Infrastructure and urban systems

ACE095

Course description 2021

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Master Programme Infrastructure and Environmental Engineering 2020

Water Environment Technology, Architecture and Civil Engineering

Chalmers University of Technology

The objective of an engineer is to help public and private decision and policy-makers to solve the problems and resolve the policy issues that they face. Engineers do this by improving the basis for decision-makers judgment by generating information and organizing evidence on their problems and in particular, on possible actions that may be suggested to alleviate them. Thus, a systems analysis commonly focuses on problems arising from the operations of a socio- technical system, considers various responses to these problems and supplies evidence about the costs, benefits, and other consequences of these problems. (Keating, 2014)

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Introduction

Economic growth coupled with increased urbanization, growing population, ageing of infrastructure assets and environmental issues, such as, climate change, are putting pressure on infrastructure demand. To solve this problem, both construction of new infrastructure but also refurbishment, lifetime extension and increased efficiency of current infrastructure stock needs to be made. The demand for infrastructure assets poses multiple challenges throughout their development, for example, planning infrastructure to be resilient to natural disasters, maximizing the efficiency while operating and lack of maintenance.

Additionally, urban areas are shaped by existing infrastructure systems that are also interrelated and interdependent. Infrastructure can enable or constrain the development of cities. Therefore, infrastructure planning and management have to consider societal needs and support a more equal and fair society. This means that knowledge about infrastructure and its connection to urban systems need to be developed with a multidisciplinary approach transcending the common "engineering" perspective. Due to the complexity of the infrastructure systems, there is a need to integrate the stakeholders' perspectives into the answers that engineers can provide to support the development of infrastructure.

Course aim

The course will provide advanced knowledge on the role of engineers on planning, design and construction, operation and maintenance and decommissioning of infrastructure with a systems perspective and with focus on urban systems. The students will learn about the challenges and needs of complex interdisciplinary infrastructure planning and management, where different stakeholders will have different objectives and needs.

Students will also learn stakeholders' relationships in terms of flows of communication, type of information needed and what impact they have on the technical work being developed by infrastructure and environmental engineering students. Additionally, students will learn about trends in infrastructure development, e.g., to be resilient, sustainable and efficient and how they affect complementary infrastructures and urban systems.

Special focus will be given to the main tracks of the MPIEE programme (infrastructure related to water and environment and transportation engineering).

The course also aims at presenting the main concepts about the following concepts, methods and tools: **Infrastructure planning and management, Strategic literature search, Qualitative research, Entity-Relationship modelling and Social network analysis.**

Learning outcomes

After completing the course, the students should be able to:

- Differentiate between the phases of infrastructure and urban systems (e.g. planning, design and

construction, operation and maintenance and decommissioning), and relate to their connection with the engineering role.
- Demonstrate the relationship between infrastructure, urban system and connected concepts, in particular land, water, transport, energy and waste.
- Describe responsibilities and types of information needed to plan, design, operate, maintain and decommission infrastructure.
- Select and collect relevant datasets related to infrastructure and urban systems.
- Select appropriate strategies for infrastructure and urban systems to make the planning, design and construction, operation and maintenance and decommissioning more resilient, sustainable and efficient.
- Quantify and argue for trade-offs, giving priorities to solutions, and how well they meet both ethical and technical constraints.
- Read and use technical texts and scholarly articles in a conscious, critical and effective manner.
- Apply systematic approaches by taking a holistic perspective.
- Specify the multiple roles that actors have and what type of activities need to be conducted depending on the stakeholder type.
- Work in groups in a multi-cultural international setting.
- Understand the type of information to communicate with different stakeholders.

Course content and organisation

The course is designed around: lectures on key aspects of Infrastructure and Urban Systems, mainly Transportation and Water; a group project; and an individual assignment. This combination of activities is planned to provide the students with information and to help them develop an understanding of critical issues in the areas of infrastructure planning and management processes.

The course is planned around 5 modules:

Module 1 include a set of lectures where students will learn about **background information on infrastructure**
Module 2 reflects on the **challenges faced today in cities** and how they affect infrastructure planning and management.
Module 3 covers the **engineering of the infrastructure sectors,** focusing on concrete aspects of planning and management within the waste, transportation and water sectors. This part includes exercises done in class and a lecture to clarify doubts.
Module 4 aims at providing **concepts, tools and methods** to understand how to describe and analyse infrastructure decision making processes throughout the phases of planning and management. This part includes exercises done in class and a lecture to clarify doubts.
Module 5 is the **assignments** module and puts into practice the concepts learned through a case study performed in groups and individually. This part includes a group project and an individual assignment.

