Univerza v Mariboru

Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Operacijske raziskave
Course title:	Operations research

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Izobraževalna matematika – enopredmetna, 2. stopnja		2.	3.
Educational mathematics single-major, 2nd cycle		2.	3.

Vrsta predmeta / Course type Izbirni / Elective

Univerzitetna koda predmeta / University course code:

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
45	15	30			90	**6**

Nosilec predmeta / Lecturer: Drago Bokal

Jeziki / Languages:	
Predavanja / Lectures:	slovensko/slovene ali angleško/english
Vaje / Tutorial:	slovensko/slovene ali angleško/english

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisits:
Poznavanje enostavnih algoritmov. Poznavanje osnov linearne algebre in vektorske analize. Vsaka izmed naštetih obveznosti v načinih ocenjevanja mora biti opravljena s pozitivno oceno. Pozitivna ocena izdelka je pogoj za pristop k ustnemu izpitu.	Knowledge of simple algorithms. Knowledge of basic linear algebra and calculus. Each of the mentioned commitments must be assessed with a passing grade. Passing grade of the output is required for taking the oral exam.

Vsebina:	Content (Syllabus outline):

Obvezna vsebina, ki pri študentih vzpostavi temeljni nabor znanj s področja operacijskih raziskav:

- Stohastični Markovski odločitveni procesi. Markovske verige. Markovsko jedro. Uporaba v univerzalnem modelu procesa.
- Uporaba Markovskih jeder v umetni inteligenci.
- Uporaba konceptov in metod operacijskih raziskav za reševanje problemov zelene transformacije, pametnih tovarn, pametnih mest.
- Uporaba konceptov in metod operacijskih raziskav v povezavi s tehnikami in izzivi umetne inteligence in digitalne transformacije.

). V okviru vsebine študentje izberejo zahtevnejši problem - projekt, s katerimi se poglobljeno ukvarjajo pri izdelku. Problem je povezan z njihovo bodočo kariero, zeleno in digitalno transformacijo (praktični problemi iz gospodarstva, teoretični problemi iz teorije operacijskih raziskav, minimiranje okoljske obremenitve, optimizacija porabe virov pri doseganju ciljnih vrednosti kazalnikov ESRS razkritij, pametnih tovarn, pametnih mest in vasi, doseganja ciljev Industrije 5.0, uporaba podatkovne analitike za zagotavljanje kakovostnih podatkov za reševanje problemov operacijskih raziskav).
Preostala predavanja se prilagodijo projektom, ki so jih izbrali študentje, in obsegajo izbrane vsebine z naslednjega seznama:

- Optimizacijski modeli s centraliziranim odločanjem, modeli teorije iger s porazdeljenim odločanjem. Deterministični, stohastični, robustni problemi.
- Nevezani ekstrem, Newtonova metoda.
- Deterministični in stohastični problemi optimizacije portfelja.
- Optimalni portfelj celoštevilskih lotov in celoštevilsko programiranje.
- Imunizacija portfelja in stohastično programiranje.

Mandatory content that familiarizes the students with fundamentals of operations research:

- The process of mathematical modelling. Modelling decisions, decision tree, branch and bound search for solutions. Dynamic programing.
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- Stochastic Markov decision processes. Markov chains. Markov Kernels. Applications in universal process model.
- Applications of Markov kernels in artificial intelligence.
- Using concepts and methods of operations research for solving problems of green transformation, smart factories, smart cities.
- Using concepts and methods of operations research related to techniques and challenges of artificial intelligence and digital transformation.

Within the coursework, the students select a problem - project whose result is coursework report. The problem is related to their future career, green and digital transition (practical problems from industry and business, theoretical problems from the areas of optimization, algorithms, modelling, minimizing environmental impact, optimizing resource usage achieving goal values of ESRS disclosures, smart factories, smart cities and villages, achieving goals of Industry 5.0, applying data analytics to ascertain quality data for solving problems with operations research).
The content of the remaining lectures is selected according to these projects from the following list:

- Optimization models with centralized decision making. Deterministic, stohastic, robust problems.
- Unconstrained optimization. Newton's method.

- deterministic and stochastic problems of optimal portfolio,
- Optimal portfolio of integer lots and integer programming.
- Portfolioimmunization and stohastic programming.
- Stock control.
- Diet problem.
- Applications of game theory: optimal strategy on a market with two competitors.
- Queues.
- Other operations research and mathematical modelling topics related to students' projects.

Within their coursework and exercisces, the students familiarize themselves with software for mathematical modelling, either commercial (Excel, Lindo, Matlab) or freely avaliable open source (Python, Neos, R).

