

VILNIUS UNIVERSITY
FACULTY OF MATHEMATICS AND INFORMATICS
INSTITUTE OF MATHEMATICS

Guidelines for Writing Bachelor's and Master's Thesis

for students of the
Financial and Actuarial Mathematics programme

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1 Introduction

Writing a Bachelor's or Master's thesis is an important part of the study process, allowing for the evaluation students' acquired theoretical and practical knowledge and competencies to apply them in a concrete situation. One can also evaluate critical and analytical thinking, creativity, ability to collect and process information, understand and use the newest scientific knowledge.

These guidelines are prepared for the students of the Financial and Actuarial Mathematics programme, to facilitate writing Bachelor's or Master's thesis. In Section 2 we describe the guidelines for the presentation of the work, and they apply universally. Other sections present recommendations for all written works (including term papers), according to their specifications. You should consult your thesis or term paper supervisor if certain deviations from these recommendations are needed. Unless specified otherwise, the guidelines below should be adhered to.

2 Presentation guidelines

2.1 General remarks

Before writing his or her Bachelor's or Master's Thesis, a student should read the "Regulations for the Preparation, Defence and Storage of Research Papers of Students Studying at Vilnius University" [4] and "The Description of the Procedure for the Administration of Research Papers in Vilnius University Study Information System" [5]. Microsoft Office, OpenOffice, Latex or other software of student's choice can be used to write the thesis. By the set date, the pdf file of thesis is to be submitted into the Vilnius University Study Information System (<https://is.vu.lt/>) and, in case it is requested, to the Virtual Learning Environment (Moodle) (<https://emokymai.vu.lt/>). Students are informed about the deadline for thesis uploading in advance. The preparation for Bachelor's and Master's Thesis begins with the choice of a thesis topic and thesis supervisor. If, during process of writing, serious problems arise, then the topic may be revised and/or changed upon approval of the thesis supervisor and the chair of the study programme committee. Two weeks before the thesis submission deadline, its title in Lithuanian and English must be sent upon request to the Studies Office of the Faculty of Mathematics and Informatics by e-mail.

2.2 Thesis length

There are no formal requirements regarding the length of a thesis. Common sense should prevail, so the subject matter is much more important than the precise number of pages. For example, it is highly unlikely that a proper introduction revealing the importance of the chosen topic or considered problem and previous research, analysis of the data used, proposed mathematical or statistical model, interpretation of the results, conclusions, and the list of references can be squeezed into 11 pages (title page included).

On the other hand, an extra-long thesis usually raises some doubts about student's ability to distinguish between important and not so important facts. We expect a thesis to be concise and to the point. A thesis can be very short if a student presents an already published or accepted by some journal scientific paper. However, such presentations are not encouraged. Usually, scientific papers contain somewhat shortened versions of the proofs with many of intermediate steps omitted. In a thesis every step in the proofs must be made explicit and properly justified.

2.3 Guidelines for text typesetting

The page format should be A4. The text should be without unnecessary spacing between paragraphs or other objects of the text. Recommended spacing throughout the text is either 1 or 1.5 lines. If a table or a graph is inserted into a paragraph, it should be removed from the text in the same way as a new paragraph. Start with 0.57 cm indent: The space between the paragraphs shall be the same as that between the rows. It is also possible, though not recommended, to use an extra space between paragraphs instead of an indent, just like presented below. The text must not protrude into margins. Recommended margins are as follows: 2 cm at the top, 2 cm at the bottom, 3 cm on the left, and 1.5 cm on the right. If the thesis or other written work is typeset using L^AT_EX, then the commands `\textwidth 6.5in` or `\textheight 9.00in` can be used. The pages are numbered at the bottom right or middle. The most commonly used fonts can normally be subdivided into having variable or constant width, as well as *serif* and *sans serif*:

1. *Serif*-type font (variable width): A random variable is a measurable function.
2. *Sans serif*-type font (variable width): A random variable is a random function.
3. Continuous-width font: A random variable is a measurable function.

Variable-width *serif* fonts are used for the main text. The *sans serif* fonts are generally used for headings and for the computer program texts of constant width. **Bold** text or text in *italics* are reserved for highlighting or singling out something important. Both options should not be used too often. It is not advisable to use underlined text or text highlighted in another color. If the thesis is written using Microsoft Office or Open Office software, the following text settings for Times New Roman are used for parts of the work:

1. The title – 14pt, **bold**;
2. Basic text – 12pt, normal font style;
3. Appendices – 12pt, normal font style;
4. Reference list – 12pt.

Courier New 10pt font size shall be used for typesetting computer programs. For the text written in L^AT_EX, standard fonts are used. Recommended font size is 11pt or 12pt. For typesetting computer programs, the following command is used: `\verb` or `\begin{verbatim} ... \end{verbatim}`. In addition, computer programs must be typeset using a smaller font size than the rest of the thesis, so the commands `\begin{small}` and `\end{small}` are employed.

