Description of course	
Code	
Name	**Intelligent Measurement and Modelling Systems in Transport**
Version	2025/26
A. Place of the course in system of studies	
Level of education	Second cycle programme
Form and mode of studies	full-time study (onsite / remote classes)
Field of studies	Transport
Profile	General academic profile
Specialisation	Main field
Place of teaching of course	Division of Information and Mechatronic Systems in Transport
Place of realization of course	Warsaw University of Technology, Faculty of Transport
Coordinator	Phd Piotr Jaskowski
B. General characteristic of the course	
Block of courses	
Group of courses	
Level of course	
Language of course	English
Nominal semester	
Preliminary requirements	no
Limit of students	
C. Effects of education and manner of teaching	
Purpose of course	This course aims to equip students with comprehensive knowledge and practical skills in designing, implementing, and analysing intelligent measurement systems and stochastic modelling methods as applied in modern transport systems. This includes understanding and manipulating physical signals, selecting and configuring appropriate sensors, applying stochastic data interpretation techniques, and supporting data-driven decision-making in uncertain and dynamic transport environments. The course emphasises real-world applicability in intelligent transport systems (ITS), autonomous vehicles, infrastructure diagnostics, and traffic monitoring. By completing this course, the student will: • Integrate theory with practice by applying sensor data and stochastic models to real-world transport problems. • Gain proficiency in simulation tools (e.g., AIMSUN, Matlab, Python, LabView) for signal processing and system modelling. • Develop analytical thinking and problem-solving skills through practical projects and data-driven tasks. • Prepare for work in advanced ITS environments, including smart infrastructure, vehicle autonomy, and traffic control. • Enhance employability by acquiring high-demand technical competencies in measurement systems and uncertainty modelling. • Strengthen teamwork and project development abilities through collaborative lab and design activities The course is designed to equip students with theoretical and practical knowledge in intelligent measurement systems and stochastic modelling, focusing on transport applications. Students will gain skills in signal acquisition, sensor integration, stochastic analysis, transport system simulation, and professional tools like AIMSUN for microscopic and macroscopic traffic modelling. The course prepares students for engineering roles involving autonomous transport systems, innovative infrastructure, and predictive traffic management under uncertain and dynamic conditions.
Effects of education	See Table 1
Form of didactic studies and number of hours per week	Lecture: 1 Exercise type of course: -