Lectures

A series of lectures on relevant topics will be given to support knowledge development. The lectures should provide basic concepts in specific topics, as well as contextualization for these topics. The lectures will be given by a combination of course and invited lecturers.

- **Course overview, Cities as complex systems, Infrastructure development case study, Group project description, Waste planning and management, Individual assignment guidelines, Social Network Analysis, Systems thinking in infrastructure development and Writing reports guidelines**, Leonardo Rosado
- **Urban Water Management,** and **Transportation planning and management**, Sébastien Rauch
- **Strategic literature searching and Qualitative research,** Divia Jiménez Encarnación
- **Future infrastructure development challenges**, Anna Kaczorowska
- **City information modelling**, Jorge Gil
- **Multi-stakeholder theories and methods,** Marco Adelfio

The lecture slides will be available on Canvas the day before each session. Complementary readings will be available before the lectures.

Concepts, tools and methods

During the course, several concepts, methods and tools will be taught covering different aspects of system analysis for infrastructure and urban systems.

Built Environment

*Discussed in lecture **Cities as complex systems***

The built environment can be described as constituting the surroundings and the existing elements created by humans. It is defined, from a social perspective, as the human-made space in which people live, work and recreate on a day-to-day basis. Parks, roads, walkways, building structures, infrastructures and cities, as well as how they are occupied or used, all come under the built environment. The built environment therefore encompasses associated interdisciplinary aspects of design, construction, management and operation of these created surroundings and artefacts. The key sectors directly concerned with these interdisciplinary aspects include the architecture, engineering and construction industry as well as the geography and urban planning.

Decision-making process

*Discussed in lecture **Cities as complex systems***

Decision-making refers to a process by which actors select a particular option among several alternatives to produce a desired result. The main purpose of decision-making is to target the resources of an institution towards a goal and reduce the gap between the actual situation and the desired. This should be done by an effective problem-solving and analyses of available alternatives. Using a step-by-step decision-making process can help make more deliberate, thoughtful decisions by organizing relevant information and defining alternatives. This approach increases the chances of choosing the best alternative solution. Steps taken in a decision-making process include: Identifying which solution needs to be made, gather relevant information, identify and compare alternatives, implement the most viable solution and review the decision and evaluate how well it achieved the goals.

Tools and methods for engineering infrastructure

*Explained in lectures **Urban Water Management, Transportation planning and management and Waste planning and management***

Systems engineers ensures that infrastructure systems technically fulfil the defined needs and requirements and that a proper system engineering approach is being followed. The systems engineer reviews and evaluates the technical aspects of the project to ensure that the systems/subsystems engineering processes are functioning properly. Particular focus is put on the development of the system architecture, defining and allocating requirements, evaluating design tradeoffs, balancing technical risk between systems, defining and assessing interfaces, providing oversight of verification and validation activities. To do these tasks, several tools and methods for engineering infrastructure have been developed that provide support in studying the various components of the system.

City Information Modelling

*Discussed in lecture **City Information Modelling***

Cross disciplinary, holistic, digital practice in which modelling, analysis and visualisation of integrated city data is used to manage and mediate the demand for land, property and environmental resources; the aim being to balance multiple stakeholders' needs in order to achieve sustainable and liveable cities whereby citizens play a major role in city governance.

Entity-Relationship Modelling

*Discussed in lecture **City Information Modelling***

The entity relationship model (ERM) is a conceptual model of the information structure of a problem domain in terms of entities and relationships. The result of modelling using the ERM is graphically represented as an entity relationship diagram (ERD). Thus, an ERD visualises the conceptual structure of a problem domain being modelled. ERDs are widely used in database design and systems analysis to capture requirements of a system or a problem domain. When used for data modelling, the ERD assists the database designer in identifying both the data and the rules that are represented and used in a database. ERDs are readily translated into relational database schemas.

Information Retrieval

*Discussed in lecture **Strategic literature searching***

The quality of a literature review depends upon a series of decisions taken by the researcher. These decisions involve choosing amongst different types of sources, selecting which databases can be used to access them, and which searching strategies will help finding the desired information. A systematic approach to literature searching consists in making strategic decisions and rigorously documenting the process. Strategic literature searching skills can be used for all academic and scientific work.