Overall, the thesis should be written in polished English, sentences should be clear to those who read them.

2.4 Guidelines for typesetting mathematics

The fonts used for mathematical text must differ from the remaining text but be of the same size, such as $F(x) = P(X < x)$. Please, note that functions are not written in italics, e.g., \max (written as `\max` in L^AT_EX) should be used instead of *max*. In some cases, L^AT_EX does not have predefined functions, these should be defined manually. For example, symbol d rather than *d* should denote the differential. This can be achieved by introducing a macro `\newcommand{\dd}{\, \mathrm{d}}`. Similarly, e should be used instead of *e* to denote exponential function. An extended formula or mathematical expressions should be typeset as separate rows:

$$\mathbb{E}X = \int_{\Omega} X(\omega)\mathbb{P}(d\omega) = \int_{\mathbb{R}} x dF(x).$$

Do not forget to end the formula with a dot, if the sentence is not continued. If the formula is followed by the related text, no new paragraph is needed and no indent is used. For example,

The mean of a random variable is computed as follows:

$$\mathbb{E}X = \int_{\Omega} X(\omega)\mathbb{P}(d\omega) = \int_{\mathbb{R}} x dF(x),$$

where $F(x)$ is the distribution function of the random variable X .

Note that for the explanation of the symbols or other quantities, the formula is followed by a comma and “where”; one could also end the formula with a period and start the new sentence with “Here” as in

$$\begin{aligned} \mathbb{E}X + 7 &= \int_{\Omega} X(\omega)\mathbb{P}(d\omega) + 7 \\ &= \int_{\mathbb{R}} x dF(x) + 7. \end{aligned}$$

Here $\mathbb{E}X$ denotes the mean of the random variable X . For example,

In case the formula ends a paragraph, the following one starts with an indent, for example:

The mean of a random variable is computed as follows:

$$\mathbb{E}X = \int_{\Omega} X(\omega)\mathbb{P}(d\omega) = \int_{\mathbb{R}} x dF(x).$$

We will apply the above formula to compute the mean of a normal random variable $X \sim N(1, 5)$.

The following rules apply for breaking mathematical expressions into separate lines: (a) each new line begins with the equality (or inequality) sign, rather than previous one ends with it; (b) all signs ($=, >, <$, etc.) for new lines are in the same column at equal spaces from the left margin; and (c) for other mathematical symbols ($+, -, \times, \div$), the new line begins slightly further from the left margin, e.g.,

$$\begin{aligned} T_{\alpha,n}(\varepsilon_1, \dots, \varepsilon_n) &= \max_{1 \leq \ell \leq n-1} \ell^{-\alpha} \max_{1 \leq k \leq n-\ell} \left| \sum_{j=k+1}^{k+\ell} \tilde{\varepsilon}_j - \frac{\ell}{n} \sum_{j=1}^n \tilde{\varepsilon}_j \right| \\ &= \max_{1 \leq \ell \leq n-1} \ell^{-\alpha} \max_{1 \leq k \leq n-\ell} \left| \sum_{j=k+1}^{k+\ell} (\tilde{\varepsilon}_j + a_j) - \frac{\ell}{n} \sum_{j=1}^n (\tilde{\varepsilon}_j + a_j) \right| \\ &\geq \max_{1 \leq \ell \leq n-1} \ell^{-\alpha} \max_{1 \leq k \leq n-\ell} \left| \sum_{j=k+1}^{k+\ell} a_j - \frac{\ell}{n} \sum_{j=1}^n a_j \right| \\ &\quad - \max_{1 \leq \ell \leq n-1} \ell^{-\alpha} \max_{1 \leq k \leq n-\ell} \left| \sum_{j=k+1}^{k+\ell} \tilde{\varepsilon}_j - \frac{\ell}{n} \sum_{j=1}^n \tilde{\varepsilon}_j \right|. \end{aligned}$$

