4TU. MSc in Construction Management and Engineering

TU Delft
Delft University of Technology

TU/e Technische Universiteit Eindhoven University of Technology

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Graduation Guide
CME @ TU/e

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CME @ TU/e

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

Eindhoven University of Technology

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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' support the education and research.
The total scope of the graduation amounts 40 ECTS; 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. A student can only start his/her Graduation project after the Research proposal has been approved by the graduation committee. The credits for the graduation are obtained after examining the final presentation and graduation project report.

Application and participation

For the subject of the individual graduation a list of topics offered under 2 main CME themes. Participation in one of these topics is obligatorily 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 research and development activities of the involved staff and PhD's.

The student who wants to start with the graduation submits a research proposal referring to a topic that is 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 committee are filled in on a form provided by the CME secretariat. When the research proposal and graduation committee are complete, both documents are handed in hardcopy through the CME secretariat for approval before the start of the new quartile.

CME students can select only those graduation topics from a predefined list (see Appendix 1). Deviations either in topic, or in staff member 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)', chairs:
  - Organization Science, especially Knowledge Acquisition and Integration Strategies (OS)
  - Quantitative Analyses of logistic control systems(QA)

Composition of the graduation committee adheres to the following TU/e Graduate School rules:

- at least three members hold an academic degree
- one of them holds a position of (associate) professor
- one of them holds a position in another group, unit, faculty or university
- if the project is executed at a company, the company's supervisor will be added to the graduation committee as an advisor. Only if the company's supervisor contributes at an academic and up-to-date level, he/she can be one of the three academic members

CME Graduation competent (associate) professors:

Prof.dr.ir. B. de Vries	(ISBE)
Prof.dr. S. Rasouli	(UP&T)
Ir. A.W.J. Borgers	(UP&T)
Dr.ir. P. Pauwels	(ISBE)
Prof.dr.ir. I.M.M.J. Reymen	(ITEM)
Prof.dr. I.J.B.F. Adan	(OPAC)
Dr.ir. B. Walrave	(ITEM)

CME Graduation competent assistant professors, fellows, lecturers:
Dr. M.M.A.H. Cloodt
Dr. G.Z. Dane
Dr. S.A.M. Dolmans
Dr. Q. Han
Dr. R.J.G. Opdenakker
Dr.ir. P.H. den Ouden
Dr. E. Petrova
Dr.ing. P.J.H.J. van der Waerden
Dr. D. Yang

CME Graduation competent PhD's:
All PhD's from the TU/e – CME chairs: ISBE, UP&T, OPAC, ITEM

CME Graduation competent external committee members:
If the graduation committee contains a mix of members from

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

then the Graduate School condition is satisfied. In other words, not all committee members should come from the same chair.

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 Managment (BIM) This may help you to find your graduation committee members.e

The research proposal is written in close collaboration with the envisioned graduation committee members.

The committee member that will act as 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 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 at the CME secretariat to obtain approval from the Examination Committee. 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 contrast with the Graduation project itself). 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 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 short description to appropriate CME staff member
Meet with CME staff member and make decision

3. *Elaboration proposal*
Collect additional graduation reports
Collect additional scientific publications
Short list possible industrial, managerial companies
Prepare short presentation

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

5. *Submission*
Submit Research proposal at CME secretariat, hardcopy
Submit form Approval graduation supervision committee at CME secretariat, hardcopy before start of the new quartile.
Submit Research proposal to Canvas (7CC40) at the Graduation year/quartile you registered for the first time

The first and the second supervisor 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 from 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 ECTS at minimum. The graduation **project** can only start if: (1) The research proposal has been approved, and (2) the student is maximum 7,5 ECTS 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 is considered as 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 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 principle 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 persons involved in the (graduation) research project. The procedure and relevant forms and all relevant information about ethical review and data management can be found on the TU/e intranet portals:
https://intranet.tue.nl/onderzoek/ethical-review/
https://intranet.tue.nl/en/university/departments/built-environment/research/research-data/

Gitlab

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 code from previous projects, if valuable and useful. They are encouraged to do this using the TUe 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 same code?
- Are you following versioning, Continuous Integration/Continuous Development process?

If any of the answers are ‘yes’, please contact Harshita Bajpai – h.bajpai@tue.nl, to know how to proceed further.

