Degree Program Documentation Master's Program "Information Technologies for the Built Environment"

Part A
TUM School of Engineering and Design
Technical University of Munich

General Information:

Administrative responsibility:	TUM School of Engineering and Design
Name of degree program:	Information Technologies for the Built Environment
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
Start:	Winter semester (WiSe) 2022/2023
Language(s) of Instruction:	English
Main Location:	Munich
Academic administrator (program design):	Prof. Dr. André Borrmann
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Dean of Studies:	Prof. Dr. Stephan Freudenstein

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1 Degree Program Objectives

1.1 Purpose

The building industry brings together many different professions such as architecture, landscape architecture, civil and environmental engineering, urban planning, and geodesy. In these fields the growing densification and complexity of metropolitan areas and their infrastructures due to urbanization poses a significant challenge in the 21st century. However, computer technologies offer new opportunities to meet this challenge in helping to shape the livability of cities in an ecologically and economically sustainable manner. Digital tools enable new forms of collaboration, provide new methods of collecting and using spatial and semantic data, facilitate the modeling of buildings, constructions, and cities over the entire building life cycle, and afford a sound basis for simulation, analysis, and the automation of processes.

In the face of this ever-growing field of possibilities, specialists are needed to bring together parallel developments in information technology in a cross-disciplinary and forward-looking manner. These specialists are experts in the methods and development of information technologies within the built world at the intersect between architecture, civil engineering, and geodesy. They combine the adaptability, technical skills, and computer science fundamentals of a systems engineer with the creativity, systemic thinking, critical reasoning, and built world understanding of an architect or civil engineer. These development specialists work in interdisciplinary teams to manage and consult on digital components of built environment activities and channel parallel developments in information technologies across building disciplines and scales. They act at different stages of the construction lifecycle, able to generate, understand, and utilize digital data representations and to connect and adapt digital information and models from a wide variety of sources. They drive the development and management of built environment information models and systems, utilizing and combining existing technologies, as well as prompting the creation of innovative new information technology approaches and solutions as the field advances.

1.2 Strategic Significance

Many internationally renowned universities are already focusing on an appropriate diversification of their degree programs in the conventional engineering fields to include more in-depth digital methods teaching. The TUM holds an almost unique position in German Higher Education in that it hosts competencies in digital methods and information technologies in architecture, landscape architecture, civil engineering, and geodesy within a single university. As such, it is well placed to offer this master's program, bringing together these digital competencies. Based on the success of the integrative research approach of the TUM Center of Digital Methods for the Built Environment (Leonhard Obermeyer Center), this method-oriented master's program in the digitization of the built environment is supported by the TUM School of Engineering and Design departments of Architecture, Civil, Geo, and Environmental Engineering, Aerospace and Geodesy, as well as the TUM Georg Nemetschek Institute of Artificial Intelligence for the Built World, the TUM School of Computation, Information & Technology, and the TUM Munich Center for Technology in Society.

The participating chairs of the TUM Leonhard Obermeyer Center are very strongly networked in their respective communities, both nationally and internationally, at a scientific and practical level. They have a long and strong history of cooperation at municipal, political, and intentional levels. They can refer to many years of experience in the field of executive education and lifelong learning (TUM EEC courses "BIM Professional" and "Digital City"), which indicate a clear need for specialists in the targeted area. The chairs are also actively involved in the development of international standards in the areas of BIM (e.g., IFC) and virtual 3D city models (e.g., CityGML, Web 3D Service, IndoorGML) in the buildingSMART Alliance[1] and the Open Geospatial Consortium[2]. Furthermore, they hold leading positions in national initiatives such as BIM Deutschland - Zentrum für die Digitalisierung des Bauwesens[3], Runder Tisch GIS[4], Zentrum Digitalisierung Bayern[5], BIM Cluster Bayer[6], and other technical groups. The master's program reflects this internationality, being offered in English and targeting both international and national students. The cooperation between domains and between research and practice are essential as the consequences of utilizing digital tools to inform urban decisions can significantly impact people and society. As a result, the program aligns with the TUM Excellence Strategy on future-orientated "Human-Centered Engineering." Through the interdisciplinary approach and the training of critical thinking, graduates possess the technical competencies and an understanding of the interconnect between technology, society, and ethical principles in technology design.

[1] https://www.buildingsmart.org
[2] https://www.ogc.org
[3] https://bimdeutschland.de/
[4] https://rundertischgis.de
[5] https://zentrum-digitalisierung.bayern/themenplattform-digitales-planen-und-bauen-und-smart-cities- and-regions/
[6] http://bim-cluster-bayern.de/

2 Qualification Profile

Graduates of the MSc Information Technologies for the Built Environment (ITBE) program are proficient in computer science methods, urban challenges, and information technology application within the built environment. They can select, apply, and adapt information technologies to meet the dynamic challenges of specific urban tasks. Additionally, they can analyze results, communicate these with a wide range of professionals and non-professionals, and critically reflect on their professional actions related to social expectations and consequences. Graduates have a holistic understanding across construction disciplines and across building scales.

The following four areas of competence have been identified to describe the qualification profile for this master's program: Knowledge and Understanding; Usage, Application, and Generation of Knowledge; Communication and Cooperation; and Scientific Self-Understanding/ Professionalism. In this way, the qualification profile meets the requirements of the Qualification Framework for German Higher Education Qualifications (HQR[7]).

