Degree Program Documentation Master's Program in Transportation Systems

Part A

TUM Department of Civil, Geo and Environmental Engineering
Technical University of Munich

General Information:

Administrative responsibility:	TUM Department of Civil, Geo and Environmental Engineering
Name of degree program:	Master's Program in Transportation Systems
Degree:	Master of Science (M.Sc.)
Standard duration of study and credits:	
	4 semester of enrollment and 120 credit points (CP)
Form of study:	full time
Admission:	Aptitude assessment (EV – Master's)
Start:	Winter semester (WiSe) 2007/2008
	Major changes, starting with WiSe 2021/2022
Language(s) of Instruction:	English
Academic director:	Prof. Dr. Constantinos Antoniou
Contact for further questions:	Dr. Birgit Vierling
	Email address: birgit.vierling@tum.de
	Phone number: +49 (0)89 289 22443
Status as of	27.05.2020
Dean of Studies:	Prof. Dr. Stephan Freudenstein

Table of Contents

1 Degree Program Objectives

1.1 Purpose

The transportation system is an important part of any economy and core element of daily human life. Mobility is not only a human basic need, it is the key factor of any modern society and economy. Nowadays, society and economy are both challenged by the growing demand for mobility as well as by the ecological and economic impacts of the increasing transportation demand. Phenomena like our globalizing world as well as pollution and climate change require new strategies in the area of transport planning, traffic control and infrastructure design. Particularly, an efficient, environmentally friendly and safe operation of transportation systems is growing in importance. “Environment” and “sustainable development” are leading topics on the international agenda.

Transport and mobility are connected with many social phenomena; they are influenced and also influence social structures and processes (e.g. changes in urban spatial structures). In general, the transportation system must be considered as part of a complex system if there shall be provided optimal transport conditions for people and goods as well as a good quality of living in urban areas. Consequently, transport planning strategies must consider and include the various interactions between transport, economy, land-use, and the natural environment.

There is a need for experts who know about rail and road design, algorithms of traffic management systems, and the planning of public transport networks. But, at the same time, those specialists also require interdisciplinary skills to successfully deal with the defiance of modern mobility. The current professional environment and development show that transport engineers must also have skills in economics and project appraisal. Besides, they need knowledge about ecology and the concepts of sustainability, so that they can cope with current and future environmental challenges (e.g. noise emissions, air pollution or land-use and soil sealing). They have to know about travel behaviour, so that they are able to consider also social aspects of transport (e.g. social impacts of transport investments, accessibility and reachability).

This program is designed to enhance the classical training program for transport engineers towards an interdisciplinary and system-orientated education, including a shift in focus towards the basic and application research field. Taking all this into account, the Master’s program prepares highly qualified professionals for the dynamically growing market of transport and mobility.

Within the Master’s program, transportation is considered with regards to the spectrum of urban fields of action: causes (e.g. land-use, urban structure, utilization structure) and effects (e.g. exhaust and noise, congestion) as well as measures (e.g. integrated land-use and transport management, traffic control). Besides, transport planning is increasingly becoming a design and management task within an overall complex system that comprises passenger and freight transport as well as all other carriers. A functional high-performing transportation system is a prerequisite for economic development. If transportation is considered as an overall system, it becomes apparent that this sector is immensely important for the economy (e.g. the transportation budget is the largest of the state’s individual budgets). Infrastructure design and construction is substantial and

also an integral part of the Master's Program in Transportation Systems. The main focal points of education are the optimization of construction principles, durability management, biogenic building substances and materials, reduction of emissions. For the academic field of transportation engineering, also capture, analysis and manipulation of spatial or geographical data are of great importance.

1.2 Strategic Significance

In its mission statement, the Technical University of Munich (TUM) is committed to promoting innovation in all scientific fields that promise to improve the quality of life and cohabitation in the long term. The responsibility owed to future generations forms the basis for the interdisciplinary focal points of "Health & Nutrition", "Energy & Natural Resources", "Environment & Climate", "Information & Communications", and "Mobility & Infrastructure". The Department of Civil, Geo and Environmental Engineering, including its central mission statements "Construction" – "Infrastructure" – "Environment" – "Planet Earth", plays a leading role in covering interdisciplinary research fields and therefore contributes to the international appeal and reputation of the TUM. With its international orientation, the Master's Program in Transportation Systems strengthens worldwide positioning of the Technical University of Munich in one of the most relevant academic fields of our modern life, transport and mobility and is so part of the interdisciplinary focal point "Mobility & Infrastructure". Within the department, the degree program covers the central academic key factors (construction – infrastructure – environment – planet Earth) in an interdisciplinary manner with a focus on transportation science.

Construction

According to the department's mission statement, civil engineering is of high relevance as building and living represent both: basic needs of human beings as well as an important industrial sector and considerable cultural good. The aim is to approach the ideal building scenario – that means a minimum consumption of resources and a minimum of emissions when producing building materials, building, operating, rebuilding, and demolishing constructions – by using sustainable building materials and constructions. Transportation infrastructure design and construction is substantial and integral part of the Master's Program in Transportation Systems. The main focal points of education are the optimization of construction principles, durability management, biogenic building substances and materials, reduction of emissions.

Infrastructure

In its overall concept the Department of Civil, Geo and Environmental Engineering considers construction of infrastructure as only one aspect of transportation. Today, efficient, environmentally friendly and safe operation of transportation systems is growing in importance. Transport planning is increasingly becoming a design and management task within an overall complex system that comprises passenger and freight transport as well as all other carriers. A functional high-performing transportation system is a prerequisite for economic development. If transportation is considered as an overall system, it becomes apparent that this sector is immensely important for the economy (e.g. the transportation budget is usually the largest of the state's individual budgets). Within the Master's Program in Transportation Systems, transportation is considered with regards to the spectrum of urban fields of action: causes (e.g. land-use, urban structure, utilization

structure) and effects (e.g. exhaust and noise, congestion) as well as measures (e.g. integrated land-use and transportation management).