If brackets (parentheses, square brackets or curly braces) are used in the formula, they must be of an appropriate size (outer larger than inner), for example,

$$\mathbb{E} \left(\sum_{i=1}^n (X_i - Y_i)^2 \right)^2,$$

as opposed to

$$\mathbb{E} \left(\sum_{i=1}^n (X_i - Y_i)^2 \right)^2.$$

Mathematical text strictly prohibits the use of computer characters, i.e., X^2Y^2 cannot be written as X^2*Y^2 . Formulas can be numbered, but only if they are referred to further in the text. For example,

$$\mathbb{E}r_t^2 = \mathbb{E}\sigma_t^2 \tag{1}$$

and

$$X_t = \log \sigma_t^2, \tag{2}$$

as well as

$$X_t \sim N(0, \sigma_\nu^2), \tag{3}$$

so from (1), (2) and (3) we obtain

$$\begin{aligned} \mathbb{E}r_t^2 = \mathbb{E}e^{X_t} &= \frac{1}{\sqrt{2\pi\sigma_\nu}} \int_{-\infty}^{\infty} e^x e^{-\frac{x^2}{2\sigma_\nu^2}} dx \\ &= \frac{1}{\sqrt{2\pi\sigma_\nu}} \int_{-\infty}^{\infty} \exp \left(-\frac{x^2 - 2\sigma_\nu^2 x}{2\sigma_\nu^2} \right) dx. \end{aligned} \tag{4}$$

Please, do not forget that formulas are part of sentences, so the usual punctuation rules apply.

2.5 Guidelines for graphs and tables

All included graphs must be of good quality, i.e., they must be clearly visible and distinguishable. Graph fonts should be of a similar size to the main body of the text. For citation purposes, graphs shall be marked with headers and numbers written in bold fonts of 10pt size. It is advisable to use black-and-white graphs (especially for printed copies of the thesis) and different types of lines. The proper form for a graph title is “variable of the y -axis vs variable of the x -axis.” For example, “beginning salary vs previous experience.” Some abbreviations are allowed, but in all cases the title of the graph and labels of axes must be understandable to the readers. For example, Figure 1 presents a plot of the independence copula $\Pi(x, y) = xy$, $x, y \in [0, 1]$.

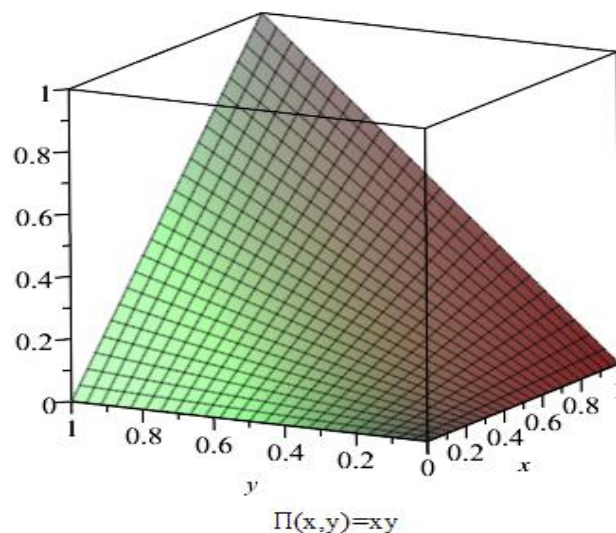


Figure 1: A plot of the independence copula.

For more about plots and \LaTeX , see, e.g., [3].

A table covering less than half of a page is placed in the text. Like graphics, tables are marked with headers and numbers written in bold fonts of 10pt size. Both tables and graphs should not exceed the width of the text on a page. Separate pages and, if needed, landscape orientation are used for larger tables. As a rule, large tables are placed in the appendices, and only references to them are included in the main body of the text. If the thesis contains multiple tables and graphs, then it is advisable to add the list of tables and figures.

Here’s an example of a table:

Table 1 shows the coefficients of the fitted model as well as their standard errors.

In Appendix A.5 you will find example tables and commands used to typeset graphs; for more examples, see, e.g., <https://web.iit.edu/gaa/latex-downloads> (Illinois Institute of Technology help website).

	Intercept	x
Coefficient	0.250452	0.744828
Standard Error	(0.195542)	(0.003312)

Table 1: Model coefficients and their standard errors.

2.6 Guidelines for the table of contents

Recommended example of the thesis table of contents:

1. ABSTRACT.....	3
2. Notation and abbreviations (if any).....	x
3. INTRODUCTION.....	x
4. TITLE OF SECTION.....	x
1.1 Title of subsection.....	x
1.1.1 Title of subsubsection.....	x
1.1.2 Title of subsubsection.....	x
1.1.3 Title of subsubsection.....	x
1.2 Title of subsection.....	x
1.2.1 Title of subsubsection.....	x
1.2.2 Title of subsubsection.....	x
5. TITLE OF SECTION.....	x
2.1 Title of subsection.....	x
2.1.1 Title of subsubsection.....	x
2.1.2 Title of subsubsection.....	x
2.2 Title of subsection.....	x
6. CONCLUSIONS.....	x
7. REFERENCES.....	x
APPENDICES A,B, etc. (if any).....	x

The table of contents contains the title of the paper, titles of parts, chapters, and sections with references to page numbers, which have to be in Arabic numbers. The numbers of parts, chapters and sections are separated from each other by points, e.g., 2.1. The abstract, introduction, conclusions, and the list of references may or may not be numbered. The appendices are numbered separately. If several abbreviations are used, they should be included in a separate list of abbreviations. A separate list is used for mathematical notation used in the text. Such lists, including the lists of tables and graphs, are not numbered.