Knowledge and Understanding

Graduates' expertise lie in digital technologies and methods applied to the domains of architecture, civil engineering, and geodesy, where their unique interdisciplinary understanding allows them to approach tasks from a holistic perspective. They combine primary knowledge of built environment requirements, processes, and structures from different domain perspectives with an understanding of specific considerations at different building scales and how these relate to each other. They recognize the constantly changing nature of information technologies and built environment tasks. Additionally, they are experts on the built environment information technology landscape and are familiar with professional and academic standards within this field. They have a deep understanding of information technologies and computer science methods and systems, and they know how to combined these to achieve specific goals. Furthermore, they understand data management and system architecture practices and standards and can capture, organize, analyze, and modifying spatial and semantic built environment data as needed. Graduates appreciate the technical, social, and ethical benefits, limitations, and consequences of employing and developing digital technologies and methods.

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[7] https://www.hrk.de/fileadmin/redaktion/hrk/02-Dokumente/02-03-Studium/02-03-02-Qualifikationsrahmen/2017_Qualifikationsrahmen_HQR.pdf

Usage, Application, and Generation of Knowledge

Using this knowledge, graduates can analyze built environment problems that can be addressed using digital technologies at different stages of planning, construction, and maintenance at different building scales. They are capable of systematically structuring digital components of built environment tasks, can formulate relevant technical and scientific questions related to information technology in the built environment, and can identify and evaluate the most effective approaches and methodologies for a specific situation. They are capable of utilizing existing information technologies and digital methods to solve tasks, have the knowledge and skills required to independently further their understanding where a task necessitate it, and can conceive and develop novel and innovative technological approaches, methods, and systems where appropriate. For example, graduates are able to develop data exchange standards and protocols or define data capturing and processing chains.

Through their education, graduates possess a critical attitude and can reflect on their proposed actions, can propose alternative courses of action, and can adapt their approaches to new situations. This is critical within the built environment context, where task requirements change based on the context, the framing of issues, and the selected solution strategies. Graduates holistic understanding of the field allows them to use, combine, conceive, and develop technology from different building domains. Combined with their deep understanding of information structures, they are able to connect information silos systematically and build bridges between different domain specific technological approaches.

Graduates are able to discern the interrelation between built environment tasks, the information technology landscape, and different methodological approaches enabling them to estimate and weigh the costs and benefits from technical, economic, social, and ethical perspectives. In combing the systemic thinking of architects with the systematic reasoning of civil engineers, graduates are capable of the autonomous use of relevant design and decision-making freedoms but can also judge their own limitations and where further resources, research, or experts are needed. As such, they are competent in the selection of suitable resources for a task and are able to identify stakeholders with the case-specific in-depth technical knowledge required for the undertaking.

Communication and Cooperation

Graduates of the program function as integrators between different built environment disciplines within multi-disciplinary teams. They are capable of presenting their work in front of scientific and professional audiences and can exchange ideas with representatives of different academic and non-academic fields on a factual and subject-related basis. They can explore alternatives and theoretically justifiable solutions with these different groups, and discuss approaches and results with scientific and non-scientific communities. Their interdisciplinary education trains graduates to be open-minded and gives them experience in working in international and intercultural environments. As a result, they can communicate and collaborate at both a national and an international level with both experts and laypeople. Through their ability to work in interdisciplinary teams, they are capable of recognizing conflict potential within the team and are well suited to proposing solutions.

Scientific Self-Understanding / Professionalism

Graduates can apply, develop, and critically question information technologies used in the built environment and are capable of analyzing and judging the resulting data and information. Furthermore, graduates can construct new research questions and adapt and develop new tools within this context, forwarding both research and practice. Graduates can work scientifically and methodically and are able to identify relevant gaps in research, form appropriate research questions, select, and develop suitable research methods to address these questions, conduct and analyze investigations, and communicate results. As such they develop a professional self-understanding based on academic and professional standards within the field. They can justify their professional actions and work independently or as part of a team. They are able to reflect on context-specific decisions and their impacts. As a result, they are capable of developing their professional actions in the field of information technologies for the built environment but are also capable of furthering the field.

3 Target Groups

3.1 Target Audience

Who is the target audience of the M.Sc. program?

The MSc Information Technologies for the Built Environment targets graduates with a bachelor's degree from a program comprising of at least 6 semester (180 ETCS) in the fields of architecture, landscape architecture, urban planning, civil engineering, environmental engineering, geodesy and geoinformation, computer science, or similar programs. The program is offered in English, welcoming both national and international candidates.

3.2 Prerequisites

What specific knowledge, skills, and competencies should first-year students have?

Applicants require at least a bachelor's degree in one of the disciplines mentioned above. Due to the interdisciplinary nature of the MSc Information Technologies for the Built Environment, applicants are expected to have different levels of existing knowledge, skills, and competencies required to complete the MSc. However, the MSc provides for this in its course structure.

Applicants must have a solid foundation of either the built environment or computer science with a strong interest in the other. This interest must be evident in their previous work and activities. While practical experience within the building industry is beneficial, applicants are required to have existing knowledge in more than one of the following areas of knowledge:

- Basics of construction methods, practices, and processes,
- Basics of construction planning and design methods, practices, and processes,
- Basics in the representation of geometric and semantic data,
- Basics in digital design methods,
- Basics in the communication processes within the built environment,
- Basics in information technology, systems architecture, and programming.

The ability to work scientifically and methodically is a prerequisite. As the course is offered in English, good English spoken and written language skills are required. Naturally, lateral entrants with the appropriate qualification requirements are also admitted.

The entrance qualifications and prerequisites for admission to the master's degree program are regulated by the aptitude procedure (EV), the subject examination, and study regulations.

3.3 Target Numbers

How many students are targeted per cohort?

The master’s program consists of approx. 40 graduates a year.

