4TU.MSc in Construction Management and Engineering

TU Delft
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TU/e Technische Universiteit Eindhoven University of Technology

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Information Package
CME @TU/e

Information Package CME @ TU/e

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Department of the Built Environment
Department of Industrial Engineering & Innovation Sciences

Eindhoven University of Technology

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Introduction

The CME information package includes information about the CME Master program needed to prepare yourself for your new Master at the Eindhoven University of Technology. For graduation a separate document is available entitled 'Graduation guide CME @TU/e'. This information package is prepared for your convenience, however, the most up-to-date information can only be found on the university website. Thus no obligations can be derived from this document.

The most important web links where you can find the most up-to-date information are:

http://www.tue.nl/cme

https://educationguide.tue.nl/gs/cme

TU/e course system (intranet, TU/e account needed):

http://osiris.tue.nl/ and http://canvas.tue.nl/

4TU-CME program, including the 4TU-CME study guide:

https://www.4tu.nl/cme/en/

In the chapter 'CME Course Planning' on page 18 you find guidelines on how to plan your individual two-year CME Master program dedicated to your personal career and ambitions. These guidelines will also help fill in your personal study program requested by the TU/e Graduate School.

The CME Information package, the Graduation guide CME @TU/e, and all other information about the CME master program can be obtained through the CME secretariat:

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CME Master program and Course list

The CME Master program contains 120 EC and consists of:

30 EC Core Courses
35 EC Specialization Electives
15 EC Free Electives
40 EC Graduation

The table presents the relevance of each CME course for the CME-related scientific areas.

CME				Scientific area	
		EC	Q	Engineering	Management
	30 EC				
1CM900	Project management	2,5	2	x	
1ZM65	System Dynamics	5	4	x	
7ZM8M0	Collaborative Design	5	3	x	x
7ZM3M0	Case Study Process Modelling of construction projects	2,5	1	x	x
7ZM5M0	Process Modeling and Information Management	5	4	x	x
7ZZ9M0	Design Science Methodology and Systems Engineering	5	1	x	x
7ZZ6M0	Legal and Governance Aspects	5	1	x	
	35 EC out of 70 EC				
7ZW7M0	Urban Research Methods	5	3	x	x
1ZM20	Technology Entrepreneurship	5	1	x	
1ZM120	Entrepreneurial Marketing	5	2	x	
7ZW4M0	Built Environment and Smart Mobility	5	4	x	
7ZM1M0	Research and Development project	10	1-2, 3-4	x	x
7ZW1M0	Big data for urban & transportation analysis /project	10	3-4	x	
7M900	Fundamentals of Building Information Modelling	5	2	x	
7ZW3M0	Urban Planning II	5	1	x	x
7RC100	Inner-city modular high-rise	5	1		x
7KP8M0	Smart Building Methodology and Technology	5	3	x	
7XC1M0	Circularity in the Built Environment	5	1	x	
7ZM7M0	Parametric design	5	3	x	

CME graduation tracks

For your convenience, CME has configured 2 tracks related to the research expertise of the TU/e-CME staff members involved in the research program DDSS (dep . Built Environment) or BETA (dep. Industrial Engineering & Innovation Sciences). These tracks serve as a starting point for your personal planning which is explained in more detail in the chapter 'CME course planning', page 18.

Track: City Information Management

Cities are inherently complex and dynamic systems with many different stakeholders and long-term policies. Nevertheless, the fast pace of urbanization causes burdens on stakeholders and policymakers who are responsible for urban management. The research in urban management focuses on understanding dynamic urban processes and formulating policies for the development of sustainable and resilient cities. Urban management research contributes to socio-economic models that are needed to manage urban systems and forecast spatial effects and financial risks of policy measures by considering the emerging area of urban informatics (i.e. using sensors, GPS, APPs, location-based social network data for urban systems). Urban informatics utilizes urban Big Data to improve strategies for dynamic urban resource management, to gain insights into urban patterns and processes, and to support and make innovations for urban management, public participation and policy analysis.

	Specialization electives	EC	Q
7ZW7M0	Urban research methods	5	3
1ZM120	Entrepreneurial marketing - Certificate course Technology Entrepreneurship and Management	5	2
7ZM1M0	Research and development project	10	1-2,3-4
7ZW4M0	Built Environment and Smart Mobility	5	4
7ZW1M0	Big data for urban & transportation analysis /project	10	3-4
7ZW3M0	Urban Planning II	5	1

	Free electives		
7ZU3M0	Managing place and property	5	2
7LY8M0	Smart cities	5	3

Track: Building Information Management

Building Information Modelling (BIM) entails methods and data structures over the whole lifecycle of the building including the construction phase to facilitate efficient and accurate exchange and processing of all information related to the built environment. Information management is crucial for improving the effectiveness and efficiency of the Architecture, Engineering and Construction processes. The lack of integration and coordination between actors is a major factor in poor project performance and the overall low productivity index of the whole sector. Standardization of data structures and communication protocols in building modelling and city modelling are needed and should also integrate advanced communication and BIG data mining. A special focus among the ongoing research in Information Systems of the Built Environment (ISBE) lies on how building-related data can be connected across knowledge domains both within AEC and its neighbouring fields using Linked Data and Semantic Web technologies, information models and structures to allow greater levels of information access and cross-domain interoperability.

	Specialization electives	**EC**	**Q**
7ZM900	Fundamentals of Building Information Modelling	5	2
1ZM20	Technology entrepreneurship	5	1
7ZM7M0	Parametric Design	5	3
7KP8M0	Smart Building Methodology and Technology - Certificate course Building Design & Technology	5	3
7ZM1M0	Research and development project	10	1-2,3-4
7RC100	Inner-city modular high-rise - Certificate course Construction Technology	5	1
7XC1M0	Circularity in the Built Environment - Certificate course Circular Design in the Built Environment	5	1

	Free electives	EC	Q
7ZU4M0	Econometric analysis of housing markets: data, tools and strategies	5	1
7LY5M0	Data science for intelligent buildings	5	1

CME Course descriptions (excl. free electives)

1CM900 - Project Management

Learning objectives

- Being able to characterize a project aiming at the realization of a physical product in terms of the dynamics, the variability and the stochasticity of the project targets, the activities be performed and their precedence relationships. The available resources and the time cost budget constraints.
- Being able to analyze the possible result of a project as a function of its targets, its activities and the deployment of resources over time.
- Being able to evaluate the possible contribution of advanced decision-making methods to improvements in project performance.