2.6.1 Cover page

The cover page includes:

- the name of university;
- the name of faculty;
- the study programme;
- work title;
- author's name;
- supervisor's name;
- year of work completion.

An example of a cover page is given in Appendix A.1, while Appendix A.2 gives the \LaTeX source code the cover page.

2.6.2 Abstract

When writing an abstract, students should bear in mind that the reader tries to grasp the main idea of the thesis first. Therefore, the abstract should succinctly describe the essence of research (objective of the work, considered problems, novelty, methodology, scope and stages of the work, results and expected areas of use) in at most 5–8 sentences. The abstract shall be accompanied by the list of keywords. An example abstract is given in Appendix A.3. Appendix A.4 contains the \LaTeX source code for the same example.

Never start writing any research work from an abstract! It should summarize the final version of your work.

2.6.3 Introduction

The introduction describes the topics covered in the thesis, demonstrates their relevance to prior research, provides student's motivation, and contains formulation of the objectives and the problems to be addressed. After reading the introduction, the reader should understand

- the objectives of the work;
- problems which are solved,
- prior studies that have been carried out;
- the results achieved; and
- the structure of the thesis.

2.6.4 Literature review/analysis

The literature review shall provide analytical material and support the methodology for the whole thesis. Start from the relevance of the problem. Then present comparative analysis of the known results discussing their advantages and disadvantages. Statistical and analytical methods used in the thesis must also have appropriate references. Please, note that the literature review/analysis is not an introduction.

2.6.5 Analytical part

This part describes models, systems, and technology used in the research, algorithms developed, detailed discussion of the results obtained and conclusions drawn. It is up to the student to decide how many sections should be included in the analytical part. Concise presentation void of unrelated information is expected. Student's contribution (new models, statements proved, algorithms developed, etc.) should be clearly identifiable in the text. All cited results must contain accurate references. For example,

Relation (**) was proved in [35, Eq. (3.5)].

or

This model was introduced in Yang et al. (2016).

The thesis structure should be agreed upon with the supervisor.

2.6.6 Conclusions and recommendations

Conclusions and recommendations summarize the main findings of the research, put forward recommendations for the application and further development of the obtained results. This part must be closely related to the introduction. If the problem is formulated in introduction, then here its (at least partial) solution is given. However, not mere statement of the results, but also some discussion is expected. In essence, conclusions must answer the question "So what?", i.e., they should explain the importance of the presented results. This section also contains suggestions for further research.

2.6.7 List of references

The reference list contains bibliographical descriptions of the sources used in alphabetical order.

- Each source cited in the text must be included in the reference list.
- Each item from the reference list must be cited in the text.
- References are provided in the original language, except for languages using non-Latin fonts. In that case, English translation is used and additional information about the original language is included in brackets at the end. For example, Yu. V. Prokhorov. *Selected works*, v. 1. Moscow, Torus Press, 2012, 775 pp. (Russian)

- Reference list should be arranged in alphabetical order by the (first) authors' surnames. General rules for references:
 1. A. Author, K. Author. Title of article, Title of journal, Year, Volume (number), p. page–page.
 2. B. Author. Title of article, In Title of book (package), City: Publishing house, Year, pp. page–page.
 3. C. Author. Name of book, City: Publishing house, Year, number of pages p.
 4. D. Author. Name of book (scientific publication), <https://mif.vu.lt/lt3/en/>

Examples:

1. Yang Yang; R. Leipus, J. Šiaulyš, Asymptotics for randomly weighted and stopped dependent sums, *Stochastics: An International Journal of Probability and Stochastic Processes*, 2016, 88(2), pp. 300–319.
2. T. Erhardsson. Stein's method for Poisson and compound Poisson approximation, In: *An Introduction to Stein's Method*. Lect. Notes Ser. Inst. Math. Sci. Natl. Univ. Singap. v. 4, Singapore: Singapore Univ. Press, 2005, pp. 61–113.
3. R. Kaas, M. Goovaerts, J. Dhaene, and M. Denuit. *Modern Actuarial Risk Theory: Using R*. (2nd edn.), Springer, Berlin, Heidelberg, 2008, 393 p.
4. V. Stakėnas, *Probability Theory and Mathematical Statistics (handouts)*, 2012, 178 p., <http://www.statistika.mif.vu.lt/atsisiuntimui/statistika/>

It is not allowed to use various types of bibliography styles, e.g., there should not be a full name used for one author, and only the first letter of the name for others, etc.