How to use GIT in your graduation project
ISBE has its own group in Gitlab, namely https://gitlab.tue.nl/ISBE, which collects several projects or ‘repositories’. This includes:

- https://gitlab.tue.nl/ISBE/researchcode : 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 graduation student. A new Project folder is set up for user/s with authorized permissions. New users could login and start with creating repositories for their code. Please refer to https://gitlab.tue.nl/help or https://docs.gitlab.com/ee/README.html to proceed.

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 registered through the TU/e student information system Osiris for your graduation (7CC40). You only need to register once. At this meeting you will receive all required information for the graduation process. Remind that registering 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. When you completed writing your research proposal and composed your graduation committee, you hand-in all documents and forms hardcopy at the CME secretariat for approval before the start of the new quartile. All of these are checked at the first day of the new quartile, and unless irregularities are found the student can start his/her graduation project.

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 (remind registration for 7CC40 has already been completed thus is not needed again). You are invited to present by the CME secretariat when your research approval has been approved. The graduate student gives a short (5-10 min.) presentation on: project goals, research methods, 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 in hard-copy and in paper format to the graduation committee members minimal 2 working days prior to 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 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 in hard-copy and digitally (in PDF and Word format) to the graduation committee members and the CME secretariat 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 such as: final presentation, approval ethics committee, data management plan, GitLab reference, consent letters and 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 and coffee/tea is arranged by the student. The room can be booked through the Vertigo reception. Coffee/tea can be arranged at the canteen of Vertigo (min. 1 day ahead). The student should contact the CME secretariat to plan the final colloquium and he/she should inform the secretariat about the location. The final colloquium procedure is as follows:
30 minutes (power point) presentation
15 minutes question and answer
15 minutes committee deliberation on grading
10 minutes final grade announcement
After the final colloquium the chairman signs the final report and all files, documents and forms will be sent to the Examination Committee (The CME scetariat will take care of this).

Summary of subsequent conditions

- if the student has completed at least 50 ECTS, the student may start preparing a research proposal
- if the student's research proposal is accepted by the graduation committee, and if the student is maximum 7,5 ECTS short of completed courses, then he/she can start the Graduation project at the first upcoming quartile
- if a check against the TU/e administration shows that not all conditions are satisfied, then a student will receive a message to withhold continuation of the Graduation
- if the research proposal has been approved by the TU/e Ethical Review Board (if applicable)
- 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

Documents and forms to be submitted at the CME secretariat

The following graduation documents and forms need to be submitted hardcopy at the CME secretariat:

- Final graduation thesis (including summaries in English and Dutch) + appendices
- Graduation supervision committee form (see Canvas under course code 7CC40)
- Declaration TU/e code of Scientific code conduct MSc thesis (see Canvas under course code 7CC40) Sign this form and submit just before the final colloquium.
- External committee member form (if applicable)

Digitally send the Word files of the English summary, Dutch summary and the abstract. (i.e., the same ones included in the final report) to the CME secretariat for submission to the OfCourse graduation thesis database.

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 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 a period of 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. 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 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 the confidential version after the embargo has expired.

Exam procedure

For more information about registering for a final examination session, look at:

https://intranet.tue.nl/en/university/departments/built-environment-be/education/ecb-for-you-and-me/regulations/application-final-exam/

If you have any questions, about registration, please contact the secretary of the Examination Committee, Examination.Committee.be@tue.nl
Please find below the final examination schedule of CME:
https://intranet.tue.nl/en/university/departments/built-environment/education/ecb-for-you-and-me/ecb-calendar/

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/organization/student-administration/terminating-enrollment-upon-final-examination/termination-of-enrollment-at-tue/

Contact information

Mrs. I.M. Dekkers-de Bruijn, secretariat of Master's degree program CME at TU/e:
i.m.dekkers@tue.nl

Education and Student Affairs dep. 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, mevr. Harshita Bajpai:
h.bajpai@tue.nl

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

Educational information Master program CME at TU/e:
http://mytue.tue.nl
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

AB = Aloys Borgers
BV = Bauke de Vries
DY = Dujuan Yang
GD = Gamze Dane
EP = Ekaterina Petrova
PP = Pieter Pauwels
PW = Peter van der Waerden
RO = Raymond Opdenakker
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 burden on stakeholders and policy makers that are responsible for urban management. The research in urban management focuses on understanding dynamic urban processes and formulating policies on the development of sustainable and resilient cities. Urban management research contributes to socio-economic models that are needed to manage urban systems and forecast spatial effects and financial risks of policy measures by considering the emerging area of urban informatics (i.e. using sensors, gps, apps, location-based social network data for urban systems). Urban informatics utilizes urban Big Data to improve strategies for dynamic urban resource management, to gain insights on urban patterns and processes, to support and make innovations for urban management, public participation and policy analysis.

