), ♀ 81 (37th place)*

Gross domestic product (GDP) *53,143 $ (15th place)*

Cars/1,000 inhabitants *403 (37th place)*

Vehicles/1,000 inhabitants *786 (4th place)*

The USA rail network stretches ***228,513 km*** *and is therefore the world's longest. The three countries following in the rankings – Russia, China and India – have a combined length of 215,505 km.*

15,000

buses transport around 10,000,000 passengers every day.

20,781,000

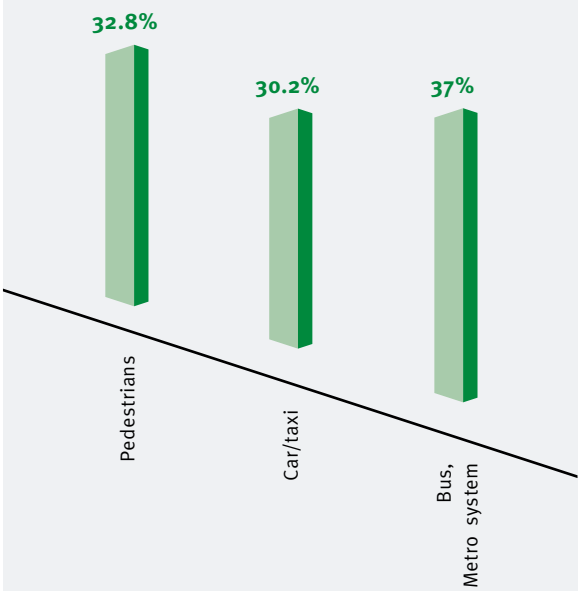
inhabitants live in the **metropolitan region São Paulo.** Consequently, the city is the world's sixth largest urban conurbation and the most densely populated city in the southern hemisphere.

As an alternative to trams, São Paulo relies on electric trolley busses. Almost 200,000 passengers use the almost 270 vehicles, which are operated by two companies.

2015

should see São Paulo's underground network break the 100 km mark. In comparison: Berlin Underground/Tram 475 km, London Underground 403 km, New York City Subway 390 km.

TRAFFIC DISTRIBUTION SÃO PAULO



Source: South American Cities – Securing an Urban Future. Urban Age 2008

FACTS BRAZIL

Inhabitants *200.4 m (5th place worldwide)*

Urbanisation *85.1% (37th place)*

Life expectancy *♂ 69 (101st place), ♀ 76 (90th place)*

Gross domestic product (GDP) *11,208 $ (77th place)*

Cars/1,000 inhabitants *179 (68th place)*

Vehicles/1,000 inhabitants *210 (Platz 68)*

Less than 15% *of Brazil's 1.6 million kilometer road network is* ***paved.***

One of the country's most important transport arteries is the ***Amazon, the world's largest river*** *by water discharge.*

SCHAEFFLER IN BRAZIL

Schaeffler has been present *in Brazil since 1958. Today, products for the automotive, heavy industry, railway and aviation are manufactured in the factory near São Paulo. Furthermore, from the same location Schaeffler Aftermarket supplies retailers and workshops with clutches, wheel bearings and other parts.*

"I CAN'T GET TO WORK ANY FASTER, MORE COMFORTABLY OR CHEAPER THAN WITH THE SCHAEFFLER BUS"

Priscilla Freitas (31), Sorocaba, Brazil
Schaeffler employee since 2012

Position *Marketing Analyst*
Distance to work *15 km (duration 20 min)*
Form of transport to work *Schaeffler company bus*
Vehicles available in household *Car*
Annual expenditure for mobility
approx. 3,000 Real (976 Euro)

"I live in the center of Sorocaba, a suburb of São Paulo. I get on board the Schaeffler company bus at 6:20 in the morning and travel the 15 kilometers northeast from Sorocaba to work. I arrive 20 minutes later. It's not possible to travel faster, more comfortably or cheaper with any other vehicle. Alternatively, I can also take a taxi or the public bus, but I only use either of them in an emergency if I've missed the Schaeffler bus. As I leave very early, the roads are still empty at this time. Things looks completely different when I travel home in the afternoon. As a result, the bus needs almost twice as long. And this in a suburb of São Paulo. Everything is much, much worse in the city itself. On the other hand, in my spare time I usually drive my own car. This individual and speedy form of mobility is very important to me, especially as I sometimes have the feeling that I should be in two places at once."

"IN CITIES LIKE TURIN AND MILAN IT CAN TAKE UP TO 45 MINUTES TO REACH THE MOTORWAY"

Valentina Temporelli (37), Arona/Milan, Italy
Schaeffler employee since 2006

Position *Marketing Manager Automotive*
Distance to work *28 km (duration 30 Min.)*
Form of transport to work *Car*
Vehicles available in household
2 cars, 2 bicycles
Annual expenditure for mobility *5,000 Euro*

"I travel a lot visiting customers in northern Italy. To this end, the car is very helpful as an extremely flexible form of transport – as long as the journey doesn't take you into the chronically congested city centers like Milan or Turin. When I have to go there, I try to park on the city outskirts and switch to public transport or car sharing providers. My permanent place of work is at Schaeffler in Momo. This is located 23 kilometers north of the Milan airport Malpensa and 28 kilometers from my hometown Arona. The 30-minute drive is often the first highlight of my day: for example, when there is a sunrise to admire or herons that strut through the wonderful nature. Because my hometown Arona is situated in a tourist region, the town often overflows between March and October. So, I ride my bicycle a lot at home or walk. For longer journeys to the mountains or to the beach I mainly use the car in my spare time. Although there is a railway station in Arona, the public transport network outside the big cities is, as a whole, not very well developed. Mobility is very important to me. My ideal vision of mobility is that I can always chose with which form of transport I travel. You have a much bigger choice in the cities than in the country for this purpose."

MILAN

is Italy's largest traffic hub. The motorways A1 (to Rome and Naples), A4 (Turin–Trieste), A7 (to Genoa) as well as the A8/A9 (connection to Switzerland) cross here. They all merge into the Milan Tangenziale, which is comprised of the A50 (west tangent), A51 (east tangent) and A52 (northeast tangent) motorways.

Covering a distance of 115 kilometers, Milan's streetcar network is one of the largest in Europe.

At 74.6 km

Milan's subway network is the longest in Italy.

2008

saw the introduction of a weekday **city toll for cars, trucks and coaches** to reduce the air pollution and traffic congestion.

3 **airports** serve the metropolitan region Milan: Linate, Malpensa and Orio al Serio near Bergamo.

1.3 million

people live in Milan, **Italy's second largest city** after Rome. The metropolitan region, with over 8 million inhabitants, even heads the list of most densely populated conurbations ahead of Naples (5 million).

FACTS ITALY

Inhabitants *59.8 m (23rd place worldwide)*

Urbanisation *68.8% (78th place)*

Life expectancy *♂ 79 (9th place), ♀ 84 (6th place)*

Gross domestic product (GDP) *34,619 $ (35th place)*

Cars/1,000 inhabitants *605 (7th place)*

Vehicles/1,000 inhabitants *682 (10th place)*

Italy has ***6,621 motorway kilometers.*** *Analogous to the level of industrialisation and economic power, the north is significantly better developed than the south.*

Italy has had an ***uninterrupted high-speed rail link*** *from north to south since 2009.*

SCHAEFFLER IN ITALY

Schaeffler has been present *in Italy for more than 50 years. Application and advisory consultation and distribution of roller bearings, engine components and linear technology is made from Momo near Milan. Together with Fiat, the Schaeffler Group 'UniAir' develops and produces the world's first fully variable electrohydraulic valve timing. Fuel consumption and pollutant emissions are reduced by as much as 25 percent as a result.*

94 km

stretches the **Mumbai Pune Expressway,** India's first six-lane carriageway. An average of 43,000 vehicles use the toll road daily. The Maharashtra state government already plans to expand it to an eight-lane expressway.

57,000,000 Euro

cost India's first **successfully completed Mars mission** in 2014 – less than the majority of passenger aircraft. The next step should see the first Indian robot vehicle landing on the Moon in 2016.

4.7 m km

is the total length of India's **road network,** slightly more than half is paved. After the USA (6.5 m), it is the world's second longest road network.

SCHAEFFLER IN INDIA

Half a century ago, *FAG became the first of the three Schaeffler product brands to open a subsidiary in India. INA and LuK followed over the years. Today, Schaeffler is represented by three factories and 13 subsidiaries. 2,300 employees produce products for the brands LuK, INA and FAG or market these.*

Only three Indian cities have an underground network with a combined length of 260 kilometers: Delhi, Kolkata (Calcutta) and Bangalore. Pune should also benefit from an underground, however, the completion date is delayed from year to year, currently 2021.

WITH 3.1 MILLION

inhabitants (5 m in communes), Pune is the second largest city after Mumbai in the state of Maharashtra, and the region's industrial center (automobile, light industry, software and mechanical engineering) and also the cultural heart.

FACTS INDIA

Inhabitants *1.252 bn (2nd place worldwide)*

Urbanisation *32% (175th place)*

Life expectancy *♂ 63 (136th place), ♀ 67 (142nd place)*

Gross domestic product (GDP) *1,499 $ (162nd place)*

Cars/1,000 inhabitants *11 (150th place)*

Vehicles/1,000 inhabitants *18 (153rd place)*

India's New Delhi and Mumbai airports handle together ***half of South Asia's civil air transport.***

India is ***one of 59 countries*** *worldwide and 16 Asian countries in which the vehicles drive on the left hand side.*

"WITH THE BUS TO WORK, BY CAR FOR FUN"

Rahul Kumar (31), Pune, India
Schaeffler employee since 2013

Position *Assistant to the Management Board, Schaeffler India*
Distance to work *36 km (duration 55 min)*
Form of transport to work *Schaeffler company bus*
Vehicles available in household *Car, motorcycle, scooter*
Annual expenditure for mobility
approx. 118,400 Rupees (1,500 Euro)

"As a Schaeffler employee I am privileged to travel to work with a company bus. I set off from my home in the center of Pune at 07:15 and walk ten minutes to the bus stop on the expressway to Mumbai. The bus needs 45 minutes for the 35 kilometers to the INA subsidiary on the outskirts. It's not possible to make the journey faster, cheaper or more comfortably. Not even by train or the taxi shuttles, which would also be theoretically possible. I only drive with my own car to work when I need to be flexible. Meanwhile, I mainly use my car for private purposes, although you can hardly drive faster than 40 km/h on the chronically congested roads. However, it's quite a few kilometers from my home to the next supermarket or recreational facility. It's simply too far on foot. For distances over 100 kilometers, I switch to the bus or train. As a rule, it's very important for me to be mobile, both privately and professionally."

"I LEAVE THE CAR WHEN POSSIBLE AND TRAVEL WITH THE UNDERGROUND"

Luyi Wang (30), Shanghai, China
Schaeffler employee since 2011

Position *Marketing Manager*
Distance to work *35–40 km (duration 90 min)*
Form of transport to work *Underground*
Vehicles available in household *Car*
Annual expenditure for mobility
4,000 US Dollar (approx. 3,100 Euro)

"Although it's always crowded, the underground in Shanghai is still the best and most punctual form of transport. There is often complete gridlock on the streets. Especially when you hit the rush hour. Leaving five minutes too late means arriving 45 minutes late if you are unlucky. Many motorists are prepared to make major detours just so they don't get stuck in the traffic jams. I only drive my car or take a taxi to the office if I have to be there very early. I also have the feeling that the traffic is getting worse and worse here in Shanghai. There is simply no space to drive cars on the roads or for parking. This is why I also mainly use the underground in my spare time and leave my Ford Focus at home, whenever it's possible. The underground network in Shanghai is extremely well developed today. You can get everywhere within the city."

SEVEN

of the ten world's biggest ports are found in China. Shanghai has held the top spot for five consecutive years now. In 2014, the capacity of around 35.3 million 20-foot containers was handled – more than the combined volume of trade of the three largest European ports Rotterdam, Hamburg and Antwerp.

While the total number of new car sales in China continues to rise, in many metropolises the number of cars registered is capped. In Shanghai, new registrations are assigned via auctions. The surcharges are occasionally more expensive than the vehicle purchase price.

FACTS CHINA

Inhabitants *1.359 bn (1st place worldwide)*

Urbanisation *53.1% (121st place)*

Life expectancy *♂ 73 (49th place), ♀ 76 (95th place)*

Gross domestic product (GDP) *6,807 $ (97th place)*

Cars/1,000 inhabitants *54 (110th place)*

Vehicles/1,000 inhabitants *69 (120th place)*

Estimates indicate that the number of vehicles in China will ***increase fourfold*** *by 2050.*

In contrast to mainland China, Hong Kong and Macau inhabitants drive on the left. On the Lotus Bridge to Macau, the road traffic is transferred via a ***360° loop*** *to drive on the right side.*

16.3 m

newly registered **cars drove on China's roads in 2013**. Far more than in every other country on the planet.

6,380 km

measures the **longest river in China** – the Yangtze River. 2,800 kilometers of the waterway is navigable from the city of Yibin to the estuary in the Pacific north of Shanghai. After the Nile and Amazon, it is the world's third longest river.

1,066 km²

has been **added to Shanghai's area** in the last 55 years. This is more than the size of Berlin. Today, the city covers 6,340 km² and grows constantly through land reclamation on the banks Yangtze.

SCHAEFFLER IN CHINA

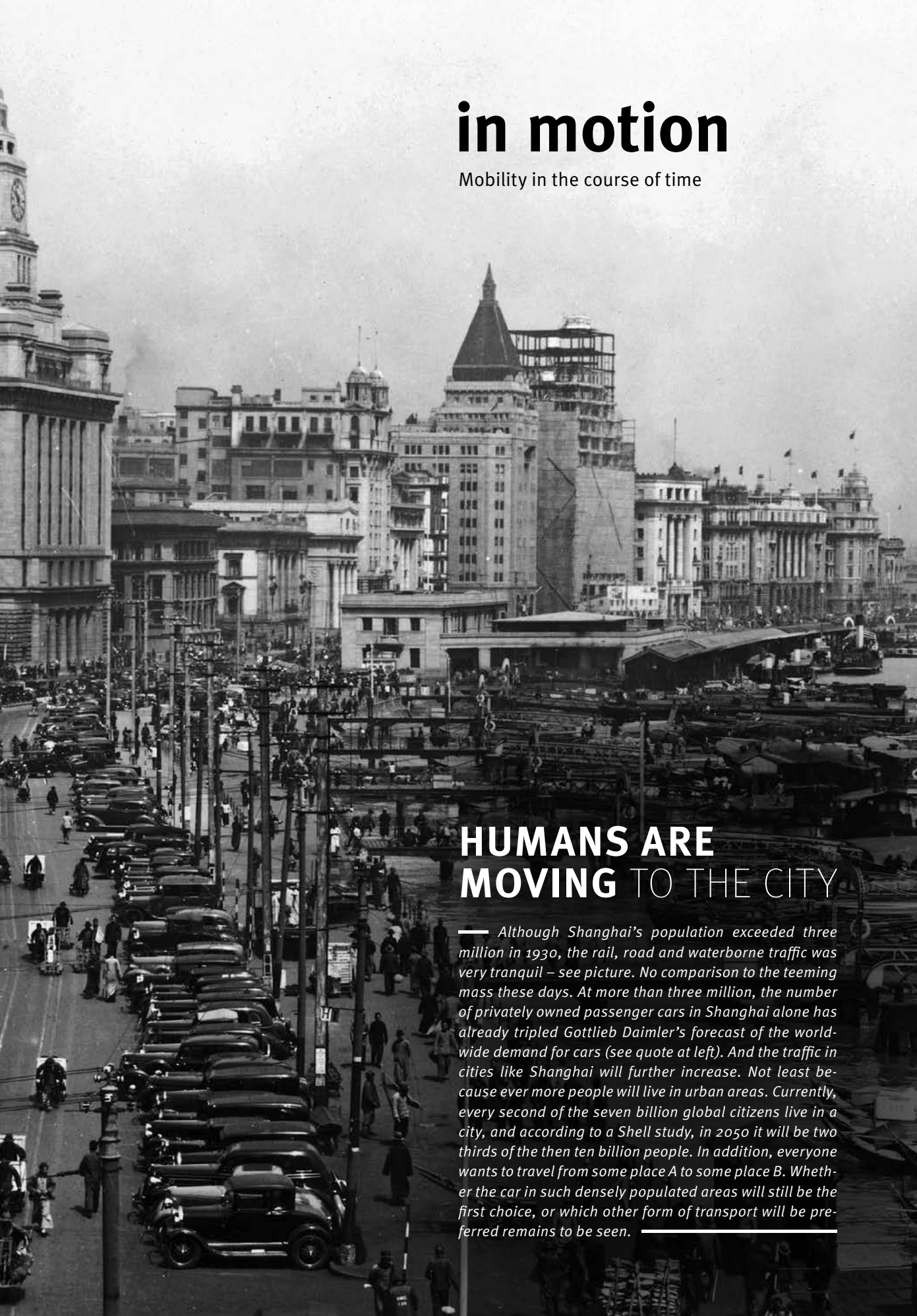
Schaeffler has been represented in China since 1955, *where the company recorded its greatest growth in 2013. Today, almost 8,000 employees work at over 29 sites for Schaeffler Greater China: in addition to 20 distribution centers there are eight manufacturing plants and one development center (Anting).*

» The worldwide demand for motor vehicles will not exceed one million – simply because of a lack of skilled chauffeurs

Gottlieb Daimler

in motion

Mobility in the course of time



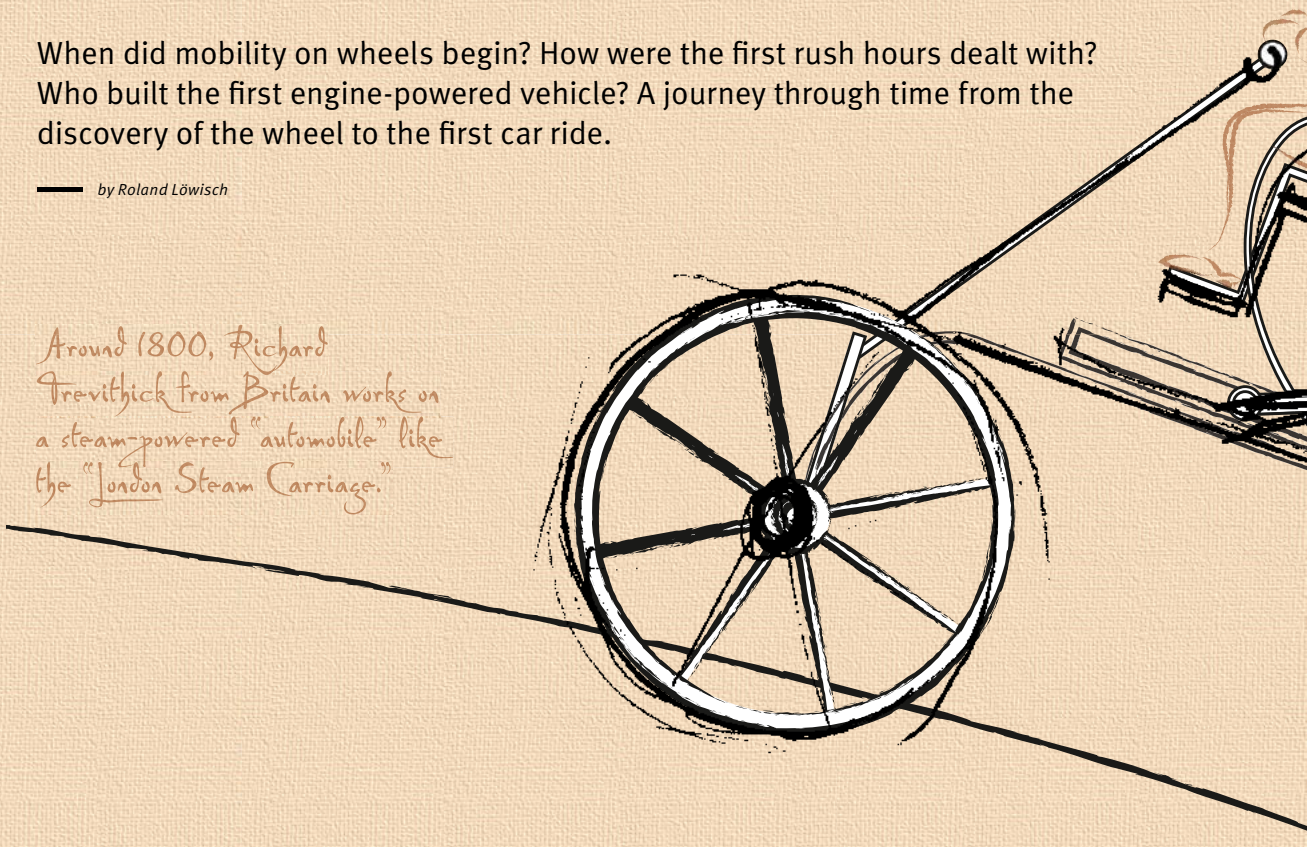
HUMANS ARE MOVING TO THE CITY

Although Shanghai's population exceeded three million in 1930, the rail, road and waterborne traffic was very tranquil – see picture. No comparison to the teeming mass these days. At more than three million, the number of privately owned passenger cars in Shanghai alone has already tripled Gottlieb Daimler's forecast of the worldwide demand for cars (see quote at left). And the traffic in cities like Shanghai will further increase. Not least because ever more people will live in urban areas. Currently, every second of the seven billion global citizens live in a city, and according to a Shell study, in 2050 it will be two thirds of the then ten billion people. In addition, everyone wants to travel from some place A to some place B. Whether the car in such densely populated areas will still be the first choice, or which other form of transport will be preferred remains to be seen.

THE LONG ROAD TO THE AUTOMOBILE

When did mobility on wheels begin? How were the first rush hours dealt with? Who built the first engine-powered vehicle? A journey through time from the discovery of the wheel to the first car ride.

by Roland Löwisch

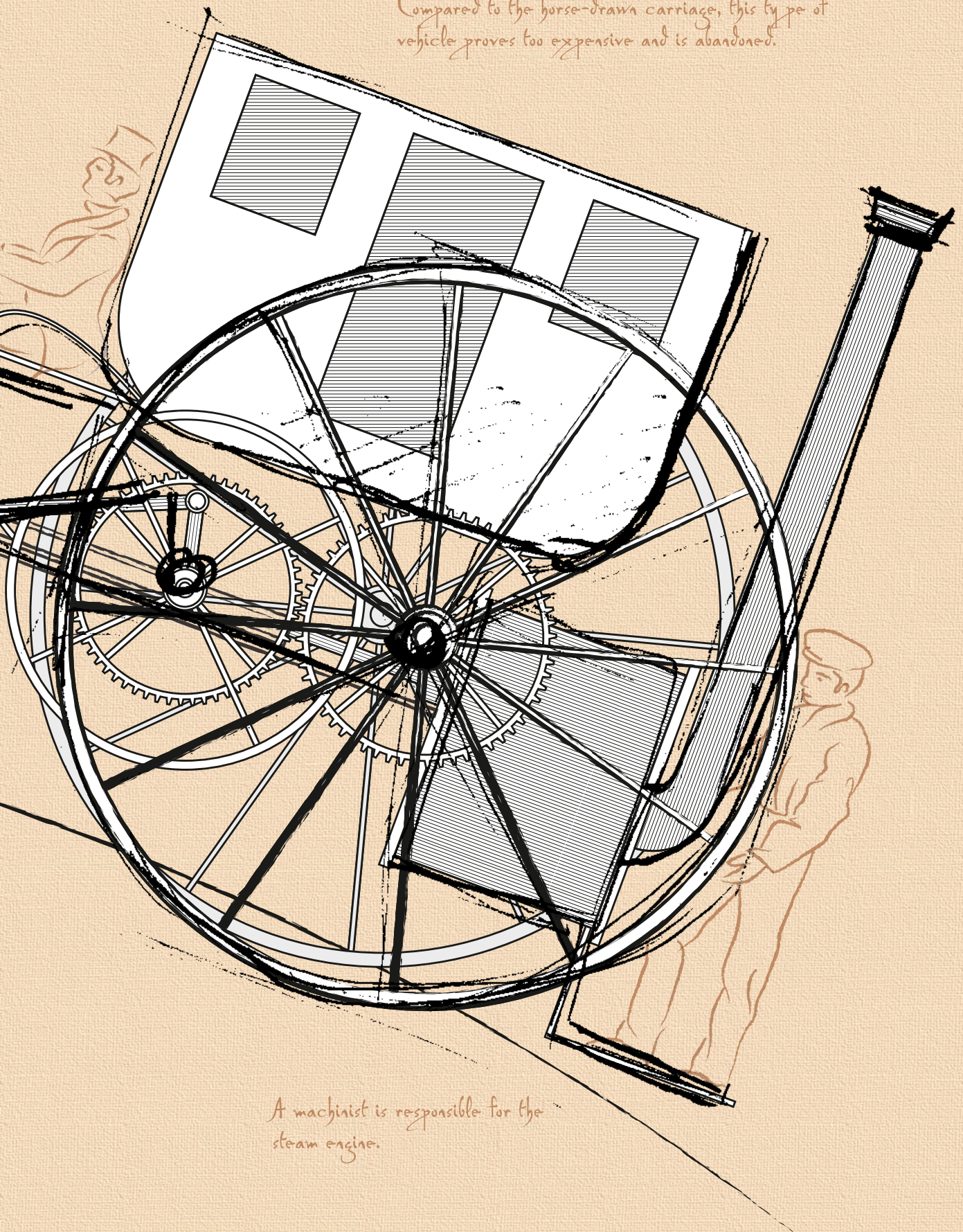


Around 1800, Richard Trevithick from Britain works on a steam-powered "automobile" like the "London Steam Carriage."

Julius Caesar was annoyed. The ruler had only just slapped a 250 kg limit on the carriage loads in his city of Rome and now he had to look on while more and more carts clogged the streets of his capital. And this displeased him. Without further ado, around 50 BC as part of his new municipal policy ("lex iulia municipalis") he issued the first driving ban in the history of the world: Between sunrise and the 10th hour no one shall move a wagon inside the world's capital – except of course temple workers, rubble transporters, vestal virgins and priests as well as all those taking part in victory marches and public games. And himself of course – after all, he would hate to miss a display of public adoration or an amusing little game.