Environment

The topic “environment and energy” represents one of the central issues addressed by the Technical University of Munich as well as by the Department of Civil, Geo and Environmental Engineering; it is also one of the leading topics on the international agenda. Dealing with natural hazards and catastrophe prevention, i.e. the issue of "preparedness" (more generally referred to as disaster and risk management) based on complex information, prevention and intervention is extremely important for the built-up and natural environment. Therefore, it is of social, ecological and economic priority. This subject represents a precautionary contribution to sustainable environmental protection and the management of ecological problems. Innovation results from the unique networking of the disciplines that previously merely existed alongside each other. In the foreseeable future the state, communes, the economy and society in general will greatly benefit from this. Inevitably, the socioeconomic aspects are pivotal for many essential research issues. The goal is to develop a continuous concept from one source for various risk areas such as flooding, food and water scarcity, landslides and mass movements etc. In this connection, the development of a dynamic system and handling concept in the shape of a complex expert system on the topic of environmental risk management is planned. Due to its high relevance, the correlation between transport and the environment plays also an important role in the curriculum of the Master’s Program in Transportation Systems (e.g. prevention of emissions, sustainable land use for transport infrastructure).

Planet Earth

The Department of Civil, Geo and Environmental Engineering is also focusing globally on our planet, as many environmental processes are global phenomena. Until the year 2019, the Institute for Astronomical and Physical Geodesy and the Institute of Photogrammetry and Cartography (both institutes are now part of the Department of Aerospace and Geodesy) have been working at the Department on realizing, analyzing and using various satellite missions. For the academic field of transportation systems, capture, analysis and manipulation of spatial or geographical data are of great importance. The curriculum of the Master’s Program in Transportation Systems still benefits from modules imported from the Chair of Cartography, the Chair of Land Management as well as from the Institute for Astronomical and Physical Geodesy.

The central themes of the Master’s Program in Transportation Systems “Mobility, Transport and Traffic” are suitable for cross-faculty networking offering opportunities to publicly present this engineering profession as a modern and interdisciplinary field. The TS program uses and combines methods and competences from other disciplines, such as geodesy, civil engineering and environmental engineering. In its particular focus on transportation this degree program is unique and differs from other master degree programs of the department (e.g. “Computational Mechanics” or “Resource-efficient and Sustainable Building”). It is obvious that in some parts there are smaller overlaps with the three master’s programs “Civil Engineering” and “Environmental Engineering”. But still, the programs in “Civil Engineering” and “Environmental Engineering” have another main focus in general engineering aspects, while “Transportation Systems” focuses on transportation engineering, with an interdisciplinary approach. The master’s program and “Rail, Transport and Logistics”, offered by TUM Asia in Singapore is a program specially developed for

the Asian education market: “German engineering with Asian relevance” as TUM Asia’s slogan promises (for further details please see chapter 5).

The TS program is embedded in the focus area “Mobility and Transportation Systems” where it plays a central role in interdisciplinary combining the knowledge of all chairs and professorships, applying it to an international perspective. Within this focus area the degree program contributes to the development and transfer of knowledge and skills as well as to the development and transfer of methods, strategies and good practice examples for transportation. The structured approach of the program is based on combining the network of teaching and research competence of the various departments at TUM to make use of the available resources, to serve the established professional degree programs and research fields, and to open up new combined teaching and research fields by procuring additional resources. One central element of this concept is the development of a knowledge network as a public-private partnership with participants from industry, public offices and science fields.

2 Qualification Profile

Graduates of this Master's program possess a wide portfolio of relevant competences, abilities and know-how in transport related areas, and they are capable to apply this knowledge and these skills when working in the dynamically growing market sector of transport systems. The qualification profile meets the requirements of the Qualifications Framework for German Higher Education Qualifications ("Hochschulqualifikationsrahmen" – HQR) from 16th February 2017. For Master's programs, the following four areas of competence have been defined: Knowledge and understanding (1), Usage, application and generation of knowledge (2), Communication and Cooperation (3), and Scientific self-understanding/ professionalism (4).

Knowledge and Understanding

Building on the competences achieved during their Bachelor's program, graduates from the Master's Program in Transportation Systems have deepened or expanded this knowledge during the course of the Master's program. For instance, they have knowledge and a sound understanding of how to plan, design and operate integrated transportation systems, and they are able to define and interpret the particular terminology and concepts of their field of study. TS graduates are able to employ their knowledge and understanding in research or practical applications. They possess a broad, detailed and critical understanding of the latest developments in transportation engineering. Besides, graduates have specialized knowledge in one of the three fields of study: Transportation Infrastructure, Intelligent Transport Systems, or Transportation Demand Management. They have the skills to identify, analyze and solve problems related to this field. Besides, graduates know and understand the interrelation between land-use demand, transportation supply, economic growth and the natural environment. They are aware of the importance of accessibility and mobility in the planning and implementation process. Apart from that, graduates understand the important concept of sustainability and the requirement of new planning and management strategies. They are able to evaluate the epistemic correctness of their specialist knowledge in consideration of scientific and methodological approaches and, based on this evaluation, solve practical and scientific problems.

