

# QUANTITATIVE METHODS OF ECONOMIC ANALYSIS DOCTORAL DEGREE STUDIES

Faculty of Economics, VSB-Technical University of Ostrava

**Basic Information** 

Academic year 2023/2024

Course guarantor: prof. Ing. Jana Hančlová, CSc.

Ostrava, September 2023

## I. TIMETABLE OF TEACHING IN DOCTORAL PROGRAMS

## Academic year 2023/2024, winter semester

#### **QUANTITATIVE METHODS OF ECONOMIC ANALYSIS (QMEA)**

#### 4-years study - 15709591/01

Common core course for all fields of doctoral studies, 1. year Lectures and consultations take place on Wednesdays in **room E704 from 9.00 – 12.15 am**.

Date	Subject - topic	Teaching	Teachers	
11. 10. 2023	Introduction to scientific work	09.00 - 12.15	prof. Ing. Jana Hančlová, CSc.	
18. 10. 2023	Quantitative methods and decision-making models I	09.00 - 12.15	doc. Mgr. Ing. František Zapletal. Ph.D.	
<mark>20.10. 2023</mark>	Data envelopment analysis	<u>09.00 – 12.15</u>	prof. Dr. Mehdi Toloo	
25. 10. 2023	Quantitative methods and decision making models II	09.00 - 12.15	doc. Mgr. Ing. František Zapletal. Ph.D.	
	Operations research methods I			
1. 11. 2023	Operations research methods I	09.00 - 12.15	doc. Mgr. Ing. František Zapletal, Ph.D.	
8. 11. 2023	Operations research methods II	09.00 - 12.15	prof. Ing. Jana Hančlová, CSc.	
15. 11. 2023	Statistical methods	09.00 - 12.15	doc. Ing. Václav Friedrich, Ph.D.	
22. 11. 2023	Econometrics	09.00 - 12.15	prof. Ing. Jana Hančlová, CSc.	
<del>29. 11. 2023</del>	Data envelopment analysis	<del>09.00 12.15</del>	<del>prof. Dr. Mehdi Toloo</del>	
29. 11. 2023	Advanced methods of artificial intelligence	12.30 - 13.30	prof. Ing. Dušan Marček, CSc.	
During the winter semester	Consultations	email	*all teachers	
19. 1. 2024	The first submission of the QMEA project to jana.hanclova@vsb.cz			

4. 10. 2023, 6. 12. 2023 – Dean's Board at Faculty of Economics – Wednesday

Lecturer	Department	Contact	Room
prof. Ing. Jana Hančlová, CSc.	Department of Systems Engineering	jana.hanclova@vsb.cz	E702
prof. Ing. Dušan Marček, CSc.	Department of Applied Informatics	dusan.marcek@vsb.cz	D340A
Doc. Ing. Václav Friedrich, Ph.D.	Department of Mathematical Methods in Economics	vaclav.friedrich@vsb.cz	B253A
prof. Dr. Mehdi Toloo	Department of Systems Engineering	mehdi.toloo@vsb.cz	On-line
doc. Mgr. Ing. František Zapletal, Ph.D.	Department of Systems Engineering	frantisek.zapletal@vsb.cz	D429

## **II. CONTENT AND STRUCTURE OF THE WRITTEN PROJECT**

## A. Purpose and aim of the project

The purpose of the project is to prove an ability to choose and apply selected quantitative methods to solve real-world problems. Students should be able to analyze the problem and describe it using the mathematical apparatus. When the problem is solved by suitable methods, an interpretation of the results has to be done.

The object of analysis should be related with the topic of a dissertation thesis or at least with a field of study of a student.

Problem selection as well as possibilities of application must be discussed with a supervisor and guarantee of the study field. It is recommended to choose rather closely defined topic and go to details than to specify the topic in a general way.

Condition for subject completion: written project, oral exam.

## B. Topic approval and project submission

The project must be submitted to prof. Jana Hančlová firstly by e-mail (jana.hanclova@vsb.cz) no later than January 19th, 2024. If you want to discuss any of the presented methods, contact any lecturer. The first submission is done electronically only. After the approval of the project and when all the revisions based on comments and notes are done, a student submits both the printed and electronic version (this version must be also approved and signed by the student and also supervisor). The topic selection must be approved by the supervisor too, and it is also recommended to discuss the whole process of works on the project with the supervisor continuously.

The final version of the project must be approved by the guarantee no later than one week before sitting for the exam. The length of the project should be in the range 20 - 40 pages.