Qualitative research

*Discussed in lecture **Qualitative research***

Qualitative research is a scientific method to gather and interpret non-numerical data. This type of research emphasizes "meanings, concepts, definitions, characteristics, and rich descriptions " rather

than "counts or measures". Qualitative research approaches are employed across many academic disciplines, focusing particularly on the social aspects within science.

Multi-stakeholder theories and methods

*Discussed in lecture **Multi-stakeholder theories and methods***

Several concepts, tools and methods are used to support stakeholder dialogues in planning. Top-down and bottom-up approaches, and driver-based and stakeholders led approaches which include an introduction to several specific tools, such as, Actor-network theory, onion diagrams, salience mode, influence-interest matrix and social network analysis among others.

Social Network Analysis

*Discussed in lecture **Social Network Analysis***

Social network analysis (SNA) is the process of investigating social structures through the use of networks and graph theory. It characterizes networked structures in terms of nodes (individual actors, people, or things within the network) and the ties, edges, or links (relationships or interactions) that connect them.

Systems thinking

*Discussed in lecture **Systems thinking in infrastructure development***

A key aspect to an infrastructure system is developing a process to enable informed decisions as to the potential for loss in the face of uncertain conditions. Decision analysis provides insight about the problem, uncertainty, objectives, and trade-offs. Such an analysis is needed to construct models of uncertainty and preferences necessary to evaluate a decision. A strategy is to reduce a complicated problem into something smaller so that it can be more readily analysed and understood. Systems analysis offers a more holistic approach to assessing a problem. The process provides a disciplined way of structured thinking grounded in a common worldview.

Learning style

The assignments are organised as a problem-based learning (PBL) project with focus on a type of infrastructure. PBL is a process that consists of four phases:

- Identification of a problem instead of facts and theories;
- Co-operative identification of skills that need to be learned or developed;
- Self-study to solve the problem;
- Summary and argumentation based on the learned and developed skills.

PBL therefore allows for the students to acquire or extend skills to improve student's knowledge that can be applied in a professional setting.

Assignments

Group Project (3,5 credits)

Supervisors: Leonardo Rosado, Sébastien Rauch and Divia Jiménez Encarnación

The aim of the project is to understand the complexity of studying an infrastructural system related to an urban challenge. You will work in groups and study a real city.

Each group will study a predefined city within their chosen topic. The case study city has a complex infrastructure system and is addressing several urban challenges, which you will present in a preparation document. The final output of the group work will be a PowerPoint and a summary report, with an overview of the case study city as well as an analysis of the proposed urban infrastructure system model. The PowerPoint presentation and summary report should use the following structure and answer the following questions:

1. **Urban challenge identification:** Define the societal challenge/s you are addressing. Motivate your choice. Connect the challenge to your chosen infrastructure system.
2. **Case study description:** Describe the city in terms of its main characteristics with focus on the chosen infrastructure system and the identified societal challenges. Show figures and numbers.
3. **Infrastructure characterization:** Characterize the existing infrastructure system by detailing its components, according to the three types described in the lectures. You can also provide maps with the infrastructure system.
4. **Build the Entity-Relationship model**: Define the domain activities associated with the urban challenge for the infrastructure system and design a conceptual diagram. Define the system components and establish their relationships. Define the key attributes of the components of the system.
5. **Data framework assessment:** Based on the Entity-Relationship model defined, identify the datasets needed to fully develop the model. List existing datasets and find ways to gather missing datasets. You can use examples on other cities and existing state-of-the-art technologies for data gathering.
6. **Model assessment:** Discuss the viability of the developed model. Discuss limitations and assumptions, availability of data, existence of technology to allow for data gathering, among other topics you think can be relevant.

Use the following methods to develop the group project:

1. Use the physical infrastructure framework to organize the system, be specific to your city and detail it in terms of networks, gateways and hubs and supporting infrastructure;
2. Use the Entity- Relationship framework to formalize the urban infrastructure system characterization.

The groups will first deliver a group project preparation document, which consists in a short document in which you will introduce to the supervisor the city and infrastructure you will study. The document should have between 2-4 pages and should contain the following information: urban challenge definition, case study description, infrastructure characterization and a list of links, reports and/or articles (titles), that you used/found with a short summary.

The groups have 2 group project consultation meetings with the supervisors, these meetings are mandatory. The schedule for each group will be provided by the course administrator.