Content

Planning work activities, costs and budgets, activity scheduling (PERT/CPM), resource allocation, and project execution (information requirements and control).

1ZM65 - System Dynamics

Learning objectives

By the end of this course, students will be able to:

- Explain how the internal structure of businesses, and societal, environmental, and economic systems create the behavior and performance of these systems.
- Apply principles of policy and business design for the successful management of complex integrative strategies.
- Can identify and analyze situations in which interventions and their outcomes are prone to be delayed, diluted, or defeated by unexpected reactions and unintended consequences.
- Can apply a range of systems dynamics tools, such as causal loop diagrams, stock-and-flow mapping, and formal mathematical modelling for modeling human behavior, supply chains, and technological innovation systems.
- Can evaluate the feedback behavior of systems through simulation analysis.
- Have basic knowledge about data collection for system dynamics model building and participatory system dynamics modeling.
- Can model basic complex systems and mathematically simulate their behavior.

Content

Why is achieving innovation so difficult? Why do many efforts to produce impactful and lasting results fail? Why is building sustainable organizational capabilities for achieving impact a challenge? How can we design effective, high-impact policies without unforeseen side effects?

Environmental stress and accelerating economic, social, and technological changes challenge managers and policymakers to learn how to design and manage high-leverage and robust strategies and policies. Thus, it is a growing requirement for us to learn how to design and manage complex systems with multiple feedback effects, long-time delays, and nonlinear responses to our decisions. However, learning in such situations is tough since we often don't face the full consequences of our decisions. To promote effective decisions, we need tools for

system thinking, dynamic complexity analysis, and accelerated organizational learning.

This course introduces the students to systems thinking for organizational policies and strategies with a specific focus on innovation and sustainability issues. They will learn to visualize an organization and its broader environment in terms of the structures and policies, which create dynamics and regulate performance. They will also perform dynamic analysis to examine the long-term side effects of decisions, systematically explore new strategies, and develop their understanding of complex systems.

On this basis, in the first lectures of the course, we will deal with a variety of subjects related to systems thinking, such as policy resistance, positive and negative feedback, bounded rationality, misperceptions of feedback, fundamental modes of dynamic behavior (exponential growth, oscillation) and causal loop diagramming. Then, we will discuss data collection and analyses for model building, pointing at various methods, including but not limited to, focus groups, interviews, and the Gioia method (assumed prerequisite knowledge), to develop grounded models. Participatory system dynamics model building, as an invaluable way to increase stakeholder engagement in model building, will also be focused on in this vein to help students learn how to build models to address issues and challenges in different organizations. We then continue with formal system dynamics modeling, by dealing with stocks and flows diagramming, the mathematical relationship between stocks and flows (integration and differentiation), delays, modeling human behavior (micro-level), modeling supply chains (meso-level), technological innovation systems (macro-level).

In the next part of the course, students will perform a group assignment in which a system dynamics model is developed based on a case description of innovation and sustainability business processes. With this model, students will better understand the mechanisms underlying the behavior of the system, and develop scenarios to improve its performance.

7ZM8M0 - Collaborative design

Learning objectives

- Understands the different roles in a building project and knows how to manage these
- Can write a project management plan using System Engineering
- Can monitor a collaborative design process
- Can assess the product and process performance in a collaborative design project
- Understands group dynamics and know how to act in a group
- Knows how to use his/her expertise in a collaborative design project
- Can write a scientific paper upon challenges in collaborative design and propose new directions
- Can use SE and BIM management tools in a collaborative design project

Content

The objective of this course is to gain insight into the problem domain of Collaborative Design with special attention to Systems Engineering (SE) and Building Information Modelling (BIM).

The course simulates a typical real-life collaborative design process. A consortium of companies will work on a design assignment for one quartile. A student is member on one of the following companies: Architects, Urban designers, and Engineers. A company consists of 3-7 students with one acting as the Chief Executive Officer (CEO), one as the Systems Engineering Officer (SEO) and the others as domain experts. The consortium management consist of all CEOs and SEOs from all three companies. The project starts with writing a project management plan. Next, the consortia execute their design projects while monitoring and evaluating the progress as defined

in the plan. The application of SE and BIM techniques and tools throughout the process is compulsory. Process support and design feedback is provided by the lecturers in dedicated sessions. A group dynamics training is also included in the course. The course concludes with a final design project presentation, a written report describing the design process, and an individual scientific paper as a contribution to the Collaborative Design research and development.

7ZM3M0 - Case study process modeling of construction projects

Learning objectives

- Select relevant information for the case study
- Identify the involved stakeholders' interests
- Specify the process phases
- Apply appropriate qualitative methods for analysis (e.g., Ishikawa diagram, stakeholder power/interest grid, SWOT, creating an action plan, etc.)
- Identify strengths and weaknesses of the process
- Provide recommendations for process improvement
- Write an academic report for case study

Content

Executing analysis for the process of a complex development project in the context of Construction Management and Engineering. At first, a real complex development project challenge is identified. The information related to the project is introduced by the involved company, students are required to use appropriate methods for analysis. Next, students are required to search all the necessary information online with similar projects using relevant selection criteria, and use appropriate methods for comparison analysis and then draw conclusions. The case study focuses more on the soft side of the process in terms of understanding the nature of the interactions between involved stakeholders and decision-making on projects within an uncertain and dynamic social, political and physical environment.