Caesar's new decree had very likely hindered the odd Roman businessman in his rise up the career ladder, but nothing could really stand in the way of the development of individual mobility. That fact that rush hours even existed back then is undoubtedly due to the benefits of the newly-discovered wheel sometime around the year 5000 BC. About 1,500 years later, the first wheeled vehicle – very likely from the Sumerians – jolts over dirt paths. 500 years later, the Mesopotamians follow in the tracks – probably still using wooden discs as wheels.

As practical as the discovery is, it has a distinctive drawback: wear and tear. But the Sumerians come up with a solution for this, as well: Around 2500 BC they



Up to 8 passengers could fit in the Puffing Devil. Compared to the horse-drawn carriage, this type of vehicle proves too expensive and is abandoned.

A machinist is responsible for the steam engine.

That rush hours even existed back then is undoubtedly due to the benefits of the newly-discovered wheel sometime around the year 5000 BC.

span leather straps around the wheel and strength it with wooden struts to make it more durable – the first spokes have arrived. Around 2000 BC, the Cretans, Greeks and Romans are leading in wagon design. Their tracks and roads are built to easily accommodate two harnessed animals alongside each other in each direction. This makes the road about two meters wide – a measurement that is still a guideline for cars today.

An early traffic regulation: men to the right, women to the left

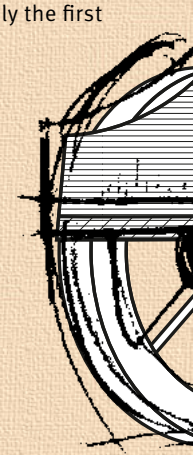
In 1880 BC, Egyptian slaves work with lubricants for the first time. 400 years later, grease is applied to the first axle bearings of chariots. Around this time the Chinese are contemplating something else: They are already thinking about left or right hand traffic. As outlined in the "Book of Rites," the right hand side of the road is reserved for men only, women go on the left, with carts in the middle.

The first seriously unpleasant punishment that an emperor decreed for the wrongful use of a road very probably ended fatally: According to martial law, those who desecrate the royal road of the Assyrian ruler Sennacherib in Nineveh are impaled without trial. Elsewhere in the meantime, others are enjoying chariot races – the oldest evidence of this can be found in Homer's "Iliad."

Somewhere around 600 BC, the Romans used "Sicilian petroleum" to illuminate their homes – which is just another name for crude oil. And around 200 BC, the inventor and scientist Hero of Alexandria prepares the way for the first steam engine that would later greatly advance the industrial revolution – at 1500 revolutions per minute, the "Aeolipile" (wind ball) is hailed as the fastest rotating object of its time. In the year 125 AD, Emperor Hadrian adopts Caesar's tough crackdown and limits the number of vehicles permitted to enter Rome – 55 years later this initiative is introduced in all large cities of the Roman Empire.

But even that can't stop the triumphant advance of the "forwardly mobile" – although it will be a while until it is the auto-mobile. In France in the year 1148, King Phillip II is responsible for the first documented stone paving. The "Saxon Mirror" legal code of the Holy Roman Empire regulates the right of way in early road traffic rules in 1220. But it's not a good time for fantasizing visionaries: In the year 1270, the Englishman Roger Bacon envisions chariots "moving at unbelievable speeds but without horses." His Franciscan order throws the man, who publically declares automobiles a realistic possibility (he's probably the first

Around 1700 BC, grease is applied to the first axle bearings of chariots.



to say this), into a dungeon for 14 years. Whether he eventually renounced his digressions and put his faith once again in leg power is not known.

Just 150 years later, the Italian Giovanni Fontana builds a man-powered vehicle that is driven by an endless rope connected to wheels. For Leonardo da Vinci, born on 15 April 1452, this is nothing but frippery. The scientist is one of the first people to design (aside from helicopter principles, tanks, etc) a steam boiler and a self-propelled car. Later, almost by accident, he invents the ball bearing.

The first reasonably comfortable carriages crop up in the mid-16th century. Springs on vehicles (with leather belts on iron C-shaped leaf springs) would only appear later. Contributing greatly to mechanical locomotion is Dutchman Christian Huygens in the year 1637: He outlines the principle of an atmospheric gas engine. It is the first machine that releases mechanical energy through combustion in a cylinder. The gunpowder machine, however, only materializes around 200 years later.

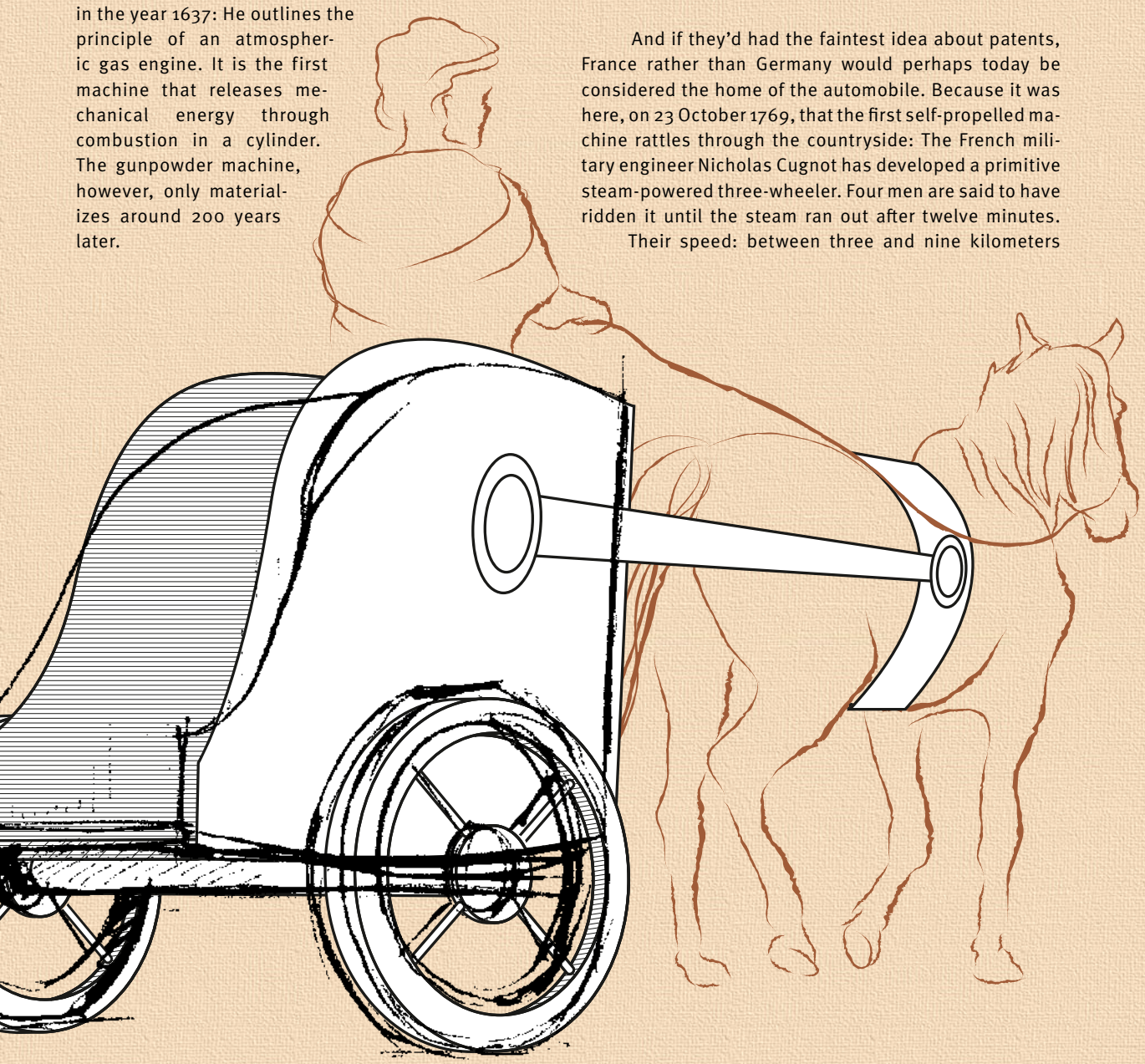
15 years later, Isaac Newton presents his design of a vehicle propelled by a jet of steam shooting out to the rear. Now the conquest of the steam machine is unstoppable: Initially, the first machines – all with a horrifying energy balance – are stationary.

Machines conquer the roads

Around 1705, the English blacksmith Thomas Newcomen teams up with the French physicist Denis Papin to develop the first well-functioning steam engine. Newcomen's device pumps groundwater from the coal mines of England for the first time in 1712. When Scottish University mechanic James Watt is asked to repair Newcomen's machine, he is so fascinated by it that he invents the capacitor and opens the way to the mass production of steam engines.

And if they'd had the faintest idea about patents, France rather than Germany would perhaps today be considered the home of the automobile. Because it was here, on 23 October 1769, that the first self-propelled machine rattles through the countryside: The French military engineer Nicholas Cugnot has developed a primitive steam-powered three-wheeler. Four men are said to have ridden it until the steam ran out after twelve minutes.

Their speed: between three and nine kilometers



an hour. On 20 November, Cugnot presents his second vehicle: “Grand Fardier” is a four-wheeled wooden monster with front-wheel-drive and a massive steam boiler as a bumper, virtually unsteerable and more of a gimmick than a serious means of transportation. The Americans come under pressure, too: shortly afterwards Oliver Evans develops another steam car.

There is no stopping the development of the “modern” car now: Watt registers a gearbox for a patent (1781), Evans in America receives the first motor vehicle patent for a high-pressure steam car (1792), and Alessandro Volta discovers storable energy and registers the battery (1800). On 24 December 1801, the British engineer Richard Trevithick looks into the feasibility of steam-powered public transport in London with his “London Steam Carriage” – a steam-driven bus for eight passengers. The Swiss inventor Isaac de Rivaz takes it one step further: He experiments with a two-cylinder “explosion” engine. In 1813 he drives his “car” equipped with an atmospheric gas engine along the shores of Lake Geneva.

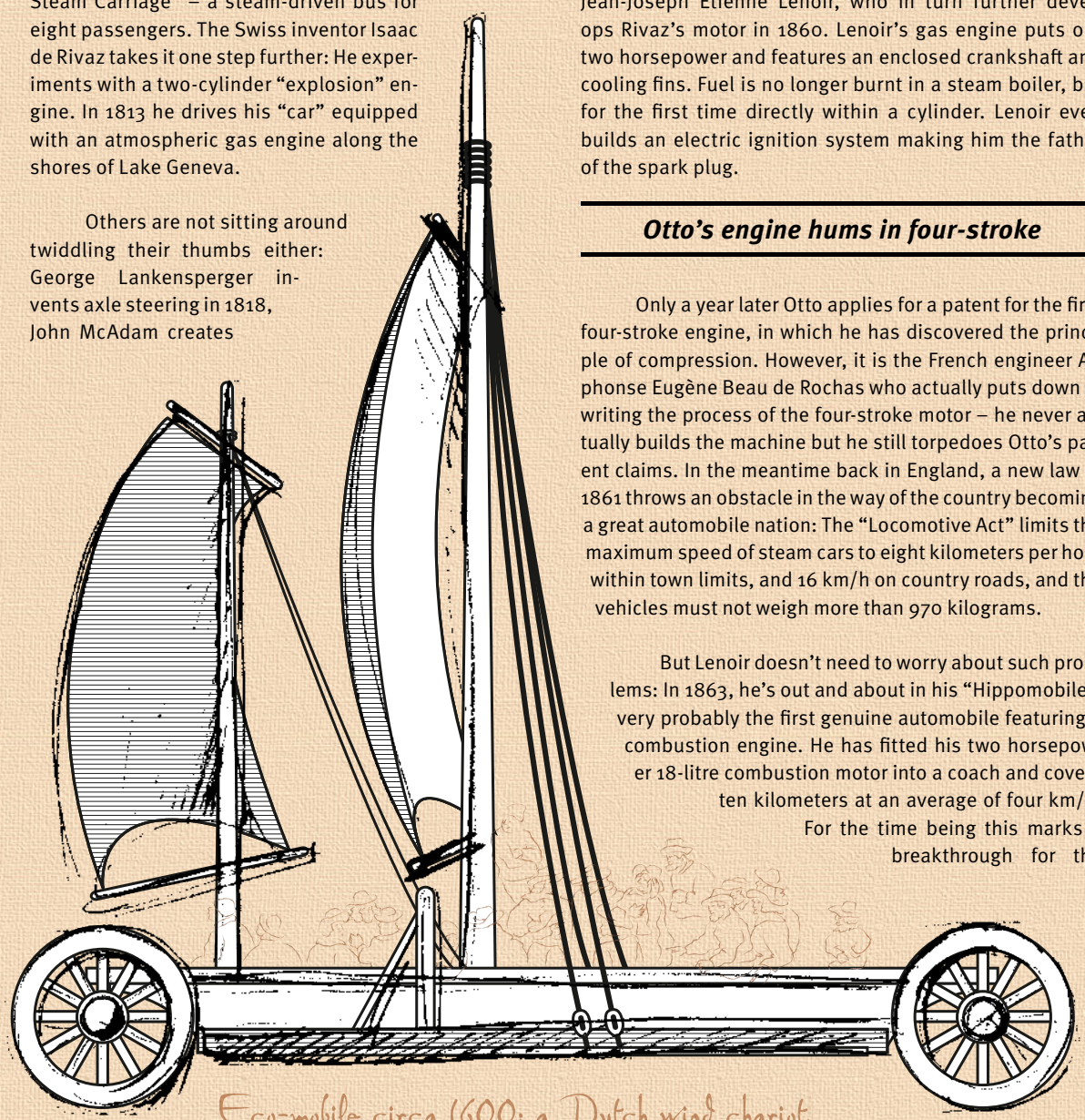
Others are not sitting around twiddling their thumbs either: George Lankensperger invents axle steering in 1818, John McAdam creates a tightly-packed gravel road called macadam pavement (1823), Joseph Aspidin produces cement (1824), William Sturgeon discovers the use of electromagnetism for the electric engine which is realized shortly thereafter (1825), Charles Goodyear invents the vulcanization of rubber (1839), Luigi de Cristoforis has engines running for the first time on naphtha as a liquid fuel (1841), and Eugenio Barsanti as well as Felice Matteucci come up with valve control and water cooling (1856). Born during this era of discovery are car geniuses of the future Nicolaus August Otto (10 June 1832), Gottlieb Daimler (17 March 1834), Carl Benz (25 November 1844), Wilhelm Maybach (9 February 1846) and Rudolf Diesel (18 March 1858).

Even the great Otto himself needs a little coaxing to devote time to engines. This comes from Frenchman Jean-Joseph Étienne Lenoir, who in turn further develops Rivaz’s motor in 1860. Lenoir’s gas engine puts out two horsepower and features an enclosed crankshaft and cooling fins. Fuel is no longer burnt in a steam boiler, but for the first time directly within a cylinder. Lenoir even builds an electric ignition system making him the father of the spark plug.

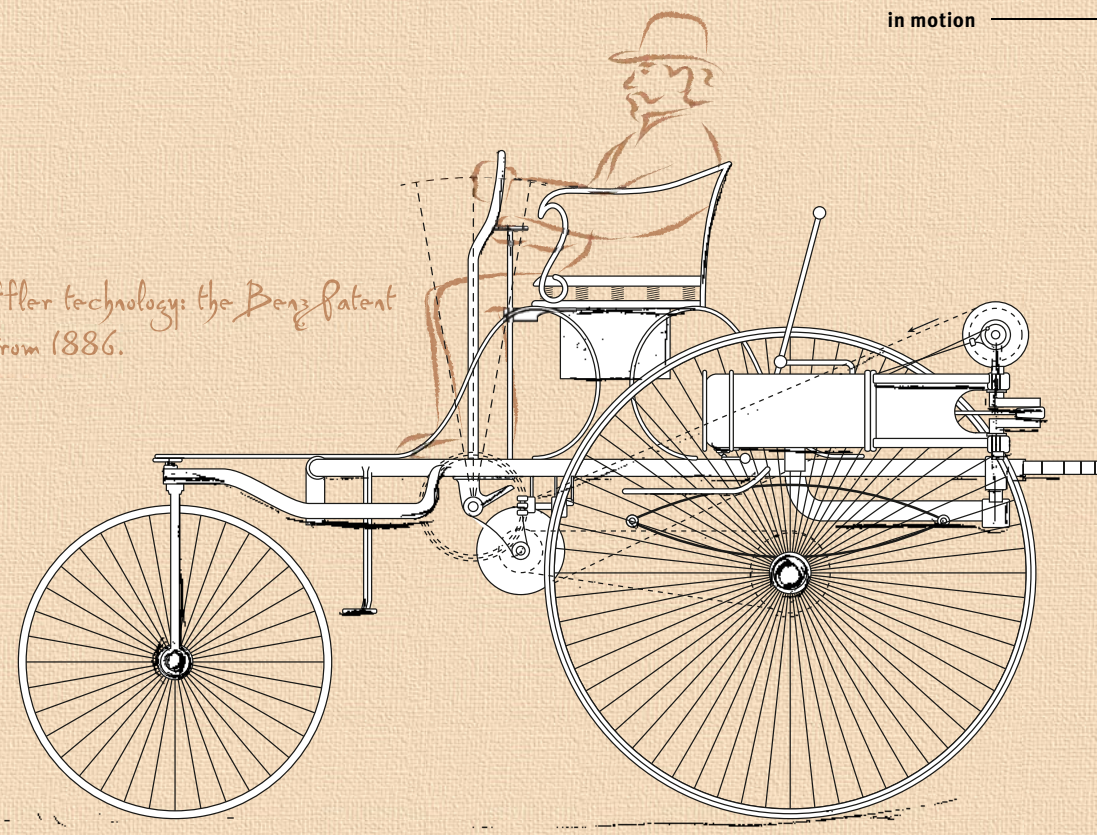
Otto’s engine hums in four-stroke

Only a year later Otto applies for a patent for the first four-stroke engine, in which he has discovered the principle of compression. However, it is the French engineer Alphonse Eugène Beau de Rochas who actually puts down in writing the process of the four-stroke motor – he never actually builds the machine but he still torpedoes Otto’s patent claims. In the meantime back in England, a new law in 1861 throws an obstacle in the way of the country becoming a great automobile nation: The “Locomotive Act” limits the maximum speed of steam cars to eight kilometers per hour within town limits, and 16 km/h on country roads, and the vehicles must not weigh more than 970 kilograms.

But Lenoir doesn’t need to worry about such problems: In 1863, he’s out and about in his “Hippomobile,” very probably the first genuine automobile featuring a combustion engine. He has fitted his two horsepower 18-litre combustion motor into a coach and covers ten kilometers at an average of four km/h. For the time being this marks a breakthrough for the



Eco-mobile circa 1600: a Dutch wind chariot.
In China such vehicles have been used since 500 BC.



Using Schaeffler technology: the Benz Patent Motorwagen from 1886.

engine, 500 of which he eventually sells for stationary use. Meanwhile in the USA, Sylvester Roper builds the first production vehicle: a four-wheeled two-seater housing a steam engine which is said to have reached 40 km/h with only two horsepower.

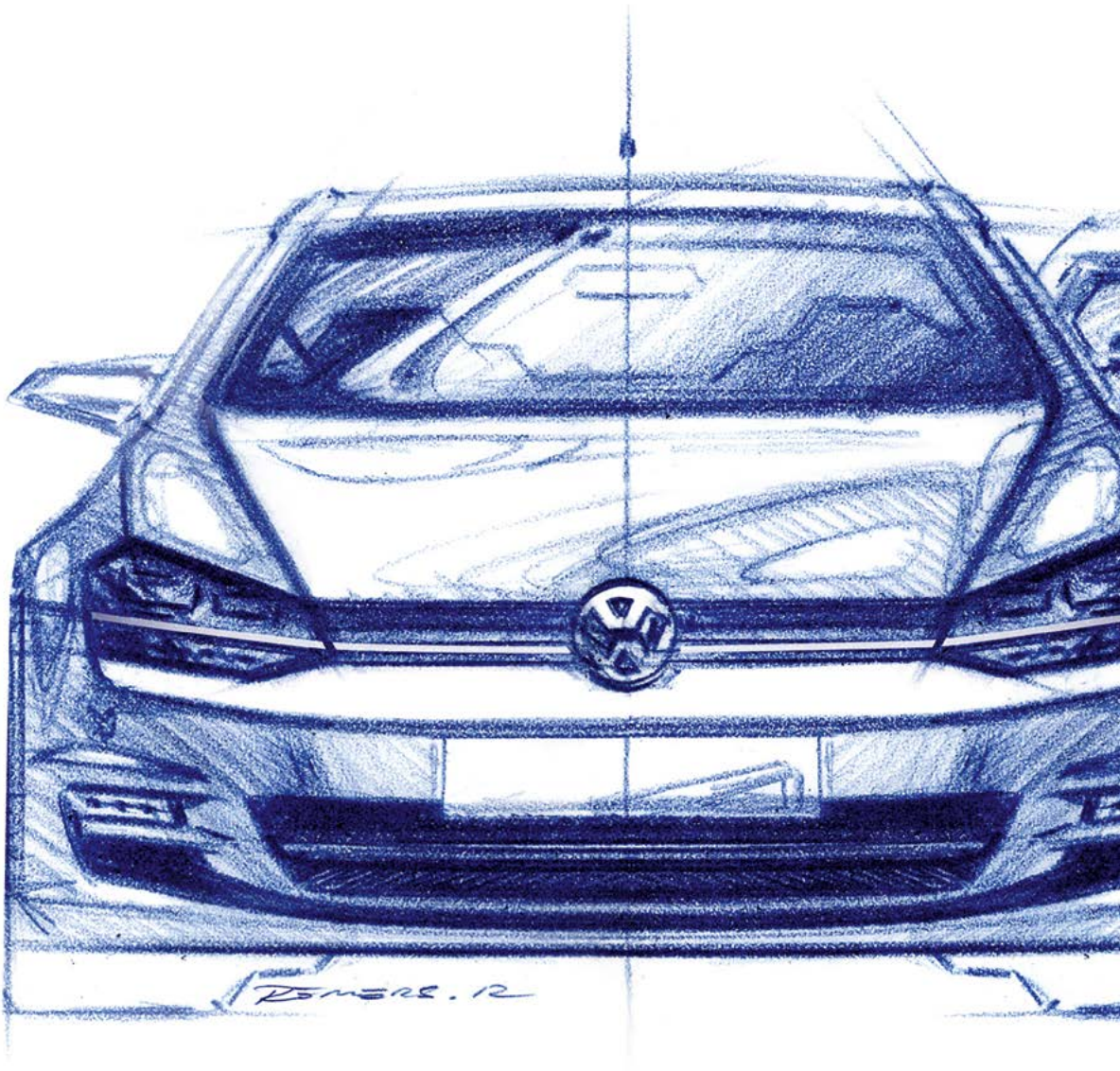
Speed limit: 3.3 km/h

Germany's Siegfried Marcus is still recovering from his maiden 200-meter drive in his home-made motor car when Great Britain tightens the regulations for the use of steam cars with the "Red Flag Act": As of immediate effect, a man must walk 55 meters in front of each vehicle holding a red flag. In addition, all steam cars must accommodate three men, maximum speed in town is capped at 3.3 km/h, in the country 6.6 km/h. As a result, no one feels much like wasting any more brainpower on further developing the automobile.

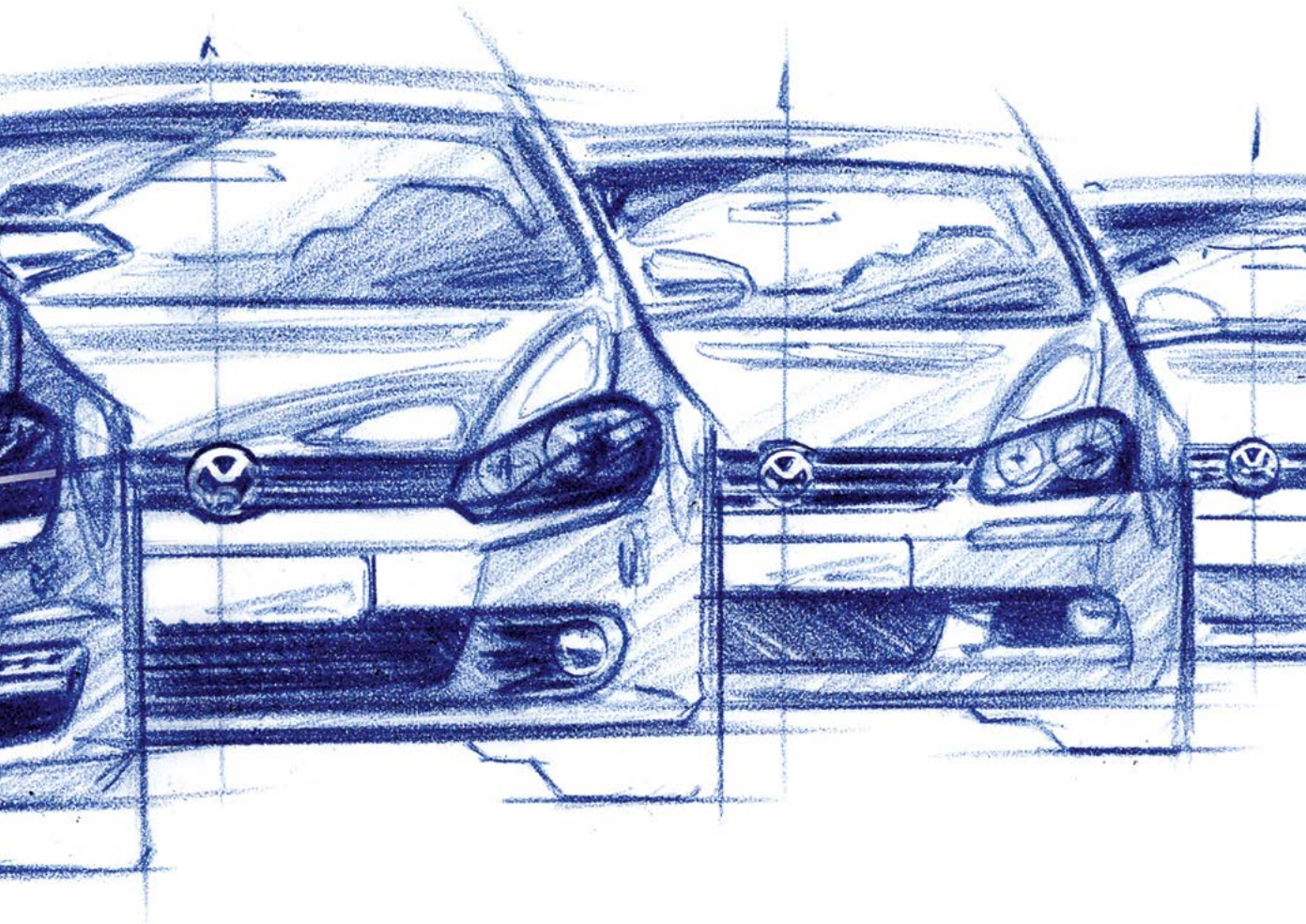
Otto, however, has joined forces with Eugen Langen and founded the Deutz gas engine factory. In 1872 they hire the ingenious designer Wilhelm Maybach and Gottlieb Daimler is made a shareholder. Almost simultaneously, the master watchmaker Christian Reithmann gets his four-stroke engine off the ground, which would ultimately lead to a patent dispute with the Deutz company: On 18 May 1876, Otto presents the first diagram of a four-stroke engine – this date is considered the birthday of the four-stroke internal combustion engine. Three years later, Carl Benz is still trying to get his two-stroke motor under control. Generating just 120 to 130 revs per minute, however, the machine has no chance to drive a car.

