FACULTY OF COMPUTER SCIENCE AND ENGINEERING

CURRICULUM

Affirm:
Dean:

CS 422

OPERATIONS RESEARCH

Accepted: Updated: Prot. №7/30.01.2019
Lecturer: Associate Professor Evgenia Nikolova, PhD

ABSTRACT

The course introduces students to the general methodology of Operations Research, including standard mathematical models and methods such as linear, nonlinear, integer, and dynamic programming, optimization problems on networks, inventory management, queueing theory, and game theory, as well as simulation modelling. The methods and methodology are illustrated with specific models of objects and processes, and an analysis of the obtained solutions is provided. The course also covers knowledge of the capabilities of modern software for conducting research, illustrating methods through specific studies with real data using conventional software products (such as Excel's Solver). Applications of the topics in practice are presented for many of the themes.

MAIN OBJECTIVES

The goal of the course is to introduce students to the fundamental methods and models of Operations Research, building initial knowledge and practical skills for constructing and applying such models in the analysis and decision-making of complex systems. The course aims to provide knowledge of the methodology of Operations Research, specific models, their economic interpretation, and the significance of the results that can be obtained from these models. Upon completion of this module, students are expected to be able to formulate typical models (linear and nonlinear, discrete and stochastic), articulate real problems in suitable mathematical specifications, apply probability concepts in practical models, and solve optimization problems using MS Excel's Solver.

PREREQUISITES

The course assumes a familiarity with the material from the disciplines of Higher Mathematics and Probability and Statistics.

STATUTE AND STRUCTURE

specialty	status	Credits	full-time study				part-time study			
			lectures	seminars	exercises	total	lectures	seminars	exercises	total
Software engineering	Mandatory	6	30	30		60	15	15		30

COURSE CONTENT

Topic 1: **Operations Management Content and Methodology.** Introduction to Operations Management. Course content and purpose. Historical overview. Modelling as a method of knowledge. Relationship between the original and the model. Types of mathematical models. Definition of the concept of a mathematical model. Advantages of mathematical modelling. Construction of operational models. Problem formulation. Stages of operational research. Model construction. Model verification and solution evaluation. Implementation of the solution and control for its correct application. Optimality and efficiency. Classification of optimization problems - linear and nonlinear, discrete and stochastic, game theory.

Topic 2: **Linear Programming, Network Models.** General formulation of linear programming problems. Economic interpretation. Basic, degenerate basic, and optimal solutions. Classification of linear programming problems - standard linear programming problems, deterministic and stochastic problems, typical problems, static and dynamic problems, problems with discrete and continuous variables. Duality in linear programming problems. Economic interpretation of the dual of the problem for maximizing profit with limited resources. Construction of linear optimization models. Integer programming.

Network models. Analysis of the optimal solution of linear programming problems - possibilities of post-optimal analysis, changes in objective coefficients, changes in constants, changes in coefficients in the constraint matrix, introduction of additional constraints. Network optimization. Tasks and models. Formulation of the optimal transport route problem. Determination of costs for the cheapest route. Determination of the route with the lowest costs. Formulation and model for single-product and multi-product networks. Equivalent networks. Model with intermediate points. Assignment problems. Schedule planning for labor resources. Models of the classical transport problem. Closed transport problem. Optimality criterion and constraints. Open transport problem. Solution approach. General concept of network planning. Basic concepts - task, event, path, complete path, critical path. Rules for constructing a network graph. Management and optimization indicators with a network model. PERT system. Network models - effective methods for planning and control in the management of various projects.

Topic 3: **Nonlinear Programming, Dynamic Programming.** Nonlinear programming. General problem formulation. Varieties. Geometric interpretation of nonlinear programming problems. Dynamic programming. Basic concepts. Features of dynamic programming problems. Basic principle of dynamic programming - Bellman's principle, recurrence relations.

Topic 4**: Inventory Management.** Essence and general characteristics of inventory management tasks. Structure of inventory management systems. Inventory regulation. Basic parameters of models. Types of models. Construction of models for inventory management. Formulation of some typical inventory management tasks. Design and information support for the JIT system for supply management and supply to the enterprise.

Topic 5: **Queueing Theory.** Queueing systems. Basic parameters. Performance indicators and optimization. Application of the analytical direction of queueing theory.

Topic 6: **Game Theory.** Preparation and decision-making in conditions of uncertainty and competition. Basic concepts. Types of games. Utility theory - basic ideas. Mathematical expectation of the

game. Pure and mixed strategies. Minimax theorem. Two-person zero-sum game. Saddle point. Some economic applications of game theory.

Topic 7: **Econometric Models.** Production functions. Types. Consumer demand elasticity functions.