4 Demand Analysis

The digital transformation reaches all areas of our modern societies. According to the Digitization Index for Medium-sized Businesses 2019/2020[8] the construction industry is far behind other industries. At the same time, the digital transformation of the building industry holds great potentials in dealing with increasing pressure on urban systems and their infrastructures. To counteract issues of productivity and to promote attractive housing and working environments, cities such as Munich, Hamburg, Vienna, Zurich, Rotterdam, and Helsinki are implementing smart city strategies with the help of digital twins of the built environment. Strategies such as this look to utilize new digital technologies such as BIM, AR, VR, AI, drones, robots, and many more, as displayed in Figure 1, which shows the trend of current and planned use of digital technologies in industry relate companies[9]. Political agendas strengthen the demand for integrating these technologies in the built environment through policy and strategies such as the BIM-Stufenplan[10] of the German Federal Ministries, the UK Government BIM Mandate[11], or the Handbook for the introduction of BIM by the EU BIM Task Group[12].

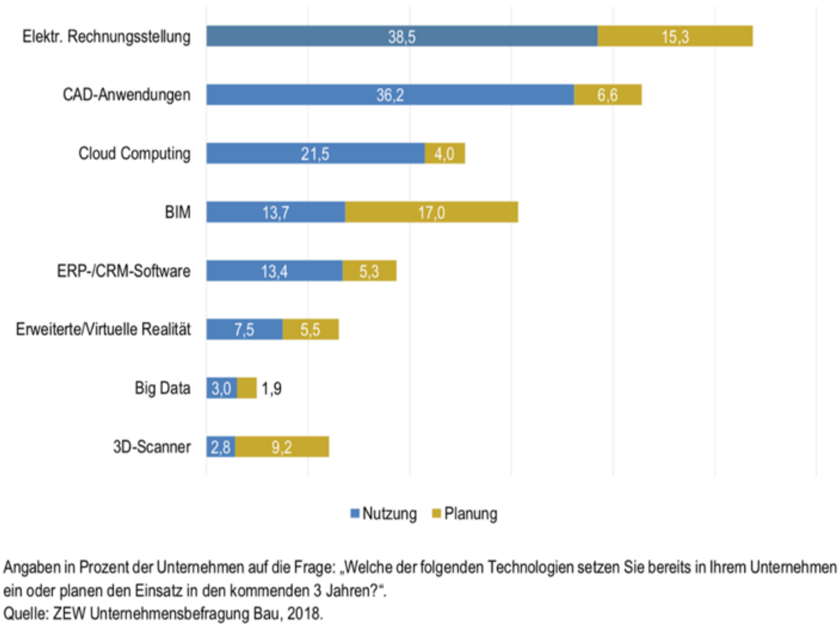

Figure 1: Use of digital technologies in the building industry incl. planning (in percent of companies)[13]

[8] https://www.digitalisierungsindex.de/wp- content/uploads/2019/11/techconsult_Telekom_Digitalisierungsindex_2019_GESAMTBERICHT.pdf
[9] https://www.bbsr.bund.de/BBSR/DE/veroeffentlichungen/bbsr-online/2019/bbsr-online-19-2019-dl.pdf?__blob=publicationFile&v=1
[10] https://www.bmvi.de/SharedDocs/DE/Publikationen/DG/stufenplan-digitales-bauen.pdf?__blob=publicationFile
[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/510354/Government_Construction_Strategy_2016-20.pdf
[12] http://www.eubim.eu/handbook
[13] https://www.bauindustrie.de/themen/news-detail/digitalisierung-am-bau-vorantreiben

To successfully implement these strategies, technologies require consistent information flows, data, and processes requiring universal digital standards[14]. However, cooperation between the different building domains, integrated working processes, and partnerships are just as important[15]. Figure 2 shows current obstacles for the successful implementation of digital technologies as seen by companies in the building industry. These include missing standards and interfaces (54,9%), insufficient overview of the information technology landscape (45,7%), lack of employee know-how (39%), or unmature digital products and services (43,1%). This indicates a lack of expertise in the understanding, use, and development of information technologies by domain specialists within the built environment. In contrast, IT specialists lack the domain specific knowledge necessary to implement for information technology management and development within the built world. That 61 per cent of companies in the construction industry[16] were looking in vain for suitable employees in 2018 (rising trend) supports this analysis. In response to these developments, Achim Dercks, Deputy General Manager of the DIHK[17], called for the strengthening of digital skills as one measure to counteract this shortage of skilled workers[18].

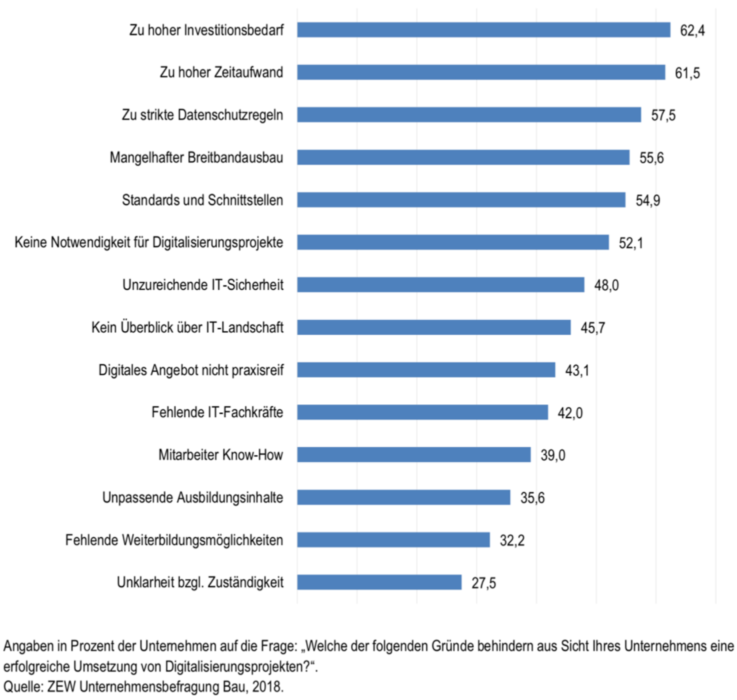

Figure 2: Barriers for the use of digital technologies in the building industry incl. planning (in percent of companies)[19]

