TUM.Mobility

Strategy on Sustainable Mobility at the Technical University of Munich within the Framework of TUM AGENDA 2030

TUM.Mobility

Foreword

The mobility sector, with Germany's traditional economic strength and innovative excellence, faces the epoch-making task of turning the complex challenges of climate-friendly and digitally networked mobility into new opportunities while researching and implementing future-ready technologies, products and services. In the competition for technological leadership in future mobility, we as a technical university are called upon now more than ever to pool our resources and establish ourselves as a powerful force field with a global reach.

In integrative research centers dedicated to the key areas of energy systems, robotics and machine intelligence, TUM bundles its competencies in autonomous, shared and electric driving across the boundaries of schools and academic departments to achieve integrated and sustainable transportation development. With the electric vehicles MUTE/Viso.M, EVA and aCar, TUM has demonstrated the ability to develop innovative and market-ready vehicles suitable for different continents and climate zones and in recent years has become a trailblazer in electromobility research. In cooperation with the affiliated Center for Innovation and Start-ups, UnternehmerTUM – designated by the Federal Ministry of the Economy as the Digital Hub Mobility in 2016 – these activities have generated innovative spinouts such as Invenox (electric energy storage) and Evum (the aCar electric utility vehicle).

Airborne mobility in every conceivable form is a focal point of research and teaching in the new Department of Aerospace and Geodesy in Taufkirchen/Ottobrunn, where a "Space Valley" is being established under the Bavarian Government's Hightech Agenda Bayern. This will stand as a beacon of innovation in such technologies as air taxis, hyperloop transport technology and renewable energy sources such as hydrogen and synthetic fuels. In addition, the close links to the German Aerospace Center (DLR) in Oberpfaffenhofen will be intensified. At the TUM Campus Straubing for Biotechnology and Sustainability, scientists are studying renewable and low-emission synthetic fuels based on regenerative raw materials. The e-conversion Cluster of Excellence promotes the networking of nanoscience and energy sciences and studies innovations in energy conversion and storage for a stable, efficient and sustainable energy supply.

TUM contributes these competencies as a participant in such leading international initiatives as the EU-funded Knowledge and Innovation Community EIT Urban Mobility, with the headquarters of a central innovation hub in Munich, and through the lighthouse project TUMCREATE in Singapore. This brings together companies and research institutions, municipalities and civil society actors to develop innovative solutions for forward-looking urban development and sustainable urban mobility concepts.

Human-focused and trustworthy innovations for future mobility that serve the interests of society require a holistic approach extending far beyond technological developments. With its competencies in technology-oriented economic and social sciences, and through the TUM Institute for Ethics in Artificial Intelligence, TUM therefore effectively integrates economic, social, political, legal and ethical aspects into the innovation processes for new mobility concepts.

In addition, the Munich metropolitan region has an unrivalled concentration of expertise in the areas of mobility and digitalization in science, business, public policy and society, with numerous regional actors such as LMU Munich, DLR, Audi, BMW, MAN, Deutsche Bahn, Münchner Verkehrsgesellschaft, Munich Airport and the city of Munich. Under this strategic, mission-driven innovation culture, these actors are working together independent of all boundaries – regardless of area of expertise, institutional affiliation or philosophical outlook – to develop the mobility of tomorrow at the regional level. This presents the opportunity to implement strategies in Germany that can serve as role models for the future of mobility everywhere.

Against this backdrop and with its experience, TUM is perfectly positioned to conduct extensive research into the mobility of the future. Working with its partner institutions, it can design and test templates and scalable solutions for mobility in growing urban regions and let the public experience them first-hand. Consequently, TUM has started activating its entire research apparatus dedicated to mobility. The TUM.Mobility innovation network bundles the wide-ranging competencies in a transdisciplinary approach for sustainable mobility and combines the research cultures of more than 40 academic chairs.

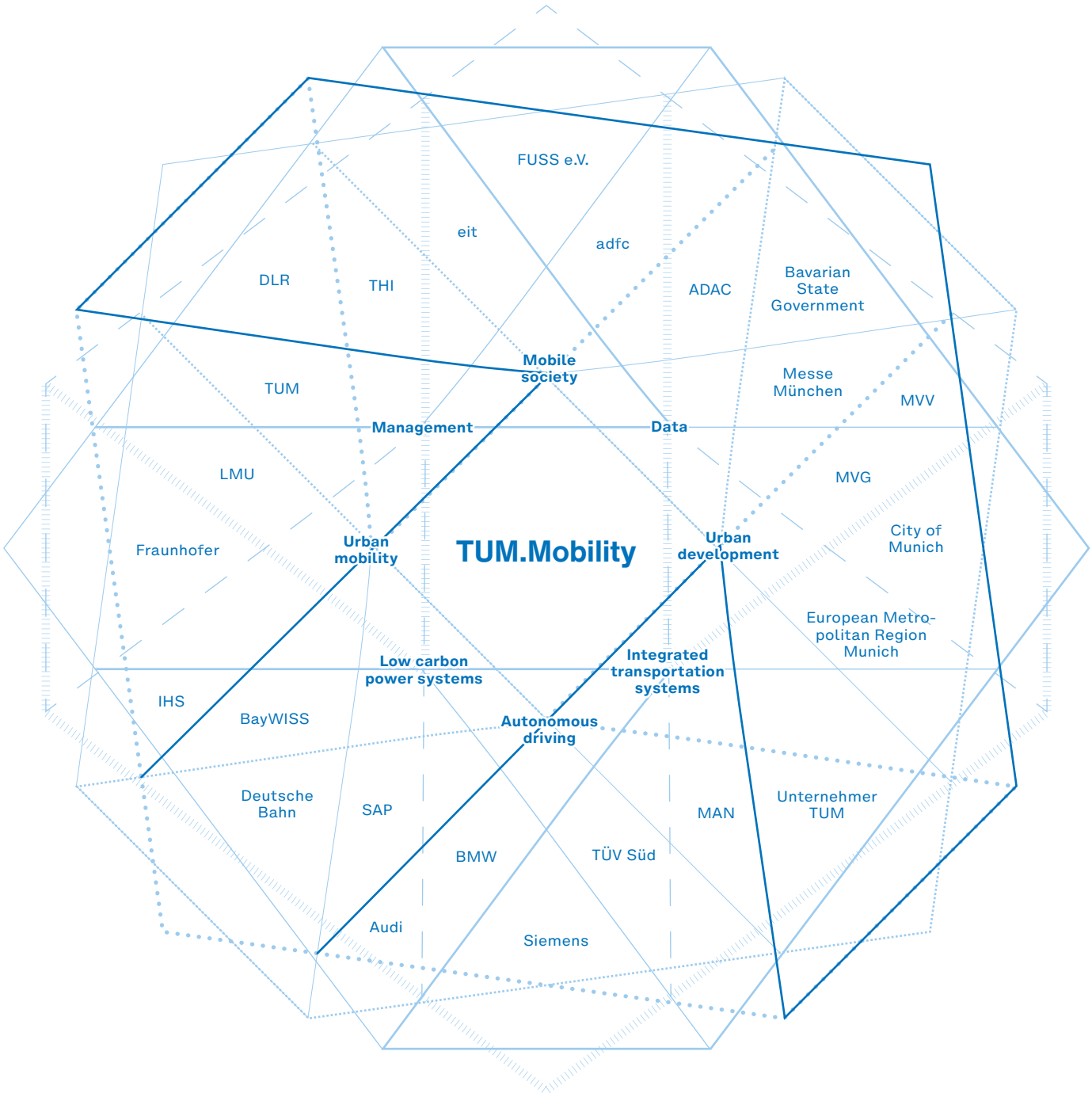
As part of **TUM AGENDA 2030**, this memorandum on **TUM.Mobility** outlines the potential of the key innovation fields defined under the future strategy **TUM.THE ENTREPRENEURIAL UNIVERSITY. Innovation by Talents, Excellence, and Responsibility**, with the specialized area "Sustainable Mobility ▪ Intelligent Traffic and Transport Systems".