Topic 8: **Simulation Modelling.** Simulation models - formulation, construction, application areas.

SEMINAR EXERCISES

Topic 1: MS Excel Solver - Features, Operation. Open-Source Operations Research Software
Topic 2: Illustration of Primal and Dual Problems
Topic 3: Post-Optimal Analysis with MS Excel Solver
Topic 4: Optimal Production Plan
Topic 5: Problems for Creating Optimal Blends
Topic 6: Maximizing Profit with Limited Resources
Topic 7: Optimization of Operational Task Distribution
Topic 8: Solving Assignment Problems with MS Excel Solver
Topic 9: Transportation Problem
Topic 10: Generalized Transportation Problem
Topic 11: Finding the Shortest Path. Dual Problem for Path Length. Equipment Replacement Problem
Topic 12: Finding the Longest Path
Topic 13: Flows in Networks. Maximum Flow
Topic 14: Finding Optimal Mixed Strategies
Topic 15: Application of the Prisoner's Dilemma - Competition vs. Cooperation
Topic 16: Inventory Management Software

COURSE PROJECT

The course project involves specific tasks for each student, including formulating optimization models, numerically solving them, and conducting post-optimal analysis.

PLANNED EDUCATIONAL ACTIVITIES AND TEACHING METHODS

1. The first lecture aims to introduce students to the program content, goals, and objectives of the discipline, as well as the preparation requirements.
2. Lectures cover topics from the syllabus. Each theme concludes with questions and self-preparation tasks.
3. During seminar sessions, students work on individual assignments, contributing to continuous assessment.
4. Continuous assessment is achieved through coursework and periodic tests.
5. Electronic materials on the Moodle platform support student preparation and provide opportunities to expand their knowledge on specific topics.

Theoretical Material Presentation:

- Books: Contain theoretical material on the topics.
- Pages: Provide brief theoretical material or additional explanations.

- Web Resources: Include articles, online journals, templates, and other materials.
- Video Materials: Comprise video tutorials.
- Files: Additional resources.

Practical Work Implementation:

- Assignments: Students independently solve tasks set by the instructor, with evaluations provided.
- Tests: Self-preparation and self-evaluation tests aid students in assessing their knowledge.
- Web Resources: Additional resources and materials.
- Video Materials: Include video tutorials for creating specific models.
- Forum: Utilized for consultations between students and instructors and information exchange among students.
- Video Conferencing: Used for periodic real-time consultations between students and instructors..

METHODS OF ASSESSMENT

Written exam and, if necessary, an oral interview are employed for evaluation. The final grade comprises scores from continuous assessment, coursework, and the written exam, according to the following breakdown:

- Continuous assessment score: 20 points
- Coursework score: 20 points
- Exam score: 60 points

The six-point grading scale is determined as follows:

- Excellent (6): 86–100 points
- Very Good (5): 74–85 points
- Good (4): 62–73 points
- Satisfactory (3): 51–61 points

To receive a comprehensive grade, students must earn a minimum of 14 points from continuous assessment during the semester and a minimum of 22 points from the exam procedure. Exemption from the exam is granted with a minimum of 36 points accumulated throughout the semester, following an interview with the lecturer.

The implementation of activity-based assessment is achieved through:

- Two control tests during seminar exercises, along with solutions to assignments.
- Assessment of coursework and its defence.
- Written exam.

RECOMMENDED LITERATURE

1. Цончев, Петров, Николова, Курс по количествени методи за икономисти и мениджъри, Издателство НБУ, 2010.

2. Гриф МО РФ Морозов, Исследование операций, В.В. Академия (Academia) Прикладная математика и информатика, 2008.

3. Н. Н. Писарук, Исследование операций, Минск, 2015, http://pisaruk.narod.ru/books/OR.pdf

4. Hillier, Lieberman, Introduction to Operations Research, E Book.pdf Stanford University, 2010 http://www.mediafire.com/?ttoljkzigyy, MCGH; 10th International edition (July 6, 2014)

5. Srinivasan G., Operations research: Principles and Applications, Second Edition, PHI Learning Private Limited, New Delhi, 2010
6. Х. Таха, Введение в исследование операций, Мир, Москва, 1985; Вильямс, Москва, 2005.

EXAM QUESTIONNAIRE

CS 422

OPERATIONS RESEARCH

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1. **Operations Research Content and Methodology**

1.1. Course Overview on Operations Research. Content and Purpose of the Course. Historical Overview.

1.2. Modelling as a Method of Knowledge. Original-Model Relationship. Types of Mathematical Models. Definition of the Concept of a Mathematical Model. Advantages of Mathematical Modelling.

