4TU.MSc in Construction Management and Engineering

TU Delft
Delft University of Technology

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

UNIVERSITY OF TWENTE.

WAGENINGEN UR
For quality of life

Graduation Guide CME @ TU/e

Graduation Guide CME @ TU/e

Version: (1.21) February 2025

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

Eindhoven University of Technology

Table of Contents

In general

The graduation is the final course to be followed to finish the master program CME at TU/e. “CME” is a Master of Science program which is part of the 4TU federation (http://www.4tu.nl/cme/en/), a federation of the four universities of Technology in Eindhoven, Delft, Twente and Wageningen. The specialization of CME at TU/e is conducted by the two departments: the ‘Built Environment’ and ‘Industrial Engineering & Innovation Sciences’.

The total scope of the graduation amounts to 40 EC; thus, an individual study charge of 1120 hours. In practice, this means a period of about 28 weeks, vacations excluded. Graduation consists of two parts: (1) Research proposal and (2) Graduation project. Register for the graduation project in Canvas (7CC40) before writing your research proposal. A student can only start his/her Graduation project after the research proposal and the composition of the committee have been approved by the chair of the graduation supervising committee. The credits for the graduation are obtained after examining the final presentation and graduation project report.

Application and participation

For the subject of individual graduation, a list of topics is offered under 2 main CME themes (BIM and CIM). Participation in one of these topics is obligatory for all students of CME at the TU/e. Four times a year, at the start of each quartile, a kick-off meeting for the graduation is organized. Each graduation will be guided by a group of specialized (assistant and associate) professors, preferably from both TU/e departments Built Environment (BE), and Industrial Engineering and Innovation Sciences (IE&IS). The students work individually, while their projects concur with research themes related to the research and development activities of the involved staff and PhDs.

The student who wants to start with graduation submits a research proposal referring to a topic selected from the list presented in Appendix 1. The format for writing the research proposal is added in Appendix 2 of this guide. Additionally, the members of the graduation supervising committee are filled in on a form, see Canvas (7CC40). When the research proposal and the committee are complete, both documents are handed in by email to the CME secretariat (cmesecretary@tue.nl) ánd on Canvas (7CC40) for approval before the start of the new quartile.

Deviations either in topics or in staff members are only allowed if approved by the graduation competent (associate) professor.

The master CME at the TU/e is conducted by 4 chairs:

- Department of the ‘Built Environment (BE)’, chairs:
  - Information Systems in the Built Environment (ISBE)
  - Urban Planning and Transportation (UP&T)
- Department ‘Industrial Engineering & Innovation Sciences (IE&IS)’, sections:
  - Operations, Planning, Accounting and Control (OPAC)
  - Innovation, Technology Entrepreneurship and Marketing (ITEM)

The composition of the graduation supervising committee adheres to the TU/e Graduate School rules (check the latest TUE-CME Examination Regulations in Canvas, these are binding). The committee is constituted as follows:

- Minimum three members.
- Chair is Professor, Associate professor or Assistant professor (UD1) from BE or IE&IS department.
- Chair is often also first supervisor, but not required, generally part of the graduation supervising committee.

- Minimum two examiners from BE or IE&IS department.
- Maximum two supervisors from the research group (chair) in which the student performs the graduation project.
- Third supervisor not from the research group (chair), this is called the external member.
- External members must be from other research group (chair) within the unit, other unit, other department, other university or outside university. The external member a degree from a technical Dutch university, under exceptional circumstances HBO diploma is acceptable if there is sufficient expertise on the topic, however, the chair and ECB must approve this, see the application form 'Approval external member graduation supervising committee' on Canvas (7CC40).
- A fourth supervisor is allowed and can be from the research group (chair) or any other origin, as long as it agrees with the requirements for an external member.
- Other people involved in the project, not in line with the requirements set above, can only act as advisors.

RECOMMENDED COMPOSITION OF THE GRADUATION SUPERVISING COMMITTEE

1st supervisor	***Prof/Assoc.prof/ UD1 Ass.prof. (research group/chair)***
2nd supervisor	*Prof/Assoc.prof/Ass.prof./postdoc/PhD student (not same research group/chair as 1st supervisor but from BE or IE&IS department)*
3rd supervisor	Pr*of/Assoc.prof/Ass.prof./postdoc/PhD student (not same research group/chair as 1st supervisor)* or External (university graduated, or otherwise approved by ECB)
(4th supervisor)	Any (university graduated, or otherwise approved by ECB)

CME Graduation competent (associate) professors or assistant professors (UD1):

Prof.dr.ir. B. Tunçer	(ISBE)
Prof. dr. S. Rasouli	(UP&T)
Dr. Q. Han	(ISBE)
Dr. P. Pauwels	(ISBE)
Dr. D. Yang	(ISBE)
Prof.dr.ir. I.M.M.J. Reymen	(ITEM)
Prof.dr.ir. I.J.B.F. Adan	(OPAC)
Dr.ir. B. Walrave	(ITEM)
Dr. M.M.A.H. Cloodt	(ITEM)
Dr. S.A.M. Dolmans	(ITEM)

CME Graduation competent assistant professors, fellows, and lecturers:

Dr. ir. P.H. den Ouden	(ITEM)
Dr. E. Petrova	(ISBE)
Dr. S. Ershad Sarabi	(ISBE)
Dr.ing. P.J.H.J. van der Waerden	(UP&T)

CME Graduation competent PhDs and postdocs:

All PhD's and post-docs from the TU/e – CME chairs: ISBE, UP&T, ITEM, OPAC.

CME Graduation competent committee members acting as third member are found in:

- All TU/e-CME chairs: ISBE, UP&T, ITEM, OPAC
- Other TU/e chairs, group, unit, faculty (e.g. Urban Systems and Real Estate, Building Physics and Systems, Structural Engineering and Design, Architectural Urban Design and Engineering)
- Other CME master programs at University Twente or Delft University of Technology

In your personal study program that you agreed upon with your mentor at the start of your CME master, you indicated the department research themes that you relate to your fields of interest. In Appendix 5 you find a table that shows how the expertise of the staff members of the ISBE chair relates to the 2 CME themes: City Information Management (CIM) and Building Information Management (BIM). This may help you to find your graduation supervising committee members.

The research proposal is written in close collaboration with the envisioned graduation supervising committee members. The committee member who will act as the first supervisor is selected from the list of graduation competent committee members for regular consultation during the graduation project. External participation of companies or institutions is highly recommended, but the prime responsibility for the CME graduation remains with the TU/e. Therefore, students are advised only to seek contact with external parties after consulting the CME graduation competent staff members. Normally the external party is added as an advisor to the graduation committee, but exceptionally he/she can be added to the committee. In that case, a form needs to be filled in with data about his/her CV that is available on Canvas (7CC40) to obtain approval from the Examination Committee BE. Due to staff capacity limitations, students cannot always be accepted by their preferred supervisors. In that case, changes in topic and/or supervisor are needed to start at the desired quartile.

Writing a research proposal will usually take 2 quartiles. In case it lasts longer than 3 quartiles you will be called by your CME mentor to discuss how to continue. The writing process includes the following steps:

1. Exploration
Write a short (1 A4) description for 2 projects (Title, Keywords, Content)
Search 2 related graduation reports; Search 2 relevant scientific publications

2. Discussion with CME staff members
Send a short description to the appropriate CME staff member
Meet with the CME staff member and make a decision

3. Elaboration proposal
Collect additional graduation reports; Collect additional scientific publications
Shortlist possible industrial, and managerial companies
Prepare a short presentation

4. Finalizing Research proposal
Present final proposal to CME staff members
Include final comments
Make final decision on committee members

5. Submission
Before the new quartile submit the Research proposal together with the form 'Approval graduation supervising committee' to Canvas (7CC40) at the Graduation year/quartile you registered for the first time. Submit this also via email to the CME secretariat: cmesecretary@tue.nl .

The first and the second supervisors assess the research proposal on the following two main criteria and give a go or no go ('sufficient') for the implementation of the research proposal.

- Quality: Does the Master Thesis Project, if executed according to the research proposal, reach a sufficient level of academic quality to allow the student to graduate at TU/e?
- Feasibility: Is the execution of the research proposal, starting with the approval of the research proposal, feasible within the remaining weeks of the Master Thesis Project?