Interested in joining us on the journey into a sustainable mobility future? Talk to us!

Munich ▪ Garching ▪ Freising-Weihenstephan ▪ Straubing ▪ Heilbronn ▪ Taufkirchen

Best regards,

Thomas F. Hofmann
President


FUSS e.V.
eit
adfc
DLR
THI
ADAC
Bavarian State Government
Mobile society
TUM
Messe München
MVV
Management
Data
LMU
MVG
Fraunhofer
Urban mobility
TUM.Mobility
Urban development
City of Munich
European Metro-politan Region Munich
Low carbon power systems
Integrated transportation systems
IHS
BayWISS
Autonomous driving
Deutsche Bahn
SAP
MAN
Unternehmer TUM
BMW
TÜV Süd
Audi
Siemens

Summary

Sustainable mobility is a vital issue for the future. Consequently, at the Technical University of Munich (TUM), the specialized field “Sustainable Mobility • Intelligent Traffic and Transport Systems” is a key component in the future concept TUM Agenda 2030, which is being implemented within the framework of the Excellence Strategy of the federal and state governments.

The Munich metropolitan region offers ideal conditions for a regionally anchored research and development network with a global reach capable of testing and implementing sustainable mobility on a sound scientific basis. This prosperous region with a high quality of life is an innovation ecosystem for shaping and developing mobility: It offers a unique constellation of innovative partners from the worlds of research, business and civil society. The research activities are also supported by public policy actors.

More than 40 research chairs at TUM are engaged in interdisciplinary research on the mobility of the future, with their efforts bundled in the TUM.Mobility research platform. The goal is to take a holistic approach to global societal challenges in order to

- develop commercially viable innovations and promote the far-reaching economic transformation processes with the support of a young and creative community,
- work with the various user groups to facilitate fair access to mobility by all members of society and
- minimize traffic-related impacts on health and the environment.

The TUM.Mobility strategy builds on TUM's established excellence in research and teaching as well as its strengths in fundamental areas of science and engineering.

TUM.Mobility encompasses eight key topic areas:

- **Urban mobility** → Mobility behavior and system analysis
- **Low carbon power systems** → Electromobility and alternative fuels
- **Autonomous driving** → Artificial intelligence and human-machine interfaces
- **Integrated transportation systems** → Infrastructure and operation
- **Urban development** → Networking and design of mobility systems
- **Data** → Traffic modeling and simulation
- **Mobile society** → Governance and participation
- **Management** → Business models and entrepreneurship

Motivation

Mobility is a basic human need. Active mobility plays an important role in healthy development and is a fundamental aspect of living independently to an advanced age. In mixed-use neighborhoods with a wide range of nearby destinations, more than half of all journeys are made by walking or cycling. Traffic safety is a duty of society, especially towards the most vulnerable. Safe and barrier-free access to traffic systems along with affordable and comfortable mobility are essential for social justice and cohesion in an open society.

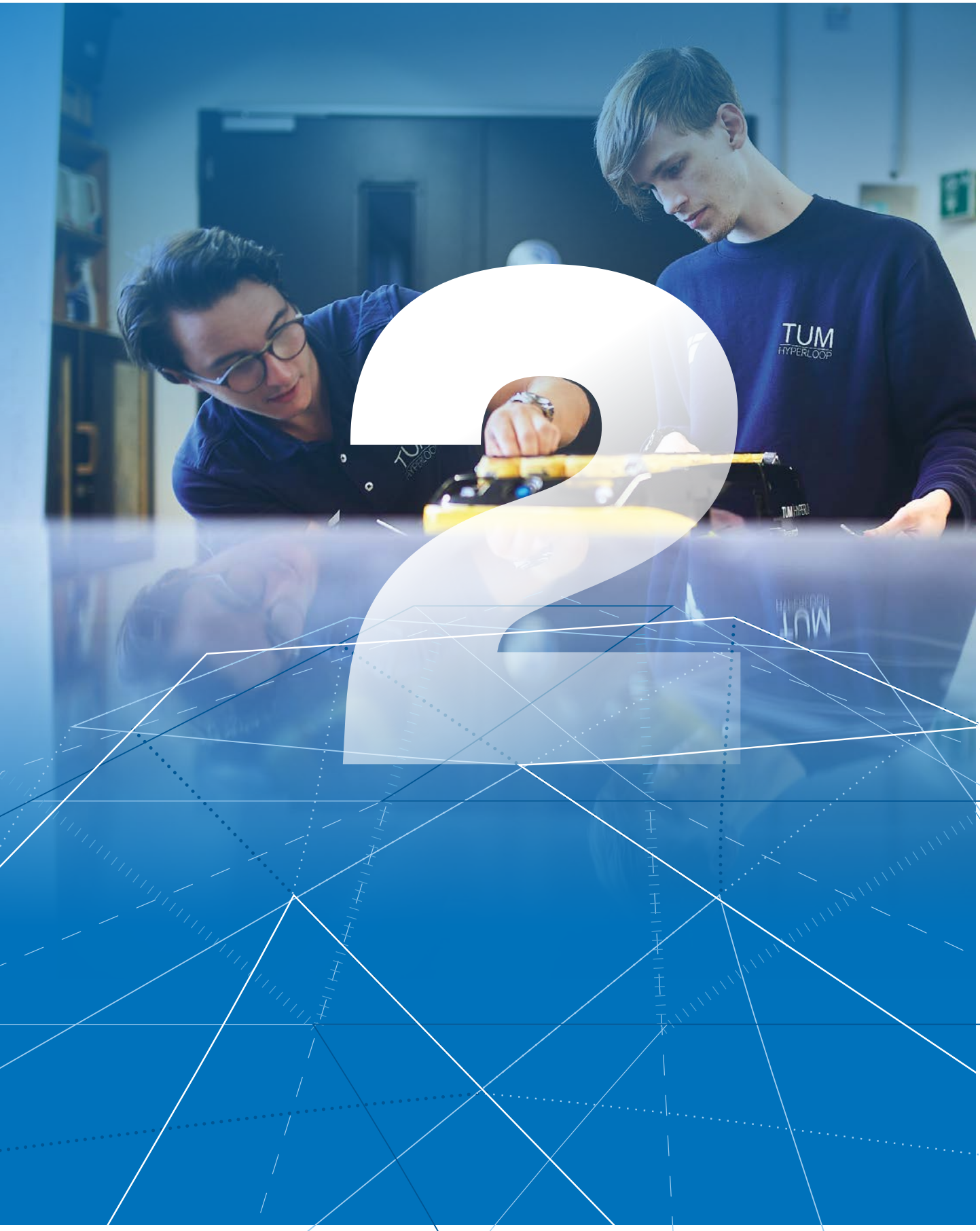
But mobility is also a global challenge. More than 25% of the world's climate gas emissions are attributable to the transport sector. The political goals of the German federal government and global climate justice call for a reduction of at least 30 percent by 2030. Efforts to date have not yet brought about significant reductions in traffic-related CO_2 emissions, however. In addition, cities and communities with high traffic volumes suffer from the effects of noise and pollutants. These pose a threat to public health. Consequently, changes in mobility behavior are needed in addition to technological solutions.

The sustainable development of mobility means creating and preserving personal mobility options and reinforcing economic and social exchange processes while reducing environmental impacts so that the world can continue to meet the mobility needs of future generations.

Mobility issues also play a key role in the future viability of the economy. The transition from fossil fuels to alternative energy sources, the technological innovations of digitalization, mobile communications, and the rise of artificial intelligence are the drivers of transformative developments such as electromobility and autonomous driving.

At the same time, a social and economic transformation is taking place, spawning entirely new business models and mobility services – for example in the areas of car sharing and taxi services. The rapid growth of online commerce and on-demand consumption and production is also transforming urban traffic in the areas of logistics, services and business in general. The car industry faces an inevitable structural transformation and rethinking process.

The Technical University of Munich wishes to team up with its diverse partners to play a decisive role in overcoming the challenges of shaping future mobility concepts while boosting Germany's economic and innovative strength.


TUM
HYPERLOOP

TUM.Mobility Agenda

Vision and mission

The Technical University of Munich is expanding its focus area “Sustainable Mobility and Intelligent Traffic Systems” into a strategic research platform. It is bundling its existing competencies and strengthening this key area of the Excellence Strategy in cooperation with partners from the research world, the private sector and civil society. Mobility at TUM now has an official address: TUM.Mobility. As a brand, it communicates local roots combined with a global ambition.

Strategic objectives

The TUM.Mobility agenda is dedicated to the goals of

- building an internationally competitive profile that creates a powerful gravitational field for regional, national and global innovations in sustainable mobility,
- overcoming existing sectoral boundaries across specialized fields and institutional structures through integrative cooperation and
- actively and responsibly shaping the dynamic socio-technical process of a future-proof mobility transformation by inviting entrepreneurial and public-sector actors to take part in the development and implementation of innovative ideas.

Implementation concept

TUM.Mobility is established as an interdisciplinary research platform to facilitate work on complex issues related to the design of sustainable mobility in conjunction with the various relevant perspectives. The following points will be decisive for achieving this objective:

1 Preparing a strategic research concept

Based on the strategic objectives, TUM.Mobility will develop a program to implement inter- and transdisciplinary research in sustainable mobility and intelligent transportation systems. This concept will be continually adapted to reflect important issues and incorporate appropriate support options and will be updated on a yearly basis.

2 Networking within TUM

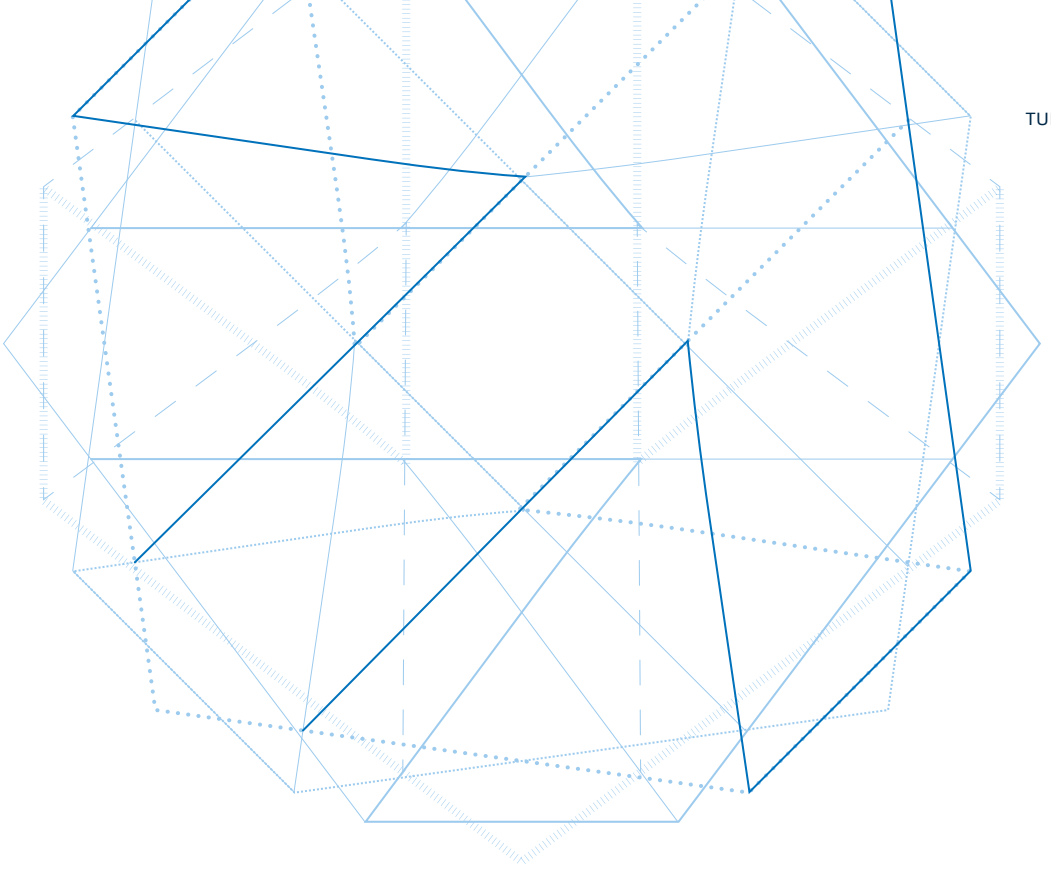
Targeted exchanges and interactions within our own institution are essential for ensuring multilateral inspiration among the diverse actors. Consequently, TUM.Mobility provides for regular encounters to bring together the participating scientists, for example in a monthly workshop with interested doctoral candidates, meetings of the members at least on a quarterly basis, and an annual strategy conference with the university leadership.

3 Regional and international cooperation

TUM.Mobility is an integral part of the ONE MUNICH strategy, which raises the cooperation with regional actors to a new level. This includes providing scientific support to the existing governance networks on questions of sustainable mobility in the Munich metropolitan region. In addition, TUM.Mobility hosts international scientific conferences and is present on regional stages and in national arenas. International contacts will be intensified and existing exchange programs such as those for TUM doctoral candidates and for guest scientists will be utilized by placing a focus on specific subject areas.

4 Inter- and transdisciplinary teaching: Master's, doctoral and continuing education programs

Right from the start, creative young talents from various scientific fields will be involved in cooperative research activities with industry partners and other practitioners to drive change and provide fresh ideas. Doctoral candidates will be offered the opportunity to join these efforts within the corresponding topic-specific program guidelines of the TUM Graduate School. TUM.Mobility is developing specific life-long learning programs for professionals.



5 Cooperative and co-creative research and development projects

The innovation program on sustainable mobility will be strengthened through the conventional funding options of the German Research Foundation (DFG), the Federal Ministry of Education and Research (BMBF) and the European Union as well as research projects commissioned by industry and the public sector. Other financing concepts will be established for independently funded research initiatives such as internal TUM incentive systems and targeted fundraising, foundations or non-earmarked industry grants. All research results will be released internationally and made publicly accessible.

6 Experimental implementation in living labs and transferable strategies

Sustainable mobility requires the courage to try things out. Innovative research results should be put into practice as soon as possible and experiments should be conducted under real-world conditions to provide model solutions for traffic problems at the local level. The coronavirus pandemic has created new opportunities to use experimentation clauses for temporary implementation of innovative projects as an important contribution to sustainable development.

7 Implementation of innovations through targeted entrepreneurship support

The most effective path for putting research results into practice is to implement them through company initiatives, start-ups and other forms of economic cooperation. With this in mind, innovative ideas are assessed right from the start in terms of economic potential and receive entrepreneurial support in cooperation with established partners. Hackathons, boot camps and incubator/accelerator programs are carried out in cooperation with strong partners such as UnternehmerTUM.

8 Public relations and societal value

The development of innovative solutions for pressing societal challenges is pushed forward in a dialog with the public and in cooperation with political actors. Citizens are included in this process through targeted media relations, public talks and discussion forums. Existing cooperative relationships such as the one with the Deutsches Museum transport branch and newly established formats such as the TUM Think Tank facilitate the transfer of scientific expertise into real-world decision-making processes.

Fields of competence at TUM

3.1

Urban mobility
→ Mobility behavior and system analysis

More than 50 percent of the world's population live in urban areas. Cities and transportation are coupled in a dynamic system in which urban mobility concepts have a major impact on our everyday behavioral options and our mobility cultures.

A key factor when creating sustainable urban mobility is the need to harmonize diverse individual mobility needs with a publicly supported urban management and transportation system. With the European innovation program EIT Urban Mobility, TUM – with more than 50 European partners – forms a focal point for education, research and entrepreneurial implementation that offers enormous potential over the next 10 years.