7ZM5M0 - Process modeling and information management

Learning objectives

- Have a multi-scale understanding of the built environment from city to building level regarding the development project.
- Construct the geo-process model to do spatial analysis (e.g., the site selection) for the development project.
- Analyze decision-making under uncertainties and develop optimization models under constraints.
- Apply information management tools in the building process.

Content

This course is about analyzing problems, optimizing processes and managing information flows in the context of urban development projects from city-scale to building level. This course consists of three interlinked modules, which sequentially cover the three key topics (Geo-process models for location selection, decision-making under uncertainty and optimization models, and information management tools in the building process). All three modules are linked to a hypothetical new development in a specific city. You can select a development type and a city in the Netherlands of your liking. The development types include a residential building (e.g., apartment

complex), a retail centre (e.g., mall), a hotel building or an office building.

7ZZ9M0 - Design Science Methodology and Systems Engineering

Learning objectives

- Understands the basics of Design Science Methodology
- Can apply Design Science Methodology to research problems in the domain of Architecture, Engineering, Construction and Operation (AECO)
- Understand the fundamental Systems Engineering (SE) principles
- Can apply SE principles in the domain of AECO project management
- Knows how to use Building Information Modelling (BIM) methods and tools in combination with web technologies to support SE

Content

Design Science Methodology' (DSM) focuses on design-science research approaches and science-based design approaches, both aiming to link science and design. A design-science research project aims to develop design knowledge; a science-based design project aims to design an artefact, thereby applying scientific design knowledge. Design science methodology offers also a systematic approach to link knowledge and skills obtained in other courses to practice. Science develops knowledge about what it already is, whereas design involves human beings using knowledge to create what should be, things that do not yet exist. Design, as the activity of changing existing situations into desired ones, therefore appears to be the core competence of all professional activities. DSM in this course is applied to research problems in the domain of Architecture, Engineering, Construction and Operation (AECO). For the management of AECO projects, Systems Engineering principles are applicable. Systems Engineering is a well-known method also from practice for structuring complex (design) projects. Structuring the design data and the design process allows for better project management and better-quality maintenance. Building Information Modelling is a technique for generating and leveraging building data to design, construct and operate built lifecycle. BIM allows all stakeholders to have access to the same information at the same time through interoperability between various software applications. With the proper knowledge and understanding, BIM techniques and tools can be used to support more complex Systems Engineering methods. Finally, state-of-the-art web technologies tailored to AECO allow for more efficient and scalable BIM-based processes. In this regard, the course focuses on conceptual system design for a specific AECO use case.

7ZZ6M0 - Legal and governance aspects

Learning objectives

- Recognize important aspects of the institutional framework of the construction process and the governance modes that develop within this framework;
- Recognize relevant legal aspects (within different phases) of the construction process and analyze these in the context of public and private institutional frameworks;
- Estimate and analyze the weight and complexity of these aspects;
- Develop ideas to deal with these aspects and provide solutions for problems or conflicts resulting from these aspects in accordance with the fundamental positions of the public and private sectors;
- Evaluate options and solutions presented by legal experts.

Content

This course is about legal & governance aspects of the construction process, especially the institutional legal and framework settings concerning the major players and the main interests concerned. Legal aspects mainly rest in limitations and possibilities created by the legal system, as a context for interactions within and across the public and the private sector boundaries, during the complete life-cycle of the construction process. The relevant legal and institutional frameworks and their underpinnings will be explained and analyzed, and put into the perspective of 'real-life' problems. Insight into legal reasoning, as a specific methodology, will be practiced through the use of legal literature and jurisprudence. The main course topics will deal with both public and private law. The place and position of the future graduate in the construction process will serve as a guideline in the selection of these topics.

7ZW7M0 - Urban research methods

Learning objectives

- Being able to develop a conceptual model for a given research problem and make choices in determining a research design
- Being able to apply the principles of state-of-the-art models and techniques for urban research and know how to apply them. The techniques considered include advanced regression analysis (including path analysis), discrete choice modelling, stated choice experiments, multi-criteria analysis techniques and research methodology.

Content

In this course, students learn core research and evaluation methods for urban planning/management. The focus is on quantitative methods and evaluation techniques. The following topics are covered:

- Decision processes in urban planning and management
- Developing a conceptual model for a research problem
- Data analysis and modeling techniques
- Regression analysis
- Discrete choice modeling (incl. stated choice experiments)
- Evaluation techniques for decision making
- Research methodologies.

Research methods are relevant in the first stages of the decision process where the aim is to generate knowledge about a problem or possible actions. Evaluation techniques are relevant in the last stage where the aim is to determine a preference ranking of action alternatives. The techniques are explicitly positioned in a decision process model. The course consists of a series of lectures and literature study. Each lecture is complementary to the literature studied and accompanied by a practical where the students apply the theory to a case.

1ZM20 - Technology entrepreneurship

Learning objectives

The central question to be addressed throughout this course is how to bring new technology from the lab to the market. The process of bringing new technology to the market is surrounded with a lot of uncertainty. Dealing with uncertainty and taking decisions despite this uncertainty is therefore a crucial skill. The objective of this

course is to create awareness, understanding and application of flexible and adaptive decision-making approaches along with more familiar prediction and planning-based methods for decision making in the face of uncertainty in new business development based on new technology. Moreover, you will learn to use various methods, frameworks and tools (such as the lean startup method, design thinking & rapid prototyping) that help innovators in dealing with this technological and market uncertainty and bring their technological inventions to the market. Together, this translates into the following learning objectives:

At the end of this course, you will have learned:

- To distinguish flexible and adaptive decision-making logics as used by expert entrepreneurs from the prediction and planning-based approaches (i.e. traditionally accepted business management practices) in bringing new technology to the market
- To argue the application of flexible versus planning-based approaches under different situations.
- To use flexible and adaptive (i.e., action-based) versus planning-based approaches to new business development and business model design
- To reflect on your experience with the different approaches to new business development in a high-tech setting and how this aligns with your personal preferences and interests

Content

Throughout this course, you will learn to apply flexible and adaptive approaches towards decision making in new business development along with more familiar planning and prediction-based approaches. Using adaptive and flexible approaches (like design thinking, rapid prototyping, effectuation), entrepreneurs take small organic steps during their decision making process and apply validated learning approaches such as the lean startup method as a way to deal with uncertainty – which is typically very high in the commercialization of new technology Accordingly, the intellectual content of the course is centered on the notion of “Validated Learning”, defined as an iterative learning process of trying out an initial idea, measuring it to validate the effect and incorporating the lessons learned into the succeeding test (Ries, 2012).