In 1881, Frenchman Gustave Trouvé exhibits an early electric vehicle at an electro-technical trade show. The three-wheeler features rechargeable lead-acid batteries and is said to achieve up to twelve km/h. Benz, however, founds the Rheinische Gasmotorenfabrik in 1883 and now builds a four-stroke unit with 0.75 hp at 450 revs per minute. That same year, Friedrich Fischer, future founder of the Fischer Aktien Gesellschaft (abbrev. FAG), constructs the "ball mill". With this invention, hardened steel balls are polished with high precision and in large volumes. Thanks to this innovation, the "Kugelfischer" begins its triumphal march around the world as ball bearings and helps automobile pioneers get their ideas rolling.

The race for the first pure car engine, however, is won by Gottlieb Daimler. On 3 April 1885, he receives a patent for his petroleum combustion engine. It weighs 50 kilos, generates one kilowatt at 360 rpm and is dubbed "grandfather clock" because of its shape. Daimler installs it into a vehicle that resembles a wooden two-wheeler with trainer wheels. On 29 August he receives the patent for the "Reitwagen" (riding car) – the vehicle, however, is not recognized as the first automobile. This honor goes to Carl Benz in October of that same year: with a 260 kg three-wheeler called the "Benz Patent Motorwagen." On 29 January 1886, he is awarded the German Imperial Patent number 37435 – marking the birth of the modern automobile and the start of automobility. The rest is history – or is it?



PROGRESS ALL

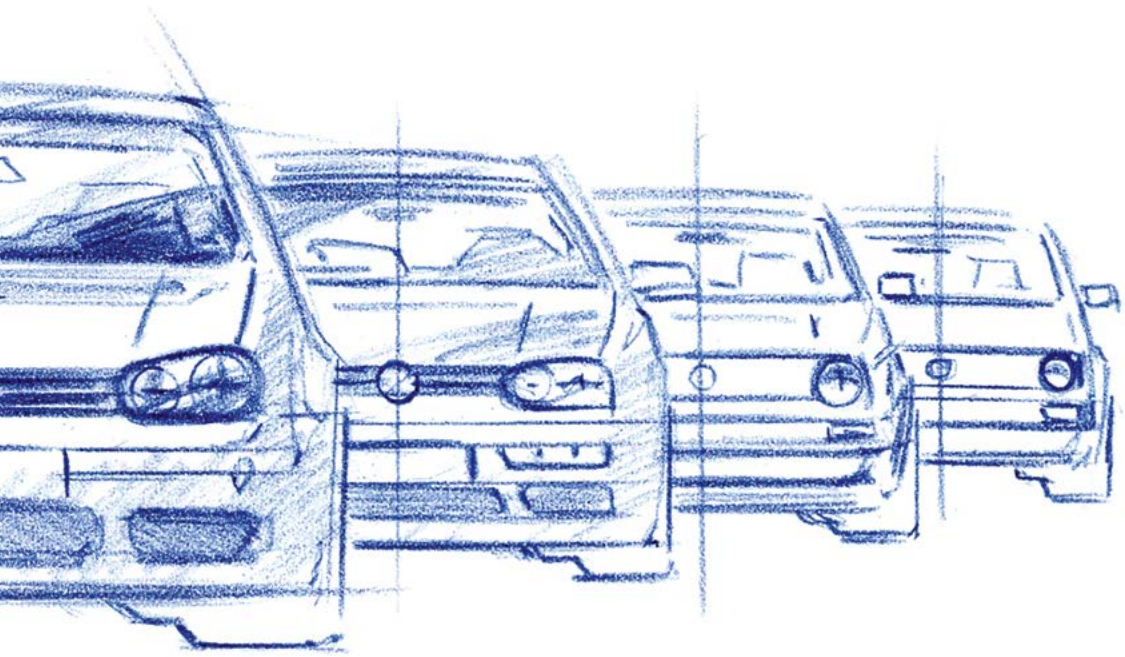


ALONG THE LINE

Developments in automotive engineering take place at a rapid pace. A fast-forward run through four decades using the example of the VW Golf (aka ‘Rabbit’).

by Michael Specht

Wheel bearings, strut bearings, cam followers, hydraulic bucket tappets, water pump bearings, cylinder heads – the list of components which Schaeffler has been supplying to the production of the VW Golf is long. A key place in the powertrain of the Golf has been occupied by Schaeffler from day one: the clutch in the manual transmission. From one Golf generation to another, Schaeffler has continually subjected the 'shifting aid' to further development, from a conventional component, to a self-adjusting one, to a world first: the dual-plate dry clutch in the 7-speed direct-shift (DSG) transmission used in the Golf V



AUTOMOTIVE MILESTONES OF SCHAEFFLER

1883

Friedrich Fischer invents the ball grinding machine, which lays the foundation for the subsequent success story of the rolling bearing. Originally designed for bicycles, the rolling bearing soon revolutionizes the production of motorcycles, cars, airplanes and trains. Since 2001, FAG Kugelfischer has been a member of the Schaeffler Group.

1910

Dr. Charles Parcival embarks on a mobility adventure that was outright awesome at the time. For two years, he travels

a grueling distance of 80,000 km from Mexico to Alaska, equipped with FAG bearings that withstand the ordeal without a single defect.

"Everything was better in the good old days" is a notion that enjoys certain popularity with people just shooting the breeze – especially when it comes to cars. Comments like "you can't repair anything yourself anymore," "that cars now have an excessive amount of onboard electronics" and that "they cost too much nowadays" are likely to be heard on such occasions. Admittedly, there's some truth to all of them. While a standard Golf I (50 hp) in 1974, its first year of production, cost the equivalent of about 4,000 Euros, today's Golf VII (85 hp) sells for more than four times that amount, although gross wages on average only went up by a factor of 3.5. But those who base their calculation on this factor alone fail to recognize reality. Today, we're also getting 'a lot more car' for our money. The Golf I and Golf VII are separated by light years not only in terms of technology and safety, but also with respect to quality, features and comfort, although even the first-generation Golf, which succeeded the legendary Beetle, was regarded as a pioneer in the automotive industry.

It marks the beginning of the greatest transformation in the history of the company based in Wolfsburg. Round becomes angular, air cooling becomes water cooling, the boxer becomes a straight engine, and rear-wheel drive becomes front-wheel drive. The Beetle, the rugged endurance runner and automotive icon of Germany's post-war economic miracle, has been running into a dead-end street ever since the late nineteen-sixties, long having been outperformed by more modern vehicles like the Opel Kadett and Ford Escort, as well as models from Fiat, Renault and Peugeot. The greatest disadvantages of what is arguably the most endearing Volkswagen of all time include its poor functionality, weak handling performance, lousy heater, noisy engine and high consumption.

A car from outer space

From this perspective, the Golf bursts into the world of the Wolfsburg automaker like a car from outer space. The transverse front engine, water-cooled, economical and quiet, gives more space to the cabin, the choice of four doors puts an end to the need of performing contortions to get to the rear seat bench, which in the Golf can even be folded – for more trunk space and easy loading through the practical tailgate: ideal for trips to the local cash and carry furniture store. Homes are decorated with floral wallpaper. Abba wins the Eurovision Song Contest in 1974 and Germany the FIFA World Cup. It's the year in which the German chancellor Willy Brandt leaves office and Helmut Schmidt takes it. A liter of regular gas costs the equivalent of 40 cents.

But the Golf I, as modern as it may seem in its day, is no more than a thin-skinned sub-compact (length: 3.70 meters) with horrible crash safety by today's standards, which means minimal occupant protection. Almost 20,000 people die on West German roads in those days. For comparison: in 2014, the number of traffic fatalities in the reunited, and thus larger, area of Germany is 3,368, in spite of a major increase in traffic density (43 versus 17 million passenger vehicles in 1974) and higher annual mileage. This success can clearly be credited to developments in vehicle safety and the increasingly important crash tests. If you ran a Golf I, which by the way was rolling off the line in South Africa until 2009, and a Golf VII against the standardized Euro-NCAP barrier under identical conditions (64 km/h, offset, 40 percent overlap) today, the occupants in the Golf VII would have perfect chances of surviving the crash with no or only minor injuries. In the Golf I, they'd be dead.

Safety leap with generation III

Initially, the 3-point seat belt no doubt plays the major role in the field of passive restraint systems. On January 1, 1976, seat belt wearing becomes mandatory in West Germany and from 1984 on, failure to buckle up is even subject to fines. As soon as belts become mandatory equipment, VW offers Golf buyers the option of an automatically retractable version: a major gain in comfort. The airbag, however, is still nearly twenty years away from making it into this vehicle class. Drivers have to settle for a steering wheel with a small impact absorber for the time being.

In the Golf II, things are not looking much better in terms of occupant protection either. Volkswagen only starts

1949

The brothers Dr. Wilhelm and Dr. Georg Schaeffler develop the INA needle roller cage – an invaluable contribution to the design of smaller, more powerful and lower-priced automobiles. Even today's automotive transmissions are hardly conceivable without these needle roller cages.

1965

LuK is the first clutch manufacturer in Europe to launch the diaphragm spring clutch on the market. Today, every third car leaving the assembly line around the world is equipped with a clutch from LuK.

1970 AND 1971

Porsche wins at Le Mans. INA valve tappets are used in the winning cars. Racing commitments like these accelerate Schaeffler's rise to the position of the leading valve train components and systems specialist.

TWO GENERATIONS – TWO WORLDS

Golf I & VII in visual comparison. The 60% weight increase is clearly visible. Compared with the current model the Golf I almost appears delicate and fragile. A typical Golf feature that has been retained for 40 years: the wide C-pillar.

Basic instruments, thin door panels, an 'anorexic' steering wheel – driving a Golf I meant settling for austerity. In contrast, Golf VII occupants, at first glance, might get the idea of sitting in a VW Phaeton.

to democratize safety in automotive engineering for the third generation that is launched in 1991. The structure of the occupant cell becomes clearly stiffer – albeit heavier – and better crumple zones at the front absorb a major portion of the impact energy while reinforcements in the doors provide higher side impact protection. For the first time, a Golf steering wheel contains an airbag and from 1993 on, it's available for the front passenger as well. Three years later, the customer – for an extra charge – can even get side airbags. The airbag soon starts trailing the seat belt as the number two life saver, as real-world accident research reveals. Today, up to eight airbags, including one for the driver's knees, are lying dormant in a Golf. Mercedes has even complemented passive safety in the latest-generation S Class with an inflatable belt bag for the rear-seat passengers.

In the eighties, declining prices for electronics open the door for another important safety element, the anti-lock braking system. ABS prevents the wheels from locking when the driver brakes hard. As a result, the car remains steerable and the stopping distance shortens. While ABS is already available as an option for a few models in the full-size luxury car class in the late seventies, it only becomes standard equipment, particularly in smaller vehicle classes, in the mid-nineties. VW starts to install ABS in every Golf in 1996 without extra charge.

A year later, a spectacular driving maneuver (the moose test) performed by a Swedish motor magazine leads to what is arguably the most significant active safety technology revolution in automotive engineering. In a simulated evasive maneuver a Mercedes A-Class flips and lands on its side. The minivan, just 3.72 meters long, is the first attempt by the Stuttgart-based brand to launch a compact-class car on the market. The debut starts swerving and Mercedes regains control of it with electronic stability control (ESC). While the swerve protection has previously been available only in very few models of the full-size luxury segment, the 'little Benz' now gets it as standard equipment and cars that have already been delivered to customers are retrofitted. If the A-Class now threatens to swerve, ESC makes a targeted intervention via the brakes and thus prevents an uncontrolled breakaway.

1974

LuK is the world's first clutch manufacturer to launch diaphragm spring dual clutches for commercial vehicles on the market.

1985

Schaeffler rings in a new era in powertrain engineering with the production of the dual mass flywheel.

1986

Schaeffler introduces automatic belt tensioning systems. Belt drives in passenger cars now last longer and are significantly quieter.

1990

For the first time, INA hydraulic variable cam timers enable continuous variation of valve timing, reducing fuel consumption and emissions.

The Mercedes safety offensive that was born out of necessity forces the competitors in this segment to offer ESC at no extra cost as well. The Golf is one of these cars and, in its fourth generation, beings to be equipped with ESC in 1998. Down to the present day, electronic stability control is considered the third major life saver alongside the belt and the airbag among accident experts. Since November 1, 2011, ESC has been mandatory for newly designed automobiles in the European Union.

Alongside ESC, belt tensioners and belt force limiters are making their way into cars in the late nineties and child seats can now be securely attached to special anchoring points (Isofix). On the active side of the house, brake assist is introduced. Because most drivers don't hit the brake pedal with enough force in emergency situations, a computer steps in and automatically triggers full braking which reduces the stopping distance by several valuable meters.

Going forward, the aim of the automakers is to prevent accidents or to at least mitigate their consequences. Volvo is making the boldest statement in this respect, claiming that by 2020 nobody will be killed in a Volvo anymore, and intends to achieve this through intelligent assistance systems that recognize hazards at an early stage. But this assistance presupposes a huge amount of processing power. Our cell phones and PCs at home have shown us the development which these devices have seen in just a few decades and the same is true for the bits and bytes in automobiles. While the first Golf already had 200 meters of cables and 170 contacts installed in it, but not a single electronic control unit, there are eight times as many cables and contacts in it today, plus 35 ECUs interconnected by a vehicle bus. A current Golf VII with all the trimmings has more onboard electronics than a rocket for the Apollo space program had in its day.

Assistants for everything

Today, more than a dozen assistance systems may be installed in a full-size luxury car. It's only a question of time before they'll be found in compact or even sub-compact cars as well – and some of them already are. Sensors, radar, laser scanners, ultrasound and multifunctional stereo imaging cameras are working discretely or in perfect interaction, depending on the situation. They warn the driver if another car is in the blind spot. Sensors recognize traffic signs or detect that the driver is tired and needs to rest. They notice when the vehicle moves out of its lane and counter-steer, either directly or by means of a unilateral braking intervention. A 360-degree camera makes it possible to maneuver with surround view, the car being shown on the display from an aerial perspective. In addition, a park pilot automatically pulls the car into parallel or diagonal parking spaces. When it's dark, the driver can leave the high beam on at all times without glaring other drivers because the light is skillfully distributed around the oncoming light source. The night vision assistant uses infrared light to detect people and animals even before they appear

THE 10 MOST FREQUENTLY SOLD CARS

In 1974, the Golf succeeded the VW Beetle and went on to become a worldwide top seller. *By 2002, the Golf had surpassed its ball-shaped predecessor in the all-time sales charts, ranking in fourth place overall. These are the top ten sellers in automotive history:*

1. **Toyota Corolla / Auris: 40 m since 1966**
2. **Ford F-Series pick-up: 35 m since 1948**
3. **Ford Escort / Focus: 30 m since 1968**
4. **VW Golf (excl. Jetta, Caddy, etc.): 27.5 m since 1974**
5. **VW Beetle: 23.5 m since 1946**
6. **Honda Civic: 18.5 m since 1972**
7. **Honda Accord: 17.5 m since 1975**
8. **Ford T-Model: 16.5 m from 1908 to 1927**
9. **VW Passat: 16 m since 1973**
10. **Chevrolet Impala: 14 m since 1958**

1999

LuK introduces CVT components for higher torque levels. The Audi Multitronic is the first efficient CVT transmission for torques higher than 300 Nm. New FAG mechatronic sensor bearings, within a very small space, enable controlling and monitoring of electric drives in vehicles.

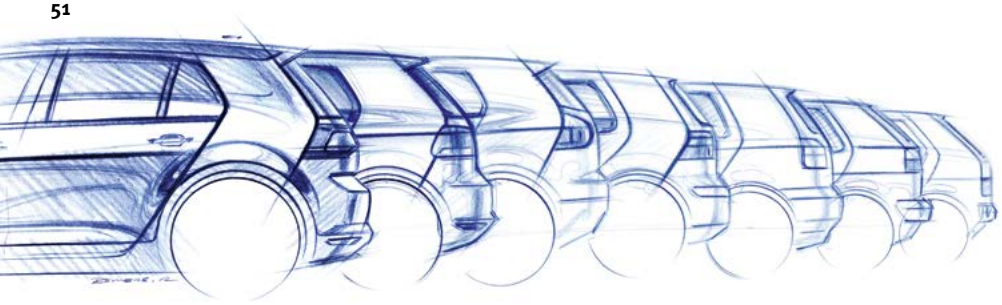
2000

LuK's automated manual transmission goes into volume production as Easytronic in the Opel Corsa – a technological world premiere.

2003

LuK is presented with the innovation award for the dry dual clutch at Equip Auto in Paris. Volume production is launched in 2007.

EQUIP AUTO



in the cone of the headlight. The electronics warn the driver of following too closely and can prevent, or at least reduce, the impact of a collision by autonomous partial braking. At city driving speed, they detect pedestrians and automatically trigger full braking. In stop-and-go traffic, cars can already autonomously follow the preceding vehicle, even in corners. If there is imminent danger of collision, preventive occupant protection events – particularly tightening of the belt tensioner – are automatically triggered. This happens within 120 milliseconds. Cars can now even detect cross traffic and autonomously apply the brakes in case of danger. The need to buy an S-Class to enjoy such extras has long ceased to exist, as they can even be found in cars of the Golf class such as the Honda Civic. In light of this, the step towards piloted driving has become smaller even in this vehicle category. Audi, BMW, Mercedes, Volvo and VW have made forays into the field of self-driving cars and even the internet company Google has put an autonomous car on wheels. Experts anticipate the first piloted production cars to be launched in 2020.

50 percent more car, 50 percent less consumption

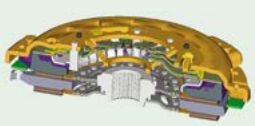
The massive increase in safety resulting from the use of electronics in our cars is matched by the reduction of emissions and consumption, as well as enhancements of comfort and convenience. The catalytic converter, which the Golf I didn't use yet and without which the amount of its harmful emissions exceeded that of today's Golf VII a hundredfold, is just one example. The modern gasoline and diesel injection systems (TSI and TDI) that manage fuel far more efficiently than ever before have contributed to improved fuel economy as well. A Golf TDI BlueMotion today delivers the same output as the most powerful Golf (GTI) did in 1976 but consumes less than half the amount of fuel, although it's clearly larger and weighs 50 percent more. And never before have customers been afforded more powertrain choices for the Golf than they have this year. In addition to diesel and gasoline engines combined with front-wheel or four-wheel drive, natural gas and electric vehicles as well as plug-in hybrid versions are available.

But the carmakers are not the only ones to make their vehicles more and more efficient. The automotive suppliers that drive the evolution on four wheels with their own development departments have been playing a major part in this as well. In Germany's 2013 ranking of patent applications, the two suppliers Bosch and Schaeffler were clearly the front runners ahead of Daimler AG in third place. The most important innovations by Schaeffler in the ten past years include the dry dual-clutch transmission, electrohydraulic fully variable valve timing, plus numerous components for E-Mobility.

But even seemingly insignificant aspects reflect the technological progress that has been achieved in automotive engineering. Service intervals have become clearly longer, bodies are galvanized and corrosion has ceased to be an issue. We now drive safer and cleaner cars. Central locking, power windows, power steering, electrically adjustable outside mirrors, electric sunroofs, height-adjustable seats, rain sensors, onboard computers, cup holders and air conditioning systems are practically basics now found in any vehicle and make motoring more pleasant, more comfortable and more convenient. Buyers of the Golf I couldn't even dream of these features. From that perspective, they paid far too much for their new cars back then compared to today.

2006

LuK introduces the first self-adjusting multi-disk clutch for use in volume production.



2009

UniAir, the fully variable electrohydraulic valve control system developed to production level by the Schaeffler Group, debuts in the Alfa MiTo 1.4 MultiAir.

2010

Together with Porsche, Schaeffler develops the 'CO_2ncept-10%' concept vehicle based on the Cayenne. Innovative and optimized components reduce fuel consumption and CO_2 emissions by 10%.

FAST FORWARD RUN THROUGH **40 YEARS OF GOLF HISTORY**

Golf I (1974–1983), 6.7 million buyers, length 370 cm, weight 750 kg
The Italian Studio Giugiaro designs the Beetle successor, which subsequently receives a more straightforward touch in Wolfsburg. Prices start at DM7,995. Pioneering models that underpin the Golf's class-leading role: the sporty GTI (from 1976), the convertible with a transverse roll bar (from 1979) and the thrifty diesels D (1976) and GTD (1982). Built in South Africa as the Citi-Golf until 2009.

Golf II (1983–1992), 6.4 million buyers, length 398 cm, weight 845 kg
Longer wheelbase, a more bulbous shape, prices starting at DM13,490. Improved corrosion protection. Available now: central locking (DM490), power steering (DM800), power windows (4 for DM995), ABS (DM1,800) and catalytic converters. Ahead of its time: the Golf Country SUV that was sneered at in its day. Top-end model: the 4x4 Rally Golf with G-Lader supercharger and 160 hp for DM44,500.

Golf III (1991–1997), 4.9 million buyers, length 402 cm, weight 960 kg
The third generation (prices from DM19,975) adopts the engine blocks, electrical systems and dimensions from its predecessor but has better aerodynamics (Cd 0.30) and is safer – and thus heavier. New: airbags, diesel direct injection and six-cylinder units (VR6). A new convertible based on the Golf III, plus the first station wagon. Innovative highlight: a Golf electric vehicle produced in a small-scale series.

Golf IV (1997–2003), 4.9 million buyers, length 415 cm, weight 1,050 kg
Minimal gap dimensions, high-grade plastic materials, galvanized body: the Golf makes its next quality leap. Prices from DM25,700. From 1999, fitted with ESC as standard equipment. In 2002, the new head of the family follows: the Golf R32 with 241 hp. Speaking of platforms: the Golf IV provides the basis for the VW Beetle and Bora, Škoda Octavia, Seat Leon and Toledo, plus the Audi A3 and Audi TT.

Golf V (2003–2008), 3.3 million buyers, length 420 cm, weight 1,155 kg
Five years after the Ford Focus, the Golf V (prices from EUR15,200) receives a more complex four-link rear suspension for better handling. New in this class: the dual-clutch transmission, xenon lights and other luxury-class goodies. The R32 top-of-the line model is the last six-cylinder Golf for the time being. New high-roof Golf Plus version and the Tiguan SUV derivative.

Golf VI (2008–2012), 2.9 million buyers, length 420 cm, weight 1,217 kg
The 6th generation (from EUR 16,500) is more of a facelift than a new model. Customers can enjoy air conditioning as standard equipment. All gasoline and diesel versions comply with the Euro 5 emissions standard. For the first time, the Golf is able to park autonomously (parking assistant). BlueMotion as an eco model with a start-stop system and energy recuperation. New Golf VI convertible.

Golf VII (since 2012), length 425 cm, weight 1,205 kg
By now, the 'top dog' has to stand its ground against 130 direct rivals – compared to ten in earlier days. Not counting special features, VW reduces the Golf's weight by 100 kg and treats its top seller to an armada of new assistance systems, some which are standard equipment. The price list (from EUR16,975) also reflects an electric and a plug-in hybrid Golf.