Future research areas include

- integration of innovative mobility services (such as scooter sharing) as complementary components in public transportation networks,
- development of inter- and multi-modal mobility stations as future mobility hubs,
- experimental realignment and design of streetscapes, giving priority to pedestrian and bicycle traffic,
- intelligent traffic and mobility management, including urban logistics and business mobility and
- dynamic mobility pricing for all forms of mobility, including parking management, geared to the local situation.

Related research chairs:

Name / *Contact	Chair	Department (School)
Constantinos Antoniou	Transportation Systems Engineering	Mobility Systems Engineering (ED)
Benedikt Boucsein	Urban Design	Architecture (ED)
Klaus Bogenberger*	Traffic Engineering and Control	Mobility Systems Engineering (ED)
Mirko Hornung	Aircraft Design	Aerospace and Geodesy (ED)
Alexander Hübner	Supply and Value Chain Management	Operations & Supply Chain Management (MGT)/Straubing
Thomas Kolbe	Geoinformatics	Aerospace and Geodesy (ED)
Werner Lang	Energy Efficient and Sustainable Design and Building	Architecture (ED)
Liqiu Meng	Cartography	Aerospace and Geodesy (ED)
Mark Michaeli*	Sustainable Urbanism	Architecture (ED)
Rolf Moeckel	Modeling Spatial Mobility	Mobility Systems Engineering (ED)
Sebastian Pfotenhauer	Innovation, Society and Public Policy	MCTS/Innovation & Entrepreneurship (MGT)
Maximilian Schiffer	Operations and Supply Chain Management	Logistics (MGT)
Miranda Schreurs	Environmental and Climate Policy	Politics (SO)
Alain Thierstein	Urban Development	Architecture (ED)
Gebhard Wulfhorst*	Urban Structure and Transport Planning	Mobility Systems Engineering (ED)

(all TUM Schools → p.42)

3.2

Low carbon power systems
→ Electromobility and alternative fuels

Climate change, increasing air pollution and rising noise emissions – many of today's forms of mobility no longer meet the needs of a sustainable society. The transformation of transportation presents the opportunity to embark on new paths: Future mobility will be based on alternative drive technologies and energy sources, with a strong focus on electromobility.

This gives rise to many questions that require a scientific approach:

- How can alternative energy sources and drive technologies be optimized to the point where they can fully replace fossil fuels?
- Which energy and vehicle concepts will generate the biggest benefits for future mobility and in which sectors?
- How can new forms of mobility be intelligently integrated into tomorrow's societies?

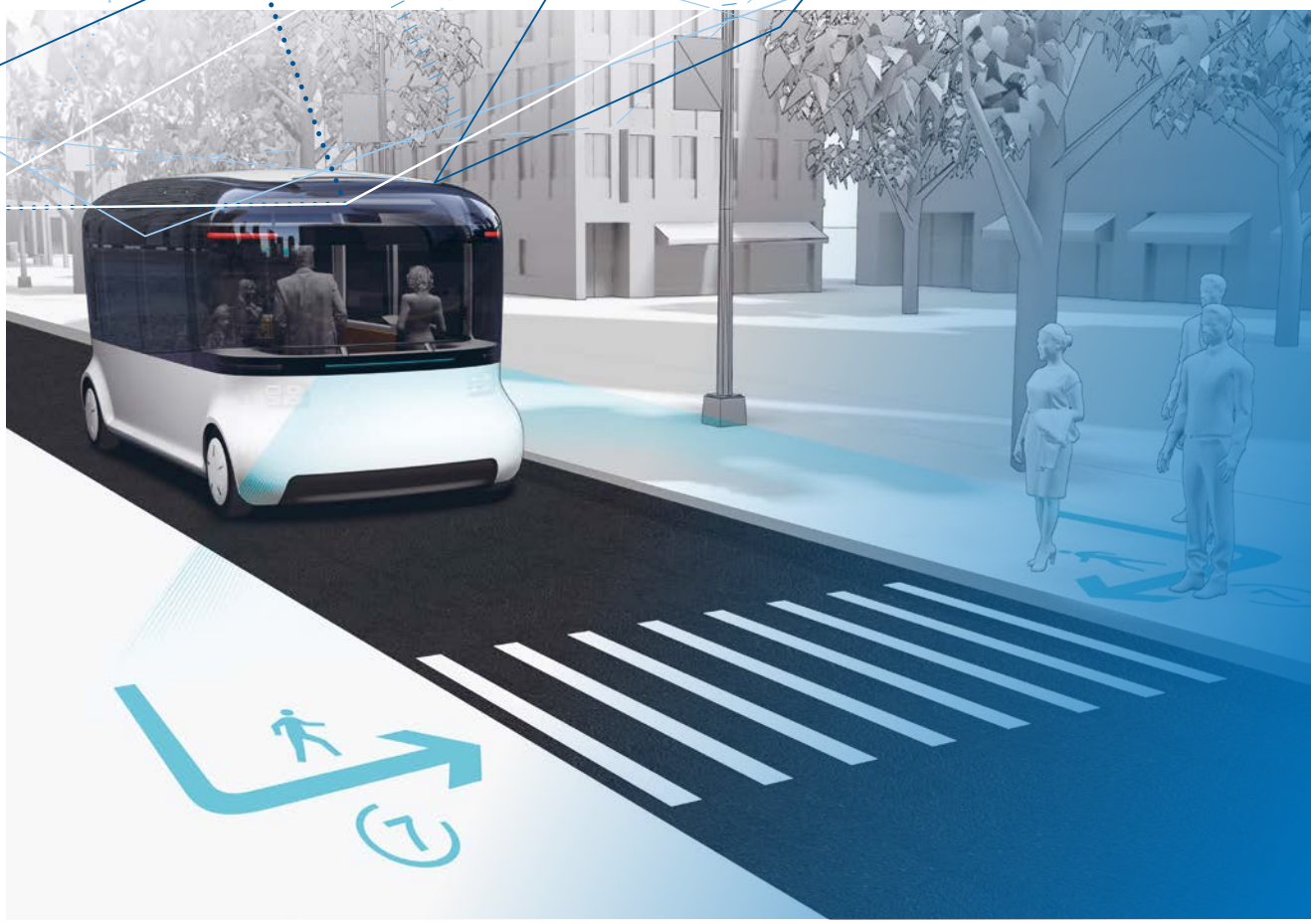
To answer these questions, the cooperation of all fields will be needed, starting with the optimization of the battery cell, the fuel cell and biological or synthetic fuels through to the intelligent integration of alternative energy sources such as hydrogen across all forms of mobility.

Related research chairs:

Name / *Contact	Chair	Department (School)
Klaus Bogenberger	Traffic Engineering and Control	Mobility Systems Engineering (ED)
Jakob Burger	Chemical Process Engineering	Chemistry/Campus Straubing (TUMCS)
Stephan Freudenstein	Road, Railway and Airfield Construction	Civil and Environmental Engineering (ED)
Hubert Gasteiger	Technical Electrochemistry	Chemistry (NAT)
Thomas Hamacher	Renewable and Sustainable Energy Systems	Energy (ED)
Agnes Jocher*	Sustainable Future Mobility	Aerospace (ED)
Andreas Jossen*	Energy Storage Technology	Energy (ED)
Markus Lienkamp*	Automotive Technology	Mobility Systems Engineering (ED)
Thomas Sattelmayer	Thermodynamics	Engineering Physics and Computation (ED)
Maximilian Schiffer	Operations and Supply Chain Management	Logistics (MGT)
Volker Sieber	Chemistry of Biogenic Resources	Chemistry/Campus Straubing (TUMCS)
Gebhard Wulfhorst	Urban Structure and Transport Planning	Mobility Systems Engineering (ED)
N.N. (successor of Prof. Frenkler)	Industrial Design	Architecture (ED)
N.N. (successor of Prof. Wachtmeister)	Sustainable Propulsion Systems	Mechanical Engineering (ED)

(all TUM Schools → p.42)

3.3



Autonomous driving → Artificial intelligence and human-machine interfaces

Significant progress in the fields of artificial intelligence harbors the promise of autonomous mobility systems becoming fully operational. Autonomous systems can bring about a disruptive transformation in transportation systems and infrastructures. A successful transformation of this kind will require a holistic approach, encompassing strategic and operational perspectives as well as vehicle technology. The impact on user acceptance must also be assessed.

The development, modeling, simulation and analysis of autonomous fleets, particularly in the context of mobility as a service, will be carried out from a system-based perspective, in which various mobility services such as public transportation, car sharing and taxi services are interconnected.

The focus of this subject area will cover such aspects as

- the interplay between automated vehicle fleets and conventional public transportation/motorized individual traffic,
- the analysis of economic viability of automated traffic,
- a game theory assessment of customer and provider reactions,
- a regulatory, ethical and social assessment of autonomous systems and
- a multi-criteria assessment of the effects and implementation paths.

On the basis of the system analysis, operational control mechanisms and algorithms will be developed to operate the systems under consideration.

Applying the “design thinking” innovation process, this area will look at the reallocation of roles between humans and vehicles and design innovative human-machine interfaces. This includes the communication of automated vehicles with other traffic participants.

Related research chairs:

Name / *Contact	Chair	Department (School)
Matthias Althoff	Cyber-Physical Systems	Computer Science Engineering (CIT)
Constantinos Antoniou	Transportation Systems Engineering	Mobility Systems Engineering (ED)
Sophie Armanini	eAviation	Aerospace (ED)
Uwe Baumgarten	Operating Systems	Computer Science Engineering (CIT)
Klaus Bengler*	Ergonomics	Mechanical Engineering (ED)
Klaus Bogenberger*	Traffic Engineering and Control	Mobility Systems Engineering (ED)
Marco Caccamo	Cyber-Physical Systems in Production Engineering	Mechanical Engineering (ED)
Florian Holzapfel	Flight System Dynamics	Aerospace (ED)
Markus Lienkamp*	Automotive Technology	Mobility Systems Engineering (ED)
Christoph Lütge	Business Ethics	Economics & Policy (SO)
Rolf Moeckel	Modeling Spatial Mobility	Mobility Systems Engineering (ED)
Jörg Ott	Connected Mobility	Computer Science Engineering (CIT)
Markus Ryll	Autonomous Aerial Systems	Aerospace (ED)
Maximilian Schiffer*	Operations and Supply Chain Management	Logistics (MGT)
Wolfgang Utschick	Signal Processing	Computer Science Engineering (CIT)

(all TUM Schools → p.42)

3.4

Integrated transportation systems
→ Infrastructure and operation

An integrated mobility system is made up of various compatible components that make efficient use of the existing infrastructure. In the strategic planning, multimodal and intermodal systems are designed and the various transportation modes are systematically integrated. The aim is to utilize and improve the efficiency of existing systems, such as rail transport, and secure it for the future.

New mobility options are continually emerging, such as car sharing, e-scooters and – if we look ahead – autonomous flight systems. Research activities will focus on mobility needs and structural integration:

- How do we operate a system of this kind?
- Who are the new users?
- What modes of transport have the customers used in the past?
- How can new mobility options be integrated into existing infrastructures?

The future automation of vehicles in combination with ride pooling and other on-demand mobility services will cause a shift in the system boundary between public transportation and motorized individual traffic. Logistics traffic and personal transportation will also be increasingly networked, for example through crowd logistics.

As existing transportation systems are optimized, entirely new technologies are emerging – from automated drones for personal transportation and logistics to revolutionary transport systems like the hyperloop. These systems will also have to be strategically planned, integrated into the multimodal infrastructure and operated efficiently. This is the only way of ensuring that they will benefit society.

Related research chairs:

Name / *Contact	Chair	Department (School)
Constantinos Antoniou*	Transportation Systems Engineering	Mobility Systems Engineering (ED)
Klaus Bogenberger*	Traffic Engineering and Control	Mobility Systems Engineering (ED)
Johannes Fottner*	Materials Handling, Material Flow, Logistics	Mechanical Engineering (ED)
Stephan Freudenstein	Road, Railway and Airfield Construction	Civil & Environmental Engineering (ED)
Florian Holzapfel	Flight System Dynamics	Aerospace (ED)
Mirko Hornung	Aircraft Design	Aerospace (ED)
Agnes Jocher	Sustainable Future Mobility	Aerospace (ED)
Stefan Minner	Logistics and Supply Chain Management	Logistics (MGT)
Maximilian Schiffer	Operations and Supply Chain Management	Logistics (MGT)
Gebhard Wulfhorst	Urban Structure and Transport Planning	Mobility Systems Engineering (ED)

(all TUM Schools → p.42)

3.5

Urban development
→ Accessibility and design of mobility systems

Urban development is concerned with the manifestation, emergence and transformation of urban spaces, and is closely networked with the development of transportation systems. When planning this spatial development, the diversity of structural elements is taken into consideration, as well as their interactions, processes and actors, in a functionally defined urban area.

Urban development is always subject to the conflicting forces of diversification and specialization, allowing a range of activities at certain locations while at others creating spatial clusters for optimized value chains.

The connectivity between the locations overcomes the boundaries between built and unbuilt spaces, different levels of scale, administrative territories and competencies. As a result, polycentric urban areas are linked at the level of metropolitan regions to cultural landscapes with a rural character in formal and informal socio-spatial production processes. With accessibility planning, the focus shifts to the interconnections between transportation networks and urban development, revealing the potential of integrated land-use and transport planning.

The mobility spaces serve as integrators across multiple spatial scales. In street spaces, a balance must be found among the contrasting expectations regarding the quality of connectivity, ease of access, and the spatial experience. The experimental transformation of streets and public spaces is a task that combines the sectoral perspectives of the respective disciplines, thus contributing to the systematic transformation of urban mobility.

Related research chairs:

Name / *Contact	Chair	Department (School)
Klaus Bogenberger	Traffic Engineering and Control	Mobility Systems Engineering (ED)
Benedikt Boucsein	Urban Design	Architecture (ED)
Regine Keller	Landscape Architecture and Public Space	Architecture (ED)
Mark Michaeli*	Sustainable Urbanism	Architecture (ED)
Stephan Pauleit	Strategic Landscape Planning and Management	Architecture (ED)
Sebastian Pfotenhauer	Innovation, Society and Public Policy	Innovation & Entrepreneurship/ MCTS (MGT)
Alain Thierstein*	Urban Development	Architecture (ED)
Gebhard Wulfhorst*	Urban Structure and Transport Planning	Mobility Systems Engineering (ED)

(all TUM Schools → p.42)

3.6

Data → Traffic modeling and simulation

Traffic models are used to model the behavior of users, and serve in particular to assess the impact of measures before implementing them. They test the effects of planned measures such as infrastructure investments or operational optimization measures as well as the potential impact of changing mobility behavior, energy costs, or outbreaks of infectious diseases, for example.

A wide range of models is developed and applied at TUM, ranging from small-scale pedestrian traffic simulations to entire urban transportation systems through to international models of inter-regional traffic flows.

The modeling methodologies used by TUM range from accessibility models to agent-based traffic simulations and holistic system dynamics models. Both passenger and freight traffic are covered, along with all modes of transport, including pedestrian and bicycle traffic, micro-mobility (e-scooters), private cars, public transportation, intercity rail, aircraft, hyperloop and air taxis. Models developed in-house by TUM include, among others, the MITO travel demand model, the SILO land use model, the City-MoS traffic simulation model, the MomenTUM pedestrian traffic simulation tool, the GOAT interactive tool for modeling the potential of active mobility and the FDM aviation fleet development model.

Extensive traffic data are continually collected, organized in databases and analyzed, applying complex model estimation processes as well as machine learning methods and taking into account personal data protection issues and the utilization of open data.