2.6.8 Appendices

Appendices contain source code of the computer programs, tables, diagrams, pictures, and any other material that complements the thesis. If the tables and pictures are reasonably small and there are only few of them, they must appear in the main body of the text. Proofs of propositions (if any) can be given in the text or in a separate appendix (especially if they are technically more involved). It is up to the student, after consulting with the supervisor, to decide how to proceed in this case.

2.6.9 Citations

By citing the idea, it is possible to reword it in your own words by mentioning who the author of the idea is and where it comes from. It is also possible to cite the exact phrase. In both cases, a proper reference is compulsory.

Examples of citations are given in Section 2.6.5. There is no need to cite trivial ideas, formulas, and definitions. If a mathematical idea you cite is essential to the work, it is always necessary to cite the source of its proof or prove it.

2.7 Guidelines for computer program code presentation

The code of the computer programs must contain comments indicating which program and what version of it was used to obtain thesis results. The used packages must be named, all their functions explained. If students write certain functions themselves, they have to comment what they perform. The requirements for computer code fonts are described in Section 2.3.

2.8 Thesis originality

Master's theses must contain original research. A student may not cite more than one paragraph from a referred paper in one place. Such behavior is treated as a plagiarism. Master's theses are uploaded to Vilnius University Information System, where the system will automatically search for the existence of any potential plagiarism.

Bachelor's theses could be expositions of the research on a particular problem, with the emphasis on the practical implementations of the methods, ideas, data analysis techniques, etc.

2.9 Thesis defence

Submitted thesis is defended in front of a committee. All the information about the formal procedures can be found in [4]. Please, also follow the instructions sent out by the Studies Office of the Faculty of Mathematics and Informatics.

3 Recommendations for a Bachelor's thesis

Students of the Financial and insurance mathematics Bachelor's programme have to write a thesis to complete their studies. The purpose of this work is to inspire each student think critically, be creative when solving real life problems and enhance professional competences. The final Bachelor's thesis shows if a student is capable of doing practical work in the chosen professional field.

3.1 Choosing a topic and supervisor

Topics of the Bachelor's theses and supervisor names are announced in the second half of the seventh semester (typically in November). Students must choose an supervisor and a topic.

Most Bachelor's theses are written individually, but some are prepared in pairs, which is subject to supervisor approval. A thesis topic is selected from the list compiled by the faculty and announced using Vilnius University

Student Information System. For more details, regarding topic selection, please, refer to [5].

Note that each thesis written by a pairs of students must clearly indicate which work is done by which student, so that the contribution of each student could be objectively graded.

3.2 Writing a Bachelor's thesis

Once the topic and supervisor have been selected, the student draws up his/her Bachelor's thesis outline with the help of the supervisor. Writing a Bachelor's thesis consists of several stages:

- Preparatory phase (literature review);
- Research phase;
- Validation and presentation of thesis results' phase.

During the preparatory phase, the student defines the subject of his/her research and performs a comparative analysis of the results from relevant literature. Typically, the beginning of the final (eighth) semester is devoted to achieving this goal. During the research phase, mathematical/statistical modeling and data analysis are performed. The obtained results, their feasibility and applicability are validated during the final phase of Bachelor's thesis writing. Please, keep in mind that a substantial part of time is needed to polish the presentation of the thesis.

3.3 Recommendations for the thesis structure

The topics of Bachelor's theses in the field of financial and insurance mathematics can be very diverse, ranging from problems in actuarial mathematics and practical aspects of insurance business, to problems from risk theory and finance. Therefore, it is not easy to give strict guidelines for the structure and contents of such Bachelor's theses. In what follows, we will give just a few examples and recommendations based on the current trends of writing a thesis by a typical student of our programme.

In essence, all Bachelor's thesis written in the field of financial and insurance mathematics can be divided into three categories. The first consists of mostly extensive literature reviews. Such works describe a specific problem and its solution based on typically several research papers suggested by the supervisor. One is required to give a broader perspective to the problem, describe its historical significance, steps leading to its solution, as well as provide more detailed proofs of statements. Often proofs in the papers contain phrases, e.g., "clearly,...," "...one can easily obtain ...," or even " we leave the proof to the reader." A Bachelor's thesis must not contain such phrases, they should be replaced by detailed proofs, thus demonstrating the ability of a student to grasp the subject matter and use learned methods and proof techniques. It is advisable (but not strictly required) for the authors of Bachelor's thesis to replicate the modeling procedure and obtain the same results as in the studied paper; this often requires the usage of

some kind of statistical software, e.g., R. To describe such work, one should submit computer program code, as well as obtained calculation results with appropriate analysis. Students often forget to mention the paper on which their thesis is based, or other used sources, so we stress that proper credit should be given in the thesis for all the used work of other authors.