The project must be written in English. The printed version is submitted in one copy with spiral binding or other type of paperback.

## **C.** Formal requirements

The project should be written in the line with the Dean's directive No. EkF\_SME\_11\_001 on Guidelines for Development of Doctoral Thesis Proposals and Doctoral Theses

https://dokumenty.vsb.cz/docs/files/en/cf8ca508-0c7c-473e-8fb2-126e74b0716c

## Structure and content of the project

Title page (see the example below).

**Abstract** (approx. 10 lines: state of research problem, state why it's an interesting problem, state what is your methodology and your solution achieves, state results and follows from your solution)), **keywords** 

## Table of contents

- **1. Introduction** problem description and reasoning, relationship of the topic to the field of study and dissertation thesis, aim of the project, description and reasoning of the methods and structure of the project.
- 2. Description of quantitative methods used/usable for the (field of) problem

Critical analysis of applicability of various methods and models which are/can be used to solve the problem. Selection of the suitable method(s). A student can use several methods and, then, compare and discuss the results.

Mathematical formulation of the problem and method(s).

## 3. Application of the method(s) to solve the model

- Verbal description of the problem.
- Mathematical formulation of the problem.
- Input data (model quantification).
- Problem solving, sensitivity analysis, discussion.
- Results and their interpretation.
- 4. Conclusion: Brief conclusion of the results and their implication.
- 5. List of literature: alphabetically.

Appendices: with large tables and figures necessary for understanding the text/analysis.

VŠB – Technical University of Ostrava Faculty of Economics

## VSB TECHNICAL | FACULTY |||| UNIVERSITY | OF ECONOMICS OF OSTRAVA |

Semestral project for Quantitative methods for economic analysis Postgraduate studies Faculty of Economics VŠB – Technical University of Ostrava

# Title of the project

FIRST NAME, SURNAME Contact: (e-mail, phone) Field of study, grade: Supervisor: Signature of the supervisor: Month/year of submission

## **III. COURSE CONTENT**

Faculty:	Faculty of Economics, VŠB - TU Ostrava
Course:	Quantitative methods for economic analysis
Number of hours given:	60 hrs

Conditions of course competition: oral exam, project

## 1<sup>st</sup> topic - Introduction to scientific work

- Methodology of scientific work.
- Journal paper writing.
- Scientific projects
- Worldwide databases (Web of Science, Scopus).
- Citations.
- Registration of publications in the OBD system
- Open Researcher & Contributor ID (ORCID)
- PhD Academy

#### Lecturer: prof. Ing. Jana Hančlová, CSc.

#### Number of lectures: 4 hours

#### Literature

#### **Compulsory literature**

LUNENBURG, F. C. a J.I. IRBY. *Writing a Successful Thesis or Dissertation: Tips and Strategies for Students in the Social and Behavioral Science*. London: Corwin Press, 2007. ISBN 978-1412942249. COOPER, Donald R. a Pamela S. SCHINDLER. *Business Research Methods*. 10. edition. NY: McGraw-Hill, 2008. ISBN 978-007-126333-7.

#### **Recommended literature**

Journal *Central European Review of Economic Issues*, Faculty of Economics, VŠB-TU Ostrava, <u>https://www.ekf.vsb.cz/cerei/cs/zamereni/</u>

ISI Web of Knowledge (access to the citation database of Thomson Reuters, direct access from the intranet of VSB-TU Ostrava) <u>http://apps.webofknowledge.com/</u>

SCOPUS (citation database of Elsevier, direct access from the intranet of VSB-TU Ostrava) http://www.scopus.com

ERIH (database focused particularly on fields of humanities) http://www.esf.org/researchareas/humanities/erih-european-reference-index-for-the-humanities/erih-initial-lists.html

Science and research in the Czech Republic (Section of deputy prime minister for the science, research and innovation) <u>https://www.vyzkum.cz</u>

Evaluation of the science and research results (methodology and results of science and research evaluation. <u>https://www.vyzkum.cz/FrontClanek.aspx?idsekce=799796</u>

Czech Science Foundation https://gacr.cz/en/

European Structural and Investment Funds http://www.strukturalni-fondy.cz/en/Homepage

- Worldwide databases (Web of Science, Scopus).
  <u>https://knihovna.vsb.cz/en/catalogues-databases/databases-and-e-sources/e-resources/</u>
- Citations. <u>https://knihovna.vsb.cz/en/study-research-support/study-sup/</u>
- Registration of publications in the OBD system