Presentations of the Group Project should be made in English and can be up to 12 minutes. The presentations will be followed by a discussion session where the group needs to answer questions during a 3 min lead by another assigned student group. The discussion lead groups will have to come up with questions based on the presentation. The discussion lead is not graded.

We expect all group members to participate in the presentation seminar, but it is up to the group to decide who does the presentation and who leads the discussion for another group's presentation. The presentation should be presented both orally and in the format of a PowerPoint. Presenters should be prepared to answer questions from anyone in the audience, not just the discussion lead group. The PowerPoint has to be uploaded in Canvas on the day that the presentation takes place.

The length of the summary report should be maximum 2,500 words (cover page, tables, figures and references excluded) with font size 11 and the document should be uploaded in Canvas with the PowerPoint pdf.

Throughout the group work, the students must submit their work, as specified below.

Group Project Timeline:

Each student will sign up in Canvas for their preferred TOPIC (between 17:00 08/09/2021 and 12:00 10/09/2021). During the afternoon of 10/09/2021, teachers will inform by Canvas who are the group members (groups of up to 5 students will be randomly formed within each topic). Specific case study cities will be assigned randomly to each group.

- Group project preparation document submission: by 17:00 16/09/2021
- Group project draft submission: by 17:00 27/09/2021
- Group project consultations: 20/09/2021 and 29/09/2021
- Group project presentation: 06/10/2021

Groups have to submit the PowerPoint and the summary report through Canvas by 17:00 08/10/2021

Individual assignment (4 credits)

Supervisors: Leonardo Rosado, Sébastien Rauch and Divia Jiménez Encarnación

Each student will prepare a report to address and expand on a specific aspect of their group project. The length should be maximum 2,500 words (include the number of words in your document), excluding abstract, tables and references (General writing guidelines can be found in the Course

information module in Canvas. Specific guidelines will be discussed in the lecture **Writing reports guidelines**). Your report needs to work as a stand-alone document.

The aim of the individual assignment is to analyze the decision-making process for an existing infrastructural project. From the city studied in the group work, each student will be studying an existing infrastructural project / solution of their choice. The solution choice is done individually. The objective is not to change the solution, but to understand and evaluate the decision-making process.

Students are expected to use the methods (and justify the use of them!) presented in the lectures, including:

Mandatory methods to be used: Strategic literature searching and Qualitative research.
Optional methods: Multi-Stakeholder theories and methods and Stakeholder mapping (e.g. Social Network Analysis)

The report should address the topics below:

1. **Select an infrastructural project** - Select an infrastructural solution (i.e., a specific infrastructural project) that is planned or implemented in the city you previously studied. Use the summary of group work to present the case study, focusing on the chosen infrastructural solution. Define the type of decision you will analyze (e.g, infrastructure location, technical materials, special features, urban challenge). Choose a complex decision type.
2. **Identify studies and information** – For the chosen infrastructural solution and type of decision, describe the studies that were conducted. Identify their types, according to the five dimensions of the infrastructure system. If needed describe a timeline of studies to properly describe the project process.
3. **Analyze technical alternatives** – Identify any technical alternatives that were considered for the chosen infrastructural solution and type of decision. Describe the pros and cons of the alternatives.
4. **Identify stakeholders involved** – Define the roles and responsibilities of the stakeholders involved in the decision-making process.
5. **Evaluate the decision-making process** – Discuss the involvement of relevant stakeholders, the existence of relevant information and studies to make the decision and if there was any review of the process. Discuss possible improvements in the decision-making process and propose recommendations. Motivate your choices.

Use the following methods to obtain information about the decision-making process:

1. Use a Scholarly Information retrieval method and describe all the methodological steps made;
2. Use Qualitative research to: define the research question/s, identify the steps in the decision-making process; including alternatives, studies and information gathered, stakeholders and roles and responsibilities.

You can also support your report by expanding the analysis of the information using the Social Network Analysis method to map the network of relationships between stakeholders (What were the

responsibilities of stakeholders? Were stakeholders more or less important during different stages of the project?) and discuss the results obtained.

The students have 2 individual assignment consultation sessions, one optional and one mandatory. Attendance to the optional consultation will be defined by a doodle link. The schedule for each student will be provided by the course administrator. Students must submit their work, as specified below.

