Aalto University
School of Science

Instructions for writing a bachelor's thesis

Systems Analysis Laboratory
Department of Mathematics and Systems Analysis

Systems Analysis Laboratory

Contents of the lecture

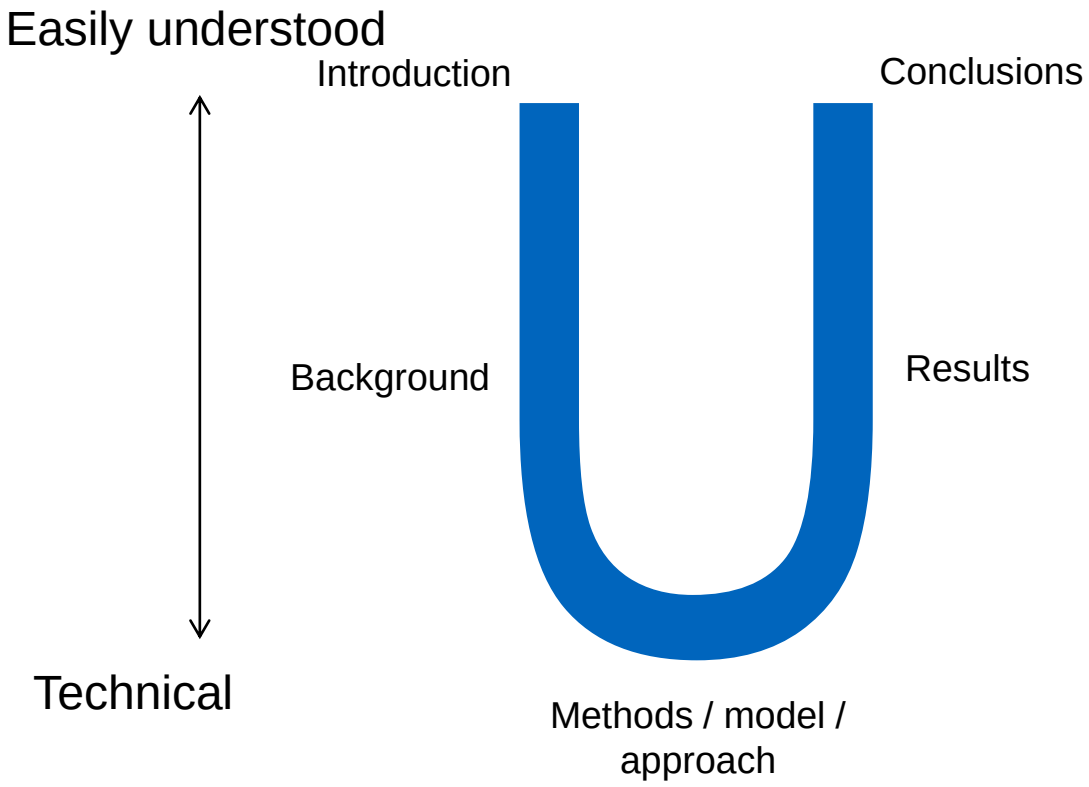
- Bachelor's thesis structure
- Principles of good scientific writing
- General guidelines

Bachelor's thesis structure

- The theses can vary in their objectives and contents
  - Literature review
  - Development of a mathematical model
  - Development and documentation of a software
  - Collecting and analyzing empirical data (eg. interviews, conducting an online survey, editing time series)
- Different theses can also have partially different structures
- This lecture adresses the general principles

Bachelor's thesis structure

- Cover page
- **Abstract**
- Table of contents
- **Introduction**
- **Background**
- **Methods / model / approach**
- **Results**
- **Conclusions**
- References
- Appendices



Bachelor's thesis structure

- **Abstract:**
  - Provides a short description, summarising the goals, research methods and core results of the work
  - Provides a clear overview that can also be understood by a reader not familiar with the field
  - Is an independent text that does not contain references to other work
  - You should not write anything in the abstract that does not appear in the actual text section of the work
  - There is no indentation in the beginning of paragraphs – the division is indicated by leaving an empty row between paragraphs

Bachelor's thesis structure

- **Introduction:**
  - Paragraph 1: Motivation and background. Why was the topic of the thesis chosen? What phenomena is it connected to?
  - Paragraph 2: Why is the topic challenging? How have these challenges been answered by previous research? What gaps remain in the literature?
  - Paragraph 3: What is done in the thesis? How does the work contribute to the collective scientific knowledge?
  - Paragraph 4: Structure of the work, i.e. a brief description of the contents of each section (not mandatory).
  - Introduction is easy to understand – keep the technical vocabulary to a minimum

