# WP 2 - Curriculum Development I: Curriculum Structure and Courses

# Outcome 2.2 - Syllabuses for all courses in the curriculum

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| **Project Acronym:** | MSIE 4.0 |
| **Project full title:** | Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry |
| **Project No.:** | 586137-EPP-I-2017-I-TH-EPPKA2-CBHE-JP |
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| **Coordinator:** | AIT |
| **Work Package:** | WP2 – Curriculum Development I: Curriculum Structure and Courses |
| **WP Leaders:** | Tomasz Nitkiewicz (CUT) and Pisut Koomsap (AIT) |
| **Task Title:** | Task 2.2. Developing courses and course learning outcomes based on a matrix that maps course learning outcomes with program learning |
| **Task Leader:** | Tomasz Nitkiewicz (CUT) |
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REVISION SHEET

| Version | Date | Author (Partner/Person) | The revision reason |
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| 1 | 08/04/2019 | CUT / Tomasz Nitkiewicz<br>AIT / Pisut Koomsap<br>AIT / Duangthida Hussadintorn Na Ayutthaya<br>Course Teams | First draft version of WP2 Task 2.2 - Outcome 2.2. Include contributions from all Course Teams and consisted of working versions of all the syllabuses for mid-term reporting purposes only. |
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| 3 | 23/04/2020 | CUT / Tomasz Nitkiewicz<br>AIT / Pisut Koomsap<br>Course Teams | Third draft version of WP2 Task 2.2 - Outcome 2.2. Include contributions from the courses 3, 5, 6, 11 and 14 teams after the finalizing the revision of courses in the period Jan-March 2020. |
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| 5 | 12/06/2020 | CUT / Tomasz Nitkiewicz<br>AIT / Pisut Koomsap | Fifth draft version of WP2 Task 2.2 - Outcome 2.2. Includes annex II with the reviews as proposed by PC. |
| 6 | 05/08/2020 | CUT / Tomasz Nitkiewicz<br>AIT / Pisut Koomsap | Sixth version of WP2 Task 2.2 – Outcome 2.2 as revised after QCMB feedback |

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# 1 Executive Summary

The following document presents the key outcome, set of syllabuses in master studies in Industrial Engineering curriculum, of the project titled "Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry – MSIE4.0" that has been funded with support from the European Commission with CBHE framework of ERASMUS+ program. The outcome is based on cooperation between 6 Thai and 3 EU universities that after identifying the gap between the currently running programs and the needs of industry and students have prepared modernized studying program. The course design process adopts the logic of backward course design concept, develops its own logic on introducing student oriented learning and active learning principles and covers Industry 4.0 technologies, management and design approaches.

The curriculum includes 16 courses, among which there are three core courses, accepted by the consortium as the basics to introduce Industry 4.0 concept into Industrial Engineering field of knowledge, one obligatory course covering transversal skills, and 12 electives covering important fields of IE programs. The integral part of the set of 16 course syllabuses is the Outcome 2.1. A modernized curriculum for Master's degree in Industrial Engineering that presents the overview of the studying program, its learning outcomes, workload and organizational structure. The integral part of this document are two annexes: Annex I. Syllabuses and Annex II. First Reviews of 16 Syllabuses.

The content of Outcome 2.2 includes executive summary, the introductory part that presents the sequence of developing course documentation, and presents in a complex way the logic used to develop courses within MSIE4.0 curriculum. The syllabuses are included in Annex I to this document. Annex II includes the 1st round internal reviews of all 16 syllabuses.

# 2 Introduction

The key activities within MSIE4.0 Project is to develop master of science curriculum in the field of Industrial Engineering that would be supportive for sustainable and smart industry in Thailand. Curriculum is a set of courses that are clearly defined and described in syllabuses, that are integral part of this document. The building blocks of the curriculum development are:

- program learning outcomes (PLOs), list of courses, matrix of PLOs and courses relationship and structure of the curriculum – Outcome 2.1 – and
- course objectives and course learning outcomes (CLOs), teaching and learning methods with the assessment approach and evaluation schemes, courses content and description of modules, references and learning resources, time distribution and study load, prerequisites – Outcome 2.2

Since there is intended gap between the two blocks, the sequence of developing them is as follows:

1. developing MSIE 4.0 program by defining PLOs, courses and its relationship to the PLOs (first version of Outcome 2.1)
2. developing course syllabuses by course teams (first version of Outcome 2.2)
3. review of the course documentation by internal experts – non-members of course teams (official version of Outcome 2.2)
4. review of MSIE 4.0 program (official version of Outcome 2.1)
5. pilot testing of selected courses by partner universities
6. second review of the course syllabuses (final official version of Outcome 2.2)
7. final review of MSIE 4.0 program (final official version of Outcome 2.1)

This version of the MSIE 4.0 program and Outcome 2.2 is official version as indicated in point 3. Its integral part, a content of 16 syllabuses, is included in Annex I. After finalizing pilot testing of selected courses it would be updated to the final version and would affect also the final shape of Outcome 2.1. The text of reviews for all 16 courses is included in Annex II to this document. For some courses there has been several rounds of reviewing but only the first one is included in Annex II.

# 3 Logic of course syllabuses development within MSIE4.0 curriculum

Basic assumption of MSIE 4.0 curriculum are defined by three different approaches to engineering education development: Bloom's taxonomy, Kolb's model and LOVE model (Figure 1). The approach is based on backward course design concept.

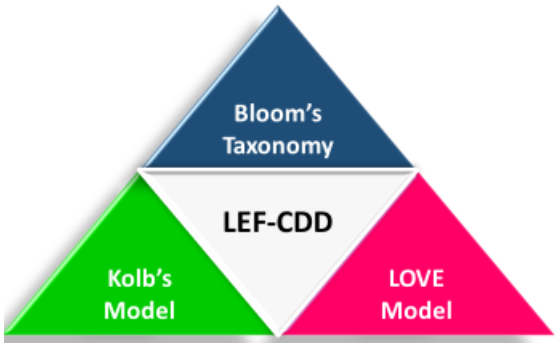


*Figure 1. Logic of MSIE4.0 curriculum development* (MSIE4.0, 2019)

## *3.1 Application of backward course design with Blooms taxonomy for defining PLOs*

Backward course design has been introduced and well accepted as an alternative to help improve student learning. With this design approach, knowledge is pulled to fulfil the requirements for achieving the learning outcomes. The instructors start thinking from a student's side with what they want students to be able to do after the completion of the course, followed by how to assess whether the students have achieved the learning outcomes, and move back towards the content development and on how to teach the content (McTighe and Wiggins, 2012). With a clear final destination, it keeps the instructors focus on achieving the final outcomes, and Bloom's taxonomy as illustrated in Figure 2 is a helpful and widely used resource for developing learning outcomes (Krathwohl, 2002).

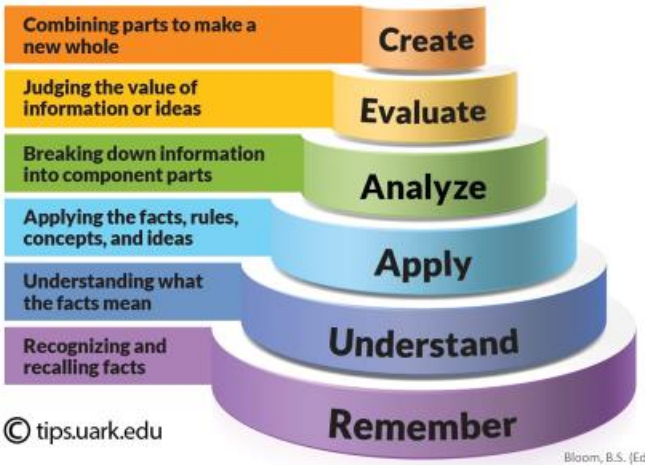


*Figure 2. Blooms taxonomy* (Shabatura, 2018)

## 3.2 Application of Kolb's experiential learning theory

Graduates who have exposure to a variety of learning activities are expected to perform much better than those who have gone through the conventional lecture, homework assignment and conducting laboratory experiment. However, not only learning outcomes and teaching and learning methods should be considered, but how the class is conducted is also important for the student learning experience. According to Kolb's experiential learning theory (Kolb, 1984), learning has a cycle having four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation, and they connect in this sequence to form a cyclic order. An instructor can design the learning process, to enter students into the learning experience cycle of a subject at any stage, and effective learning occurs when the students cycle through the four stages. Therefore, it is very important for all instructors to be aware of a journey that students walk through and try to ease their learning and to create a strong experience (Koomsap *et al.*, 2019). The schematic illustration of Kolb's learning cycle is presented on Figure 3. The intention of the curriculum is to come through with this learning cycle with every course and its module. That would guarantee perfect knowledge and skills absorption by the students.

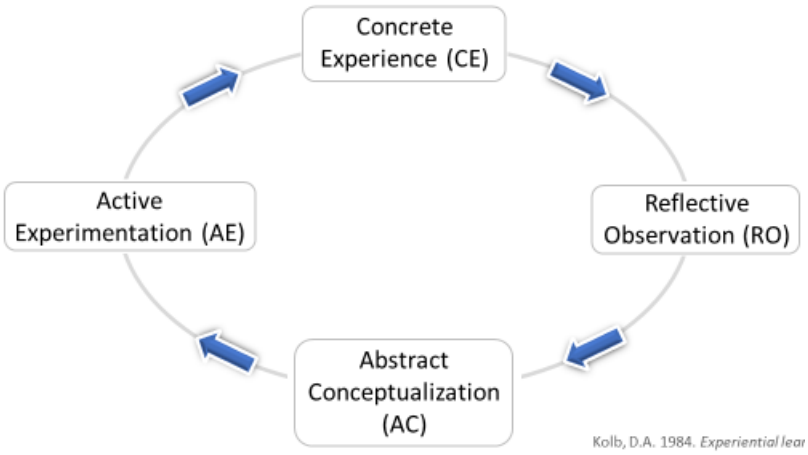


*Figure 3. Kolb's model* (Kolb, 1984)

## 3.3 Providing diverse learning experience with LOVE model

Recently, a LOVE model has been introduced to describe learning experience (Hussadintorn Na Ayutthaya and Koomsap, 2017). Student involvement in any educational process can be seen either as active or passive and it would usually depend on the type of approach used by teachers, methods and tools used, and also on students attitude. The nature of the learning process represents the type of connection offered to students during coursework.

The general concept of LOVE model is presented in Figure 4. Absorption occurs when a teacher brings the ready-to-use content to the students. As opposite, students can physically get involved in the process, by participating in it. Learner role implies active engagement of students but with rather specific, teacher originating, content. Observer role is a passive type of experience that is also made on teacher-based content. Visitor role is also passive but the circumstances are not ordinary ones and students can get immersed with the experience that is not, or not completely, prepared by the teacher. Experimenter role is both active and immerse type of experience that gives students partially or fully opportunity to use its own understanding and competences to participate and create the experience. In order to attain to researcher role, students must gain a variety of experiences which are transformative, influential, practical, effective and memorable to shape their research capability (Hussadintorn Na Ayutthaya and Koomsap, 2018). The outcome of this transformation is changing students from knowledge consumers to knowledge producers (Lovitts, 2005; Gardner, 2008).

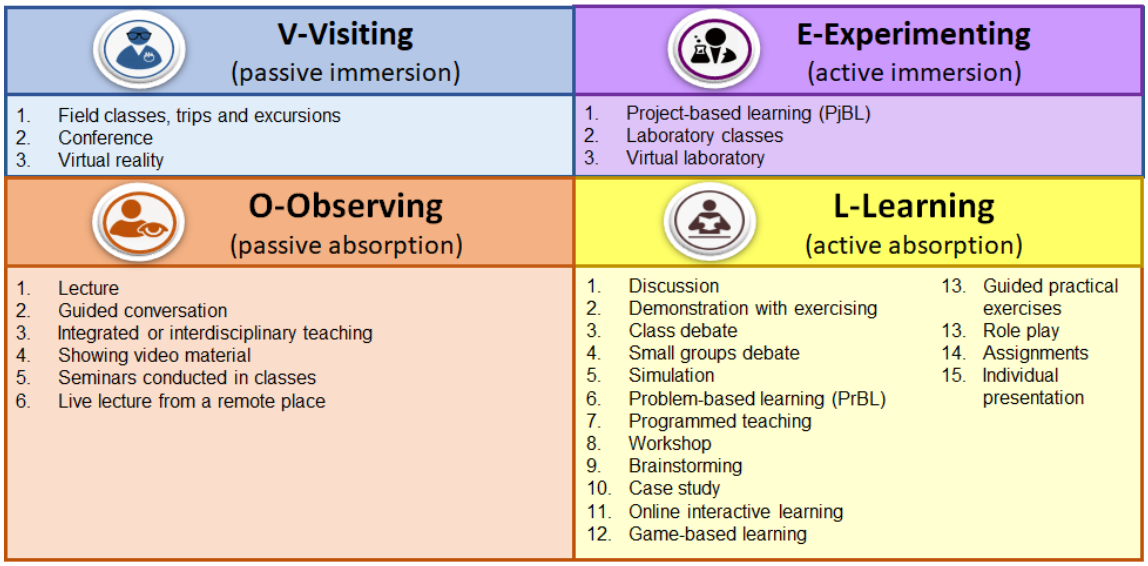


*Figure 4. LOVE model (**Hussadintorn Na Ayutthaya et al., 2019**)*

## 3.4 Sequence of MSIE4.0 curriculum development

The sequence of MSIE4.0 curriculum development and its inherent courses results from the defined and adopted logic. Therefore, the WP1 recommendations and pre-defined objectives of the curriculum are contributing to defining general outline of curriculum as well as its content, approaches, industrial scopes and teaching methods. The recommendations and objectives are used to defined program learning outcomes (PLOs) at the first place, as an attempt to define the desired shape of future graduate of MSIE 4.0 program. As the next step, the set of courses is defined that could fully match the PLOs. Defining the course names and its objectives sets up the ground for defining course specific learning outcomes (CLOs) that could contribute to the achieving PLOs on program level and at the same time could provide appropriate skill set and competences of students. Finally, CLOs are transferred for content that could contribute to the desired outcomes. The complexity of content

development, including actual topics of course work, but also its reference to the assessment methods proposed, teaching and learning methods and approaches and possible division within the course on independent module, gives a perfect range for using Bloom's taxonomy, Kolb's and LOVE model for approaching this task. Figure 5 presents the sequence of curriculum development as adopted for MSIE 4.0.

Backward course design approach for MSIE 4.0 development is presented in Figure 5. The sequence of MSIE 4.0 curriculum development. Some rules concerning the courses development process have been recommended by WP2 team during in-person and online meetings. Also, assumed structure of MSIE 4.0 curriculum had affected the process. The following recommendations were specified:

- each course should have clear and specific objective and 4-8 learning outcomes,
- each course should consist of modules, and each of the module should be considered as a potential complex and stand-alone educational feature,

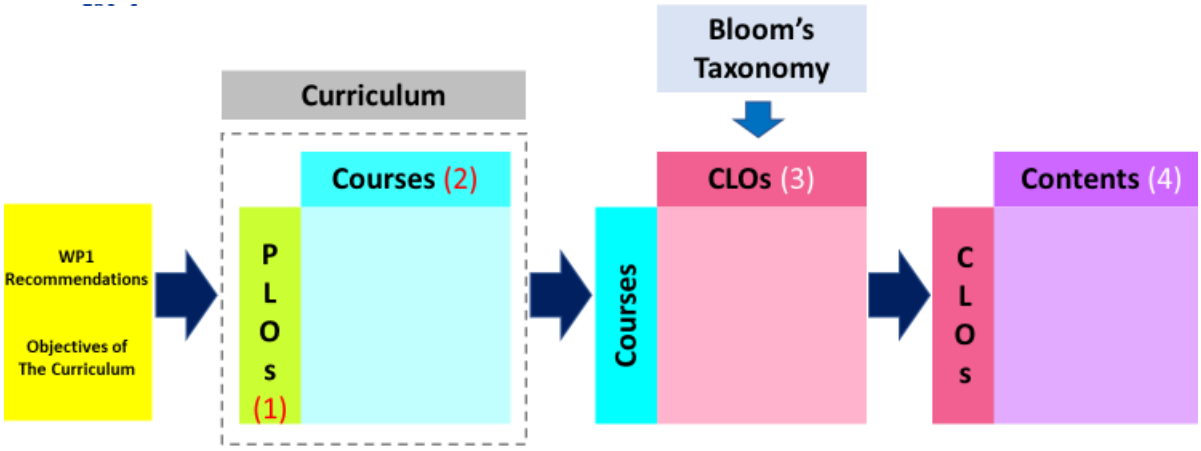


*Figure 5. The sequence of MSIE 4.0 curriculum development* (MSIE4.0, 2019)

## 3.5 Teaching and learning approach in the curriculum

As a consequence of adopted logic for curriculum development and selected methods for educational approach the specific sequence need to be introduced while developing course objectives, learning outcomes and matching it with specific methods and content. It was agreed that each course would try to follow Kolb's logic of designing the course on the basis multiple learning cycles and using LOVE model classification for selecting appropriate methods. Figure 6 presents the schematic procedure of organizing learning loops within course development process.

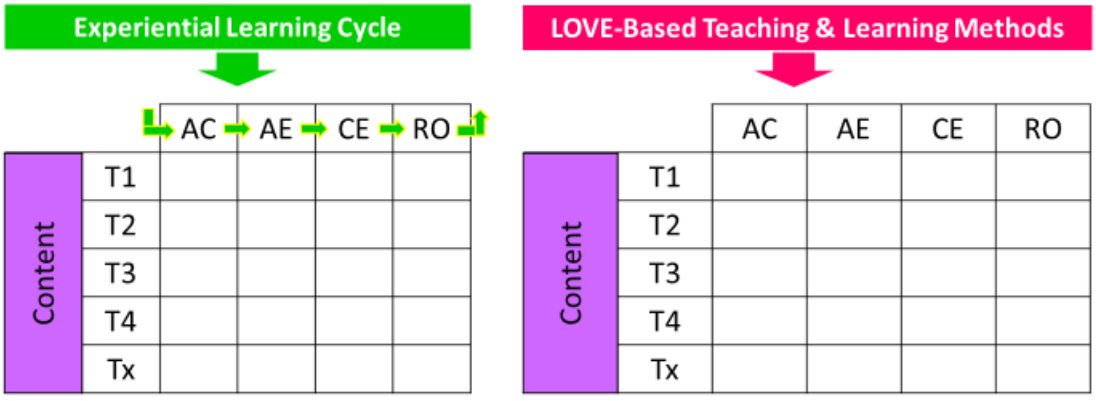


*Figure 6. Teaching and learning approach to the MSIE 4.0 development* (MSIE4.0, 2019)

# 4 Course Syllabuses

All the course syllabuses for MSIE4.0 curriculum would be available in its final version on Project website: https://msie4.ait.ac.th/courses/. Its current versions are included in Annex I to this document.

## *4.1 Course syllabuses evaluation process*

Before the final version the course syllabus development progress was evaluated by 2 internal experts that did not participate in developing the specific course. The evaluation criteria was based on adopted curriculum and course development approach and the objectives and assumptions of the project. The general criteria referred to the course syllabus alignment to the syllabus template and reliability and quality of information provided. Matching criteria referred to the syllabus coherence with regard to the adopted logic of course development and internal integrity of syllabus. Innovation and attractiveness criteria referred to the novelty of content and teaching and learning methods prosed as well as to its contribution to employ active teaching approach. The complete list of issues raised in the evaluation form is presented in Table 1 below.

*Table 1. Evaluation criteria for course syllabuses within MSIE4.0 curriculum*

| No. | Issue |
|---|---|
| 0 | Are they similar IE courses being offered? |
| 1.1 | Quality of the content for the objective |
| 1.2 | Quality of writing for the objective |
| 1.3 | Suggestion for revision for objective |
| 1.4 | Quality of the content for the CLOs |
| 1.5 | Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy? |
| 1.6 | Quality of writing for CLOs |
| 1.7 | Suggestion for revision for CLOs |
| 1.8 | Does the syllabus has a prerequisite section? |
| 2.1 | Does the course content relate directly to the title, objective, and CLOs? |
| 2.2 | Quality of the course content |
| 2.3 | Quality of writing for course content |
| 2.4 | The originality of the course content relative to existing IE courses |
| 2.5 | Has the course been designed with modular architecture? |
| 2.6 | How many modules are in this course? |
| 2.7 | Has the content been designed with the logical flow? |
| 2.8 | How likely will the course be delivered to cover all topics? |
| 2.9 | Does the course has workshop or laboratory sessions? |
| 2.10 | Quality of the workshop or laboratory sessions |
| 2.11 | Is there any topic or subtopic that should belong to another course? |

| | |
|---|---|
| 2.12 | Suggestion for revision for course content, workshop and laboratory sessions |
| 3.1 | Have references been written properly and consistently? |
| 3.2 | Teaching and learning methods to be applied in the course |
| 3.3 | Suggestion for additional teaching and learning methods |
| 3.4 | Time distribution and study load |
| 3.5 | Relationships between course assessment and CLOs |
| 4.1 | Based on the information provided in the syllabus, what type of course is this course? |
| 4.2 | Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively? |
| 4.3 | Based on the information provided in the syllabus, how likely the skills will be built effectively? |
| 4.4 | Based on the information provided in the syllabus, how likely competence will be built? |
| 4.5 | Overall assessment for this course |
| 4.6 | How confident are you with your answers? |

The 1st round of the reviews for all the syllabuses is presented in Annex II to this document.

## 4.2 Evaluation results

The review and revising process has taken a couple of months between November 2019 and March 2020. The procedure of the evaluation has been as follows:

1. Review of course syllabus by two internal experts
2. Classification of review outcome by Task 2.2 leaders (Minor / Major revision needed)
3. Revision of syllabuses by course teams
4. Verification of syllabuses
    a. By Task 2.2 leaders in case of minor revision
    b. By Reviewers and Task 2.2 leaders in case of major revision
5. Acceptance of syllabuses

If the verification process in point 4a or 4b was not satisfactory the Task 2.2 leaders returned the syllabus to the course team to revise it once again. Course status in curriculum and concerning its evaluation is presented in **Error! Reference source not found.**.

*Table 2. List of MSIE4.0 course syllabuses*

| No. | Course name | Course status in curriculum | Course development status[1] |
|---|---|---|---|
| 1 | Enterprise Management in Digital Economy | elective | Accepted version |
| 2 | Project Management for Industry 4.0 | elective | Accepted version |
| 3 | Smart Operations Management | core | Accepted version |
| 4 | Quality Management for Extended Enterprise | elective | Accepted version |
| 5 | Sustainable Supply Chain Management | elective | Accepted version |
| 6 | Digital Factory | core | Accepted version |

| | | | |
|---|---|---|---|
| 7 | Advanced Optimization: Techniques and Industrial Applications | elective | Accepted version |
| 8 | Intelligent Decision Support Systems | elective | Accepted version |
| 9 | Applied Data Analytics | core | Accepted version |
| 10 | Cyber-Physical Industrial Systems | elective | Accepted version |
| 11 | Collaborative Manufacturing Systems | elective | Accepted version |
| 12 | Additive Manufacturing for Industry 4.0 | elective | Accepted version |
| 13 | Innovative Product Design and Development | elective | Accepted version |
| 14 | Human-Centric Design for Operator 4.0 | elective | Accepted version |
| 15 | Customer Experience-Driven Design | elective | Accepted version |
| 16 | Communications and People Skills Development for Engineering Leaders | compulsory | Accepted version |

[1] the status of the courses as follows:
Final version – version of syllabus after finalizing pilot testing and reviewing whole curriculum (Task 2.3 and 2.4)
Accepted version – version submitted after the review and revision, accepted by the reviewers or task leaders
Revised version – version submitted after the review and revision, waiting for the acceptance by the reviewers or task leaders

# 5 References

Gardner, S. K. (2008) '"What's too much and what's too little?": the process of becoming an independent researcher in doctoral education', *The Journal of Higher Education*, 79(3), pp. 326–350.

Hussadintorn Na Ayutthaya, D. and Koomsap, P. (2017) 'Identify Student Participation in Co-Creation of Learning Activities', *Inted2017: 11Th International Technology, Education and Development Conference*, (March), pp. 5298–5307.

Hussadintorn Na Ayutthaya, D. and Koomsap, P. (2018) 'An Application of " LOVE " Model for Assessing Research Experience', in Peruzzini, M. (ed.) *Transdisciplinary Engineering Methods for Social Innovation of Industry 4.0*, pp. 712–720. doi: 10.3233/978-1-61499-898-3-712.

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Koomsap, P. *et al.* (2019) 'Course Design and Development: Focus on Student Learning Experience', in *PAEE/ALE'19 Preparing Teachers and Students for Challenging Times in Engineering Education*, pp. 144–154.

Krathwohl, D. R. (2002) 'A revision of Bloom's taxonomy: An overview', *Theory into practice*, 41(4), pp. 212–218.

Lovitts, B. E. (2005) 'Being a good course-taker is not enough: a theoretical perspective on the transition to independent research', *Studies in higher education*, 30(2), pp. 137–154.

McTighe, J. and Wiggins, G. (2012) *Understand By Design Framework*.

MSIE4.0 (2019) *WP 1 - Gap Analysis. Outcome 1.6. Competitive Factors For The Curriculum*. Available at: https://msie4.ait.ac.th/wp-content/uploads/sites/5/2019/02/GD-T1.5_O1.6-V4.pdf.

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# 6 ANNEX I – Syllabuses

# 7 ANNEX II – First Reviews of 16 Syllabuses

# WP 2 - Curriculum Development I: Curriculum Structure and Courses

# Outcome 2.2 - Syllabuses for all courses in the curriculum

# ANNEX I - Syllabuses

| | |
|---|---|
| **Project Acronym:** | MSIE 4.0 |
| **Project full title:** | Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry |
| **Project No.:** | 586137-EPP-I-2017-I-TH-EPPKA2-CBHE-JP |
| **Funding Scheme:** | Erasmus + KA2 - Capacity Building in the field of Higher Education |
| **Coordinator:** | AIT |
| **Work Package:** | WP2 – Curriculum Development I: Curriculum Structure and Courses |
| **WP Leaders:** | Tomasz Nitkiewicz (CUT) and Pisut Koomsap (AIT) |
| **Task Title:** | Task 2.2. Developing courses and course learning outcomes based on a matrix that maps course learning outcomes with program learning |
| **Task Leader:** | Tomasz Nitkiewicz (CUT) |
| **Last version date:** | 05/08/2020 |
| **Status:** | Final draft |
| **Dissemination Level:** | Department / Faculty - Institutional - National -International |

## Course 1: Enterprise Management in Digital Economy (1-4-0)

**Course Objective:** Digital economy has brought business entities to the limits of their capacity of traditional resources and competences while transforming the markets and opening new strategic approaches for business management. . The objective of this course is to provide the students with knowledge and competences on using integrated and system solutions in advancing the management to the requirements of Digital Economy. In this course students will learn on how to adopt management, its strategies and functions to smart and sustainable solutions that 4.0 era has brought to enterprises.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Analyze and recommend the use sustainable business model with digital technologies and tools in order to improve market performance of specific companies (analyze)
CLO2. Define and assess the strategy (strategic objectives, mission and vision, competitive factors, company functions: production; purchasing; marketing; logistics, financing, human resources) of I4.0 oriented companies (create)
CLO3. Define and assess internal and external driving factors for digitization and position them in strategy and business model (evaluate)
CLO4. Propose organizational structures appropriate for I4.0 set-up (apply)
CLO5. Use strategic analysis tools to understand internal and external determinants influencing the company performance and propose improvements with different approaches (evaluate)
CLO6. Demonstrate entrepreneurial attitude towards I4.0 opportunities for business (analyze)

**Prerequisite:** basic of management

**Course Outline:**

Module 1: Business perspective to understand the digital economy and its influence

1. How digital economy innovations and its social context impacts different types of businesses?
2. Digitalization in the context of needs, markets, channels, products and services and management and organizational set-up - identification of different way digital era changes the business
3. How the pace of changes affects the business in the digital economy: New business imperatives
4. Organizational structures and management functions of today: reshaping structures, combining resources and competences and building relations

Module 2: Sustainable and digital: new patterns for strategies and business models

1. Strategy or business models? Different approaches to lead your business
2. Sustainable or digital: Emerging business models and its components
3. Following technical innovations with sustainable business models
4. Defining unique value proposition and designing customer relationships
5. Collaboration and competition in the age of networking

Module 3: Strategic analysis tools and its use to capture the competitive advantage in digital economy

1. Business model canvas: capturing the key of digital business
2. Mapping the value streams: visualizing the flows and relationships

3. Decision support with strategic analysis tools: business at strategic crossroads

**Workshop Sessions:**

Impacts of digital economy innovations and social context different types of businesses

Identification of different way digital era changes the business

New business imperatives

Reshaping structures, combining resources and competences and building relations

Different approaches to lead your business

Emerging business models and its components

Sustainable business models

Defining unique value proposition and designing customer relationships

Collaboration and competition in the age of networking

Business model canvas: capturing the key of digital business

Mapping the value streams: visualizing the flows and relationships

Decision support with strategic analysis tools: business at strategic crossroads

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

N.J. Foss, T. Saebi (Eds.), Business Model Innovation: the Organizational Dimension, Oxford University Press, Oxford (2015)

P. M. Abernathy, J.A. Sciarrino, The Strategic Digital Media Entrepreneur, Wiley-Blackwell, (2018)

A. Osterwalder, Y. Pigneur, Business Model Generation: a Handbook for Visionaries, Game Changers, and Challengers, Wiley, Hoboken, NJ (2010)

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D. Wiraeus, J. Creelman , Agile Strategy Management in the Digital Age, Springer International Publishing_Palgrave Macmillan (2019)

P. Novo Melo, C. Machado, Management and Technological Challenges in the Digital Age-CRC Press (2018)

M. Skilton, Building Digital Ecosystem Architectures: A Guide to Enterprise Architecting Digital Technologies in the Digital Enterprise. Springer International Publishing Palgrave Macmillan (2016)

K. Sandkuhl, J. Stirna - Capability Management in Digital Enterprises-Springer International Publishing (2018)

**Journals and Magazines:**

Long Range Planning - Elsevier

Organization Science - Informs

Journal of Business Strategy - Emerald Insight

Journal of Business Models - Business Design Lab

**Teaching and Learning Methods:** This is an project-based course. During the course, the students, would be divided into project groups that would be coupled with partner companies that are challenged with digital economy issues. Each group would prepare strategy and business model and perform strategic analysis for real life business conditions. All the tasks, group and individual, would be assigned to the specific project.

**Time Distribution and Study Load:**

Lectures: 15 hours

Workshop and project: 60 hours

Study visits and consultation with business partners: 15 hours

Self-study: 45 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Class discussions (15%); Individual assignments and presentations (20%); Group assignments and presentation (15%); Final group project report (20%); Final group project presentation (20%); Peer Assessment (10%).

An "A" would be awarded if a student can demonstrate clearly skills in developing strategy and business models and perform strategic analysis.

A "B" would be awarded if a student can show good progress in developing strategy and business models and perform strategic analysis.

A "C" would be given if a student can show reasonable progress in developing strategy and business models and perform strategic analysis.

A "D" would be given if a student shows a lack of improvement in developing strategy and business models and perform strategic analysis.

**Course Developers:** Tomasz Nitkiewicz (Tomasz.Nitkiewicz@wz.pcz.pl) (CUT), Andrei Szuder (szuder@ctanm.pub.ro) (UPB), Uttapol Smutkupt (uttapol@eng.cmu.ac.th) (CMU), Jorge Cunha (jscunha@dps.uminho.pt) (UMinho)

## Course 2: Project Management for Industry 4.0 (2-2-0)

**Course Objective:** In the new world of Industry 4.0, digitized connectivity may be considered the main driver of change industries have to deal with. This change increases the opportunities to create new business models, exploring network of systems that will allow to increase the cooperation between and across companies and industries. It is expected an increase in customized services that ultimately can become a service for each customer. In this case, we will be dealing with a project service for each customer each time. These projects will be developed by interdisciplinary distributed teams using digital platforms.

This course aims to prepare graduates to perform in and manage projects and teams in the new highly agile digitized challenging smart industries.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Discuss Project Management relevance in the context of IND4.0 (Apply)
CLO2. Evaluate the needs of an organization regarding IND 4.0, taking into account maturity / readiness models (Evaluate)
CLO3. Plan, develop and manage projects in the context of IND 4.0, using frameworks of project management, such as PMI, IPMA and Agile/Lean (Create)
CLO4. Support team decision making processes in accordance with the contingencies and uncertain environments of IND 4.0. (Evaluate)
CLO5. Perform as a member of an extraordinary team, either distributed or co-located, using different tools and techniques, considering the team development phases (Create).
CLO6. Develop a project within a real context, in interaction with an industry organization.

**Prerequisite:** None

**Course Outline:**

Module 1: Management of Industry 4.0 Projects

1. Introduction to Project Management in a new era of digitalization
2. Industry 4.0 maturity models (Acatech and PWC models)
3. Project Management Processes of initiating and planning a project for evaluating I4.0 maturity levels
4. Agile project management for fast adaptation in the era of the fourth industrial revolution
5. Project Management execution - time management and project indicators for assessing projects related to I4.0 maturity levels

Module 2: Project Team Management for Industry 4.0

1. Project communication management in a new era of digitalization
2. Project Management monitoring and control – time compression and team project indicators
3. Project team management in a new era of digitalization. Team formation and development of distributed and multicultural teams in Industry 4.0 environments
4. Software tools for project management in a new era of digitalization
5. Decisions under high uncertainty in the context of fast changing environments of the of the fourth industrial revolution

Workshop Sessions: Project supervision sessions

1. Team formation and team dynamics
2. Project selection – development of instruments for assessing the Industry 4.0 maturity level
3. Exploring the dimensions of the Industry 4.0 maturity model
4. Visual planning of the project for I4.0 maturity model self-diagnosis
5. Developing the methodology for maturity level self-diagnosis
6. Creating and validating the I4.0 maturity self-diagnosis model
7. Applying the I4.0 maturity self-diagnosis model
8. Creating and validating the I4.0 maturity self-diagnosis model

**Workshop Sessions:**

1. Team formation and team dynamics
2. Project selection – development of instruments for assessing the Industry 4.0 maturity level
3. Exploring the dimensions of the Industry 4.0 maturity model
4. Visual planning of the project for I4.0 maturity model self-diagnosis
5. Developing the methodology for maturity level self-diagnosis
6. Creating and validating the I4.0 maturity self-diagnosis model
7. Applying the I4.0 maturity self-diagnosis model
8. Creating and validating the I4.0 maturity self-diagnosis model

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Schuh, G., Anderl, R., Gausemeier, J., Hompel, M. t. and Wahlster, W. (2017) Industrie 4.0 Maturity Index – Managing the Digital Transformation of Companies: Acatech. Available at: https://en.acatech.de/wp-content/uploads/sites/6/2018/03/acatech_STUDIE_Maturity_Index_eng_WEB.pdf (Accessed: 2019.06.03).

Oehmen, J. (Ed.). (2012). The Guide to Lean Enablers for Managing Engineering Programs, Version 1.0. Cambridge, MA: Joint MIT PMI INCOSE Community of Practice on Lean in Program Management. http://dspace.mit.edu/bitstream/handle/1721.1/70495/Oehmen%20et%20al%202012%20-%20The%20Guide%20to%20Lean%20Enablers%20for%20Managing%20Engineering%20Programs.pdf

Jeff Sutherland (2014) SCRUM - A Arte de Fazer o Dobro do Trabalho em Metade do Tempo. Leya

Harold Kerzner (2009) Project Management: A Systems Approach to Planning, Scheduling, and Controlling; John Wiley & Sons; ISBN: 0470278706.

PMI-PMBOK (2013) "A Guide to the Project Management Body of Knowledge (PMBOK Guide 5th ed.)". Pennsylvania, USA: Project Management Institute (PMI).

Finocchio Junior, José (2013) