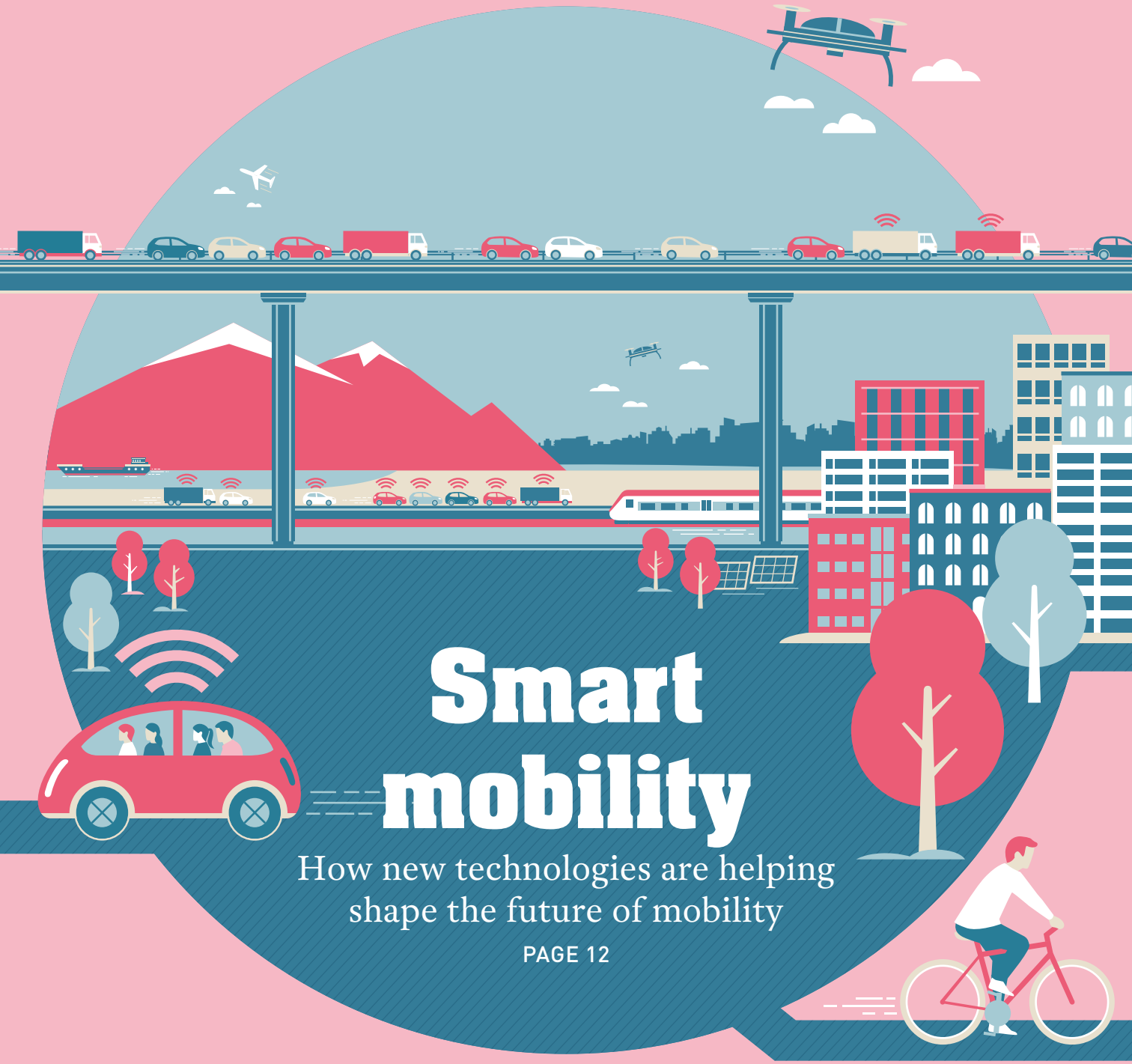
ETH zürich

NO. 4/2018

GLOBE



Smart mobility

How new technologies are helping shape the future of mobility

PAGE 12

SUSTAINABLE MOBILITY

Lino Guzzella, President of ETH Zurich

Functioning transport systems are one of the key drivers of our prosperity. Yet the steady rise in demand for mobility is putting an ever-increasing strain on our environment, climate and infrastructure. Finding intelligent, environmentally friendly forms of mobility for the future is a significant challenge.

Over 30 professors at ETH Zurich are involved in areas of research that help make our mobility low carbon, cost-effective and reliable. They carry out this work on many levels, including the national SCCER Mobility research network, collaboration with industry partners in the ETH Mobility Initiative, and projects run by ETH's own mobility platform to promote sustainable campus mobility. Their research covers a wealth of topics ranging from innovative drive technologies and enhanced methods of infrastructure management to new ways of inspiring behavioural change.

This issue of *Globe* focuses on new mobility concepts and technologies, driven by digitalisation. It explores what we can achieve with autonomous vehicles, the sharing economy, and the app-based use of mobility data. Read on to discover what researchers think of these key issues and what solutions they are proposing for the future.

Turn to page 12 to find out how ETH researchers are helping shape the future of mobility.

Talking of mobility, this December marks the end of my tenure as ETH President and my transition to a new set of responsibilities. Before I go, I would like to express my sincere appreciation for your interest in ETH Zurich and our ETH magazine *Globe*. I very much hope you enjoy reading this issue!

Lino Guzzella, President of ETH Zurich

Cover image and focus: Pia Bublies / Editorial: Giulia Marthaler

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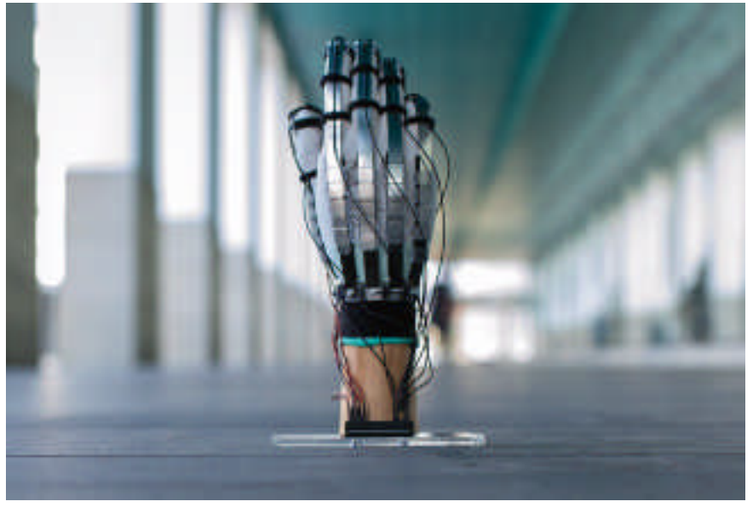
Images: Daniel Winkler; MAN/Jan Hölzl, Deutsche Bahn AG; Annick Ramp

NEW AND NOTED

Virtual Reality

"TOUCHING" VIRTUAL OBJECTS

Researchers at ETH Zurich and EPF Lausanne have developed an ultra-lightweight glove called DextrES that enables wearers to "touch" and manipulate virtual objects. Weighing less than 8 grams and just 2 millimetres thick, the glove provides the wearer with extremely realistic haptic feedback. According to the researchers, potential application areas include gaming, the healthcare industry – especially for teaching surgical procedures – and augmented reality applications.



At present, the haptic glove draws power from a very thin cable.

Computer science

SECURITY LOOPHOLES IN THE 5G MOBILE NETWORK

Again and again, criminals manage to hack connections between smartphones and the mobile network, intercepting calls or stealing data. 5G, the fifth and latest generation of mobile communications, promises users much higher levels of security than ever before. Using Tamarin, a security protocol verification tool, a team of ETH researchers from the group headed by David Basin, Professor of Information Security, systematically analysed the 5G AKA protocol, focusing in particular on the specified security goals.

Developed by Basin's research group over the last eight years, Tamarin is one of the most effective tools for analysing security protocols. The team's findings confirm that the new protocol is a big step forward in data protection compared with the 3G and 4G standards.

"However, we did discover that the protocol permits certain types of traceability attack," says Lucca Hirschi, a senior scientist and co-author of the study, commenting on the results of the analysis. In this kind of attack, the mobile phone no longer transmits the user's full identity to the tracking device – a loophole in older standards that was previously exploited by IMSI-catchers – but it does still indicate a person's presence in the immediate vicinity. Basin's team is now working closely with the organisation responsible for creating the 5G standard to help improve the new protocol.

Research on migration

BANS ON EMPLOYMENT ARE COUNTERPRODUCTIVE

A study carried out by the Immigration Policy Lab at ETH Zurich in conjunction with Stanford University has shown that refugees who are banned from accessing the job market for a relatively short time find a job faster than those excluded for a longer period. Five years after the end of the ban in each case, the employment rate for refugees excluded for a shorter period was 20 percentage points higher.

Images: ETH Zurich; Keystone/DPA/Bernd Settnik

NEW AND NOTED

ETH Week 2018

RETHINKING ENERGY

"Energy matters" was the theme of this year's ETH Week. A total of 164 students spent six days focusing on a broad range of different topics from the realms of energy production, distribution and storage. Working in interdisciplinary teams, they took on the task of pinpointing a socially relevant issue and developing a proactive solution. Scientific methods and design thinking strategies both played a part in the resulting innovation process.

The event also included visits to real-world partner companies such as the ETH spin-off Climeworks, which has set itself the goal of reducing the amount of CO_2 in the atmosphere. The company has built the world's first commercial-scale CO_2 capture plant in Hinwil (pictured). The 10-metre-tall facility uses filters to remove some 900 tonnes of CO_2 from the ambient air annually. This can then be used for applications such as enhancing plant growth in greenhouses.

ETH Week:
→ www.ethz.ch/ethweek

Climeworks:
→ www.climeworks.com

Eighteen ventilation units direct the flow of ambient air through a filter that absorbs CO_2 molecules like a sponge.

Image: Alessandro Della Bella

ETH GLOBE 4/2018

Computer science

Light-speed Internet

Ankit Singla wants to add radio antennas and satellites to the Internet. That could make it many times faster, allowing us to transfer data almost at the speed of light.

The vision is to transmit data at 299,792,458 m/s.

The Internet is getting faster and faster. All over the world, companies are busy laying new fibre optic cables and speeding up data transmission by boosting bandwidth. But the Internet still isn't fast enough for Ankit Singla, an Assistant Professor at ETH Zurich's Department of Computer Science since 2016. "If we could communicate with each other with nearly zero delay, then we could achieve true telepresence." By that Singla means that we could be sitting on our sofa at home and using virtual reality glasses and sensors to visit friends holidaying on a beach in Tenerife, interacting with them virtually and merging fiction and reality in the process. But to make that kind of experience immersive and authentic, you need to cut the time it takes a signal to traverse the Internet from point A to point B – what we call latency – to less than 20 milliseconds. Right now, that figure is often many times higher, depending on the distance and connection in each case. That makes certain things impossible – for example professional musicians in different parts of the world rehearsing with each other online.

Inspired by high-frequency traders

Singla is from Chandigarh in northern India. The 32-year-old studied engineering in Mumbai before completing his doctorate in computer science at the University of Illinois. It was there that he and his colleagues composed a manifesto for a faster Internet in 2014. Their vision was to transfer data at the speed of light (299,792,458 m/s), the maximum speed that is physically possible. "Today's Internet is, on average, 37 times slower than what is theoretically possible, and often up to a hundred times slower," says Singla. "And that's not because of issues such as available bandwidth." He explains that this high latency has three causes: the geographical distance between communicating parties, the protocols that govern data transmission, and the physical infrastructure of the Internet – in other words cables, servers and routers. "The first factor remaining fixed, we can optimise the other two," he says. "My research focuses on the infrastructure – and my goal is to reduce latency."

Singla's research is in part inspired by high-frequency trading on the New York, Chicago, London and Frankfurt stock exchanges. Traders can win or lose millions in a matter of microseconds, which is why they came up with the idea of building their very own, optimised "Internet". This involves installing radio antennas on high buildings such as skyscrapers and towers located at intervals of 70 to 100 kilometres and using them to transmit data from point to point in the form of microwaves. With this approach, latencies within 5 percent of the minimum possible – at the speed of light in vacuum along the shortest path – are achievable.

"We want to make this kind of system available to everyone," Singla says. To achieve that goal, he is collaborating not just with computer scientists, but also with two physicists from Yale University and the University of California, both of whom also consult for the high-frequency trading industry. In one of their most recent publications, the researchers pooled their efforts to simulate the infrastructure required to provide 85 percent of the US population with Internet speeds very close to that of light. Their results showed that all it would take would be a network of radio antennas installed on 2,526 existing towers, each of which is situated within 70 kilometres of its closest neighbour. They put the price tag at 253 million dollars for installation and 96 million dollars a year in running costs. "That's relatively affordable compared to the cost of laying the new underwater Internet cable from London to Tokyo across the Arctic Circle, for example, which is earmarked at 850 million dollars." But how does Singla intend to connect continents across the world's oceans with a system that relies on high towers to transmit data? His idea is to use a network of satellites to extend light-speed Internet overseas. "SpaceX is looking to put around 2,000 new satellites into operation by 2024. We could use those satellites to transmit the signal, because most of them will be in low-Earth orbit."

"Today's Internet is often up to a hundred times slower than what is theoretically possible."

Benefits for interactive applications

Singla envisages light-speed Internet supplementing the existing fibre optic network rather than replacing it, in part because the data transfer bandwidth of microwave links is up to a thousand times lower than that of fibre optic cables. "That's why it wouldn't make sense to use radio transmission for video streaming and file sharing, which make up over 70 percent of data traffic in the US at peak times." He sees the biggest benefits in interactive applications such as telepresence, multiplayer games and musicians playing together online. Industry has also expressed a keen interest in this type of high-speed Internet: Amazon has calculated that 100 milliseconds of additional latency lead to a one percent drop in sales on its online platform, while Google sees search volumes drop by 0.74 percent when latency increases by 400 milliseconds. That's why Singla believes that private companies will get the ball rolling by building small-scale microwave networks. It's also one of the reasons motivating his collaboration with a researcher from Akamai, an American cloud service provider that could benefit from these types of networks for its own services.

Up to now, Singla's work on light-speed Internet has been theoretical. But over the next few months, he is planning to work with his partners in the US to carry out preliminary experiments over an existing microwave network used by high-frequency traders – for instance the one that covers the 1,200 kilometres between New York and Chicago. "We want to find out which applications work best over this kind of network and what needs to be modified to connect it to the existing Internet." In practice, seamless integration will also require new protocols that can handle the consequences of expanding the system, such as faster and more frequent changes in data transmission paths. Singla hopes to lay the foundations for that with a combination of experiments, analytics and simulations. — Samuel Schlaefli

Ankit Singla's latest publication on light-speed Internet:
→ arxiv.org/pdf/1809.10897.pdf

Scientists use underwater seismometers to take measurements at the bottom of a lake.

Natural hazards

UNDERSTANDING LAKE TSUNAMIS

Researchers have begun a large-scale, multi-university study of natural hazards in Switzerland. Their goal is to identify the causes and risks of lake tsunamis and determine how often they have occurred in the past. The project centres around seismic measurements in Lake Lucerne.

Electrical engineering

A TRANSFORMER FOR ENERGY TRANSITION

The medium-voltage converter is a component of the new smart transformer.

Electrical engineers at ETH have developed a smart electronic transformer that is highly efficient at converting medium voltage into low voltage. Considerably more compact than conventional transformers, it is particularly suitable for situations where space is at a premium or weight is an issue – in rail locomotives, for instance.

The two doctoral students leading the project at the Power Electronic Systems Laboratory had to develop many of the components for the transformer themselves, as there are few components available off the shelf for the medium voltage of 10,000 volts they work with. Silicon carbide components, which enable extremely fast switching, were particularly crucial. Using these, the electrical engineers succeeded in converting medium voltage to a frequency of up to 75,000 hertz and achieving extremely high levels of energy efficiency. The transformer system they built is just one-third the size of previous smart transformers with similar power ratings.

Unlike conventional transformers, smart transformers are controllable. That makes them suitable for use in future power grids, where they could actively manage the distribution of power and balance out fluctuations in electricity generation and demand. One day, it might also be possible to deploy them in large-scale fast charging stations for electric vehicles.

Molecular biology

GENETIC DISEASE HEALED USING GENOME EDITING

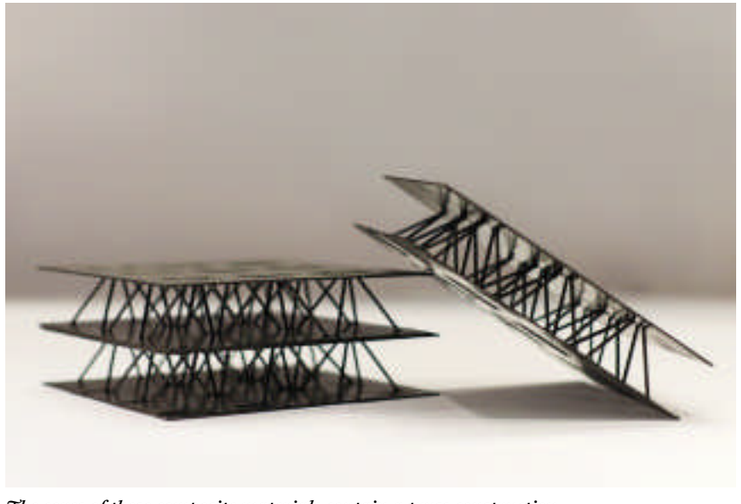
Every newborn baby in Switzerland is tested for phenylketonuria, a metabolic disorder that causes the amino acid phenylalanine to accumulate in the body, retarding mental and motor development. Phenylketonuria is caused by a genetic mutation. A team of researchers led by ETH professor Gerald Schwank has now discovered a method of correcting both mutated genes in liver cells, enabling them to cure the disease in mice. Using a CRISPR/Cas9 system extended by one enzyme, the researchers systematically altered the DNA sequence of the corresponding gene in adult mice, with the result that the liver cells were once again able to produce functioning PAH enzymes.

Images: Peter Rüegg; Daniel Rothmund

Material sciences

CARBON FOR SANDWICH COMPOSITES

Paolo Ermanni – Professor of Composite Materials and Adaptive Structures at ETH – is developing the composite materials of the future. The goal of his research is to obtain the same performance with fewer resources, or better functionality with the same amount of material. Sandwich structures are often used for lightweight construction because they are stiff and strong as well as extremely light. They typically consist of two thin and stiff cover layers and a low-density core material. Ermanni's group is developing high-performance sandwich composites made of carbon fibre reinforced polymers, also known as CFRPs, or simply carbon. In this approach, the core consists of a truss structure of carbon fibre rods. Such core structures have greater stiffness and stability than conventional foam or honeycomb cores and, at 30 kilograms per cubic metre, are also markedly lighter than conventional sandwich composites. That makes these composites ideal for use in aerospace applications, where structural efficiency is key. Their deployment is now being put to the test in the EU's ALTAIR project led by the French national aerospace research centre ONERA. Ermanni's research group is participating in that project, developing the load-bearing structures of new deployment systems for small satellites. In addition, a doctoral student has co-founded a spin-off that is developing 3D printing processes for the robust and flexible manufacturing of high-quality carbon fibre components – such as the rods for sandwich structure cores.



The cores of these composite materials contain a truss construction of carbon fibre rods, which can be tailored to suit different applications.

Images: Christoph Karl/CMASLab; Eva Reynaert/Eawag

The recycling plant for greywater during field testing in Zurich

Environmental technology

WASHING HANDS CAN SAVE LIVES

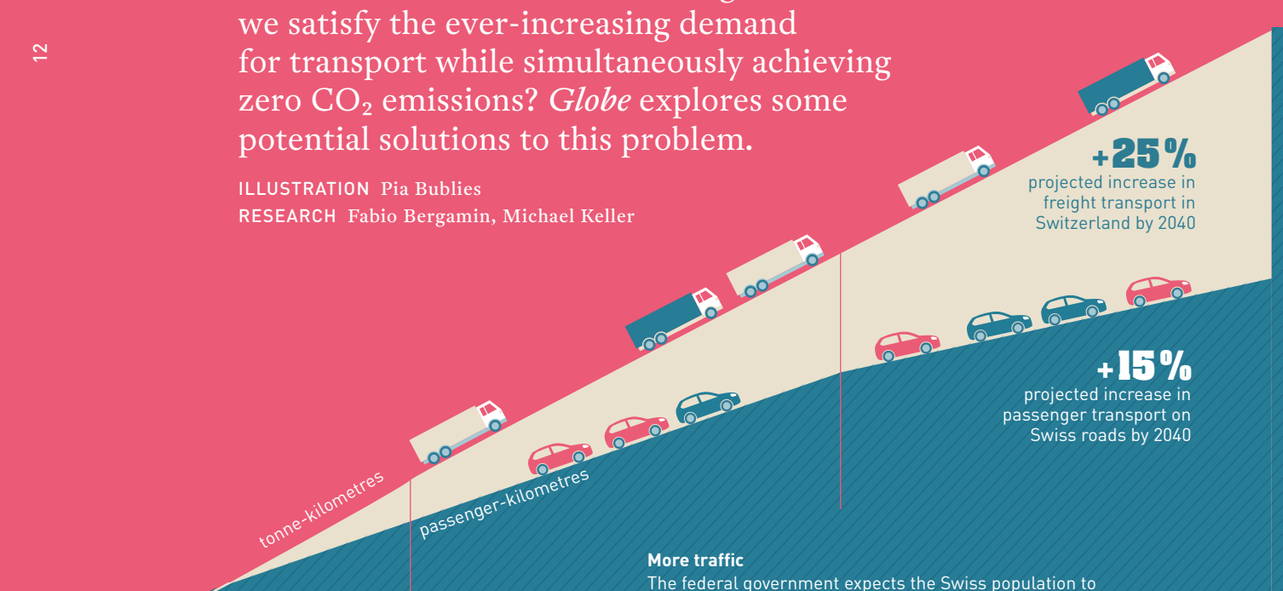
Every year, 4 million people die as a result of diarrhoea or respiratory infections, caused in most cases by poor hygiene or a lack of access to safe drinking water. Professor Eberhard Morgenroth and his team at ETH are hoping to alleviate this problem with a handwashing system that recycles greywater. The key component of the unit is a fine-pored plastic membrane that uses ultrafiltration to remove pathogenic organisms. The microbial biofilm which develops on the membrane breaks down faecal and urinary contaminants in the wastewater, while an activated carbon filter removes any remaining traces of organic matter. In the final step of the process, an electrolytic cell is used to produce chlorine from dissolved salt, so as to disinfect the water during storage. After several treatment stages, the greywater is odourless and colourless. Testing of the handwashing system will begin in January in a township near Durban, South Africa.

You can find more information on these topics and other research news from ETH Zurich at:
→ www.ethz.ch/news-en

Smart mobility for the future

Today, people take mobility for granted. But we face an enormous challenge: how can we satisfy the ever-increasing demand for transport while simultaneously achieving zero CO_2 emissions? *Globe* explores some potential solutions to this problem.

ILLUSTRATION Pia Bublies
RESEARCH Fabio Bergamin, Michael Keller



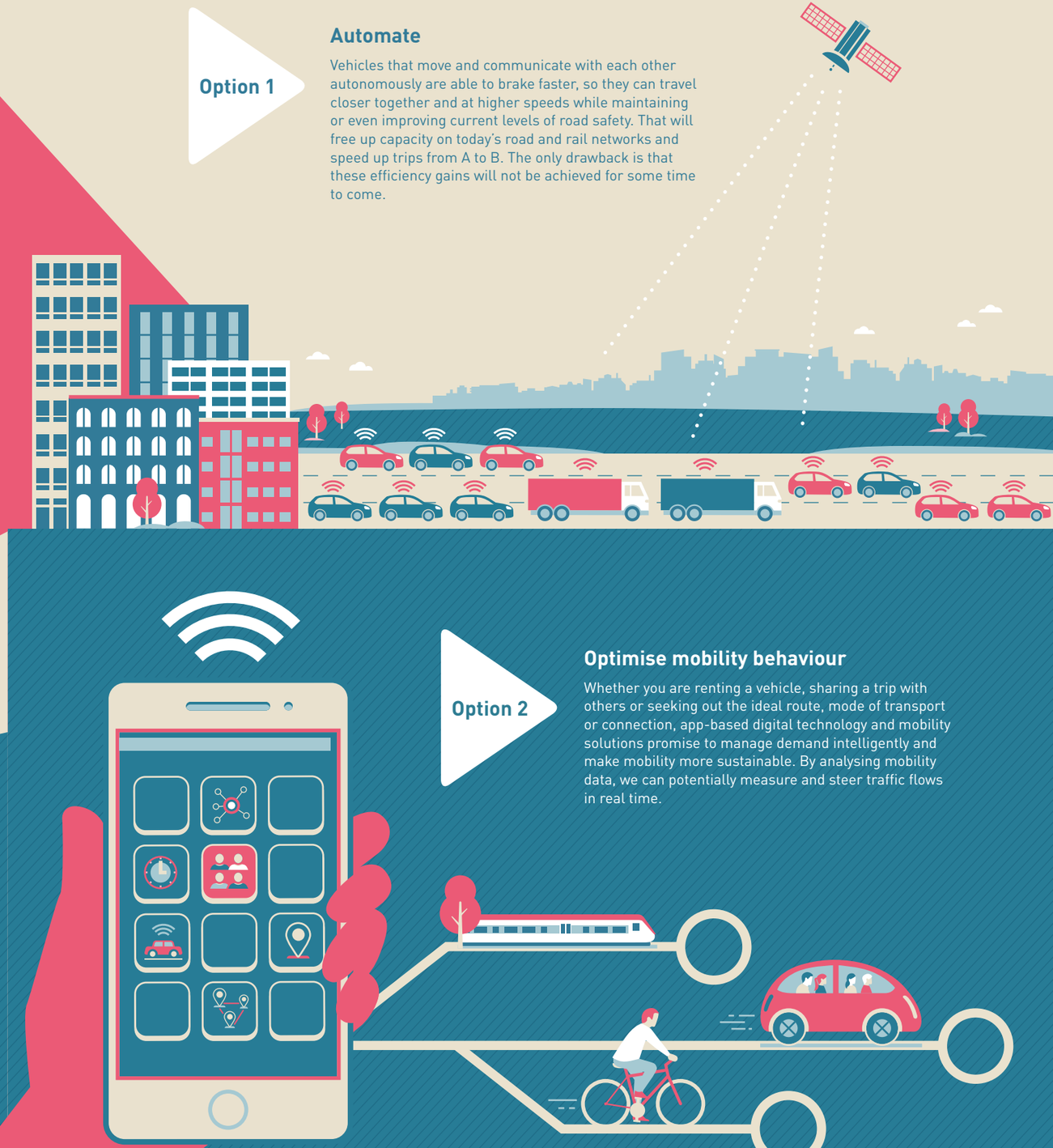
More traffic
The federal government expects the Swiss population to grow by 1.5 million between 2015 and 2040. On top of that, the economy is globalising, Europe is pushing ahead with greater integration, and much of the expected economic growth is based on increases in the flow of goods. The result will be a rise in the number of people and goods in transit on Switzerland's roads.

Source: Federal Office for Spatial Development (ARE) / K. Boulouchos

Option 1

Automate

Vehicles that move and communicate with each other autonomously are able to brake faster, so they can travel closer together and at higher speeds while maintaining or even improving current levels of road safety. That will free up capacity on today's road and rail networks and speed up trips from A to B. The only drawback is that these efficiency gains will not be achieved for some time to come.



Option 2

Optimise mobility behaviour

Whether you are renting a vehicle, sharing a trip with others or seeking out the ideal route, mode of transport or connection, app-based digital technology and mobility solutions promise to manage demand intelligently and make mobility more sustainable. By analysing mobility data, we can potentially measure and steer traffic flows in real time.

Option 3

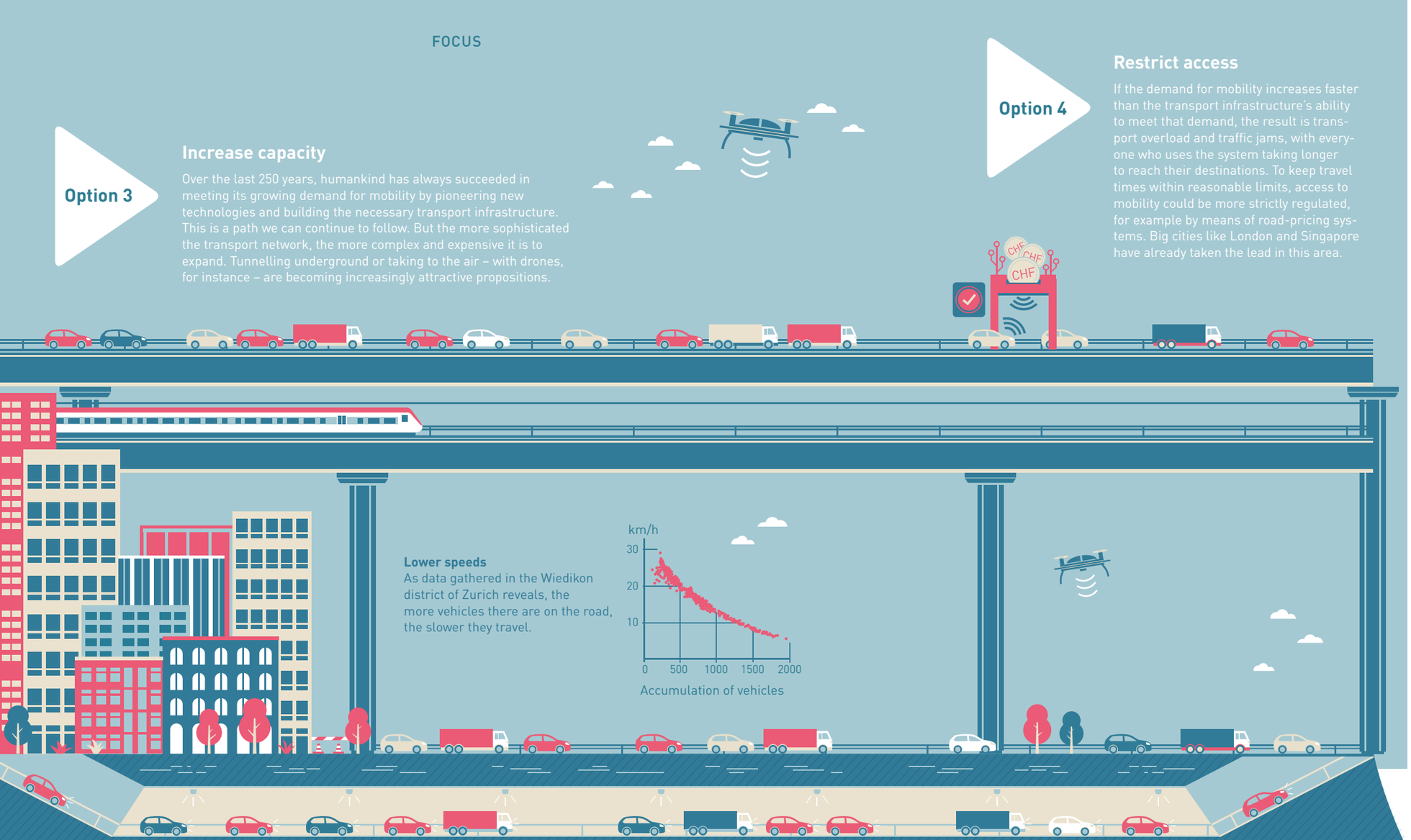
Increase capacity

Over the last 250 years, humankind has always succeeded in meeting its growing demand for mobility by pioneering new technologies and building the necessary transport infrastructure. This is a path we can continue to follow. But the more sophisticated the transport network, the more complex and expensive it is to expand. Tunnelling underground or taking to the air – with drones, for instance – are becoming increasingly attractive propositions.

Option 4

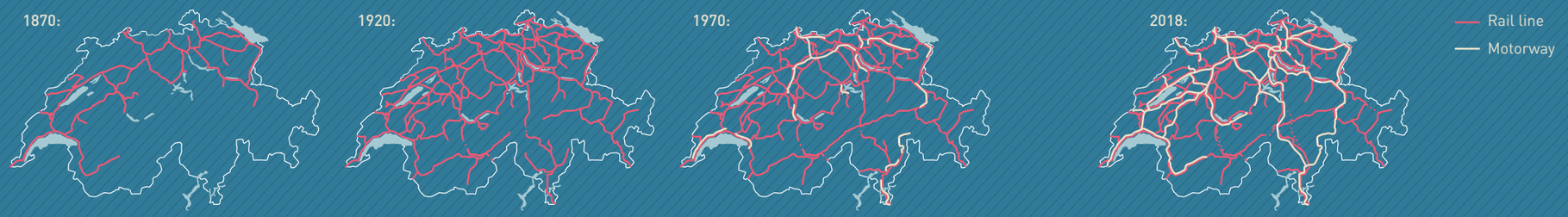
Restrict access

If the demand for mobility increases faster than the transport infrastructure's ability to meet that demand, the result is transport overload and traffic jams, with everyone who uses the system taking longer to reach their destinations. To keep travel times within reasonable limits, access to mobility could be more strictly regulated, for example by means of road-pricing systems. Big cities like London and Singapore have already taken the lead in this area.



Lower speeds
As data gathered in the Wiedikon district of Zurich reveals, the more vehicles there are on the road, the slower they travel.

Continual expansion
In the past, Switzerland expanded and upgraded its transport infrastructure gradually – building roads, then rail lines and, more recently, motorways. This expansion served to enhance accessibility and reduce travel times.



Source: A. Loder et al. 2017,
Base map data: atlas of Switzerland

"Do we want to keep building new roads, rail lines and tunnels?"

**Kay Axhausen,
Professor of Transport Planning**

Mobility is what drives our prosperity. The population of Switzerland looks set to continue growing. If we do not act, the transport system will slow down, leading to poorer accessibility and rising travel times. As a society, we face far-reaching decisions. Do we want to keep building new roads, rail lines and tunnels, or do we want to invest in new technologies? How do we deal with the externalities transport produces – like pollution, safety issues and the cost of traffic jams? And should we regulate the use of existing infrastructure if it has reached its capacity limits?

It is undeniable that the larger and more complex the transport network, the more expensive it is to expand. That makes the capacity gains promised by autonomous vehicles an attractive proposition. But just how much capacity can these vehicles free up? According to estimates, the increase in accessibility that a fully automated vehicle fleet could achieve in Switzerland would roughly equal the last 15 years' gains from expansion of the country's road network.

It will take 40 to 50 years before this potential is realised and all the vehicles on our roads are fully autonomous. During the transition period, the autonomous vehicles will be on the move in a restrained way. In fact, available capacity is more likely to fall in the initial phase of the transition.

In view of this situation, it is conceivable that, even in Switzerland, additional restrictions may be placed on access to mobility by means of taxes and levies, the aim being to adjust demand to match available capacity and ensure certain minimum travel speeds. The government could use this income to increase capacity by building roads where they are really necessary and subsidising public transport. Another option would be to grant subsidies for establishing autonomous taxi fleets, which would supplement the existing public transport system.

“Long-haul transport will determine our carbon footprint.”

Konstantinos Boulouchos, Professor of Aerothermochemistry and Combustion Systems

If Switzerland is serious about addressing climate change, it must aim to reduce the mobility sector’s CO_2 emissions to virtually zero within 40 years.

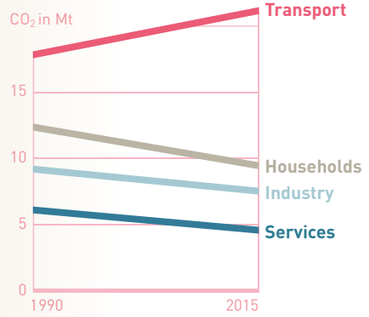
The first step is to make mobility more efficient on all levels. We should invest in the design of lighter vehicles with more efficient powertrains and, more generally, reassess the use of motor vehicles. That includes changing our own behaviour and being more willing to use public transport or ride a bike. It also encompasses potential efficiency gains from shared mobility and automated driving. Though we need to adopt all these measures, they will still not be enough. Once we remove taxi, bus and lorry drivers from the equation and switch to driverless vehicles, mobility will become much cheaper – and that could drive demand for mobility even higher.

A transition to renewable energy sources is therefore imperative. The best approach is to electrify the transport system, but we should bear in mind one thing: we will need to build new power stations to generate electricity from renewable sources, over and above those needed to replace decommissioned nuclear and coal-fired plants. We should not embark on wide-scale electrification until we are certain we can produce the electricity needed for mobility with only minimal CO_2 emissions.

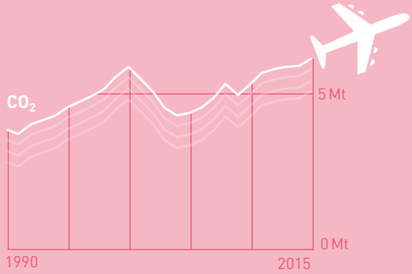
Renewable energy and fuels produced using that energy – such as hydrogen and synthetic hydrocarbons – will be the defining factors in mobility over the long term. However, even if electric power enables us to make urban mobility and short-to-medium-haul freight transport carbon-free in the medium term, emissions from the rapidly growing aviation and shipping sectors will continue to rise. It won’t be possible to electrify aircraft or container ships in the foreseeable future, and the idea of powering them with renewable synthetic fuels is also very much a long-term proposition. The production of synthetic fuels is highly energy-intensive, so it would require huge amounts of renewable electricity.

When it comes to mobility, it is long-haul transport – particularly international shipping and aviation – that will ultimately determine the size of our carbon footprint.

What Switzerland emits
In Switzerland, transport was the only sector to record an overall increase in CO_2 emissions in recent years – and our more frequent use of air travel has been the main driver.



46%
Transport (including air transport) accounts for 46% of greenhouse gas emissions in Switzerland.

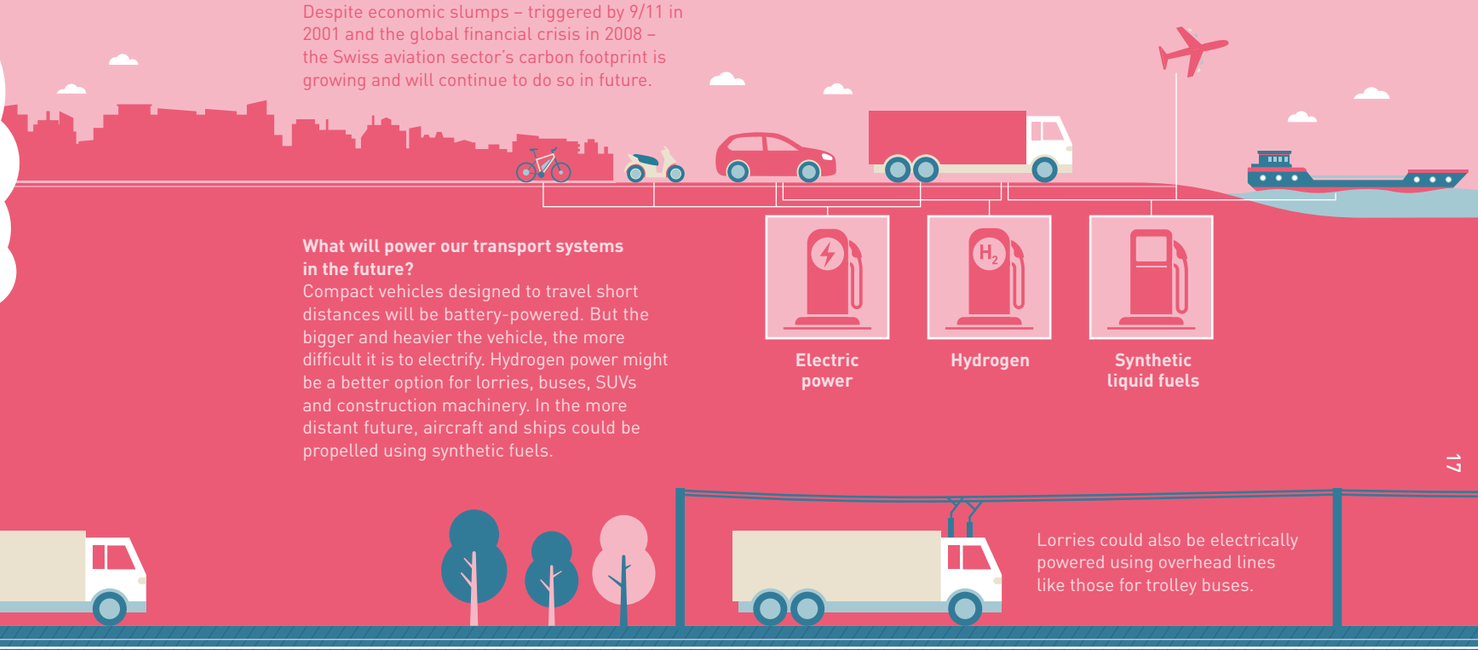


Frequent flying
Despite economic slumps – triggered by 9/11 in 2001 and the global financial crisis in 2008 – the Swiss aviation sector’s carbon footprint is growing and will continue to do so in future.

Option 6

Replace

If we are to reach our global climate targets, we must replace fossil fuels with renewables. Electromobility powered by renewable energy is one option; hydrogen and synthetic fuels produced using renewable energy are another. But it takes a lot of energy to produce hydrogen, and even more to manufacture synthetic fuels.



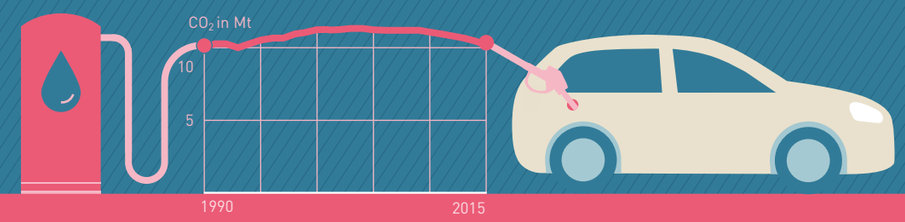
What will power our transport systems in the future?
Compact vehicles designed to travel short distances will be battery-powered. But the bigger and heavier the vehicle, the more difficult it is to electrify. Hydrogen power might be a better option for lorries, buses, SUVs and construction machinery. In the more distant future, aircraft and ships could be propelled using synthetic fuels.

Lorries could also be electrically powered using overhead lines like those for trolley buses.

Option 5

Enhance energy efficiency

Energy consumption is falling thanks to more efficient combustion engines, hybrid technology and lighter vehicles – and the potential for further efficiency gains remains high.



Trend reversal in passenger car emissions
Regulatory measures are already having an effect. Even though cars have become more numerous, larger and more heavily motorised over the last quarter of a century, the efficiency gains of recent years have led to a slight overall reduction in CO_2 emissions from motor traffic in Switzerland.

Source: Federal Office for the Environment (FOEN)

Algorithms take the wheel

Car sharing with autonomous vehicles could improve cities in many different ways. Singapore is taking a pioneering role, working with ETH researchers to explore the potential of personalised, electrified and automated public transport.

TEXT Samuel Schlaefli

The future of mobility is measured in milestones: this February, Google subsidiary Waymo announced that its fleet of self-driving cars had covered over 8 million kilometres on public roads. This came shortly after Uber's announcement that it had completed 3 million kilometres of autonomous driving. If industry has its way, then we will soon be sharing all our streets with vehicles controlled by algorithms instead of drivers. But is that a realistic scenario? Or simply a rose-tinted vision of a tech-driven future? We asked one of the leading experts in this field, Italian researcher Emilio Frazzoli, Professor of Dynamic Systems and Control at ETH Zurich since October 2016. "It all depends what level of autonomous mobility you have in mind," he replies. "I would say it will be at least another 15 years before you can buy a self-driving car from a dealer. But if you mean a limited kind of car sharing, then it's already happening." In fact, this latter concept is a core part of Frazzoli's own research. In mid-2018, the ride sharing company Lyft launched a service on the Las Vegas Strip that allows anyone to book one of a fleet of 30 BMWs through its app. The driverless cars are controlled by algorithms developed by vehicle technology company Aptiv, which acquired NuTonomy – the start-up founded by Frazzoli – in October 2017.

Rethinking urban mobility

Before joining ETH, Frazzoli spent ten years as a professor at the prestigious MIT in Boston. Autonomous systems – initially aircraft and drones – were the focus of his work right from the start. "The technical side of that was generally pretty cool, but it wasn't really doing much to help solve the challenges society is facing." In 2009, he found himself pondering a fundamental question: "Back then, the main argument for conducting research into self-driving cars was the idea that they would make road traffic safer." While acknowledging the truth of that statement, at least in the long term, Frazzoli realised there was potentially a much larger, medium-term benefit to be gained from completely rethinking the issue of individual mobility for city dwellers.

"The goal of my research group is a form of mobility that combines the convenience of a private car with the sustainability of public transport." In other words, a kind of Uber, but driverless and therefore much more economical and available. Plus – thanks to electrification and better capacity utilisation – a solution that offers significantly lower energy consumption and CO_2 emissions. Right now, people use private cars, on average, just 5 percent of the time, which means the cars spend the remaining 95 percent of the time standing idle in car parks and garages or on the street. This makes no sense in terms of sustainability, urban development or resource efficiency.

Frazzoli's start-up NuTonomy, which develops control software for autonomous vehicles, began drawing up plans to test self-driving cars in Singapore back in 2014. At around the same time, the professor published an article in which he investigated how replacing all the private vehicles in the 719-square-kilometre city-state with shared, self-driving vehicles would affect traffic volumes. His results showed that the mobility needs of Singapore's entire population could be met with some 40 percent of the vehicles (350,000 instead of 800,000).

One year later, Prime Minister Lee Hsien Loong unveiled his vision of a "car-lite future" based on autonomous vehicles, the expansion of public transport and the fostering of slow traffic such as walking and cycling. With 5.5 million inhabitants and a population density of 7,697 people per square kilometre – compared with Switzerland's figure of 203 – Singapore is more dependent on efficient transport than any other major metropolitan area. That is why Singapore has spent years trying to crack down on demand for private cars by imposing high taxes and charging up to 70,000 dollars for the certificates of entitlement required to own a vehicle. More than ten companies are currently testing their systems in a 2-hectare test facility at Nanyang Technological University in the western part of Singapore Island. And plans are already in place to operate the first self-driving buses outside rush hours in three of the city's suburbs starting in 2022.

Simulating transformation

Pieter Fourie's "laboratory" is located in the western part of Singapore. He works in a sunlit office on the sixth floor of the CREATE Tower, a building encased in vertical foliage at the National University of Singapore (NUS). Here, he conducts research into the cities of the future on behalf of ETH Zurich's Future Cities Laboratory. Fourie heads up the Engaging Mobility project, which brought together government authorities and universities at a preliminary workshop in July 2017. The goal was to define the basic conditions required to implement city-wide, on-demand mobility using autonomous cars and buses. The researchers used the results of the workshop to formulate key research questions such as: What do we do with the current supply of parking spaces if the majority of vehicles are constantly on the road? Do we need to redefine the layout of our roads? And what effect will automated, electrified transport have on existing public transport, energy requirements and safety?

Fourie explores these and similar issues using the MATSim simulation platform developed by a group led by Professor Kay Axhausen at ETH Zurich's Institute for Transport Planning and Systems. MATSim is agent-based, which means the simulation is driven by the behaviour of individual agents rather than by overarching ›

Emilio Frazzoli's start-up NuTonomy develops control software for autonomous vehicles and uses Singapore as a test bed.

Image: NuTonomy

rules. “On the basis of Singapore’s most recent demographics, we are modelling a synthetic population that is as close as possible to the real one,” Fourie says.

Within this population, each individual agent exhibits a certain mobility behaviour and has a specific destination based on real-life traffic data. Fourie is now at the stage of tinkering with the underlying conditions, including the number of vehicles employed, their size, the maximum permissible waiting times for passengers, the availability of parking spaces and a variety of different traffic flows. He then lets the synthetic population loose on the simulation for 24 hours. The system automatically evaluates how efficiently the individual agents were able to reach their destinations in each scenario.

Right now, Fourie’s team is programming these kinds of simulations for the waterfront area of Tanjong Pagar, a district of some 2 square kilometres in the western part of Singapore. This site is currently being converted from a container terminal into a residential and commercial area. Fourie has already simulated more than 200,000 trips involving 60,000 individual agents. This included calculating how big the fleet of autonomous vehicles would need to be and how many kilometres the vehicles would have to cover to achieve an equivalent level of service in three different street typologies. The researchers also simulated four different parking strategies for a fleet of 4-, 10- and 20-seater vehicles. Preliminary results suggest that the transport system is at its most efficient if the shared vehicles are allowed to park in the street when they stop receiving requests for pick-ups. That holds true even if it means temporarily reducing the roadway capacity by one lane. The researchers’ findings also suggest that having fewer, but correspondingly larger, pick-up and drop-off stations has a favourable impact on traffic flow by reducing the detours cars have to take to collect passengers. The stations also need to be big enough to accommodate different vehicle sizes. Fourie is hoping to have these kinds of simulations up and running for the entire island as early as next year.

> “The goal of my research is a form of mobility that combines the convenience of a private car with the sustainability of public transport.”
>
> Emilio Frazzoli

Decision-making dilemmas

Despite these rapid developments in Singapore and the fledgling services coming online in Las Vegas, Emilio Frazzoli still sees plenty of challenges ahead, especially when it comes to dealing with chaotic environments. “We still don’t know exactly how autonomous vehicles should behave in traffic,” he says, explaining that this involves dozens of decision-making dilemmas that are an integral part of everyday traffic situations. For example, should a self-driving car cross a double line in order to avoid a potential collision? And what if an innocent road user is injured as a result of a manoeuvre designed to save a culpable driver from a fatal crash? These are the kinds of decisions that have to be defined when programming control algorithms. One key focus of Frazzoli’s current research is therefore the “rulebooks” that should be used to prioritise these various decision-making criteria in control algorithms. At the top of the hierarchy are rules designed to ensure road users’ safety. At the bottom are rules designed to enhance passenger comfort.

In a recent article, Frazzoli and his team estimated that it would take 200 rules in 12 hierarchy groups to prepare vehicles for every possible scenario, including low-priority rules such as not frightening animals on the edge of the road. Frazzoli feels the time has come for a broader public debate on autonomous driving: “The coding of safety and liability rules is not something we should simply leave in the hands of engineers working for private companies”. Ultimately, he argues, it is in everyone’s interest to incorporate our new, virtual drivers into urban traffic as smoothly as possible – much like we do with new human drivers, but with the greater levels of safety, predictability and efficiency that autonomous vehicles offer. ○

Emilio Frazzoli’s group at the Institute for Dynamic Systems and Control:
→ www.idsc.ethz.ch/research-frazzoli

Pieter Fourie’s research project “Engaging Mobility”:
→ www.ethz.ch/engaging-mobility

Image: Giulia Marthaler

“Reliability is still an issue”

Roland Siegwart has been conducting drone research for over a decade. He doesn’t believe they will be revolutionising our transport system any time soon.

INTERVIEW Samuel Schlaefli

Autonomous vehicles have made major progress over the past few years. How much harder is autonomous mobility in the air?
Roland Siegwart: It’s tempting to think that flying through relatively empty skies should be simpler, because there are fewer obstacles, and that the only tricky parts would be take-off and landing. But it’s when something goes wrong in the air that you have a real problem, because the consequences for passengers can quickly be fatal. That means you need far more safety features than on the road, which is why we will see drones transporting goods much sooner than drones carrying people.

Researchers have acquired plenty of insights into drones over recent years. Can they apply that knowledge directly to manned drones?
In principle, yes. In fact, you could argue that manned drones actually have an advantage over traditional drones because their larger dimensions allow them to incorporate greater computing power and better sensors. But we still don’t have a system that can autonomously pinpoint a safe landing spot in any given situation or detect large flying objects over significant distances. That’s the focus of our research right now.

Whatever the drawbacks, plenty of companies seem to be investing in drones as a future mode of transport. Airbus is developing prototypes. Toyota and Volvo have acquired start-ups that are working on flying cars. Uber is collaborating with NASA and looking to expand its ride-sharing model to the skies. So are flying cars on the verge of moving from science fiction to science fact?
There’s a lot of hype at the moment. The people investing in those kinds of companies tend to be very wealthy, but I have yet to witness even one flight by a fully autonomous, manned drone. Reliability is still an issue, especially during landing. I’ve the feeling that investors are still five to ten years too early with their investment.

ROLAND SIEGWART
Head of the Institute of Robotics and Intelligent Systems

How about ten years from now?
Tomorrow’s drones will be much easier to fly than today’s helicopters. Combine that fact with mass production, which is making them progressively more affordable, and semi-autonomous systems could become a genuinely realistic option for certain tasks in selected cities. Perhaps in medical emergencies, for example. But personally I doubt whether any of us really wish to see manned drones deployed on a wide scale.

Why not?
Sustainability has a key role to play in any discussions about alternative modes of transport. It would hardly be very sustainable if everybody suddenly started flying around in quadcopters!

Even if they were electrically powered like most drones? And if the electricity came from renewable sources?
Helicopters are inefficient and require much more power than cars or fixed-wing aircraft. That’s why they’re so noisy. Assuming batteries remain relatively heavy – and we’re already pushing the physical boundaries of how light they can get – then manned drones are not going to be sustainable. The only exception might be combining the properties of a lightweight, fixed-wing aircraft with those of a helicopter, which would be much more efficient in terms of aerodynamics and energy use. The ETH spin-off Wingtra is already offering that kind of system for professional aerial mapping applications.

How much general acceptance is there of drones in public spaces?
The decision of whether or not to use manned drones to augment our public transport system lies with society as a whole. Drones that operate like helicopters make a lot of noise. Are we willing to accept that? And remember that not everyone likes the idea of drones watching them on their patio. As I said, I have my reservations. ○

The destination is the goal

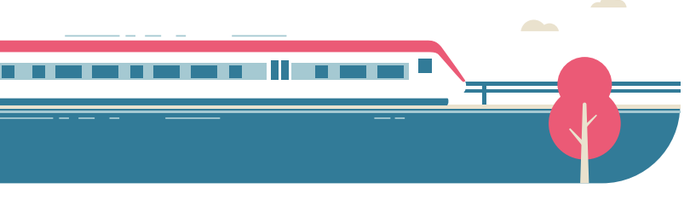
In an ideal future, smart public transport systems will make travelling so seamless and convenient that we will hardly have to spare a thought for the journey itself.

TEXT Michael Walther

Zurich in the year 2050: it's seven in the morning and a woman is leaving her apartment to head to a meeting in Basel. Her virtual assistant has her schedule planned and knows she needs to get to work, so it guides her to a minibus that is just pulling up. She uses the bus journey to get some work done, not even noticing that the specially assigned commuter bus has taken a detour to avoid a broken water pipe. With the short route to the main train station completely blocked, the high-speed train to Basel is no longer an option, so the bus drops the woman off at Escher-Wyss-Platz. There, a self-driving taxi is already waiting to take her to Aarau where she can catch a different train to Basel.

This is a fictionalised account of what public transport might look like in the future, but it reflects real issues that transport researchers are working on at ETH Zurich.

One of those researchers is Professor Francesco Corman, who conducts research into the analysis and optimisation of transport systems. He sees the biggest future innovations in public transport as less about futuristic vehicles and more about the interplay between multiple modes of transport: "When we go online we don't care what route the data takes. All we care about is seeing the results. Public transport will follow a similar pattern: the issue of changing from one mode of transport to the next will be secondary because they will interconnect seamlessly." The key to public transport in the future will be its ability to tailor services to passengers' needs – much like logistics responds to customers' needs in the realm of e-commerce, for example.



Punctuality and reliability

In concrete terms, that could mean buses and trams running when people need them, stopping where people are waiting, and providing whatever mode of transport is most appropriate to get someone from A to B in the quickest and most convenient manner. But this vision of the future is still some way off. Right now, Corman and his team are focusing on punctuality and reliability. These are two of the most critical factors in public transportation – and they can both be improved by using automated systems. Corman has shown that an automated transport control system can reduce knock-on delays following a breakdown by as much as a third.

These systems employ mathematical models to automate certain tasks, particularly decision-making. For example, they can suggest which connections need to be guaranteed and which can be cancelled. They can also help trains accelerate or brake in a coordinated fashion, something that is already happening at railway junctions on Swiss Federal Railways (SBB) lines in Zurich and Killwangen-Spreitenbach. SBB is hoping to extend this successful model to the rest of Switzerland, with the help of Corman's team among others.

Corman also examines how travellers respond to disruptions such as delayed or cancelled trains. By drawing on simulations and tracking test subjects, his research group reconstructs the routes passengers take. That yields knowledge that can subsequently be channelled into providing passengers with accurate information and re-routing public transport to enable as many passengers as possible to continue their journeys.

Local bus timetables are already coordinated with the train schedules; this integration will become even smoother in the future.

ETH Mobility Initiative

ETH Zurich launched the ETH Mobility Initiative in January 2018 in collaboration with Swiss Federal Railways (SBB). Working with companies and public transport providers, ETH aims to achieve a major expansion in mobility research and adopt a leading role in this field. The ETH Zurich Foundation is currently seeking partners for this. The first research projects to receive funding under the ETH Mobility Initiative were approved in September this year. Project topics so far include the potential of on-board systems to monitor the structural health of trains (Eleni Chatzi and Francesco Corman); new, accurate and reliable train positioning systems (Roland Siegwart and Margarita Chli); prediction models for railway wheel wear (Olga Fink); and the future competitiveness of rail freight transport (Konstantinos Boulouchos).

→ www.ethz-foundation.ch/en

No more breakdowns

In an ideal future, public transport systems would boast not just greater efficiency, but also virtually no breakdowns. Transport operators would be able to predict breakdowns based on sensor data and high-precision models. Armed with this information, trams would make their own way to the repair shop before they came to an abrupt standstill, and trolley wires would be replaced automatically before they could snap. What's more, even the biggest construction sites would be so well coordinated that they would have a minimal impact on journey times.

This latter aspect is the research specialty of Bryan Adey, Professor of Infrastructure Management at ETH Zurich, who is working on ways of automating infrastructure management in transportation networks. In a future railway network, for instance, this could involve a digital system controlling and coordinating work on rail tracks, embankment maintenance, tunnel renovation, bridge strengthening and maintenance of signals and points. The system would keep tabs on the structural health of the infrastructure using a combination of sensors and simulations. It would also take into account target parameters such as capacity, speed and punctuality and plan maintenance work based on the level of investment. This would ultimately make the network more efficient, reducing the amount of disruption experienced on congested railway lines.

And Adey's vision encompasses plenty more. Automated infrastructure management would provide a panoramic perspective, a "bird's eye view" in which all the relevant data would be modelled. "As well as maintenance costs, travel times and prices, this kind of system could also take into account targets such as energy use, CO_2 emissions, and noise emissions in residential areas," he says. Automated management could make it easier for railway operators to plan not just how to maintain their networks, but also how to expand them.

Adey and his team are currently conducting research into specific aspects of this futuristic vision. For example, they are creating automated maintenance strategies for individual components of the railway infrastructure such as tracks, bridges, tunnels, points and signals. They are also developing methods of coordinating maintenance work on road and rail infrastructure using algorithms. As part of a research project funded by the EU, they are working on ways of identifying risks for European rail infrastructures and slotting these risks into a standardised classification system to enable more systematic maintenance of European rail networks. ›

Image: © SBB CFF FFS

Better prepared for bad weather
Adey believes that even severe weather events will have less of an impact on public transport in the future. For instance, his team has used simulations to calculate the effects of heavy rain on transport systems – including the additional time a journey might take due to flooding and landslides.

But there are still plenty of obstacles to actually putting this vision into practice. A truly comprehensive system would need to surmount all sorts of political and organisational hurdles to get through the planning and implementation stages. Traditional organisations are likely to become irrelevant, and new ones will have to be created. Demand will soar for new kinds of specialists who can offer a combination of engineering, computer science and managerial skills, because even systems with a panoramic perspective will require someone who understands how they work – and who has a Plan B up their sleeve if something goes wrong. Equally challenging will be the sheer amount of time and money that large-scale systems typically require. But the vision put forward by Corman and Adey is far from being a mere pipedream.

Future travellers will regard mobility in the same way we currently view running water, electricity and Wi-Fi – all things we simply take for granted. In the future, our fictional manager may be zipping from one city or region to the next, taking trams or taxis, and switching between automated and manual systems but – whatever the circumstances – her biggest concern will be getting to her destination on time. ○

Chair of Transport Systems:
→ www.ivt.ethz.ch/en/institut/vs.html

Chair of Infrastructure Management:
→ www.im.ibi.ethz.ch/en

Last-mile delivery and zero emissions – challenges facing freight transport

Globalisation, online retail and the internet of everything are fuelling a significant increase in freight volumes. The logistics industry is clamouring for smart freight transport solutions with lower CO_2 emissions.

TEXT Martina Märki

Image: MAN/Jan Hölzl, Deutsche Bahn AG

Real-life platooning hits the road with the world's first deployment of connected truck convoys on the A9 in Germany.

It's midday on a residential street in Switzerland. The mail van has been and gone, leaving a couple of parcels from a well-known online clothing retailer perched on top of the letterboxes. Soon after, a distributor's truck pulls up to make a home delivery, closely followed by an international express delivery service that drops off a small parcel a few doors along.

Cut to the A9 motorway in Germany: since July this year, autonomous trucks operated by the Deutsche Bahn subsidiary Schenker have been plying the route between Munich and Nuremberg in "platoons". In this system, only the first vehicle in the convoy needs an active human driver, while the remaining vehicles are steered by a computer. According to a press release, the goal of the joint project between DB Schenker and vehicle manufacturer MAN – scheduled to run until the end of 2019 – is to make transport safer, more efficient and more eco-friendly.

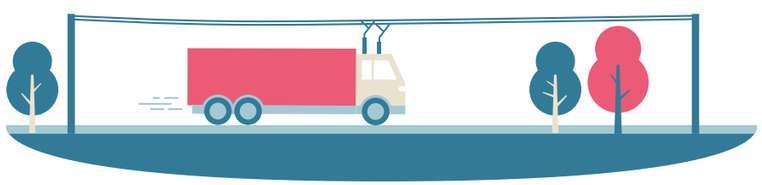
Driven by digitalisation
Both scenarios are driven by recent developments in digital transformation. "The new opportunities we are seeing now are giving a huge impetus to the logistics industry," says Professor Stephan Wagner, Chair of Logistics Management at ETH Zurich. A boom in freight transport is one of the consequences of this new momentum. One of the key drivers is e-commerce, with online shopping experiencing strong growth in recent years. "The forecasts suggest there will be another doubling in growth between 2017 and 2021," says Wagner.

Truck drivers are already in short supply, which is why the logistics industry is so interested in solutions such as platooning that offer an opportunity to reduce manpower, says Wagner. But platooning offers a whole series of other benefits, too. Autonomous vehicles cause fewer accidents and can drive closer together, which helps save energy. On a motorway, autonomous trucks can travel just 15 metres apart – as opposed to the normal statutory requirement of 50 metres – and Schenker reckons that this "slipstreaming" strategy cuts fuel consumption by ten percent. Based on his logistics expertise, however, Wagner cautions that platooning will most likely remain restricted to long-haul routes for several years to come. He also notes that the biggest challenge in the logistics industry is the ever more demanding nature of last-mile delivery. "Customers are ordering smaller quantities more frequently and expecting their orders to arrive within a narrow time window."

Gil Georges, a senior scientist from the Institute for Energy Technology at ETH Zurich and Head of the LAV Energy Systems Group, sees both these developments as cause for concern: "They put a spanner in the works of all the efforts we have made in recent years to shift as much freight transport as possible to the railways." That's because transporting goods by rail scores high on eco-friendliness and reliability, but low on the issue of last-mile delivery. What's even more worrying is that railways will no longer be able to compete with the low cost of road haulage once more autonomous vehicles come into play. "If we leave things to market forces, then we will see far more goods being carried by road in the future, which will lead to a significant increase in CO_2 emissions," Georges says.

According to figures released by the Swiss Federal Office for the Environment, heavy and light goods vehicles on the roads are currently only responsible for some 5 percent of all greenhouse gas emissions, while passenger traffic is responsible for almost 25 percent – but that situation is likely to change. Based on the traffic forecasts for Switzerland issued by the Federal Office for Spatial Development (ARE), ETH researchers assume that freight transport by road will increase by around 25 percent between 2015 and 2040, while motorised passenger traffic will increase by just 15 percent. "That means road haulage will play an increasingly significant role in our overall carbon footprint," Georges says. He notes that this development will become even more pronounced if the electrification of passenger vehicles continues and if we switch to a global perspective: "For countries such as China and India, experts are predicting that road haulage will see growth rates of 600 percent by 2050."

Electromobility for trucks?
Action clearly needs to be taken. But where is the best place to start? And what technical solutions are available to build trucks that emit little or no CO_2? That's what Georges and his team are investigating as part of the SCCER Mobility project. Data on ›



the Swiss performance-related heavy vehicle charge (LSVA) compiled by the Federal Customs Administration provided the researchers with a detailed picture of truck movements in Switzerland. Based on this information, they evaluated the pros and cons of a wide range of drive and technology options. Would battery-powered electric trucks be capable of covering the required number of kilometres? Or would hydrogen-powered trucks be a better bet? And how do the figures stack up for biofuels?

From a purely technical standpoint, Georges says there are numerous viable options, many of which are already being tested. In real-life applications, however, he notes that some of these would be impractical, financially untenable, or infeasible in terms of energy use or environmental impact. For example, biofuels offer similar benefits to fossil fuels in terms of performance, but their environmental credentials are questionable, and energy technology experts argue that they are not necessarily the most efficient means of exploiting the valuable energy potential of biomass. The Swiss company Coop is currently testing hydrogen as a drive system. Experts note that one of the biggest challenges of this technology is to achieve carbon-neutral hydrogen production and distribution over the long term. Electric trucks would be the best solution in terms of energy consumption, but they are saddled with some significant hindrances to widespread use. These include short ranges, long charging times and increased vehicle weight – a combination of factors that continues to cast battery power in a negative light, at least for large trucks embarking on long-haul routes. Even swapping – in other words replacing batteries instead of recharging them – fails to solve the electric truck dilemma. "My concern there is that nobody would want to replace a battery weighing up to three tonnes and repeat that process several times a day," Georges says. He argues that a better option in terms of energy use would be to supply power to electric trucks through overhead lines or inductive charging plates embedded in the ground. "Decarbonisation of freight transport is feasible whichever solution we opt for, but the infrastructure costs will be high," Georges concludes.

Start-ups provide new impetus

With so much uncertainty in play, it is hardly surprising that nobody really knows what a successful system might ultimately look like. "Electric vehicles already offer a genuine alternative for transporting passengers, but the situation for trucks is very different," Georges says. "There simply isn't a catch-all solution that addresses all the issues involved." He thinks the most likely way forward will be a combination of multiple technologies.

Stephan Wagner feels that logistics management is heading down a similar route: "Until clear standards are defined, it will continue to be very hard for the logistics industry to make forward-looking decisions. We are currently in an extreme test phase." Like Georges, he believes that an all-encompassing solution is unlikely to emerge and that companies need to engage on all levels. He also thinks that optimising logistics processes could be part of the solution. His team is already pursuing that avenue in collaboration with a logistics service provider in one of India's biggest cities. Together, they are trying to find better ways of combining first-mile and last-mile distribution networks to reduce the number of kilometres travelled. Improving cooperation between different service providers could also help reduce unnecessary journeys. "What I like about these kinds of approaches is that they reduce kilometre counts, fuel use and emissions while also cutting costs – and that makes them very interesting to businesses and customers alike," says Wagner.

Wagner is particularly keen to see new impetus coming from fledgling start-ups in the form of route optimisation, improved pooling of goods and capacities, greater transparency and improved collaboration. "I'm confident that new IT business ventures in the fields of optimisation and machine learning will inject plenty of new momentum into the industry," he says. That's why he and his team decided to investigate what impact start-up companies have on the logistics industry. One of the companies on their radar is Berlin-based start-up FreightHub, which quickly made a name for itself by developing a digital platform that optimises the planning and execution of freight forwarding processes. He is also interested in Deutsche Post's decision to acquire StreetScooter, a low-cost electric vehicle start-up that stemmed from a research initiative at RWTH Aachen University. He sees this as a clear indication that these kinds of initiatives can generate real momentum. "When big players in the industry start joining forces with innovative start-ups, that's when things get really exciting!" Wagner says. ○

> "Road haulage is playing an increasingly significant role in our overall carbon footprint."
>
> Gil Georges

Energy Systems Group:
→ www.ethz.ch/energy-systems

Chair of Logistics Management:
→ www.scm.ethz.ch

ETH strategy: responsible air travel

ETH Zurich is promoting a shift in thinking toward more responsible air travel. The aim is to help resolve the conflict between mitigating climate change and meeting the need for researchers to travel.

TEXT Michael Keller

ETH Zurich is facing an all-too-familiar dilemma: researchers need to network and collaborate across borders, but air travel is bad for the world's climate. As Ulrich Weidmann, Vice President for Human Resources and Infrastructure at ETH Zurich, remarks: "ETH Zurich is committed to sustainability, but the success of our researchers hinges on enabling them to collaborate internationally and providing them with the best possible development opportunities – it's a typical conflict of interests."

Air travel accounts for over 50 percent of the university's CO_2 emissions, and technical solutions that could reduce air travel emissions to zero are still a long way off. "When it comes to CO_2 emissions, ETH Zurich is seen as a role model for society, and everything it does is closely scrutinised," Weidmann argues. That is why the Executive Board launched an initiative in April 2017 encouraging people to take fewer flights.

A new approach to air travel

But researchers collaborate in international projects and work in academic departments that are autonoomous. So how do you win them over to this idea – especially at a university with an explicit strategy of internationalisation? Well, not by imposing directives from above, as Susann Görlinger knew from the start. She is co-manager of the mobility platform, a hub for mobility-related topics at ETH. The platform focuses on sustainable mobility on campus and also encompasses the air travel project, which aims to change the way staff view air travel.

"We cannot achieve a shift in thinking of this magnitude without getting the target groups involved in a meaningful way," says Görlinger. She insists that it has nothing to do with moralising or trying to discredit flying altogether, but is simply a means of encouraging everyone at ETH to get to grips with the problem. ETH Zurich is pursuing a bottom-up approach based on participation and personal responsibility. Although the Executive Board did ask the academic departments to come up with ways to reduce the number of flights, it did not set any specific targets. As Görlinger emphasises: "It's up to each individual to determine exactly how they wish to contribute. We're neither prescribing nor prohibiting anything."

A change in thinking

And yet, at least initially, there were a lot of objections from ETH staff, some of them quite strong. "At first there were quite a few misunderstandings and, in some cases, opposition, but we also received a lot of support," explains Görlinger. One and a half years and numerous workshops later, all of the academic departments are doing their bit. They have committed to reducing emissions by between 3 and 20 percent over the period 2019 to 2025, with an average reduction target of around 11 percent. They have also defined the measures they will adopt to achieve their targets – from internal CO_2 taxes and the use of video-conferencing technology to incentives for rail travel and specific recommendations for avoiding short-haul and business-class flights.

Effective monitoring

The departments were keen to have an effective monitoring system in place to track their individual emissions on an ongoing basis. They are currently working together with the mobility platform to establish a database for the years 2016 to 2018 that will be taken as the reference period. The database comprises all flights purchased by ETH Zurich for its staff and guests, plus flights taken by students as part of their curriculum.