You will use various methods for flexible and adaptive decision-making as well as planning based approaches to support an entrepreneur or innovator with a key decision in the process of bringing novel technology to the market. These key decisions cover topics like the selection of a market or customer segment, how to position the technology in the market, how to expand internationally, how to select and build a partner (network), how to grow the team, etc.

The following topics will be discussed in the course:

- Identifying market opportunities for novel technologies
- Business models and business model innovation
- The entrepreneur and the winning team
- Technology commercialization strategies: the market for technology versus the market for products
- Risk & uncertainty
- Revenue models
- Growth and exit

This course uses a blended learning format, where the theory and content is delivered by means of web lectures, podcasts and articles. The time is the classroom is used to contribute to panels and participate in workshops and coaching sessions that assist the students in supporting entrepreneurs with their key strategic decision.

1ZM120 - Entrepreneurial marketing

Learning objectives

This course equips advanced undergraduate and postgraduate students of marketing strategy, entrepreneurial marketing, and entrepreneurship with the fundamental tools to succeed in entrepreneurial activities.

After the course, students are able to:

- apply the core principles of the effectual approach for entrepreneurial marketing
- discuss mechanisms for stimulating adoption and overcoming network effects
- identify necessary commercial firm competencies, in relation to the development phase of the firm
- select business opportunities under technology uncertainty
- apply the methods of segmentation, targeting and positioning to maximize the value of the new application
- develop a marketing and sales plan bottom up, in context of limited resources

Content

How do you sell an innovative product to a market that does not yet exist? Entrepreneurial businesses often create products and services based on radically new technology that have the power to change the marketplace. Existing market research data will be largely irrelevant in these cases, making sales and marketing of innovative new products especially challenging to entrepreneurs. Entrepreneurial Marketing focuses on this challenge. Classic core marketing concepts, such as segmentation, positioning, and the marketing mix undergo an 'extreme makeover' in the context of innovative products hitting the market. In the course, we will discuss concepts such as principles of affordable loss, experimentation, and adjustment for emerging opportunities, as well as cooperation with first customers. Entrepreneurial Marketing provides a vital guide to successfully developing customer demand and a market for innovative new products.

In the lectures, the first hour will be used to present theory. In the second hour, a group class exercise will be conducted in which the theory of the first hour needs to be applied. In group assignments outside the lectures, students need to apply the learned theory and skills to a specific business opportunity.

7ZW4M0 - Built environment and smart mobility

Learning objectives

- After successful completion of this course, students will be able to:
- Describe and explain the dynamic relationship between the built environment and mobility, and the (potential) role of technology in it.
- Demonstrate a critical understanding of the transportation and land use theories, including issues related to travel demand, accessibility measures and land use-transportation interaction. This includes evaluating the underlying principles, limitations and methodologies of relevant modeling techniques.
- Identify and discuss the major urban mobility issues and their effects on urban (public) space, quality of life (e.g. health and well-being) and environment, both in general and in specific cases.
- Discuss the potential of urban planning, design strategies and smart mobility solutions in addressing contemporary urban mobility challenges, considering their effectiveness and integration possibilities.
- Critically examine the societal, behavioral and environmental impacts of different technological solutions within the context of urban mobility (e.g. Mobility as a Service) through case studies, identifying key

bottlenecks and success factors.

- Propose (innovative) integrated approaches for the future of urban accessibility and mobility, considering factors such as multimodal connectivity, land use integration and the promotion of sustainable transportation modes. Utilize scientific literature as a primary source to inform the development of these strategies.
- Communicate innovative ideas and research findings effectively using appropriate communication means and formats suitable for the target audience.

Content

Wherever urban development takes place, people will want to come and go. And wherever people come, go, or pass through, opportunities for urban development arise. There is continuous interaction between the built environment and mobility in general, and smart mobility specifically.

In this course we will discuss the current state of knowledge of how to plan and design our cities with the aim of keeping them liveable, clean and safe, offering opportunities to satisfy wants and needs, while simultaneously keeping them accessible for all.

The course addresses key concepts and state of the art methods concerning the relationship between (smart) mobility and the built environment. Examples of applications are discussed, while assignments allow you to master the methods and better understand the concepts.

The following topics will be dealt with:

- Built Environment and Transportation: relations between transportation, accessibility, land use and travel patterns.
- Urban mobility issues with a focus on the impacts of car-oriented mobility on the environment and quality of life: inefficient use of time and space, energy consumption, emissions and exposure; safety, health and well-being.
- Urban planning and design solutions to mitigate urban mobility issues: urban structures and mobility, suburbia and walkability, New Urbanism, TOD.
- Smart mobility: how technology and innovative transportation and ICT solutions (for example, Mobility as a Service) may (or may not) help in dealing with urban mobility issues and keeping our cities accessible and sustainable.
- Theories and models related to real estate, accessibility and transportation: concepts of accessibility in land-use and transport planning strategies; measurement of accessibility; models of transport demand; theories and methods of transport and land use interaction.