Usage, application and generation of knowledge

On a general level, TS graduates have the ability to develop and optimize solutions for a wide range of different tasks in transportation science and engineering. They are capable to systematically structure engineering tasks as well as to methodologically work out approaches to deal with different engineering and mathematical problems. Graduates know how to achieve knowledge and competence in special fields of engineering and they can use their theoretical-analytical skills on complex applications. More specifically, TS graduates have the competence to analyze the complex system of contemporary mobility, including aspects of sustainability. They can identify the correlations between transportation infrastructure, transport control, means of transport as well as transportation of persons or goods. The graduates are able to discern the interrelation between land-use demand, transport supply, economic growth and the natural environment. They know about the importance of accessibility and mobility and consider it in the planning and

implementation process. Graduates have sound knowledge of the current methods of processing traffic data as well as of the standard applications and functions for visualization. They know and understand how to plan for an integrated transport system together with the skills to identify, analyze and solve problems related to this field.

TS graduates are all-round experts, competent in analysis methods, transport theories and modelling as well as project appraisal and planning instruments. Thus, they have the expertise to implement and apply different assessment methods and techniques in a relevant, issue-related way. In addition, they have know-how in traffic control and intelligent transport systems applied in an urban or motorway context. Besides, they are able to use their knowledge and insights gained in the field of transportation to develop new solution strategies for problematic transportation systems as well as for efficient transport engineering and planning. They are capable to overview and to give consideration to relevant economic, social and environmental aspects of transport for sound decision making. TS graduates are familiar with the important concept of sustainable development which requires new planning and management strategies. They know and understand significant sociological, ecological and economic concepts and theories. For instance, graduates can estimate and analyze benefits and costs of infrastructure measurements and modifications. They are also aware of the external costs of transport operations and are able to plan and evaluate transport infrastructure investments. Furthermore, they are trained to consider ecological aspects like noise and vehicle emissions. In this way, they are able to contribute to more efficient and environmental-friendly mobility conditions.

Furthermore, graduates know how to find and absorb the required information and how to evaluate and edit it in a specific context. They are able to develop relevant research questions, to structure complex issues, and to present their findings in a logical and convincing way. Thus, they have profound competence in the use of scientific methods as well as in the development of solutions for practical problems based on scientific findings. Graduates from the Master's Program in Transportation Systems are able to design research projects related to current scientific fields of transportation engineering. Besides, they can select appropriate and concrete scientific approaches for their specific research topic and justify these chosen ways of implementing research. TS graduates are able to reflect about different research methods and to select the most suitable method as well as to justify this selection. Furthermore, they are capable to explain the results of their research, to interpret them critically, and to situate their research results within the current state of research.

TS graduates developed intellectual and social competence through abstract, analytical and networked thinking. They have the ability to familiarize with new, unknown fields of work quickly and methodically, as well as the ability to act interdisciplinary.

Subject-related competencies: Fields of Study

Graduates of the Master's Program in Transportation Systems have specialized knowledge and skills in one out of three specialization areas. Depending on that choice, graduates have specialized knowledge and expertise either in transportation infrastructure, intelligent transport systems (ITS), or transportation demand management. The knowledge in one of these fields can be deepened by the attendance of specific electives offered for the respective field of study. Nonetheless, every TS graduate gained basic competences in all of these focus areas, as the principles are all taught within the required modules of the program. However, with a specific focus

on one so-called “field of study” graduates have the opportunity to develop an individual academic profile. In short summary: After graduation, students of the Master’s Program in Transportation Systems are transport engineers with a specialization either in infrastructure construction, traffic engineering and control or in urban structure and transportation planning.

Field of Study I: Transportation Infrastructure

TS graduates with focus on transportation infrastructure have acquired skills they need to deal with the design and the construction procedures of roads and railways and their life-cycle costs. They have profound competence in the construction procedures for sustainable roads, airfields and railway tracks. With specialization in transport infrastructure TS graduates know how to design sustainable asphalt and concrete pavements, they are aware of load actions on and within those pavement structures and understand the respective road layout criteria, design tools and calculation methods. Apart from that, graduates know how to deal with stations or any other types of turn-out configurations regarding the layout of railway lines, signaling and other safety installations. They are able to design railway tracks by considering load actions and reactions of the track superstructure and the respective substructure. They have the competence in designing and construction permanent ways and ballast-less tracks covering also special track solutions like floating slab tracks dealing with vibrations and structure born noise problems.

Field of Study II: Intelligent Transport Systems (ITS)

Students of the Master’s Program in Transportation Systems who concentrated on Intelligent Transport Systems (ITS) have deepened their knowledge in the design and application of traffic control methods, the architecture of ITS projects and traffic control algorithms. Thus, they are able to improve traffic situations by designing signalized intersections and applying ITS related components. They have a sound understanding of traffic flow and its numerous facets, coherencies and interdependencies. Graduates are able to e.g. model delay and queuing processes and to consider kinematics and dynamics of driving as well as car-following-models. Besides, they are experts in signal control and can for instance design signal plans or progressive signal systems. Graduates with this field of study have detailed knowledge about the different system approaches and technologies which are used around the world for urban traffic control, motorway control, integrated traffic information and management as well as mobility and demand management.

Field of Study III: Transportation Demand Management

If specialized in transportation demand management (TDM), TS graduates know the theories and concepts of integrated land-use and transport modelling and are able to analyze and evaluate them in a systematic way. They are able to model integrated land-use and transport as well as to compose research surveys about e.g. urban mobility. They know the relevant feedback mechanisms and can analyze them. For instance, graduates are able to elaborate the limits of classical transport models with regard to implementing complex feedback mechanisms, especially concerning land-use interactions. Besides, they are able to discuss and to apply modelling approaches within classical transport models and beyond (activity-based modelling approaches, integrated land-use and transport models, system dynamics, and sensitivity model). Additionally, they have a complex understanding of transportation demand management measures, including an international approach. The graduates are aware of common obstacles in planning practice

during the implementation of a TDM and can discuss relevant preconditions of TDM. In general, graduates with this specialization are experts in transportation demand and mobility management.