Graduation can only start if the student has completed 50 EC at minimum. The graduation project can only start if: (1) The research proposal has been approved, and (2) the student is a maximum of 5 EC short of completed courses. Graduation projects begin at the start of a Quartile. From that time on the graduation project is completed in 2 Quartiles. Because time planning and management are considered an important aspect of the CME program, finishing according to planning is strictly monitored and one of the grading criteria (see Appendix 4B). In case it lasts longer than 3 Quartiles you will be called by your CME mentor to discuss how to continue. In individual cases, the CME graduation competent (associate) professors can give dispensation for the given conditions at the request of the student.

Ethics and Data management

All proposals for TU/e research with human participants or recognizable data of individuals will have to be ethically reviewed, starting January 2020. The TU/e has appointed the Ethical Review Board (ERB) for this purpose. Before the start of the data collection, if that involves human participants, the online form for ethical review of the research project on the intranet needs to be filled out. In case a student is the principal researcher, e.g., a graduation research project, the graduate student is responsible for this procedure. The supervisors can assist him or her in this. For secure and safe storage of research data during the research phase, the Department of the Built Environment has developed guidelines for Research Data Management (RDM). The RDM guidelines need to be followed by all people involved in the (graduation) research project. The procedure and relevant forms and all relevant information about the ethical review and data management can be found on the TU/e intranet portals:

https://tuenl.sharepoint.com/sites/intranet-ethical-review

https://tuenl.sharepoint.com/sites/intranet-built-environment/SitePages/research.aspx

ISBE Gitlab and ISBE website

Collaboration, sharing, and re-use of source code (MATLAB, Python, R, C#, etc.) is typically done using GIT (https://git-scm.com/). GIT is used in commercial software teams (often using a DevOps approach), but also by data managers, researchers, and any group that actively works with line-based code or data. Sharing can be done openly or privately.

CME master students that actively work with code, in particular in their graduation projects, are strongly encouraged and requested to share their source code, and re-use source codes from previous projects, if valuable and useful. They are encouraged to do this using the TU/e Gitlab facilities (information below). A good tutorial for novices on how to use GIT is available at: http://swcarpentry.github.io/git-novice/.

Getting started with ISBE TU/e Gitlab:

- Are you wondering how to store or save your code?
- Are you collaboratively working with your colleagues and supervisors on the same code?

- Are you following versioning, Continuous Integration/Continuous Development process?

If any of the answers are 'yes', please contact Kazici, Simay <s.kazici@tue.nl>, to know how to proceed further.

How to use GIT in your graduation project: ISBE has its group in Gitlab, namely https://gitlab.tue.nl/ISBE, which collects several projects or 'repositories'. These include:

- https://gitlab.tue.nl/ISBE/research code produced in previous graduation projects
- https://gitlab.tue.nl/ISBE/python code behind the ISBE Python tutorial
- https://gitlab.tue.nl/20180340/isbe-bwk code behind the ISBE website

Students can request their own project code to be hosted in an ISBE code repository. In particular, in https://gitlab.tue.nl/ISBE/researchcode, student source code is collected and made available per folder for each graduate student. A new Project folder is set up for user/s with authorized permissions. New users could log in and start creating repositories for their code. Please refer to https://gitlab.tue.nl/help or https://docs.gitlab.com/ee/ to proceed.

You can upload a very short description and illustrations of your graduation project for publication through the ISBE website. Use the following Microsoft form:

https://forms.office.com/Pages/DesignPageV2.aspx?subpage=design&token=513457ccc0a44457b3a71e911ac4b442&id=R_J9zM5gD0qddXBM9g78ZDbHayuJstZKmOA1iDdRf8hUQU42TU4zUDJOT0hBMzdLRVZMNlZCR1hLRi4u

The following subsequent meetings are important milestones in the graduation process: (1) Kick-off meeting, (2) Intermediate colloquium, (3) Green Light meeting, (2) Final Colloquium. The requirements and purposes of these meetings are explained in more detail below.

Kick-off meeting

In the first week of every quartile, a graduation kick-off meeting is planned. You will be invited for this kick-off if you register through Osiris for your graduation (7CC40). You only need to register once. At this meeting, you will receive all the required information for the graduation process.

Remember that when you register for graduation means that you can start writing your research proposal but it does not automatically mean that you can start your graduation project.

Directly after the kick-off meeting, you make an appointment with your mentor to discuss your Personal Study Plan (PSP). Therefore you should bring an up-to-date overview of your study progress. If all requirements are fulfilled the definite PSP is submitted by the student to the Examination Committee BE. When you complete writing your research proposal and compose your graduation supervising committee, you hand in all documents and forms via email to the CME secretariat for approval before the start of the new quartile. All of these are checked on the first day of the new quartile, and unless irregularities are found the student can start his/her graduation project.

Documents and forms submitted to the CME secretariat before the start of graduation:

- Research proposal
- Form 'Approval Graduation supervising committee' (see Canvas under course code 7CC40)
- External committee member form (if applicable)

Remember that graduation can only start on the first day of every quartile and that the documents need to be

received by the secretariat before that day, or else the start will be delayed by 1 quartile.

Intermediate colloquium

In the second week of every quartile, an intermediate colloquium is organized together with all supervisors, where CME graduation students will give a short presentation of their research proposal. This colloquium marks the start of the graduation project (reminder registration for 7CC40 has already been completed and thus is not needed again). You will be invited by the CME secretariat to give a presentation when your research approval has been approved. The graduate student gives a short (5-10 min.) presentation on: project goals, research methods, and expected results. The audience can comment on your presentation and you can make contact with fellow graduate students, staff members and PhD researchers.

Green light meeting

At the Green Light (GL) meeting the graduation thesis needs to be complete, otherwise evaluation whether the student is admissible for the final colloquium is impossible. Send the draft thesis digitally to the graduation committee members with a minimum of 2 working days before the green light meeting. Students should contact the CME secretariat to plan this GL meeting and the final colloquium approximately 2 weeks later. At the GL meeting, the student will give a brief (max. 10 minutes) presentation of his/her work. Following the graduation committee will discuss the graduation thesis page by page and give their comments. Finally, the graduation committee will conclude if Green Light is granted to the student. If GL is granted the student can prepare him/herself for the final colloquium approximately 2 weeks later and write the final version of the graduation thesis including the committee's comments. If GL is not granted, then a new GL will be planned.

Final colloquium

Send the final thesis + appendices, summary (Dutch and English), abstract, form Code of conduct and datafiles via Surffilesender: https://filesender.surf.nl/ (in PDF and Word format) to the graduation committee members and the CME secretariat (cmesecretary@tue.nl) minimal 2 working days prior to the final colloquium.

Upload your graduation thesis + appendices to Canvas (7CC40) at the Graduation year/quartile you registered for the first time, for plagiarism check. Also upload additional graduation documentation to Canvas such as:

- final presentation
- approval ethics committee, data management plan, GitLab reference, consent letters
- related data files (e.g., questionnaires, collected data and graphics)

By uploading the final presentation, you consent to usage for promotional purposes through public media. In case you have no access (anymore) to Canvas or if you cannot upload all files for other reasons, contact the CME secretariat.

The final colloquium is presented in public. The presentation is in English; the discussion with the audience may take place in Dutch. The presentation room can be arranged by the secretariat and coffee/tea is arranged by the student at the canteen (min. 1 working day ahead). The student should contact the CME secretariat to plan the final colloquium. The final colloquium procedure is as follows:

30 minutes (PowerPoint) presentation
15 minutes question and answer
15 minutes committee deliberation on grading 10 minutes final grade announcement

After the final colloquium, the chair signs the final report and all files, documents and forms will be sent to the

Examination Committee BE (The CME secretariat will take care of this.).

Summary of subsequent conditions

- If the student has completed at least 50 EC, the student may start preparing a research proposal
- If a check against the TU/e administration shows that not all conditions are satisfied, then a student will receive a message to withhold the continuation of the Graduation
- If the research proposal has been approved by the TU/e Ethical Review Board (if applicable), then a student can carry out data collection
- If the final report is approved by the graduation committee at the Green Light meeting, then he/she can present the project at the Final Colloquium
- If the final graduation report passes the plagiarism check in Canvas, then it is passed on to the Examination Committee BE.

