UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Ime predmeta:	MODELIRANJE INTRALOGISTIČNIH SISTEMOV
Course title:	MODELLING OF INTRALOGISTICS SYSTEMS

Študijski program in stopnja Study programme and cycle	Študijska smer Study option	Letnik Year of study	Semester Semester
LOGISTIKA SISTEMOV 2. stopnja		2.	3.
SYSTEM LOGISTICS 2nd degree		2.	3.

Vrsta predmeta (obvezni ali izbirni) / Course type (compulsory or elective)	IZBIRNI ELECTIVE
Univerzitetna koda predmeta / University course code:	MAG

Predavanja Lectures	Seminar Seminar	Vaje Tutorial			Klinične vaje Clinical training	Druge oblike študija Other forms of study	Samost. delo Individual work	ECTS
16 e-P 24 a-P		a-V	e-V	LV			100	6
			15	25				

Nosilec predmeta / Course coordinator:	**TONE LERHER**
Jeziki /Languages: **Predavanja / Lectures:**	SLOVENSKI/SLOVENE
Vaje / Tutorial:	SLOVENSKI/SLOVENE

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites for enrolling in the course or for performing study obligations:
Ni pogojev.	None.

Vsebina (kratek pregled učnega načrta):	Content (syllabus outline):
1. Intralogistika ("Layout", avtomatizirano in robotizirano skladiščenje, notranji transport, oskrba in strega delovnih mest, metodologije in analitični/numerični modeli, pretočna zmogljivost in sledljivost). 2. Pametne tovarne (pametni izdelki, stroji in procesi, novi poslovni modeli "Batch size 1", koncept delovnega mesta "Operator 4.0", model gibke platforme pametne tovarne). 3. Pametna skladišča (procesi v pametnem skladišču, robotizacija skladiščnih procesov, obogatena in virtualna resničnost, pametne palete in zaboji, umetna inteligenca, AGV in avtonomni mobilni roboti AMR, lokalizacija in navigacija). 4. Sistematična prostorska razvrstitev "layout" fleksibilnih proizvodnih in skladiščnih sistemov	1. Intralogistics (layout, automated and robotised storage, internal transport, workplace supply, and loading/unloading system, methodologies and analytical/numerical models, throughput performance and traceability). 2. Smart factories (smart products, machines and process, new business models "Batch size 1", concept of the working environment "Operator 4.0", smart factory flexible platform model). 3. Smart warehouses (process in a smart warehouse, robotisation of warehouse process, augment and virtual reality, smart pallets and bins, artificial intelligence, AGV and autonomous mobile robots AMR, localization and navigation). 4. Systematic layout planning of flexible production and storage systems (material flow diagrams, rough and fine layout planning, Sankey diagrams,

(diagrami toka materiala, grobo in fino planiranje, Sankey diagram, matrike toka materiala, DIJKSTRA algoritem, analitično in numerično modeliranje "layout-a" proizvodnih in skladiščnih sistemov).
5. Avtomatizirani skladiščni sistemi in mobilni roboti za podporo komisioniranju (avtonomni mobilni roboti AMR, kolaborativni mobilni roboti KMR, avtonomni viličarji AGV, analitični in numerični modeli za izračun učinkovitosti sistemov).
6. Simulacijsko modeliranje transportno-skladiščnih sistemov v intralogistiki (zvezna in diskretna optimizacija transportno-skladiščnih sistemov v intralogistiki, enojna- in več-objektna optimizacija, digitalni dvojček transportno-skladiščnega sistema).

material flow matrixes, DIJKSTRA algorithm, analytical and numerical layout planning of flexible production and storage systems).
5. Automated storage systems and mobile robots for supporting order-picking system (autonomous mobile robots AMR, collaborative mobile robots KMR, autonomous forklift trucks AGV, analytical and numerical model to determine the system performance).
6. Simulation modelling of transport and storage systems in intralogistics (discrete and continuous optimization of transport and storage systems in intralogistics, single- and multi-objective optimization, digital twin of transport and storage system).