Communication and Cooperation

The graduates of the Master's Program in Transportation Systems are able to give presentations in front of an academic audience and to discuss their scientific findings with international experts. Besides, they have the expertise to prepare papers about their results and recommendations for scientific publishing. The graduates know how to obtain their goals, how to organize themselves and how to work in an independent and self-consistent way.

TS graduates are aware of the importance of cultural differences and know how to deal with cross-cultural issues in an effective way. They are experienced in working together in multinational and interdisciplinary groups and have also achieved cross-cultural competence and the ability to work efficiently in diverse teams. Thus, graduates are trained to be open-minded, pragmatic but thorough, analytical and structured, good communicators, and quick thinking. Graduates are able to act in a tolerant and responsible way. Thus, they have social and strong communication skills, combined with the ability to handle conflicts in an adequate way.

Apart from that, TS graduates have the ability to enter into dialog with both academics and non-academics from various disciplines and fields. They are able to discuss feasible alternatives for solving discipline-specific and subject-related problems.

Scientific self-understanding / professionalism

Graduates of the Master's Program in Transportation Systems at TUM have developed a professional self-understanding based on the objectives and standards of professional action in academia as well as in society. They are able to justify their own professional actions in the field of transportation engineering with theoretical and methodological knowledge and reflect on alternatives. During their studies they have learned to assess their own abilities and to make use of their freedoms of disciplinary design and decision-making independently, and to further develop them under supervision. TS graduates recognize situation-specific and extra-situational conditions for professional action and are able to reflect on decisions, also with ethical responsibility. They have learned to critically reflect their professional actions with regard to social expectations and consequences. They are also capable to further develop their professional actions in the field of transportation systems.

3 Target Groups

3.1 Target Audience

The Master's Program in Transportation Systems at the Technical University of Munich (TUM) focusses on applicants holding Bachelor's degrees in a transport-related area. It addresses national and international graduates and junior experts with a strong interest in planning, managing and optimizing transportation systems. With its international focus the program aims not only at attracting the best candidates worldwide, but also at providing knowledge transfer as well as at fostering the development of the transportation sector in emerging and developing countries. Last, but not least, the program is committed to contribute to the excellent worldwide reputation of "German engineering".

3.2 Prerequisites

Generally, application is open to candidates with a relevant Bachelor's degree in the areas of Transportation Engineering, Civil Engineering, Environmental Engineering, Electrical Engineering, Mechanical Engineering, Computer Sciences, Communications Engineering, Economics, Architecture or other scientific area related to transportation systems.

During an elaborate aptitude assessment, there will be examined if the single applicant has the required engineering skills related to transportation systems (e.g. algorithmic, informatics, programming, computer-aided simulation, drive engineering, communications engineering, sensor technology; geo-informatics, surveying, mathematics and statistics, bridge construction or engineering mechanics). Applicants should be able to demonstrate that they are open-minded and able to work scientifically respectively principle-based and method-oriented. They should have a scientifically oriented interest in engineering problems from the field of transportation and in the solution of those problems. As applicants and students of this Master's program come from all over the world and graduated from different education systems, we require at least some basic knowledge in transportation science (e.g. urban development and planning, transportation planning, traffic engineering and control, transportation infrastructure).

To study this international program, every student has to prove adequate knowledge of the English language. This is usually done by submission of a language test certificate (e.g. TOEFL, IELTS). Since the year 2018, international students also have to demonstrate at least basic skills in the German language. In case, they cannot demonstrate any knowledge of German at the time of the application, they have one year to achieve the required (basic) skills.

3.3 Target Numbers

The degree program is designed for a limited number of students in order to provide an optimal individual learning atmosphere. Lectures, labs and exercises are laid out for approximately 40 students per intake and thus strengthen the ability of students to exchange and interact with lecturers and classmates. Rooms are available in a sufficient number to keep the degree program running. However, the increasing number of applicants and students, see illustration 1, represent a success story, but also a challenge: The numbers of new enrollments are rising and with more than

45 new enrollments in two following years (2017 and 2018), they are currently challenging TUM room capacities (esp. CIP pools). The department BGU is still working on improving the study conditions in cooperation with the central TUM administration. The focus is currently on providing additional rooms. With regard to the decline of the number of applicants and enrollments in the years 2018 and 2019 (introduction of “VPD” for non-EU applicants in 2018), this situation could also improve. The introduction of the fully digital application process at TUM (in 2020 for TS), however, could again cause higher application numbers.

The Master’s Program in Transportation Systems started in the year 2007 with 21 students. In the following years the degree program gained national and international reputation and therefore continuously received a rising number of applications from countries all over the world. In 2017, there was a peak with 517 applications. However, there was a decline in the following year, probably caused by some changes in the application procedure. International applicants from outside the European Union and the European Economic Area (EEA) now have to pay approx. 80 euro for the so-called “Preliminary Documentation” of their graduation documents by uni-assist. Besides, since then, international applicants also have to demonstrate at least basic German language skills. Since 2019, the Master’s Program in Civil Engineering at TUM can be studied in German and/or English. Therefore, international graduates who are mainly interested in doing this degree program in English language, can now directly apply for the Master’s Program in Civil Engineering.

