KTH Industriell teknik och management

Course Syllabus ML2302 VT21

Course name: Modelling, Simulation and Optimization of Sustainable Production

Course code: ML2302

HP/ECTS:	9.0
Teachers:	- Albin Eriksson Östman (albin01@kth.se) - Károly Szipka (szipka@kth.se) - Amita Singh (amitas@kth.se) - Yongkuk Jeong (Jake) (yongkuk@kth.se) (course responsible) - Jannicke Baalsrud Hauge (jmbh@kth.se)
Industry engagement:	- Problem owner for course project task as well as input for the labs - Guest lectures from industry for the project work
Examiner:	Jannicke Baalsrud Hauge
Grading:	A-F
Language:	English

Learning objectives and course content

Intended learning objectives (ILOs) of the course (Swedish is binding- the English is the corresponding non-binding translation).

Upon successful completion of this course, the student shall be able to:

- (ILO1) Describe the central elements in and main application fields for modelling, simulation and optimisation at development of sustainable production and logistic.
- (ILO2) Apply analytical heuristic and experimental methods and tools to analyse resource and flow efficiency of system for sustainable production and logistic.
- (ILO3) Create analyse and critically evaluate different production and logistics solutions by modelling, simulate optimise and evaluate developments also with limited information, as well as considering sustainable development and to the preconditions and needs of people.
- (ILO4) Reflect on difficulties with to model simulate and optimise during the different stages in a development process regarding production and logistic.

- (ILO5) Reflect on role of modelling simulation and optimisation in a future development towards a digitalized production and logistic.

Course main content

Course's major aim is to convey an understanding of analytical, heuristic and simulation based methods for the analysis of production and logistics systems with industrial application fields and needs. This will prepare the students for tasks as developers of a sustainable production and logistics operations.

The work in the course is built around lectures, laboratory sessions and project work concerning course's central fields. Through the laboratory sessions students will get acquainted with a number of methods to analyse typical problems regarding resource and flow efficiency of system for production and logistic. Furthermore, by using different simulation software, the laboratories will convey an understanding of the advantages/disadvantages, opportunities and limitations of different software for simulating resource- and flow efficiency of system for production and logistic. Through a project work the students obtain an understanding of how a simulation model is designed, verified and validated and how this thereafter can be a basis for relevant experiments, analysis and conclusions. Students will train on reflecting on difficulties experienced during the different stages of a simulation study and to identify and analyse requirements that are imperative for implementation. The course creates also a basis for the analysis of environmental and social aspects at modelling simulation and optimisation of production and logistic.

The student will get an introduction to four different simulation tools as lab exercises: Arena, Anylogic, MATLAB, and SUMO

Disposition

The course is delivered in several formats including: lectures, group exercises (project work) and lab activities. Guest lectures are held on selected topics as a part of the project work and related topics from both industry and academia. Students shall communicate their understanding of the subject matter through oral presentation, written project reports, as well as providing logically coherent reflections in INL1 as well as in the project reports.

Course assessment and grading

Assessment

INL1 - Assignment, 3.0 credits, Grading scale: A, B, C, D, E, FX, F

LAB1 - Laboratory work, 2.0 credits, Grading scale: P, F

PRO1 - Project work, 4.0 credits, Grading scale: A, B, C, D, E, FX, F

Final grade and grading details

INL1 PRO1	A	B	C	D	E	F
A	A	B	B	C	C	F
B	B	B	C	C	D	F
C	B	C	C	D	D	F
D	C	C	D	D	E	F
E	C	D	D	E	E	F
F	F	F	F	F	F	F

The INL1 is divided in two parts (INL1a and INL1b) and it is individual work. The Lab exercises are examination on site. A supplementary protocol answering a set of relevant questions needs to be submitted at individual basis in Canvas. Each lab module needs to be passed in order to pass this examination moment.

The project work is a group delivery. It is scored based on the written report and the final presentation. The contribution of each group member to the assessed ILOs (ILO 3 & 5) needs to be clearly stated in the report and in the project presentation and will be assessed according to expectation of what 120h work for each student should comprise.

Based on recommendation from KTH's coordinator for disabilities, the examiner will decide how to adapt an examination for students with documented disability.

The examiner may apply another examination format when re-examining individual students.