Topic	Supervisor
Modeling and simulation of pedestrian behavior in urban areas	AB, BV
Modeling and simulation of sustainable land use transformation	AB
Land use suitability assessment using geographical information systems and multi-criteria decision methods	AB, GD, PW
Agent-based modeling of urban transformation (concerning land use, housing, energy, climate change)	AB, QH
Big data in Smart cities to support citizen's Quality of Life and urban planning	BV, DY, QH, RO
Development of an open data platform for Smart Eindhoven City, combining static data (e.g. urban maps) and real time data (e.g. GPS)	BV, GD
Environmental assessment (noise pollution & air pollution) using sensors/apps and geographical information systems	GD
Understanding citizen perception (opinion mining) of urban areas using Location-Based Social Network (LBSN) data	GD
Determining the dynamic use of urban space in the city using LBSN data (redefining neighborhoods, finding different land usage patterns during day or seasons)	GD
Generating multi-modal data platform for environmental visualization (using LBSN data, sensor data, census data, digital maps, etc.) For instance: Visualization tool for outdoor physical activity route choice	GD

Influence of new technologies (i.e. autonomous cars, car sharing) on urban form	GD, RO
Using VR/AR technologies for researching urban design interventions	GD
Visualization of citizens' preferences in the city using GIS (combining choice experiments results with GIS)	GD, PW
Systems Engineering for infrastructure projects using Semantic Web Technologies	BV
Smart parking in urban areas (residential, commercial, leisure, ...)	PW
Parking facilities in the era of self-driving cars	PW
Social network analysis in stakeholder management	QH
Public participation in (re)development projects	QH
Integrating microscopic traffic (including pedestrian and cyclists) simulation, urban land use, facility management, and environment models for smart cities development	DY
Business model for urban living labs - Strijp-S case	RO
Online participatory mapping for walking/cycling infrastructure	GD
Linked Data and the semantic web technology applications in the intelligent transportation system	DY
New opportunities in urban transformation: Nature-based solution, Circular economy, Low carbon, Gas free, Energy Neutral, etc.	BV, QH

Theme: Building Information Management

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

Topic	Supervisor
ICT and use of the built environment	AB, BV
3D City modeling and Geographic Information Systems for Urban Digital Twinning	BV, GD
Linked data in Architecture and Construction	PP, EP
Artificial Intelligence (AI) and Building Information Modelling (BIM)	PP, EP
Data mining and BIM-based design	PP
Building Information Modeling (BIM) and Systems Engineering (SE)	BV
Building Information Modeling (BIM) and City modeling (CityGML)	BV, PP
Integration of sensor and actuator networks into Building Information Models	PP, RO
Building Information Modeling for interoperability	EP, PP

Retrieving building information from semantic networks	EP, PP
Identifying promising locations/buildings for transformation using GIS	PW
Collaboration in BIM: barriers, drivers, enablers, and application of Game theory model	QH, RO
Supporting Circular Economy with BIM	BV,QH
Open data platforms for smart city development	BV
Creativity in virtual project teams when using BIM tools	RO
Artificial Intelligence, sensor data and digital Construction	DY, BV, EP
Improving future transportation and infrastructure through linked urban data	DY
BIM-based LCA, LCC, Circularity optimization	QH, BV
The use of BIM data and on-site collected data in construction site progress monitoring	PP
Cobots for industrialised construction	PP
Digital Building Twins for construction sites and existing buildings	EP, PP
Robotisation and automation of construction sites and existing buildings	EP, PP
Digital building twins for Indoor Environment Quality (IEQ) optimization	DY
Digital building twins for asset management	DY
Spatial decision making with integration of GIS and IoT	GD

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 pages)
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, other data sources

3. Research approach (2~3 pages)
This section describes the broad philosophical underpinning to your chosen research methods. Since you did not yet actually undertake 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 pages)