The second group, albeit less numerous as of late, of Bachelor's theses contains the so-called research works. They contain new theoretical statements, formulas, algorithms, etc., and their proofs. As for earlier described works, a theoretical research thesis must contain the formulation of a problem and describe the history of its solution. Moreover, one has to justify the novelty of the presented statement, formula, or algorithm. Of course, such a theoretical work can be supplemented with various computations, computer programs, to illustrate the theoretical findings.

Last but not least, the third group of Bachelor's thesis comprises mostly practical works. As a basis for such a thesis, one selects some known and important practical problem in the field of financial and insurance mathematics. A thesis with a dominant practical part should contain a detailed and mathematically precise description of a problem, offer a broad relevant literature review, provide all the needed statistical tests, modeling tools (if they are needed), computer program code, as well as computation results, complemented by their analysis and conclusions.

4 Recommendations for writing a Master's thesis

Master's degree is the first scientific degree, so the students must demonstrate not only their ability to apply theory in practice, but also their contribution to science. A simple review of known results is not acceptable as a Master's thesis.

4.1 Choosing a topic and thesis supervisor

Topics of the Master's theses and supervisor names are announced in the first half of the second semester. Students must choose an supervisor and a topic. Master's thesis is written individually.

4.2 Writing a Master's thesis

Once the topic and supervisor have been selected, the student draws up his/her Master's thesis outline with the help of the supervisor. Writing a Master's thesis consists of several stages:

- Preparatory phase (literature review);
- Research phase;
- Validation and presentation of thesis results' phase.

During the preparatory phase, the student defines the subject of his/her research and performs a comparative analysis of the results from relevant

literature. Typically, the second study semester is devoted to achieving this goal. During the research phase, mathematical/statistical modeling and data analysis are performed. The obtained results, their feasibility and applicability are validated during the final phase of Master's thesis writing. Please, keep in mind that a substantial part of time is needed to polish the presentation of the thesis.

4.3 Guidelines for the thesis structure

Typically, a Master's thesis consists of three parts:

- Literature review;
- Scientific research;
- Practical application of theoretical results.

The main aspects of the literature review are discussed in Section 2.6.7. During the scientific research phase, the student first chooses the research methodology. It must clearly reflect how the main objective is to be achieved. See Section 4.4.5 for more details on the research methodology. In the second part of the research, student works with data. Monte Carlo and similar data simulation methods are also allowed. There must be a clear distinction between student's contribution and contributions of other researchers. After the research phase, the student presents obtained results, conclusions, and discussion. If a new model or method of data analysis is proposed, then its beneficial comparison with existing models or methods must be given.

4.4 What is a Master's thesis?

This section provides useful information on what scientific research is and what is required for it. The main scientific objective is the *discovery* of new knowledge. It is *written* in clear logical sequences. Researchers have to *prove* their claims. Each researcher must convince the reader that his/her research is *correct* and can be replicated. Correctness amounts to the proper use of the chosen *methodology*. All this ensures *reliability*. All the words marked in italics are explained in the following subsections.

For more tips, when writing your Master's thesis, see [2].

4.4.1 Discovering new knowledge

At the beginning, student should clearly highlight his contribution to the research, i.e., he/she must explain what is new and original in the prepared Master's thesis. The arguments of originality must be based on the author's knowledge of the current situation and historical development, which is the result of reading the relevant literature. The student must convince the reader that the work is innovative, important and correct, according to the author.

4.4.2 Writing the text

The text must be written in a reader-friendly way that it is easy to follow from the beginning to the end. Reading is facilitated by references to text and formulas, as well as to literature sources. However, essential and non-trivial information should be included in the text. If an idea is continued, it must be marked. For example, "... the properties of this estimate will be demonstrated in Section 3.4...". In order to recall the previous chapters, the words "... as defined in Chapter 2.3 ..." may be used. All chapters of the main body, if they have sections, must contain an introductory paragraph. Such introductory paragraphs will help the reader (and the author himself/herself) to follow the logical division of the chapter into sections. The introductory paragraph can include:

- (1) presentation of further sections (the titles can be named);
- (2) the reasons for the inclusion of the sections;
- (3) how these sections relate to the question/problem under consideration;
- (4) how they will contribute to achieving the research target.

It is recommended to number theorems or definitions in each section in the same list (except for Definitions), e.g., Theorem 2.1, Corollary 2.2, Lemma 2.3, etc.

4.4.3 Argumentation

While conducting research, it is necessary to prove or substantiate the case under investigation. The thesis consists of two types of reasoned argumentation: statements and selection of alternatives. This will be discussed below.