7ZM1M0 - Research and development project

Learning objectives

- Identify a research challenge
- Specify a research goal
- Select the appropriate state-of-the-art methods or techniques
- Execute a method or implement a technique
- Evaluate the results
- Write a scientific report

Content

Executing a Research and Development project for a specific case in the research areas of Smart Cities and Smart Buildings, targeting societal challenges such as climate change, energy transition, circular economy, digital twinning, etc. Firstly, a research and/or development problem is identified by each student. These research and/or development problems can follow from an on-going project in the DDSS (Design and Decision Support Systems) research group, but also from society or industry. In the given time frame, goals and criteria of the project are specified to solve the defined problem. To reach the goal, research and development methods/techniques are selected that are not yet known by the student, but are relevant for the student's education. These methods/techniques are the state-of-the-art in DDSS research projects such as Discrete Choice Analysis; Regression Analysis; Bayesian belief networks; Building Information Modelling; Geographical Information Systems; Linear Programming. In addition, Information Systems Lab facilities (such as virtual reality lab and 3D printer) are available to support the experiments of students. With support from the staff, these new methods/techniques are learned by doing. The results should be interpreted by the student taking into consideration the pre-defined criteria. Finally, a scientific report is written that reflects upon the achieved results.

7ZW1M0 - Big data for urban & transportation analysis/project

Learning objectives

After completion of the project the student is able to:

- Formulate a research question for a problem in urban planning (e.g., transportation, tourism, energy, healthy living environment, housing)
- Find relevant big data source(s)
- Identify a suitable big data analysis technique for the research question concerned
- Carry out all the steps involved in the chosen methodology
- Assess various future planning scenarios and identify implications for planning
- Judge the limitations of the carried out research and identify remaining problems for future research.

Content

To find good solutions one needs to have a good understanding of the problem. This holds true also for the problems and challenges urban planners are facing in areas such as mobility (congestion and accessibility), health (air pollution, passive lifestyles), energy (smart grids and transformation to renewable sources of energy), ageing (social exclusion, loneliness), and tourism (crowding). In this project you consider a planning problem of your choice, select a big data source and apply a suitable analysis approach to better understand the problem and evaluate scenarios.

The approach includes information from big data source(s): (i) data from devices: e.g., smartwatch data, WIFI data, sensor data; (ii) user generated data such as online textual data (Twitter), photo data (Flickr); or (iii) transaction data: web search data, online booking data, that provide rich information on micro-level of individuals and or the environment. In this approach the data, or combination of data sources are analyzed with advanced modeling approaches such as data mining (e.g., Bayesian network learning), choice modeling (e.g., mixed logit model), regression analysis (e.g., multilevel regression), or machine learning approaches to achieve a better understanding of behavior of individuals with regard to the planning problem considered. During the project, the following steps will be carried out: formulation of a research question; literature research; specification of a conceptual model; identification of relevant variables; finding and obtaining relevant big data;

preparation of the data; conducting the analysis and interpreting the results. The data and analysis technique(s) used will be chosen depending on the specific research question.

7M900 - Fundamentals of building information modeling

Learning objectives

- Apply the basics of the visual modelling language UML and ER for conceptual data modelling.
- Describe, interpret, and use existing modeling and information exchange standards used in Building Information Modelling, including primarily the Industry Foundation Classes (IFC).
- Understand the use of BIM in practice.
- Understand, use and apply XML and XSD for representing data in a hierarchical data model.
- Understand, use and apply Graph Databases (RDF and OWL) for representing building data.

Content

This course is of importance to everyone handling building information in practice, developing novel ways to address current and future challenges in ICT-supported collaboration in building and construction and doing fundamental research in the field. In particular, BIM has become a generally accepted method in the construction industry including civil engineering and building services. Through BIM processes and BIM tools, one is able to represent building information in a comprehensive model and exchange all building information with peers in the building life-cycle. BIM models are nowadays created for different purposes with different aspects for a wide range of applications throughout the lifecycle of buildings, ranging from simple geometric models to detailed building component specifications. In this course, the student is introduced to various data and information modelling techniques of use in combination with mainstream BIM tools and processes. The course starts with an introduction to BIM and the conceptual modelling language UML. UML can be used to specify interaction diagrams as well as information management diagrams and thus is a crucial tool for the data scientist. Furthermore, several very different data modelling and information modelling techniques are taught in detail, including XML/XSD, EXPRESS and IFC, and graph databases (RDF, OWL). The student learns to use and apply each of these data modelling techniques through practical and relevant construction-related examples and assignments. The final assignment and lectures teach the student how to use these data models and techniques in state-of-the-art software development environments, using Python as a reference scripting language.

7ZW3M0 - Urban planning II

Learning objectives

After completing the course, students are able to the quality and viability of retail facilities and public services in an existing urban area. In addition, students will be able to suggest how to improve the situation. Furthermore, students will be able to forecast population and quantitative housing demand and they will have knowledge about and some experience in models describing the development of urban areas. Finally, students will have basic knowledge about the organisation of spatial planning in the Netherlands and other countries.

Content

The course starts with a short introduction into spatial planning in the Netherlands and other countries. The next part deals with planning retail facilities and public facilities, both in terms of supply and demand. Retail facilities will be discussed at the level of urban areas and the level of shopping centres. Small groups of students compare and assess facilities in different cities. Transport-oriented development will be discussed as well. The last part of

the course is about predicting the development of urban areas. Methods to predict the size and composition of the future population and the corresponding housing demand, as well as so-called land use models are introduced. Students will gain experience with such methods and models.

7RC100 - Inner-city modular high-rise

Learning objectives

The course aims to become familiar with the tender process of a construction project. At the end of the course the student:

- Can describe the diverse types of procurements, understands the differences and is capable of judging if a type of procurement is used in the right manner in the right project.
- Understand options and solutions presented by legal experts

Content

Inner-city Modular High-rise (previously known as 'Procurement') is one of the three courses that together form the Construction Technology certificate program. The course addresses the issues of tendering, design and realization from a contractor's perspective, by describing the total process of a project. In addition to the relevance of social elements such as environment, circularity, structural design, costs, planning & logistics, and safety with the associated responsibilities. There is also attention for cooperation from the various disciplines in a construction process in order to ultimately make a difference.