2011

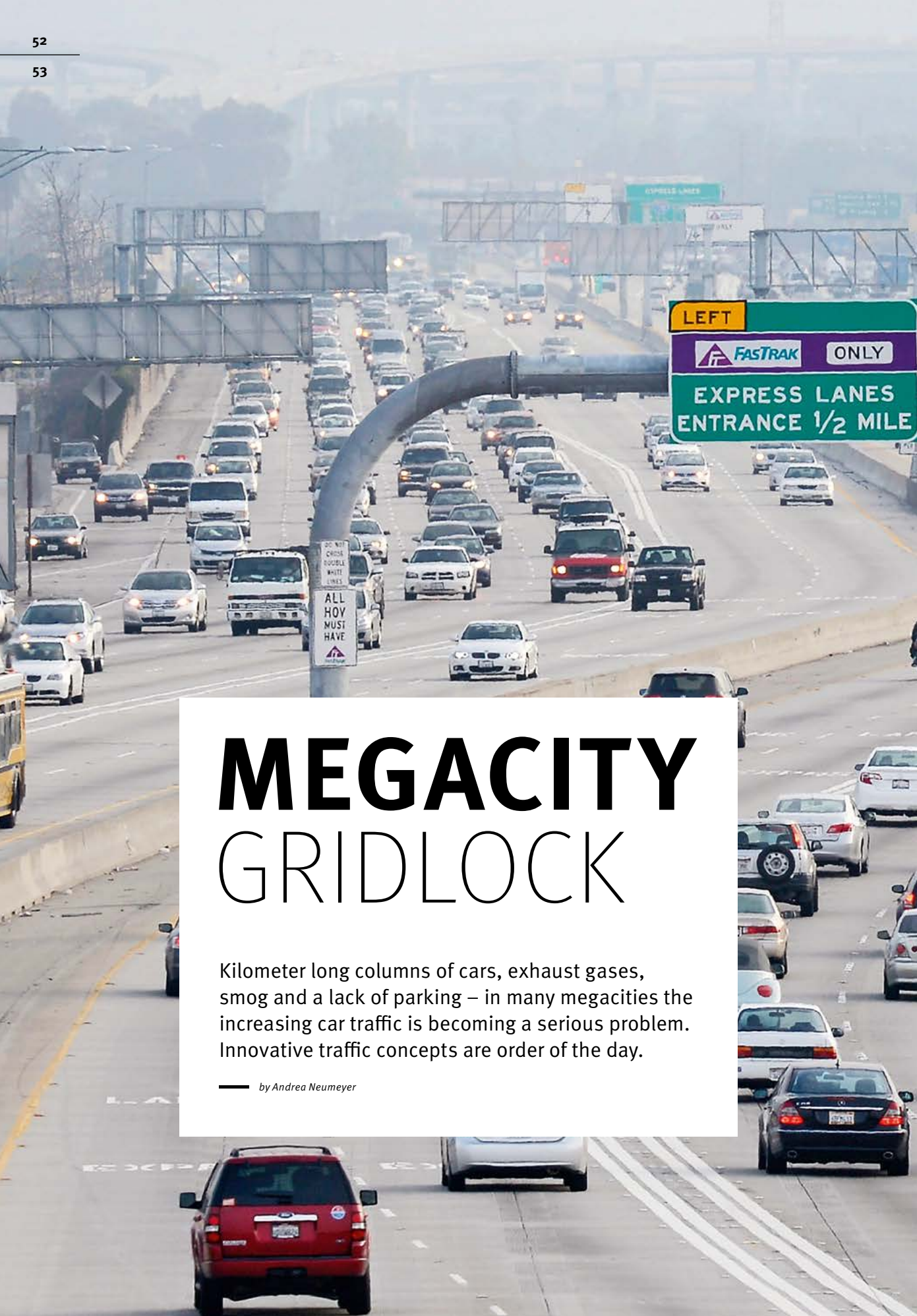
Schaeffler receives the prestigious PACE award for the lightweight balancer shaft with rolling bearing support and pools its electric mobility expertise in the eMobility Systems Division.

2012

Schaeffler is presented with more quality awards than ever before (among others, by Renault, Nissan and GM). For the centrifugal pendulum-type absorber, which significantly enhances comfort and reduces fuel consumption, Schaeffler receives the 'Steel Innovation Award.'

2013

Together with Ford, Schaeffler develops a concept car with electric wheel hub motors based on the Fiesta. Honda, in its i-DCD hybrid system, uses Schaeffler's dual clutch technology.



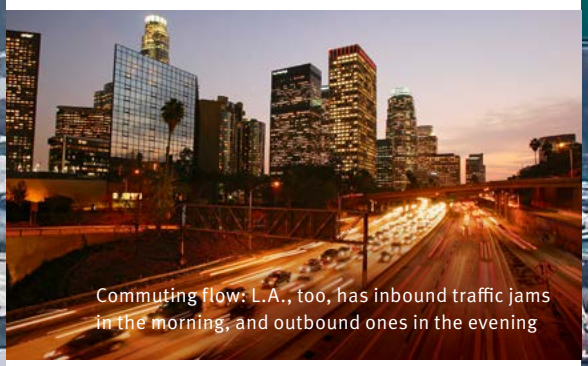
MEGACITY GRIDLOCK

Kilometer long columns of cars, exhaust gases, smog and a lack of parking – in many megacities the increasing car traffic is becoming a serious problem. Innovative traffic concepts are order of the day.

by Andrea Neumeyer

LOS ANGELES (USA)

Founded *1781*
Inhabitants *3.8m (urban area), 13.1m (metropolitan region)*
City area *1,290 square kilometers*
Underground and city railway *140 km*
Cars *540 per 1,000 inhabitants*



Commuting flow: L.A., too, has inbound traffic jams in the morning, and outbound ones in the evening

Motorists in Los Angeles spool off more than 330 million kilometers daily – this equals twice the distance from the earth to the sun. Every commuter in L.A. spends an average of 72 hours annually in traffic jams. Other megacities like Tokyo, São Paulo, Shanghai and London face the threat of quite literally suffocating in road traffic: Smog is becoming a problem in many places. However, congestion not only damages the environment, but also the wallet. The overall economic cost for the 234 million hours spent stationary on German roads only, is estimated by the Federal Highway Research Institute (BASt) to be 3.5 billion Euro per annum.

Growing urban sprawl and increasing prosperity in emerging nations boost the traffic problems still further. The renowned Fraunhofer Institute assumes that over two billion vehicles will role on the earth by 2050. The call for more roads is loud from those plagued by congestion. “Every new motorway increases the overall traffic,” summarize Canadian mobility researchers. In keeping with the motto “Whoever sows streets, harvests traffic,” new roads only lure ever more commuters into the driving seat – so, the opposite effect is achieved.

There is no miracle cure for the jam from Austin to Zagreb. In fact, traffic planners develop bespoke

TOKYO (J)

Founded *1446*
Inhabitants *9.1m (urban area), 37m (metropolitan region)*
City area *622 square kilometers (city), 13,572 (region)*
Underground and city railway *290 km*
Cars *450 per 1,000 inhabitants*

Under control: every traffic jam is registered in the ITS control center in Tokyo

concepts that take into account regional, geographic and also cultural factors.

State-of-the-art traffic technology prevents Jams in Tokyo

Tokyo also has a bespoke concept: more than 37 million people live in suburbs around the Japanese capital, around two million motorists are held up daily in the center. There is no space for new highways. In the country with a strong automotive industry, commuters are reluctant to dispense with their own cars. Tax beneficial subcompact cars (Kei Cars) save space.

With the help of state-of-the-art technology, the authorities managed to keep the honking columns rolling. The Tokyo prefecture invested seven billion Euro in the new traffic management system ITS (Intelligent Transport System), which networks all mobility control systems with new possibilities in navigation technology. Over 800 cameras and 1,600 so-called ITS spots capture every angle of the 300 kilometer long city motorway. Information is transmitted to

MEXICO CITY (MEX)

Founded *1521*
Inhabitants *8.8m (urban area), 20m (metropolitan region)*
City area *1,500 square kilometers (city), 7,800 (region)*
Underground and city railway *250 km*
Cars *360 per 1,000 inhabitants*

Mexico City: There are traffic jams even though many people travel with the bus or moped.

the cars in real-time: it warns of accidents and traffic jams, and even from earthquakes. The traffic has eased significantly in Tokyo since 2011.

Efficient and cheap: the express buses of Mexico City

The situation is entirely different in Mexico City: every morning, five million people flood into the 20-million metropolis city center. The majority already use the local public transport – especially old buses. A new express bus system with dedicated lanes and a new underground should alleviate the air pollution and accelerate the traffic. As is the case in many emerging nations, the express bus is the alternative to constructing an underground: the building cost per kilometer is 10 to 50 times cheaper, furthermore the express bus route is operational earlier. Higher taxes and parking charges should also make the car less attractive. And the city promotes cycling: every Sunday between 7:00 and 14:00 the city's most congested avenue, Paseo de la Reforma, is closed to all cars. At the same time, Mexico City battles against further urban

sprawl: around 400,000 inhabitants moved out of the city last year, new mixed residential and commercial areas in the center aims to stop this trend.

London to become cyclist's paradise

Cars out of the city – so the saying goes in London. Introduced in 2003, the city toll of about 12.50 Euro has made trips into the city center an expensive pleasure. Since introducing the toll, traffic has sunk around 30 percent, however it continues to pile up. And this even though the local public transport is well developed: London has the world's oldest underground boasting the longest network in Europe as well as a closely meshed bus system.

The ambitious London Mayor Boris Johnson has set the goal of transforming the metropolis of millions on the River Thames into a paradise for cyclists. A difficult task, as London did not previously enjoy a good reputation among cyclists: narrow and congested roads, virtually no cycle paths and jostling between double-decker buses on the narrow bus lanes. Meanwhile the picture has changed: an increasing amount of Londoners discover the freedom on two wheels. Over the forthcoming years, a billion Euro should be invested in the cycle path network. According to the plans of star architect Sir Norman Foster, the city's most important traffic arteries should be covered by suspended bicycle motorways. Ten routes should connect the city's most important points. The six million residents living within the system's catchment area could, according to the city planners' calculations, save up to 29 minutes compared to the car and public transport.

Elevated tracks: the cycle highway in London could look like this according to plans from Foster + Partners

LONDON (GB)

Founded *47 AD*
Inhabitants *8.4m (urban area), 13.6m (metropolitan region)*
City area *1,572 square kilometers*
Underground and city railway *402 km*
Cars *304 per 1,000 inhabitants*

Los Angeles is a synonym worldwide for a car city. The rapid development of the Pacific harbours in Los Angeles and Long Beach caused a sharp increase in freight traffic. Furthermore, the distance covered by commuters has almost double since 1982, as a result the peak times expand to such an extent that the morning rush hour almost merges with the evening rush hour. The average speed on the motorways in L.A. like the Interstate 405 sinks to a dawdling 22.8 km/h during peak times. The topography of a valley basin in the east and the Pacific in the west permits very few alternative routes. To cope with the traffic, the number of motorway lanes were increased, bottlenecks eliminated and an intelligent traffic light control system introduced. Road toll charges must be paid subject to traffic conditions. Dedicated lanes are reserved for car sharing.

Up to 1930, Los Angeles had a dense tram network

However, the errors made in the past by traffic planners are difficult to remedy: around 1930, Los Angeles had one of the world's longest tram networks as 2,500 kilometers. Afterwards, car traffic was given priority: one tram line after the other was decommissioned, wide freeways were built. Meanwhile, Los Angeles does indeed invest in a new urban railway, but doesn't even have a tenth of the old network. A complete rethink is necessary: rail, bus and cycling are not popular. Pedestrians even appear suspicious in some areas, as a Police Officer explains: "Normally only prostitutes and dealers are on foot."

Copenhagen is a model for cycle mobility throughout the world

In Copenhagen, on the other hand, pedestrians and cyclists belong to the cityscape. The Danish capital is a global pioneer when it comes to cycle mobility: phased traffic lights cyclists, flashing lights that warn motorists of approaching cyclists, bevel-top rubbish bins to for the coffee-to-go cup 'hole in one' throw – many small comforts ease switching to bicycles in the Danish capital. The term Copenhagenize, which means the cycle friendly transformation of cities, has even found its way into the English language. Filmmaker Mikael Colville-Andersen explains: "For years the people were encouraged to switch to the bicycle for environmental reasons. It has no effect. Only those who have the feeling that they arrive faster and more cheaply at their destination swap."

In the meantime, these people represent the majority in the Danish metropolis, which is traditionally expensive for motorists: in the city of 570,000 inhabitants, there are 650,000 bicycles and only 125,000 cars. On several approach roads in the city, more than 35,000 cyclists are counted per day. Sometimes, the traffic volume on the 'cyclist motorways' is so high that jams form at the traffic lights, because not all the bicycles manage to cross the junction when the lights are green. With traffic-flow controlled traffic lights, three lane paths and bike bridges across the heavily used intersections, Copenhagen also aims to defeat this problem. This is obviously a luxury problem from the view point of the permanently congested megacities on this planet.

COPENHAGEN (DK)

Founded *1167*
Inhabitants *0.57m (urban area), 1.25m (metropolitan region)*
City area *86.2 square kilometers*
Underground and city railway *28 km*
Cars *219 per 1,000 inhabitants*

Today, 36 percent of commuters in Copenhagen use a bicycle, the target is 50 percent

TRANS CONTINENTAL EXPRESS

A journey on the Trans-Siberian Railway route has been one of the greatest mobility adventures for 100 years now. Author Bastian Hamacher took on the mammoth tour and has plenty to report.

The first thing I notice in the dimly lit train compartment is the faint snoring emanating from the upper bunks. On the platform in front of the window bags and suitcases are still being lugged around, a conductor keeps a beady eye on proceedings. The neo-classical railway station of Krasnoyarsk dawns in a doze, the sun rises just above the metropolis on the banks of the Yenisei. The compartment is veiled in semidarkness, it's not easy to stow the luggage under the seats without waking the sleeping. The first impression should be good: after all, I don't know how long I'll share this compartment with them on this three day rail journey. This Trans-Siberian Railway locomotive hauls me around 6,000 kilometers eastwards along the Baikal-Amur mainline. Waiting for me at a small station in Ust'-Nyukzha at the end of the line are a native hunter and his German wife, with whom I wish to live in the Taiga for a few weeks. However, until then the route follows one of the world's most legendary railway lines. Through endless forests, across nameless rivers and along mountain slopes still snow covered during the brief summer, it runs along the northern end of Lake Baikal deep into the east until the Sea of Okhotsk and Vladivostok are less than 2,000 kilometers away – compared to the 10,000 kilometers to Moscow a mere stone's throw.

Backbone and lifeline

This railway line has formed the backbone and lifeline of the Russian Empire for over 100 years. The Cossacks had conquered the impenetrable forests far beyond the Urals for the Russian Czars. Without a regular connection it would have remained a worthless venture. Siberia in itself is the earth's largest country – bigger than Canada,


80-202

Transsib construction was started in 1891. From time to time as many as 90,000 people worked at the construction sites

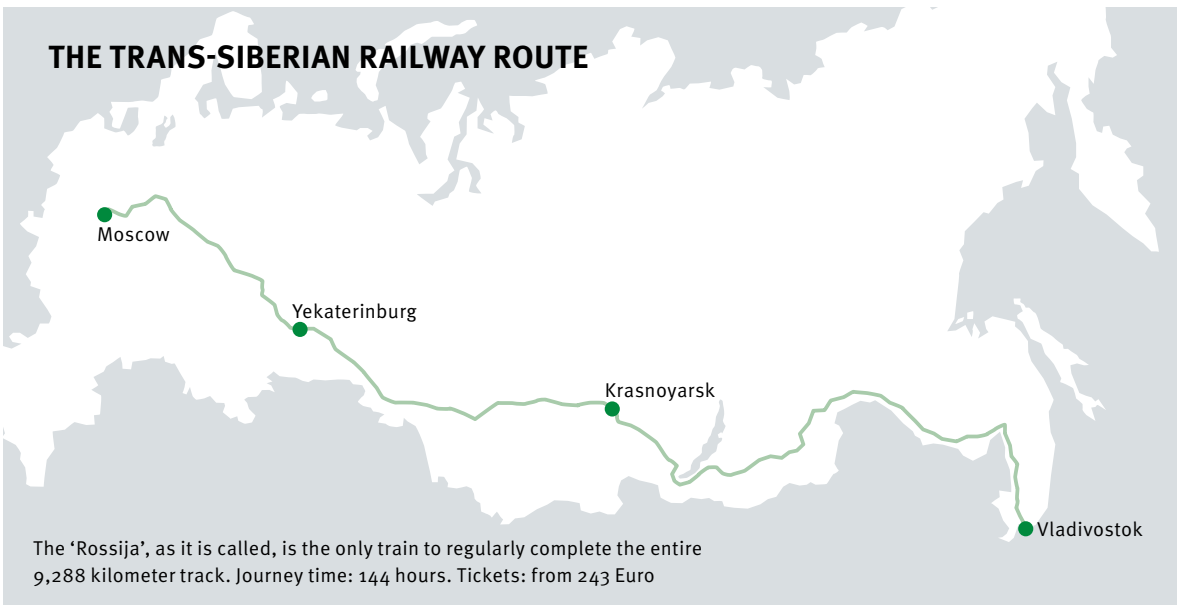
China or Australia. Not quite two people per square kilometer live here. Despite the loneliness, the country is of inestimable value: precious metals, coal, gas, oil and last but not least the wood of the forests. All these Siberian treasures travel by railway from east and west, to China and Europe.

After all the luggage is stowed and new passengers have boarded, the train pulls away with a jolt. Outside, industrial towns drift by: derelict land, chimneys and blocks of flats. Afterwards the meadows grow, dusty roads and datschas, small wooden houses in the midst kitchen gardens full of potatoes, beanstalks and cucumbers. Siberia has a short growing season – in May the ice in the rivers disperses, in October the temperature drops below zero degrees again. Now in August it is 30 degrees Celsius during the day, in the train ten degrees hotter.

By ten o'clock the snoring above my head ends and foot and calf suddenly dangles in my face. A woman around 60 wearing an apron dress climbs down, grins briefly, says two short words and leaves. Before she returns, the chunky conductor drops by and checks the passports and tickets again, before handing over fresh linen, a towel and flannel. They don't look particularly appetising. But barely half an hour later I really don't care – it's hotter, the train starts sweating. Irina – as I soon learn the little old lady is called – returns. She sits down, folds up the table and unpacks: dried fish, bread, tomatoes, cucumbers and tea. Breakfast. Without a word, she pushes everything towards me. Irina is Ukrainian as I find out after much gesticulation and a Russian dictionary with Latin characters, and on the way to visit her daughter in deepest Siberia. Her journey takes six days.

The Transsib must run like clockwork

Outside the landscape changed: everywhere firs, pines, birches. Sometimes a river, occasionally a road. The Taiga is the world's largest forest belt, it stretches on the permafrost ground around the North Pole. In summer, this thaws to a depth of about 50 centimeters. Many houses along the railway line are on stilts for this reason, airfields in the forests can barely be kept operational; asphalt landing strips don't even survive two winters. Roads are hidden under meters of snow to minus 40 degrees Celsius for six months. Everything – people, equipment, goods and industrial products – must be transported via the Transsib line. That's why it's kept in tip top condition.



The 'Rossija', as it is called, is the only train to regularly complete the entire 9,288 kilometer track. Journey time: 144 hours. Tickets: from 243 Euro

25 years

lasted the construction of the Trans-Siberian Railway, starting in 1891. **The costs exceeded 500 million Roubles** (approx. 10 billion € at today's value). As a monument to the construction workers, the world's only marble station was built in 1904 at Sljudjanka on Lake Baikal.

10,267 km

Measures the **world's longest direct rail connection.** It leads from Moscow to Pyongyang in North Korea and uses large parts of the Transsib.

80%

of the Transsib route **runs through Asia**, 20% through Europe. The train crosses the continental border at kilometer 1,777 coming from Moscow.

The Transsib must run like clockwork. Its rhythm slowly creeps into my consciousness: the wheels clattering over the rail joints, a reminder of days gone by on western rail networks. Always the same rhythm, always the same speed. For hours and days on end. The trains roll into the stations exactly according to plan and pull away again exactly to the second. The carriages also remind a little of the old German trains. The seats upholstered in artificial red-brown leather, imitation wood wall panelling, nets for bits and bobs hanging overhead, a collapsible table under the windows. The similarities are not without reason: the trains were produced until the final years of the GDR in a coach building VEB (nationally owned enterprise) and delivered to the brotherly state as compensation.

The friendly train-spirit Irina shows me all I need to know about a journey on the Transsib: where the info boards are, how long the train stops and where (you can't disembark at every station), that the clocks along the route are set to Moscow time, how to get all the supplies you need on specific platforms. The conductor is the train's other good spirit: two conductors share the supervision in twelve-hour shifts. They ensure there is hot water and check embarking passengers, they count their sheep when they stretch their legs and round them

The Trans-Siberian Railway is a rolling window on the huge Russian empire

up again punctually. They vacuum and wash the corridor and compartment daily and occasionally keep the peace.

A rolling crash course in all things Russian

The Trans-Siberian Railway is by no means just a railway, it's a company, a name. In the 19th century, it should form a fixed link from Moscow via Mongolia to Peking. At that time, the line ran along the Amur to Novosibirsk. When the rivalry between the Soviet Union and China threatened to escalate into a border conflict, the route was diverted to the north away from the border to form the Baikal-Amur mainline around Lake Baikal. Today, the Transsib trains run at different intervals along various sections of the track, you can embark in Cologne or Warsaw and travel to the Ukraine, Ulan Bator, Beijing or Shanghai.

Anyone wishing to discover Russia as it really is day-to-day need look no further than a journey on the Trans-Siberian Railway tracks. You don't meet magnificent Moscow and Saint Petersburg and their chic inhabitants, but in fact oil and gas workers who climb aboard at night while travelling between drilling fields and who have disappeared again before sunrise; students on their way home, hunters on the way to the forests and families on holiday.

You also meet backpackers from all corners of the world. They embark and disembark in the large cities along the track. Historical cities that adventurous readers visited as youths with Jules Verne's 'Michael Strogoff': Omsk and Tomsk, Yekaterinburg and Irkutsk. Cities with history and culture and hospitable people. Tourists on the Trans-Siberian Railway can also not escape vodka with gherkins, loud songs and sentimentality – if they are lucky.

MOBILE FUTURE ON RAILS

The importance of the railroad for the international mobility-mix grows. For passenger rail traffic, but even more so for long-haul rail-freight traffic. The Schaeffler brands FAG and INA support development with innovative products – for more than 100 years now.

Compared to 2005, the volume of rail-freight traffic should almost double in the European Union by 20150 (+87%). Utopian? Certainly not. In other countries, the railway plays a greater role than in the EU. For example, although the railway's market share of rail-freight traffic grows continuously in Germany, it nevertheless represents a scant 17.5 percent (status as of 2014). In comparison: 70.4 percent is transported by road, 9.3 percent by water and 2.8 via pipeline. The figures are similar Europe-wide. Other countries are significantly further. Territorial countries like Australia, China, Russia and the USA are already there where the EU aims to be: at a rail- freight traffic volume of up to 45 percent.

The railways should also improve their share of passenger rail traffic and entice travellers away from the road and aeroplanes. As respectably achieved over the last few years: between 1994 and 2011, countries like Great Britain (+95%), France (+51%), Switzerland (+47%) and Germany (+30%) have registered significant growth rates in passenger rail traffic. The great railway nations China, Japan, Canada, Russia and the USA, which are jointly responsible for 50 percent of the global public passenger transport services by rail, have, with the exception of Russia, also increased over the last decade. In China alone the performance increased by 7.6% annually.

Schaeffler's Railway Sector Management is development partner and supplier to various projects for the expansion of the high-speed long-distance traffic, freight traffic and urban public transport in the growing megacities. As a result, Schaeffler is development partner for both the high-speed project CRH3 in China as well as development partner for the Velaro RUS high-speed train used in Russia. For instance, in urban transport for the Metro Singapore or projects in China.

Among the FAG and INA brand portfolios are axlebox bearings as well as bearings and components for traction motors and gearboxes, articulation and tilting systems and doors and sliding panels.

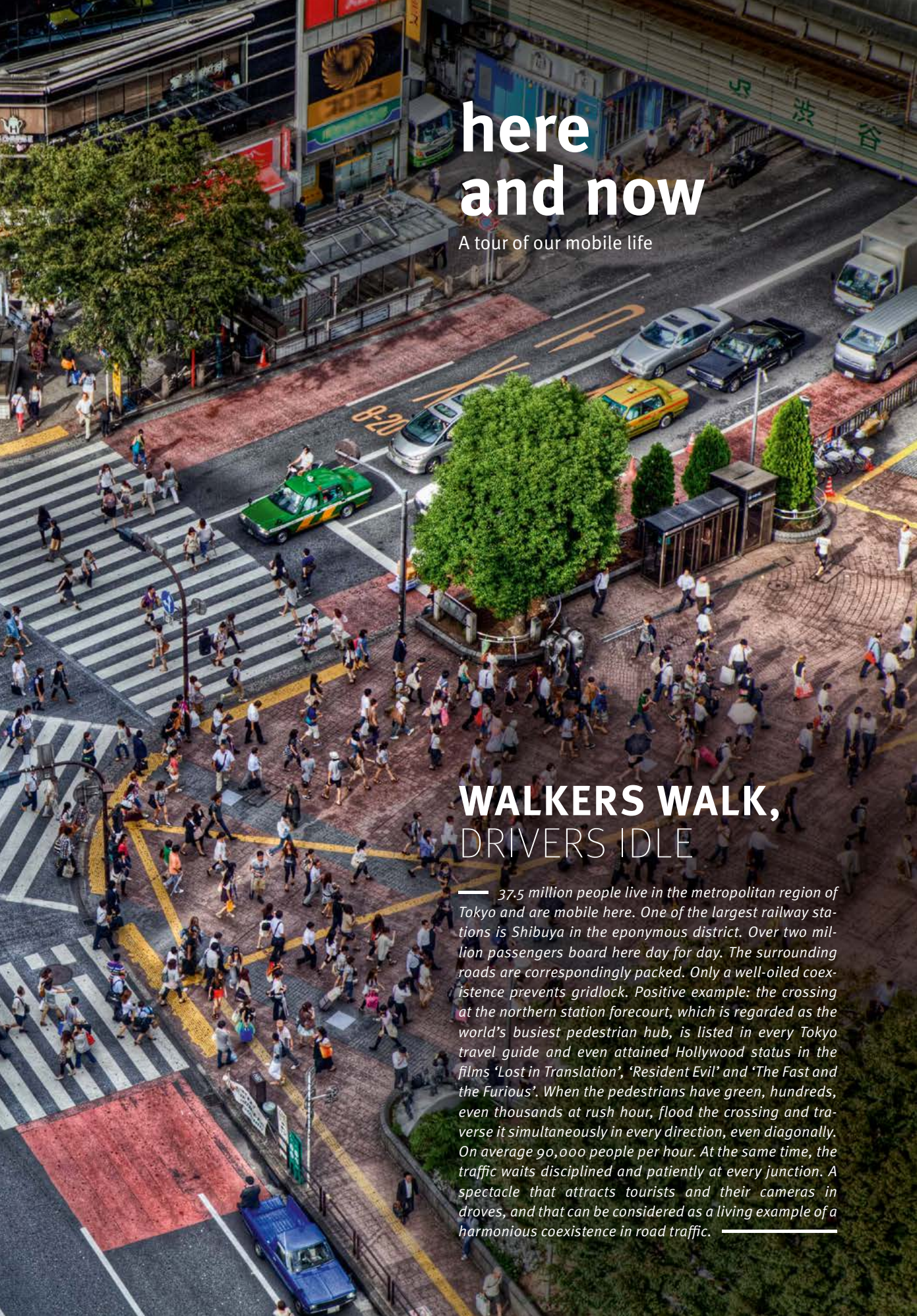
The TSS-F wheel bearing generator supplies energy for the monitoring system

Among the FAG and INA brand portfolios are axlebox bearings as well as bearings and components for traction motors and gearboxes, articulation and tilting systems and doors and sliding panels.