Related research chairs:

Name / *Contact	Chair	Department (School)
Nikolaus Adams	Aerodynamics and Fluid Mechanics	Mechanical Engineering (ED)
Constantinos Antoniou*	Transportation Systems Engineering	Mobility Systems Engineering (ED)
Klaus Bogenberger*	Traffic Engineering and Control	Mobility Systems Engineering (ED)
André Borrmann	Computational Modeling and Simulation	Civil & Environmental Engineering (ED)
Agnes Jocher	Sustainable Future Mobility	Aerospace (ED)
Mirko Hornung	Aircraft Design	Aerospace (ED)
Alois Knoll	Robotics, Artificial Intelligence & Embedded Systems	Computer Science Engineering (CIT)
Boris Lohmann	Automatic Control	Engineering Physics and Computation (ED)
Markus Lienkamp	Automotive Technology	Mobility Systems Engineering (ED)
Florian Matthes	Software Engineering for Business Information Systems	Computer Science Engineering (CIT)
Rolf Moeckel*	Modeling Spatial Mobility	Mobility Systems Engineering (ED)
Jörg Ott*	Connected Mobility	Computer Science Engineering (CIT)
Thomas Sattelmayer	Thermodynamics	Engineering Physics and Computation (ED)
Wolfgang Wall	Computational Mechanics	Engineering Physics and Computation (ED)
Gebhard Wulfhorst	Urban Structure and Transport Planning	Mobility Systems Engineering (ED)

(all TUM Schools → p.42)

3.7

Mobile society
→ Governance and participation

The future of mobility involves both technological and social implications. Mobility determines where we live and work, how we live together, and which aspects of life are open to which members of society. Aspects of mobility are at the heart of many societal challenges and the approaches to tackling them, for example with respect to the Sustainable Development Goals of the United Nations.

At the same time, innovations in mobility create new challenges for policy makers and society: How can we test and regulate autonomous driving? Do the different groups in society have equal access to shared mobility services? How can we make innovations compatible with the needs of society. How can we build inclusiveness, co-creativity and a sense of responsibility into innovation processes? What kind of mobility do we want in the future and how can we keep the disruptions of transformation processes to a minimum?

With its unique focus on technology-oriented social sciences, TUM is capable of systematically studying and shaping mobility as a socio-technological phenomenon.

The TUM School of Management and the School of Social Sciences, currently being established, have numerous methodological competencies at their disposal in inter- and transdisciplinary research and broad expertise in such areas as:

- participative and co-creative innovation processes,
- societal transformation processes,
- comparative studies on mobility systems, user behavior and regulation,
- interrelationships between mobility, sustainability, climate and social justice,
- technology assessment and new regulatory approaches and
- social responsibility in research and development.

Related research chairs:

Name / *Contact	Chair	Department (School)
Klaus Bengler*	Ergonomics	Mechanical Engineering (ED)
Christian Djeffal	Law, Science and Technology	MCTS (MGT)
Claudia Doblinger	Innovation and Technology Management	Innovation & Entrepreneurship (MGT)/Straubing
Stefan Minner	Logistics and Supply Chain Management	Logistics (MGT)
Ruth Müller	Science and Technology Policy	Economics & Policy/MCTS (MGT)
Sebastian Pfotenhauer*	Innovation, Society and Public Policy	Innovation Entrepreneurship/ MCTS (MGT)
Miranda Schreurs*	Environmental and Climate Policy	Politics (SO)
Christoph Ungemach	Marketing and Consumer Behavior	Marketing, Strategy & Leadership (MGT)
Stefan Wurster	Policy Analysis	Economics & Policy (SO)
Gebhard Wulfhorst	Urban Structure and Transport Planning	Mobility Systems Engineering (ED)

(all TUM Schools → p.42)

3.8

Management
→ Business models and entrepreneurship

The structure and organization of mobility in passenger and freight transport is undergoing a major economic upheaval. Companies are currently facing massive disruptions that are also posing challenges for the entire German economy. The market capitalizations of innovative electric vehicle manufacturers exceed those of established car makers in some cases. Platform-based mobility solutions and delivery services are throwing established service sectors and social structures into turmoil. Technology companies and start-ups are increasingly capturing shares of the mobility market, creating new business models based on user data, and offering mobility as a service. At the same time, digitalization and growing awareness of sustainability around the world are causing shifts in consumption patterns.

TUM.Mobility will continually develop new approaches for the successful implementation, dissemination, scalability and financing of innovative business models in this dynamic environment. Technological innovations will be treated without exception in conjunction with economic and business considerations and in the context of broader issues of sustainability and social responsibility.

Topics addressed in interdisciplinary research at TUM and through the start-up activities under the auspices of UnternehmerTUM include:

- market and platform design issues,
- assessment of economic, ecological and social mobility options from the standpoint of various stakeholder groups,
- financing and pricing mobility infrastructure,
- planning and controlling mobility networks and intermodal mobility services using artificial intelligence methods,
- user behavior and marketing strategies, company strategies and organization and
- entrepreneurship training and support for young start-ups.

Related research chairs:

Name / *Contact	Chair	Department (School)
Martin Bichler	Decision Sciences and Systems	Computer Science (CIT)
Johannes Fottner*	Materials Handling, Material Flow, Logistics	Mechanical Engineering (ED)
Gunther Friedl	Management Accounting	Finance & Accounting (MGT)
Hanna Hottenrott	Economics of Innovation	Economics & Policy (MGT)
Stefan Minner*	Logistics and Supply Chain Management	Logistics (MGT)
Sebastian Pfotenhauer*	Innovation, Society and Public Policy	Innovation Entrepreneurship/ MCTS (MGT)
Maximilian Schiffer	Operations and Supply Chain Management	Logistics (MGT)
Isabell Welpe	Strategy and Organization	Marketing, Strategy & Leadership (MGT)

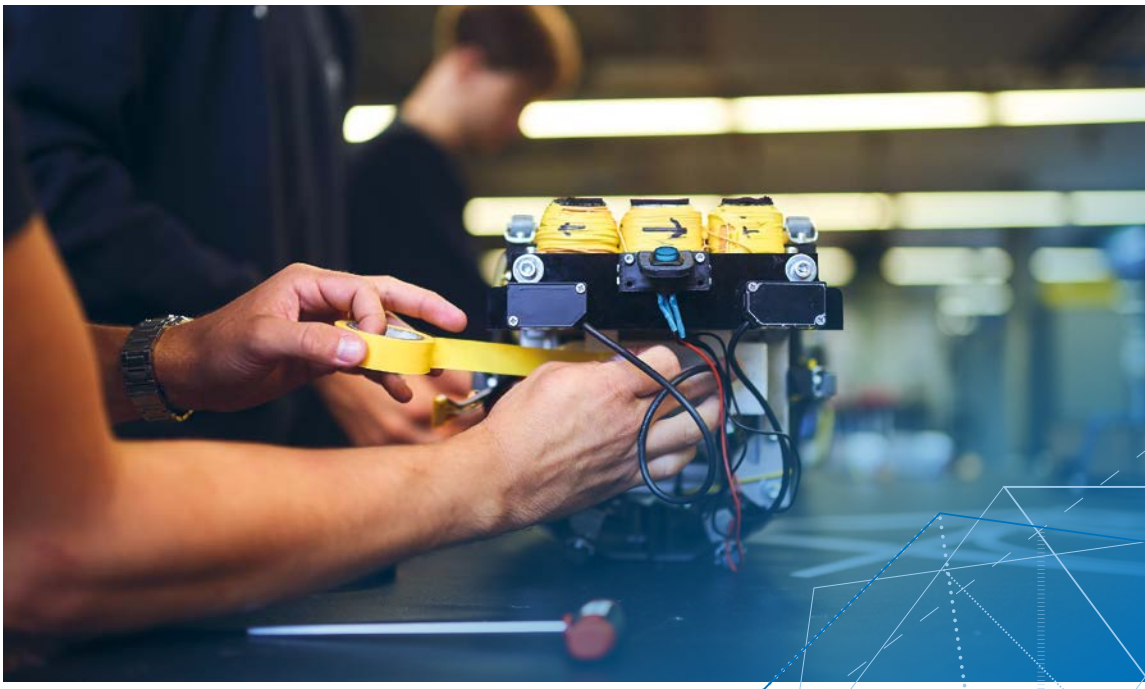
(all TUM Schools → p.42)

Working together to shape the future of mobility

Building on its specialized competence, TUM is bundling its intellectual and financial resources with the goal – through interdisciplinary approaches – of fostering and developing future-oriented teaching, excellent research and market-oriented innovations to make sustainable mobility a reality.