- Optimizacija zalog.
- Problem prehrane.
- Aplikacije teorije iger: optimalna strategija na tržišču z dvema konkurentoma.
- Čakalne vrste.
- Druge vsebine s področja operacijskih raziskav in matematičnega modeliranja, povezane s študentskimi projekti.

V okviru seminarskih nalog se študentje srečajo tudi s programsko opremo za matematično modeliranje, komercialno (Excel, Lindo, Matlab) oz. prostodostopno in odprtokodno (Python, NEOS, R).

Temeljni literatura in viri / Readings:

1. J. Franklin, Methods of Mathematical Economics: Linear and Nonlinear Programming, Fixed-Point Theorems. Classics in Applied Mathematics 37, SIAM, 2002.
2. R. Rardin. Optimization in Operations Research. Prentice Hall, Inc., Upper Saddle River, New Jersey, 2000.
3. Novak, T., Povh, J., & Žerovnik, J. (2020). Izbrana poglavja iz operacijskih raziskav (str. 227). Fakulteta za strojništvo.

Dodatna literatura / Additional Readings:

1. J. Curwin, R. Slater. Quantitive Methods for Business Decisions. Third Edition. Chapman & Hall, London, 1991.
2. L. Neralić, Uvod u matematičko programiranje 1. Udžbenici Sveučilišta u Zagrebu, Zagreb, 2001.
3. S. A. Zenios, Financial Optimization. Cambridge University Press, Cambridge, 1993.

Cilji in kompetence:

Usvojiti proces matematičnega modeliranja.

Razviti kompetenco samostojnega apliciranja matematičnih metod na probleme iz finančne optimizacije, ekonomije, ter širše iz gospodarstva.

Spoznati tehnološka orodja, s katerimi se srečujemo pri reševanju optimizacijskih problemov in problemov matematičnega modeliranja.

Spoznati Okvir digitalnih kompetenc za državljane 2.2 in Evropski kompetenčni okvir za trajnostnost kot primer učnih prostorov.

Prepoznati bistvene kompetence v navedenih kompetenčnih okvirih in samooceniti svoje znanje. Zaznati potrebo po nadgradnji izbranih kompetenc omenjenih okvirov in pridobiti informacije za njihovo nadgrajevanje.

Objectives and competences:

Familiarize the students with the process of mathematical modelling.

Develop competent skills of independent application of mathematical methods to the problems from financial optimization, economics, and broader from industry.

Familiarize the students with technological tools that assist solving optimization problems and problems related to mathematical modelling.
Learn about The Digital Competence Framework For Citizens and GreenComp competence framework as examples of learning spaces.

Recognize most relevant competences in the

	above competence frameworks and self-evaluate their knowledge of these competences. Recognize the need for upgrading the selected competences of these frameworks and obtain relevant information for their upgrading.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študent pridobi pregledno znanje v predmetu obravnavanih konceptov, kar utrjuje s smiselnim pogovorom o navedenih temah na predavanjih, vajah in konzultacijah. Naučene pojme, njihove zakonitosti in razmerja pojasni s pogovorom o obravnavanih temah na ustnem izpitu. Izbrano od obravnavanih vsebin študent prouči poglobljeno, kar izkaže z uporabo relevantnih konceptov v izdelku, seminarski nalogi, kjer z uporabo konceptov izbrane teme razreši konkreten problem, ki je aktualen ali splošno v izobraževanju, ali v povezavi s snovjo, ki jo bo poučeval, ali s problemom potencialnega delodajalca, ki izhaja iz okolja, v katerem bo izobraževal. Prenesljive/ključne spretnosti in drugi atributi: Direktne aplikacije v finančni matematiki, ekonomiji, poslovnih vedah, inženirstvu, kemiji in številnih drugih družboslovnih in naravoslovnih vedah. Obenem principi linearne optimizacije tvorijo osnovo za matematično programiranje.	Knowledge and Understanding: The student gains a comprehensive understanding of the concepts covered in the subject, which is reinforced through meaningful discussions on these topics during lectures, exercises, and consultations. They articulate the learned terms, their principles, and relationships by engaging in an oral exam focused on the subject matter. The student conducts in-depth research on selected content from the course, demonstrating their mastery by applying relevant concepts in a project. In the project, they address a specific issue relevant to education, their future teaching materials, or a potential workplace problem derived from the educational environment in which they will be teaching. Transferable/Key Skills and other attributes: Direct applications in finacial mathematics, economy, business, engineering, chemistry, and numerous other social and natural sciences. Also, principles of linear optimization are foundations for mathematical optimization.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Na predavanjih študentje spoznajo predpisano snov predmeta. Z uporabo obrnjenega (flipped) poučevanja na	At the lectures, the students are familiarized with the required contents of