Documents and forms submitted to the CME secretariat to complete the graduation

The following graduation documents and forms need to be submitted digitally to the CME secretariat a minimum of 2 working days before the final colloquium:

- Final graduation thesis (including summaries in English and Dutch) + appendices (in PDF and Word format)
- English summary, Dutch summary and the abstract. (i.e., the same as included in the final thesis) for submission to the graduation thesis database
- Signed Declaration concerning the TU/e Code of Scientific Conduct for the Master's thesis (see Canvas under course code 7CC40) For transferring the files to the CME secretariat you need to use SURFFilesender (https://filesender.surf.nl/). See Canvas for a user manual.

Graduation project company agreement

In many graduation projects, CME students will cooperate or collaborate with a company or other institution.

For this occasion, a Graduation project company agreement may be signed by the parties involved, but this is not always necessary. Such an agreement describes conditions/arrangements regarding such things as working hours, an internship allowance, intellectual property rights and (if necessary) a duty of confidentiality (see next section: Confidentiality). There are three options:

1. TU/e work placement agreement: This TU/e graduation agreement is a tripartite agreement: you, the company and TU/e (represented by the Managing Director BE) must all sign. You need to fill in the Annex form internship agreement that must be signed by the chair of your supervising committee. Send the Annex form and agreement to esa.be@tue.nl. They take care of the Managing Director BE signing the agreement.
2. A company agreement between you and the company, approved by the Managing Director of the BE department: You need to fill in the Annex form internship agreement that must be signed by the chair of your supervising committee. Before you submit the form and agreement to be signed off, a check by the TU/e Education lawyer (educationlawyer@tue.nl) is necessary. Send the Annex form, agreement and approval Education Lawyer to esa.be@tue.nl. They take care of the Managing Director BE signing the agreement.
3. A company agreement between you and the company: The TU/e is excluded from the agreement and

thus is not accountable for the contract provisions. Care must be taken that the agreement is not in conflict with the TU/e regulations. If the company offers you a contract itself, it is important to note the following information as regards clauses concerning non-disclosure/confidentiality and intellectual property rights.

We strongly advise you to use option (1), and if that is not possible, option (2). We do not recommend option (3).

You can find information about the TU/e graduation project company agreements at:
https://educationguide.tue.nl/programs/internships-and-graduation-projects

For more information see about CME internships (which include Graduation projects):
https://educationguide.tue.nl/programs/graduate-school/masters-programs/construction-management-and-engineering/curriculum/internships (Here you can download the Annex form.)

Whatever agreement you choose, make sure that your first supervisor is informed upfront and that you send a copy of the signed Annex form and agreement to the CME secretariat.

If you need any help to fulfil the TU/e regulations, contact the CME secretariat (see Contact information).

Confidentiality

In principle, graduation theses are public and Open Access. This means that a thesis must be included/published in the TU/e library.

If a company/organization involved in the preparation of the thesis believes that (commercial) interests may be harmed by the publication of the thesis, the company/organization may impose a temporary embargo of up to two years. This means that the thesis may not be published for two years and may therefore not be included in the TU/e library. The imposition of an embargo must have been announced by the company/organization in good time; at the latest two weeks before the student submits his/her thesis to the thesis committee.

If the company/organization deems it necessary to impose an embargo for more than two years, the company/organization will have to submit a substantiated request to the dean of the department BE. The dean may decide to extend the confidentiality period by a maximum of another 3 years. The submission of the substantiated request must be made in good time; at the latest two weeks before the student submits his/her thesis to the thesis committee.

In the event of a two-year embargo, a publicly available summary of the thesis (hereinafter: public summary) must be made available in addition to the confidential version (read: original version). The student may choose to write a public version of the thesis instead of a public summary.

If there is an embargo of more than two years, a public version of the thesis must be made available in addition to the confidential version. The confidential version of the thesis will be used for purposes related to the assessment. For this reason, the confidential version will be made available to the Thesis Committee, the Examination Committee BE and, if necessary, the Examination Appeals Board and review committees of the NVAO. The public summary or public version of the thesis is checked for plagiarism using plagiarism detection software. The investigation into plagiarism of the confidential version of the thesis is carried out by the student's supervisor(s). The public summary or public version of the thesis will be included/published in the TU/e library after the thesis has been defended. The public summary or public version of the thesis will be replaced in the TU/e library by a confidential version after the embargo has expired.

Exam procedure

Note that students should apply for the final exam 10 working days before the meeting of the Examination

Committee BE. For more information about application for the so-called final exam, look at: https://tuenl.sharepoint.com/sites/intranet-built-environment/SitePages/application-final-exam.aspx

If you have any questions, about registration, please contact the secretary of the Examination Committee BE: Examination.Committee.BE@tue.nl.

Please find below the final exam schedule of CME (meetings Examination Committee BE): https://tuenl.sharepoint.com/sites/intranet-built-environment/SitePages/ecb-calendar.aspx

An email from the Education and Student Affairs (ESA-BE) will follow with information about the graduation ceremony after the exam meeting.

Termination of enrollment at TU/e

On the following website, you can find information about the termination of enrollment at TU/e: https://educationguide.tue.nl/practical-info/student-administration/termination-of-enrollment

Please be sure that you make a request for the termination of your enrollment at TU/e and if you need to make some other arrangements, please check this link for more information and the downloads on that site:

https://educationguide.tue.nl/practical-info/student-administration/termination-of-enrollment/termination-of-enrollment-upon-graduation

Contact information

Mrs. Ingrid Dekkers-de Bruijn, secretariat of Master's degree program CME at TU/e: cmesecretary@tue.nl

Education and Student Affairs, department of the Built Environment (ESA-BE): esa.be@tue.nl

Ethics and Data management, Mrs. M. van de Sande: m.v.d.sande@tue.nl

Gitlab, Mrs. Kazici, Simay: s.kazici@tue.nl

Study association Of CoUrsE! info@ofcoursecme.com http://www.ofcoursecme.nl/

Educational information Master program CME at TU/e: http://educationguide.tue.nl/gs/cme

General website CME at TU/e: http://www.tue.nl/cme

Appendices

Appendix 1. Master project themes and supervisors

SES = Shahryar Ershad Sarabi
BT = Bige Tunçer
DY = Dujuan Yang
EP = Ekaterina Petrova
IA = Ivo Adan
PP = Pieter Pauwels
PW = Peter van der Waerden
QH = Qi Han

Theme: 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 CIM research considers the emerging field of urban informatics (including geospatial data, sensor data and 3D city data). The focus is on utilizing urban data for the development of models representing and simulating real-urban realm phenomena. It caters to various stakeholders, helping them to make informed decisions using urban analytics in the context of smart cities; stakeholders include municipalities, citizens, architects, urban planners, transport engineers, and construction companies.

Topic	Supervisor
Big data analysis and urban science	BT
Multi-source, multi-scale, multi-time data modeling for evidence-based design and decision support	BT
Data driven outdoor urban thermal comfort modeling for urban heat mitigation	BT
Parametric modeling, generative development, and multi-criteria optimization for urban decision making	BT
Predictive performance assessment of urban public areas for use and usability by pedestrians	BT
Information visualization for digital twins	BT
Modeling and simulation of sustainable land use transformation	SES
Land use suitability assessment using geographical information systems and multi-criteria decision methods	PW, SES
Agent-based modeling of urban transformation (concerning land use, housing, energy, climate change)	QH, SES
Spatial information systems for urban resilience	SES
Assessing ecosystem service using information systems	SES
Artificial Intelligence (AI) and City Information Modelling (CIM)	SES
Traffic Management based on Big Data	PW
Public participation in (re)development projects	QH, BT
Managing Smart Mobility and Road Infrastructure (Personalized Transportation Information Systems for transport mode, parking, and route choices)	PW

Social network analysis in stakeholder management	QH
Developing Extended Reality applications for public engagement and urban planning	SES
Investigating data-driven methods for urban resilience in the face of climate change, energy shortages, and policy uncertainty	DY, SES
Sensing the city to anticipate changes and support decision-making for urban sustainability	DY, BT
Developing a Predictive Digital Twin Model for Urban Sustainability and Resilience	DY, SES, BT
Examining stakeholder preferences and participation in sustainable urban development initiatives	DY
Studying the relationship between urban regeneration, smart technologies, and climate change through modeling and simulation	DY
Assessing urban service accessibility and satisfaction in smart cities for inclusive development	DY
Modeling and optimizing smart buildings at the community level in response to climate change and policy uncertainty	DY
Exploring factors influencing the success of tenders for smart city development	DY
New opportunities in urban transformation with performance assessment: Nature-based solution, Circular economy, Low carbon, Gas free, Energy Neutral, etc.	QH
Identifying promising locations/buildings for transformation using GIS	PW, SES

Theme: Building Information Management

Building Information management handles and manages building information throughout the building life cycle. The focus is on improving the Architecture, Engineering, Construction, operation, and demolishment process. This is achieved by using both static data (including building models and point clouds) and dynamic data (including sensor data and IoT). This approach enables the creation of digital twins of buildings and their occupants, and real-time data processing employing AI technology in the context of smart buildings.