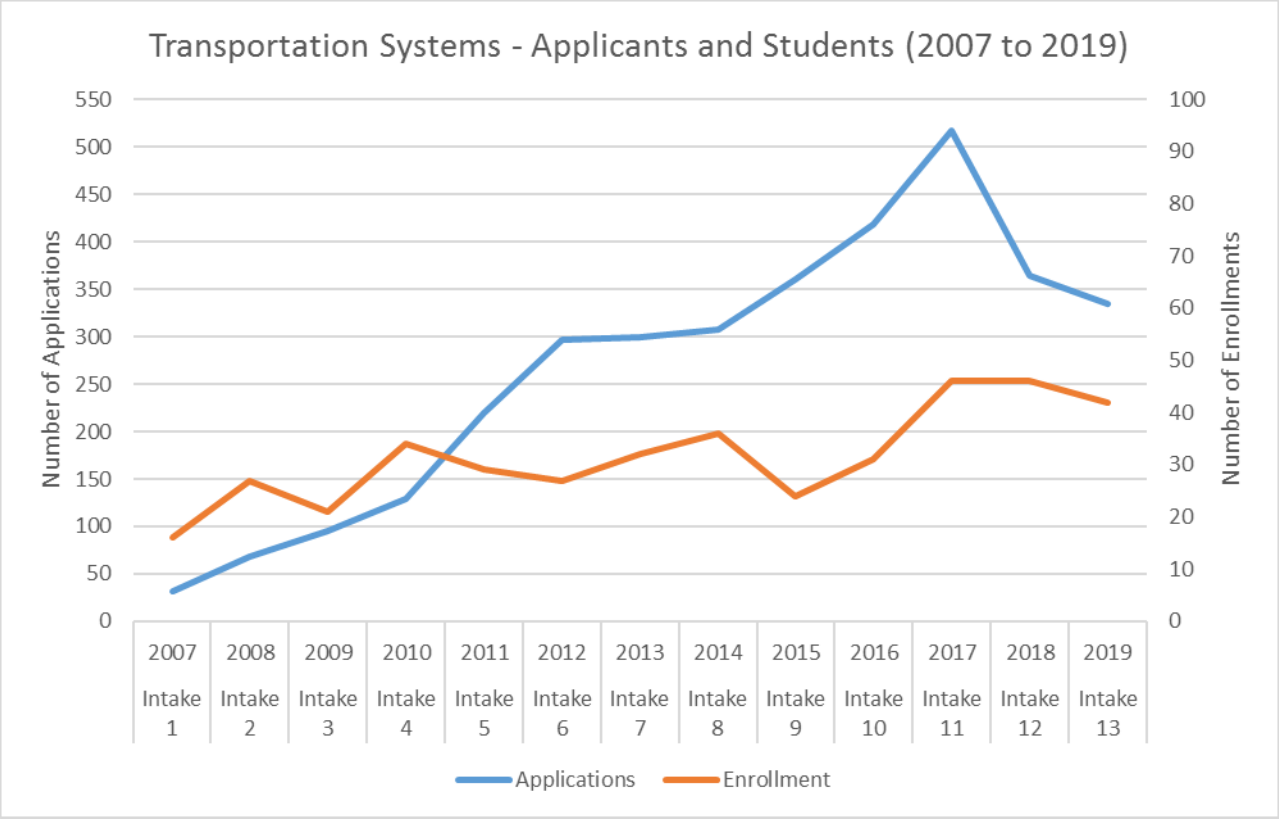

Illustration 1: Development of applications and enrolments since the start of the degree program in 2007

The Master’s Program in Transportation Systems works with a complex and elaborated aptitude assessment; every single application is evaluated individually. The significant difference between

the number of applicants and the number of admitted students results from the fact that only applicants meeting the stipulated aptitude criteria are admitted to the degree program.

The big majority of applicants and students come from abroad (around 95%). Among all continents, the highest amount of applicants and students of the Master's Program in Transportation Systems is from Asia (approx. 2/3). The numbers of applicants and students from Europe, America and Australia are more or less stable since the start of the program in 2007, while we are receiving a steadily increasing number of applications from Africa.

4 Analysis of Need

The need for transportation engineers in Germany is constantly very high – also with regard to the essential importance of transport and mobility for every economy. There are currently around 100,000 engineers working in the German transportation sector (Staufenbiel Institut GmbH, 2020). Already in 2013, the Federal Association of Road Construction and Transportation Engineers (Bundesvereinigung der Straßenbau- und Verkehrsingenieure e.V. – BSVI) stated a great need for transportation engineers and that the future demand will be much higher than the expected number of graduates in this field. Therefore, in Germany almost all graduates of transportation engineering find employment very easily and quickly. Apart from that there is a worldwide demand for well-trained transportation experts, especially in developing and emerging countries, where the majority of the TS students comes from.

Transportation engineers often work for governmental and non-governmental agencies, public transport authorities, or for urban and regional planning departments, but also for the private sector like transportation companies, transportation engineering consultancies, freight and logistic enterprises, the automotive and infrastructure industry or for infrastructure-maintaining companies. The experience of staff at the TUM Department of Civil, Geo and Environmental Engineering, and from outside TUM (public and private sector) as well as the feedback obtained by students and alumni (e.g. in surveys) show a high demand for highly qualified professionals in the field of transportation engineering all over the world. Feedback from alumni emphasizes the high demand for transportation professionals at the labor market and stressed the importance of the integrated design of this degree program regarding all different aspects of transportation.

The Master's Program in Transportation Systems is a unique feature offering a broad and highly professional education in transport issues. Graduates can e.g. design roads and railways, simulate traffic, apply and design intelligent transport systems, analyze transport data and statistics or consult municipalities in questions regarding transport planning strategies of today and for future demand. Besides, transportation experts also need interdisciplinary knowledge, they need good presentation and writing skills (e.g. working out concepts and present them in front of an audience), They also need good communication skills and must be able to work together in teams as well as to work individually and independently (Staufenbiel Institut GmbH, 2020).