Course is assessed through a written assignment compulsory laboratory session concerning methods and tools as well as through project work where student should show his ability to analyse different solutions based on a broad evaluation.

Grading criteria

The overall grading of the course shall be a combination of INL1 and PRO1 according to the rule set in the table below. The final passing grade is assigned on condition that all mandatory activities are completed.

ILOs	INL1	LAB1	PRO1
ILO1	X		
ILO2		X	
ILO3			X
ILO4	X		
ILO5			X

ILO1 (INL1)

ILO1 is examined with grading scale E/F.

Grade E:

- The student can use concepts and choose methods from the different areas of the course, to describe and solve small/standard problems within the realm of the course.

ILO4 (INL1)

ILO4 is examined with grading scale A, B, C, D, E, FX, F.

Grade E:

- The student can reflect on the choices, trade-offs, and difficulties, in a modelling and simulation process. The reflections uses some concepts and standard interpretations. The reflections are well structured, and relates to relevant theory and analytical methods in a mostly correct way.

Grade D:

- The student fulfils the criteria for grade E and mostly for grade C.

Grade C:

- The student can, on a more complex level, reflect on the choices, trade-offs, and difficulties, in a modelling and simulation process. The reflections uses several

concepts and/or complex interpretations. The reflections are well structured, and relates to relevant theory and analytical methods in a correct way.

Grade B:

- The student fulfils the criteria for grade C and mostly for grade A.

Grade A:

- The student can, on a complex level, reflect on the choices, trade-offs, and difficulties, in a modelling and simulation process. The reflections uses several concepts and/or complex interpretations. The reflections are well structured, and relates to relevant theory and analytical methods in a correct and precise way.

ILO2 (LAB1)

ILO2 examined with grading scale P (Pass) and F (Fail).

Grade P (Pass):

- The student understands how the main features of the different simulation tools can be used for analysing resources and flow efficiency of systems.
- The student is able to apply the features in an efficient and suitable way to given examples.
- The student can sufficiently well-structured apply analytical heuristic and experimental methods with modelling, simulation and optimization tools addressing specific given problems.

ILO3 (PRO1)

INL3 examined with grading scale A, B, C, D, E, FX, F.

Grade E:

- The student can explain the strengths and weaknesses of different alternative solutions to a given problem related to the simulation modelling process as a whole.
- The student can provide an abstract model considering the limited information and the preconditions.

Grade D:

- The student fulfils the criteria for grade E and mostly for grade C.

Grade C:

- The student is able to methodically and structured analyse strengths and weaknesses of different solutions.
- The student can interpret the limited information and the requirements and provide solutions with appropriate stochastic distribution through rational assumptions.

Grade B:

- The student fulfils the criteria for grade C and mostly for grade A.

Grade A:

- The student can systematically analyse the preconditions and requirements of the given problem, and provide a thinking process for the structural abstract model.
- The student can provide not only a rational abstract model but the optimal alternative and quantitatively compare different solutions with appropriate indicators.

ILO5 (PRO1)

INL5 examined with grading scale A, B, C, D, E, FX, F.

Grade E:

- The student can provide and justify alternatives to solve the problems of production and logistics by using limited use of modelling, simulation and optimization methods.

Grade D:

- The student fulfils the criteria for grade E and mostly for grade C.

Grade C:

- The student can present alternatives to solve the problems of production and logistics by using modelling, simulation and optimization methods and discuss the disadvantages and advantages of the different alternatives.
- The student can explain the role and impact of modelling, simulation, and optimization in solving problems and presenting alternatives in production and logistics.

Grade B:

- The student fulfils the criteria for grade C and mostly for grade A.

Grade A:

- Analytical, well-structured and methodically evaluate the chosen approach for solving the given problem in terms of the limitations and opportunities both of the process as well as of the given simulation tool.
- Discuss and argue on the suitability of the developed simulation (or optimisation) models in relation to the theoretical foundation of simulation, modelling and optimisation methods and the selection of the most suitable one.