Statements. A thesis usually includes statements in some form. For example, "Lithuania's GDP growth also depends on foreign GDP growth". However, this statement must be explained in detail: there must be a definition of GDP (real, nominal), what foreign countries author has in mind, what period is covered, and so on. All this must be proved or demonstrated by data. It is not enough to believe that something is right or rely on your personal experience. The author must convince the reader. There are two ways of doing so. The most common way is the citing of relevant literature. An alternative is to base the statement on well-known facts or acceptable knowledge. This approach is quite "dangerous" for the student, as it will not necessarily be well known to the reader. If there is doubt about the statement, it should better be based on literature sources. There are also claims that are trivial and well known. In such a case, there is no need to state reasons, but the boundary between known and unknown is very narrow. If you have serious doubts, consult with your supervisor.

Choosing among alternatives. While doing research, one is often forced to select among several alternative directions to follow since one cannot pursue all the possibilities at once, or when there is simply too much to do. Alternatives may include a choice of different research methods, criteria

for comparison, etc. The student must always give reasons for any choice she/he makes. For example, after constructing several models, the best of them is selected. The performance criteria may relate to model error testing, prediction, or other model characteristics, etc.

4.4.4 Correctness

In research, it is not sufficient to know that the result is correct. The author must convince the others that this is the case. Alternative approaches to the problem should be considered, too. Note that modeling of phenomena always means a certain simplification of reality, since strict mathematical assumptions for the model (independence, normality, etc.) are made. Model reliability depends on the degree to which these assumption are met. Apart from satisfying purely formal mathematical assumptions, any model should be consistent also with the field of research it is applied to. Thus, economic models must be supported by Economics theory.

The notion of correctness is also related to that of objectivity. In science, being objective means that everything should be based on studies and experiments. In financial and insurance mathematics, human behavior plays an important role and that is naturally related to reduced objectivity. Therefore, when modeling we make assumptions which, in turn, increase objectivity. And so, in reality, one often hears that there exists “objective” truth, independent of the views of a researcher.

How can this be related to the research area? First, one should not select one particular point of view as being the right one. This point of view is often suggested by the considered problem and chosen methods. The correctness of research and its connection to objectivity are related to the goal of the overall research.

Summarizing, we can say that:

- each study should be conducted using a methodology which leads to correct results;
- different methods could produce different results;
- each method gives a different understanding of the origins of truth;
- and different understanding leads to the “real truth.”

4.4.5 Research methodology

Different approaches lead to different models and different conclusions. Thus, a particular choice of research methods must be reasoned and explained. Knowledge of research methods used by other researchers can be of great help. A possible alternative is to modify a known method. In such a case, the modifications must be clearly defined, reasoned, and commented on. It does not suffice to say that a certain approach to solve a problem is used. It is necessary also to convince the reviewer that this method is appropriate for the considered problem. Presenting results without any reliable method, literature references, motivation, and reasoning might result in a rejected thesis.

4.4.6 What is considered an unacceptable Master's thesis?

This section describes the types of theses (or parts thereof) which are not acceptable. Descriptions are accompanied by a statement of reasons why such a submitted thesis will not be accepted.

Report. (Description) A report is limited to the model, algorithm, or method applied. It does not contain context, a literature review, a clearly defined study of methodology, and author's contribution to the field of research. (Reasons for rejection) One specific case is presented, lacking any comparisons and research background.

Daily notes. (Description) This work is all about what the author has done as an individual. It has many phrases such as "I have traveled to the library..."; "I have communicated with scientists...", etc. (Reasons for rejection) Such descriptions are often wrongly considered as steps in the testing methodology. However, they are only steps taken by the author as an individual, and are not recognized as scientific methods.

Literature review. (Description) The thesis consists only of a literature review. There is no student's contribution. (Reasons for rejection) Although a literature review is a very important part of the Master's thesis, the researcher must contribute to science and create new knowledge.

5 Guidelines for presentations during defence

All research papers (term papers, final theses, practical training reports) are defended orally in front of a committee. Students must prepare a presentation for defence. The presentation can be prepared with Microsoft PowerPoint, L^AT_EX (Beamer), or any other software, but all presentation must be converted to a pdf file to avoid problems with displaying on public computers during the defence. It is recommended that all students prepare slides with L^AT_EX (Beamer class is used). A lot of information can be found online on how to create slides with Beamer. Some possible sources are listed below:

1. <http://web.mit.edu/rsi/www/pdfs/beamer-tutorial.pdf>
2. <https://warwick.ac.uk/fac/sci/physics/research/cfsa/people/pastmembers/wuensch/workshoplatex/beamertutorialkwuensch.pdf>
3. <https://ctan.mirrors.hoobly.com/macros/latex/contrib/beamer/doc/beameruserguide.pdf>
4. <https://userpages.umbc.edu/~rostitamia/beamer/>
5. <https://gist.github.com/btbytes/17c5a50c0ff0fc41321e>
6. etc.