Topic	Supervisor
Industrialized smart circular housing processes	IA
Parametric modeling, generative development, and multi-criteria optimization for design decision making	BT
Digital twin use case development and implementation	BT
Information visualization for digital twins	BT
Robotisation and automation of construction sites and existing buildings	PP, EP
Linked data in Architecture and Construction	PP, EP
Artificial Intelligence (AI) and Building Information Modelling (BIM)	EP, PP
Data mining and BIM-based design	EP, PP
Digital Building Twins for construction sites and existing buildings	EP, PP
Building Information Modeling (BIM) and City modeling (CityGML)	PP
Integration of sensor and actuator networks into Building Information Models	PP
Building Information Modeling for Interoperability	EP, PP
Retrieving building information from semantic networks	EP, PP
The use of BIM data and on-site collected data in construction site progress monitoring	PP
Robots for industrialised construction	PP
Artificial Intelligence, sensor data and digital Construction	EP
(BIM-based) LCA, LCC, Circularity assessment and optimization	QH
Collaboration in BIM: barriers, drivers, enablers, and application of Game Theory model	QH
Circular Transition in construction	QH
Examining stakeholder preferences and participation in ACE industry digitalization	DY
Exploring the impacts of smart/digital technologies on worker well-being	DY
Sensing buildings and using user feedback to enhance building management and satisfaction	DY
Exploring the potential of digital twin models to design and test interventions for improving smart building performance and evaluating their effectiveness	DY

Appendix 2. Format research proposal

Research title

Supervising committee
Personal information
Company name (if applicable)

Contents

1. Introduction (Background, context and motives) (3~4 pages)
2. Research problem (0 .5~1 page)
   - *2.1. Problem analysis and research question(s)*
   - *2.2. Research objectives and limitations*

     In case of company involvement: discussion of field data, field site, and other data sources
3. Research approach (2~3 pages)

   This section describes the broad philosophical underpinning of your chosen research methods. Since you have not yet actually undertaken the research, you should use this section to set out exactly what you plan to do, in which order and why.

   - *3.1. Methodological justification*
   - *3.2. Research design (diagnosis and design, methods; how to deal with the research questions)*
4. Expected results (0 .5~1 page)
5. Ethics and Data management (0 .5~1page)
6. Roadmap and time planning (1 page)
7. References (1 page)

About 10 pages in total

Appendix 3. Final report formatting instructions

This paper contains some easy-to-follow instructions concerning the format of the final report for students who follow the CME graduation program. It contains several sections about general layout, the (front) page, making chapters, sections, paragraphs, reference lists and so on.

Software and saving your document

We assume everyone will use Microsoft Word. The filename is a concatenation of your family name and your student ID number, format: 'fam-name_0000000'. While your paper might be created on different systems, be sure that the extension ".doc" or ".docx" is added at the end of the filename. For example: Prins_1234567.doc.

Paper settings

Start with making page layout settings. Just set the paper format to A4 size and set the left, right and upper and under margin on 2.5 cm. The text must be fully justified on both the left and right sides. Set the line spacing to single and 0 points before and after. Leave a blank line between the paragraphs.

Other general instructions

Please write your final report using font Calibri, and font size 12 points for the main text, 14 points for the title and subtitle. Do the following things:

- Number your pages continuously
- Number your chapters, sections or paragraphs
- Only footnotes, endnotes etc. when necessary
- Use headers and footers in the title of the chapter or the number of the chapter

Making the (front) pages

The final report should be written according to the following rules from the TU/e Graduate School.

- The title page of the thesis should cover the following information:
  - The title (and subtitle, if applicable) of the graduation project
  - Surname student + initials + student number
  - Names of all members of the graduation supervision committee
  - Name of the course (7CC40) and the University
  - Study load (# of EC) of the graduation project
  - Academic year of graduation
  - Date of final presentation
  - Name of Master's program (CME)
  - An indication of whether or not the thesis is public information, and if not, the date of publication
  - A statement that the Master's thesis has been carried out following the rules of the TU/e Code of Scientific Integrity
- The second page should be blank.
- The table of contents starts with page 3.
- Every new chapter should start with an odd page number (such as 1, 3, 5) and end with an even page

number (such as 2, 4, 6).

- The structure of the final report, see Appendix 3A "Report structure for instructions". These are generic names of the chapters, please avoid them and be as specific as possible regarding your project topic.
- Using any reference manager (e.g., reference manager, Mendeley, Endnote, etc.) from the start. That will make your reference properly written and save you some time!

Using pictures, figures, logos, tables and so on

Please be careful when adding pictures etc. to the document. Try to limit the size of imported files preferably by using the graphical editor of Word or importing files which are saved as low-resolution JPegs (.jpg format). Do not make use of auto-link facilities, for instance Excel when using tables. Don't use company logos; this is not allowed according to the 'Regulations for the Examination Committee of the Department of the Built Environment'.

Using references

Please follow the regular APA (6th edition) reference style. Check that your references are indeed necessary and specified in the reference list.

Making the covers of the hard copy

You have the freedom to design your own cover. Please be aware that the graduation company name and/or logo are not published on the cover. Furthermore, these things need to be published on the cover: Author, Title (+ subtitle), Construction Management & Engineering, 20XX-20YY.

Printing the final report

As you probably know, the activities of the Print service department have been outsourced to ADC Nederland (formerly Dereumaux). All layout works are carried out by ADC Nederland (formerly Dereumaux). Of course, you can also use another print service.

Sending in your final report

At least two working days before the final presentation, your final report is sent in digital format to each of your graduation committee members.

Check the chapters "Final colloquium" and "Documents and forms to be submitted at the CME secretariat" for instructions on where, how and when to upload your files.

Appendix 3a. Report structure instructions

Table of contents

Summary

English summary of two pages, which is readable independent of the thesis and contains a brief overview of the objective of the graduation assignment, the methods and means used to achieve this objective, and the results and conclusions set against the goals originally defined.

Samenvatting

A Dutch summary of two pages is required for Dutch students and optional for international students.

Abstract (max. 350 words)

It is a microcosm of the entire paper – contains key information from each section, but it is brief and contains essential information only. It covers research highlights, gives the research problem and/or main objective of the research, indicates the methodology used, and presents the main findings and conclusions. The readers shouldn't have to read the whole report to get essential points. The abstract is also copied into the online CME graduation report database provided by Of CoUrsE!

Keywords (max. 5, no abbreviation)

List keywords that help you find your graduation report through search engines.

List of Abbreviations/Glossary

A summary of the important definitions, notions, classifications, etc. related to the chosen problem.

List of figures

List of tables

1. Introduction (max. 2000 words)

This chapter explains the research problem and its context, the importance of the problem (Why does it matter? Why is more information needed?), the reason and goals for the study, and the limitations of the research performed. Note that the goals of the research should be specified, not the goals of the company!