7KP8M0 - Smart Building Methodology and Technology

Learning objectives

The student:

- Selects and analyses different emerging technologies, design and research approaches, building principles and methodologies to solve a problem in the given context.
- Applies emerging technologies and design and research approaches to solve fundamental problems and industry challenges
- Generates an integral solution (design) in which different building principles, building methodologies, and design and evaluation approaches are selected and applied critically, showing enough technical detail to demonstrate the technological feasibility of the developed concept.
- Revises the design following a rigorous design process in a methodological manner through critical iterative production.
- Discusses and defend specific solutions in the design, showing (self-)criticism and capacity for peer-review by bringing their own expertise and knowledge into the team.
- Applies architectural presentation materials and techniques to communicate effectively their design solutions.

Content

Nowadays, technology advances at high speeds and building designers and engineers are faced with new technologies which applications are not always clear. On the other hand, the building industry is facing important challenges to meet climate agreements, while still providing heathy buildings in a human centric manner at realistic costs. This course aims at expanding the intellectual horizon of students regarding the application of

emergent building methodologies and technologies to meet problems faced by our society. To achieve the objectives of this course, the theoretical approaches and building principles, outlined in the weekly lectures, are reinforced by their application in real-world problems. For example, by applying AI-based solutions to design and develop smart cities, new housing typologies and using user-centered methodologies to understand real-life problems. The lecturers will provide an overview of recognized building principles, methodologies, concepts and approaches, and will discuss the application of state-of-the-art of technologies in architectural design. Every week has a specific theme on which the lecture and the weekly assignment will be presented.

7XC1M0 - Circularity in the Built Environment

Learning objectives

- Have a critical understanding of the systemic problems of circularity, and how the need for ecological resource management relates not just to design and technology, but also to economic models, habits and arrangements; growth and consumption; population; mindset and behavior.
- Have a critical understanding of design and technology assessments (e.g., Life Cycle Analysis, Circularity Indicators, Embodied Land assessments) and what they do (and do not) measure; you can use these to evaluate design proposals and decisions.
- Have a critical understanding of how design and technology on the levels of spatial planning, building, product and material can (and cannot) contribute to solving the problems; you can use this knowledge to make effective circular design proposals.
- Can synthesize the lessons learned in a conclusion and then develop your own meaningful follow-up research questions, from various disciplinary angles.

Content

This course introduces first of all circularity as the problem of planetary (resource) management, with a central role for rates and planetary boundaries. Energy, materials, waste and emissions are studied separately and in cohesion. Then we explore the idea of a circular economy, highlighting 21st-century attempts to (re)define boundaries, “progress” and “costs” and consider fair distribution. We will study and exercise various circularity and sustainability assessments. After this broad introduction, we move on to the built environment and zoom in from large to small. What does circularity mean for planetary and urban spatial planning? How to design circular buildings on conceptual and technical level? How to redesign the numerous existing buildings that were not designed with these considerations? What is a circular product or component? And how to select materials? What should we know about their impacts, their availability, their mining and their recycling? After exploring these issues, you are asked to define 3 personal research questions in the domains of technology, economy and humanities.

7ZM7M0 - Parametric design

Learning objectives

In this course, the students will learn computational design methods and tools that enable designers and engineers to generate, analyze and optimize built structures on various levels of detail and at different planning and design stages.

After completing the course, the students are able to:

- Practice design space exploration relying on parametric 3D modelling tools, visual programming and scripting (e.g., Grasshopper).

- Evaluate how the choice of parameters and the structure of a parametric script influence the resulting 3D shape.
- Apply optimization algorithms (e.g., evolutionary solvers) to solve complex design problems.
- Transform a visual script into a procedural script (e.g., using Python, C#) and understand the affordances and implications.
- Design and defend a collaborative parametric design project given a specific design brief.

Content

The underlying conceptual approach of this course is the notion of parametric objects that are generated, modified, and mutated mainly with respect to their geometry and spatial arrangement. To allow high flexibility combined with the precision required ,e.g., for automated fabrication processes, advanced, parametric geometries such as Non-Rational Uniform B-Splines (NURBS) are introduced. Specialized modules and components that are of interest to architectural design, structural design, building physics, and/or construction management students are also introduced.
Next to one main project assignment performed in groups, there are three individual assignments dedicated to specific parametric design techniques, e.g., parametric variation, optimization, and scripting with Python. The course addresses the following topics:

- Iterative and/or interactive form-finding and design space exploration in the early architectural design stages, e.g. through the creation of parametric design variations using visual programming with Grasshopper.
- Analysis and optimization of topology and/or individual building components and assemblies based on requirements and optimization goals from the areas of structural design, building physics, or other engineering domains that should be tightly integrated into the design process.
- Scripting components (e.g., using Python, C#) to get input and produce output from and to other standard Grasshopper components.
- Integration with (digital) manufacturing techniques, focusing on making sure that the parametric design can also be built into practice, thereby using the latest digital fabrication tools and techniques.

Furthermore, the course includes several invited guest lectures from industry and advanced computational design experts.