5. Ethics and Data managment (0.5~1 pages)

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 final report for student that 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 left and right side. Set the line spacing to single and 0 point 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 use 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) of the graduation project
  - Surname student + initials + idnr.
  - Names of all members of the thesis committee
  - Study load (# of ECTS) of the graduation project
  - Academic year of graduation
  - Date of final presentation
  - Name (daily/first) supervisor
  - Name of Master's program
  - An indication on 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 in accordance with 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 odd page number (such as 1, 3, 5) and end with 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 to for instance Excel when using tables. Don't use company logo's; 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 is 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 and hard copy format to each of your graduation committee members.
Check the chapters 'Final colloquium' and 'Documents and forms to be submitted at the CME sceretariat' for the instructions where, how and when to opload 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, 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 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, presents the main findings and conclusions. The readers shouldn't have to read whole report to get essential points. The abstract is also copied into the on-line CME graduation report database provided by Of CoUrsE!

Keywords (max. 5, no abbreviation)
List keywords that help finding your graduation report through search engines.

List of Abbreviations/Glossary
A summary of the important definitions, notion, 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 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-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') This article is freely

accessible through: https://scholarworks.umass.edu/pare/vol14/iss1/13/. 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. 20.000 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 for the suitable methodology to use in your graduation project, and the best way to report it. Dependent 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 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

3.1. Introduction
3.2. Method (research approach /development/design, etc.)
3.3. Data collection (and analysis, simulation)
3.4. Results
3.5. Discussion

4. 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.

4.1. 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.?
4.2. Societal relevance
4.3. Recommendation (for possible follow-up research)

References

Check online for APA style guides: http://www.apastyle.org/

Appendices (not limited # words)

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

- Be aware this is the general guideline. The order is flexible in that 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, 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 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 with reference to 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 study, in-depth interview, field observation, document analysis in product/model design and development; while applying think-aloud protocols, survey and expert interview 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 the 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 refinements that you made as your work progressed and the motivation of 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. Dependent 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 observation, 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.

Dependent 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 to learn 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.

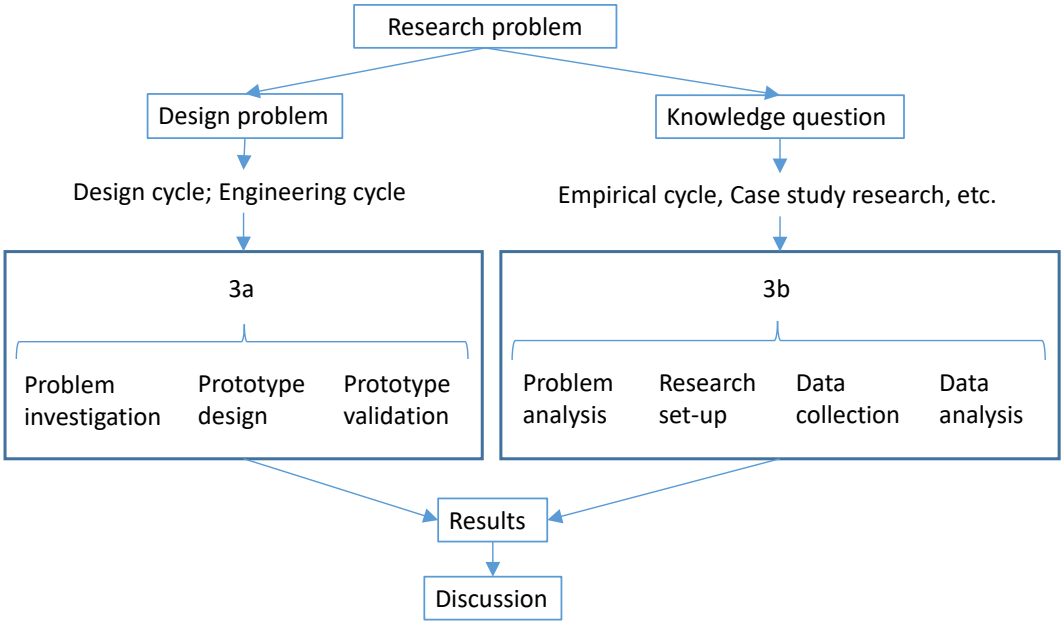
Reflective research cycle
The reflective Cycle encourages people to think systematically about the experiences they had during a specific situation, event, or activity that developed by Gibbs. It offers a framework for learning through (personal) reflection to make sense of an experience – learning by 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 an iterative process and often includes steps: Plan to identify research question; Design case studies; Prepare to collect case study evidence; Collect case study evidence, Analyze case study evidence; Report and reflecting.