For more safety in passenger traffic, Schaeffler develops the TSS-P monitoring system, which monitors the functionality of the various components. The TSS-F version for freight traffic also transmits GPS data to determine the position of individual waggons and thus act as anti-theft feature, but also to optimize logistical procedures.

» Let each of you look not only to his own interests, but also to the interests of others

Epistle of Paul to the Philippians 2:4



here and now

A tour of our mobile life

WALKERS WALK, DRIVERS IDLE

37.5 million people live in the metropolitan region of Tokyo and are mobile here. One of the largest railway stations is Shibuya in the eponymous district. Over two million passengers board here day for day. The surrounding roads are correspondingly packed. Only a well-oiled coexistence prevents gridlock. Positive example: the crossing at the northern station forecourt, which is regarded as the world's busiest pedestrian hub, is listed in every Tokyo travel guide and even attained Hollywood status in the films 'Lost in Translation', 'Resident Evil' and 'The Fast and the Furious'. When the pedestrians have green, hundreds, even thousands at rush hour, flood the crossing and traverse it simultaneously in every direction, even diagonally. On average 90,000 people per hour. At the same time, the traffic waits disciplined and patiently at every junction. A spectacle that attracts tourists and their cameras in droves, and that can be considered as a living example of a harmonious coexistence in road traffic.

ABC OF DRIVING **EFFICIENCY**

Schaeffler components are found in cars and motorcycles. Cleverly combined, they achieve amazing results: they reduce the fuel consumption by up to 15 percent. Four concept vehicles demonstrate how Schaeffler finds the correct technology mix for the respective market.

A LIKE ATLANTA

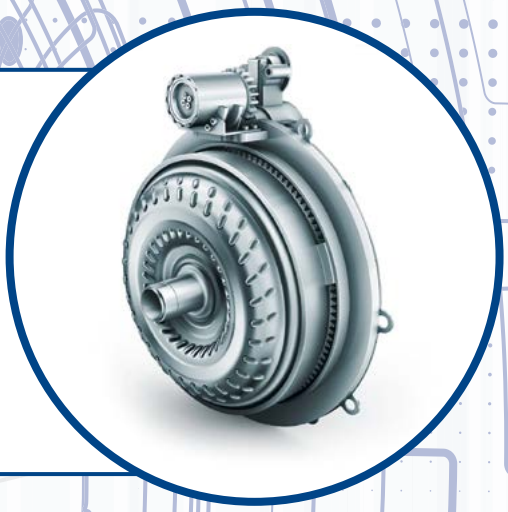
Concept car
Efficient Future Mobility North America

The roads are long, petrol is cheap, great freedom just around the corner. Nevertheless: in view of stricter consumption regulations, the frugal use of fuel will also belong to the automobile's DNA in the USA in the future. Schaeffler's 'Future Mobility North America' demo vehicle shows how 15 percent of fuel can be saved with the technologies available today.

STOP IN THE NAME OF FUEL

START-STOP WITH ENGAGED GENERATOR

All of a sudden total gridlock, *bumper to bumper the traffic rolls along the eight-lane North American highway. Whoever has a car with start-stop automatic saves significant amounts of fuel because the engine doesn't just idle away for no reason. One of Schaeffler's bright ideas ensures that motorists really accept such an idea: the starter motor (the component above the torque converter) is permanently engaged, so that restarting the engine happens significantly quicker and more comfortably.*



NO TIME FOR LOSERS

VARIOUS REDUCTIONS IN FRICTION

Friction creates heat, *so lost energy for transportation. In the North American technology demonstrator, Schaeffler shows how unnecessary friction in every corner of the vehicle can be reduced. For example, when the balance shaft, to counteract engine vibrations, runs in roller bearings instead of plain bearings. Or if slip can be dispensed with in the torque converter (photo) in the automatic gearbox, without the noise level increasing. Many at first glance small measures add up to make a hefty fuel saving.*

HANG ON, BABY

ALL-WHEEL DRIVE (AWD) CLUTCH

Those wishing to conquer new terrain *must occasionally leave terra firma. In such a situation, all-wheel drive is the safe option. However, in many driving situations, for example when driving on dry, paved roads, the propulsion of two axles leads to unnecessarily high fuel consumption. To this end, Schaeffler has developed an electronically controlled clutch, with which one axle can always be disconnected from the drivetrain if it is not required at that moment. The fuel saving is as much as six percent.*


1

HARMONIOUS

ELECTRONIC CLUTCH MANAGEMENT

The average speed in Indian cities *is only 15 km/h. Constant braking and pulling away are part of everyday motoring, and as a result also coupling and changing gear, because only very few can afford an automatic gearbox. Schaeffler's electronic clutch management (clutch photo 1) provides significantly greater comfort at moderate cost. A small, electronically controlled actuator (photo 2) takes over the driver's footwork. In combination with gear detection (photo 3) in the shift mechanism a harmonious start-stop function can also be implemented.*


2


3

HAPPY TO ADJUST

VARIABLE CAMSHAFT TIMING

Open and closed, round and round, again and again. *In India, the camshaft also performs no other task than to control the opening and closing of the valves. In the Schaeffler demo vehicle, these times are not fixed, but in fact can be adjusted variably by a unit fitted on the engine to suit the respective driving situation. Schaeffler manufactures such actuators, also referred to as a camshaft phase adjuster, in large quantities today.*

B LIKE BANGALORE

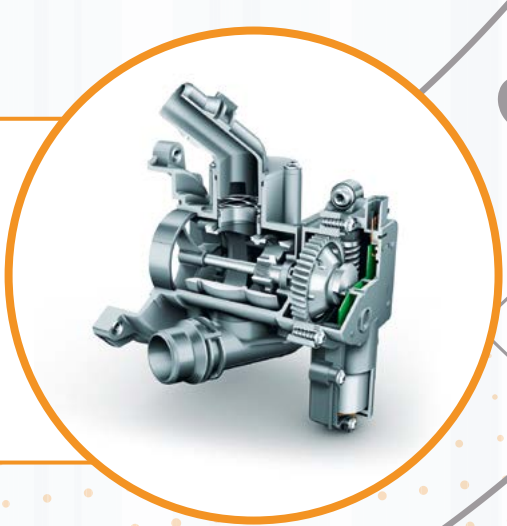
Concept car Efficient Future Mobility India

The capital of the Indian software industry never sleeps, even at three o'clock in the morning the roads are full of vehicles and pedestrians. Mobility is vital for the Indians, but it must be affordable. How 10 percent less CO_2 emissions can be achieved with proven, cost-effective technologies was shown by Schaeffler with the 'Efficient Future Mobility India' demo vehicle.

BALANCED

THERMAL MANAGEMENT MODULE

Snow in the mountains, heat haze inland. *Not only should the driver in the cockpit, but also engine and gearbox always work in ideal conditions. This also means that after a cold start, the initial waste heat energy flowing very sparsely from the engine is perfectly distributed. A new thermal management module from Schaeffler assumes this task. If the engine and gearbox warm up faster, not only do the frictional losses and consumption sink, but also the emissions from exhaust pollutants.*

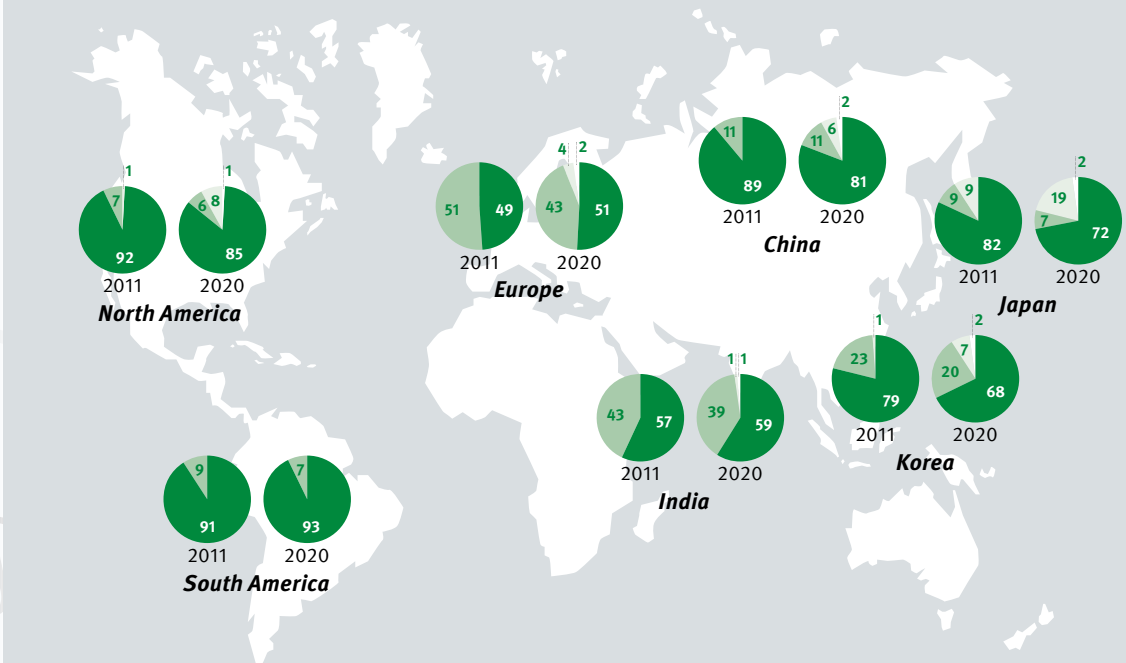


C LIKE CANNES

Concept car System 48 Volt

The human should be noble, beautiful and good hearted, as is the belief in Europe since ancient times. Consequently, four-wheeled human transportation must also satisfy these demands and combine comfort, driving dynamics and suitability for everyday use with minimum environmental damage. With the ‘System 48 Volt’ concept car, Schaeffler presents an exciting and economical perspective on the subject hybrid.

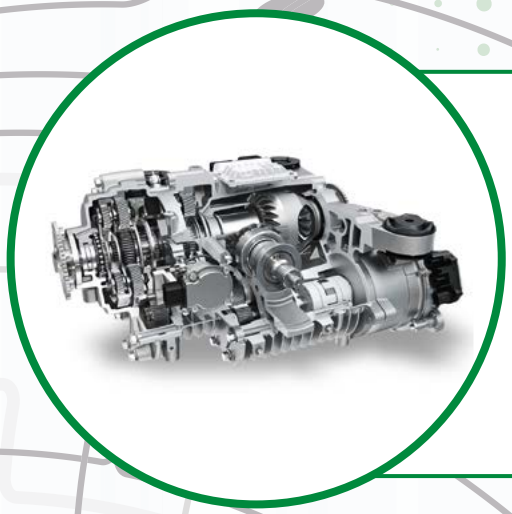
SHARE OF PRODUCTION OF THE DIFFERENT DRIVE CONCEPTS 2011 AND 2020 IN PERCENT



Petrol Diesel Hybrid Electric vehicle

Source: IHS 2013

INTEGRATED AND POWERFUL



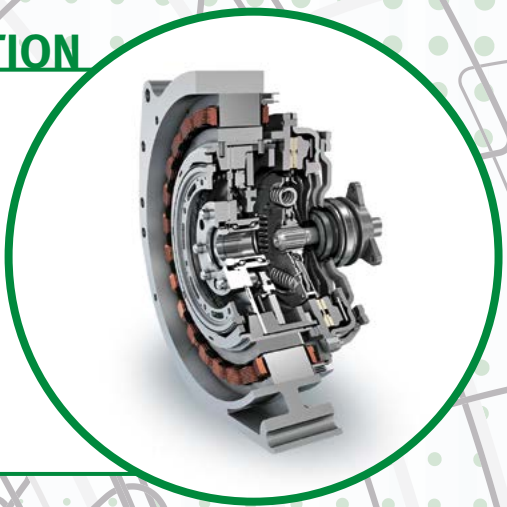
ELECTRIC AXLE WITH UP TO 1,500 NM

Schaeffler has developed three drive variants for the 48-volt hybrid, *one of which is the axle drive with integrated e-motor and upgraded starter generator. The 12 kW (16.3 hp) e-motor can be installed in the differential without modifications to the bodywork or suspension. An integrated single-speed or two-speed gearbox provide a high starting torque (up to 1,500 Nm) and allow pure electric motoring up to 20 km/h. Equipped with an additional planetary gear set, the electric axle distributes the torque specifically to the wheels ('Torque Vectoring') and thus increases the vehicle agility significantly.*

KEEPING ABREAST OF THE SITUATION

48-VOLT HYBRID FOR MANUAL GEARBOXES

Alternatively, the 12 kW e-motor *can also be integrated, instead of a torque converter, into an automatic gearbox. But what is with the manual gearboxes that still predominate in smaller vehicle categories? For this purpose, Schaeffler has developed the first hybrid module (photo) for cars with manual gearboxes. A rapid shifting and automated impulse clutch enables the 48-volt e-motor to be implanted between combustion engine and gearbox. Additionally, reengaging the clutch allows the engine to be started via the electric motor. A typical starter motor can be omitted.*



FAST AND COOL

ELECTRIC POWER BY BELT

The third version of a 48-volt hybrid drive *developed by Schaeffler: powerful e-motors are connected to the crankshaft by a belt. In this way, the engine is assisted electrically when starting and under acceleration. The oscillations occurring in the belt drive are eliminated by the Schaeffler developed belt pulley decoupler (photo). If the belt pulley decoupler is complemented with an electromagnetic actuator, the starter generator can also drive the air conditioning compressor when the engine is idle.*

NON-STOP

CHAIN TENSIONER AND TOOTHED CHAIN

Not much will run without them in the future either: *the dependable chain is and remains the link to transfer engine power to the driven rear wheel on the majority of two-wheelers. But tried and tested can also be improved: the hardwearing and long-lasting toothed chain from Schaeffler reduces friction, vibration and noise. Additionally, as an alternative to sophisticated hydraulic chain tensioners, Schaeffler also provides specifically for smaller machines a mechanical variant, which compensates for the effective chain elongation and thermal expansion – and all this for significantly less weight and installation space.*

LESS IS MORE

STARTER FREEWHEEL

Before anything else it has to be matched: *the new INA starter freewheel saves 44 percent weight compared to previous versions, but transmits higher torques. The new, robust design ensures maximum shift reliability even in the event of overloading. On top of this, the extremely compact design facilitates simplified installation and reduces, as a result, not only the system weight considerably, but also sinks the installation costs.*

KEEP SEALED

WHEEL BEARING WITH ELS SEAL

Friction costs energy and increases wear. *This is why friction reduction on motorcycles is also an aspect for Schaeffler to create more efficient and ecological mobility. For example, using FAG wheel bearings with ELS seals. These exclude dirt and water from penetrating the bearing internals and simultaneously prevent the grease from escaping. As a result, the coefficients of friction are reduced by a third compared to wheel bearings without ELS seals.*

2 LIKE TWO-WHEELER

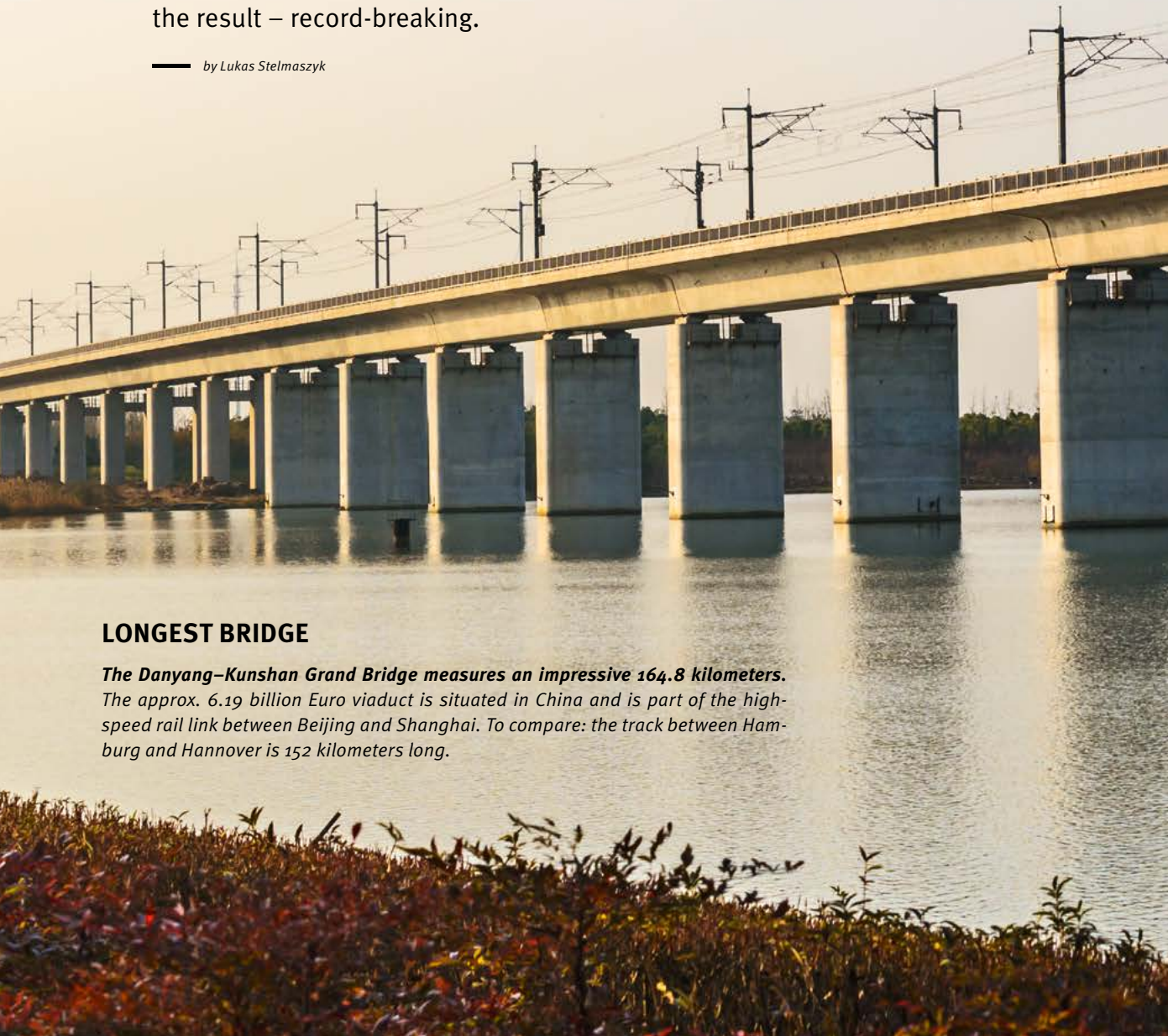
Concept motorcycle
For small to medium power categories

Especially in the Asian and South American emerging economies is the motorcycle a widespread yet cost-effective form of transport, which is gaining popularity through the growing need for mobility. However, the motorcycle can also be an interesting alternative to the car in the ever more congested and populated urban centers in the industrialized nations. Schaeffler takes account of this development in the two-wheel sector with numerous newly developed components for engine, gearbox and suspension. These are not only economical and energy-efficient but also durable.

LONGER, HIGHER, WIDER

To satisfy the ever increasing thirst for efficient mobility, an architectural race is currently underway worldwide. Imposing buildings that reach the physical limits are the result – record-breaking.

by Lukas Stelmaszyk



LONGEST BRIDGE

The Danyang–Kunshan Grand Bridge measures an impressive 164.8 kilometers. *The approx. 6.19 billion Euro viaduct is situated in China and is part of the high-speed rail link between Beijing and Shanghai. To compare: the track between Hamburg and Hannover is 152 kilometers long.*

LONGEST ROAD BRIDGE

The Bang Na Expressway holds this record at a length of around 54 kilometers. *The six-lane beam bridge in Bangkok has a total surface area of 1.9 million square meters, enough space to accommodate the Potsdamer Platz in Berlin 28 times. Construction costs: over 725 million Euro.*

HIGHEST BRIDGE PILLARS

The bridge pillars used for the Millau Viaduct rise as high as 343 meters *above the Tarn Valley northwest of Montpellier. Star architect Sir Norman Foster was one of several people involved in the planning of the 400 million Euro steel construction. Before its opening in 2004, endless steel convoys frequently trundled through the Tarn Valley and caused traffic jams of up to 50 kilometers at the beginning of the holiday.*

LARGEST AIRPORT TERMINAL

Terminal 3 at the Beijing airport is a proud 3,250 meters long. *The enormous steel-glass construction was opened to coincide with the 2008 Olympic Games, and measured on the total floor area is the sixth largest building in the world. Currently over 60 million passengers are handled in the terminal annually and is thus more than the entire Frankfurt Airport (58 million).*

LONGEST RAILWAY TUNNEL

At a length of 67.3 kilometers, *there is no other railway tunnel on earth longer than the shaft of the subway line 3 in Guangzhou. The tunnel is part of the Guangzhou Metro, which transports about 5.6 million passengers daily along its eight lines consisting of 260 kilometers of track, and which cost more than 1.21 billion Euro.*

LONGEST ARTIFICIAL WATERWAY

The Grand Canal in China stretches just about 1,800 kilometers *and connects Hangzhou in the south with the capital Beijing in the north. It was completed in 13th century and is considered a masterpiece of canal engineering. To compare: at 325.3 kilometers, the Mittelland Canal is the longest artificial waterway in Germany.*

LONGEST ROAD TUNNEL

The Lærdalstunnel in Norway measures 24.5 kilometers. *The 113 million Euro construction is a part of the route from Oslo to Bergen. An average of 1,000 vehicles pass through the toll-free tunnel daily. Peculiarities are the sweeping lines and in the three intermediary caverns a new type of indirect illumination, which should recreate daylight in order to minimize the risk of accidents.*

WIDEST ROAD

The Avenida 9 de Julio in Buenos Aires with its 18 lanes *is 140 meters wide. As a result, the road is twice as wide as the Avenue des Champs-Élysées in Paris. Pedestrians need several minutes and two to three traffic lights sequences to cross the Argentine capital's most important road corridor. Usain Bolt crosses it faster: the Jamaican sprint star would need about 15 seconds without stopping in between.*

Engineering masterpiece: the ocean liners are manoeuvred around 50 meters up or down in the Panama Canal's locks.

BEARINGS IN CONSTRUCTION WORKS ARE SENSITIVE INTERFACES

Whether at sea or on land, bearings must withstand weights totalling several tons *– they must tolerate great heat and biting cold, are exposed to sandstorms or aggressive saltwater. What the sector demands is implemented in creative bearing technology by Schaeffler.*

ELGES plain bearings were for example fitted to Porta d'Europa. The world's largest double bascule bridge – 106 meters wide – is in Barcelona and with its two majestic arms does in fact look like the gate to Europe. The Millennium Wheel reigns over London just as imposingly. The Ferris wheel, also known as the London Eye, provides the most impressive view over the English capital – thanks to bearings from INA and FAG.

Central America currently boasts the world's largest construction site. One hundred years after the Panama Canal opened, the 82-kilometer waterway, which connects the Atlantic and Pacific, is being expanded. Main focus of the building activity are a third shipping channel and the locks on the Pacific and Atlantic sides. Schaeffler high-performance products are also used in this project, so that the sliding lock gates weighing over 3,000 tons can open and close smoothly from mid-2016.