6 Concluding remarks

We hope that all the guidelines and recommendations presented in this document will provide support for students writing term papers and final theses. However, we want to stress that every work and topic are unique, so not all the points mentioned can be applied to specific cases. It is recommended to consult with your supervisor if you have any doubts or questions

GOOD LUCK!!!

References

- [1] R. (Chandra) Chandrasekhar, *How to Write a Thesis: A Working Guide*, The University of Western Australia, 2008, https://www.student.uwa.edu.au/__data/assets/pdf_file/0007/1919239/How-to-write-a-thesis-A-working-guide.pdf
- [2] How to Structure a Dissertation, <https://www.scribbr.com/category/dissertation/>.
- [3] Illinois Institute of Technology, L^AT_EX downloads, <https://web.iit.edu/gaa/latex-downloads>
- [4] Vilnius University, *Regulations for the Preparation, Defence and Storage of Research Papers of Students Studying at Vilnius University*, <https://www.vu.lt/en/studies/academic-info-for-students/regulations>
- [5] Vilnius University, *Description of the Procedure for the Administration of Research Papers in Vilnius University Study Information System*, <https://www.vu.lt/en/studies/academic-info-for-students/regulations>

A Appendix

A.1 Example title page



**Faculty of
Mathematics
and Informatics**

VILNIUS UNIVERSITY

FACULTY OF MATHEMATICS AND INFORMATICS
(MASTER'S STUDY PROGRAMME/ BACHELOR'S STUDY PROGRAMME)
(NAME OF STUDY PROGRAMME)

Final thesis title

(Master's Thesis/ Bachelor's Thesis/ Term paper)

Author: (student's Name Surname)

VU e-mail address: (student's VU e-mail address)

Supervisor: (pedagogical title Name Surname)

Vilnius
(Year)

A.2 L^AT_EX code for the title page

```
\thispagestyle{empty}
\vskip 10pt
\begin{figure}[ht]
  \centering
  \includegraphics[width=3in]{MIF_simbolis.png}
\end{figure}

\vskip 10pt
\centerline{\bf \large VILNIUS UNIVERSITY}
\bigskip
\centerline{\large {FACULTY OF MATHEMATICS AND INFORMATICS}}
\centerline{\large (MASTER'S STUDY PROGRAMME/ BACHELOR'S STUDY PROGRAMME)}
\centerline{\large (NAME OF STUDY PROGRAMME)}

\vskip 100pt
\centerline{\bf \LARGE \textbf{Final thesis title}}
\vskip 20pt
\begin{center}
  {\bf \Large (Master's Thesis/ Bachelor's Thesis/ Term paper)}
\end{center}

\vskip 30pt

\hskip 1.5in{Author: (student's Name Surname)}\newline

\hskip 1.5in{VU e-mail address: (student's VU e-mail address)}\newline

\hskip 1.5in{Supervisor: (pedagogical title Name Surname)}

\vskip 140pt
\centerline{\large {Vilnius}}

\centerline{\large (Year)}
```

A.3 Abstract

Work title

Abstract

Abstract text

Keywords: several keywords

A.4 \LaTeX code for Abstract

```
\begin{center}{\large\textbf{Work title}}\end{center}
```

```
\begin{small}
```

```
\vspace{2\baselineskip}
```

```
\begin{center}\textbf{Abstract}\end{center}
```

```
Abstract text
```

```
\vspace{\baselineskip}
```

```
\noindent\textbf{Keywords:}
```

```
several keywords
```

```
\end{small}
```


A.5 L^AT_EX code for graphs and tables

The following is the code for an example graph drawn using R:

```
#####  
##          Plotting a graph          ##  
#####  
library(ggplot2)  
t <- seq(-3, 3, by = 0.1)  
y <- function(x) dnorm(x)  
pdf(file = "H:/requirements for final works/graph.pdf")  
qplot(t, y(t), geom = c("point", "line"),  
      main = "Density of a standard normal random variable",  
      xlab = "Index", ylab = "Density")  
dev.off()
```

L^AT_EX code to include the graph into text:

```
\begin{figure}[t]  
  \begin{center}  
    \includegraphics[width=100mm,height=80mm]{graph.pdf}  
    \caption{Density function of a standard normal random variable.}  
    \label{fig:snadt}  
  \end{center}  
\end{figure}
```

L^AT_EX code to include a table:

```
\begin{table}[h]  
  \begin{center}  
    \begin{tabular}{|c|c|c|}  
      \hline & Intercept &  $x$  \\ \hline  
      Coefficient & 0.250452 & 0.744828 \\ \hline  
      Standard Error & (0.195542) & (0.003312) \\ \hline  
    \end{tabular}  
    \caption{Model coefficients and their standard errors.}  
    \label{lent:mod}  
  \end{center}  
\end{table}
```