1 .1 . Problem definition / objective of the thesis
1 .2 . Research question(s)
1 .3 . Research design
1 .4 . The practical / social and/or theoretical / scientific importance of the thesis
1 .5 . Reading guide (the organization of the thesis)

2. Literature review (max. 10.000 words; 30+ references)

This chapter should review the state-of-the-art literature related to your research problem in the field and already used methods for this problem. (i.e., what happened, what approaches are used to find solutions, what the findings are, etc.) You summarize and evaluate the literature that you have used in your study by considering: how that literature has contributed to your area of research; the strengths and weaknesses of previous studies; how that literature informs your own research and understanding of the research problem. It is recommended to study the article of Randolph ('A guide to writing the dissertation literature review' (2009)) This article is freely accessible through: https://openpublishing.library.umass.edu/pare/article/id/1516/. Additionally, you can also watch the web lectures that you can find in the folder Integrating Literature on Canvas for the CME graduation

project (7CC40).

3. Methodology (max. 10.000 words)

The Methodology part describes in detail how the study was conducted, including conceptual and operational definitions of the components used in the study. Different types of studies will rely on different methodologies. Discuss with your supervisor the suitable methodology to use in your graduation project and the best way to report it. Depending on the type of research (e.g., design-oriented, policy-oriented, or evaluation research), you will follow some methodological cycle, such as the empirical cycle, regulative cycle, reflective cycle, or combination. (See Appendix 3b)

This part includes a description of the working method used. What theories / methods / techniques have been used to achieve the goal of the research and/or development and /or design, and why? How these theories / methods / techniques have been applied during the graduation project and explain the motivations of each step (why use this one, why make this adjustment, the advantages and disadvantages) . It is more important to deal with "why and what" questions with a reflective scientific mind-set than to provide good answers to "how to" questions.

It should be structured highlighting your major contribution or added value, inform readers of research results precisely, concisely, and specifically. It is the research, and not your activities, that are of interest to report here. Check the explanation in Appendix 3B for more detail. Or find more at:
https://www.scribbr.com/dissertation/methodology/ or
http://www.skillsyouneed.com/learn/dissertation-methodology.html

4. Data collection

Discuss with your supervisor the suitable structure of this chapter and find a clear way to present your work.

5. Results and discussion

Discuss with your supervisor the suitable structure of this chapter and find a clear way to present your work. You may want to split the results and discussion into two chapters.

6. Conclusion (max. 1000 words)

This chapter includes: what was learned through research, what remains to be learned, weaknesses and shortcomings of study, strengths of study, possible applications of study (how it can be used), and recommendations.

6 .1 . Scientific relevance incl. reflection on research question(s)
The project must be critically evaluated, e.g., has the objective been achieved, what could have been done better, etc.?

6 .2 . Societal relevance

6 .3 . Recommendations (for possible follow-up research)

References

Check online for APA style guides: https://apastyle.apa.org/style-grammar-guidelines

Appendices (not limited # words)

Here you should report all additional material related to your thesis.

- Be aware this is the general guideline. The order is flexible, those sections can be combined or

subdivided. For example, some theses combine results and discussion; others have experiment design and data collection combined. Before writing, consider: why you are writing, what you hope to achieve, and who you are writing for. These considerations will help you determine the content, organization, etc.

- Headings and subheadings should be specific and helpful, used to break up text and “chunk” information, used to guide readers’ attention. It can be used to keep track of various parts of a project. For example: “identifying indicators,” and “assessing indicators”.

Appendix 3b. Methodology / approach

1. Introduction

It is usually helpful to start the section on methodology by discussing briefly your research questions, and how you plan to address each of them. This is the point at which to set out your chosen research methods, including their theoretical basis, and the literature supporting them.

You should then move on to set out the conceptual framework in which you plan to operate regarding the key texts on that approach. You should be clear throughout about the strengths and weaknesses of your chosen approach and how you plan to address them. You should also note any issues of which to be aware, for example in sample selection or to make your findings more relevant.

You should make clear whether you think the method is 'tried and tested' or much more experimental, and what kind of reliance you could place on the results. You will also need to discuss this again in the discussion section. Your research may even aim to test the research methods, to see if they work in certain circumstances.

You should conclude by summarizing your research methods, the underpinning approach, and what you see as the key challenges that you will face in your research. Again, these are the areas that you want to revisit in your discussion.

2. Methodology and methods

It is common for a research project to utilize multiple research methods and designs for different phases of the project. For example: using case studies, in-depth interviews, field observations, document analysis in product/model design and development; while applying think-aloud protocols, surveys and expert interviews in product/model evaluation and validation. However, a complete description of the methods used enables the reader to evaluate the appropriateness of your methods and the reliability and validity of your results. You should be clear about the academic basis for all the choices of research methods that you have made. 'I was interested' or 'I thought' is not enough; there must be good academic reasons for your choice. The methodology should explain what you did, with any refinement that you made as your work progressed and the motivation for doing it this way. Again, it should have a clear academic justification of all the choices that you made and be linked back to the literature. Depending on the type of research, you may follow different methodological cycles addressing specific focus.

There is a general research cycle with some main steps:

- Questioning- determine the problem to be solved and the questions to ask to get it done
- Planning- decide where to seek information and how to store it
- Gathering- refer to the plan and collect sources
- Sorting & Sifting- reduce the gathered information to what is relevant and insightful
- Synthesizing- information is restructured into a new whole to find focus
- Evaluating- decide to move on to the next stage or revise efforts with another cycle
- Reporting- production of final work

The research triangle that helps you organize your work includes three key elements: Clear research questions, relevant theory, and appropriate methods. The relationship between the three elements is:

- Clear research questions are grounded in relevant theory.
- Relevant theory informs methodology to generate appropriate methods.

- Appropriate methods are necessary to answer the research questions.

Experiments, Surveys, Questionnaires, Interviews, Case studies, Participant and non-participant observations, Observational trials, Delphi method, Urban research methods, etc. The methods mentioned above are just a small part of all the methods you learned and may consider using in your graduation. Discuss with your supervisor to find the exact methodology that fits and use the research triangulation to organize it logically. Depending on the research subject, the following methodological research cycles are recognized in academic research.

Engineering research cycle

The engineering cycle encompasses a mindset that emphasizes open-ended problem-solving and encourages learning from failure. There are common steps in the engineering research cycle: Ask: identify the need and constraints; Research: the problem; Image: develop possible solutions; Plan: select a promising solution; Create: build a prototype; Test: and evaluate prototype; Improve: redesign as needed.

Design research cycle

The Design Cycle is the problem-solving process that you have been following, unconsciously, for years. In the past, you most likely used the George Polya method of problem-solving without knowing it, which is normally taught as Read, Plan, Solve, and Check.

Empirical research cycle

The empirical cycle captures the process of coming up with hypotheses about how stuff works and testing these hypotheses against empirical data systematically and rigorously. There are common steps: Observation, Induction, Deduction, Testing, and Evaluation.

Regulatory research cycle

The regulatory cycle is a common, practice-oriented research cycle developed by Van Strien. The word “regulatory” means that the cycle focuses on decisions. This is in contrast to the empirical cycle, which aims at producing scientific knowledge. The regulatory cycle can be applied to business and social science problems. The common steps include Issues, Diagnosis, Plan (design), Intervention (implementation), and Evaluation.

Reflective research cycle

The reflective Cycle encourages people to think systematically about the experiences they had during a specific situation, event, or activity that was developed by Gibbs. It offers a framework for learning through (personal) reflection to make sense of an experience – learning by doing. Using a circle, reflection on those experiences can be structured in phases: Description of the experience, feelings and thoughts about the experience; Evaluation of the experience, both good and bad; Analysis to make sense of the situation; Conclusion about what you learned and what you could have done differently; Action plan for how you would deal with similar situations in the future or general changes you might find appropriate.