CME Course roster

CODE	Q1	EC	CODE	Q2	EC
7ZZ9M0	Design Science Methodology and Systems Engineering	5	1CM900	Project management	2,5
7ZM3M0	Case study process modelling of construction projects	2,5	7M900	Fundamentals of Building Information Modelling	5
7ZZ6M0	Legal and governance aspects	5	1ZM120	Entrepreneurial marketing	5
7ZW3M0	Urban Planning II	5			
7XC1M0	Circularity in the Built Environment	5			
7RC100	Inner-city modular high-rise	5			
1ZM20	Technology Entrepreneurship	5			
7ZM1M0	Research and Development project				10
7CC40	Graduation				40

CODE	Q3	EC	CODE	Q4	EC
7ZM8M0	Collaborative design	5	7ZM5M0	Process modeling and information management	5
7ZW7M0	Urban research methods	5	7ZW4M0	Built Environment and Smart Mobility	5
7KP8M0	Smart building methodology and technology	5	1ZM65	System dynamics	5
7ZM7M0	Parametric design	5			
7ZM1M0	Research and Development project				10
7ZW1M0	Big data for urban & transportation analysis /project				10
7CC40	Graduation				40

Core course
Specialization elective

CME Course planning

In general, the priority in which you make your individual CME course planning is:

1. Core courses (at the TU/e)
2. Specialization electives (from the TU/e, TUD, or UT)
3. Free electives (from the TU/e, TUD, or UT)
4. Academic skills (at the TU/e) 5.
5. Graduation (at the TU/e)

The core courses are followed at the Graduate School of the TU/e. If you choose from the specialization electives of the CME course list (35 out of 70) then your individual CME course program will receive positive advice from your mentor by default. You can also select Specialization elective courses from the other – non- CME – Master programs at the Eindhoven University (TU/e) and the 4TU-CME Master programs of Delft University of Technology (TUD) or University of Twente (UT) (see 4TU-CME study guide at CME website or ask a copy at our CME secretariat). In the latter case, you need advice from your mentor because he/she will maintain coherence in your individual CME course program. The same non-CME TU/e and 4TU-CME TUD/UT Master programs are available for the Free elective courses but for these courses, you don't need your mentors' advice. If you want to follow courses at TUD or UT, you need to be enrolled in their program as well. Ask our CME secretariat for help if needed. Obviously, if you follow courses at TUD or UT this usually involves traveling or moving temporarily. Therefore you need to make your own arrangements. Language courses are only allowed at level C as Free elective courses with maximum total of 5 EC (see TU/e Language Center at TU/e website: https://educationguide.tue.nl/career-skills/language-courses-and-academic-writing-skills, contact: languagecenter@tue.nl). In all cases, your individual CME program needs finally to be approved by the Examination Committee of the Department of the Built Environment.

To ensure that every CME student has learned sufficient academic research methods you must choose at least one of the following courses as a specialization elective:

7ZW7M0 Urban research methods
7ZM1M0 Research and development project
7ZW1M0 Big data for urban and transportation analyses/project

The TU/e Graduate School highly promotes students to visit a foreign university as part of their internationalization. International experience matches also with the nature of the TU/e CME Master program. Internships give students an opportunity for an orientation in the professional field. Even the combination of internationalization and internship is possible, but all within certain conditions that you need to check with your mentor. How to plan your international courses and internship is explained in more detail in the next chapter.

From experience, we know that depending on their prior Bachelor's education, students might face a lack of academic skills, especially scientific writing. We advise you to overcome this legacy as soon as possible, because writing scientific reports comes back in many CME courses and is often also part of the grading. There is no regular course on scientific writing, however, the TU/e offers the Skillslab (https://educationguide.tue.nl/career-skills/language-courses-and-academic-writing-skills) with online courses that you need to follow in your own time. We strongly advise you to at least follow the module: 'Master's thesis writing in English using TU/e Skillslab'. Secondly, students sometimes also lack basic research skills. In the CME program, you will learn advanced research methods and techniques, but you can only understand these if you already know the basics. We advise

you not to take the course Research and Development project (7ZM1M0) in the first semester of your Master program, unless you already have profound CME research skills or unless you aim to focus on acquiring programming skills in this course.

CME Graduation consists of two parts: (1) Research proposal, and (2) Graduation project. Normally speaking, if you aim to complete your Master study in two years, you will register for your Graduation at the beginning of the second year of your CME Master. Graduation can be started every Quartile. For more information about your Graduation please refer to the 'Graduation guide CME @ TU/e'.

Your individual CME course program should constitute a coherent Master program that is in line with the CME Master learning goals. Therefore you should start by determining your personal ambitions. Ask yourself what type of career you want to pursue. With that in mind, you can determine the subject of your graduation project and the courses you need to follow to be prepared. The career perspectives for a CME student are very wide and were very good right from the start. First of all, you must decide if you want to pursue an academic or professional career. Students that pursue an academic career will opt for a PhD position at any university around the world, with a suitable research topic. Students that pursue a professional career, typically find jobs at the following companies: Engineering Consultancy offices, Governmental institutes, Start-Ups, and Contractors. Because these are complex but nevertheless important decisions you get help from your CME mentor. Your mentor might advise negatively about a specific course if it does not fit the TU/e-CME expertise in Construction Management and Engineering. To learn more about the TU/e CME Graduation topics, you can check the CME graduation guide.

A typical planning of the CME master program is presented in the tables below. In the first year, you follow compulsory and specialization elective courses. In the first semester of the second year, you follow the remaining courses and already start working on the research proposal for your graduation. Dutch students follow courses this semester at a foreign university, international students follow courses at the TU/e. During the last semester, you will work on your graduation project.

Course planning Dutch students

	Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
Year 1	Courses	Courses	Courses	Courses
Year 2	Research proposal & Int. Courses	Research proposal & Int. Courses	Graduation project	Graduation project

Course planning International students

	Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
Year 1	Courses	Courses	Courses	Courses
Year 2	Research proposal & TU/e Courses	Research proposal & TU/e Courses	Graduation project	Graduation project

Make a course planning for the whole 2-year's CME Master preferably before you start. You should plan a minimum 15 EC per Quartile, but it is better to keep a safety margin (2,5-5 EC more) in case you fail for a course. To support you in planning and managing your CME Master program, you will be assigned a mentor shortly after the start of your study. If you want to contact a CME mentor before you start, then ask the CME secretariat to arrange an appointment.

The mentoring procedure consists of two stages.

Stage 1: Student and Mentor meet within 6 months after enrollment of the student.