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. Definition of 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 case, 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 and gives additional detail with regards 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 case of software development, for example, you refer to the programming languages and modules you will use, and most importantly, why; in 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 a 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 can not be obtained by any "regular" IT consultancy company. The prototype needs to add value and contribute with novelty. This needs to be checked in this final part of prototype evaluation.

Therefore, a clear evaluation mechanism needs to be selected and documented, including why you choose such 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 meets 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. Dependent 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 making generalizations. Qualitative researches are often more flexible, allowing you to explore ideas, concepts, and experiences in-depth, which are 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 conduct the 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 you used (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 represents 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 theory predicts large (or statistically significant) ones. Do not hide uncomfortable results by omission. Be sparing in the use of tables and figures, 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 includes: the explanation for results, comments on unexpected results and offering a hypothesis for them, 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 literature by considering questions: Does your research confirm previous studies? 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 used methods, and address alternative explanations of the results.

End the Discussion section with a reasoned 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')

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-programme 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 Master's thesis committee (the student is not present at this meeting). The assessment is performed by the university members of the Master's thesis 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:

With respect to content: quality of research or design[1] (product)
Working and 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 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-programmes.

After determination of the final grade, the Master's thesis 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 chairman of the graduation committee and returned to the Examination Committee -BE. The CME secretariat will arrange the submission.

[1] This aspect has to score sufficient or more to lead to and sufficient overall score

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 • Extent to which the student independently introduces new concepts • Contribution to new knowlegde / 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 substantiate 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 and reasons for alterations (keeping up with a work planning, follow up on appointments made) • The extend 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, to draw conclusions from the results and to 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
Time needed to finish the MSc thesis project	• Duration of the process. The process start 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 • Lay out, 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 in subject matter and in 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 for assessment.

6: Sufficient / meets the requirements

With respect to content, the research was conducted sufficiently. The report is mediocre. Weak points can clearly be pointed out, but are compensated 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 for assessment.

7: Amply sufficient / good

With respect to content, a solid piece of research was delivered. The report is carefully edited. Either the research process or the mastery of 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 for assessment and 'good' on some aspects.

8: Good mainstream / contains new elements

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

9: Very good / excellent

The research is innovative and can be converted to an article for a renowned (scientific) magazine without putting in too much effort. With respect to 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 features good writing skills. The student's own input and independence are large. The student clearly stands above subject matter and is able to defend his or her statements in discussions well. The student scores at least 'good' on all aspects for assessment and 'very good' or 'excellent' on some aspects.

10: Excellent

The research is innovative and can be converted to 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 disposes of excellent communication skills (written and oral). The student scores on average 'excellent' on all aspects for 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 Master's 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 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 independent, incorporate feedback and cooperate with others.	Limited communication skills. To some extend skilled in working independently, incorporating feedback and / or cooperating.	Adequate in cooperating, incorporating feedback and / or cooperating. Can work independent.	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 enthusiast.	Professional attitude. Active attitude during meetings.	Strives for personal development. Very committed, enthusiast 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 clearly and takes much care of details. Good answers on questions and discussions. Gives much insight in the subject matter. Very good presentation.	Profound presentation with eye openers. A lot 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
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;
Gamze Dane	Spatial Behavioral Analyses	X		International Journal of Sustainable Transportation; Transportation Research Part A: Research and Practice; Environmental Sciences	Research and development project; Process modeling and information management
Qi Han	Sustainable urban (re) development	X	X	Energy Policy, Environment and Planning B; Journal of Urban Planning and Development; Land use policy; Sustainability; International journal of project management.	Case study process modeling; Process modeling and information management; Research and development project
Bauke de Vries	Systems Engineering	X	X	Automation in Construction; Advanced Engineering Informatics; Computers Environment and Urban Systems; International Journal of E-Planning Research	Systems Engineering; Collaborative Design;
Duyuan Yang	Energy behavior modeling	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;