Examination

INL1

- INl1 is examined in two parts INL1a and INL1b. INL1a examines ILO1, and INL1b examines ILO4. The grade for INL1 is determined by the grade on INL1b, provided you get an E on INL1a.
- INL1a is composed of (add number) exercises. Each exercise is graded with either E or F, according to the grading criteria for ILO1. To get an E on INL1a you need an E on each exercise. If you get an F on one or more exercise, you will have a second chance to hand in INL1a. If you are late for the first submission, you only get the second chance to submit (see schedule below).
- INL1b is composed of 4 exercises. Each exercise is graded with 0, 1, 2 or 3 points, according to the grading criteria for ILO4 (E=1, C=2, A=3). To get an E (or better) on INL1b you need a 1 (or better) on each exercise. If you get a 0 on one or more exercise, you will have a second chance to hand in INL1b. If you are late for the first submission, you only get the second chance to submit (see schedule below).
- The following table shows how the grade on INL1b is determined provided you have at least one point on each exercise.

Points	Grade
4-5	E
6	D
7-8	C
9-10	B
11-12	A

LAB1

- LAB1 is examined in five lab sessions which are AnyLogic, Arena, SUMO1, SUMO2, and MATLAB.

- Each lab session has a quiz and a report. The quiz focuses on making sure that students have learned enough of the materials provided in advance. The quiz must be submitted prior to the lab session, and only students who pass the quiz can participate in the lab session.
- The report focuses on whether you can use the tools you have learned to answer given questions. You need to submit the report with the appropriate answers within the time given. If you do not pass, you will have a second chance to submit the report.
- To get "Pass" in LAB1, the student must get "Pass" in every lab session. In order to get the final grade for the course, “Pass” from the LAB1 is required.

PRO1

- PRO1 examined by final report and simulation model. The students have the opportunity to supplement the final report and simulation model through supervision, workshop, and final presentation.
- The following table shows how the grades from ILO3 and ILO5 are combined for the final grade from PRO1.

ILO3 / **ILO5**	**A**	**B**	**C**	**D**	**E**	**F**
A	A	B	B	C	C	F
B	A	B	C	C	D	F
C	B	B	C	D	D	F
D	B	C	C	D	E	F
E	C	C	D	E	E	F
F	F	F	F	F	F	F

Course literature

Selected book

Main book will be Jerry Banks et al.: Discrete-event system simulation, 5.th edition,

Paperback, Publisher: Pearson Education Limited; 5th edition,
ISBN-10: 1292024372, ISBN-13: 978-1292024370

In addition, there will be a set of articles for specific area that are not sufficiently covered in the main book as well as information related software.

Adapted examination for students with disabilities

The application for compensatory assistance in case of disability is made via KTH FUNKA, more information can be found via the link:

https://www.kth.se/en/student/studentliv/funktionsnedsattning/stod-for-studenter-med-funktionsnedsattning-1.39736

For students with disabilities who have a statement from KTH's FUNKA unit on recommended support measures in the examination, the following applies in this course:

All support actions under code R (i.e. adjustments relating to space, time and physical circumstances) are granted without special decision by the examiner

Support measures under code P (educational adaptation) must be actively granted or rejected by the examiner after contact has been made by the student in accordance with KTH's rules. Normally, support actions under code P will also be approved.