predavanjih aktivno spoznavajo povezavo med snovjo in njihovimi projekti. ●Študentski projekti so osrednji element predmeta. Študentje se jih lotevajo v skladu s smernicami projektnega in sodelovalnega učenja. ● V okviru seminarskih vaj študentje razumevanje snovi utrjujejo na projektih, povezanih z njihovo bodočo kariero. Razporejeni so v manjše skupine, ki po metodah projektnega učenja in sodelovalnega učenja delajo na izbranih projektih. ● V okviru seminarja študentje uporabljajo, analizirajo in vrednotijo svoje projekte za potrebe ustvarjanja novih rešitev za okolje, iz katerega izvirajo problemi. ● Z uporabo tehnik izkušanja matematičnega modeliranja študenti merijo svoj napredek pri predmetu, ga reflektirajo in tako uporabljajo njegov matematični model za spodbujanje sprotnega dela, opazovanje izboljšanja, ki izvira iz matematično podprtega odločanja. ● Dve predstavitvi njihovih rezultatov pomagajo študentom priučiti se suverenosti javnega nastopanja in zagovarjanja doseženih rezultatov. Osredotočeni dvodnevni organizirani hackathon pomaga študentom izkusiti veselje ob osredotočenem raziskovanju in sodelovanju z vrstniki. ●obrnjeno učenje se izkaže s pomočjo formativnega spremljanja študentskih skupin, ki predstavijo napredek zadnjega tedna, mentor pa jih usmeri k aktivnostim višjih taksonov Bloomove taksonomije.	the course. Applying flipped learning approach, they discuss their coursework projects in relation to the material of the course. ●Student projects are the central element of the course. Students work on them according the principles of project-based learning and collaborative learning. ● Within the coursework, the students deepen their understanding of the material on projects, related to their future careers. They are organized in smaller groups who apply the principles of project based learning and collaboration learning on projects of their choice. ● At the seminar, the students apply, analyse, and evaluate their projects in order to create new solutions desired by the environment the problems are coming from. ● Applying embedded mathematical modelling, the students measure and reflect upon their progress thus encouraging ongoing work, using its mathematical model to experience improvement coming from mathematically supported decision making. ● Three presentations of their results help students acquire confidence with public presentation and defending their results. ● Focused two-day workshop-style organized hackathon helps students experience the joy of focused research and collaboration with peers. ●Flipped learning is expressed through formative assessment of student groups, which discuss progress of the previous week and the mentor directs them towards activities higher in the Bloom taxonomy.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**

Izdelek Ustni izpit	**75** **25**	**Output** **Oral exam**

Reference nosilca / Lecturer's references:

BOKAL, Drago, DVOŘÁK, Zdeněk, HLINĚNÝ, Petr, LEANÕS, Jesús, MOHAR, Bojan, WIEDERA, Tilo. Bounded degree conjecture holds precisely for c-crossing-critical graphs with c≤12. Combinatorica. Oct. 2022, vol. 42, iss. 5, str. 701-728. ISSN 0209-9683.

BOKAL, Drago, CHIMANI, Markus, NOVER, Alexander, SCHIERBAUM, Jöran, STOLZMANN, Tobias, WAGNER, Mirko H., WIEDERA, Tilo. Properties of large 2-crossing-critical graphs. Journal of graph algorithms and applications. 2022, vol. 26, no. 1, str. 111-147. ISSN 1526-1719. DOI: 10.7155/jgaa.00585. [COBISS.SI-ID 144719363]

BOKAL, Drago, JEREBIC, Janja. Guarding a subgraph as a tool in pursuit-evasion games. Discussiones mathematicae. Graph theory. 2022, vol. 42, no. 1, str. 123-138. ISSN 12343099. https://www.dmgt.uz.zgora.pl/publish/view_vol_article.php?E8F29296C3FB4B933A2E. [COBISS.SI-ID 8147219]

Smole, A., Jagrič, T., & Bokal, D. (2021). Principal/Two-Agent model with internal signal. Central European Journal of Operations Research, 29(3), 791-808.

Bokal, D., & Steinbacher, M. (2019). Phases of psychologically optimal learning experience: task-based time allocation model. Central European Journal of Operations Research, 27(3), 863-885.