The "generalist, but specified" education of the TS program has allowed our graduates to easily start their career as transport professionals in Germany, but also in international companies and authorities. The feedback from alumni as well as from companies and authorities cooperating with the degree program has supported the general layout of the program as meeting the labor market requests. Therefore, graduates are best qualified for the modern transportation market. However,

this Master's degree in Transportation Systems qualifies graduates to apply for admission to doctoral studies/ PhD-course (postgraduate research program). Graduates of the Master's Program in Transportation Systems have the option of undertaking further research or studies in many different research institutions and organizations all over the world.

Graduates are able to start a career in many different areas of the transportation sector as well as in academia.

5 Competition Analysis

The TUM Department of Civil, Environmental and Geo Engineering offers plenty of different Master's programs. There are two degree programs at the department in Munich, the Master's Program in Civil Engineering as well as the Master's Program in Environmental Engineering, which also offer education in transportation science. The Master's Program in Civil Engineering, has a quite broad curriculum. Students must select four specializations out of 20. That means, they can, e.g. choose up to two transport-related fields ("Road, Railway and Airfield Construction" and/or "Traffic Engineering and Transport Planning"), but they will have to take two further specializations. Thus, after graduation, students will have achieved a scope of competences in at least four different scientific fields of civil engineering.

Students of the Master's Program in Environmental Engineering have the opportunity to choose two fields of studies out of eleven. If they are interested in transportation, they can focus on "Sustainable Urban Mobility Planning" and/or "Transportation Engineering and Control". As the title of the degree program promises, the focus of both specializations is on environmental effects of transportation. The design of both specializations has a clear strategic direction towards sustainable urban and transportation planning, while, in contrast, students of the Master's Program in Transportation Systems also learn about the construction and design of transportation infrastructure (railways, roads, and airports).

Some modules of the TS program are also integrated into the specializations of the two other Master's programs at the department. But, to conclude, it can be underlined that the specialization areas in both degree programs, civil as well as environmental engineering, represent only some limited aspects of transportation. Therefore, graduates are either civil or environmental engineers who have also deeper knowledge in transportation. Graduates of the Master's Program in Transportation Systems, in contrary, are transportation engineers. They have comprehensive knowledge in all aspects of transportation.

Moreover, another Master's program of the Technical University of Munich was created in Singapore taking the TS program as example of good practice. It is carried out at GIST – the German Institute of Science and Technology, a subsidiary of Technical University of Munich in Singapore (TUM Asia). This new Master's program launched in August 2009 and was called "Transport and Logistics", and renamed in 2019 to "Rail, Transport and Logistics". It is suited to management-oriented students without engineering background.

Hence, the TS program at the Technical University of Munich is a stand-alone degree program without comparable degree programs at the department or university.

6 Program Structure

The Master's Program in Transportation Systems consists of four semesters and takes 24 months overall. Every student of the Master's Program in Transportation Systems has to achieve a minimum of 120 ECTS credits. It is based on different modules containing seminars and lectures combined with exercises, grounded as much as possible on real life studies. There are also several smaller excursions to construction sites, traffic management centers, or transportation companies. The language of instruction is English. The modular structure of the degree program includes required modules as well as elective modules. Each semester, the elective modules catalogue is updated to meet the changing demand within the transportation sector. Students are informed about the update prior to semester start. A general overview of the curriculum is given in illustration 2.

Master's Program in Transportation Systems							
Semester	Modules						Credits/ number of exams
1.	Travel Behaviour and Environmental Impacts (required) written exam 6 CP	Applied Statistics for Transportation Systems (required) written exam 6 CP	Land-Use and Transport - Strategies and Models (required) written exam 6 CP	Traffic Management (required) written exam 6 CP	Cross-cutting Fundamentals and Methods (required) scientific paper 3 CP	Infrastructure Planning (required) 3 CP	30/5
2.	Project Appraisal and Planning Processes in Transportation (required) written exam 6 CP	Public Transport Concepts, Planning and Operation (required) written exam 6 CP	Intelligent Transport Systems (FoS II) (elective) written exam 6 CP	Transportation Demand Management (FoS III) (elective) written exam + scientific paper 6 CP	Elective with general educational value (elective) to be announced 3 CP	written exam (6 CP in total) 3 CP	30/6
3.	Project Seminar (required) report 12 CP	Road and Rail Design (FoS I) (elective) written exam 6 CP	Object-oriented Programming for Transport Engineers (elective) exercise 6 CP	Transportation Economics (elective) project work 6 CP			30/4
4.	Masters thesis 30 CP						30/1
Key:	light grey = required modules, dark grey = elective modules, black: general education module light blue = elective modules (Field of Study) dark blue = final thesis						

Illustration 1: Degree chart "Transportation Systems"

During the first study year, students achieve the required general, sound and broad-based background in transportation engineering, but also in several related disciplines like travel behavior, transport economics or general tools for scientific work within the required eight modules. There are so many required module since the program addresses applicants with a broad variety of previous study. Therefore, the students deepen the theoretical knowledge of the overall concepts of transportation systems within all fields of transportation engineering: transportation planning, traffic engineering and control, as well as transportation infrastructure. The students learn about the most relevant theories, concepts and models. The general competences gained during the first semester also include soft skills, the ability to prepare scientific presentations and to write scientific papers. They are able to familiarize themselves with a transport-related topic, as well as to present and to discuss the topic with an academic audience (within a predetermined time). Students know the basic standards of scientific work and publishing and are able to apply them. In

addition, they are aware of the importance of cultural differences when working together in multicultural groups, and they are able to deal with those cross-cultural issues in an effective way.