Hands-on teaching

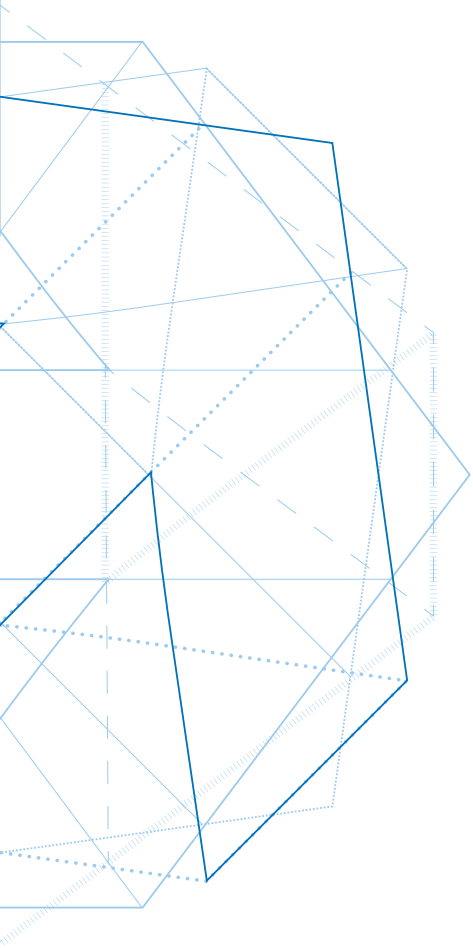
In TUM.Mobility, students and doctoral candidates working on sustainable mobility topics from the perspective of their various disciplines are integrated at the earliest possible stage.



The experience gained in the interdisciplinary master project "euMOVE – European Mobility Venture", in which students from five study programs compared mobility concepts from European cities such as Barcelona, Helsinki and Stockholm with those of Munich, is feeding into new inter- and trans-disciplinary student projects. Project weeks serve to promote international participation and offer the opportunity to take part in thematic summer schools, for example together with European partners with hands-on roles in the mobility sector, and in entrepreneurial teaching modules.

Under the auspices of the innovation network EIT Urban Mobility, a European doctoral training network is currently under development. Doctoral candidates in TUM.Mobility subject areas will be able to take part in an interdisciplinary program line at the International Graduate School of Science and Engineering (IGSSE). This will encourage dialog across the boundaries of subject areas and sectors to complement the participants' intensive engagement in their own specialized fields.

Regional actors, companies and entities serving public functions, some of which have their own educational and doctoral programs in the area of mobility (such as BMW, MAN, Siemens, the State of Bavaria, various foundations), will also have the opportunity to explore the potential and synergies of a strategic partnership in transdisciplinary teaching. This will give the regional partners access to creative ideas and innovative input from a young and dynamic research community. At the same time, the talented young scientists at TUM will benefit from the entrepreneurial mindset and the exchanges of ideas with real-world practitioners.



Exploring the potential and synergies of a strategic partnership in transdisciplinary teaching

The experiences gained through online teaching will be used to create programs and content designed for life-long learning. In conjunction with the programs of EIT Urban Mobility and regional cooperation partners such as UnternehmerTUM, TUM.Mobility is developing massive open online courses (MOOCs), webinars on entrepreneurial learning and specific training and coaching content for managers in government and public administration, the private sector and society.

Excellent research

An important priority for project development in sustainable mobility is the bundling and strengthening of scientific projects. Above and beyond the excellent research activities already taking place, new forms of cooperation will be developed with the TUM.Mobility platform.

EIT Urban Mobility offers outstanding opportunities for European cooperation on all topics related to the future of mobility. One of five regional hubs, the Innovation Hub Central, with headquarters in the future Munich Urban Co-Lab in the city's creative district, will be formed by TUM along with private sector partners (such as BMW, Siemens, MAN), research partners from the Fraunhofer-Gesellschaft or UnternehmerTUM, and the city of Munich, as well as institutions in Stuttgart, Milan, Vienna, Switzerland and Istanbul/Turkey. More than 50 partners from across Europe are involved. The challenges facing European cities in shaping sustainable mobility will be addressed in innovation projects, reference projects involving the general public, and start-up funding, but also in new, entrepreneurial teaching formats. TUM will be involved in the implementation of numerous projects right from the start. The program currently has total funding of up to 400 million euros (2020–2026). The annual project calls are also open to new partners and will be continued beyond 2026.

In addition, **M Cube** – the Munich cluster for the future of mobility in urban areas – is now taking shape at TUM. At present it is receiving funding from the Federal Ministry of Education and Research (BMBF) in a concept development phase. Together with a large number of regional actors, TUM is drawing up a nine-year cluster strategy and plans the first implementation projects for 2021 to 2024. Following a highly competitive pre-selection process open to applications from across Germany, the program will be nominated as a future cluster to the Federal Ministry of Education and Research (BMBF). If the bid is successful, annual funding of up to 5 million euros can be expected. The emphasis will be on research and development projects in the areas of:

- electrification and automation of traffic systems,
- developing and integrating mobility options and
- networking locations and designing mobility spaces.

3

Dimensions:

Quality of time
Quality of space
Quality of air

Each individual project would have at least two project leaders from different scientific disciplines along with a private-sector and a public-sector partner. All projects will be implemented in a dialog with the public and will pursue strategic goals geared to improvements along the three dimensions: "Quality of time", "Quality of space" and "Quality of air".

Based on the sustainable mobility experiences gained in many **living labs** in Munich (including the new Parkstadt Schwabing and Domagkpark/CIVITAS ECCENTRIC, the existing districts in Sendling/City2Share and the urban renewal concept in Neu-Aubing/Westkreuz/SmarterTogether) and strategic projects such as EASYRIDE, new innovation sites and test areas for automated driving are currently being developed in the north of Munich.

Since 2018, preparations have been underway at TUM for a large-scale research project on the **hyperloop**. The hyperloop is a proposed transport system in which a high-speed train would travel at close to the speed of sound through a tube maintained at a partial vacuum. The hyperloop network was established after the TUM student team attracted worldwide attention after repeatedly winning top honors in the SpaceX Hyperloop Pod Competition, where they went head to head against the world's leading universities. In this competition, student teams from around the world were challenged to design and build the fastest "pod" – as the capsules intended to transport passengers through the tube are known. An increasing number of research chairs from various disciplines have supported the project with scientific and engineering expertise and supervision of thesis projects. Since the beginning of 2020, these research projects have been funded by the Bavarian state government.

TUM is the driving force powering numerous mobility initiatives

Singapore is a special location for TUM with regard to mobility. It has now been 15 years since the **Campus TUM Asia**, located in the Asian megacity, began offering a two-year, full-time master's program in Rail, Transport and Logistics, which prepares graduates to work as specialists in that rapidly growing field. The international research and innovation campus TUMCREATE in Singapore has been studying electromobility and autonomous, networked public transport systems for 10 years. Continuing its strong presence, TUM is now working alongside local partners to establish an interdisciplinary Transport and Logistics research and training center.

Co-creative networks

The Technical University of Munich has been an active participant in regional, national and international networks for the design and development of sustainable mobility for many years.

Under the Inzell Initiative, the city of Munich and BMW are working with around 150 regional actors to develop solutions for local traffic problems and strategies to shape the future of mobility. TUM's partners were involved in creating a mobility vision for the Munich region for 2050 and in the model city for 2030. Now it is time to join forces with partners working in the field to act on these ideas and realize the proposals made in the form of a regional strategic mobility concept. The city's new mobility department will be an ideal strategic partner starting in 2021.