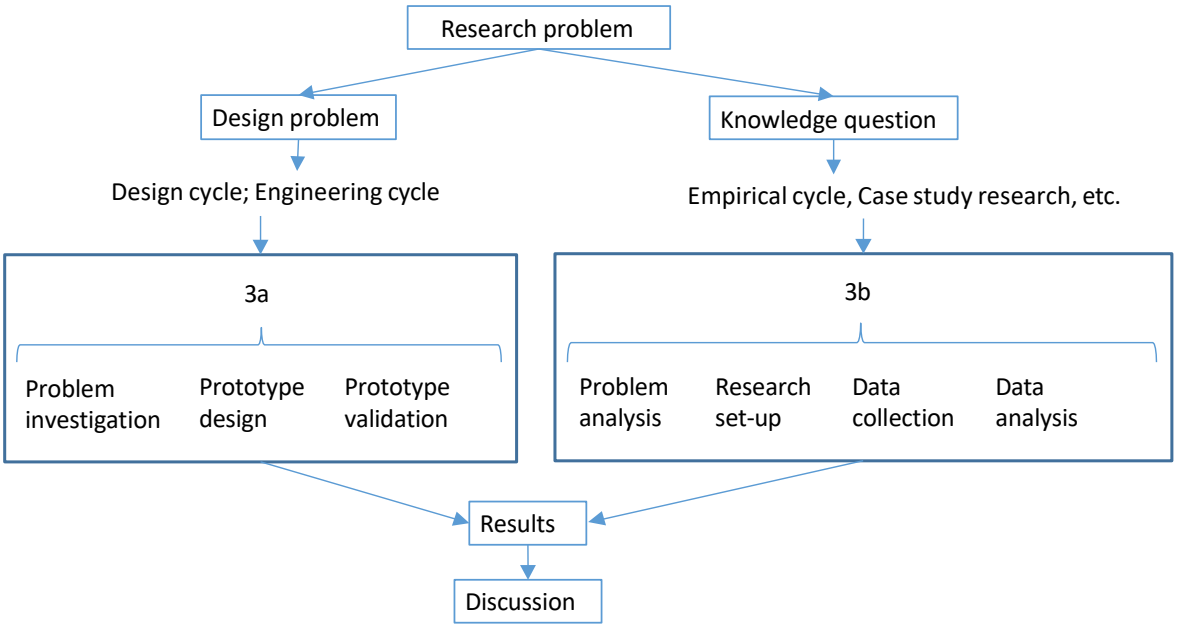
Case study research cycle

A case study is a research strategy and an empirical inquiry that investigates a phenomenon within its real-life context. Case studies are based on an in-depth investigation of a single individual, group, or event to explore the causes of underlying principles. Case studies may involve both qualitative and quantitative research methods. The case study research also follows a clear methodological path. It is also a linear, but iterative process and often includes steps: Plan to identify research questions; Design case studies; Prepare to collect case study evidence; Collect case study evidence, Analyze case study evidence; Report and reflect.

3. Methodology roadmap: Design problem or Knowledge question

Overall, we distinguish two main paths, depending on your choice to do either (3a) engineering or design

research; or (3b) empirical, regulatory, reflective, or case study research. These are two slightly different methodological approaches. The definition of the research problem, achievement of results, and analysis and discussion of results remain identical (adapted from R.J. Wieringa (2014) Design Science Methodology).



3.a. Design and Engineering Research aiming at prototype development

Once you have introduced your overall methodological approach, you should give full details of the methods you will use to conduct the research. This consists of four steps, namely: data collection, system architecture design, prototype development, and prototype validation.

Data collection

In any situation, and especially with a prototype development approach, you need to work with data. There are a number of options. Most predominantly, you need to choose and specify whether you will work with real data or simulated data.

Ideally, you choose to work with real data, in a real context. In such cases, you need to secure data ownership, privacy and security concerns, as well as potential ethical restrictions. Most commonly, data will come from a private partner, which means that you need to make an agreement with this partner. You agree and secure that the data remains theirs fully, including responsibilities, and you use the data for research purposes only. Any publication needs to be checked by the private partner and can only be published with their consent, unless otherwise agreed.

If such data is not available, and you decide to work with simulated data (not real), indicate in your research proposal the limitations of this choice and the impact on the final research results. Working with simulated data has considerable risks: incorrect conclusions may be drawn from incomplete or wrong datasets, the prototype might not be scalable (the “toy prototype problem”), and so forth. Be aware of such limitations and implications before you start. Of course, limited simulated data may be a better choice, in case you want to investigate in detail how certain algorithms and functionalities work (scoped contained experiments).

Whichever you choose, list your data sources clearly, ideally with a number of statistics and a concise reason why you chose this data.

Prototype design – system architecture

An absolutely crucial step in your prototype design for the design or engineering research is the prototype design or system architecture. This section can be relatively short, but it needs to include a diagram that comprehensively and concisely indicates to an unfamiliar reader what the architecture is of your proposed diagram. Discuss the diagram briefly, indicating key choices. References to existing paradigms are ideally included, either through references or through footnotes with hyperlinks to relevant supporting material online (only trustworthy sources allowed).

Prototype development

This section is longer than the previous one and gives additional detail with regard to how you will implement the individual parts of the overall system architecture. In discussing how you will implement and develop your prototype, you clearly refer to the sources and methods and tools you will use. In the case of software development, for example, you refer to the programming languages and modules you will use, and most importantly, why; in the case of database development, you refer to the database technologies you'll use and why; and so forth.

Furthermore, we strongly recommend and encourage that you incorporate a stepwise approach in your prototype development. Instead of building a tool that has too broad scope and cannot be realized in time, aim to define parts in your prototype. You implement the most critical part first and implement additional features on demand. Distinguish between need-to-have and want-to-have.

Prototype evaluation

Development simply for the purpose of development is not allowed. It is not research. So, the development of your prototype needs to serve a purpose that cannot be obtained by any "regular" IT consultancy company. The prototype needs to add value and contribute to novelty. This needs to be checked in this final part of the prototype evaluation.

Therefore, a clear evaluation mechanism needs to be selected and documented, including why you chose such an evaluation method. Common evaluation methods for prototypes are alpha testing and beta testing. In the former case, you do not involve end users and only test the prototype yourself; in the latter case, you release the prototype to end users and evaluate their feedback and responses. In both cases, you need to design the test, so that you are sure that your prototypes meet the research goals that were set in the beginning.

3.b. Empirical, regulatory, reflective, or case study research aiming at data analysis

Once you have introduced your overall methodological approach, you should give full details of the methods you will use to conduct the research. Outline the tools, procedures, and materials you will use to gather data, and the criteria you will use to select participants or sources. There are many ways to categorize different types of research. Depending on the type of knowledge you aim to produce or the type of data you will collect and analyze, a common distinction can be made: quantitative research and qualitative research. Quantitative research deals with numbers and statistics, while qualitative data deals with words and meanings that often address "why" and "how" questions.

Quantitative research generally requires a larger sample size, allowing you to test a hypothesis by systematically collecting and analyzing data, which are best for measuring, ranking, categorizing, identifying patterns, and generalizing. Qualitative research is often more flexible, allowing you to explore ideas, concepts, and experiences in-depth, which is best for describing, interpreting, contextualizing, and gaining in-depth insight into specific concepts or phenomena. However, they can't be used to make statistical generalizations about large groups.

Data collection

Consequently, there are different ways to collect data and analyze data: while quantitative data collection uses surveys, experiments, simulation data, existing data, etc.; qualitative data collection uses interviews or focus groups, participant observation, existing data, etc. It's also possible to start with a survey to find out the overall trends (quantitative), followed by interviews to better understand the reasons behind the trends (qualitative) . In the following, a few commonly used methods are listed.

Quantitative methods of data collection

- Surveys: Describe where, when, and how the survey was conducted. How did you design the questions, and what form did they take (e.g., multiple-choice, rating scale)? What sampling method did you use to select participants? Did you conduct surveys by phone, mail, online, or in person, and how long did participants have to respond? What was the sample size and response rate? You might want to include the full questionnaire as an appendix so that your reader can see in detail what data was collected.
- Experiments/simulations: Give full details of the tools, techniques, and procedures you used to experiment. How did you design the experiment (e.g., between-subjects or within-subjects)? How did you recruit participants? What tools or technologies did you use in the experiment? In experimental research, it is especially important to give enough detail for another researcher to reproduce your results.
- Existing data: Explain how you gathered and selected material (such as publications or archival data) for inclusion in your analysis. Where did you source the material? How was the data originally produced? What criteria did you use to select material (e.g., date range)?