Bachelor's thesis structure

- **Background:**
  - Describes, what has been previously published on the topic
  - Format: "People X studied Y and concluded that Z"
  - The contributions of the thesis work can be compared to the literature, but that should not be the main focus of the chapter
  - Technical vocabulary may be used, but no formulas or other mathematical notation
  - Note: Sometimes this chapter is combined with the introduction by extending the paragraph 2

Bachelor's thesis structure

- **Methods / Model / Approach**
  - The methodoly / model is presented exhaustively and mathematically rigorously
  - Help the reader
    - By proceeding in a logical order
    - By providing examples
    - By defining all the symbols and notation as they are used for the first time
  - Explain why you have chosen this exact model / method / approach / problem formulation / distribution / etc.
  - This is the technical part of the bachelor's thesis

Bachelor's thesis structure

- **Results**
  - The research material used to get the results must be described
    - Simulation: What parameters (and other assumptions) were used and why?
    - Empirical data: How did you collect the material?
  - The results can be illustrated using pictures and tables
  - The results should also be interpreted when they are presented: What implications do theyhave for the studied phenomenom? Are they sensible? Are they statistically significant?
  - Sensitivity assessments – how do the modeling assumptions / parameter choices affect the results?
  - The results should be understandable without delving too deeply into the methods chapter – avoid being overly technical.

Bachelor's thesis structure

- **Conclusions**
  - What did you do in this work?
  - What are the most important results?
  - What conclusions can you draw about the studied phenomenon based on your results?
  - How do the assumptions and/or data limit the applicability of your conclusions?
  - What questions were left unanswered – what should be studied in the future?
  - Keep the conclusions easy to understand

Contents of the lecture

- Bachelor's thesis structure
- Principles of good scientific writing
- General guidelines

Principles of good scientific writing

- Provides facts, not experiences
  - Do not draw conclusions without sound a basis

Laajaan kansainväliseen aineistoon perustuen Flyvbjerg et al. (2002) osoittavat, että julkisten infrastruktuurihankkeiden toteutuneet kustannukset ovat merkittävästi arvioituja suuremmat.

Kokemukseni mukaan projekti kestää aina noin 50% kauemmin ja maksaa aina noin 33% enemmän kuin alun perin arvioitiin.

- Do not use colloquial expressions

Laskennan kannalta haasteellisimmaksi osoittautui vikaantumiskombinaatioiden suuri lukumäärä. Sen nopeuttamiseksi tarkastelu rajattiin vikaantumis-kombinaatioihin, joiden todennäköisyys oli vähintään 0.1%.

Laskennassa meni aivan tuhottomasti aikaa, ja sekös meikäläistä kismitti.

Principles of good scientific writing

- The text is unambigious
  - Minimize the possibility of misunderstanings

Työssä kehitetyllä optimointimallilla voidaan muodostaa kokonaiskestoltaan lyhin tuotantosuunnitelma, joka ottaa suunnitelmaa koskevat aikataulu- ja resurssirajoitukset huomioon.

Tässä työssä kehitettiin optimointimalli, jonka avulla voidaan muodostaa kokonaiskeston minimoiva tuotantosuunnitelma, joka huomioi siihen liittyvät aikataulu- ja resurssirajoitukset.

  - Use terms consistently; however, avoid unnecessary repetition

Vaihtoehtoja arvioitiin edellä kuvattujen attribuuttien suhteen siten, että attribuuttikohtaiset arvot oli skaalattu välille [0,1]. Attribuuttipainot määritettiin SMARTS-menetelmää käyttäen (Edwards & Barron, 1994). SMARTS-menetelmässä…

Vaihtoehtoja arvioitiin edellä kuvattujen attribuuttien suhteen siten, että kunkin osatavoitteen arvot oli skaalattu välille [0,1]. Kriteeripainot määritettiin SMARTS-menetelmää käyttäen (Edwards & Barron, 1994).

  - Define the terms you use as soon as they appear for the first time

Principles of good scientific writing

- The author stays away from the spotlight
  - Do not use the word I/me

Työssä kehitetyllä optimointimallilla voidaan muodostaa kokonaiskestoltaan lyhin tuotantosuunnitelma, joka ottaa suunnitelmaa koskevat aikataulu- ja resurssirajoitukset huomioon. Simulointitestien perusteella optimaalisen suunnitelman laskenta-aika pysyy kohtuullisena, kun…

Tässä työssä kehitin optimointimallin, jonka avulla voin muodostaa tuotannon kokonaiskeston minimoivan tuotantosuunnitelman siten, että huomioin suunnitelmaan liittyvät aikataulu- ja resurssirajoitukset. Mielestäni malli toimii hyvin, ja lisäksi sen rakentaminen oli minulle varsin opettavainen kokemus.