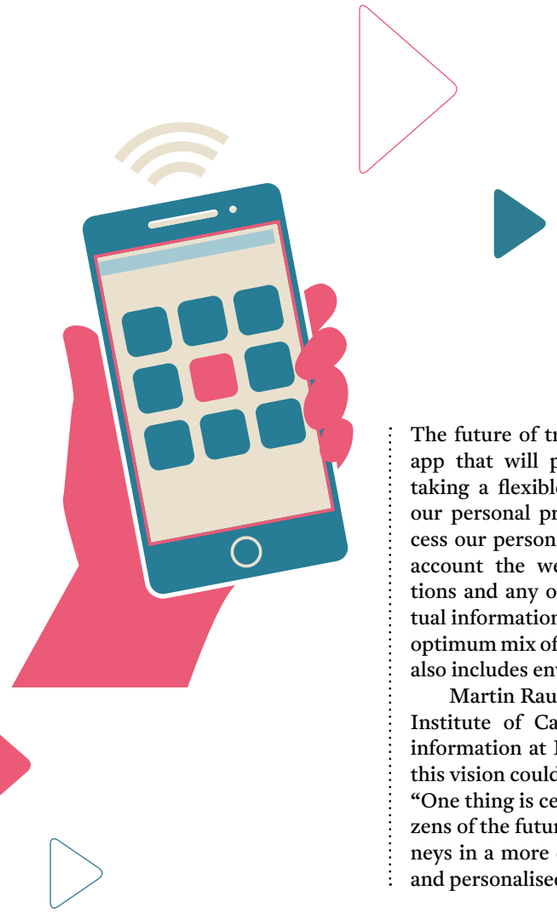
All departments will begin reducing their emissions in 2019 and a mid-term evaluation will take place after three years. This ETH-wide change process will be analysed in a dissertation. "That's the plan, at least. All we have to do now is put it into action," says Görlinger. She is motivated by the fact that other universities and organisations have expressed an interest in what ETH is doing. "Society at large can benefit from our experiences as well," she says. ○

Mobility platform:
→ www.ethz.ch/mobility

Paving the way for smart mobility

Modern IT solutions not only give us a better understanding of human mobility behaviour – they also help improve environmental performance and enable intelligent demand management.

TEXT Michael Keller



The future of travel is a smartphone app that will plan our mobility by taking a flexible approach based on our personal preferences. It will access our personal schedule, take into account the weather, traffic conditions and any other relevant contextual information, and then suggest an optimum mix of transport modes that also includes environmental criteria.

Martin Raubal, a professor at the Institute of Cartography and Geoinformation at ETH Zurich, believes this vision could soon become reality: "One thing is certain: the mobile citizens of the future will plan their journeys in a more efficient, eco-friendly and personalised way."

Raubal studies human mobility by analysing spatio-temporal data. He is particularly interested in discovering whether IT solutions can promote sustainable mobility behaviours. "Whatever technical solutions we introduce to make the transport sector more efficient, we can't address the challenges involved unless people change their behaviour and attitudes," he argues.

Multi-modal mobility

Transport experts emphasise the increasing importance of multi-modal travel – in other words splitting a journey across different forms of transport. Done well, this approach reduces CO_2 emissions, shortens journey times and avoids traffic jams.

As part of the GoEco project, Raubal's team recently carried out a long-term study to discover the best ways of encouraging people to increase their use of bicycles, public transport and car sharing. GoEco, which ran from 2016 to 2017, is the biggest participatory mobility project ever carried out in Switzerland. It was jointly headed up by ETH Zurich and the University of Applied Sciences and Arts of Southern Switzerland (SUPSI).

Trip analysis with feedback

Some 400 residents of the cantons of Ticino and Zurich took part in the GoEco project, using a smartphone app of the same name to keep track of all the trips they made over the course of a year. Drawing on a combination of location data and machine learning, the software verified which modes of transport people used and calculated their energy consumption and CO_2 emissions. The users received regular updates on their mobility behaviour, including suggestions on how to improve their environmental footprint – for example by taking alternative routes or using more efficient modes of transport. The researchers also tested game elements such as points and competitions designed to motivate people to choose sustainable mobility behaviours.

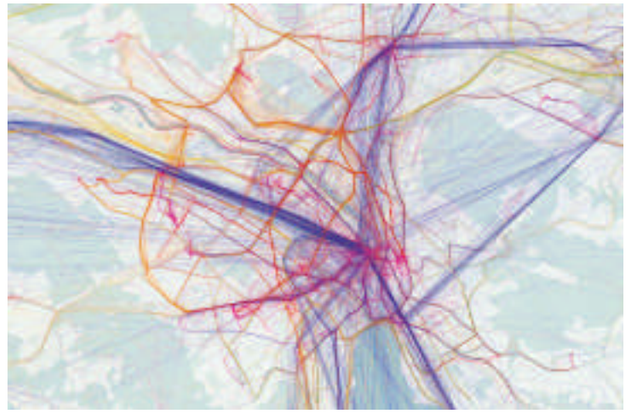
Subsequent analysis revealed that this approach was largely successful: the participants responded to both the feedback and the game elements, significantly reducing their CO_2 emissions on regular journeys such as their commute to work. The researchers also found some indications of users maintaining their new mobility behaviour on a long-term basis.

CO_2 emission mitigation strategy

Raubal insists that the potential of such multi-modal route planners and environmental feedback tools should not be underestimated. "But it's essential that the applications are reliable and that they genuinely free up users from the time-consuming tasks of seeking out and comparing different options." If those criteria are met, his experience with GoEco suggests people are willing to embrace these kinds of decision-making aids.

The Green Class pilot project launched by Swiss Federal Railways (SBB) and various other partners in autumn 2016 demonstrates that people will opt for multi-modal transport if they are given the option – for instance if they can choose freely between different modes of transport. Participants received a combined, one-year mobility package consisting of a first-class travelcard, an electric car, parking at the station, and a subscription to a car sharing and electric bike sharing service. SBB commissioned Raubal's team to conduct a scientific analysis of the project.

Perhaps the most striking finding was that people used the electric car for around one-third of the journeys they had previously made in a combustion engine vehicle, in many cases for short, last-mile trips from the station to their home. Frequent train use also emerged as a key part of the mobility mix. "Most participants reduced their CO_2 emissions significantly, even though, overall, people actually travelled more during the pilot phase than they had before," Raubal says.



Anonymised tracking data from the GoEco project: the different colours of the journeys indicate different modes of transport.

Image: Martin Raubal

Smart mobility management

The results of both of these projects are based on spatio-temporal analyses of all the trips made. The researchers recorded each participant's location data using the GPS locators in their smartphones and cars. This kind of tracking is fast becoming an integral part of transport management and has witnessed a corresponding increase in use worldwide.

So should commuters be worried about sharing their data in this way? Raubal doesn't think so: "Protecting people's privacy is obviously very important, just like in many other areas of our lives, but I think mobility data is less sensitive than people's health or banking data." What's more, mobility data is typically processed in an anonymised and aggregated form, because its usefulness really comes to the fore in bulk.

Mobility data ultimately offers the potential to measure entire traffic flows in real time, optimise their control, and carefully manage demand. This will lead to a better understanding of collective mobility behaviour which, in turn, can serve as a basis for making better decisions on intelligent housing policies and spatial planning – in other words, insights into mobility behaviour can be used to design infrastructure in line with demand. Within the scope of the Swiss Competence Center for Energy Research – Efficient Technologies and Systems for Mobility (SCCER Mobility), for example, Raubal's group is investigating how traffic flows can be used to optimise the layout of future charging stations for e-mobility. "At the end of the day, everyone will benefit if we put our mobility data to reliable and sensible use," he says. ○

Chair of Geoinformation Engineering:
→ www.gis.ethz.ch/en

COMMUNITY

Joël Mesot, the next President of ETH Zurich

Appointed

NEW ETH PRESIDENT

Joël Mesot, Director of the Paul Scherrer Institute (PSI), has been appointed as the new President of ETH Zurich. He will take over from the current President, Lino Guzzella, on 1 January 2019. Mesot has been Director of the PSI since 2008 and holds a dual professorship in physics at ETH Zurich and EPF Lausanne. He grew up in Geneva and studied physics at ETH Zurich, obtaining a doctorate in solid-state physics in 1992. After periods spent in the USA and France, Mesot joined PSI in 1999, becoming Head of the Laboratory for Neutron Scattering in 2004.

Quantum Flagship

SUCCESSFUL ETH RESEARCHERS

In mid-2017, the European Commission launched a flagship project in the field of quantum technologies. Following in the footsteps of the Human Brain Project and the Graphene Flagship, the Quantum Flagship is the EU's third major research initiative dedicated to promoting future and emerging technologies. The EU plans to invest some 1 billion euros over the next ten years to help Europe secure a leading position in the quantum technology sector. Among the sub-projects that have now been selected are six that involve ETH researchers. These six projects will receive a total of 6.5 million Swiss francs in funding.

Stemming from the fields of quantum computing, quantum simulations and quantum sensors, the projects are led by the ETH researchers Christian Degen from the Laboratory for Solid State Physics, Jérôme Faist and Jonathan Home from the Institute for Quantum Electronics, Sebastian Kozerke from the Institute for Biomedical Engineering, Matthias Troyer from the Institute for Theoretical Physics, and Andreas Wallraff from the Laboratory for Solid State Physics.

"Quantum technology is opening up new horizons in all scientific disciplines," says Professor Detlef Günther, ETH Vice President for Research and Corporate Relations. A network of 18 research groups is working on these technologies at ETH Zurich.

Donation

LYMPHOMA RESEARCH

ETH alumnus and co-founder of Actelion Walter Fischli and his wife Edith Fischli recently donated a substantial sum to support cancer research at ETH Zurich. The donation will be used to fund a chair in the field of tumour heterogeneity. It will also provide financial support for the "Lymphoma Challenge" research funding initiative. This initiative aims to help postdoctoral students work with medical researchers from a university hospital on clinically relevant projects involving various types of blood cancer.

Image: Paul Scherrer Institute

1 *Cybathlon*

2 *CeBit*

3 *Digital Day*

ETH President Lino Guzzella

Keep moving and shape the future

Lino Guzzella spent four years as President of ETH Zurich. During that time, he dedicated himself to ETH Zurich and to promoting Switzerland as a research powerhouse. A retrospective in pictures:

Lino Guzzella is a big fan of keeping things moving and committing to a goal, whether in sport or science. The 2016 Cybathlon (1) – a competition in which athletes with disabilities use robotic assistive devices – was one of the highlights of his tenure. He promoted a targeted combination of medicine and technology and established a Bachelor's degree in human medicine at ETH Zurich.

Guzzella played an active part in continuing to build ETH Zurich's formidable international reputation. He understood how to inspire enthusiasm for ETH and its research, applying that skill in equal measure to the public at large and to preeminent political and business leaders, including German Chancellor Angela Merkel at CeBIT 2016 (2).

Boosting Switzerland's readiness to face the future of digital transformation was one of his key concerns. This topic was highlighted at the ETH programming workshop for children on Digital Day 2017, which he attended together with Swiss Federal Councillor Johann Schneider-Ammann (3).

Guzzella was convinced that future readiness also means encouraging students to think critically, creatively and independently across disciplinary boundaries. The Critical Thinking initiative he pioneered gives ETH students the tools they need to achieve that. Since 2015, for example, ETH Week (4) has brought together more than 100 students from the academic departments at an annual event that challenges them to work in interdisciplinary teams to develop forward-looking solutions for societal issues.

Guzzella also redoubled efforts to forge alliances with industry partners. At WEF 2018 Federal Councillor Doris Leuthard, SBB CEO Andreas Meyer and Lino Guzzella launched the ETH Mobility Initiative (5), which aims to achieve a major expansion of research and teaching in the field of mobility.

Under his tenure, ETH Zurich also boosted its position as a leading international university with a series of outstanding achievements in research, teaching and technology transfer. Perhaps the most impressive indicator of this success was the award of the Fields Medal to ETH mathematician Alessio Figalli in 2018, pictured here at the centre of a photograph taken at the ETH reception held in his honour (6).

Guzzella set another milestone on the university's path to a successful future with the ETH+ initiative, which aims to encourage concerted efforts to achieve a substantial increase in the number of professorships (7). ○

Images: Alessandro Della Bella (2); Claudia Levetzow; Jan Lichtensteiger

4 *ETH Week*

5 *WEF*

6 *Fields Medal ETH reception*

7 *ETH+ strategy*

What began in late 2017 as a faculty retreat in Lucerne has already yielded an initial batch of projects with concrete goals.

Images: PPR/Christian Merz; Andreas Eggenberger; Heidi Hostettler

Philanthropy

UPLIFT

By Donald Tillman

The quest to bring about quantum leaps in science. The desire to give something back to the university. The commitment to foster innovation and technology transfer. Or simply the sheer delight of supporting young talented people. The reasons for donating to ETH Zurich are as diverse and distinctive as the donors themselves – but what matters is the willingness they share to support research and teaching.

To inspire you to support research and teaching at ETH, we have created "Uplift", which we will be enclosing with *Globe* on a regular basis from now on. "Uplift" stands for upward momentum and new beginnings, for impetus and improvement. "Uplift" also shows how philanthropy can boost top-class research and fuel people's ambitions. We kick off with the topic of talent featuring Michelle Rüegg, who tells us how an Excellence Scholarship gave her self-confidence a boost, and Adrian Weiss, who offers us some first-hand insights into his philanthropic work.

We look forward to joining forces with many of you to advance research and teaching at ETH.

→ www.ethz-foundation.ch/en

University of Basel and ETH Zurich

RESEARCH INTO CHILDREN'S HEALTH

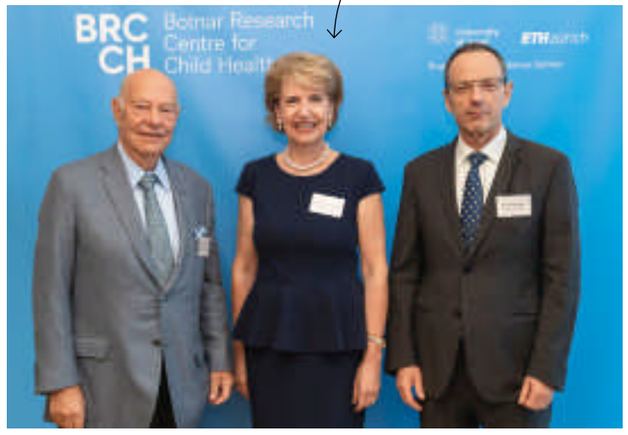
The University of Basel and ETH Zurich have jointly founded the Botnar Research Centre for Child Health (BRCCH) in Basel. The BRCCH brings together outstanding science and clinical research from various disciplines to develop new methods and digital innovations for worldwide use in paediatrics. It is supported by 100 million Swiss francs in funding from Fondation Botnar in Basel, divided equally between the ETH Zurich Foundation and the University of Basel.

Fondation Botnar is committed to improving the health and well-being of children and adolescents in fast-growing cities across the world. The BRCCH operating institutions are the University of Basel and ETH Zurich. The Research Centre's network also includes partner institutions such as the University Children's Hospital Basel and the Swiss Tropical and Public Health Institute in Basel. It combines the expertise of both universities in systems biology, medicine and various health-related areas of life sciences, engineering, social sciences and information technology.

The BRCCH's mission is to help prevent diseases, develop new types of treatment, improve diagnoses and effectiveness forecasts, and make healthcare systems more affordable. The primary focus is on countries with limited resources – but the goal is to develop universally applicable solutions.