<table>
<tr><td rowspan="2"></td><td>Laboratory</td><td>1</td></tr>
<tr><td>Project type of course</td><td>2</td></tr>
<tr><td>Contents of education</td><td colspan="2">
1. Signal and measurement system fundamentals:
• Classification and characteristics of physical signals.
• Sensor types (contact and non-contact) and their transport applications.
• Sensor calibration, error analysis, and uncertainty quantification.
• Signal preprocessing and conditioning (amplification, filtering, sampling).
2. Measurement system architecture:
• Design and implementation of intelligent measurement chains.
• Serial and wireless communication standards.
• ADC conversion principles, sampling theory, and resolution trade-offs.
• 3D measurement methods in transport diagnostics.
3. Stochastic process theory and applications:
• Introduction to stochastic processes: Bernoulli, Poisson, Wiener, Gaussian, Markov.
• Stationary vs. non-stationary processes, ergodicity, and continuity.
• Modelling of signal noise, randomness, and probabilistic system behaviours.
• Frequency domain analysis of stochastic signals (Fourier and spectral analysis).
4. Modelling and simulation of transport systems:
• Introduction to transport modelling principles:
○ Macroscopic, mesoscopic, and microscopic modelling approaches.
○ Simulation vs. analytical methods in transport analysis.
• AIMSUN simulation platform:
○ Basics of network building, demand modelling, and signal control logic.
○ Integration of real-time data into simulations (e.g., from sensors, detectors).
○ Scenario development: urban traffic flow, incidents, and ITS policies.
• Calibration and validation of simulation models.
• Coupling measurement data with AIMSUN for adaptive transport modelling.
5. Inference and filtering under uncertainty:
• Kalman filters and Bayesian estimation in dynamic systems.
• Hidden Markov Models (HMMs) for state prediction.
• Dempster-Shafer theory for reasoning with incomplete data.
• Kramers-Moyal and Fokker-Planck equations for dynamic transport modelling.
6. Applications in intelligent transport systems:
• Smart sensor networks for road traffic and rail systems.
• Data fusion techniques for vehicle automation and infrastructure monitoring.
• Real-time traffic prediction and adaptive signal control.
• Diagnostics of transport infrastructure using stochastic signal modelling.
7. Practical implementation and tools:
• Software platforms: Matlab, R, AIMSUN, Microsoft Office.
• Signal filtering and transformation (FFT, convolution, digital filtering).
• Project-based simulations (traffic control, vehicle interaction, bottleneck analysis).
• Group project: Design, simulate, and evaluate a transport system using real or simulated data.
8. Integration and project work:
• Team development of a prototype intelligent system (e.g., predictive traffic control, vibration-based maintenance alert).
• Simulation validation using AIMSUN and measured signal input.
• Technical documentation and oral defence of the final project.
• Focus on interdisciplinary teamwork, innovation, and application to real transport challenges.
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<tr><td>Methods of education</td><td colspan="2">
• Lectures enriched with multimedia presentations and live sketching.
• Computer labs using AIMSUN, Matlab, R.
• Team-based project work with supervisor consultation.
• Case study analysis of real-world transport systems using stochastic data modelling.
• Individual and group discussions to promote critical thinking.
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Methods of evaluation	• Midterm Test (20%) – Theoretical understanding of signal theory and stochastic principles. • Lab Reports (30%) – Practical exercises on data acquisition, modelling, and analysis. • Final Project (30%) – Team-based modelling and implementation with oral presentation. • Final Test(20%) – Written exam evaluating integration of knowledge and practical understanding.
Methods of verification of the effects of education	• Written assessments (midterm + final) for theoretical knowledge. • Lab reports and project documentation for practical skills. • Oral presentation and Q&A for soft skills and applied comprehension. • Instructor observation during labs for collaboration and engagement.
Exam	No
Literature:	**Required Reading:** • Pallas-Areny, R., & Webster, J. G. (2022). *Sensors and Signal Conditioning* (3rd Edition, Reissued). Wiley. • Dixit, A., & Sharma, R. (2022). *Stochastic Differential Equations: Theory and Applications*. CRC Press. • Barceló, J. (Ed.) (2020).*Fundamentals of Traffic Simulation: AIMSUN and Microscopic Simulation (2nd Edition).* Springer. • Bentley, J.P. (2005). *Principles of Measurement Systems*. Pearson. **Recommended Reading:** • Tapkın, S., & Çelik, H. (2023). *Smart Urban Transport: Modeling, Planning, and Simulation*. Springer. • Chen, C., et al. (2021). *Data Analytics for Intelligent Transportation Systems*. Elsevier. • Papoulis, A. (2012) *Probability, Random Variables and Stochastic Processes*, McGraw-Hill. • Brzeźniak, Z. & Zastawniak, T. (2002). *Basic Stochastic Processes*, Springer. • Bouleau, N. & Lepingle, D. (1993). *Numerical Methods for Stochastic Processes*, Wiley.
www	
D. Student's activity	
Number of ECTS points	8
Number of hours of a student's job for the achievement of the education effect (description):	Participation in lectures 15 h Participation in laboratory/computer classes 15 h Involvement in project work 30 h Literature study and preparation for tests 40 h Development of lab reports 30 h Final exam preparation 30 h
Number of credits ECTS on the course with the direct participation of academic teacher	3
Number of credits ECTS on practical activities on the course	3
E. Additional information	
Notes	As long as it does not cause changes in the relationship of a given subject with the directional effects in the content of education, changes may be introduced on an ongoing basis, taking into account the latest scientific achievements.
Date of last edition	13.06.2025
Table 1. General academic profile	

Effect:	Field effects	Verification:	Area effect
Knowledge			
Has a basic knowledge of stochastic processes. He knows symbols, basic concepts, theorems, and examples of stochastic processes. Knowledge of the theory of signals and their basic characteristics in the time and frequency domains.	W01	Lecture tests	Tr2A_W01, Tr2A_W07
He knows the basic applications of the theory of stochastic processes in analysing signals.	W02	Lecture tests	Tr2A_W01, Tr2A_W10,
Has detailed knowledge of digital-to-analogue processing.	W03	Lecture tests	Tr2A_W07, Tr2A_W11
He knows the rules of inference under conditions of uncertainty when applying dynamic Bayesian networks to direct transport systems.	W04	Lecture tests Lab reports	Tr2A_W01, Tr2A_W10
Knowledge of selecting sensors, measuring transducers, and the correct work and calibration conditions.	W05	Lecture tests Lab reports	Tr2A_W07, Tr2A_W11
Skills			
He can formulate and solve simple problems of applying the theory of stochastic processes.	U01	Lab reports Project report	Tr2A_U03
He can use information from literature and use Internet databases	U02	Lab reports Project report	Tr2A_U01
It can synthesise the measurement path using computer techniques.	U03	Lab reports Project report	Tr2A_U06
Can estimate selected characteristics and interpret the results.	U04	Lab reports Project report	Tr2A_U06
I can cooperate with other people during teamwork and take the lead in a team.	U05	Lab reports Project report	Tr2A_U20
Social competences			
Understands the need for continuous training and refreshing the acquired knowledge, in particular in	KS01	Lab reports Project report	Tr2A_K01

the field of stochastic processes			
Can think and act in a creative and enterprising way.	KS02	Lab reports Project report	Tr2A_K04