HIGHEST HIGHWAY

The Karakorum Highway is a 1,284 kilometer long highway *linking the Chinese city Kashgar with Havelian in north-west Pakistan. The highest point of the road is reached at 4,693 meters when crossing the Khunjerab Pass – simultaneously the China-Pakistan border. Construction of the road opened in 1978 was a huge challenge due to the frequent landslides on the mountain slopes and the altitude. The road is also open to tourists since 1986 and is currently being extended. The goal is to reduce the journey time from 30 to 20 hours.*

HIGHEST RAILWAY STATION

The unstaffed station Tanggula *is situated in the Tibet Autonomous Region (TAR) within the People's Republic of China. It is the highest railway station in the world at a height of 5,068 meters – about 2,400 meters higher that the Schneefernerhaus station of the Bavarian Zugspitze Railway. Opened in 2006, the station, part of the world's highest railway line, was originally planned as an observation platform. Because of the low level of oxygen in the atmosphere and the extremely high temperatures, due in part to global warming, travellers are prohibited to board or disembark at the station since 2010.*

FIRST SUSPENDED ROUNDABOUT

The Hovenring in Holland is the first 'hovering roundabout' for cyclists. *The approximately eleven million Euro construction close to Eindhoven hangs from a 70-meter high column. 24 steel cables suspend the near 1,000 ton steel roundabout. In the wake of the expansion of the infrastructure for cyclists, other urban planners are also backing new traffic concepts: in London the SkyCycle – a bicycle highway – with a total length of 220 kilometers should be built. In Cologne, 6,000 commuters should ride everyday along an eight kilometer bicycle express way in the future.*

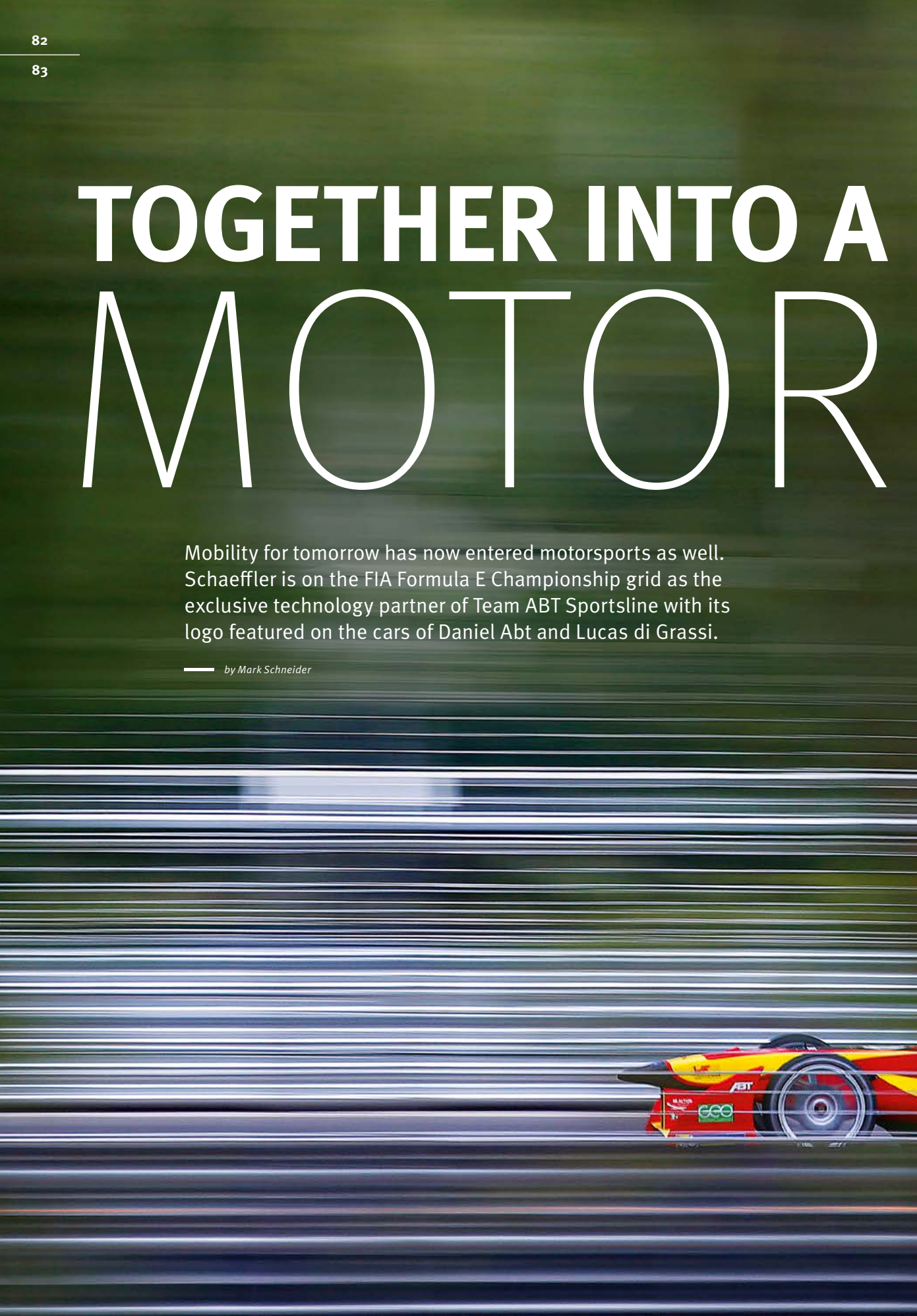
LARGEST SHUNTING YARD

Bailey Yard in the US state Nebraska is the world's largest shunting yard. *About 2,100 of the 14,000 freight wagons rolling daily through the railway yard are connected to new freight trains. The railway yard covers an area of 11.5 square kilometers and has 507 track kilometers, which equates to the track from Frankfurt am Main to Hamburg. Europe's largest shunting yard is not far from the northern German metropolis. However, the track network 'only' consists around 300 kilometers.*

TOGETHER INTO A MOTOR

Mobility for tomorrow has now entered motorsports as well. Schaeffler is on the FIA Formula E Championship grid as the exclusive technology partner of Team ABT Sportsline with its logo featured on the cars of Daniel Abt and Lucas di Grassi.

by Mark Schneider



NEW ERA OF SPORTS

Formula E marks the beginning of a new generation of motorsports. For the first time, automobile races are contested with full-electric race cars. The identical single-seaters reach a speed of up to 230 km/h, accelerating from zero to 100 km/h in less than three seconds, and hold their races in major cities around the world.

"Helping to shape the electrification of the automobile is one of our key strategic topics of the future. Schaeffler is an innovation leader in this field, frequently pioneering new ideas. Formula E is bold and visionary, which makes it a perfect fit for us and an ideal complement to our commitments in the DTM, the WEC and Formula Student," says Chief Technology Officer Prof. Peter Gutzmer. "Motorsports are not only ideally suited to accelerating the further development of new technologies but energize the topic of electric mobility with emotions in a fascinating way. The inaugural event in Beijing perfectly proved the point."

Technology expertise meets motorsports experience

The collaboration with ABT Sportsline has a long-range focus and far exceeds a pure sponsoring arrangement. We're going to support the further development of the race car and its components with the know-how and experience of our engineers in the future," adds Gutzmer.

SPARK SRT_01E

Vehicle *formula car, carbon/aluminum monocoque chassis*
Power unit *rear-wheel drive from two motor generator units (MGUs)*
Transmission *sequential 5-speed, with paddle shifters*
Output *(practice and qualifying) 200 kW (270 hp)*
Output *(race) 150 kW (202.5 hp), additional power output of 30 kW (40.5 hp) by #FanBoost for three drivers*
Acceleration *0–100 km/h in 2.9 sec*
Top speed *225 km/h*
Minimum weight *896 kg (incl. driver)*
Length/width/height *5,000 mm/1,800 mm/1,250 mm*
Tires *low profile tires (front: 9R18, rear: 11R18)*

Schaeffler's Chief Technology Officer Prof. Peter Gutzmer with Harry Unflath and Hans-Jürgen Abt from ABT

#11

LUCAS DI GRASSI (30)

Date of birth
11 August 1984
Place of birth
São Paulo (BR)
Domicile
Monaco (MC)
Height/weight
1.79 m/75 kg

#66

DANIEL ABT (22)

Date of birth
3 December 1992
Place of birth
Kempten (D)
Domicile
Kempten (D)
Height/weight
1.79 m/70 kg

56 kWh of energy is available to each driver per race

=

2-person household (6 days)

Refrigerator, 150 l (210 days)

Dishwasher (70 washing cycles)

TV set (15 days non-stop)

Light bulb, 60 W (39 days non-stop)

On course for success: di Grassi won the season opener of the Formula E in the streets of Beijing

TEAM ABT
@abt_formula_e
abt.fiaformulae.com

SCHAEFFLER
@schaefflerpress
schaeffler.de

"We're delighted that in Schaeffler we've got a perfect partner for the challenges in Formula E on board, as from the company's presence in the DTM we've come to know the passion with which all the employees support motorsports," says team boss Hans-Jürgen Abt. "The collaboration in the field of technology is a very important aspect. Starting in the second season, ABT will subject some of the vehicle's components to further development – so a partner with such a wealth of engineering expertise and experience in electric mobility is obviously worth a mint."

ABT Sportsline is the only German team in an international field which includes outfits from the United States, India, China and Europe. The former Formula One stars Alain Prost and Jarno Trulli are on the grid with their own teams as well as adventurer Richard Branson and actor Leonardo DiCaprio. More than ten drivers have experience in Formula One.

They include the Brazilian Lucas di Grassi (30), who as an Audi factory driver competes in the FIA World Endurance Championship (WEC) and for ABT in Formula E. The second cockpit is occupied by the German youngster Daniel Abt (22) who also ran in GP2 as part of the Formula One supporting program.

Races in the world's major cities

Formula E doesn't hold its races on permanent race tracks but on street circuits in the heart of major cities. After Beijing, where the track included a loop around the Olympic Stadium, Formula E travels to Putrajaya (Malaysia), Punta del Este (Uruguay), Buenos Aires (Argentina), Miami and Long Beach (both USA), Monaco, Moscow (Russia), Berlin (Germany) and to London (Great Britain), where the finale will take place on June 28, 2015. Free practice, qualifying and the race are all held on a single day.

Worldwide media interest in the series is huge. The inaugural race alone was watched live by 25 million people. The statistics reflect 2,600 printed articles that reached 740 million readers around the globe.

In Germany, Sky airs live coverage of all Formula E races. The sports channel SPORT1 broadcasts a half-hour summary of the highlights presented by Schaeffler on the day after each race.

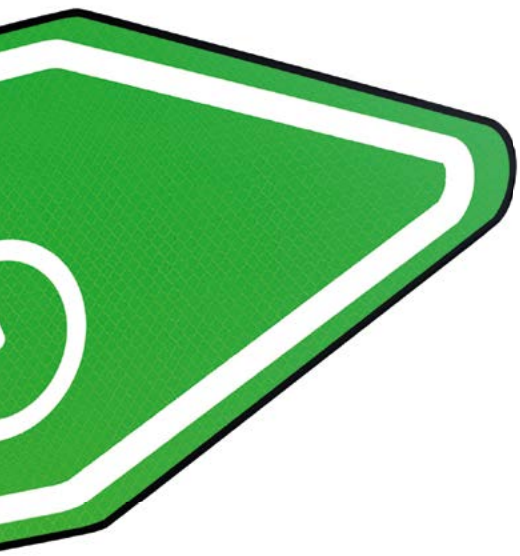
TWO-WHEELED STREAMER

Full speed ahead using half the muscle power – the Pedelec or e-bike makes this possible. Bicycles equipped with electric motors are not just fun to ride; they also extend the range and relieve the environment – no surprise then that they are a mobility best seller around the globe.

by Ulrich Frieß

What the electric car world has been fighting for years for has long since been implemented by the two-wheel fraternity: the change to hybrid mobility. Pedelecs are now a common everyday sight in traffic – be it Munich, Beijing or Tel Aviv. In Germany, the number of e-bikes last increased by around 400,000 per annum, in 2014 the number broke the 2 million mark for the first time. An amazing figure. However, a mere drop in the ocean when you look to China, where 120 million e-bikes are in use – tendency on the rise rapidly here as well.

Despite the current success, the e-bike also encountered difficulties to begin. In addition to many private tinkerers, who had already electrified their cycles more than 40 years ago, there were also bicycle manufacturers in the 1980s with corresponding aspirations. For example, in 1985 Hercules developed the prototype of a Pedelec as we know it today: with hub motor and rechargeable battery on the luggage rack. However, because laws governing their use on the road (bicycle or motorcycle?) were lacking in many places, the bicycles were not mass-produced.



Today, the Pedelec riders travel on juridically safe ground. A driving licence is not required and the Pedelec is regarded from the transport viewpoint as bicycle, if it fulfils certain conditions. The pioneer Egon Gelhard created the basic principles for this in 1982: the motor can only operate when the pedals move. Two more restrictions were introduced later: the motor's nominal power is limited to 250 Watts, and assisted propulsion ends above 25 km/h. At least in Germany. On the other hand, in other countries the e-motors drive the wheels even when the rider is not pedalling. And the speed limit is not as strictly policed everywhere. Here, the boundary between e-bike and moped is vague.

Pedelecs conquer the market

Mobility is a small piece of cherished freedom irrespective of country. To this end, the bicycle traditionally plays an important role, because it is simple and affordable for almost anybody. Development of the Pedelec has further extended the range of applications for the bicycle. The electric motor makes the cycle more versatile and raises its acceptance as every day and recreational form of transport even for less athletically ambitious people. Pedelecs do not need charge points (the plug at home or in the office suffices) and they can still be moved if the battery is flat. In addition, whoever can ride can also ride a Pedelec with minimum familiarisation.

Modern lithium-based battery technology and highly efficient brushless electric motors make distances of between 40 and even 100 kilometers possible today. The energy consumption to achieve this is unbeatably low: a single battery charge costs less than 20 cents on average. With its largely ecological drive – in addition to the little electric current, the Pedelec requires only muscle power – it is in tune with the green trend.

THE BICYCLE HAS A TRADITION AT SCHAEFFLER

Even before Friedrich Fischer's invention of the ball grinding machine in 1883 *went down in industrial history and laid a foundation for today's Schaeffler Group, his father, Philipp Moritz Fischer, attracted attention with a mobility innovation. As the professional instrument maker found traveling to his customers on a dandy horse (aka 'Draisienne') too slow and tiring he installed pedals on the front wheel – somewhere along the line between 1844 and 1853 – marking the birth of the treadwheel. Although power has since been transmitted to the rear wheel by a chain in the middle of the bicycle, we still have to pedal today.*

At the same time, Pedelecs have dispensed with their senior citizens image. Until recently, they were regarded as mobility concept for the generation 60 plus, the cycles became increasingly trendy and more technically refined. As a result, the Pedelec is a genuine alternative for many motorists – especially in the urban traffic turmoil. Normally only a few kilometers stretch between departure and arrival, the average speed achieved with the car only about 30 km/h. If searching for a parking space and the short walk to the true destination are considered, the average speed drops drastically once again. These distances can be covered easily in the same time with the Pedelec. Another advantage: they require less parking space. In this way, the electric bike is the perfect companion for urban mobility – especially in mega metropolises plagued by chronic smog and congestion. The residents in Chinese cities with over a million inhabitants have long since realized. In the world's most populous country, there are about 3,000 Pedelec manufacturers offering bicycles for around 200 Euro. However, the technology (inefficient and poisonous lead batteries, safety equipment) used on these cheap cycles is at a low level in keeping with the purchase price.

PROHIBITIVE BASIC MOBILITY

On the mobility scale, the bicycle is the second step after walking. *In the world's poorest regions, this step remains a step too far for many people, because even the simplest bicycle is prohibitively expensive. In this case, travel by bicycle increases the efficiency of transportation many times over. When compared to walking, a bicycle improves access to education, healthcare and commercial opportunities: the bicycle enables the human to carry more, to cover longer distances and, at the same time, save valuable time on the way to and from schools, clinics and markets. The maximum load capacity compared to somebody on foot increases fivefold. A cyclist can cover four times the distance within the same time compared to somebody on foot. A cyclist saves three hours per 16 kilometers compared to a person walking. World Bicycle Relief is committed to making people in Africa mobile with bicycles. Donations help the organization in this endeavor.*

worldbicyclerelief.de

Things are completely different in the western industrialized nations where thanks to strong batteries the Pedelecs are a rapid companion for long rides into the country. Day trips of 50 kilometers and more on a single charge are possible without problems. Relaxed travelling included.

Pedelecs are intuitive to use

The majority of bicycle manufacturers around the world now have a broad range of e-bikes on offer. Customers can chose between electrically assisted trekking bikes, city and mountain bikes, women's bikes as well as transport and folding bicycles or tricycles. The S-Pedelecs capable of speeds up to 45 km/h are still a niche market. From the legal viewpoint – at least in Germany – they are mopeds and therefore a helmet, registration and insurance are compulsory. Biggest disadvantage: cycle paths and other paths closed to motorized vehicles may not be used. However, the S-Pedelecs are a real alternative to the car for commuters facing longer journeys outside built-up areas. Whether S or normal Pedelec: the designers are spoilt for choice when it comes to positioning the motor. There are hub motors in the front or rear wheel, as well as centrally mounted bottom bracket motors. In the meantime, motor management and torque sensors are standard: the harder you pedal, the more the motor. In addition, a handlebar mounted switch allows the rider to adjust the maximum motor power in several steps (between 50 and 250 Watts). Displays show information about the distance travelled and remaining range, fitness functions and an integrated navigation system complement the allround package. Because the additional weight and greater drive dynamics can negatively affect the stability and handling, stiffer and heavier frame designs are necessary. So, it is not only due to the additional drive components that Pedelecs normally weigh considerably more than 20 kilos. Their drive more than compensates for the greater weight.

All this means that Pedelec riders enjoy a previously unknown level of comfort. However, more sporty riders also get their money's worth from motorized bikes: sparsely equipped, lightweight fitness Pedelecs and full-suspension mountain bikes with e-drive offer more fun on the saddle and are very much in vogue. In general, Pedelecs are gaining in popularity among young and active sporty riders. An inconceivable variety of different Pedelecs for every conceivable purpose could be admired during Europe's largest bike show, the Eurobike 2014. In the future, designers and manufacturers could possibly devote more time to the interactive interplay between the individual drive components. The technology then automatically adjusts the gear ratio and motor power to suit the route profile and rider. However, you'll still have to mash the pedals just a little.

AUTOMATICALLY **BETTER**

Schaeffler presented an innovative development for bicycles in 2014: the automatic FAG-VELOMATIC gearshift.

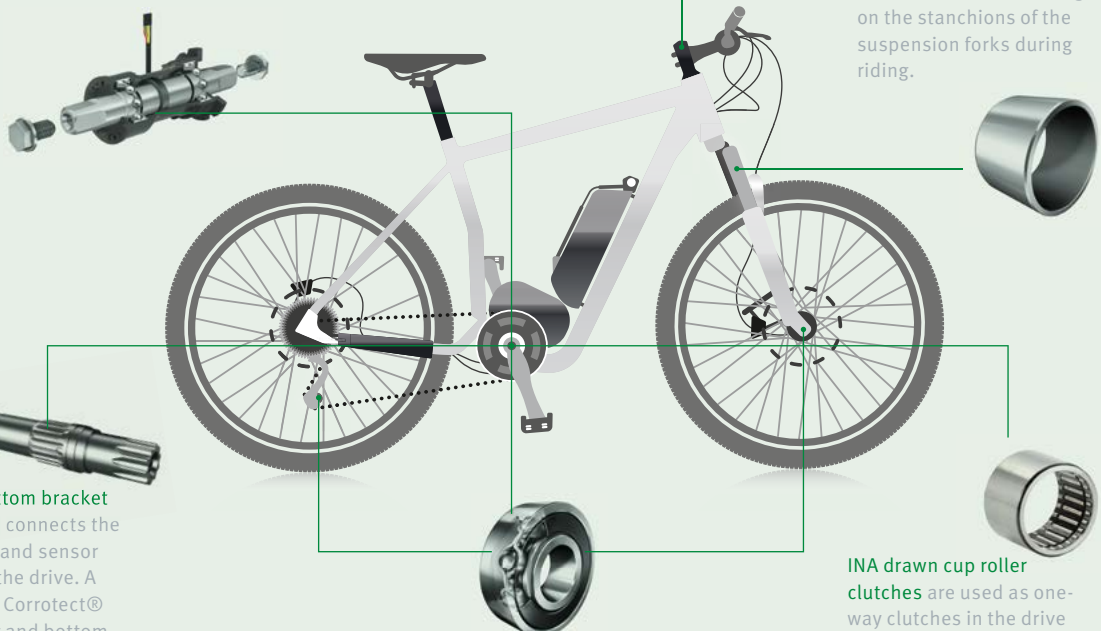
Be it uphill, downhill or on level ground, with a conventional bicycle with derailleur gears or hub gears or an e-bike – the FAG-VELOMATIC calculates the ideal gear and optimum shift point based on pedalling cadence, power, bicycle speed and incline. This guarantees excellent riding comfort while maintaining maximum flexibility. This also includes a manual mode, which can be activated if required. Thanks to open standards, the gearshift is compatible with every type of bicycle and every drive. Owing to the narrow, extra light form (24 x 180 mm, approx. 200 grams), the gearshift is mounted in the down tube or in the seat tube and is invisible from outside as a result. With the associated App VELODAPTIC, cyclists can create a bespoke gearshift program. Additionally, the App accompanies the cyclist on their tours and records GPS, movement and performance data.

BEARING EXPERTISE FOR PEDELECS

The FAG torque sensor bottom bracket BBRTTS determines the total torque from the sum of the pedal force from the left and right pedals. The rider is thus provided with optimum assistance in every situation.

FAG angular contact ball bearings fitted as headset bearings in the connecting point between the handle-bar stem and the bicycle fork ensure the necessary precision and safety.

INA plain bearings with ELGOGLIDE® support and transmit the forces acting on the stanchions of the suspension forks during riding.



The bottom bracket spindle connects the pedals and sensor unit in the drive. A special Corrotect® coating and bottom bracket spindles of various designs are available.

FAG deep groove ball bearings are used in front wheels, rear wheels and the center drive. They provide optimum smooth running.

INA drawn cup roller clutches are used as one-way clutches in the drive of the electric motor. They transmit high torques in one direction.

» You cannot look into the future, but you can lay foundations for the future – for the future can be built
Antoine de Saint-Exupéry

mobility tomorrow

How we move around in the future

QUO VADIS, MOBILITY?

How and with what will we move around in the future? The solutions to these questions are just as varied as the mobility needs of humans. A study made by the International Energy Agency (IEA) predicts, for example, a bright future for the car in India, where the number of cars should increase by factor ten to 160 million by 2035. Other emerging nations face a pent-up demand for automobiles in the forthcoming decades. The registration figures are heading in the opposite direction in the world's cities. Even today, only every second household in megacities like New York or Paris owns its own car. A finely meshed public transport network or other attractive transportation alternatives on one hand, as well as insufficient parking space, high costs and regulations on the other hand are reason for inner-city residents relinquish the car. The intra-urban mobility with railways and aeroplanes will enjoy significant growth. Innovative ideas here must also ensure that this growth functions without drastic consequences for the environment. However, not only people, but also goods need to be moved in growing quantities. On land, on water and in the air, and possibly in the future underground – in a pipeline system for solid cargo. Initial plans already exist for this. Just as they do for a magnetic monorail train, which races through a vacuum tunnel at 6,400 km/h. Without doubt: mobility remains a moving subject in the future.

“INNOVATION ALWAYS BEGINS **WITH A QUESTION”**

From electro-taxi in New York to cable car in Medellín: mobility all over the world has many aspects. Heinrich Schäperkötter, Head of Innovation Strategy at Schaeffer, aims to inject a little order into this conundrum with a new mobility study.

by Johannes Winterhagen

» ***We also want to generate attention about the fact that we must not think from a Eurocentric perspective for the development of new solutions, in keeping with the motto: what works here, works anywhere in the world***

— *Mr. Schäperkötter, suppliers like Schaeffler normally manufacture precision components. How did you come up with the idea of producing a study about mobility of the future?*

Innovation always begins with a question. We must first discover a problem in order to be able to ask ourselves whether we have a solution for it. This is why the search for the mobility of the future starts by asking where and how people live. When you do this you find various mobility solutions all over the world. We then considered which patterns are behind this. It was clear to us before starting that there must be regional patterns. Because all the ideas for a common 'world car' have failed so far.

Just how different are the regional patterns?

They differ significantly between large cities and rural areas. The infrastructure differs considerably depending on how well developed a country's economy is. Ultimately, the level of purchasing power plays an essential role

MANHATTAN, NEW YORK CITY, U.S.A.
(city, industrialized country, high purchase power)

WHAT'S THE QUICKEST WAY?

The high density of traffic in the New York district of Manhattan *leads specifically during the day to permanently congested roads. That's why the 1.6 million inhabitants' willingness to use the public transport network (MTA) is pronounced despite the high average income of 48,000 US dollars. For the majority of New Yorkers, minimizing journey time has absolute priority. However, the MTA's capacity is reaching its limits. Simultaneously, the city aims to reduce the noise and pollutant emissions resulting from the traffic by around 44 percent by 2030. Among the various solutions are not just expanding the MTA and promoting cycling, but also the introduction of small, agile electric vehicles to maximize the traffic infrastructure. As part of the sustainability initiative 'PlaNYC', the city intends to establish a dense network of charging stations for electric vehicles. In addition, municipal vehicle fleets should be expanded to include electric vehicles.*

for personal mobility. The result is an extremely colourful spectrum.

And you want to inject some order into this spectrum?
Yes, and even more. We also want to generate attention about the fact that we must not think from a Eurocentric perspective for the development of new solutions, in keeping with the motto: what works here, works anywhere in the world. Therefore, we developed a three-dimensional matrix with which we can cluster regional mobility needs. For this purpose, we use the dimensions urbanization level, user purchasing power and the state of economic development.

With this you classify every aspect of mobility even beyond the scope of the automobile?
Obviously we consider all components of mobility, even the elevator – without which megacities simply couldn't exist. And vice versa, we can also use the matrix to identify target markets for new technologies. For example for electromobility: due to the costs it assumes the user has high purchasing power, the short ranges justify its use in the cities and the required investment in the charging infrastructure for industrial countries.

Don't you believe that the countries with economic growth align themselves to us and in the medium-term everybody strives to drive a German premium class limousine?
A five-meter luxury limousine wouldn't be a good solution for a megacity even if they function completely autonomously. Because it's simply too big. We shouldn't forget that the number of cars will almost double by 2025. Ever bigger, another door, even more horsepower, this isn't the way. Autonomous driving and car sharing will not be the only solutions.

You evaluated mobility patterns for selected regions. How representative are these?
The mobility patterns each represent a quadrant of the three-dimensional matrix, and this very vividly. If you understand representative to mean "transferable to comparable regions," then I advise caution. Because in addition to the three dimensions, there are other aspects characterizing regional mobility patterns. Think about the cable cars from our example 'Medellín'. They are only meaningful where the topology is clearly mountainous, but boast enormous transport capacity in such areas. Depending where people live, the solution is probably a little different. This is also a gain in knowledge.

But it would be good to be able to derive a few megatrends to give a direction for the basic development.
We did, however, do exactly this. We ultimately narrowed down the results to just four spotlights. You can say that every spotlight represents a search field and behind each of these is a question of great importance for the world.