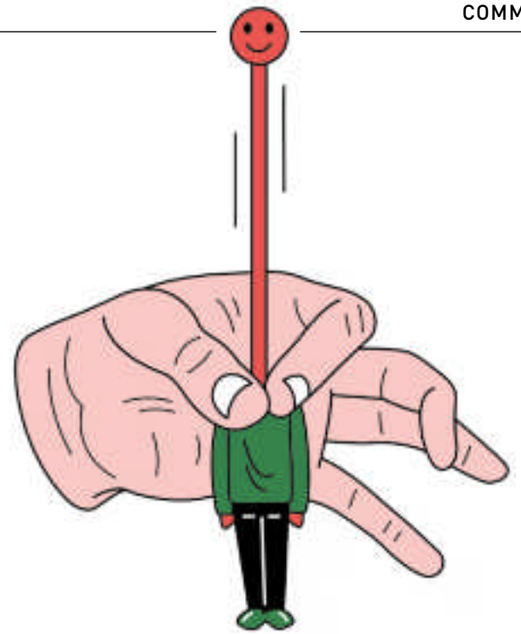
→ www.ethz-foundation.ch/en

"We want to have an impact on the lives of children and adolescents," says Andrea Schenker-Wicki, Rector of the University of Basel.



Peter Lenz, President of the Fondation Botnar board, Andrea Schenker-Wicki, Rector of the University of Basel, and ETH President Lino Guzzella

Images: Eline Keller-Soerensen; Peter Hauck



Column

Why we fail to grow

April 2012. I was a visiting professor at Tokyo University, and my dad had come to visit.

During dinner one evening, I shared with him that I was feeling out of my depth at work, struggling at times, that maybe I wasn't good enough. He listened intently, as he always did, and said, "Manu, one's ambition should always exceed one's talent". He meant that what I was feeling was a good thing, as I was pushing myself to grow and learn. The wisdom of generations captured in an incisive quip.

A Russian psychologist, Lev Vygotsky, embodied this wisdom in his theory of cognitive development. He called it the Zone of Proximal Development (ZPD). There are things we can accomplish on our own. For example, I can ride a bike without needing any help. There are other things, however, that we cannot do by ourselves. I cannot salsa. If I tried it, I would be uncomfortable, and make a fool of myself. But with the right help, perhaps I can learn it. Vygotsky's idea was that development and growth happen in the second case, in the zone where you're trying to learn something that is beyond your current abilities. That is, by yourself alone, you will not be able to learn. But with the help of an expert you will be able to build on your abilities, grow, and learn. Over time, perhaps even I can salsa. In the wisdom of generations, what you want to learn – your ambition – must exceed your current abilities – your talent.

So how do we use Vygotsky's theory to design our own growth?

First, practise productive discontentment. Don't be contented with your current abilities. Get out of your comfort zone. Channel productive discontentment to seek and work on things that are beyond your current ability and skill set. You will struggle. You may fail. But you will also give yourself the opportunity to grow.

Second, embrace productive discomfort. It's not a nice feeling to struggle. Tell yourself it's okay to fail. It's okay to doubt. Your mindset matters. Tell yourself it's actually a good thing to be in this zone. Because in there you have an opportunity to grow and learn. The more you embrace it, the more you become comfortable with being uncomfortable, and the more you will grow.

Third, leverage productive failure. Struggle and failure alone do not guarantee learning. Even the healthiest of mindsets alone are not sufficient. To make the failure productive, we need to be resourceful, seek out the right kind of expert help, work with people, and plug into and build a support community around ourselves.

Of course, it sounds easier said than done. But my dad never said it was going to be easy. He just said it had to be done.

Manu Kapur is professor for learning sciences at ETH Zurich. Previously he taught and researched in Hong Kong and Singapore. He dedicates this column to his father, who passed away last year.
→ www.manukapur.com

Illustration: Benedikt Rugar; Image: Courtesy of Manu Kapur

When high tech goes underground

ANYmal, a robot developed at ETH, can see and hear, and even open doors. An international research team is now working to ensure the robot can function in extreme conditions – a mission that takes them to the labyrinth of drains and tunnels below Zurich.

TEXT Andres Eberhard IMAGE Daniel Winkler

Two men lift the 30-kilogram high-tech machine and lower it into the dark shaft using a rope. We put on reflective overalls, trade our shoes for thigh-high rubber boots and attach them firmly to our outfits. Then comes a helmet, a flashlight and disposable gloves for each of us. Fully kitted out, we begin our descent, following the steps down the wall of the shaft one by one until we reach Zurich's sewerage system, four metres below the surface.

On this warm autumn day a team of researchers is performing tests underground. Their aim is to determine whether ANYmal – a robot jointly developed by Robotic Systems Lab and ANYbotics, an ETH spin-off – could one day be deployed in sewerage systems. It might be used, for instance, to help the City of Zurich employees who regularly have to walk or crawl through the some 100 kilometres of accessible shafts and drains underneath the city and whose job it is to check the walls and floors for damage. This work not only poses a health risk, but is also potentially lethal, given that the drains can fill up with water very quickly without warning. Another advantage of robots in such an environment is that they could operate in narrow sewers that cannot be accessed with the technology in use today.

Initial test run

The researchers place the robot upright at the bottom of the shaft. It is about 50 cm tall and has four articulated legs as well as something resem- ›

ANYmal on its first tour of inspection in Zurich's sewerage system

ANYmal
ANYmal is a four-legged robot that can be deployed autonomously in challenging conditions. Thanks to its laser sensors and cameras, the robot can identify its surroundings, determine its precise location, plan its own route and carefully choose where to place its feet as it moves around.

→ www.anybotics.com/anymal

The workers carefully manoeuvre the high-tech robot into the narrow shaft.

bling a head that consists of a camera and various sensors.

Péter Fankhauser, co-founder of the ETH spin-off that is commercialising ANYmal, radios his colleagues on the surface, who are responsible for coordinating the test and sending commands to the robot. Fankhauser then twiddles with a joystick and the robot plods forward. As this is the first test in unknown terrain, he takes partial control of the robot even though it is capable of moving autonomously. "It's a precautionary measure," says Fankhauser, "Just because something works in the lab doesn't always mean it will in the real world." After all, the conditions underground are not what the robot is used to: the chamber is wet and slippery, with lower temperatures and higher humidity than in the lab. What's more, it's very, very dark.

"It's hard to distinguish much down here," says Fankhauser, almost with a hint of resignation in his voice, as the robot moves at a slow pace through the roughly three-metre-high and five-metre-wide tunnel. The robot emits a uniform electromechanical sound – a kind of rhythmic whirring – that blends with the sound of rushing water emanating from the main sewer nearby. We are in quite a large overflow sewer with only a trickle of water in it. Given that the robot is on its maiden test run four metres below ground level, the researchers have taken the precaution of avoiding large volumes of water.

Finding its way in the dark
The goal of the three-year research project entitled THING (sub-Terranean Haptic InvestiGator) is to design robots that can move about on their own and are better able to identify their surroundings. Robots generally use 3D cameras and laser sensors for orientation. But such devices can malfunction in adverse conditions – such as when the ground surface is wet or the air full of dust. That's why the researchers consider enhanced haptic perception – orientation by touch – to be a possible solution. The project has brought together ETH researchers with colleagues from universities in Edinburgh, Pisa, Oxford and Poznań.

> "Just because something works in the lab doesn't always mean it will in the real world."

All these institutions are experimenting with ANYmal robots, and the project participants from the various locations meet up on a regular basis. In addition to the tests in the sewerage system, next year the researchers will deploy the robot in a Polish copper mine. That will determine whether it can function in an entirely different microclimate, one characterised by hot, dusty air and gravel surfaces. ETH is represented in the project by the Laboratory for Robotic Systems led by Professor Marco Hutter, who has been conducting research into legged robots for many years. He received support from ETH soon after embarking on this research in the form of an ESOP scholarship and a Pioneer fellowship.

One of the key questions on this first day of testing is whether the robot can find its way around at all in the darkness of the sewerage system. Initially, two helpers with big LED lamps illuminate the surroundings so that we can clearly see what's going on. Then, Fankhauser asks the helpers to turn off the lamps and radios his colleagues on the surface to tell the robot to use its own lights. The robot's sense of touch isn't the only thing that helps it find its way in the dark, as Hutter explains: "The robot uses laser sensors and cameras to scan its surroundings. By identifying irregularities in the surface of the concrete, it can determine where it is at any given moment."

All that can be seen in the darkness now are the small round LEDs in the robot's "head". The atmosphere is other-worldly: the darkness, the sound of rushing water, the electromechanical whirring, the robot's LED eyes. Then someone breaks the eerie silence momentarily with a droll comment: "Its eyes are a bit like a Rottweiler."

ANYmal reaches the bottom of the shaft unscathed.

Underground and offshore
Researchers at ETH have been working on quadrupedal robots since 2009. The first ANYmal prototype was completed in 2015 and, one year later, ETH established the spin-off ANYbotics. The fledgling company's mission is to make robots deployable in all types of terrain so that they can be used in a wide range of practical applications. The company's slogan is "Let Robots Go Anywhere". On-site tests are carried out two or three times a month. For instance, Fankhauser and some members of his team recently headed to an offshore platform in the middle of the North Sea. The hope is that robots could one day perform inspections on such ›

As a precautionary measure, an operator uses a joystick to take partial control of the robot's first steps before switching to autonomous mode.

ANYmal can enter spaces too small for humans.

platforms. On its pilot run at least, ANYmal autonomously completed several inspection routes with flying colours.

After almost ten years of research, there's a lot ANYmal can do. It can not only walk autonomously, but also boasts the sensory capabilities of sight, hearing and touch. These enable it, for instance, to read the air pressure display on a machine, identify sounds and recognise objects – for example to determine whether or not a fire extinguisher is in the right place. The robot can even perform certain manual tasks on its own. Equipped with an additional gripping arm, it can open doors, dispose of refuse or press a lift button. It also delivers data that is more precise than our own eyes, ears and noses can perceive. It can identify the ambient temperature and detect the presence of gases in the air. Its latest trick is recognising the composition of the ground beneath it. "Some of its powers are superhuman," says Fankhauser.

Despite the lack of light in the sewer, the robot seems to be finding its way quite well, plodding through the shallow channel at a leisurely pace. When the high-tech machine reaches a 20-centimetre-high ledge in a dry side arm of the sewer, Fankhauser brings it to a halt with a flick of the joystick.

"Some of the robot's powers are superhuman."

Initially, he is reluctant to give the robot the command to climb over the ledge. Although it has easily mastered this manoeuvre in laboratory conditions, down here it is a risky undertaking. "It's an expensive machine," says Fankhauser. But he gives it a try anyway. ANYmal doesn't manage it at its first attempt. It stops at the ledge like a horse balking at a jump. "Default, start again," radios Fankhauser. Now the robot elegantly places one leg after another over the ledge.

Huge data volumes

While Fankhauser and Hutter watch the robot continue on its patrol for a while, I return to the surface via the entry shaft. Sitting on a bench under a white canopy, their eyes firmly fixed on a laptop, are two assistants from ETH. A generator is buzzing and a router is blinking – and many a cyclist passing by along the main road looks on in bemusement at the hubbub around the open manhole at the side of the road. Looking over the researchers' shoulders, I can see an almost constant stream of data flickering across the screen. And thanks to state-of-the-art 3D and laser technologies, live images constantly transmitted by the robot from underground are visible on a separate monitor.

When Fankhauser radios from below that he wants the robot to touch the wall of the sewer with one of its legs, the two assistants have their work cut out for them. The software they are using has not been programmed for this. They respond quickly, however, taking an algorithm originally programmed to teach ANYmal to shake hands. But to make sure the robot doesn't hit the wall with force, the researchers have to adapt the parameters. In this case, the problem is the angle at which the robot is to raise its leg. One of the assistants types in 100 and then gradually ratchets up the number. At 180 the perfect level is reached and the robot's manoeuvre is successful.

Fankhauser and Hutter emerge from the cool, humid environment of the sewerage system into the warm autumn sunshine. They slowly begin to relax as they take off their reflective overalls. "The robot was in non-stop operation and collected a lot of data," says Fankhauser as he undoes his high rubber boots and removes his protective clothing. Professor Hutter is satisfied, too: "All the teams will be taking home a huge volume of data to incorporate in their research." They are now one step closer to their goal of delivering a robot that can function properly in challenging conditions underground. But their work is far from finished. The robot recorded 500,000 measurements per second over the course of the day. "That's enough data to keep us busy for six months," says Fankhauser with a laugh. ○

Video ANYmal underground:
→ youtu.be/ZqRj9q-6Rg4

Video ANYmal offshore:
→ www.anybotics.com/2018/10/25/worlds-first-autonomous-offshore-robot

Mission accomplished: Marco Hutter and Péter Fankhauser are pleased with the results of the test.

Researchers on the surface track ANYmal's movements underground.

CONNECTED

1 *Digital Day*

FACE THE FUTURE

On Swiss Digital Day more than 100 school students visited ETH to delve into the world of computer programming. ETH staff taught the children some skills that will help them get to grips with the digitalised world of tomorrow. At an exhibition held in the hall of Zurich's main railway station, Swiss President Alain Berset and ETH President Lino Guzzella listened attentively to an explanation of the Myosuit exoskeleton developed by ETH spin-off MyoSwiss.

2 *ETH Day*

HONOURED

At this year's ETH Day, ETH Rector Sarah Springman (first from left) and ETH President Lino Guzzella (first from right) presented three honorary doctorates: Nobel Laureate Stefan W. Hell (second from left), director of two Max Planck Institutes, in Göttingen and Heidelberg, was awarded the accolade for his theories on breaking the diffraction barrier in optical microscopy and on the development of super-resolution fluorescence microscopy; Lia Addadi (third from left), a professor at the Weizmann Institute of Science, was singled out for her work on biomineralisation; while Naomi Oreskes (fourth from left), a professor at Harvard University, was honoured for her research into the history of earth sciences and for her contributions to the debate on anthropogenic climate change. Hans Hengartner (second from right) was appointed to the position of Honorary Councillor, in particular for his achievements in building bridges between universities, the research sector and society at large.

3 *Wilhelm Schulthess Foundation*

NEW PROFESSORSHIP

Franz von Meyenburg (left), President of the Wilhelm Schulthess Foundation, and ETH President Lino Guzzella (right) have every reason to be pleased. As part of ETH's rehabilitation initiative, the Foundation is funding a new professorship in Data Science for Personalised Health. The purpose of the new chair is to improve the diagnosis and treatment of musculoskeletal disorders.