Individual Assignment Timeline:

- Optional consultation: 13/10/2021
- Draft report submission: by 17:00 15/10/2021
- Mandatory consultation: 20/10/2021

Students have to submit the report through Canvas by 17:00 27/10/2021

In-lecture exercises (Pass/Fail)

Exercises in class for the lectures on ***L06 Entity relationship modelling, L07 Waste planning and management, L08 Transportation planning and management, L09 Urban Water Management, L10 Strategic literature searching, L11 Qualitative research,*** *and* ***L14 Social Network analysis*** have to be handed in. Students can only pass the group project and the individual assignment if they submit their exercises in Canvas. The submission is individual. The exercises purpose is to allow students to practice on the tools and topics that are going to be done during the group project and individual assignment. Exercises will not be evaluated. Feedback can be provided by the specific lecturers, if asked. You will have 4 weekdays to submit your exercises.

Literature

Recommended reading for this course will be provided on the Canvas course page. Further information can be found from a variety of sources, including scientific journals (available from the Chalmers library website), books and the internet. Ensure that the information you get (especially from the internet) is reliable.

We recommend the use of scientific databases available on the Chalmers Library website, including Science Citation Index, Scopus, ScienceDirect and Springer Link. Some of the articles and books can be read online.

Physical and online moments

The ACE095 course will be mostly done with the Zoom online conference system. The success of the course will depend on the same commitment we all bring to the physical classroom. Everyone should adopt the same rules and norms (take notes; participate by asking and answering questions). For everyone's benefit, join the course in a quiet place whenever possible. Turn on your video whenever possible. Mute your microphone unless you are speaking. Close browser tabs not required for

participating in the lectures. If you are not familiar with Zoom let us know and we can share information about it.

Students will have the option to join some physical sessions at Chalmers. Individual and group supervision meetings will be planned in regular classrooms/meeting rooms following the guidelines for social distancing defined at Chalmers.

The lectures consist of 45 minute slots (i.e. 2 hour lecture will consist of two 45 minute slots). Each slot will have the following structure:

- a set of pre-recorded lectures (20-25 minutes), which will be made available, at the latest, the day before.
- a 45 minute zoom session open for discussions around in-lecture exercises and questions. Students will have access to breakout rooms for 20 to 25 minutes to discuss in groups the topics of the lectures and the remaining time will be used for a general discussion where everyone is welcome to share their findings.
- whenever a new teacher presents a lecture a welcome video of the teacher will be presented for students to familiarize with the staff. We welcome also the use of video whenever students actively participate in the discussions.

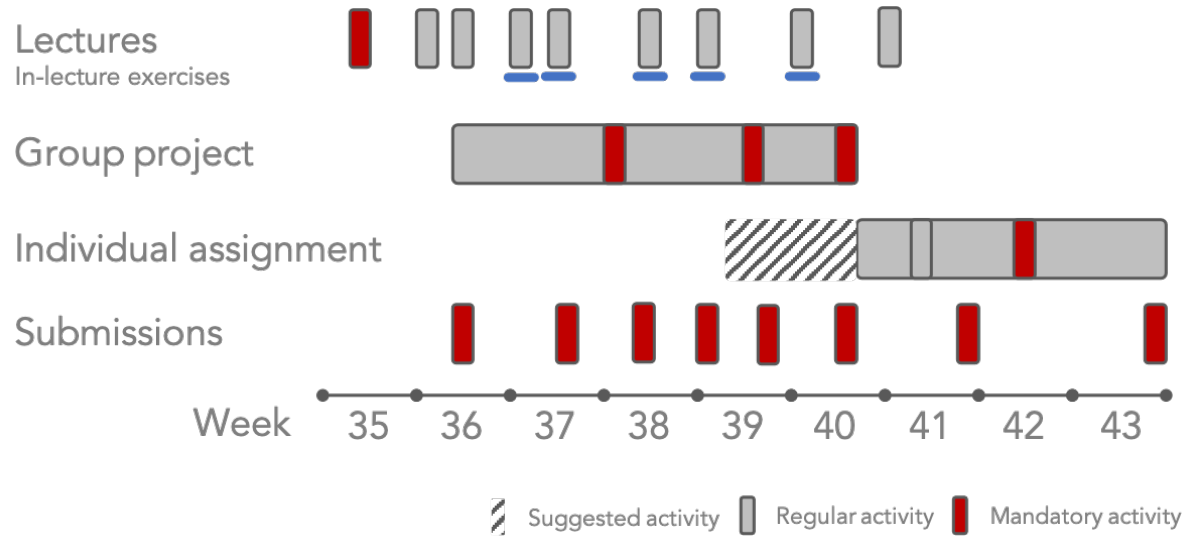
There is a recurring Zoom meeting for days in which lectures are scheduled. This meeting can be accessed for all the zoom sessions that occur on the same day. The link and password to join each meeting are available below, as well as in the Canvas Calendar, in the events called “Zoom link - ACE095”. The link and password remain the same throughout the course.

