Warsaw University of Technology

COURSE OFFERED IN THE DOCTORAL SCHOOL

Code of the course	4606-ES-0AFGHIM-0165	Name of the course	Polish	Digital twins i digital shadows w transporcie, logistyce i produkcji
			English	Digital twins and digital shadows for transport, logistics and production
Type of the course	Specialty subjects			
Course coordinator	Mariusz Kostrzewski, Ph.D., D.Sc., – Associate Professor			
Implementing unit	Faculty of Transport	Scientific discipline / disciplines*	architecture and urban planning, civil engineering, geodesy and transport, environmental engineering, mining and energy, management and quality sciences, materials engineering, mechanical engineering	

Level of education	Doctoral studies	Semester	Summer semester		
Language of the course	English				
Type of assessment:	credit with a grade	Number of hours in a semester	15	ECTS credits	2
Minimum number of participants	10	Maximum number of participants	30	Available for students (BSc, MSc)	Yes/~~No~~

Type of classes		Lecture	Auditory classes	Project classes	Laboratory	Seminar
Number of hours	in a week		3			
	in a semester		15			

* does not apply to the Researcher's Workshop

1. Prerequisites

No requirements.

2. Course objectives

The aim of the course is to present the fundamental contexts and the discussion on the application of simulation methods in the modeling of processes for digital twins and digital shadows, in particular processes of logistics, transport, production, and technological processes. During the meetings, Ph.D. students will be introduced to the basic issues of applying simulation methods and developing simulation models, in particular for the mentioned processes. In addition, participants will work on their own simulation model on an ongoing basis, which will allow for continuous verification of the obtained results.

3. Course content (separate for each type of classes)

Auditory classes

Elements of modeling and simulation theory. Differences between digital twins, digital shadows and digital models. Classification of simulation models and selected methodological aspects of research using simulation models. IT tools applied to analyze processes of logistics, transport, production, and technological processes in simulation methods. Stages of building simulation models. The original applications of simulation models of selected elements of logistics, transport, production, and technological systems and processes. Other topics developed on an ongoing basis.

4. Learning outcomes

	Learning outcomes description	Reference to the learning outcomes of the WUT DS	Learning outcomes verification methods*
Knowledge			
K01	A participant gains a basic knowledge of simulation methods as a fundamental research methodology that covers theoretical foundations and selected specific	SD_W2	test

	issues appropriate to the discipline represented, including the latest scientific advances in the field of research.		
Skills			
S01	A participant gains a basic abilities of simulation methods as a fundamental research methodology in the disciplines represented in the doctoral school.	SD_U1, SD_U6, SD_U7	project evaluation, presentation evaluation
Social competences			
SC01	A participant learns selected ways of recognizing the importance of knowledge and scientific achievements in solving cognitive and practical problems.	SD_K2	presentation evaluation

*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests

5. Assessment criteria

The grade for the course will be obtained by the participant as a result of (1) passing the exam in the form of a test described below, and (2) constructing a simulation model for a process of logistics, transport, production or technological process of a participant's choice. Construction of a simulation model should be carried out taking into account the stages of construction presented during the meetings. The simulation model can be built in the simulation tools discussed during the classes. The simulation model together with the results will be presented to all participants of the course, as the audience. The presentation is obligatory, however, no separate points are awarded for it. The simulation model will be documented by a participant in the form of a written report showing the development of each stage of model construction with detailed example results. Up to 10 points will be awarded for each stage of the simulation model construction (data and parameters, conceptual model, simulation model, verification, validation, experimentation, and results; a total maximum of 60 points). At the end of the course, there will be an examination on the subject in the form of a choice or supplementary test. A maximum of 21 points can be obtained from the test.

The points obtained on the basis of the report and the test translate into the following grades: 0 - 40 points -> 2.0, 41 - 50 points -> 3.0, 51 - 60 points -> 3.5, 61 - 70 points -> 4.0, 71 - 76 points -> 4.5, 77 - 81 points -> 5.0.

6. Literature

Basic:

[1] Bangsow, S. Manufacturing Simulation with Plant Simulation and SimTalk. Usage and Programming with Examples and Solutions. Berlin Heidelberg: Springer-Verlag, 2010. ISBN 9783642050732

[2] Bangsow S.: Tecnomatix Plant Simulation. Modeling and Programming by Means of Examples. Springer International Publishing Switzerland 2015. ISBN 978-3-319-19502-5

[3] Kostrzewski M., Modelowanie i badanie wybranych elementów i obiektów logistycznych z wykorzystaniem metod symulacyjnych (ISBN 978-83-7814-750-3), Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2018.

Additional:

[1] Kosacka-Olejnik, M.; Kostrzewski, M.; Marczewska, M.; Mrówczyńska, B.; Pawlewski, P. How Digital Twin Concept Supports Internal Transport Systems?—Literature Review. Energies 2021, 14, 4919. https://doi.org/10.3390/en14164919

[2] Kostrzewski, M. Sensitivity Analysis of Selected Parameters in the Order Picking Process Simulation Model, with Randomly Generated Orders. Entropy 2020, 22, is. 4, 423, pp. 1021. https://doi.org/10.3390/e22040423

7. PhD student's workload necessary to achieve the learning outcomes**

No.	Description	Number of hours
1	Hours of scheduled instruction given by the academic teacher in the classroom	15
2	Hours of consultations with the academic teacher, exams, tests, etc.	5

3	Amount of time devoted to the preparation for classes, preparation of presentations, reports, projects, homework	25
4	Amount of time devoted to the preparation for exams, test, assessments	15
	Total number of hours	**60**
	ECTS credits	**2**

** 1 ECTS = 25-30 hours of the PhD students work (2 ECTS = 60 hours; 4 ECTS = 110 hours, etc.)

8. Additional information	
Number of ECTS credits for classes requiring direct participation of academic teachers	1
Number of ECTS credits earned by a student in a practical course	1