Despite its success in research, it is also a priority for TUM to make a substantial contribution to the future of sustainable mobility "on its own doorstep". Building on the experiences gained through the mobility management concept created for the Weihenstephan/Freising campus, TUM also plans to improve the conditions at Campus Garching, for example with improved connections to the surrounding region and the airport with flexible public transport systems, at the main campus (where priorities include the quality of the surroundings in the museum district, traffic safety, and convenient and secure bicycle parking) and at many other locations in Bavaria, in Heilbronn and abroad.

Over the coming years, the city of Munich plans to act as a role model for putting exemplary solutions into action by hosting an International Building Exhibition (IBA) dedicated to the theme of Mobility Spaces. Over a period extending until around 2030, outstanding projects will be honored and included in the exhibition of experimental implementations. This creative framework will offer unique opportunities to bring innovative ideas to life in the Munich region, allow researchers to study them in action, and invite public debate.

The International Motor Show (IAA) will also take place in Munich in 2021, in its first-ever visit to the Bavarian capital. In this edition, TUM will have a larger presence in the global spotlight offered by the IAA than in past years. It will advocate a shift away from the event's traditional character as a celebration of the German car industry toward a role as an innovation hub driving the rise of sustainable mobility.

TUM is already well positioned to support the creation of a German center for the future of mobility in the Munich region. Together with its strategic partners in this setting – the city of Munich, the BMW Group and UnternehmerTUM – TUM has already presented a draft concept to the German Ministry of Transport, which will provide guidance as the center develops.

Delivering a big boost to sustainable mobility – also "on our own doorstep".

The European metropolitan region of Munich has already maintained its own mobility working group for many years. The group also supports scientific innovation projects such as the TUM Accessibility Atlas and the study "Residence – Work – Mobility". Many partners from this extensive region – from Kaufbeuren to Kelheim and from Garmisch-Partenkirchen to Donau-Ries – have also contributed to the TUM-designed networking study through best practice projects, demonstrating that innovative ideas are finding imitators further afield.

Integrative research

Having successfully applied for "Excellence University" status on multiple occasions, the Technical University of Munich is in a position to expand its strategy of networking key fields of interest.

Interdisciplinary research centers rooted in strategic priorities have already been established and are also addressing mobility-related topics.

The Institute for Advanced Study (IAS) facilitates cooperation with international experts through the fellowship program. Innovative research ideas can be supported here with start-up funding. In the future this will also be possible in the TUM Innovation Networks – interdisciplinary and creative research groups with regional partners, doctoral candidates and students in master's programs. The goal is to provide dynamic teams with the freedom they need to launch trailblazing innovations and thus to nurture larger research clusters. Proposals can be submitted at any time.

Major potential for further developments in mobility research at the interface between technological development and social sciences is embodied in the Munich Center for Technology in Society (MCTS). A wide range of disciplines come together here to work on creative and co-creative solutions through the interaction of science, politics and society. The MCTS thus forms the bridge to the technology-related aspects of social and political sciences. Vital cultural, ethical and political issues provide many valuable reference points for TUM.Mobility.

The Munich School of Robotics and Machine Intelligence (MSRM) can also serve as a reference model for integrative research. One of the six methodological and thematic clusters is already addressing the mobility of the future from the specific standpoint of artificial intelligence and the related potential for autonomous systems and virtual networking (the Internet of Things).

The research clusters in energy research also contain numerous interfaces and cooperative possibilities for in-depth exploration. The Center for Energy and Information (ZEI) has become a respected name and point of contact, for example with regard to energy networks and electromobility (smart grid) and battery research.

Interdisciplinary mobility research directed toward sustainable development will now have its own address at the Technical University of Munich (TUM): **TUM.Mobility** will be established as a platform for cooperative research and systemic innovation in the area of sustainable mobility. This new, open network takes a holistic view of mobility needs and is based on intelligent transport systems for passengers and freight. The goal is to bring individual mobility needs into line with the economic, social and ecological boundary conditions to enable the transportation sector to meet the requirements of sustainable development in the future – not only in the prosperous metropolitan region of Munich, but also worldwide.

Giving dynamic teams the freedom they need to launch trailblazing innovations.

Together we will shape the technological transformation

Future outlook

Our goal at the Technical University of Munich is to provide the key area of "sustainable mobility and intelligent transportation systems" with strategic support and to promote its ongoing development.

This complex field builds on fundamental research and technological development. It requires cross-disciplinary cooperation within TUM and also depends on cooperation with numerous other actors from the worlds of research, business and civil society. As the Technical University of Munich, we will work together to identify possible scenarios for the mobility of tomorrow and develop new technological options to address them through our networked research. To bundle the numerous and diverse research and innovation projects, keep moving forward with interdisciplinary teaching and continuing education programs, and strengthen the necessary network activities, we plan to build an interdisciplinary, cross-sector structure for this specialized field in the form of an integrative research platform.

Through the Hightech Agenda of the state of Bavaria, strategic developments within the university, and cooperation with foundations, we will also be able to strengthen important subject areas through new academic appointments. In the TUM Venture Labs, we will explore prospects for entrepreneurial implementation of innovative research and development results. Here, too, synergies are available for emerging young start-ups in mobility research. In addition to our international scientific presence in conferences and publications, we also intend to exert a greater impact than before through consultation at the political level. With the newly established TUM Think Tank, we will support strategic decision-making processes in politics and the world of business, taking a holistic view of the need for sustainable mobility – in economic, social and ecological terms.

To shape the future of mobility, we need the courage to take the first step. We cannot predict with any certainty what future developments will look like. But we are conscious of our responsibility for coming generations and the many different regions around the world and are not afraid to undertake the experiment. We learn new things every day and are prepared to share our personal experience, our expertise and our scientific knowledge.

Let's take up the challenge of future mobility together and make use of the opportunities we have at hand today. Get in touch with us and start the conversation. Together we can achieve a lot.

We look forward to meeting you in person.

Prof. Gerhard Kramer

Executive Vice President for Research and Innovation

Imprint

TUM.Mobility

Strategy on Sustainable Mobility at the
Technical University of Munich (TUM) within
the Framework of TUM AGENDA 2030
February 2021

Publisher:
Technical University of Munich
The President
Arcisstrasse 21
80333 Munich
www.tum.de

Editors:
Technical University of Munich
Dr. Andrea Glogger,
Strategy and Excellence Development
Prof. Dr.-Ing. Gebhard Wulfhorst,
Chair of Urban Structure and Transport Planning
Tina Heun-Rattei, Stefanie Reiffert,
Corporate Communications Center

Design and layout:
ediundsepp Gestaltungs mbH

Printing:
Walch Druck Augsburg
Printed on recycled paper

Contact:
Prof. Gerhard Kramer
Executive Vice President for Research and
Innovation
Technical University of Munich
Arcisstrasse 21
80333 Munich
Tel. +49 89 289 25259
Fax +49 89 289 25260

TUM.Mobility:
info@mobility.tum.de
www.mobility.tum.de

Photo credits:
p. 5 Astrid Eckert/TUM
p. 8 iStockphoto.com/LV4260
p. 10 Fabian Vogl/TUM
p. 14 Uli Benz/TUM
p. 16 Andreas Heddergott/TUM
p. 18 Andreas Heddergott/TUM
p. 20 TUMCREATE
p. 22 ediundsepp Gestaltungs mbH
p. 24 raumzeug – Atelier für Landschaftsarchitektur
p. 26 Prof. Moeckel/TUM
p. 28 Uli Benz/TUM
p. 30 Andreas Heddergott/TUM
p. 32 Astrid Eckert/TUM
p. 34 Fabian Vogl/TUM
p. 40 Astrid Eckert/TUM

TUM Schools
- Computation, Information and Technology (CIT)
- Engineering and Design (ED)
- Natural Sciences (NAT)
- Life Sciences (LS)
- Medicine and Health (MH)
- Management (MGT)
- Social Sciences (SO)

TUM.Mobility