Schedule

Week	Date	Time	Type	Hours	Topics
2021 03	21-Jan	08:00-12:00	Lecture #1 (**online**)	2	- Course Introduction (ILOs, planned schedule, course structure) - Overview of simulation software
				2	- **Textbook** Chapter 1-4 (Typical logistics problems and different approaches)
		- **INL 1a** (Submission date: Feb 15 at 11.59 PM, Resubmission date: Mar 17 at 11.59 PM)			
2021 04	26-Jan	08:00-12:00	Lecture #2 (**online**)	1	- **Guest lecture** Project description – Scania case
				1	- **Guest lecture** Project description – AstraZeneca case
				1	- **Textbook** Chapter 5 (Summary and statistical models in simulation)
				1	- **Textbook** Chapter 5.3 and 5.4 (Particular distribution)
	27-Jan	08:00-12:00	Lab #1A	4	- **AnyLogic A**** Supply chain and transportation simulation, results analysis
		13:00-17:00	Lab #1B	4	- **AnyLogic B**** Supply chain and transportation simulation, results analysis
2021 05	02-Feb	08:00-12:00	Lecture #3 (**online**)	2	- **Textbook** Chapter 6 (Queuing theory and models)
				1	- Sensitive analysis (additional materials will be provided)
				1	- **Textbook** Chapter 9 (Input modeling 1)
	03-Feb	08:00-12:00	Lab #2A	4	- **Arena A**** Input data modeilng, queuing model, results analysis
	04-Feb	08:00-12:00	Lab #2B	4	- **Arena B**** Input data modeilng, queuing model, results analysis
2021 06	08-Feb	08:00-12:00	Study visit #1A	4	- **Study visit 1A***** Scania or AstraZeneca
		13:00-17:00	Study visit #1B	4	- **Study visit 1B***** Scania or AstraZeneca
	10-Feb	08:00-12:00	Lab #3A	4	- **SUMO 1A**** Basic modeling
	11-Feb	08:00-12:00	Lab #3B	4	- **SUMO 1B**** Basic modeling
2021 07	16-Feb	08:00-12:00	Lecture #4 (**online**)	1	- **Textbook** Chapter 9 (Input modeling 2)
				2	- Optimization thoughts (analytical models and heuristics), simulation modeling
				1	- **Textbook** Chapter 10 (Verification, calibration and validation)
	17-Feb	08:00-12:00	Lab #4A	4	- **SUMO 2A**** Urban logistics simulation and sustainability
		13:00-16:00	Supervision (**online**)	3	- Supervision for the project work
	18-Feb	08:00-12:00	Lab #4B	4	- **SUMO 2B**** Urban logistics simulation and sustainability
2021 08	22-Feb	08:00-12:00	Study visit #2A	4	- **Study visit 2A***** Scania or AstraZeneca
		13:00-17:00	Study visit #2B	4	- **Study visit 2B***** Scania or AstraZeneca
	23-Feb	08:00-12:00	Lab #5A	4	- **MATLAB A**** Fault detection for industrial, remaining life time estimation, safety and risk
	24-Feb	08:00-10:00	Lecture #5 (**online**)	2	- **Textbook** Chapter 11 (Estimation of absolute performance)
		15:00-17:00	Lecture #6 (**online**)	2	- **Textbook** Chapter 12 (Estimation of relative performance)
	25-Feb	08:00-12:00	Lab #5B	4	- **MATLAB B**** Fault detection for industrial, remaining life time estimation, safety and risk
2021 09	02-Mar	08:00-12:00	Lecture #7 (**online**)	2	- Calibration and validation from industrial cases
				2	- **Guest lecture** Probabilistic optimization and applications

	03-Mar	08:00-12:00	Lecture #8 (**online**)	2	- **Textbook** Chapter 13.3 (Issues in manufacturing and material handling simulations)
				2	- **Guest lecture** industrial cases
	04-Mar	08:00-12:00	Workshop (**online**)	4	- Summary and feedback of the project work
		- **INL 1b** (Submission date: Mar 17 11.59 PM)			
2021 11	17-Mar	08:00-18:00	Presentation (**online**)	10	- **Final presentation**
	18-Mar	- **PRO1** Final project report and simulation models submission (11.59 PM)			

*Some of on-site sessions can be changed to online session according to the KTH recommendations. But the lab sessions should be conducted on-site because of the examination.

**The students will be separated into two groups due to limited number of people in the lab.

***Study visit groups are divided into Scania and AstraZeneca groups according to the assigned project work. Depending on the industrial partner and KTH recommendations, it can be replaced with a virtual visit or divided into morning/afternoon visits.

Link for the distance lectures

- Lecture #1 (Jan 21) https://kth-se.zoom.us/j/63859753393
- Lecture #2 (Jan 26) https://kth-se.zoom.us/j/68304991208
- Lecture #3 (Feb 2) https://kth-se.zoom.us/j/66659609186
- Lecture #4 (Feb 16) https://kth-se.zoom.us/j/67666025096
- Supervision (Feb 17) https://kth-se.zoom.us/j/63739271004
- Lecture #5 (Feb 24) https://kth-se.zoom.us/j/69043997680
- Lecture #6 (Feb 24) https://kth-se.zoom.us/j/65565939931
- Lecture #7 (Mar 2) https://kth-se.zoom.us/j/68154228111
- Lecture #8 (Mar 3) https://kth-se.zoom.us/j/67018043334
- Workshop (Mar 4) https://kth-se.zoom.us/j/63919054763
- Presentation (Mar 17) https://kth-se.zoom.us/j/62250701642