[14] https://www.bauindustrie.de/themen/news-detail/digitalisierung-am-bau-vorantreiben
[15] https://www.bauindustrie.de/themen/news-detail/digitalisierung-am-bau-vorantreiben
[16] https://de.statista.com/statistik/studie/id/13186/dokument/bauhauptgewerbe-in-deutschland--statista- dossier/
[17] https://www.dihk.de/de
[18] https://de.statista.com/statistik/studie/id/53842/dokument/arbeitsmarkt-in-deutschland/
[19] https://www.bauindustrie.de/themen/news-detail/digitalisierung-am-bau-vorantreiben

The demand for higher education in this field is also evident in the rising demand and interest in education on information technologies for the built environment at the TUM. Courses such as “BIM”, an interdisciplinary module between the Chair of Computational Modeling and Simulation and Chair of Architectural Informatics show a contiguously rising interest in the subject with growing student numbers, which has led to a more frequent offer of the module in both winter and summer semesters. Further evidence are the constantly increasing numbers of participants in the advanced study programs “BIM-Professional” and “Digital Twin” offered by the TUM LLL, as depicted in Figure 3.

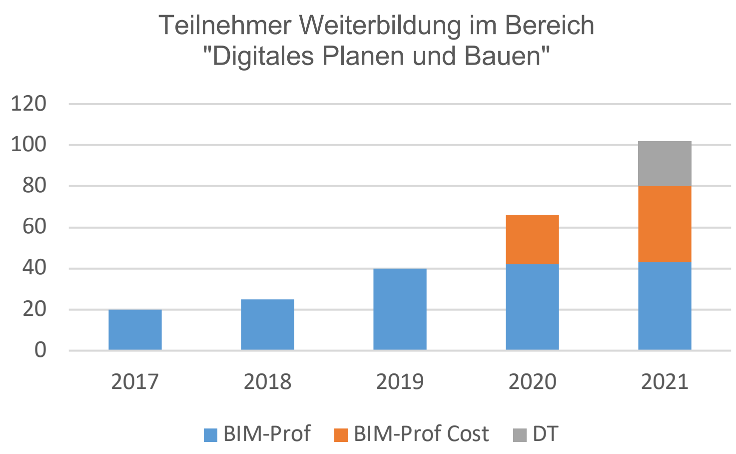

Figure 3: Participant numbers of the TUM LOC advanced study programs “BIM-Professional” and “Digital Twin”.

Graduates of the MSc ITBE program cannot solve all the issues related to digitalization in the building industry as listed above however, they are key to the development and implementation of digital standards, tools, and interfaces and have a deep understanding of the information technology landscape for built environment activities across different building scales and domains.
Graduates of the program enter the following fields of employment:

- System analysts and designers for complex, distributed software systems for multi-scale Built Environment applications
- Software developers and data engineers in the field of the Built Environment
- BIM experts (BIM managers, BIM consultants, BIM project managers, etc.)
- Specialists in the use of Geographic Information Systems for Smart Cities applications

- Experts in the use of modern digital acquisition methods (photogrammetry, laser scanning, drone deployment, point cloud processing)
- Experts in scale-spanning Digital Twins

They are active, in areas of research, business, and administration, such as:

- Software industry with a focus on construction, geoinformatics and related fields
- Research and development
- Construction industry and construction machinery companies
- Administration (ministries and municipalities)
- Planning and surveying offices

In addition, graduates can be expected to launch a wide variety of start-up initiatives.

5 Competition Analysis

5.1 External Competition Analysis

There are several degree programs worldwide, listed in the table below, that use terms such as "Building Information Modelling/ Management (BIM),"[20] "Digital Architecture/ Design/ Technologies/ Construction,"[21] "Geographical information systems/ Geographic Information Science (GIS),"[22] or "Smart Cities"[23] in their title. Similarly, there are study courses at other universities which provide students with the methodological tools and applications in the respective disciplines in digital design and planning processes, operation of buildings and cities[24] , and geomatics[25] (photogrammetry, GIS, geodesy). While these programs target bachelor graduates from different domains, they focus on domain specific theory and application. A more interdisciplinary approach is taken by the specialization in the civil engineering master's program[26] at the OTH Regensburg, established in 2018 as part of the endowed professorship *"Digitalisiertes Bauen", with the* aim to strengthen links to other departments such as computer science. The RWTH Aachen is planning a similar study program titled *"Digital Engineering for Construction"*[27] for the academic year 2020/2021.

The MSc Information Technologies for the Built Environment however goes a step further in strongly connecting the different planning domains. An overarching, interdisciplinary course of study focusing on information technology fundamentals of the built environment (cross-scale from buildings to cities to regions) and the development of digital models and processes does not yet exist. This approach is uniquely represented by the structures of the TUM *Leonhard Obermeyer Center for Digital Methods for the Built Environment,* which established the program. Furthermore, the TUM holds a unique position, at least within Germany, in housing information technology expertise within the necessary fields to cover different domain-related scales within a single university.