Temeljni literatura in viri / Reading materials:

- E-gradivo predmeta.
- Lerher, T. (2021). Skladiščno-komisionirni sistemi. Univerza v Mariboru, Fakulteta za strojništvo.
- Lerher, T. (2021). Avtomatsko vodeni in avtonomni vozički ter mobilni roboti v intralogistiki. Univerza v Mariboru, Fakulteta za strojništvo.Heinrich, M. (2016). Transport- und Lagerlogistik: Systematik, Planung, Einsatz und Wirtschaftlichkeit. Springer Vieweg.
- Bartholdi, J.J., Hackman, S.T. (2017). Warehouse and distribution science, Release 0.98. The Supply Chain & Logistics Institute, H. Milton Stewart School of Industrial and Systems Engineering, Georgia Institute of Technology Atlanta, USA.
- Kay, M.G. (2016). Production system design. Department of Industrial and Systems Engineering, North Carolina State University, USA.
- Glock, C., Grosse, E. (2017). Warehousing 4.0 - Technische Lösungen und Managementkonzepte für die Lagerlogistik der Zukunft. B + G Wissenschaftsverlag.
- Stephens, M.P. (2019). Manufacturing Facilities Design & Material Handling: Sixth Edition (6th ed.). Purdue University Press. https://doi.org/10.2307/j.ctv15wxptd
- Tompkins, J.A., White, J.A., Bozer, Y.A., Tanchoco, J.M.A. (2011). Facilities Planning: Fourth Edition (4th ed). John Wiley & Sons Inc., New York, United States.

Cilji in kompetence:

Cilji predmeta:
- opredeliti vlogo sodobnih tehniških rešitev in njihovo uporaba v intralogistiki,
- predstaviti možne tehnično-tehnološke rešitve za uporabo v pametnih tovarnah in pametnih skladiščih,
- predstaviti primer načrtovanja in analize prostorske razvrstitve "layout-a" fleksibilnih proizvodnih in skladiščnih sistemov,
- pojasniti pomen uporabe avtomatiziranih in robotiziranih transportno-skladiščnih rešitev v pametnih tovarnah in pametnih skladiščih,
- opredeliti sistematični pristop pri reševanju različnih tehniških izzivov v intralogistiki,

Objectives and competences:

Objectives:
- to define the role of modern technical solutions and their application in intralogistics,
- to present possible technical-technological solutions for the application in smart factories and smart warehouses,
- to present layout planning and analysis of flexible production and storage systems,
- to explain the importance of automated and robotised solutions in smart factories and smart warehouses,
- to define a systematic approach to solving various technical challenges in intralogistics,

- predstaviti primer modeliranja in optimizacije intralogističnih sistemov z uporabo naprednih modelov in računalniško podprtih orodij,
- nadgraditi znanje na področju načrtovanja in razvoja novih modelov za reševanje izzivov intralogističnih sistemov.

Kompetence, ki jih študentje osvojijo:
- spoznati in razumeti delovanje različnih sodobnih tehnoloških rešitev v pametnih tovarnah in pametnih skladiščih,
- se usposobiti za izdelavo in analizo "layout-a" fleksibilnih proizvodnih in skladiščnih sistemov,
- se usposobiti za izbiro in implementacijo avtomatizirane in robotizirane transportno-skladiščne tehnike in tehnologije,
- se usposobiti za izbiro optimalnega transportnega sredstva pri skladiščenju, komisioniranju, oskrbi delovnih mest, pakiranju in stregi.
- sposoben je izdelati model tovarne ali skladišča ter simulirati, optimirati in analizirati transportne, skladiščne in oskrbne procese v intralogistiki.

- to present an example of modeling and optimization of intralogistics systems using advanced models and computer-aided tools,
- to upgrade knowledge in the field of planning and development of new models for solving the challenges of intralogistics systems.

Competences that students acquire:
- get familiar and to understand the operation of various modern technical solutions in smart factories and smart warehouses,
- gain the ability to perform and to analyse the layout of flexible production and storage systems.
- gain the ability to select and to implement automated and robitised transport and storage technical-technological solutions
- gain the ability to evaluate and select the optimal transport device for storing, order-picking, workplace supply, packaging and loading/unloading system.
- to be able to create a model of a factory or warehouse and to simulate, optimize and analyze transport, storage and supply processes in intralogistics.

Predvideni študijski rezultati:

Študent je ob zaključku predmeta zmožen:
- razumeti in kritično ovrednotiti priložnost uporabe sodobnih tehniških rešitev za izboljšavo procesov v intralogistiki,
- načrtovati, analizirati in ovrednotiti prostorsko razvrstitev "layout" fleksibilnih produkcijski in skladiščnih sistemov,
- načrtovati, analizirati in optimirati rešitve avtomatiziranih transportno-skladiščnih sistemov v intralogistiki,
- načrtovati in analizirati mobilni robotizirani sistem za podporo procesu komisioniranja,
- uporabiti standarde (ISO, EN) in tehnična priporočila (VDI, FEM) za modeliranje intralogističnih sistemov,
- aplicirati analitične modele in računalniško podprta orodja za modeliranje intralogističnih sistemov,
- oceniti potencial uporabe mobilnih avtonomnih vozičkov tudi na ostalih področjih priložnosti (uporaba v bolnišnicah, mestnih središčih, letališčih).