MECKLENBURG-VORPOMMERN, GERMANY
(rural, industrialized country, low purchase power)

OLDER PEOPLE, OLDER CARS

***The north German state Mecklenburg-Vorpommern** has, like Manhattan, about 1.6 million inhabitants – spread, however, over an area 260 times larger. Not just the population density, but also the average income of about 25,000 Euros/person (approx. 27,600 US dollars) is significantly less. The public transport network outside the city boundaries is under-developed due to weak demand. Correspondingly, the majority of passenger movement is made using predominantly older used cars. Because the population is getting older at the same time, an increase in mobile services is to be expected. Even today a mobile medical service is being tested in Mecklenburg-Vorpommern. With 'AGnES', trained medical personnel should provide an improvement in medical care for older, immobile patients. The expansion of local public transport often appears impossible from a cost perspective, so experiments with demand-led forms are being carried out (shared taxi).*

MEDELLÍN, COLUMBIA
(city, emerging industrial nation, low purchase power)

CABLE NETWORK

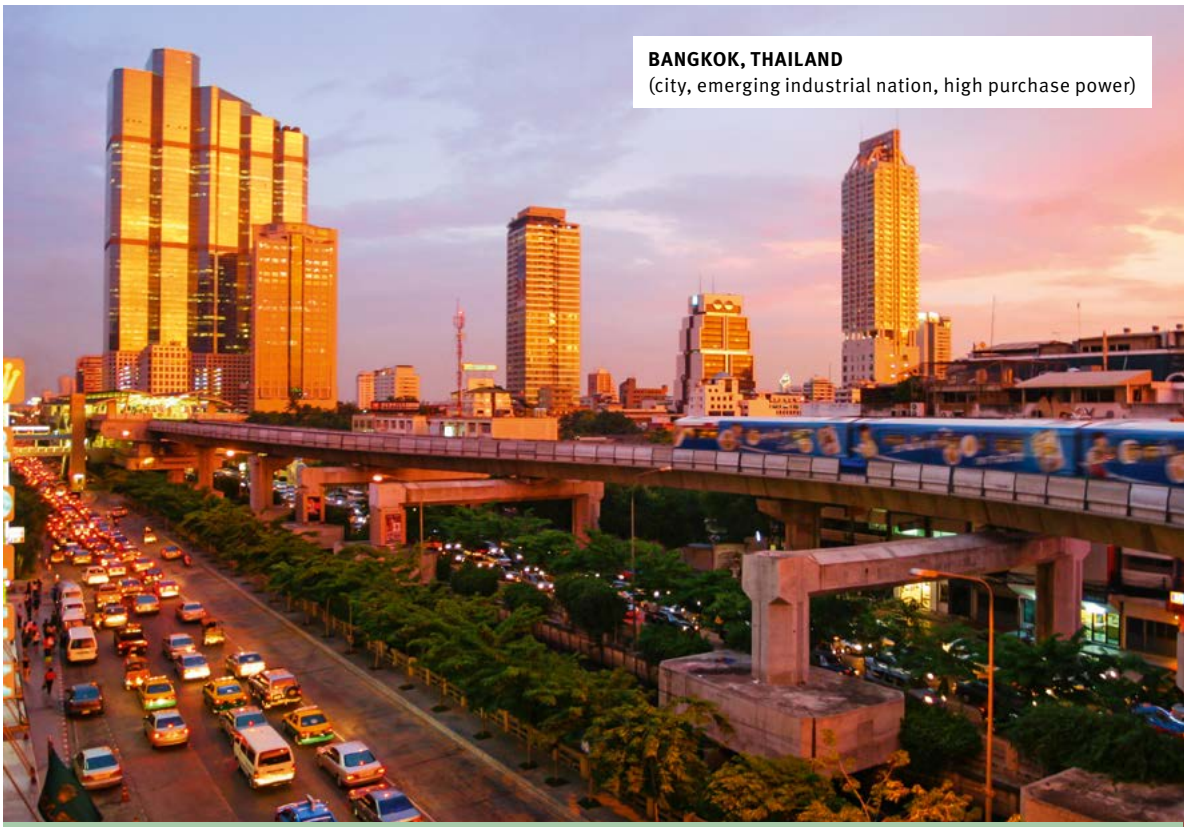
The population density *in the 2.7 million inhabitant city Medellín is very high at more than 7,000 people per square kilometer. A large percentage of the poor population lives in unofficial settlements (favelas) on the city outskirts. 'Paratransit' is currently the preferred form of transport used to travel into the city center. This consists of privately operated small busses or minivan taxis without a fixed route or defined stops. Expansion of the official public transport network and stricter emission standards for vehicles could relieve the smog plagued city center. On top of this comes an unusual idea: Medellín has two cable cars integrated into the regular public transport network. They connect the favelas on the city hillsides with the city itself and boast a transport capacity of 3,000 people per hour. "More than any other cable car in the world," says the operator. 20,000 tonnes of CO_2 per annum are saved by the switch from bus to cable car.*

ABOUT 3.5 MWH

(Megawatt hours) of energy is required to produce a car – this equates to the annual consumption of a four-person household. On top of this so called 'grey energy' and its emissions comes the energy needed for the provision of fuel – be it electric, hydrogen or fossil fuel – and also for its operation. Schaeffler provides energy efficient as well as resource and environmentally friendly system solutions along the complete value chain from manufacturing via power generation for vehicle operation to motoring itself. And not just for the automobile, but also for other urban and interurban mobility forms like railways and aviation.

For example, "Consideration of the entire energy chain." What does this mean?
According to our assessment, it will be insufficient in the future to simply consider a vehicle's local CO_2 emissions. Politics and environmentalists increasingly consider the entire production and consumption chain with regard to their climate impact and their pollutant balance (see info box above). This also includes the energy used to produce alternative energy sources like electricity or hydrogen. And obviously also the 'grey energy' required for the manufacture of every vehicle component.

Is it possible to summarize how mobility in the city of the future will look?
In spite of all the differences between the cities of this world there are similarities. For example, that intermodal transport, where users jump between different forms of transport, will be inherent in the future. Also, the population in many cities outside traditional industrial countries will develop a very pragmatic understanding of mobility.



BANGKOK, THAILAND
(city, emerging industrial nation, high purchase power)

DEDICATED LANES PAY DIVIDENDS

The Bangkok metropolitan region with more than 14 million inhabitants *today boasts considerable prosperity for a developing country. The annual household income is around 15,000 US dollars (2011), equating to about 13,200 Euros. The road network is completely congested, the inhabitants' willingness to commute to work using public transport correspondingly high. However, the widespread diesel powered urban busses wait with the cars in the same traffic jams. Expansion of the rail transport system and specifically a metro network has been pushed since 2004, but is time-consuming and expensive. With this in mind, Bangkok backs a 'Bus Rapid Transport' system like other conurbations in emerging nations. This consists of urban busses using dedicated lanes and metro-like stops completely detached from the normal traffic lanes. The transport capacity is very high at 18,000 people per day on the first, 16.5 km long track. The cost is about 20 times less than an overhead railway.*

For these people it will be about getting from A to B as cost effectively and as quickly as possible.

Does the same apply to interurban transport?
Yes and no. Because the traffic between the largest conurbations and metropolitan regions on this planet is to a certain extent a phenomenon of the economic elites. The greater the prosperity the larger this section of the population becomes. Time efficiency plays the most important role in the choice between modes of transport, complemented increasingly by resource efficiency. For this reason, further expansion of the high-speed train network at the expense of car and plane traffic is probable.

All in all, energy efficiency is becoming more important. Good news for Schaeffler?
Even today Schaeffler generates a large proportion of its turnover with components that improve the efficiency of drive systems, combustion engines and electric motors. This includes optimized roller bearings and complete hybrid drive modules. Since the vehicle drive system determines to a large extent a vehicle's environmental impact, the development of more energy efficient drives will also enjoy highest priority in the future – in automobile manufacture just the same as in the railway or aviation industries or even with the drives for elevators in skyscrapers.

MOVING FORWARD WITH THRUST

More traffic, lower emissions: The aviation industry banks on new ideas to make it greener.

by Volker Paulun

1969. The first human lands on the Moon, Willy Brandt becomes German chancellor, 'Once Upon a Time in the West' starts playing at theaters, VW begins to think about a successor for its top-selling Beetle and on February 9, the first Boeing 747 takes to the skies. That the giant of the skies, colloquially known as Jumbo Jet, is still found in the current Boeing product range shows that the aviation sector has a tradition of using a carefully evolutionary approach to its technological developments. And this approach has certainly been successful. Between 2000 and today, global air transport has grown by 53 percent – while kerosene consumption has only gone up by three percent, according to Airbus. Compared to the days when the jet age was still in its infancy, the engines have become 75 percent quieter. But air transport will be doubling again in the next 20 years. At the same time, the industry is called upon to achieve further significant reductions of fuel consumption, as well as noise and exhaust emissions compared to today's levels. Therefore, it is not surprising that experts such as Prof. Rolf Henke, Member of the Executive Board of the German National Aeronautics and Space Research Center, demand: "Aircraft have seen evolutionary improvements in the past, now we need a revolution." The next pages will show what this revolution might look like.

GROWTH MARKET AVIATION

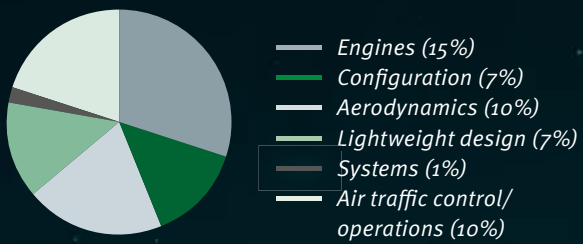
Aircraft (passenger planes – 30 seats or more and cargo)

Source: Boeing

Number of passengers

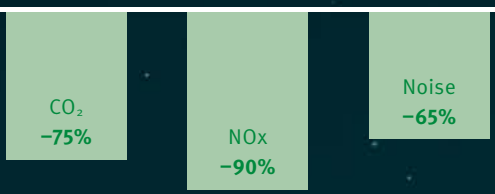
Source: Airbus

SAVINGS POTENTIAL IN AVIATION



Anticipated contributions to ACARE goal achievement (50% energy savings with new aircraft from 2000 to 2020)

GOALS OF THE EU INITIATIVE 'FLIGHTPATH 2050'



Reduction versus new aircraft designs in 2000

» If anyone would ask if Airbus and Boeing could be threatened by new competitors in the next ten years, the answer would have to be no. But looking at 20 years, the situation is different. In 20 years from now, there will probably be a Chinese aircraft manufacturer that could pose a major threat to Boeing and Airbus

Airbus COO – Customers John Leahy

JET CONCEPTS

DOUBLE BUBBLE

- *Example: D8 of the Massachusetts Institute of Technology*
- *Two fuselages are merged into one. This provides ample space*
- *Due to the high nose and low tail the fuselage creates extra lift*
- *Weight reduction due to composite materials*
- *Optimal inflow of energy-efficient turbofan jet engines due to shape of fuselage and embedding aft of the wings*
- *Cruising speed Mach 0.72 (765 km/h)*
- *Anticipated 70% fuel savings compared with current Boeing 737-800, with 49% attributed to fuselage design*
- *Possible maiden flight: 2035*

COMPACT REGIONAL AIRLINERS

- *Example: 20-seater by GE Aviations*
- *Oval lightweight fuselage offers aero advantages and provides more space*
- *Fuel cells supply electrical systems*
- *Ultra-quiet turboprop engines with sufficient thrust to enable short takeoffs*
- *Use of smaller short-haul aircraft is intended to decongest major airports and to carry passengers to more specific destinations*
- *1,480 km range at Mach 0.55 (584 km/h)*
- *Possible maiden flight: 2030*

FLYING WINGS

- *Example: X-48 and Blended Wing Body (BWB) by Boeing*
- *The wings and fuselage form an aerodynamically efficient unit*
- *97% of the craft's surface is used for lift (conventional jets: 50%)*
- *This allows the use of smaller (and thus more fuel-efficient and quieter) engines*
- *20% higher fuel efficiency targeted*
- *To reduce noise, engines are positioned above the fuselage and may be flanked by rear wings, allowing 24-hour operation*
- *Disadvantage: difficult boarding and no side windows for passengers*
- *Possible maiden flight: 2025*

BOX WING

- *Example: Lockheed Martin, Bauhaus Luftfahrt*
- *Modern, non-metallic materials and advances in landing gear design make it possible to implement the box wing concept, which is more than 100 years old, in commercial airliners*
- *More lift, less drag than conventional jets*
- *Jet aircraft with 600 and more seats are feasible with wingspans meeting today's typical maximum limits*
- *Stable attitude*
- *Disadvantage: complex design*
- *Possible maiden flight: 2025*

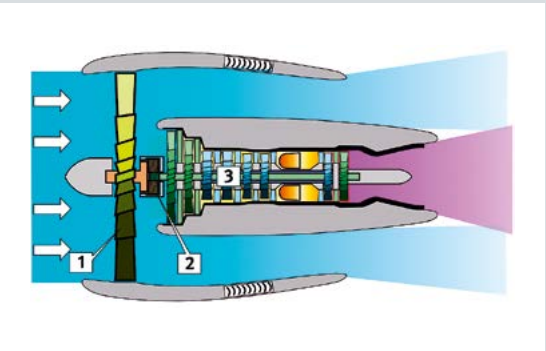
CONCEPT PLANE

- *Example: Airbus*
- *Larger wingspan but slimmer wings for lower aerodynamic drag*
- *Lightweight design*
- *Integration of more efficient engines into the fuselage to reduce drag and noise*
- *Change from tube-like to curved and shaped fuselages which are aerodynamically optimized and provide more internal space*
- *Double entrance/exit doors*
- *Engines with no risk of failure eliminate the need for vertical tails which provide directional stability in the event of engine failure in today's aircraft. Instead, a U-shaped empennage is used to reduce external noise pollution.*
- *Possible maiden flight: 2050*

ENGINES OF THE **FUTURE**

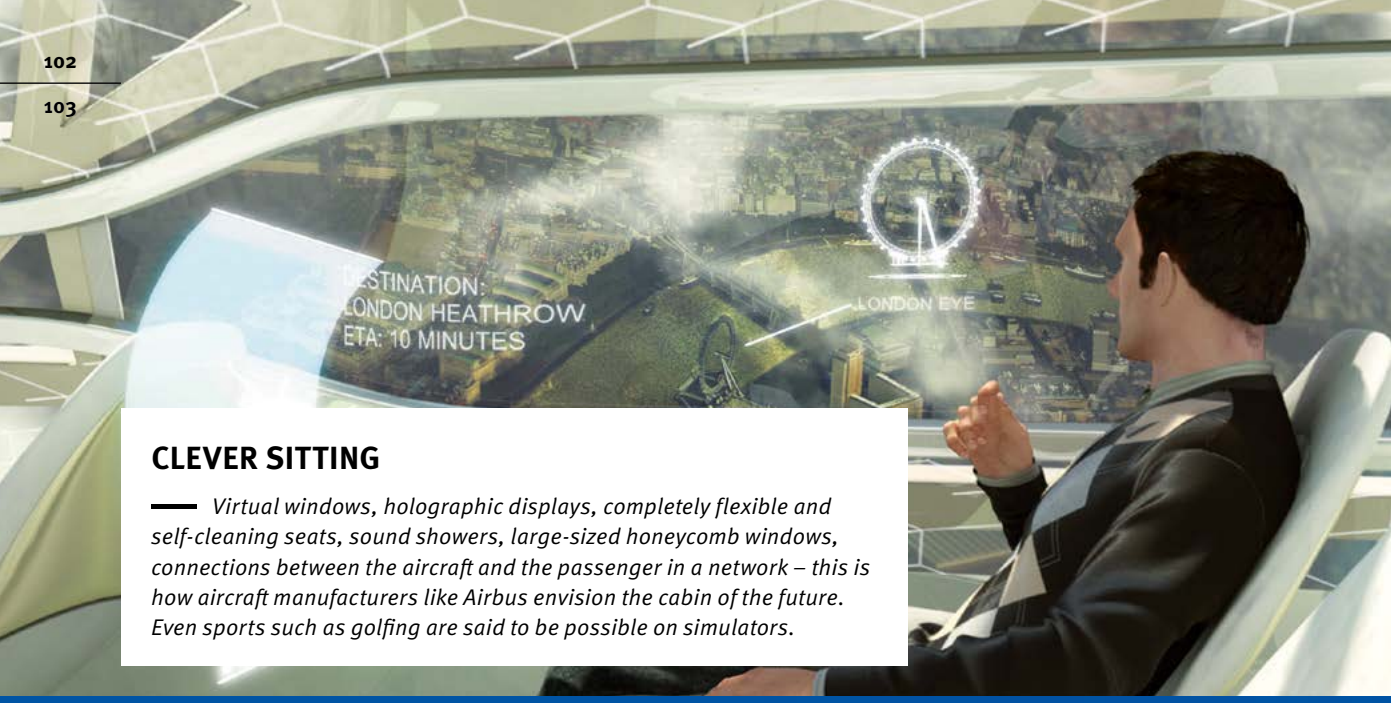
The turbofan (aka fanjet) is practically used in all jet aircraft today. Future goals for emission standards can be achieved with these engines only to a limited extent.

Therefore, leading engine manufacturers such as MTU, Pratt & Whitney and Rolls-Royce regard the geared turbofan as the engine of the future. In contrast to the turbofan design, the fan and the low-pressure turbine, in which the inflow is compressed and ejected, are decoupled by a gearbox in the geared turbo fan design. As a result, the fan can run at lower speed and the low-pressure turbine at higher speed, which increases efficiency and reduces noise. Bypass ratios of 12:1 and higher are achievable, which means that twelve parts of air are conducted behind the fan past the low-pressure turbine and are directly used for propulsion with very high efficiency. The turbine itself settles for part of the inflow (current standard: 5:1). An alternative to the geared turbofan is the three-shaft system which allows the interaction of various engine components to be optimized. In this case, higher bypass ratios are possible as well (about 9.3:1 with the new 56,000 hp Rolls-Royce Trent XWB). From the perspective of fuel efficiency, turboprop engines with unshielded propellers offer very interesting prospects too but, due to their noise emissions, are more critical than encapsulated systems.



Cross-sectional view of a future geared turbofan: The fan **[1]** is decoupled by a gearbox **[2]** from the turbine **[3]**

In contrast, alternative power systems are hardly considered viable options, according to experts. "I'm not expecting a new technology. By 2050, fuel cells may possibly replace the auxiliary power units in aircraft but a one-megawatt cell today has the size of a 50-megawatt engine. Before a fuel cell alone can provide propulsion there's still a long road to travel in terms of miniaturization," said Ric Parker, Director for Research and Technology of the Rolls-Royce Group, in an interview with the trade magazine 'Flugrevue.' The utilization of kerosene derived from renewables, for example, is far more realistic. Boeing is a driving force in this field and has been conducting test flights with bio kerosene since 2008.



CLEVER SITTING

Virtual windows, holographic displays, completely flexible and self-cleaning seats, sound showers, large-sized honeycomb windows, connections between the aircraft and the passenger in a network – this is how aircraft manufacturers like Airbus envision the cabin of the future. Even sports such as golfing are said to be possible on simulators.

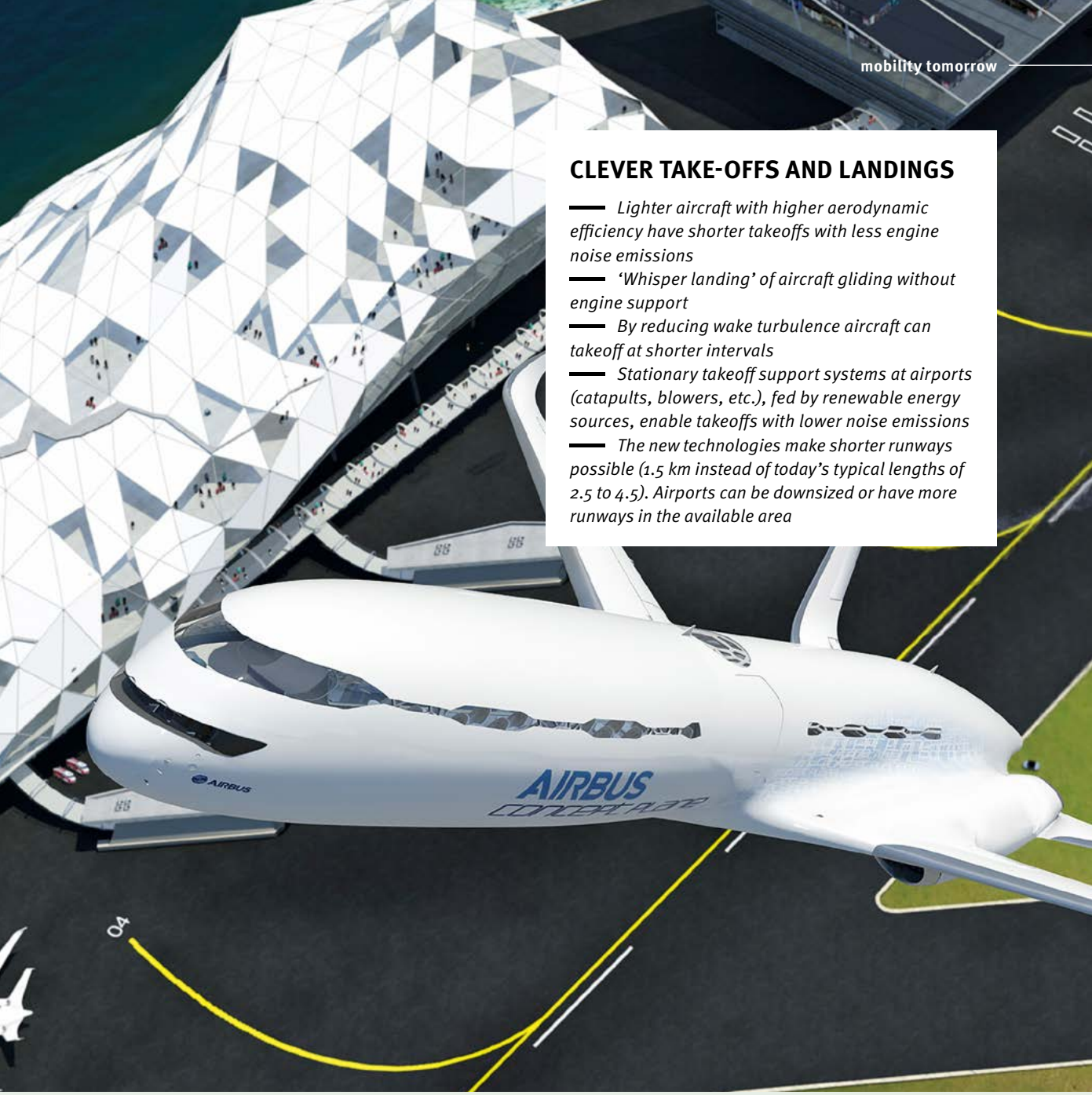
CLEVER FLYING

Not only the aircraft but flying itself harbors a lot of savings potential:

- *Formation flights, like those copied from birds, can reduce fuel consumption by 10 to 12% and emissions even by 25%, according to Airbus*
- *The fragmentation of the international air space forces pilots to fly many detours and zigzag routes. Straightening the routes would save a lot of time and money*
- *A reduction of today's typical cruising speed by 5 to 10% to Mach 0.7 Mach (743 km/h) combined with higher cruising altitudes would help reduce fuel consumption as well. In a current Airbus A330, for instance, fuel consumption increases by 173 kg/1,000 km at Mach 0.01 (11 km/h) above the optimum cruising speed*

FURTHER INFORMATION

- ***cleansky.eu***
- ***airbus.com/innovation***
- ***aeronautics.nasa.gov***
- ***acare4europe.com***
- ***bauhaus-luftfahrt.net***



CLEVER TAKE-OFFS AND LANDINGS

- *Lighter aircraft with higher aerodynamic efficiency have shorter takeoffs with less engine noise emissions*
- *'Whisper landing' of aircraft gliding without engine support*
- *By reducing wake turbulence aircraft can takeoff at shorter intervals*
- *Stationary takeoff support systems at airports (catapults, blowers, etc.), fed by renewable energy sources, enable takeoffs with lower noise emissions*
- *The new technologies make shorter runways possible (1.5 km instead of today's typical lengths of 2.5 to 4.5). Airports can be downsized or have more runways in the available area*

SCHAEFFLER EXPERTISE **IN WORLDWIDE DEMAND**

For all new environmentally friendly engine concepts for aerospace applications, *Schaeffler develops energy-efficient bearing supports. This innovation prowess has a long tradition, as we have been supplying advanced products to aerospace companies for decades. To name just one example: Charles Lindbergh's spectacular transatlantic flight in 1927 took place in an aircraft equipped with the company's bearings. Today, special-purpose bearings and precision components made by Schaeffler are used in nearly all aerospace applications – from the engines in a Boeing or an Airbus to the Ariane rocket engines. The aerospace industry makes unique demands on rolling bearing solutions. Every component has to resist extreme temperature changes and high acceleration forces – while operating without the slightest problem. This can only be achieved if every part perfectly fits in with the whole. Our engineers make sure that it does.*


