**COURSE OFFERED IN THE DOCTORAL SCHOOL**

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| Code of the course | | 4606-ES-00000BC-0032 | | | Name of the course | | | Polish | | | Metody optymalizacji | | | | |
| English | | | **Optimization Methods (**OPME) | | | | |
| Type of the course | | specialized | | | | | | | | | | | | | |
| Course coordinator | | dr hab. inż. Artur Tomaszewski, prof. uczelni | | | | | | | | | | | | | |
| Implementing unit | | WEiTI | | | Scientific discipline / disciplines\* | | |  | | | | | | | |
| Level of education | | | Doctoral studies | | | Semester | | | Winter | | | | | | | |
| Language of the course | | | English | | | | | | | | | | | | | |
| Type of assessment: | | | Graded credit | | | Number of hours in a semester | | | 60 | | | ECTS credits | | | 5 | |
| Minimum number  of participants | | | 10 | | | Maximum number of participants | | | 24 | | | Available for students  (BSc, MSc) | | | Yes/~~No~~ | |
| Type of classes | | | | Lecture | | | Auditory classes | | | Project classes | | | Laboratory | Seminar | | |
| Number of hours | in a week | | | 1 | | | 1 | | | 1 | | | 1 | 0 | | |
| in a semester | | | 30 | | | | | | 15 | | | 15 | 0 | | |

\* does not apply to the Researcher’s Workshop

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| 1. Prerequisites | | | | |
| Fundamentals of programming and algorithms, basic notions of calculus, algebra, set theory, discrete mathematics. | | | | |
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| 1. Course objectives | | | | |
| Introduce the subject, making students familiar with concepts, theory, methods and tools of linear and integer programming, and of combinatorial optimization, and their application in operations research related to diverse domains: computer, road, railway and utility networks; transportation and logistics; resource, system and process management; job scheduling and crew assignment, etc. A particular area of application is optimisation of intelligent complex systems SoS (System-of-Systems) – autonomous interacting technology-intensive systems, communicating and interacting with the environment, involved in real-time decision-making – computer networks, mobile networks, sensor networks (potentially utility networks as well), and systems providing services and applications in those networks – in particular, 5G and Internet of Things services, targeting problems of design, management and real-time control of systems related to structure optimisation, resource allocation, job scheduling, etc. | | | | |
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| 1. Course content (separate for each type of classes) | | | | |
| Lecture | | | | |
| Optimization problem. Application examples of linear and integer programming.  Elements of convex analysis; separation theorem.  Linear Programming (LP) problem; formulation, feasible set, basic solutions, solution approaches. Applications. Problem modelling and formulation examples. Simplex algorithm and its variants. Linear programming duality. Constraint generation. Column generation algorithm; restricted master and pricing problems.  Elements of complexity theory; NP-completeness.  Integer Programming (IP) problem: formulation, characteristics. Applications. Problem modelling and formulation examples. Strong formulations and relaxations. Cutting plane method. Branch and bound algorithm and its variants. Lagrangean relaxation method. | | | | |
| Laboratory | | | | |
| Mathematical modeling language AMPL and its environment. Problem formulation, and declarative and procedural programming in AMPL. Problem solving and problem management in the AMPL environment.  Linear and integer programming solvers – CPLEX and GUROBI. Solver configuration and AMPL problem solving. Programming environments and native libraries of the solver. Basic linear and integer programming with solvers. Advanvced integer programming with solvers – management of constraints, cuts, solutions. | | | | |
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| 1. Learning outcomes | | | | |
|  | Learning outcomes description | Reference to the learning outcomes of the WUT DS | Learning outcomes verification methods\* | |
| Knowledge | | | | |
| K01 | Ma wiedzę z zakresu podstaw teoretycznych optymalizacji liniowej. | SD\_W2, SD\_W3 | active participation during classes,  homework,  written test | |
| K02 | Ma wiedzę na temat metod i algorytmów obliczeniowych optymalizacji liniowej oraz ich skuteczności. | SD\_W2, SD\_W3 | active participation during classes,  homework,  written test | |
| K03 | Ma wiedzę z zakresu podstaw teoretycznych optymalizacji całkowitoliczbowej. | SD\_W2, SD\_W3 | active participation during classes,  homework,  written test | |
| K04 | Ma wiedzę na temat metod i algorytmów obliczeniowych optymalizacji całkowitoliczbowej oraz ich skuteczności. | SD\_W2, SD\_W3 | active participation during classes,  homework,  written test | |
| Skills | | | | |
| S01 | Potrafi formułować zagadnienia projektowania systemów i procesów jako zadania optymalizacyjne i komunikować się na ich temat. | SD\_U1, SD\_U4, SD\_U6 | active participation during classes,  homework, written test, report evaluation | |
| S02 | Potrafi wykorzystywać języki, środowiska i narzędzia  modelowania i rozwiązywania problemów optymalizacyjnych (liniowych, całkowitoliczbowych, kombinatorycznych) i komunikować się na ich temat. | SD\_U1, SD\_U4, SD\_U6 | active participation during classes, homework, written test, report evaluation | |
| Social competences | | | | |
| SC01 | Rozumie rolę badań operacyjnych w optymalizacji systemów i procesów różnych dziedzin oraz ma świadomość znaczenia i zakresu stosowania metod optymalizacji (liniowej, całkowiitoliczbowej, kombinatorycznej) w tym zakresie. | SD\_K2 | active participation during classes | |
| \*Allowed learning outcomes verification methods: exam; oral exam; written test; oral test; project evaluation; report evaluation; presentation evaluation; active participation during classes; homework; tests | | | | |
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| 1. Assessment criteria | | | | |
| Results of the written test, homeworks, laboratories and project will produce the final grade. | | | | |
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| 1. Literature | | | | |
| Basic References:  [1] S. Bradley, A. Hax, T. Magnanti, “Applied Mathematical Programming”, Addison-Wesley, 1977  [2] L. Wolsey, “Integer Programming”, Wiley, New York, 1998  [3] R. Fourer, D. Gay, B. Kernighan, “AMPL: A Mathematical Programming Language”, Management Science 36 (1990), 519–554  Additional references:  [1] A. Schrijver, “Theory of Linear and Integer Programming”, Wiley, New York, 1998  [2] G. Nemhauser, L. Wolsey, “Integer and Combinatorial Optimization”, Wiley, New York, 1998 | | | | |
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| 1. 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 | | | 60 |
| 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 | | | 70 |
| 4 | Amount of time devoted to the preparation for exams, test, assessments | | | 5 |
| **Total number of hours** | | | | **140** |
| **ECTS credits** | | | | **5** |
| \*\* 1 ECTS = 25-30 hours of the PhD students work (2 ECTS = 60 hours; 4 ECTS = 110 hours, etc.) | | | | |