1.3. Construction of Operational Models. Problem Formulation. Stages of Operational Research. Model Construction. Model Verification and Solution Assessment. Implementation of the Solution and Control of its Proper Application.

1.4. Optimality and Efficiency. Classification of Optimization Problems - Linear and Nonlinear, Discrete and Stochastic, Game Theory. Multicriteria Problems.

2. **Linear Programming, Network Models**

2.1. General Formulation of Linear Programming. Economic Interpretation. Basic, Degenerate Basic, and Optimal Solutions. Classification of Linear Programming Problems - Standard Linear Programming Problems, Deterministic and Stochastic Problems, Typical Problems, Static and Dynamic Problems, Problems with Discrete and Continuous Variables.

2.2. Duality in Linear Programming Problems. Construction of Linear Optimization Models. Integer Programming.

2.3. Network Models.

2.4. Analysis of the Optimal Solution to the Linear Programming Problem - Possibilities of Post-Optimal Analysis, Changes in Objective Coefficients, Changes in Constants, Changes in Coefficients in the Constraint Matrix, Introduction of Additional Constraints.

2.5. Tasks for Creating an Optimal Production Plan. General Model of a Production Program. Optimal Loading of Interchangeable Machines. Optimal Plan with Production Capacity Constraints. Optimal Plan with Minimum Total Costs.

2.6. Resource Allocation Tasks. Optimal Cutting of Materials. Modelling Resource Distribution. Optimal Distribution of Cropland.

2.7. Tasks for Creating Optimal Mixtures. Optimal Mixtures in Livestock Farming. Optimal Mixtures in Chemistry and Metallurgy.

2.8. Network Optimization. Tasks and Models. Formulation of the Optimal Transportation Route Problem. Determining Costs for the Cheapest Route. Determining the Route with the Lowest Costs. Formulation and Model in Single-Product and Multi-Product Networks. Equivalent Networks. Model with Intermediate Points. Assignment Tasks. Calendar Planning of Labor Resources. Models of the Classic Transportation

Problem. Closed Transportation Problem. Optimality Criterion and Constraints. Open Transportation Problem. Solution Approach.

2.9. General Concept of Network Planning. Basic Concepts - Work, Event, Path, Critical Path. Rules for Constructing a Network Diagram. Management and Optimization Indicators with a Network Model. PERT System.

3. **Nonlinear Programming, Dynamic Programming**

3.1. Nonlinear Programming. General Problem Formulation. Varieties. Geometric Interpretation of Nonlinear Programming Problems.

3.2. Dynamic Programming. Basic Concepts. Features of Dynamic Programming Problems. Basic Principle of Dynamic Programming - Bellman's Principle, Recurrent Relationships.

4**. Inventory Management**

4.1. Essence and General Characteristics of Inventory Management Tasks. Structure of Inventory Management Systems. Inventory Regulation. Basic Parameters of Models.

4.2. Types of Models. Building Models for Inventory Management. Formulation of Some Typical Inventory Management Tasks.

5. **Queueing Theory**

5.1. Queueing Systems. Basic Parameters. Indicators of Efficiency and Optimization.

5.2. Application of the Analytical Approach to Queueing Theory.

6. **Game Theory**

6.1. Preparation and Decision-Making Under Conditions of Uncertainty and Competition. Basic Concepts.

6.2. Types of Games. Utility Theory - Basic Ideas.

6.3. Mathematical Expectation of the Game. Pure and Mixed Strategies. Minimax Theorem. Zero-Sum Game. Saddle Point.

6.4. Duality and Game Theory.

7. **Econometric Models**

Production Functions. Types. Consumer Demand Elasticity Functions.

8. **Simulation Modelling**

Simulation Models - Formulation, Construction, Application Areas. Simulation Systems - Types and Structure.

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1. Цончев, Петров, Николова, Курс по количествени методи за икономисти и мениджъри, Издателство НБУ, 2010.

2. Гриф МО РФ Морозов, Исследование операций, В.В. Академия (Academia) Прикладная математика и информатика, 2008.

3.Н. Н. Писарук, Исследование операций, Минск, 2015, http://pisaruk.narod.ru/books/OR.pdf

4. Hillier, Lieberman, Introduction to Operations Research, E Book.pdf Stanford University, 2010 http://www.mediafire.com/?ttoljkzigyy, MCGH; 10th International edition (July 6, 2014)

5. Srinivasan G., Operations research: Principles and Applications, Second Edition, PHI Learning Private Limited, New Delhi, 2010
6. Х. Таха, Введение в исследование операций, Мир, Москва, 1985; Вильямс, Москва, 2005.