Intended learning outcomes:

At the end of the course, the student is able to:
- understand and critically evaluate the possibility of using modern technical solutions to improve processes in intralogistics,
- plan, analyse and evaluate layout of flexible production and storage systems,
- plan, analyse and optimize solutions of automated transport and storage systems in intralogistics,
- plan and analyse mobile robot systems to support the process of order-picking,
- use standards (ISO, EN) and technical guidelines (VDI, FEM) for modelling intralogistics systems,
- apply analytical models and computer supported tools for modelling intralogistics systems,
- assess the potential of mobile autonomous vehicles in other areas of opportunity (use in hospitals, city centers, airports).

Metode poučevanja in učenja:

Learning and teaching methods:

Predavanja: pri predavanjih študent spozna teoretične vsebine predmeta. Del predavanj se izvaja na klasični način v predavalnici, del pa v obliki e-predavanj (e-predavanja se lahko izvajajo na videokonferenčni način ali s pomočjo posebej v ta namen didaktično pripravljenih e-gradiv v virtualnem elektronskem učnem okolju). Vaje: pri vajah študent utrdi teoretično znanje in spozna aplikativne možnosti. Del vaj se izvaja na klasični način v laboratoriju, del pa v obliki e-vaj (e-vaje se lahko izvajajo na videokonferenčni način ali s pomočjo posebej v ta namen didaktično pripravljenih e-gradiv v virtualnem elektronskem učnem okolju).	Lectures: Students understand the theoretical frameworks of the course. Part of the lecture course is in a classroom while the rest is in the form of e-learning (e-lectures may be given via video-conferencing or with the help of specially designed e-material in a virtual electronic learning environment). Tutorials: Students enhance their theoretical knowledge and are able to apply it. Part of the seminar is in a laboratory while the rest is in the form of e-learning (e- tutorials may be given via video-conferencing or with the help of specially designed e-material in a virtual electronic learning environment).

Načini ocenjevanja:	Delež (v %) / Share (in %)	**Assessment methods:**
Način (pisni izpit, ustno izpraševanje, naloge, projekt): • Opravljene domače naloge. • Projektna naloga. • Pisni izpit (teoretično in praktično znanje).	 10 % 40 % 50 %	Method (written or oral exam, coursework, project): • Completed home-works. • Project work • Written examination (theoretical and practical knowledge).

Reference nosilca / Course coordinator's references:

LERHER, Tone, FICKO, Mirko, PALČIČ, Iztok. (2020). Throughput performance analysis of automated vehicle storage and retrieval systems with multiple-tier shuttle vehicles. Applied mathematical modelling. [Print ed.]. Available online 29 October 2020, str. 1-35, ilustr. ISSN 0307-904X. DOI: 10.1016/j.apm.2020.10.032. [COBISS.SI-ID 36277251].

LORENC, Augustyn, LERHER, Tone. (2020). PickupSimulo - prototype of intelligent software to support warehouse managers decisions for product allocation problem. Applied sciences. Vol. 10, iss. 23, str. [1]-29, ilustr. ISSN 2076-3417. https://doi.org/10.3390/app10238683, DOI: 10.3390/app10238683. [COBISS.SI-ID 41594883].

KÜÇÜKYAŞAR, Melis, EKREN, Banu Y., LERHER, Tone. (2020). Cost and performance comparison for tier-captive and tier-to-tier SBS/RS warehouse configurations. International transactions in operational research, ISSN 1475-3995. [Online ed.]. https://doi-org.ezproxy.lib.ukm.si/10.1111/itor.12864, doi: 10.1111/itor.12864. [COBISS.SI-ID 25139715].

RAJKOVIĆ, Miloš, ZRNIĆ, Nenad Đ., KOSANIĆ, Nenad, BOROVINŠEK, Matej, LERHER, Tone. (2019). A multi-objective optimization model for minimizing investment expenses, cycle times and CO2 footprint of an automated storage and retrieval systems. Transport, ISSN 1648-4142. [Print ed.], vol. 34, iss. 2, str. 275-286, ilustr. https://doi.org/10.3846/transport.2019.9686, doi: 10.3846/transport.2019.9686. [COBISS.SI-ID 512990781].

LERHER, Tone. (2018). Aisle changing shuttle carriers in autonomous vehicle storage and retrieval systems. International Journal of Production Research. Vol. 56, iss. 11, str. 3859-3879. ISSN 0020-7543. DOI: 10.1080/00207543.2018.1467060. [COBISS.SI-ID 21416470].