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[20] z.B. University of Salford Manchester, Cardiff University, University of Liverpool, University of Nottingham, University of the West of England Bristol
[21] z.B. University of Brighton, Nottingham Trent University, University of Reading, University of Twente
[22] u.a. University of Edinburgh, Georgia Tech
[23] u.a. University College London, Erasmus University Rotterdam, University of Bedfordshire
[24] u.a. MSc "*Digital Innovation in Built Asset Management*"
[25] u.a. TU Delft sowie ETH Zürich
[26] OTH Regensburg
[27] personal communication with Profs Blankenbach, Beetz, van Treeck (all RWTH)

Universities Germany/ Austria/ Switzerland

Location/ institution	Program	Target group
Aachen/ RWTH Aachen	Digital Engineering for Construction	?
Zürich/ ETH Zürich	Geomatik	AR/ CI/ EV/ GE/ UP
Weimar/ Bauhaus-Universität Weimar	Digital Engineering	CI/ CS/ EV/ GE/ ME

University of Applied Sciences Germany/ Switzerland

Location/ institution	Programme	Target group
Basel/ FH Nordwestschweiz	Digitales Bauen	AR/ ME/ CI/ RE
Regensburg/ OTH Regensburg	Digitalisiertes Bauen	?

Universities international (language: English)

Location/ institution	Programme	Target group
Atlanta/ Georgia Tech	Geographic Information Science and Technology	AR/ CE/ CS/ EV/ UP
Brighton/ University of Brighton	Digital Construction	?
Bristol/ University of West of England	Building Information Modelling (BIM) in Design Construction and Operations	AR/ CE/ EV/ UP
Cardiff/ University	Building and Infrastructure Information Modelling (BIM) for Smart Engineering	AR/ CI/ EV
Delft/ TU Delft	Geomatics	AR/ CI/ CS/ EV/ GE/ UP
Edinburgh/ University	Geographical Information Science	?
Liverpool/ University	Building Information Modelling (BIM)	AR/ CI/ CS/ UP
London/ University College	Digital Engineering Management	AR/ CI/ CS/ ME
London/ University College	Digital Innovation in Built Asset Management	AR/ CI/ FM
London/ University College	Smart Cities and Urban Analytics	AR/ CS/ EV/ RS/ GE
Luton/ University of Bedfordshire	Sensors and Smart Cities	?
Manchester/ University of Salford Manchester	BIM and Digital Built Environments	AR/ CI/ EV/ UP
Nottingham/ Trent University	Digital Architecture and Construction	AR/ CI
Reading/ University	Digital Design and Construction	CI
Rotterdam/ Erasmus University	Urban Environment, Sustainability and Climate Change – Nature-Based Solutions for Smart and Resilient Cities	CI/ EV/ GE/ UP
Twente/ University	Digital Technologies in Construction	CI/ ME

Legend - Target group:

AR – Architecture, CE – Civil/ Construction/ Structural Engineering, CS – Computer Science, EV – Environmental Engineering/ Science/ Management, FM – Facility/ Asset Management, GE – Geography/ Geodesy/ Geomatic engineering, ME – Mechanical Engineering, RE – Real Estate, RS – Remote Sensing, UP – Urban Planning

5.2 Internal Competition Analysis

In the existing conventional courses in architecture, civil engineering, and geodesy at the TUM, students are educated in domain-specific digital methods and technologies. Examples include the MSc Geodesy and Geoinformatics, the MSc Computational Mechanics, the specialization "Computation in Engineering" in the MSc Civil Engineering, or the specialization "Computational Design" in the MA Architecture program. Due to the necessity of teaching a broad range of highly relevant non-digital competencies to achieve the professional standards and prepare graduated for the demands of these domains' professional profiles, students are structurally limited in deepening their understanding of information technology. Furthermore, these programs focus on domain-specific information technologies and methods meaning they lack the trans-disciplinary perspective offered in the MSc Information Technologies for the Built Environment.

In contrast, computer science programs at the TUM offer state-of-the-art education on computational methods, software engineering, and systems structures. Naturally, the focus here lies on fundamental computer science aspects in terms of designing algorithms and data structures. At the same time, however, graduates lack the domain knowledge and understanding of built environment issues required to capture, map, analyze, interpret, and manipulate complex, semantic, domain-specific information.

The MSc Computational Mechanics offers more in-depth teaching of computational methods applied to engineering problems than other existing programs at the TUM. However, the digital methods taught focus on numerical methods for analyzing and simulating physical phenomena. In contrast, the MSc Information Technologies for the Built Environment provides a broader access to information technology education while focusing on Built Environment applications, covering highly relevant aspects such as semantic modelling, geometric modelling, cloud-based information management, and digital twinning as well as the use of these information technologies to design, develop, and manage attractive, livable environments.

6 Program Structure

The MSc Information Technologies for the Built Environment is a full-time study program with a standard duration of study of 4 semesters, adding up to a total of 120 credit points (CP) per the European Credit Transfer System (ETCS). The study program furthers the education of bachelor graduates in architecture, civil engineering, geodesy, and computer science (or similar), specializing them in the use of digital methods and information technologies within the built environment, across different building and construction scales and disciplines. The main language of the program is English.

<table>
<tr><th>Semester</th><th>1. Semester</th><th>2. Semester</th><th>3. Semester</th><th>4. Semester</th></tr>
<tr><td rowspan="6">Modules</td><td>Geospatial Information Science
(required)
6 CP</td><td>Semantic Modeling of the Built World*
(required)
6 CP</td><td rowspan="3">ITBE Fusion Lab*
(required)
12 CP</td><td rowspan="6">Master Thesis
(required)
30 CP</td></tr>
<tr><td>Computational Design in Architecture
(required)</td><td rowspan="2">BIM Fundamentals*
(required)
6 CP</td></tr>
<tr><td>Photogrammetry and Remote Sensing
(required)</td></tr>
<tr><td>Professional Software Engineering
(required)
6 CP</td><td>Platform Oriented Construction Management
(required)
6 CP</td><td>Distributed and Cloud-Based Systems*
(required)
6 CP</td></tr>
<tr><td>Elective
6CP</td><td>Elective
6CP</td><td>Elective
6CP</td></tr>
<tr><td>Elective
6CP</td><td>Elective
6CP</td><td>Elective
6CP</td></tr>
<tr><td>Credits / No. of Exams</td><td>30 / 6</td><td>30 / 5</td><td>30 / 4</td><td>30 / 1</td></tr>
</table>

Figure 4: Degree chart for the four-semester master's program Information Technologies for the Built Environment (*interdisciplinary module).