Qualitative methods of data collection

- Interviews or focus groups: Describe where, when, and how the interviews were conducted. How did you find and select participants? How many people took part? What form did the interviews take (structured, semi-structured, and unstructured)? How long were the interviews, and how were they recorded?
- Participant observation: Describe where, when, and how you conducted the observation. What group or community did you observe, and how did you gain access to them? How long did you spend conducting the research, and where was it located? How did you record your data (e.g., audiovisual recordings, note-taking)?
- Existing data: Explain how you selected case study materials (such as texts or images) for the focus of your analysis. What type of materials did you analyze? How did you collect and select them?

Data analysis

Next, you should indicate how you processed and analyzed the data. Avoid going into too much detail—you should not start presenting or discussing any of your results at this stage. There are many possible techniques to use, but what is important is that the technique that you use is consistent with the methodology of your research.

Quantitative methods of data analysis

In quantitative research, your analysis will be based on numbers. In the methods section, you might include: How did you prepare the data before analyzing it (e .g ., checking for missing data, removing outliers, transforming variables)? Which software did you use to analyze the data (e.g., SPSS or Stata)? Which statistical methods did you use (e.g., regression analysis) to discover commonalities or patterns in the data? The results are often reported in graphs and tables. The reliability and validity of the results should be

checked.

Qualitative methods of data analysis

In qualitative research, your analysis will be based on language, images, and observations (often involving some form of textual analysis). Specific methods might include:

- Content analysis: categorizing and discussing the meaning of words, phrases, and sentences
- Thematic analysis: coding and closely examining the data to identify broad themes and patterns
- Discourse analysis: studying communication and meaning with their social context

This part explains how data was gathered or generated and how data was analyzed. It is both conventional and expedient to divide this section into subsections if needed. Include in these subsections the information essential to comprehend and replicate the study. Insufficient detail leaves the reader with questions; too much detail burdens the reader with irrelevant information. Consider using appendices for more detailed but less relevant information.

4. Results

In the results part, use visual and textual representations for research findings, such as graphs, tables, diagrams, charts, and explanatory text. The text should point out the most significant portions of research findings, indicate key trends or relationships, and highlight expected and unexpected findings. Mention all relevant results, including those that are not expected; be sure to include small effect sizes (or statistically non-significant findings) when the theory predicts large (or statistically significant) ones. Do not hide uncomfortable results by omission. Be sparing in the use of tables and figures and ensure that the data presented in tables do not duplicate results described elsewhere in the text. Be careful with the generalization of the results.

5. Discussion

After presenting the results, you are in a position to evaluate and interpret their implications. When the discussion is relatively brief and straightforward, some authors prefer to combine it with the Results section, creating a section called Results and Discussion. In the discussion, you will examine, interpret, and qualify the results, and draw inferences and conclusions from them, which include: the explanation for results, comments on unexpected results and offering a hypothesis for them, and comparison to literature. It is important to link your results back to the research question: do your research results provide answers to your research question? It is important also to link your results back to the literature by considering questions: Does your research confirm previous studies? Do they deviate from them? Why? Try to explain how the findings can be applied in a broader context by emphasizing any theoretical or practical consequences of the results. Similarities and differences between your results and the work of others should be used to contextualize, confirm, and clarify your conclusions. Do not simply reformulate and repeat points already made; each new statement should contribute to your interpretation and the reader's understanding of the problem.

Acknowledge the limitations of your research, reflect on the methods used, and address alternative explanations of the results.

End the Discussion section with a reasonable and justifiable commentary on the importance of your findings. This concluding part may be brief or extensive provided that it is tightly reasoned, self-contained, and not overstated. In this section, you might briefly return to a discussion of why the problem is important (as stated in the introduction), what larger issues might hinge on the findings, and what propositions are confirmed or dis-confirmed by the extrapolation of these findings to such overarching issues.

Note: For the data collection, remember to check if it falls in the requirement of Ethics review mandatory as of 2020 (see section ‘Ethics and Data management‘, page 8).

Appendix 4. Formal Assessments 4TU-CME master thesis project

This protocol was set up to support the assessment of Master's theses within the 4TU MSc-program Construction Management & Engineering (CME).

The assessment of the Master's thesis takes place after the public colloquium and the discussion/ questioning afterwards. This is done in a short, closed meeting of the supervising committee (the student is not present at this meeting). The assessment is performed by the university members of the supervising committee.

External members have an advisory vote. At the assessment, several aspects are taken into account. Regarding the assessment aspects, three main aspects are distinguished:

- Quality of research or design (**product**) Working of the content
- Learning process during Master's thesis project (**process**)
- Communication (**presentation**)

Appendix 4A lists all aspects within these three main categories. When assessing a Master's thesis, the committee will address these main aspects and determine the strong and weak points of the student's work. This is registered by the main supervisor (chair supervising committee) on the **Assessment Form Master's thesis 4TU-CME**. Subsequently, the committee determines the final grade for the Master's thesis according to the final grading profiles.

Appendix 4B presents profiles for final grading that indicate how the quality of the Master's thesis as a whole can be translated into a final grade. The list of aspects for assessment and the profiles for final grading offer guidelines for a more equalized assessment of master theses and offer clarity to the student about the way he or she will be assessed. The aspects for assessment and the grading profiles were set up according to the learning goals of the Master's thesis and (partially) on the final qualifications of the MSc-programs.

After the determination of the final grade, the chair of the supervising committee announces the final grade to the student and presents the feedback on the assessment form orally to the student during the final public assembly.

The assessment form is filled after the final colloquium by the chair of the supervising committee and returned to the Examination Committee BE. The CME secretariat will arrange the submission.

Appendix 4a. Assessment criteria

1. With respect to content; quality of research / design (product) 50%

Assessment criteria	Indicators
Contribution to a new concept	• Creativity • Inventiveness • Originality • The extent to which the student independently introduces new concepts • Contribution to new knowledge/contribution to a concrete product, design or model
Literature review & Theoretical framework	• Use of earlier results of research (and integration of these results) • Depth (detailed elaborations, use of literature) • Critical reflection
Research method/design	• Clear research questions • Applying the correct research and design methodologies and substantiating the choices made • Use models in the right way • Systematic/methodical approach • Data collection and analysis/validation of the design • The extent to which the original research proposal has been met is the reason for alterations (keeping up with work planning, follow-up on appointments made) • The extent to which management theory and technical knowledge are combined
Conclusions & recommendations / Contribution to theory & practice	• Reasoning and argumentation of conclusions (are research questions answered?) • Generalizability • Relevance (scientifically: could the work lead to a scientific publication, applicability: the usefulness in practice / being able to put research in context) • Analyze and discuss the results, draw conclusions from the results and reflect on the results in the wider societal and scientific context

NB When the research has a balanced focus on technique and management, this will be valued positively. When this is not (or to a lesser extent) the case, this does not have to lead to a negative influence on the assessment.

2. Working and learning process during Master's thesis project (process) 25%

Assessment criteria	Indicators
The time needed to finish the MSc thesis project	• Duration of the process. The start of the process is marked by the approval of the research proposal
Output compared to the time taken to finish the Master Thesis	• Amount of work done • Time taken • Obtained versus required results
Independence and professional skills	• Independence • Cooperation • Communication skills • Incorporation of feedback
Attitude	• Commitment/enthusiasm • Attitude to strengthen his / her personal development • Student's attitude during progress meetings (proactive/passive) • Reflection upon his / her own work • Functioning within the organization where the project is carried out • Dealing effectively with compromises

3. Communication (presentation) 25%

Assessment criteria	Indicators
Report	• Composition, structure, writing style, use of language • Consistency • Readability: clarity/sharpness of formulations • Layout, images and tables (usefulness, added value) • References to literature
Oral presentation and defense	• Effective presentation of the content (is the message coming across?) • Captivating way of presenting (verbal capabilities, posture) • Distinction between important points and minor aspects • Insight into subject matter and coherence between different parts of the project • Structure/outline presentation • Care of details/neatness • Answering questions/discussion / defense

Appendix 4b. Profiles for final grading

These profiles are used as a framework of reference to provide general characterizations of the graduation process and product that leads to the final grading. It will not be used to fill out the feedback boxes in the Assessment Form. At CME in Eindhoven and Delft, grading in 0 .5 marks is possible.

5: Insufficient

The research and/or report are insufficient, and the student was strongly directed by his or her supervisors. Weak points can clearly be pointed out. The student did not show an academic attitude. On average, the student scores 'insufficient' on all aspects of assessment.