At the end of semester 1, the students decide about their specific specialization area (field of study). There is one information session, where professors present the different fields of study. Consequently, in the second semester, students can start creating their own professional profile and achieve the required engineering competences. Students select one out of three fields of study. They can focus on one specific field of the transportation sector: transportation infrastructure, intelligent transport systems or transportation demand management. Each area of specialization contains one core module, providing them with deeper understanding of their selected specialization and skills that help them select, and make the most out of, their elective subjects. Students can choose additional subjects from the elective module catalogue to strengthen their individual profile. These specialization modules are offered during the second and third semester, and they allow the students to steer the program towards their specific professional interests. These modules also allow them to deeper explore their topics of interest, potentially also helping them select an appropriate direction for their Master's thesis.

The core of the third semester is the project seminar. During this module, students deal with real-life problems in transportation project planning and application – usually in cooperation with local authorities and companies. By working on a specific project, students explore scientific research and practical solutions in an experimental environment. In multinational and interdisciplinary groups, they work out a survey concept and realize field work. Besides, they analyze and discuss their findings with research staff, experienced practitioners and authorities involved in the respective project. So, they train and demonstrate communication and cooperation skills, not only in working together in academia but also in non-academia.

Finally, students will write their Master´s thesis on a transportation-related subject, where they implement the gained engineering knowledge and research skills. Frequently, the thesis is done in cooperation with a company or authority, but supervised and evaluated by academic TUM professors. The students have six months to complete the thesis. They can conduct the thesis either in Germany or abroad.

The illustrations 3 to 5 below show a sample degree chart for each field of study, including possible combinations of elective modules which complement the chosen field of study:

Master's Program in Transportation Systems							
Semester	Modules						Credits/ number of exams
1.	Travel Behaviour and Environmental Impacts (required) written exam 6 CP	Applied Statistics for Transportation Systems (required) written exam 6 CP	Land-Use and Transport - Strategies and Models (required) written exam 6 CP	Traffic Management (required) written exam 6 CP	Cross-cutting Fundamentals and Methods (required) scientific paper 3 CP	Infrastructure Planning (required) 3 CP	30/5
2.	Project Appraisal and Planning Processes in Transportation (required) written exam 6 CP	Public Transport Concepts, Planning and Operation (required) written exam 6 CP	Multimodal and intermodal Freight Transport (elective) project work 6 CP	Road Safety (elective) project work 6 CP	Elective with general educational value (elective) to be announced 3 CP	written exam (6 CP in total) 3 CP	30/6
3.	Project Seminar (required) report 12 CP	Road and Rail Design (FoS I) (elective) written exam 6 CP	Object-oriented Programming for Transport Engineers (elective) exercise 6 CP	Transportation Economics (elective) project work 6 CP			30/4
4.	Masters thesis 30 CP						30/1
Key:	light grey = required modules, dark grey = elective modules, black: general education module light blue = elective modules (Field of Study) dark blue = final thesis						

Illustration 2: Example Field of Study I: Transportation Infrastructure

Master's Program in Transportation Systems							
Semester	Modules						Credits/ number of exams
1.	Travel Behaviour and Environmental Impacts (required) written exam 6 CP	Applied Statistics for Transportation Systems (required) written exam 6 CP	Land-Use and Transport - Strategies and Models (required) written exam 6 CP	Traffic Management (required) written exam 6 CP	Cross-cutting Fundamentals and Methods (required) scientific paper 3 CP	Infrastructure Planning (required) 3 CP	30/5
2.	Project Appraisal and Planning Processes in Transportation (required) written exam 6 CP	Public Transport Concepts, Planning and Operation (required) written exam 6 CP	Intelligent Transport Systems (FoS II) (elective) written exam 6 CP	Optimization for Transportation Systems (elective) exercise 6 CP	Elective with general educational value (elective) to be announced 3 CP	written exam (6 CP in total) 3 CP	30/6
3.	Project Seminar (required) report 12 CP	Discrete Choice Methods for Transportation Systems Analysis (elective) exercise 6 CP	Object-oriented Programming for Transport Engineers (elective) exercise 6 CP	Transportation Economics (elective) project work 6 CP			30/4
4.	Masters thesis 30 CP						30/1
Key:	light grey = required modules, dark grey = elective modules, black: general education module light blue = elective modules (Field of Study) dark blue = final thesis						

Illustration 3: Example Field of Study II: Intelligent Transport Systems (ITS)

Master's Program in Transportation Systems							
Semester	Modules						Credits/ number of exams
1.	Travel Behaviour and Environmental Impacts (required) written exam 6 CP	Applied Statistics for Transportation Systems (required) written exam 6 CP	Land-Use and Transport - Strategies and Models (required) written exam 6 CP	Traffic Management (required) written exam 6 CP	Cross-cutting Fundamentals and Methods (required) scientific paper 3 CP	Infrastructure Planning (required) 3 CP	30/5
2.	Project Appraisal and Planning Processes in Transportation (required) written exam 6 CP	Public Transport Concepts, Planning and Operation (required) written exam 6 CP	Applied Transport Modeling with MATSim (elective) written exam 6 CP	Transportation Demand Management (FoS III) (elective) written exam + scientific paper 6 CP	Elective with general educational value (elective) to be announced 3 CP	written exam (6 CP in total) 3 CP	30/6
3.	Project Seminar (required) report 12 CP	Urban Transportation Systems: Operations Research & Emerging Mobility Technologies (elective) written exam 6 CP	Object-oriented Programming for Transport Engineers (elective) exercise 6 CP	Transportation Economics (elective) project work 6 CP			30/4
4.	Masters thesis 30 CP						30/1
Key:	light grey = required modules, dark grey = elective modules, black: general education module light blue = elective modules (Field of Study) dark blue = final thesis						

Illustration 4: Example Field of Study III: Transportation Demand Management

The modules of the Master's Program in Transportation Systems take place at Munich main campus. The courses of all required modules are offered without any time overlap.