- Open Researcher & Contributor ID (ORCID) <u>https://orcid.org/</u>
- PhD Academy (<u>https://www.vsb.cz/phdakademie/en</u>) <u>https://knihovna.vsb.cz/en/study-research-support/research-sup/</u>

## 2<sup>nd</sup> topic– Quantitative methods and decision making models

- Decision making: single-criteria, multi-criteria, under certainty, risk, uncertainty.
- Decision-making analysis.
- Dynamic models, decision-making and management: branched decision making, decision trees, dynamic programming. Properties and methods of creating dynamic systems.
- Weights of criteria methods how to assign and normalize them.
- Selected methods of multi-criteria decision making (TOPSIS, AHP, ANP, PROMETHE).

#### Lecturer: doc. Mgr. Ing. František Zapletal, Ph.D.

#### Number of lectures: 6 hours

#### Literature

#### **Compulsory literature**

SAATY, Thomas L. *Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process.* Pittsburg: RWS Publications, 2006. ISBN 0-9620317-6-3.

#### **Recommended literature**

TRIANTAPHYLLOU, E. *Multi-Criteria Decision Making Methods: A comparative study*. Kluwer: Academic Publishers, 2000. ISBN 0-7923-6607-7.

WISNIEWSKI, M. Quantitative Methods for Decision Makers. 4th ed. Prentice Hall, 2006.

## **3<sup>rd</sup> topic – Operations research**

#### **Optimization models**

- Optimization methods and their classification.
- Models of mathematical programming their structure and applications.
- Condition for existence of the optimal solution in mathematical programming.

#### Game theory

- Models of game theory and their applications.
- Matrix games mathematical model, real-world applications, solution by linear programming.
- Bi-matrix games mathematical model, real-world applications.
- Cooperative games coalitions, concepts of solution, profit distribution.

#### Leontief's input/output model, chessboard tables

- Leontief's model, chessboard table
- Balance equilibrium assumptions
- Balance equations
- Optimization problems in I/O

#### **Project Scheduling**

- Project scheduling based on expected activity times (CPM, PERT)
- Considering time-cost trade-offs

Lecturers: doc. Mgr. Ing. František Zapletal, Ph.D., prof. Ing. Jana Hančlová, CSc.

#### *Number of lectures:* 6+4 hours

#### Literature

#### **Compulsory literature**

HILLIER, F., LIEBERMANN, G. J. *Introduction to Operations Research*. 9th ed. 1047 p. New York: McGraw-Hill Higher Education, 2010. ISBN 978-0-07-337629-5.

ANDERSON, D. R. et al. An Introduction to Management Science: Quantitative Approaches to Decision Making. 14<sup>th</sup> ed. Boston, USA: Cengage Learning, 2016, ISBN 978-1-111-82361-0. **Recommended literature** 

WINSTON, W. L, GOLDBERG, J. B. *Operations research: applications and algorithms.* 1418 p. Brooks/Cole Belmont, 2004. ISBN 0-534-42362-0.

## 4<sup>th</sup> topic – Statistical Methods

- Basic concepts; types of measurements for variables, numerical descriptive statistics, exploratory data analysis, some probability distributions.
- Statistical inference; populations, samples, estimation, hypothesis testing.
- Inferences on a single and two populations. Analysis of variance.
- Correlations. Linear regression (simple and multiple); least square method, model assumptions, inferences for regression.
- Categorical data analysis; contingency tables, test for homogeneity and independence. Measures of association.

Lecturer: doc. Ing. Václav Friedrich, Ph.D.

#### Number of lectures: 4 hours

#### Literature

#### **Compulsory literature**

ROSS, S. M. Introduction to Probability and Statistics for Engineers and Scientists. Elsevier Academic Press, 2009. ISBN 978-0-12-370483-2.

MENDENHALL, W. a T. SINCICH. *Statistics for Engineering and the Sciences*. New York: Macmillan Publishing Company, 2006.

AGRESTI, A. *An Introduction to Categorical Data Analysis*. John Wiley & Sons, 2007. ISBN 978-0-471-225618-5.

#### **Recommended literature**

ANDERSON, D. R., D. J. SWEENEY a T. A WILLIAMS. *Statistics for Business and Economics*. South- Western: Cengage Learning, 2012. ISBN 978-0-538-48164-9.