4 *ESA BIC Demo Days*

A HUB FOR DISCUSSION

This year, 130 visitors turned up at the ESA BIC Switzerland Demo Days, eager to find out more about aerospace start-ups. Detlef Günther (pictured on left), ETH Zurich Vice President for Research and Corporate Relations, was a guest speaker at the event. In addition to listening to speeches and a panel discussion, the attendees had ample time to mingle and network with their peers.

5 *Informal chat*

MICROSOFT CEO VISITS ETH

On his visit to ETH, Microsoft CEO Satya Nadella (pictured) chatted with ETH President Lino Guzzella about how businesses and the research sector compete – but also how they collaborate. The Mixed Reality & AI Zurich Lab represents the latest partnership between Microsoft and ETH Zurich.

Images: Jan Lichtensteiger; Eline Keller-Soerensen; Andreas Eggenberger

1 *Digital Day*

Alain Berset – intrigued by an ETH spin-off

3 *Wilhelm Schulthess Foundation*

5 *Informal chat*

4 *ESA BIC Demo Days*

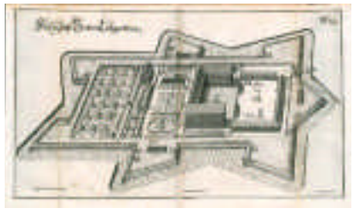
2 *ETH Day*

Images: Giulia Marthaler; Oliver Bartenschlager; Udo Sollberger (2)

Agenda

PUBLIC TOURS

26 March 2019, 6.15–7.15 p.m.
The golden age of fountains
In old prints, gardens and fountains are presented as an integral part of private and public spaces. They have long been a favourite subject of landscape architects, engineers and famous copper engravers.
ETH Zurich, Zentrum campus,
Library
→ www.tours.ethz.ch



22 January 2019, 6.15–7.15 p.m.
Thomas Mann's home in Pacific Palisades
The Thomas Mann Archives present a tour of the photo exhibition "Thomas Mann's home in Pacific Palisades" by German-American photographer Ina Jungmann.
ETH Zurich, Hönggerberg,
Thomas Mann Archives building
→ www.tours.ethz.ch

A test facility of the Laboratory of Hydraulics, Hydrology and Glaciology (VAW)

THE POWER OF WATER – HOW IT AFFECTS US

5 February 2019, 6.15–7.15 p.m.
The Laboratory of Hydraulics, Hydrology and Glaciology (VAW) conducts research into hydroelectricity, protection against natural hazards, and renaturation of watercourses. In this tour you can find out first-hand how researchers analyse flood events and ice flow.

ETH Zurich, Hönggerberg,
Campus Info entrance
→ www.tours.ethz.ch

150TH ANNIVERSARY OF ETH ALUMNI

18 May 2019
The ETH Alumni Association is celebrating its 150th anniversary next year. The highlight of the celebrations will be a gala event and supporting programme that will take place in the ETH main building. There will also be a series of small and major events linked by the motto "Science for Society". These will be held at ETH Zurich and at many Alumni Association affiliate locations across the globe.

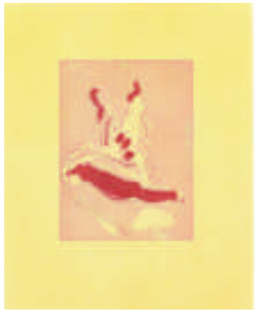
Alumni Association members can register here:
→ www.ethz.ch/alumni-anniversary

Images: ETH Library; Ina Jungmann; VAW;

MUSIC

5 February 2019, 7.30 p.m.
West Side Story
The Melisma Quartet, featuring violinist Gwendolyn Masin, will perform a concert in honour of Leonard Bernstein's 100th birthday (1918–1990). In a Swiss premiere, they will reduce *West Side Story,* Bernstein's classic Broadway musical, to its very essence: the music.
ETH Zurich, Zentrum campus,
Auditorium Maximum
→ www.musicaldiscovery.ch/konzerte/5

EXHIBITION



Thomas Schütte, untitled, print from the book Sweet Nothings, 2008

Until 27 January 2019
Sweet Nothings
Flowers are a perennial favourite in the fine arts and have delighted people since time immemorial. In this exhibition of works by Thomas Schütte, flowers can be observed in all their sweetness and delicacy – but the German artist often fractures this "sweet" idyll with striking effect.
ETH Zurich, Zentrum campus,
Graphische Sammlung
→ gs.ethz.ch/agenda

Daniel Schwartz, Vertigo

Until 17 February 2019
Daniel Schwartz – Glacier Odyssey
Glaciology in images would be a fitting description of the work produced by photographer Daniel Schwartz over recent years. He has even created some of his works in collaboration with glaciologists at ETH. His photographs feature glaciers not only as dynamic systems and archives of climate history, but also as places of personal remembrance and reservoirs of finite resources.
Museum of Fine Arts,
Bahnhofstrasse 35, Chur
→ www.buendner-kunstmuseum.ch/en

Listen up!
In its first four instalments, the new ETH podcast will shine a light on the dedicated researchers who are driving technology transfer. They include not only students from the Swissloop project who are taking part in Elon Musk's Hyperloop competition, but also Michela Puddu, co-founder of ETH spin-off Haelixa, whose job includes getting new investors on board. Have a listen and experience for yourself the true spirit of entrepreneurship at ETH Zurich.
→ www.ethz.ch/podcast

Recommended reading

ZURICH AIRPORT: ANATOMY OF A COMPLEX PLACE

Airports symbolise mobility, flows of passengers and freight, commerce, and an absence of history. But they are closely intertwined with their environment in many different ways. They are complex structures in which technology, nature, science, business, society, past and future are intermingled. *Æther* 01 explores one such place of complexity: Zurich-Kloten Airport. *Æther* is a new publication by ETH Zurich's Chair of Science Studies. The first issue is entitled "Kloten Airport: Anatomy of a Complex Place". It is the product of a research and writing workshop held as part of the ETH Master's course in the history and philosophy of knowledge. The students involved analysed every facet of Zurich airport.

intercom Verlag
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The explorer

Herbert Bay has done what others only dream of: the ETH alumnus sailed a yacht halfway round the world with his family. Now, he is immersing himself in foreign worlds on a professional basis – at Magic Leap, a company specialising in augmented reality.

TEXT Claudia Hoffmann IMAGE Annick Ramp

In his personal life, Herbert Bay has both feet firmly on the ground – but at work, he mixes the real world with the virtual. The 44-year-old is Principal Software Engineer, Digital Health & User Perception at the Zurich office of Magic Leap. The US company specialises in "mixed-reality" applications, in which 3D images are superimposed on real space. Together with health insurer CSS, Magic Leap recently demonstrated the prototype of a virtual physiotherapist. Projected into the user's living room using 3D glasses, the virtual figure guides them through their physical exercises. Further applications are in the development phase. "I've always been fascinated by the idea of virtual teleporting," says Bay. His vague notions of what it might involve really took shape when he saw Star Wars at the cinema as a 12-year-old.

Bay joined Magic Leap just a few months ago. Prior to that, he had a different passion: he spent four years sailing the high seas in a 12-metre yacht – together with his wife and two sons, who are now six and eight years old. Their journey took them across the Mediterranean, Atlantic and Pacific to faraway New Zealand. They often spent weeks, sometimes months, in one spot.

A yen for travel and adventure is in Bay's blood: his grandfather was a mechanic who went overseas to assemble machinery; his mother spent several years of her childhood on the Caribbean island of Curaçao. Even as a boy, Bay spent hours studying nautical charts while dreaming of travel. Growing up in Kreuzlingen on Lake Constance, he learned to sail and windsurf.

After secondary school, he followed in his grandfather's footsteps and completed an apprenticeship as a machine mechanic: "Like him, I wanted to explore the world." Having completed his military service, Bay packed up his surfboard and headed to the United States. He moved around a lot, worked nights as a bouncer and went windsurfing during the day; he lived life to the full and enjoyed every minute of it.

Fateful encounter

But he soon felt the need to learn more. After seven months in the US, he returned to Switzerland, gaining entrance to study mechanical engineering at Konstanz University of Applied Sciences. But then he had another idea: why not become a diplomat? The profession would enable him to see the world and learn all sorts of new things. "The travel bug had bitten me again," says Bay with a laugh. The fastest way to reach his goal was to study at university, so the then 21-year-old made a beeline for EPF Lausanne to get the qualifications he needed and to brush up his French. He completed a one-year preparatory course for the entrance examination, an option also open to foreigners who do not have a recognised qualification to study at a Swiss university. It was a decision that was to change his life. One of his fellow students on the course was a Tunisian woman called Asma – and she would later become his wife.

The two became inseparable. They began studying microengineering at EPF Lausanne and later spent an exchange semester together in Montreal, Canada. After they had both graduated with honours, Asma found a position as a doctoral student at IBM Research in Rüschlikon. Bay also looked for a job close by and, coincidentally, landed one at IBM as ›

"I've always been fascinated by the idea of teleporting."

ABOUT

Herbert Bay

After completing an apprenticeship as a machine mechanic, Herbert Bay studied microengineering at EPF Lausanne. He obtained a doctorate at ETH Zurich's Computer Vision Lab and founded two start-ups: kooaba and Shortcut Media. Today, he works as a software engineer at Magic Leap, a company specialising in 3D glasses and mixed-reality applications. After four years sailing the world, Bay now lives with his family in Wädenswil.

"I'd invested everything I had in the company."

well – but in the e-learning unit of the company's commercial arm. However, he soon grew frustrated with the work there. The idea of virtual teleportation that had inspired him since childhood resurfaced in his mind once again. To get a step closer to this goal, he began working on a thesis at ETH Zurich's Computer Vision Lab.

In his thesis, he developed a new, faster process for creating 3D reconstructions of a scene using only two images. The algorithm he developed, which is also suitable for image recognition and video stabilisation, is in widespread use today, for instance in smartphones.

Back then, in 2006, mobile phones were still a relatively new phenomenon, as was virtual reality. "The algorithm came at exactly the right time," says Bay. Together with his fellow doctoral student Till Quack and ETH professor Luc van Gool, Bay founded the spin-off kooaba, the purpose of which was to develop applications for image recognition on mobile phones. The trio made the company a success: in 2014, kooaba was acquired by chip manufacturer Qualcomm and integrated in its subsidiary Vuforia, which specialises in mixed-reality applications for mobile devices.

Hitting rock bottom

With the sale of kooaba in the offing, Bay felt the time had finally come to set off on his long-awaited sailing trip. He and his wife had been looking for a yacht and came across one in the south of France; both of them had also obtained their boat licences. They already knew from holiday sailing trips that it was feasible to sail with two small children aboard. But then something shocking happened: in August 2013, one day after they had signed the contract for their new yacht, Asma suffered a stroke. Although she recovered relatively quickly, she initially said she could no longer face the idea of a sailing trip.

"We hit rock bottom at Christmas," says Bay. The sale of kooaba was getting closer, but not yet done and dusted. "I'd invested everything I had in the company." He had only 50 francs left in his account, and the family's monthly income was immediately eaten up by rent, food and childcare fees. That's when Asma made the decision that they should set sail after all. She had suffered a stroke in the supposed safety of her own home, so what could possibly happen to her out at sea that would be worse than that?

In paradise

They weighed anchor in June 2014. In the Caribbean, and later in French Polynesia, they felt like they were in paradise: swimming, diving, wending their way in their dinghy through coral reefs to get to land, making new friends and, again and again, discovering unknown islands and stretches of coastline. The boys, in particular, enjoyed their life at sea: "We could hardly coax them off the boat." In an effort to stay creative and at the top of his game in terms of technology, Bay developed apps while on the trip and, from the helm of his yacht, managed Shortcut Media, another start-up he had set up before the sale of kooaba.

The journey was not without its ups and downs: once they sought refuge in a bay from an approaching storm, but the wind turned and unleashed its full force on their boat. Luckily, their anchor held.

After four years of travel – the Bays had reached New Zealand in the meantime – they knew they had to make a decision: should they keep going or bring their journey to an end? With time, life on board had become rather strenuous, and New Zealand was a long way from family and friends. The country also offered very little in the way of professional opportunities: "I was itching for a new challenge in the tech sector and for a chance to make a difference." With heavy hearts, the family decided to sell their yacht and return to Switzerland.

Although it has taken some getting used to, Bay likes putting down roots again. "Perhaps my inner rebel is a bit tamer now," he says. What's more, after the simple lifestyle at sea, he appreciates the luxury of being able to go to a supermarket and buy anything he wants. For the time being, he says, things are fine just the way they are. But what if the travel bug bites again sometime in the future? The question elicits a wry smile: "We'll see." ○

5 QUESTIONS

Sereina Riniker argues that we should always be open to changing our plans: *“Great opportunities often come out of the blue”.*

1 *What is your favourite spot at ETH?*

The rooftop terrace on the ETH main building. The views are fantastic, and you get to see Zurich from an unfamiliar perspective. Unfortunately I don’t go there as often as I would like because I spend most days on the Hönggerberg campus. Up here I like the Piazza in summer, when you can sit outside, though I think it would be even nicer if it had a few more trees and tables.

2 *How did you get where you are today?*

I would say it was a combination of curiosity, a passion for learning, logical thinking, creativity and discipline. I also received support from a lot of amazing people – in fact I still do. And there was a little bit of luck and serendipity involved too of course. The thing that motivates me is the desire to understand how things work.

I think it’s good to focus on what you enjoy and try to pursue that. And I also think that, whatever plans we may have, it’s important to remain open to new, and perhaps even unexpected, opportunities. There are many aspects of a career that you can’t plan in advance.

Sereina Riniker has been Professor of Computational Chemistry since 2014. This autumn she won the ETH Zurich Latsis Prize, which is awarded to exceptional researchers under the age of 40.
→ www.riniker.ethz.ch

3 *What’s the most significant problem you hope to solve through your research?*

To predict, using computational methods, how the 3D structures and dynamics of molecules change when parts of them are mutated. Flexible molecules such as proteins do not generally have a fixed 3D structure. Instead, they feature a certain amount of flexibility that can be an important part of how they work. To understand what’s going on when molecules interact with each other, you first need to know all the possible 3D structures. We can study the dynamics of molecular systems with the help of computer simulations. If we can reliably predict what effect mutations will have on the 3D structures, then we can make specific changes that can be used for therapeutic purposes.

4 *What makes you laugh out loud?*

The absurdity of life – plus animal videos and good satire! I like the monologues by American comedian Stephen Colbert for example, even though he often jokes about some pretty uncomfortable topics.

5 *Is there anything in life that you find impossibly difficult?*

Remembering people’s names when I first meet them. I have an excellent memory for faces, but I’m notoriously bad at names. That can sometimes be embarrassing at academic conferences, especially if I miss that window of opportunity when I find myself face-to-face with someone again and could still ask them to repeat their name without seeming too rude.

— Interview: Isabelle Herold

Image: Giulia Marthaler