Compulsory Modules

The course is structured as shown in Figure 4 to ensure the qualification competencies described in Chapter 2. This is primarily achieved through the compulsory modules in the first three semesters (totaling 54CP) and the master thesis (30CP). Compulsory modules offered in the first semester give students from different domain backgrounds knowledge on key components, developments, requirements, and constraints of information technologies from multiple building domain perspectives. This generates a common understanding on different domain specific information silos and approaches. To generate a holistic and integrated understanding of the field across domains and construction scales, compulsory modules in the second and third semesters focus on specific built environment information technology issues from multiple (at least two) domain perspectives. The acquired methodological and theoretical knowledge is then put into practice in the third semester within the interdisciplinary practical project, ITBE Fusion Lab.

Students receive state-of-the-art theoretical and methodological education in topics such as:

- Spatial modelling (both geometric and semantic) at different scales,
- Methods in data acquisition, selection, analysis, and interpretation related to the built environment,
- The application of digital methods within the context of architectural design, construction and engineering and the construction processes,
- Digital collaboration within planning and construction processes with both other professionals and laypeople,
- Fundamentals in software engineering and system architecture,
- Knowledge on the application of state-of-the-art technologies such as distributed systems, cloud computing, and semantic web technology.

Compulsory modules are taught as a combination of 3CP and 6CP lectures, exercises, and seminars specifically designed to transfer core knowledge on information technologies in the built environment. They are offered by the area's architecture, civil engineering, and geodesy from the TUM School of Engineering and Design. Modules such as “BIM.fundamentals” (architecture and civil engineering), or “Semantic Modeling for the Built Environment” and “Distributed and Cloud-Based Systems” (civil engineering and geodesy) are taught collaboratively, by different professors from different domain backgrounds. Additionally, elements of modules such as Semantic Modelling of the Build World (ITBE and GuG) or BIM.fundamentals (ITBE, AR, BI) are available to students in multiple built environment master's degrees connecting students across disciplines.

The ITBE Fusion Lab (12CP) forms a core component of the study program. This compulsory, practical, interdisciplinary project enables students to implement their theoretical and methodological knowledge from the initial two semesters in a practical scenario within interdisciplinary, collaborative, team settings. In the Lab, students are given a broad but realistic task, such as an urban design task, a data acquisition task, or a process management task, which they solve using digital methods and information technologies. The ITBE Fusion Lab requires students to work in interdisciplinary teams to identify specific issues within the frame of the task, select appropriate methods and technologies to address the selected issue, manage the development process, delegate and share jobs, and reflect on their approach. This promotes the interaction of students from different domain backgrounds as they work together in interdisciplinary teams on a common issue and are exposed to other domain perspectives. It enabling students to communicate and collaborate with people from different professional backgrounds, gives them the ability to integrate and involve different planning stakeholders according to their expertise, and provides them with the opportunity to identify and resolve conflict situations within a team. Interdisciplinarity is not only given through the interaction of students, but also through the interdisciplinary teaching and feedback provided by professors and scientific experts from the different domains within this Lab. While built environment activities can never occur without considering social implications, the Project Week within this module actively strengthens social participation aspects though sprint with student in other departments both within and outside the TUM School of Engineering and Design.

In the master thesis (30CP), students identify a research question and select and develop an appropriate method to address a specific built environment research gap. They carry out a scientific investigation and analyze results. This work is documented and communicated in a scientific paper and an oral presentation.

Electives

As information technologies in the built environment is a growing and fast changing field, the study program is structured to allow students flexibility in their curriculum in the form of elective modules totaling 36CP. This flexibility has a number of different reasons. It allows students from different backgrounds to supplement their personal profiles with knowledge from other areas. For example, a student with a computer science background may supplement their existing knowledge with more detailed knowledge on built environment processes. A student with a civil engineering background has prior understanding of built environment processes but may supplement their understanding with software engineering methods. Furthermore, the elective modules also allow new technologies and methods to be integrated within the program as the field develops. Different electives allow students to gain knowledge on many different technologies and approaches, which supports their holistic understanding of the field.

A core of elective modules is presented in Table 1 and Table 2. These are continuously updated by the examination board in order to secure state-of-the-art teaching in a fast-moving field and to provide an attractive range of electives. The current and comprehensive version of the elective catalog is available on the program website. This catalogue contains interdisciplinary modules from other departments and fields of specialization. Although there is always an element of ethical and social consideration within built environment task, minimum of 3CP gained through a selection of elective modules in the area of “ethics and the human factor” ensures graduates active confrontation with ethical and social consequences of designing and using information technologies. Figure 6 and Figure 6 shows an exemplary degree chart with selected electives. Modules from other faculties and universities can be taken by students, provided they meet the requirements of this master’s degree.

Table 1: Elective Module Catalogue for the Area Ethics and the Human Factor (minimum of 3CP is required).