Concerning mobility of students, one of the core elements of the Bologna Process, the Master's Program in Transportation Systems offers plenty of opportunities. However, the clear majority of the TS students already come from all over the world; only approximately five percent of all TS students have German origin. Hence, the Master's program significantly contributes to the internationalization strategy of TUM and the general research location Germany. Thanks to the European Credits Transfer System (ECTS), academic records achieved at universities of countries belonging to the European Higher Education Area (EHEA) can be easily recognized at TUM. The Master's program is designed for four semesters; therefore, the third semester is best suited for a stay abroad. There is only one required module (project seminar) that can be also done at one of the partner universities. Most of the students come from abroad (more than 90%) and explicitly decided to come to Germany and do their Master's studies at TUM. Therefore, there is only little interest in going abroad so far. National students, however, often did their semester exchange already during their Bachelor's program. This usually lasts six semesters and thus exchange programs can be integrated in an easier way – considering the long planning and application process. Therefore, only a few TS students are interested in going abroad. These students often decide to write their Master's thesis at partner universities. For instance, there are close ties with the TUM CREATE Research Center at Singapore, namely the research team "Transportation and Traffic Engineering".

7 Organization and Coordination

The Master's Program in Transportation Systems is offered at the TUM Department of Civil, Geo and Environmental Engineering of the Technical University of Munich, where it is jointly taught by professors of the Focus Area "Mobility & Transportation Systems". As it has an interdisciplinary approach, and therefore several other chairs, professorships and departments of the TUM are involved. Several elective modules can be attended at the TUM Department of Architecture, the Munich Center for Technology in Society, and at the TUM School of Governance. Besides, as mentioned above, the program has a long history of collaboration with the TUM CREATE Research Center at Singapore (esp. for Master's thesis).

The following administrative tasks are performed by:

- Student Advising:
  TUM Center for Study and Teaching (TUM CST)
  Student Advising and Prospective Student Programs
  Email: studium@tum.de
  Phone: +49 (0)89 289 22245
  Provides information and advising for prospective and current students (via hotline/service desk)
- Departmental Student Advising:
  Program Coordinator and Academic Advisor
  Dr. Birgit Vierling
  Email: birgit.vierling@tum.de
  Phone: +49 (0)89 289 22443
- Academic Programs Office
  Examination Administration and Advising
  Christine Göppel
  Email: christine.goeppel@tum.de
  Phone: +49 (0)89 289 28194
- Study Abroad Advising/Internationalization:
  TUM-wide: TUM Global and Alumni Office,
  globaloffice@tum.de
  Departmental: International Affairs Delegate
  Nadin Klomke, M.A.
  Email: n.klomke@tum.de
  Phone: : +49 (0)89 289 22427
- Gender Equality Officer:
  TUM-wide: Dr. Eva Sandmann
  Email: sandmann@tum.de
  Phone: +49 (0)89 289 22335
  Departmental: Dr.-Ing. Annette Spengler
  Email: annette.spengler@tum.de
  Phone: +49 (0)89 289 27102
  Prof. Dr.-Ing. Markus Disse
  Email: markus.disse@tum.de
  Phone: +49 (0)89 289 23916

- Advising – Barrier-Free Education:
  TUM-wide: Office for Disabled and Chronically Ill Students (TUM CST)
  Email: Handicap@zv.tum.de
  Phone: +49 (0)89 289 22737
  Departmental: Dipl.-Ing. Michaela Wenzel
  Email: m.wenzel@tum.de
  Phone: +49 (0)89 289 25261
- Admissions and Enrollment:
  Advising and Information (TUM CST), Admissions and Enrollment
  Email: studium@tum.de
  Phone: +49 (0)89 289 22245
  Admissions, enrollment
  StudentCard, leaves of absence,
  student fees payment, withdrawal
- Aptitude Assessment (EV):
  Where applicable:
  TUM-wide: Advising and Information (TUM CST), Admissions and Enrollment
  Departmental: Aptitude Assessment Commission,
  Chair: Prof. Dr. Constantinos Antoniou
  Program coordinator: Dr. Birgit Vierling
  Email: birgit.vierling@tum.de
  Phone: +49 (0)89 289 22443
- Semester Fees and Scholarships:
  Advising and Information (TUM CST), Semester Fees Management
  Email: beitragsmanagement@zv.tum.de
- Examination Office:
  Central Examination Office (TUM CST)
  Campus Munich
  Graduation documents, notifications of examination results, preliminary degree certificates
- Departmental Examination Office:
  Christine Göppel
  Email: christine.goeppel@tum.de
  Phone: +49 (0)89 289 28194
- Examination Board:
  Prof. Dr. Constantinos Antoniou (Chair)
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  www.lehren.tum.de/startseite/team-cst/
  Departmental: Consultants for Studies and Teaching
  Dr. Lars Fuchs, lars.fuchs@tum.de
  Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de
  Prof. Dr. Stephan Freudenstein (Dean of Studies)
  Organization QM Circle: Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de

Evaluations Representative: Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de
Coordination, Module Management : Dipl.-Ing. Sandra Spindler, sandra.spindler@tum.de