KVANLI, A. H., R. J. PAVUR, a A C. S. GUYNES. *Introduction to Business Statistics - A Computer Integrated, Data Analysis Approach.* New York: South-Western College Publishing, 2003.

NEWBOLD, P. Statistics for Business and Economics. London: Prentice-Hall, 2006.

NORUŠIC, M. J. SPSS 10.0 Guide to Data Analysis. New Jersey: Prentice Hall, 2000.

## 5<sup>th</sup> topic - Data envelopment analysis - DEA

- Performance evaluation.
- Production function and Production Possibility Set (PPS).
- Mathematical programming approaches for measuring efficiency.
- Multiplier models v.s. Envelopment models.
- Different types of efficiency: technical, scale, mix, Slacks-Based Measure (SBM), profit, ...
- Various weight restrictions and their applications (DEA with multiple layers)
- Data selection in DEA: flexible and selective measures, dual-role factors.
- Efficiency change over time
- Advanced topics: Discriminate-Analysis, Network DEA, Game DEA

#### Lecturer: prof. Dr. Mehdi Toloo

#### *Number of lectures:* 4 hours

#### Literature

#### **Compulsory literature**

COOPER, W. W., SEIFORD, L. M. a K. TONE. *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. 2<sup>nd</sup> Edition, US: Springer, 2007. ISBN 0-387-45281-8

#### **Recommended literature**

TOLOO, M. *Data Envelopment Analysis with Selected Models and Applications*, SAEI, Vol. 30. Ostrava: VŠB-TU Ostrava, 2014. ISBN 978-80-248-3738-3.

## 6<sup>th</sup> topic – Econometrics

- Process of classical econometric modeling.
- Classical Multiple Regression Model (estimation by least squares method, assumptions and characteristics of estimation, criteria for assessing regression model, hypothesis testing, qualitative explanatory variables, nonlinear regression).
- Econometric generalization of linear regression (essence, detection, elimination heteroscedasticity, autocorrelation, multicollinearity, testing of model specification, model stability).
- Discrete explained variable.
- Other estimation methods (maximum likelihood, moments estimation, two-stage least squares estimation).

Lecturer: prof. Ing. Jana Hančlová, CSc.

#### *Number of lectures:* 4 hours

#### Literature

#### Compulsory literature

GUJARATI, D. N. and PORTER, D. C. *Basic Econometrics*. Singapore: Mc Graw-Hill, 2008. 944 p. ISBN 978-0073375779.

DOUGHERTY, CH. *Introduction to Econometrics*. Oxford: Oxford University Press, 2016. 590 p. ISBN 978-0199676828.

ENDERS, W. Applied Econometric Time Series. Hoboken, NJ: Wiley, 2015, 485 s. ISBN 978-8125672731.

#### **Recommended literature**

GREENE, W. H. *Econometric Analysis*. New Jersey: Prentice Hall, 2008, 1178 s. ISBN 978-0-13-513740-6.

WOOLDRIDGE, J. *Introductory Econometrics: A Modern Approach*. Singapore: Cengage Learning Asia Pte LtD, 2020, 826 p. ISBN 978-9814866088.

#### Lecturer

# prof. Ing. Dušan Marček, CSc. *Contents of lectures*

## 7<sup>th</sup> topic Advanced methods of artificial intelligence

- UNS with supervised learning
- Biological neuronal morphology
- Measure of similarity.
- Mathematical model of a neuron, Fuzzy neuron: Synaptic and somatic operations.
- Multi-layered neural networks.
- Learning methods that learn from examples: Back-propagation algorithm.
- Applications in finance.
- Recurrent networks, UNS uncontrolled learning
- Recurrent networks.
- Hebbian learning rule, extracting main components.
- Competitive learning, data clustering, SOM network type.

# *Lecturer:* prof. Ing. Dušan Marček, CSc. *Number of lectures:* 1 hours

#### Literature

#### **Compulsory literature**

HERTZ, J., KROGH, A. a R. G. PALMER. *Introduction to the Theory of Neural Computation*. Redwood City, CA: Addison-Esley, 1991.

KECMAN, Vojislav. Learning and Soft Computing: Support Vector Machines, Neural Networks, and Fuzzy Logic Models. Cambridge: MIT Press, 2001. ISBN 0-262-1125508.

RUSSELL, S. a P. NORVIG. *Artificial Intelligence: A Modern Approach*. New Jersey: Prentice-Hall, 1995.