Principles of good scientific writing

- Scope the research topic appropriately (not too broad or narrow)
  - Agree on these very early on with your instructor and supervisor
- The structure and the content are clear
- The text does not contradict itself
- The whole work is easy to read
  - The reader does not have to read everything to understand key results
- The use of language is impeccable

Contents of the lecture

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General guidelines: figures

- All figures should be numbered and include a caption (usually below the picture)
- All figures should be referenced in the text

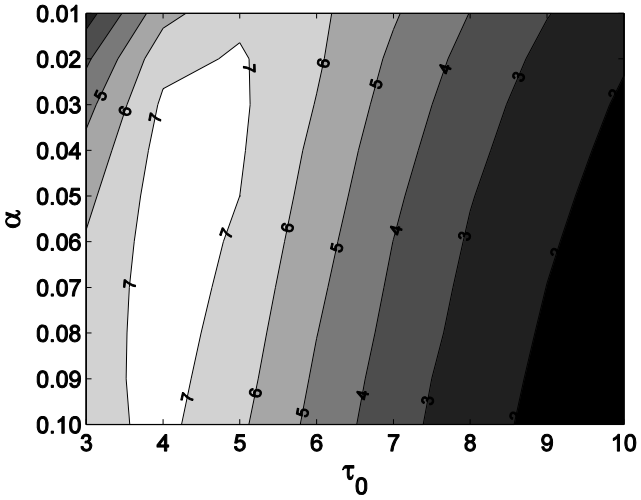


Figure 1 The value of the option as a function of standard deviation of the estimate error τ_0 and the threshold value α.

In Figure 1 the contour lines of the value of the option have been presented as a function of the standard deviation τ_0 and threshold value α. The figure shows that…

General guidelines: tables

- All tables should be numbered and include a table text (usually above the table, sometimes below – pick one and be consistent)
- All tables should be referenced in the text
- If there is a need to include large raw data tables, they should be attachments

Table 1 The benefits and costs of projects A through J. The chosen projects have been marked in green.

Project	Benefit	Cost
A	9	6
B	7.5	2
C	8.5	5
D	9	2
E	10	6
F	10	3
G	8.5	2
H	7	2
I	7	4
J	7.5	3

General guidelines: equations

- Equations are numbered if they are referred to.
- Symbols appearing in the equations are explained in connection with the formula (or sometimes even before the formula)

The value $V(x_j)$ of the option x_j can be calculated as weighted sum of its attribute values v_{ji}

$$V(x_j) = \sum_{i=1}^{n} w_i v_{ji}, \qquad (1)$$

where w_i is the weight of attribute i. Based on equation (1) we see that…

General guidelines: references

- Literature sources are preferably referred to by name and year
  - Numeric references can also be used, but they make the text more difficult to read
- If there are more than two authors, use the structure “et al.”
- All sources listed in the references must also be referenced in the text
- All sources must be listed in the references
- All references must be in the same format

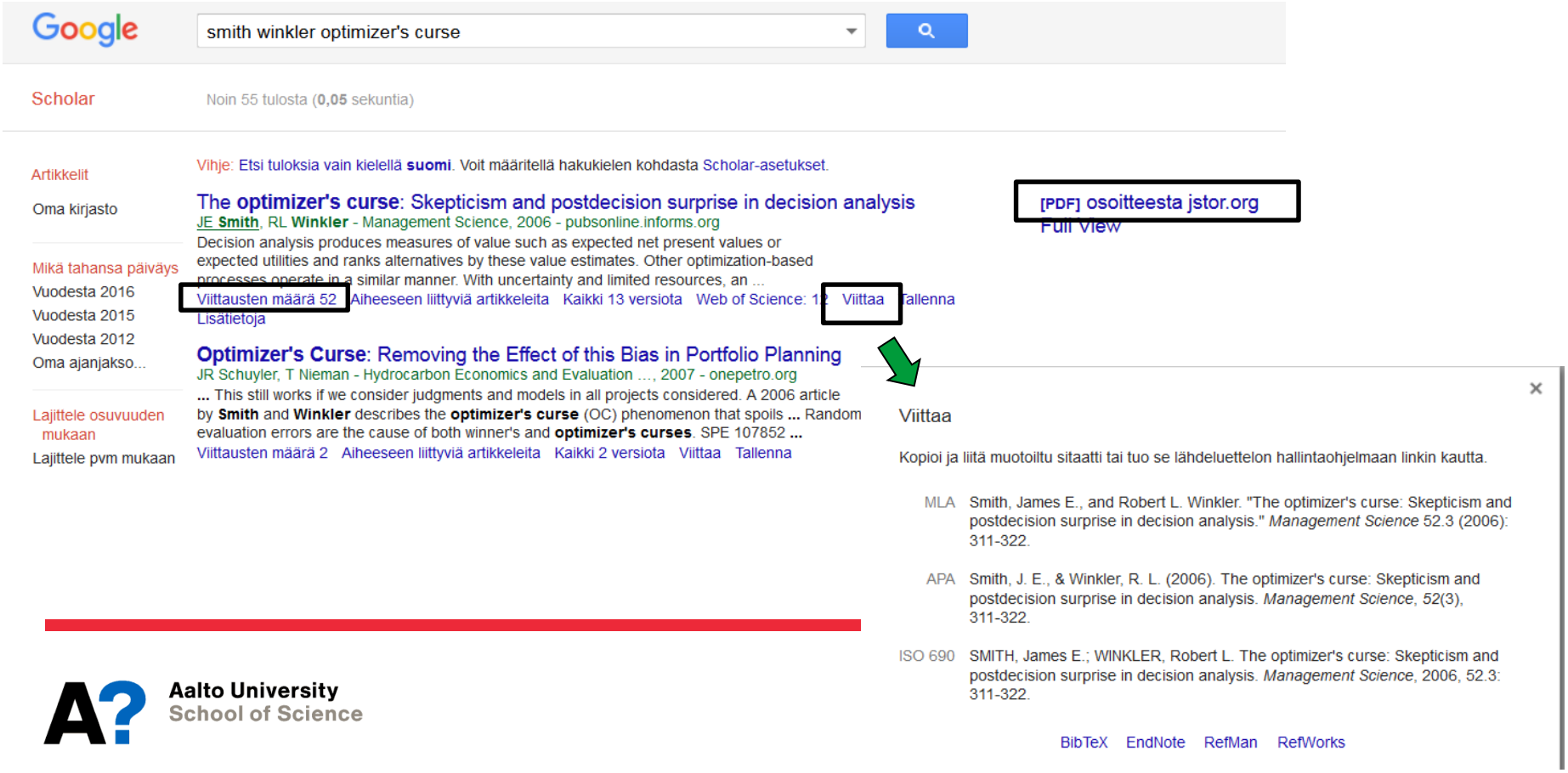
Based on extensive international data, Flyvbjerg et al. (2002) show that the actual costs of public infrastructure projects are significantly higher than estimated. The underestimated costs can be partly explained by the so-called *optimizer's curse* (Smith & Winkler, 2006), meaning…