Module	**ECTS**	**SWS (Type)**	**WiSe/ SoSe**
Interaction Prototyping	4	3 (P)	WiSe
Menschliche Zuverlässigkeit	5	2 + 1 (V + UE)	SoSe
Software-Ergonomie	5	2 + 1 (V + UE)	WiSe

SWS = Weekly hours per semester; SoSe = Summer semester; WiSe = Winter semester
V = Lecture; UE = Exercise; VI = Lecture with integrated exercise; S = Seminar; P = Practical.

Table 2: General Elective Module Catalogue (minimum of 21CP required).

Module	**ECTS**	**SWS (V, U, S)**	**WiSe/ SoSe**
Software Lab	6	2 + 2 (S + S)	WiSe/ SoSe
Internet of Things in the Built Environment	5	4 (VI)	SoSe
Spatial Data Management and System Architectures - Advanced Methods	5	3 + 2 (V + UE)	WiSe
Big Geospatial Data	3	2 + 1 (V + UE)	SoSe
Principles of Spatial Data Mining and Machine Learning	3	2 + 1 (V + UE)	WiSe
Parametric Design	6	4 (S)	SoSe

Interactive Visualization	6	4 (S)	WiSe
Performance Based Design	6	4 (S)	WiSe
Rendertube	6	4 (S)	SoSe
Principles of Databases	5	3 (VI)	WiSe
Spatial Decision Support Systems	5	3 (VI)	WiSe
Engineering Databases	3	2 (V)	WiSe
Robotische Fabrikation in der Architektur	6	4 (S)	SoSe
Modeling Urban Development	6	2 + 2 (V + S)	WiSe

SWS = Weekly hours per semester; SoSe = Summer semester; WiSe = Winter semester
V = Lecture; UE = Exercise; VI = Lecture with integrated exercise; S = Seminar; P = Practical.

Modules Under 6 ETCS-Credits

The compulsory modules "Computational Design in Architecture" and "Photogrammetry and Remote Sensing" both comprise of 3CP. The module scope of 3 credits promotes the interdisciplinary teaching of information technologies and is sufficient and appropriate to the required workload to achieve the learning outcomes assigned to these modules as well as the qualification objectives of the degree program.

The elective module catalog offers students the opportunity to deepen their knowledge in highly complex areas of information technologies in the built environment and to adapt their education to meet their future career goals. Different topics include data protection, agile methods, specific programming languages and methods, or specific technologies. These different topics are offered by individual lecturers on the basis of their latest research results in a few hours per week, thus only requiring a few credits. The benefit of these smaller credit modules for students is that they gain significant knowledge and insights into state-of-the-art technology and research. For lecturers, these small modules are often the only opportunity for them to integrate very current and very specific content within their teaching in a timely manner.

On the other hand, the electives offered promote the interdisciplinary character of the degree program. Students come from different backgrounds and therefore require cross-disciplinary supplementary modules within the whole range of subjects offered within the context of this degree, so that they can meet the study program requirements. In order to guarantee the students a maximum of choice and combination possibilities for their individually chosen orientation, modules with fewer credits are offered in addition to larger modules with a workload of 6CP. In general, however, a sufficient number of large elective modules are offered so that studying within the planned examination load of max. 6 examinations/semester is guaranteed.

Student Mobility

The study program is offered in English. This means, the target group of the degree program includes both national and international students. Therefore, mobility aspects need to be considered both for national students who wish to study abroad at a foreign university for one or more semesters (outgoing students) and for students from abroad who wish to visit the TU Munich for one or more semesters as part of an exchange program (incoming students).

Within the framework of this study program, the second and fourth semesters are suited to study abroad. The compulsory modules offered within the second semester are offered both in the summer and winter semesters meaning students can take these in semesters other than the second semester. The flexibility of the study program through the high degree of elective modules supports student mobility, allowing for students to fill elective modules with courses at other universities. Where these measures are not possible (e.g. Semantic Modelling of the Built World), virtual participation in the module is offered. The modules studied abroad need to be agreed upon with the TUM before the start of the study abroad period. To further promote student mobility, the master's program offers the possibility of writing the master thesis abroad under the joint of a foreign collogue and a TUM professor. This promotes international collaboration at a scientific level and strengthens international research networks and partnerships.

As a result of these different measures, it is possible for students to study abroad for one or two semesters without extending the study period of four semesters.

Exemplary Degree Chart A - with Electives

1. Semester	2. Semester	3. Semester	4. Semester
Geospatial Information Science (required) 6 CP	Semantic Modeling of the Built World* (required) 6 CP	ITBE Fusion Lab* (required) 12 CP	Master Thesis (required) 30 CP
Computational Design in Architecture (required) 3 CP Photogrammetry and Remote Sensing (required) 3 CP	BIM Fundamentals* (required) 6 CP		
Professional Software Engineering (required) 6 CP	Platform Oriented Construction Management (required) 6 CP	Distributed and Cloud-Based Systems* (required) 6 CP	
Modeling Urban Development (elective) 6CP	Robotische Fabrikation in der Architektur (elective) 6CP	Spatial Data Management and System Architectures (elective) 5CP	
Interactive Visualisation (elective) 6CP	Parametric Design (elective) 6CP	Engineering Databases (elective) 3CP Interaction Prototyping (elective) 4CP	
30 / 6	30 / 5	30 / 6	30 / 1

Figure 5: Exemplary degree chart A - including modules (*interdisciplinary module).