Before the meeting:

- The student has written a personal study plan (PSP).
- The student has written a personal development plan on professional skills.
- If internationalization is part of the PSP: the student has contacted the coordinator International Experience, mrs. H. Houben (H.A.M.Houben@tue.nl)

After the meeting:

- Student submits his/her provisional PSP through the Examination Committee BE.

Stage 2: Student and Mentor meet directly after the Graduation kick-off and before he/she starts writing the research proposal. During the meeting Student and Mentor will discuss if the PSP needs to be adjusted. When needed Student submits his/her updated, definite PSP through to the Examination Committee BE.

Finally, if you encounter any problem (other than programmatic problems) before or during your study you can seek help from Education and Student Affairs (ESA-BE): esa.be@tue.nl.

Internationalization and Internship

Internationalization

The TU/e Graduate School strongly promotes Internationalization, but this does not apply to foreign students since they already have international experience. For Dutch CME students, this usually means that you will visit a foreign university for two Quartiles and follow a total of a minimum of 15 EC courses that you will count as Free electives in your individual CME course program. Contact our student exchange officer Mrs. Houben (h.a.m.houben@tue.nl, VRT 2.12) for a list of universities with an exchange agreement with our department. Indicate your preferences by sending an e-mail to Mrs. Houben before the following internal deadlines: March 1 for exchanges in TU/e semester A, September 1 for exchanges in TU/e semester B.

Whether you can actually go depends on many factors, such as available seats, available courses relevant to CME, etc. Because of the complexity you need to make arrangements already halfway through the first year of your CME Master. Usually while following courses at another university you will also write your Research Proposal for your Graduation project. You will do that together with your anticipated first supervisor (see CME Graduation guide for more details). When you return back to TU/e after two quartiles, you have two quartiles left to complete your Graduation project. For help in organizing your internationalization contact your CME mentor and discuss how to include this in your Personal Study Plan.

Internship

One of the courses you can follow as a Free elective is an internship, but it depends on your personal ambitions if this should be part of your CME program. Three types of internships are offered:

- Internship CME/USRE Academic Work Experience (7ZAWE0) (15 EC)
- Internship CME/USRE Relevant Work Experience (7ZRWE0) (5 EC)
- Internship as part of Graduation (0 EC)

On top of the conditions that are set by the Department of the Built Environment, the CME Master program imposes for internship type (1) and (2) the following conditions.

Dutch student:

5 EC nationally allowed; discuss your internship plan with your CME mentor 15 EC nationally is not allowed

5 EC abroad is allowed; discuss your internship plan with your CME mentor

15 EC abroad is allowed, but should have a strong academic research and development component; discuss your internship plan with your CME mentor

Foreign student:

5 EC is nationally allowed; discuss your internship plan with your CME mentor

15 EC nationally is allowed, but should have a strong academic research and development component; discuss your internship plan with your CME mentor

5 EC abroad is allowed; discuss your internship plan with your CME mentor

15 EC abroad is not allowed

For internship type (1) and (2) you need to contact the coordinator on behalf of CME, Mr. Feixiong Liao (F. Liao@tue.nl, VRT 8.24) as the responsible teacher for this course. Check the TU/e study guide Canvas for the course description. Mr. Liao will access your internship plan and process your application. After your internship,

he will assess your results. The required forms can be obtained through the CME secretariat.

For an internship type (3) as part of your Graduation, you need to describe it in your Research proposal. Discuss with your first supervisor how the internship is integrated with your graduation project. In all cases, the Graduate School can only approve an internship if:

- The responsible teacher has approved the subject
- The contract (if any) is acceptable; this is the case if
  - It is a standard contract (Nuffic, Erasmus, TU/e)
  - The TU/e legal officer (educationlawyer@tue.nl) approves elsewise; ask the CME secretariat for help.

Certificate programs

The Department of the Built Environment offers three certificate programs: 'Construction Technology', 'Building Design & Technology' and 'Circular Design in the Built Environment'. These certificates are supplementary to the regular CME master program. All three certificate programs have an extent of 15 EC, 5 EC will come on the top of the regular master program. The extent of the subjects that can be used in the Specialization elective course space of the regular CME master program is 10 EC. However, this is only allowed after the approval of your mentor. Additional courses are entered as Free elective course space.

For more information, see:

https://www.tue.nl/studeren/graduate-school/master-construction-management-and-engineering/certificate-programs

The department of Industrial Engineering & Innovation Sciences in collaboration with the TU/e Innovation Lab offers the certificate program 'Technology Entrepreneurship and Management'. The certificate program has two variants: (1) broad and (2) in-depth, both to the extent of 15 EC. Some courses in this certificate program are also offered in the Specialization elective course space of the regular CME program. Additional courses are entered as Free elective course space.

For more information, see:

https://studiegids.tue.nl/opleidingen/certificaatprogrammas/technology-entrepreneurship-and-management-msc

Additional information

The following information is available on request through the CME secretariat or through the TU/e CME website (See Introduction for the contact data and web links).
https://educationguide.tue.nl/gs/cme

CME the Personal Study Plan (PSP):
https://educationguide.tue.nl/programs/graduate-school/masters-programs/construction-management-and-engineering/personal-study-plan-psp

Study semester abroad:
https://educationguide.tue.nl/programs/graduate-school/masters-programs/construction-management-and-engineering/international-experience/

Annex form internship agreement:
https://educationguide.tue.nl/programs/graduate-school/masters-programs/construction-management-and-engineering/curriculum/internships

4TU-CME study guide:
https://www.4tu.nl/cme/en/

Extra challenges and opportunities:
https://educationguide.tue.nl/programs/graduate-school/masters-programs/construction-management-and-engineering/extra-challenges-and-opportunities

For TU/e CME students (and other students) a GitLab repository is set up with a collection of online materials related to software programming in/for the built environment (e.g., Python, IFCOpenshell, PyQGIS, etc.) maintained by ISBE staff members and students.
https://gitlab.tue.nl/ISBE