Flyvbjerg, B., M.Skamris Holm., S. Buhl. 2002. Underestimating costs in public works projects – error or lie? *Journal of the American Planning Association* **68** 279-295

Smith, J. and Winkler, R. (2006) The Optimizer's Curse: Skepticism and Postdecision Surprise in Decision Analysis, Management Science, Vol. 52:3, pp. 311-322.

General guidelines: references

- One useful tool for finding source literature is Google Scholar (scholar.google.fi)



General guidelines: appendices

- Mathematical proofs are included as appendices
  - When the theorem is presented, it is stated that the proof can be found in appendix XX
- Appendices are numbered (Appendix 1, Appendix 2…) or are referred to by capital letters (Appendix A, Appendix B…)
- Software code is included as an appendix, if its development has been an integral part of the work

General guidelines: archiving the thesis

- The completed thesis is sent to the seminar organizer in pdf format
- The thesis will be added to the SAL website if you include the following text to the cover page:

> *”Työn saa tallentaa ja julkistaa Aalto-yliopiston avoimilla verkkosivuilla. Muilta osin kaikki oikeudet pidätetään."*
> *"The document can be stored and made available to the public on the open internet pages of Aalto University. All other rights are reserved.”*

- When the thesis is published online, you can link to it, for example, in a job application
  - You still retain all the immaterial rights to your work
- The work must also be filed with the Aalto University eAge system
  http://sal.aalto.fi/files/opinnot/kurssit/mat-2.kandi/eage-ohjeet.pdf

Good practices

- Do not ever or under any circumstances copy someone else's work!
  - Text can be cited, but the original source must be referenced
  - If you cite a text word-for-word beyond a few words, put the citation as a quote.
  - Also, pictures and tables are usually copyrighted: draw / make your own and add the reference to the original.

Good practices

- Be critical of you sources
  - You should be primarily referring only to peer-reviewed articles and books
  - Master's theses and other theses can be referred to, but they should not be your only source
  - There should be no references to lecture slides
  - Do not just refer to the articles written by your instructor and supervisor - explore the literature more widely, especially the most referenced articles

Writing guides

- Kauranen, I., M. Mustakallio & V. Palmgren: Tutkimusraportin kirjoittamisen opas opinnäytetyön tekijöille
  https://aaltodoc.aalto.fi/handle/123456789/12621

- Aaronson, S: Style in Scientific Writing
  http://www.garfield.library.upenn.edu/essays/v3p004y1977-78.pdf

- Brown, G.G: How to Write About Operations Research
  https://faculty.nps.edu/gbrown/docs/Brown-%20howtowriteaboutor3.pdf

- American Scientist: The Science of Scientific Writing
  https://www.americanscientist.org/blog/the-long-view/the-science-of-scientific-writing