LINK: https://chalmers.zoom.us/j/63571438955
PASS: MPIEE_21

In the schedule, there is information about the type of lecture occurring: PR – pre-recorded zoom lectures; O – online lectures in real time; W – workshops in real time; F2F – face to face supervision sessions.

Schedule

The schedule for the course is detailed on the ACE095 course schedule pdf file. Below a general description of the activities for the course.



Communication

We ask for communication between students and teachers is made through Canvas messages or email using Chalmers credentials (Chalmers email). For group work, students should identify a spokesperson that communicates with the supervisor. Teachers will reply to students' enquiries as soon as possible.

Writing guidelines

Report writing

For report writing please read "**Writing guideline for reports, BSc theses, MSc theses at Chalmers University of Technology**" (*available in Canvas in Course Information module*). Number all tables and figures; table notations above the tables, and figure captions below the figures. Refer to all tables, figures and references in the text. Summarise and discuss them in the text and make conclusions from the results. When writing the report, *you must use your own words* (no copy from references) and cite (in-text) the references you use. Follow the Harvard system (author-year) for in-text citation. This means that the author's last name and the year of publication should appear in the text, e.g. "Safe water is key to sustainable development (Jones, 1998)" for one author, (Jones and Smith, 1998) for two authors, or (Jones et al., 1998) for three authors or more. It may also be on the format: "According to Jones (1998), Safe water is key to sustainable development". A complete reference should appear in the reference list at the end of the report. The complete reference implies that you give the information needed for another person to find that reference (e.g. URL for Internet sources, complete report title, publisher, ISBN etc.).

Plagiarism

Direct copying from the Internet, literature or your classmates is strictly prohibited!!

We verify all assessments via the Urkund system. Urkund controls all documents submitted against three main sources; the Internet, published material, and Urkund archives (e.g. reports from previous years). All documents, which are controlled through the system, are stored in Urkund archives and prevent plagiarism from former and fellow students. For further information, please read the document "Academic honesty and integrity at Chalmers".

Assessment and grading

Continuous assessment is the central examination form in this course. Grading is based on the individual assignments and the group work, as described below. All assignments are graded on a scale of 0.0-5.0. The final grade is F (fail), 3, 4, 5 with 5 being the highest grade.

Exercises for lectures on ***L06 Entity relationship modelling,*** ***L07 Waste planning and management, L08 Transportation planning and management,*** ***L09 Urban Water Management, L10 Strategic literature searching, L11 Qualitative research*** *and* ***L14 Social Network analysis*** are mandatory, need to be submitted individually, and are graded only pass or fail. The grade for the group work is the same for all the group members.

Assignment	Component	Percentage of credits	Credits
Group work	Powerpoint Presentation Report In-lecture exercises (L06, L07 and L08)	40% 10% 50% Pass/Fail	3,5
Individual assignment	Report In-lecture exercises (L10, L11 and L13)	100% Pass/Fail	4

Compulsory attendance

Attendance to supervised group sessions and presentations is compulsory and will be verified. If you miss any of these instances, please email the course administrator Divia Jiménez Encarnación and provide a motivation.

You are expected to actively participate and contribute to the group work. Submission of all assignments (Individual assignments, group work, selected exercises) is compulsory and should be done according to the schedule.

Updates from previous course edition

There has been a substitution of some lecturers in lectures: Some lectures were removed (***Wicked problems and infrastructure and Exercises discussion***) since there was a need to introduce other type of content that fits better the learning goals. New lectures were included, namely the ***Strategic literature searching*** (L10) and the ***City Information Modelling / Entity relationship modelling*** (L06) to provide students more tools and methods that support their learning.

An overhaul of the content of the course has been made, and a clarification about the decision-making process in the individual assignment was made. The introduction of strategic literature searching methods will also allow students to conduct more systematic studies which in the long-term will also support the work to be made during the Master thesis.