6: Sufficient / meets the requirements

Concerning content, the research was conducted sufficiently. The report is mediocre. Weak points can clearly be pointed out but are compensated for by aspects on which the student performs better. The student has shown little input of his own and was strongly directed by his or her supervisors. On average, the student scores 'sufficient' on all aspects of assessment.

7: Amply sufficient/good

Concerning content, a solid piece of research was delivered. The report is carefully edited. Either the research process or the mastery of the subject matter leaves room for improvement. The supervisors clearly had a steering influence on the final product. The student scores at least 'sufficient' on all aspects of assessment and 'good' on some aspects.

8: Good mainstream / contains new elements

Concerning content, the research was set up solidly and was carried out accurately. The report is carefully edited regarding language as well as layout. The student has worked independently and was able to put forward his or her own initiatives. The guidance provided by the supervisors was minimal. On average, the student scores 'good' on all aspects of assessment.

9: Very good/excellent

The research is innovative and can be converted into an article for a renowned (scientific) magazine without putting in too much effort. Concerning content, the research is very solid with some points that can clearly be pointed out as strong. The report is carefully edited and shows that the student has good writing skills. The students' own input and independence are large. The student clearly stands above the subject matter and is able to defend his or her statements in discussions well. The student scores at least 'good' on all aspects of assessment and 'very good' or 'excellent' on some aspects.

10: Excellent

The research is innovative and can be converted into an article for a renowned (scientific) magazine without putting in too much effort. With respect to content, the research is excellent. The student is capable of conducting research independently. The report and the presentation show that the student has excellent communication skills (written and oral). The student scores on average 'excellent' on all aspects of assessment.

Appendix 4c. Assessment rubrics

Assessment rubrics with respect to content; quality of research/design(product) 50%

Assessment Criteria	< 5	6	7	8	9	10
Contribution to a new concept	Not innovative; no creativity, inventiveness and originality.	Somewhat innovative; limited creativity, inventiveness and originality.	Creative, inventive and original, but some room for improvement.	Student is perfectly able to introduce new, innovative and original concepts.	Very well thought out innovative project. The concept can be knowledge, a product, design or model.	The Master thesis is an excellent contribution to new knowledge, a product, design or model.
Literature review & Theoretical Framework	No depth, no use of earlier academic materials. Unclear and inadequately explained.	Limited depth and use of earlier academic materials.	Adequate depth and use and nitration of earlier academic materials. Use of a theoretical framework.	Well-explained and critical evaluation of the latest literature. More than average depth.	Profound and critical evaluation of literature and demonstrating that the student is very skilled in integrating this literature.	Excellent and original; suitable for journal publication.
Research method/design	Unsystematic, not validated and unclear. No link to the correct research and design methodologies.	Limited explanation; justified using academic literature and showing some systematic approach.	Adequate use of research and design methodologies Student is using the literature and dataset.	Well-explained and well justified, using the right research and design methodologies.	Profound and critical use of research and design methodologies. Very clear and validated design.	Excellent demonstration of research and design methodologies.
Conclusions & recommendations, Contribution to theory & practice	Vague, irrelevant, not able to analyze and discuss the results.	Clear and rather relevant, but shortage of arguing the conclusions.	Appropriate conclusions and recommendations. Contributes to theory and practice.	Clearly, relevant and very critical conclusions and recommendations. Valuable contribution to theory and/or practice.	Profound and original conclusions and recommendations. Very valuable contribution to theory and/or practice.	Excellent conclusions and recommendations.

Assessment rubrics with respect to working and learning process during Masters Thesis project (process) 25%

Assessment Criteria	< 5	6	7	8	9	10
Time needed to finish the Master's Thesis project	Master's Thesis finished in >1 year.	Master's Thesis finished in 10-12 months.	Master's Thesis finished in 8-9 months.	Master's Thesis finished in 7 months.	Master's Thesis finished in 6-7 months or less.	Master's Thesis finished in 6 months or less.
Output compared to the time taken to finish the Master Thesis	Work done and results achieved within the time was taken not satisfactory.	Limited work done and results achieved within the time taken.	Reasonable amount of work done and results achieved within the time taken.	Good amount of work done and results achieved within the time taken.	Large amount of work done and results achieved, more than required.	Excellent amount of work done and results obtained, much more than required.
Independence and professional skills	Inadequate to work independently, incorporate feedback and cooperate with others.	Limited communication skills. To some extent skilled in working independently, incorporating feedback and / or cooperating.	Adequate in cooperating, incorporating feedback and/or cooperating. Can work independently.	Independent; very good demonstration of skills.	High degree of independence; superior demonstration of skills	Excellent professional skills.
Attitude	Not the attitude to strengthen his / her personal development. Very passive attitude in meetings.	Limited commitment and enthusiasm. Limited active attitude in meetings	Positive attitude in strengthen his / her personal development. Active and enthusiastic.	Professional attitude. Active attitude during meetings.	Strives for personal development. Very committed, enthusiastic and positive attitude during meetings.	Excellent attitude.

Assessment rubrics with respect to Communication (presentation) 25%

Assessment Criteria	< 5	6	7	8	9	10
Report: writing style and structure	Poor illogical structure.	Readable, clear and consistent.	Adequate consistent report with a readable writing style. Adequately argued.	Professional report with a very clear composition.	Profound report. Very clear writing style and structure. Potentially worth journal publication.	Excellent report.
Oral presentation and defense	Vague and unclear presentation and defense.	Clear, but limited based on the reported findings. Satisfactory.	Effective and structured presentation of the content. Insight in the subject matters. Good presentation.	Very clear and takes much care of details. Good answers to questions and discussions. Gives much insight into the subject matter. Very good presentation.	Profound presentation with eye-openers. A lot of care of details, without going off-topic. Very strong presentation and defense.	Excellent presentation and defense.

Appendix 5. Expertise ISBE staff

Name	Expertise	CIM	BIM	Journals	Courses
Bige Tunçer	Data and information modeling AI (Big) data informed design and planning support Dashboard/platform design and implementation Parametric modeling and generative design Design optimization Information visualization	X	X	Environment and Planning B: Urban Analytics and City Science, Automation in Construction, Cities, Design Studies, Landscape and Urban Planning, Urban Forestry & Urban Greening, AI EDAM Artificial Intelligence for Engineering Design, Analysis and Manufacturing, IEEE Internet of Things Journal, IEEE Transactions on Big Data, Computers, Environment and Urban Systems, City, Culture and Society	Research and development project, Collaborative design and engineering, Case study process modeling, legal and governance aspects
Ekaterina Petrova	AI in Construction		X	Automation in Construction; Advanced Engineering Informatics; Architectural Engineering and Design Management; Research in Engineering Design	Product and Process Modeling; Collaborative design and engineering; Systems engineering; Research and development project
Qi Han	Data-driven Sustainable Transition	X	X	Sustainable Cities and Society, Applied Energy, Land use policy, Energy Policy, Journal of Environmental Management, International Journal of Project Management. Ecological Indicators	Case study process modeling; Process modeling and information management; Research and development project
Dujuan Yang	Smart cities	X	X	Energy Policy; Energy Research and Social Science; Energy Economics; Energy and Environment; International Journal of environmental policy and decision making; Sustainable cities and society; Transportation Research Part D: Transport and Environment; Journal of Urban Economics; International Journal of Sustainable Transportation	Process modeling and information management; Research and development project; Smart cities;
Pieter Pauwels	Building Information Modelling		X	Automation in Construction; Advanced Engineering Informatics; Architectural Engineering and Design Management; IEEE Transactions on Industrial Informatics; Structural Survey; AI in Engineering, Design and Manufacturing (AIEDAM); Journal of IT in Construction; International Journal of Design Sciences and Technology; International Journal of Heritage in the Digital Era; Buildings; Design Issues	Fundamentals of Building Information Modeling; Research and development project; Parametric Design;

Shahryar Ershad Sarabi	City Information Modelling – Urban Systems Studies	X	Journal of Environmental Management, Sustainable Cities and Society, Sustainability, MethodsX, Resources, Urban Forestry & Urban Greening	Project Smart Cities, Process modeling and information management, Research and development project