#### **Recommended literature**

GUPTA, M.M., D.H. RAO. On the principles of fuzzy neural networks. *Fuzzy Sets and Systems*1994, 61, 1-18.

HASTIE, N.R., TIBSHIRANI, R. a T. FRIEDMAN. *The Elements of Statistical Learning, Data Mining, Inference, and Prediction*. New. York: Berlin: Springer-Verlag, 2001.

## **IV. EXAM QUESTIONS**

The course should prove knowledge on quantitative methods and procedures including exact mathematical formulations of selected problems which can be applied within Ph.D. field of studies at Faculty of Economics, VSB – Technical University of Ostrava. Such knowledge is necessary as a methodological basis for a dissertation thesis. An approved semestral project is a prerequisite to sit for the exam.

#### Oral exam:

The questions can be divided into two categories:

A – general questions about description, categorization, presentation of basic principles and procedures.

B – particular questions about mathematical formulation which can prove the ability to express particular problems in a precise mathematical way.

A student gets one question from each category at random to prove both general overview of the methods and the ability to define a mathematical model for particular problems.

## A. General question

- 1. Procedure of decision-making. Classification of decision-making methods. Describe the basic elements of decision-making using some simple practical example.
- 2. Types of criteria and how to assign them. The importance of thresholds and weights. Methods for weights assignment and their critical comparison. Normalization of weights.
- 3. Decision trees their description and application. Critical comparison of selected methods of multi-criteria decision-making suitability of use.
- 4. Input/output analysis. Economic system and its description by Leontief's model. Quadrants of chessboard tables.

- 5. Mathematical programming type of models, classification of mathematical programming methods and their applicability. Phases of MP model's solution.
- 6. Linear programming applications, structure of the model, methods for solving LP models.
- 7. Game theory principles and terminology. Concept of Nash equilibria. Applications of matrix games. Bi-matrix games and their application. Cooperative games profit distribution.
- 8. Project scheduling. The concept of a Critical Path, CPM and PERT methods and their use, resource/cost optimization.
- 9. Statistical data, their classification and graphical representation
- 10. Statistical population and a random sample. Principals of hypothesis testing, test criterion, statistical significance.
- 11. Inferences on a single population. Comparing populations (parametric and nonparametric methods).
- 12. The principle of one-way analysis. Correlation analysis; correlation coefficients.
- 13. Simple linear regression; least squares method, testing for significance, model quality evaluation.
- 14. Classification and description of basic estimation methods for econometric models: least squares method, maximum likelihood method, method of moments. Basic properties of estimated parameters, criteria of selection a suitable estimation method.
- 15. Selecting input and output factors and measuring the efficiency in DEA. Concept of different types of efficiency, efficient frontier and PPS. Modelling of performance evaluation using DEA approach. Multiplier and envelopment forms applications and structure of the models.

## **B.** Questions about mathematical formulation

- 1. Decision-making under the risk. Decision trees. Expected value.
- 2. Decision-making under uncertainty. Decision criteria (Optimistic, Pessimistic, Laplace, Hurwitz).
- 3. Weights of criteria and methods. Normalizing the weights. AHP method description and formulation.
- 4. Input/output Leontief models equilibrium of the model with 1st and 2nd quadrant. Description of the model with three quadrants.
- 5. Optimization model general formulation. Conditions for global optima existence. Formulation of the model of linear programming.
- 6. Game theory matrix and bi-matrix game specification, solution of the matrix games in mix strategies graphically and using linear programming method.
- 7. Game theory cooperative games and ways to divide the profit.
- 8. CPM/PERT. Finding critical path using CPM (latest start time, latest finish time, slack associated with each activities). PERT (uncertain activity times, the critical path expected time and the variance in completion of the project, computing the probability of each project paht meeting).

- 9. Least squares method; mathematical formulations and deriving of the regression equation.
- 10. The principle and procedure of one-way analysis of variance.
- 11. The procedure, formulation of the t-statistic, application of the t-test for statistical significance of regression parameters.
- 12. Assumptions of the least squares method, derivation and exact mathematical formulation of the least squares method, determination of regression function's parameters. Graphical representation.
- 13. The procedure of hypothesis testing in contingency tables.
- 14. Logistic regression model deriving the equation.
- 15. DEA models under CRS and VRS assumptions description, formulations. The interpretation of optimal solution of the envelopment and multiplier forms.

Ostrava, September, 2023

prof. Ing. Jana Hančlová, CSc.