E WHEEL DRIVE
SCHAEFFLER
LuK
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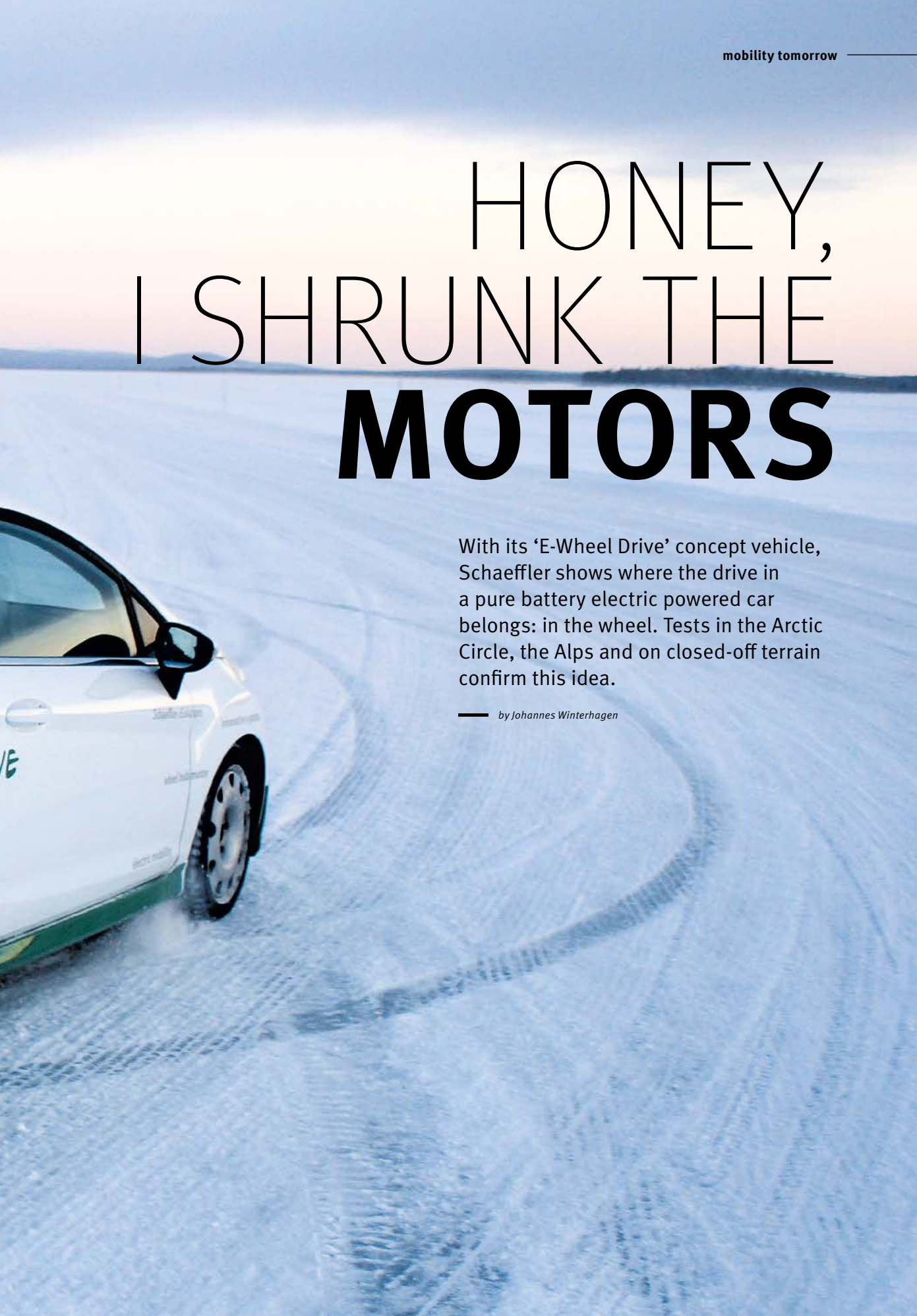
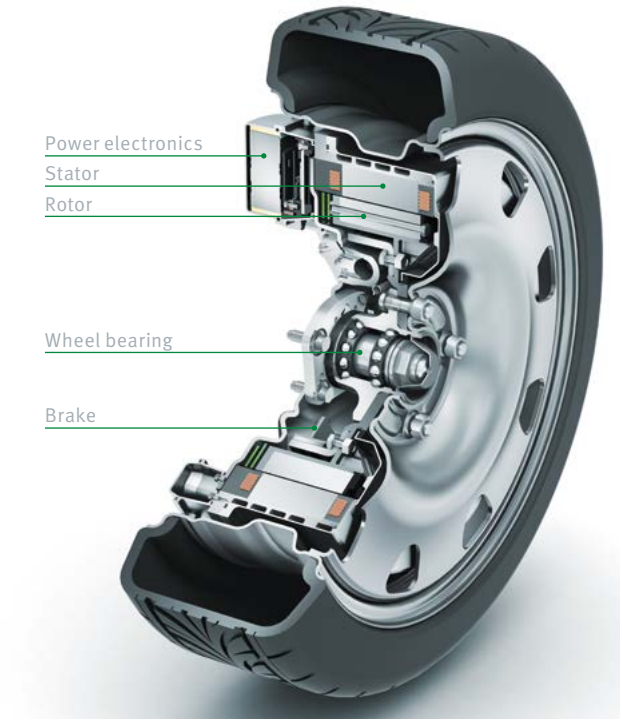
eMobility
SCHAEFFLER
Ford
E WHEEL DRIV

HONEY, I SHRUNK THE **MOTORS**



With its ‘E-Wheel Drive’ concept vehicle, Schaeffler shows where the drive in a pure battery electric powered car belongs: in the wheel. Tests in the Arctic Circle, the Alps and on closed-off terrain confirm this idea.

by Johannes Winterhagen



Except for the battery, the Schaeffler wheel hub motors unite all the important elements for propulsion in a single location: the wheel. Despite the concentrated mass of technology, every commercially available standard tire fits the innovative component and even changing tires requires no extra effort

Minus 33 degrees. It's not as cold as this every day in Norrbottens län, the northernmost of all Swedish counties. But it is so this evening, well today because at the end of February its actually always night, and the couple of twilight hours around midday are not worth a mention.

Schaeffler engineer Raphael Fischer shows no signs of winter depression, he's happy that his car works despite the cold, and even though snow collected and solidified in the suspension while driving. This should not be taken for granted, especially as his car is the only one of its kind in the world. The car in question is a modified Ford Fiesta with rear wheel drive.

Just a moment: rear wheel drive? In a Fiesta? Fischer must begin with some background information to explain that the Fiesta he is testing in Sweden is the prototype of a perfect car for the urban jungle. The catalyst for his ideas: if you are going to develop an electric car for urban traffic of the future, how should it look exactly? The surprising answer: completely different to today's cars, the external shape of which is dominated by an engine compartment, because a relatively large combustion engine and accompanying gearbox must be installed in the car – and also for the practical mechanical power transmission between engine-gearbox unit and axle.

The logical solution: the motor in the wheel

However, installation in the rear wheels also increases the manoeuvrability, since the drive torque of the individual wheels can be selectively controlled. This function named torque vectoring by the engineers helps in many situations, for example when pulling away in winter and one of the two drive wheels is on ice. Not only does greater dynamic stability increase safety, but also the fact that in the event of a frontal impact the engine can no longer penetrate the passenger cell.

Even more important for Fischer is, however, a constantly perceptible quality, which he calls 'control performance'. This means a spontaneous, predictable execution of the driver input due to the direct power transmission without gearbox and driveshafts. "People will not only buy electric cars for good reason, to do something against climate change for instance," explains Fischer and claims: "E-cars must be fun to drive."

So much for the theory, which Schaeffler chooses to ignore. Because since 2007, the supplier has been developing a practical wheel hub drive. At that time, an initial study showed that it was actually possible to accommodate a drive motor in a wheel. A first prototype installed in an Opel Corsa subsequently followed. Its maximum torque of 530 Nm per wheel initially made hill starts possible. However, the power electronics to control the electric motor were not integrated in the wheel.

More torque and greater integration were the objectives pursued by Schaeffler for the current generation of wheel hub drive. In addition, it did actually prove possible to house the complete drive including the two electronic boxes (power electronics and motor control) in a 16-inch wheel. "It was important for us that every commercially available standard tire can be used on the high-tech wheel," explains Fischer. "And the tire can also be changed at every workshop." The mounting points for the bolts correspond with today's standards. "The entire layout is realized in such a way that changing tires requires no additional effort."

On the other hand, Schaeffler engineers invested extra effort where the motorist is completely unaware. The wheel bearing is twice as stiff as a conventional component, which is not only due to the wheel's greater weight of 53 kilos, but also because the gap between the stator and rotor on the electric motor is only one millimeter. Even when the suspension is subject to extreme loads, there is no contact between stator and rotor. It is not a matter of short circuits, which wouldn't have any dramatic consequences anyway, as tests by Schaeffler revealed. In fact, the different surfaces should be prevented from grinding on each other to prevent corrosion.

Whoever has a reasonable knowledge of electric motors knows that their direction of rotation can be changed to operate them as a generator. Exactly this occurs with Schaeffler wheel hub motors: the generator decelerates the car, at the same time generating valuable electricity, which is stored in the vehicle battery. Tests with the Fiesta prototype prove that even on mountain roads with long descents and downhill gradients of up to 18 percent, the e-machine can be used exclusively for braking. Despite this, the Schaeffler engineers do not (yet) wish to abandon the rear drum brakes. On one hand, they gave the new technology an additional safety element during testing, on the other they also act as parking brake.

The maximum torque of 700 Nm produced by the water-cooled motors – 1,400 Nm across the axle – is sufficient for a Fiesta with four passengers to pull away on a 25 percent uphill gradient. Torque of 350 Nm (per wheel) is permanently available, at least to a speed of around 100 km/h before being capped at 130 km/h. "For an electric city car with limited range, it makes sense to draw this line," says Fischer. Because higher speeds could only be achieved if the engine speed was lowered again using a gearbox. For this, there is insufficient space in the wheel. Fischer suggests: "You must decide what type of car you want. Wheel hub motors are perfect for electric urban city traffic." Conversely, those wishing to cover additional cross-country distances in fast motorway jaunts will find in Schaeffler's portfolio hybrid modules specially adapted for plug-in hybrid vehicles.

Schaeffler prototype sets new benchmarks

Consistency pays dividends, not only do the tests in the Arctic Circle and Alps confirm this, but also special vehicle dynamic tests on a proving ground belonging to the Ford research centre in Lommel (Belgium). The prototype, which is just as light as an identical model with diesel engine, achieves results in every category that are as good as the production car. This is also valid for comfort criteria such as ride comfort or steering wheel vibration. "It's bias to say that the increase in unsprung mass automatically leads to inferior ride comfort," summarizes Fischer. The prototype set some new benchmarks when performing manoeuvres using the active torque distribution. In a double lane change test – distance between cones 18 meters – the maximum speed through the obstacle could be increased by around 10 km/h.

As impressive as the Schaeffler prototype drives today, it will still be unavailable to buy tomorrow. In a next step, the supplier works together with Ford, Continental and two university institutes to optimize the software and vehicle architecture so that wheel hub drive's full potential can be exploited. The next prototype should see the light of day this year – but only as virtual vehicle on the computer. It could still be revolutionary because the car should manage completely without engine compartment.

» ***Wheel hub motors are perfect for electric urban city traffic***

Dr. Raphael Fischer, Head of Product Group Wheel Hub Drivers at Schaeffler

CTRL + C

On land, on water, in the air – how engineers copy Mother Nature's masterpieces.

by Andrea Neumeyer

Mobility and conservation: Two of the world's megatrends call for new ideas: to produce planes, cars and ships in a way that conserves resources and run them more efficiently and quietly. Researchers are finding inspiration in nature: After all, evolution has optimized plants and animals over millions of years.

Bionic research – a portmanteau of the words biology and technology – decodes the blueprints of sharks, dolphins, lotus flowers and butterflies and uses them in technical innovations. But turning to flora and fauna for copying is not something new: Leonardo da Vinci looked to nature when he constructed his "flying machine" at the beginning of the 16th century – alas, he lacked the materials and manufacturing techniques to turn his idea into reality.

"People learned how to fly from birds. Today the challenge is to improve an existing product through optimizing airflow. In cars, lightweight components that have been optimized using bionics make the body lighter and help conserve fuel," explains Prof. Dr. Antonia Kesel, head of the study program for bionics at the University of Bremen.

Birds and fish are technological pioneers

Many detailed solutions from nature have long been established in technology: lightweight technology and material structures that are as delicate yet as sturdy as

bone, contributed greatly to the success of the Audi Space Frame. The spokes of modern wheels also mimic bone structures. A car tire with sipes sticks to the road like geckos to a wall.

Engineers at Mercedes-Benz took a holistic approach and chose the tropical boxfish as a model for a concept vehicle. Despite its cuboid shape and bulky body, the yellow and black creature is astoundingly streamlined. In wind-tunnel tests, a replica of the fish achieved a drag coefficient of 0.06, with the finished concept car yielding a sensationally low 0.095 (Golf VII: 0.27). The boxfish was also used as a model in the design of the chassis: Its skin consists of bone-like six-sided plates that provide strength with minimal weight. The fish-inspired Bionic Car maintained its stability, rigidity and crash safety standards but weighed about a third lighter.

Bionics specialists also found inspiration in nature for shipbuilding. The shark, for example. Initially it was thought that a smooth surface provides the low resistance of the fast predator. But a glimpse into a microscope shows that tiny ridged scales, called riblets, prevent cross turbulences that increase flow resistance. Thanks to this micro-groove profile, barnacles are unable to attach to the skin and slow the shark down. Ships can now be painted with an artificial shark-skin that minimizes fouling on the hull and reduces drag by 15 percent.

Even in the air, riblets work real miracles (in savings). Flow-optimized paints and coatings reduce fuel consumption by one percent. Is that all, you think? The real figure is much more impressive: 4.48 million tonnes of kerosene could be saved worldwide every year. Winglets, the curved tips at the end of jet wings, are borrowed from nature too: from the outspread primary wing feathers of many types of birds. In both cases, the wingtips reduce vortices and cross-flow resistances. In birds this conserves muscle power, in aircrafts fuel consumption is three to five percent lower. And a positive side-effect: the wingspan is shorter. In conventional design, the Airbus flagship A380 would be three meters too wide for most airports.

The advantages of formation

In the world of small animals, aircraft manufacturer Airbus was also successful in finding innovative ideas: To fly efficiently, insects have a delicate wing structure. Soft membranes and blood vessels stiffen or relax to adjust the wing while flying. Airbus engineers have developed aircraft wings the shapes of which can be altered by means of ‘pneumatic muscles.’ As a result, the wings have optimal aerodynamics in any flight situation. The elimination of the typically used flaps with design-induced gaps additionally reduces aerodynamic drag.

But it not only pays to mimic nature in vehicle design – we can learn a great deal from animals in the field of locomotion, as well. Take a flock of birds, for example. When flying in formation they generate vortices which give the trailing birds additional uplift. This saves energy and also works in an aircraft. But although airforce pilots fly in formation, the wake turbulence created by commercial aircraft is considered dangerous … at the moment. In the distant future, long-haul aircraft may fly in formation to reduce fuel consumption and emissions.

Formation is a principle of mobility that is interesting and well worth replicating under water. Humans can learn a lot from schooling fish. Thousands of animals move side by side at high speed without colliding – even in a life-threatening situation such as being attacked by a predator. The principle behind this is incredibly simple, as the American researcher Brian Partridge discovered in the eighties: Follow the fish in front of you and maintain the speed of the fish next to you. Fish are not the only ones that adhere to this formula, many others animals move in swarms, including birds and insects.

So simple and yet so difficult – at least for the driver of a car. Suddenly you find yourself at a standstill on a busy autobahn or expressway but there is neither a construction site nor accident. The problem sits behind the wheel: Drivers leave too big a gap to the car in front or slam on the brakes. The solution: Motorists should not be given the job of deciding, instead networked cars should interact with each other, just like fish: keep up with the car ahead and match the pace of the car alongside. Vehicle distance sensors help locate other vehicles via radio wave radar – a principle that Mother Nature perfected in bats. Using echolocation, the animals can even maneuver around a pitch black room with wires strung throughout without injuring themselves.

The ultimate bionic goal: self-healing products

Despite all the advances in bionics, there is still a great deal to decipher. “Self-healing structures are the greatest mystery of this field,” said bionics specialist Kesel. “When a person is injured, the wounds heal quickly. With technical structures the part has to be replaced. Biological structures start off small and then grow according to their requirements, such as trees which continue to grow in a different direction when their path is blocked. It would be fantastic if we could tap into this biological ability to adapt.”

5 IDEAS, 1 SOLUTION

To produce less climate harmful CO_2 is the goal of the entire automobile industry. A common path suitable for all brands, vehicle classes and regions is, however, not in view. This is why the supplier Schaeffler works on different technologies.

by Johannes Winterhagen

LESS IS MORE

Optimized combustion engine

Even in 2020, the overwhelming majority of cars worldwide will be powered by a combustion engine. To lower the consumption of these cars, Schaeffler aims to reduce the power loss in modern engines significantly. Unnecessary energy losses occur for example during the charge cycles, meaning as the air enters and exits the cylinder. The charge cycle can be made low-loss if opening and closing times of the engine valves are matched precisely to suit the respective operating points. Schaeffler camshaft phase adjusters facilitate this. The fully variable valve train system UniAir also permits the valve stroke to adapt smoothly to suit the operating point.

More than eight percent of the energy contained in fuel is lost through friction in the engine. The valve train consumes a particularly high percentage at low engine revs. Schaeffler reduced the friction losses by around 50 percent by using nanotechnologically coated valve actuating components. Similar results were achieved by using a roller bearing mounted balance shaft, and which thanks to bionic design permitted a weight saving of about one kilogram per engine. So that friction is less dominant in a cold engine, Schaeffler developed a thermo management module that channels the heat where it is specifically required.

Greater valve train variability, optimized surfaces and low-friction bearings are important elements with which Schaeffler helps to further increase efficiency of the combustion engine.

LOW EXPENDITURE
GREAT EFFECT

Mild 48-volt hybrid

Hybrid drives are regarded as being very costly, and therefore hold relatively low market shares in most parts of the world. At the moment. Because, Schaeffler is developing a hybrid drive that costs only half as much as today's full hybrids yet still reduces fuel consumption by up to 15 percent. This is made possible by abandoning the complex high-voltage technology. Instead, Schaeffler relies on the partial conversion of the vehicle's power network to 48 volts. This enables – subject to application – efficient energy recuperation when decelerating, electric pull-away, upgrade to all-wheel drive as well as so-called boosting while driving and when rolling in stop and go traffic.

The electrification kit modules from Schaeffler make provision for three 48 V hybrid solutions: firstly, the e-machine can be installed between the combustion engine and gearbox as with today's Toyota Prius and Porsche Cayenne full hybrids, this version changes the least for the automobile manufacturers. The 48 V hybrid module interacts with planet gearboxes, dual clutch gearboxes, continuously variable transmissions and manual gearboxes.

The second solution – similar to the Smart's micro-hybrid system – consists of replacing the current starter with a more powerful electric motor, which is connected to the engine crankshaft via a belt. If an additional clutch is installed between crankshaft and belt pulley, the air conditioning compressor can also be operated when the combustion engine is not running.

The third solution: an electric axle replaces the rear axle not driven by the combustion engine, and so upgrades the front-wheel drive vehicle to all-wheel drive. The torque can be distributed to specific wheels. This torque vectoring significantly improves vehicle handling.

Schaeffler's mild hybrid supplies its 48-volt battery with energy recuperated during braking events. When the vehicle accelerates, this energy is made available again and can be used to assist in the operation of the internal combustion engine. As 48-volt technology makes it possible to use electric motors with outputs of up to 12 kW, even starting the vehicle from rest and non-acceleration 'coasting' are possible strictly in electric mode.

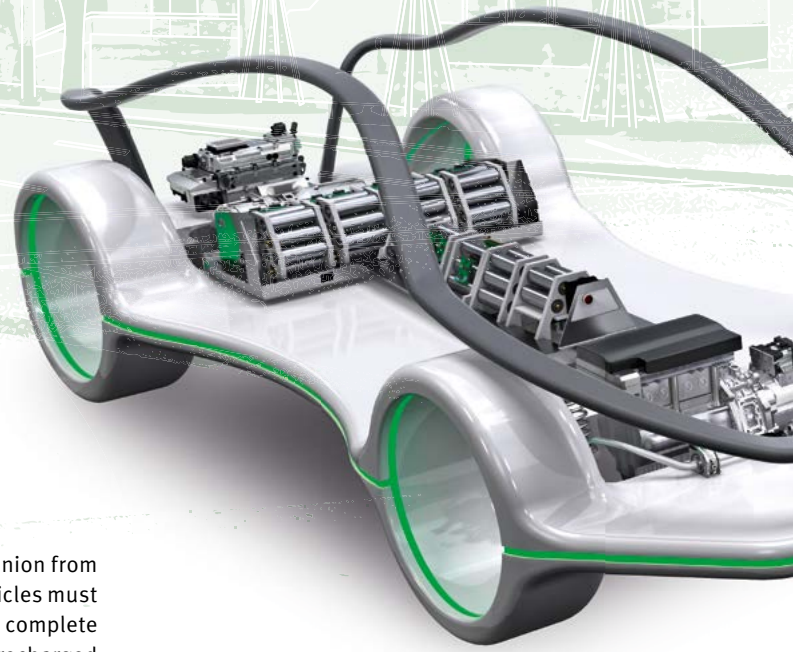
IN FOCUS: START-STOP SYSTEMS

Up to 15% of fuel *can be saved in urban traffic with start-stop systems, and even 4% in the combined cycle.*

In 2015, *every third new car should be equipped with such a system.*

The number of starts during an engine's lifetime *increases with a start-stop system from 30,000 to 40,000 to between 200,000 and 400,000. With hybrid cars, it is significantly more. Reliable components must withstand this additional load.*

Schaeffler optimizes the interaction between all relevant components and systems *to make the start-stop processes cause less wear and to be more comfortable and efficient. For example, with efficient bearings. Or with pins that lock the hydraulic valve train in a favourable positon to restart the engine when stationary and without oil pressure. Or with shift detents for manual gearboxes. For automatic gearboxes, Schaeffler works on compact units comprised of a converter and lockup clutch, which reacts with low inertia and high ramp-up speeds.*



JUST A SECOND

Plug-in hybrid

The CO_2 limits imposed by the European Union from 2021 are so strict that many large and heavy vehicles must be equipped with a plug-in hybrid: the vehicles complete the entire test cycle electrically, before being recharged by plugging into a socket afterwards. In addition, driving is even more fun, since the power from the combustion engine and electric motor can be combined briefly.

Hybrid modules for production cars have been an issue at Schaeffler since 2010. Their power density had to be increased for future plug-in hybrid vehicles. This was achieved with a new generation of high-voltage hybrid modules, which, in spite of the extremely compact dimensions, still briefly produce up to 80 kW and can generate torques of up to 280 Nm. Above all, however, the hybrid module also copes with very powerful combustion engines. The transferable torque is around 800 Nm. This is possible when only a part of the entire torque is transmitted via the decoupler, which is anyway a part of the module. Torques of more than 300 Nm on the other hand are transferred in parallel via a freewheel unit towards the gearbox.

The permanently excited synchronous machine used by Schaeffler in the hybrid module was optimized logically with regard to maximum efficiency. The large reluctance percentage also enables the motor to be operated at high revs and with high performance. In the future, the e-motor should even help to dampen oscillations in the combustion engine. Intriguing further developments by Schaeffler ensure that plug-in hybrids release their full potential.

25% of the near 43 million cars licensed in Germany are second or third cars. On average, they are driven 27.5 kilometers daily, a journey that plug-in hybrid vehicles cover purely under electric power.

» Almost all automobile manufacturers favour plug-in hybrid drives. Powerful and large vehicles in particular will be equipped with plug-in technology in the future.

Chief Technology Officer
Prof. Peter Gutzmer

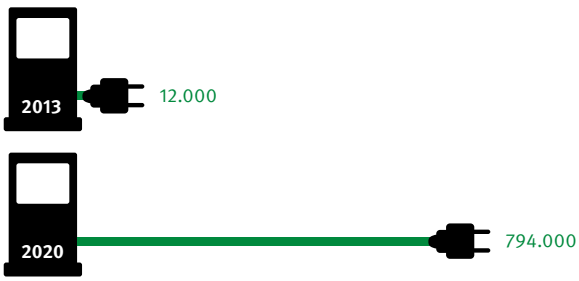
A PIECE OF FREEDOM

Battery-electric drive

Electric driving, silent and zero emissions locally, fits perfectly into the rapidly growing mega metropolises of this world. Despite all the hurdles ranging from battery costs to ever lacking charging infrastructure, many cities and communities support the trend to e-mobility – from New York via Oslo to Paris. The experts at Schaeffler are convinced that electric cars for inner city areas will not be 1:1 copies of their combustion engine relatives in the medium term. Because their shape is characterized by the type of drive, which is why cars today have an engine compartment. In densely populated urban areas, road space and parking are rare commodities; the goal is to accommodate as much car as possible for the passengers while consuming as little space as possible. Schaeffler's electric wheel drives, whose technology we introduce in detail on page 104, are an excellent foundation for this.

A good CO_2 balance, low infrastructure demands – as reasonable and modest as this may sound, city vehicles will not be sold solely because of this. This is why Schaeffler designs its electric drives in such a way that the fun of motoring is not lost. For example, with high steering lock angles to increase manoeuvrability significantly in narrow streets. Or with torque vectoring, the selective distribution of the drive torque between the wheels. From Schaeffler's perspective, battery electric vehicles will form a small minority in the near future. This makes it even more important to research the right technologies in good time.

ELECTRIC FILLING STATIONS IN EUROPE



Source: Institute for Mobile Systems (IMS)

MORE IS REALLY MORE

Range extender

Electric cars fascinate many people with their silent power. Nevertheless, the same question arises time and again: what happens if I must spontaneously drive further? Due to high battery costs, the majority of electric cars will also have to manage with a range of around 200 km in 2020. Unless you have a small auxiliary power unit on board, the range extender.

Schaeffler has developed a new concept for a range extender. It is a three-speed gearbox with integrated electric motor, which can be connected to a conventional small combustion engine. In most situations, a vehicle equipped with the range extender gearbox runs purely on electric power: such as when pulling away or in town. The combustion engine is only activated under rapid acceleration – as well as in the areas where direct drive of the axle via the combustion engine is most favourable from the energy aspect.

The combustion engine can however also drive the electric motor directly. As a generator, it then generates electricity, which is stored in the battery for later use. This functions when stationary as well as while driving. Latest simulations show that CO_2 emissions of less than 50 g/km will very probably be achieved. This would equate to a consumption of about 2 l/100 km.

MASTHEAD

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Schaeffler AG
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Communications, Marketing and Investor Relations
Christoph Beumelburg
(Senior Vice President)
Jörg Walz (Automotive)
Martin Adelhardt (Industry)
Jasmin Löffler (Corporate)

Concept
Jörg Walz (Schaeffler)
Thomas Voigt (Speedpool)

Editor-in-Chief
Jörg Walz

Editorial Team · Production
Speedpool GmbH
www.speedpool.com

Executive Editor
Volker Paulun

Coordination
Carina Chowanek,
Benjamin Hoffmann

Copy Editors
David Feist,
Christoph Kirchner

Pre-press Stage
Julien Gradtke, Mathias Mayer,
Anke von Lübken

English Translation
Kaye Müller,
Helga Oberländer

Printing
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Graphic Design
Manuela Mrohs (AD), Gökhan Agkurt,
Oliver Breilmann, Tilmann Fabel,
Hella Fassauer, Jana Herbst, Thomas Wildelau

Authors
Ulrich Frieß, Bastian Hamacher, Roland Löwisch,
Andrea Neumeyer, Sonja Schmidt, Mark Schneider,
Torben Schröder, Michael Specht, Lukas Stelmaszyk,
Tom Teßmer, Johannes Winterhagen, Roland Zumsande

Photo Editor
Lutz Gernert

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