Exemplary Degree Chart B - with Electives and Credit Deviation

<table>
<tr><th>1. Semester</th><th>2. Semester</th><th>3. Semester</th><th>4. Semester</th></tr>
<tr><td>Geospatial Information Science
(required)
6 CP</td><td>Semantic Modeling of the Built World*
(required)
6 CP</td><td rowspan="3">ITBE Fusion Lab*
(required)
12 CP</td><td rowspan="8">Master Thesis
(required)
30 CP</td></tr>
<tr><td>Computational Design in Architecture
(required)
3 CP</td><td rowspan="2">BIM Fundamentals*
(required)
6 CP</td></tr>
<tr><td>Photogrammetry and Remote Sensing
(required)
3 CP</td></tr>
<tr><td>Professional Software Engineering
(required)
6 CP</td><td>Platform Oriented Construction Management
(required)
6 CP</td><td>Distributed and Cloud-Based Systems*
(required)
6 CP</td></tr>
<tr><td rowspan="2">Modeling Urban Development
(elective)
6CP</td><td>Menschliche Zuverlässigkeit
(elective)
5CP</td><td rowspan="2">Spatial Data Management and System Architectures
(elective)
5CP</td></tr>
<tr><td rowspan="2">Internet of Things in the Built Environment
(elective)
5CP</td></tr>
<tr><td rowspan="2">Performance Based Design
(elective)
6CP</td><td>Engineering Databases
(elective)
3CP</td></tr>
<tr><td>Big Geospatial Data
(elective)
3CP</td><td>Principles of Spatial Data Mining and Machine Learning
(elective)
3CP</td></tr>
<tr><td>30 / 6</td><td>31 / 6</td><td>29 / 5</td><td>30 / 1</td></tr>
</table>

Figure 6: Exemplary degree chart B - including modules with a credit deviation (*interdisciplinary module).

7 Organization and Coordination

The following administrative tasks are performed partly by the TUM Center for Study and Teaching (TUM CST) and its administrative units, partly by offices in the schools or departments:

• Student Advising:	Student Advising and Information Services (TUM CST) 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: Sarah Jenney M.A., MBA Email: s.jenney@tum.de Phone: +49 (0)89 289 25023 Academic Advisor: Prof. Dr. André Borrmann
• Academic Programs Office:	Study Office Dr. Thomas Wagner
• Study Abroad Advising/Internationalization:	TUM-wide: TUM Global & Alumni Office internationalcenter@tum.de Departmental*: International Affairs Delegate, Nadin Klomke, M.A. Email: n.klomke@tum.de Phone: +49 (0)89 289 22335
• Gender Equality Officer:	TUM-wide: Dr. Eva Sandmann sandmann@tum.de, Tel. +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: Service 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:	Admissions and Enrollment (TUM CST) Email: studium@tum.de Phone: +49 (0)89 289 22245 Admissions, enrollment, Student Card,

leaves of absence, student fees payment, withdrawal

- Aptitude Assessment (EV): TUM-wide: Admissions and Enrollment (TUM CST)
  Departmental*: Aptitude Assessment Commission,
  Prof. Dr. André Borrmann
  Prof. Dr. Frank Petzold
  Prof. Dr. Thomas H. Kolbe
  Prof. Dr. Konrad Nübel
  Prof. Dr. Uwe Stilla
- Semester Fees and Scholarships: Fees and Scholarships (TUM CST),
  Email: beitragsmanagement@zv.tum.de
- Examination Office: Central Examination Office (TUM CST),
  Campus Munich/Garching/Weihenstephan/
  Klinikum rechts der Isar
  Graduation documents, notifications of examination results, preliminary degree certificates
- Departmental Examination Office*: Examination office:
  Manuela Schillo M.A.
  Email: m.schillo@tum.de
  Tel.: 089 289 22405
- Examination Board: Prof. Dr. André Borrmann (Chair)
  Prof. Dr. Frank Petzold (Secretary)
- Quality Management – Academic and Student Affairs:
  TUM-wide: Study and Teaching –
  Quality Management (TUM CST),
  www.lehren.tum.de/startseite/team-hrsl/
  Departmental*: Consultants for Studies and
- Teaching Dr. Lars Fuchs, lars.fuchs@tum.de
  Dipl.-Ing. Sandra Spindler-Kozlik,
  sandra.spindler@tum.de
  Prof. Dr. Stephan Freudenstein (Dean of Studies)
  Organization QM Circle: Dipl.-Ing. Sandra Spindler,
  Evaluations Representative*:
  Dipl.-Ing. Sandra Spindler-Kozlik,
  sandra.spindler@tum.de
  Coordination, Module Management*:
  Dipl.-Ing. Sandra Spindler-Kozlik,
  sandra.spindler@tum.de

*During the TUM School transition period, administrative positions may change; the most current contact information can be found on the study program website.

8 Enhancement Measures

The Master’s Program Information Technologies for the Built Environment started in the winter semester 2022/23. The initial reasons were that the needs for information technology experts in the built environment cannot be covered by the conventional education of architects, civil engineers, geodesics, or information scientists and that a cross-disciplinary and cross-scale understanding of information technologies for the built environment is necessary to address spatial issues with increasing complexity. The MSc Information Technologies for the Built Environment represents one of the first programs worldwide to take this holistic approach. It aims to break down the information silos between different built environment domains, shaping interdisciplinary experts with the holistic understanding of different building domains and scales, as well as information methodologies to actively manage, drive, and shape the information technology landscape within the building industry. As one of the first programs under the new School structure at the Technical University of Munich, in the School of Engineering and Design, it embodies core values of the university as an entrepreneurial, interdisciplinary, international, technology-based program focusing on “Human-Centered-Engineering”.

The program structure provides a rigid foundation, necessary to bridge the gap between domain information methods and technologies but provides a flexible and practice orientated framework which is regularly updated and adapted to meet developments in this dynamic, growing field, continuously providing state-of-the-art education. Regular quality management reviews of the degree program, ensure the MSc meets its goals, the market requirements, and its high educational standards.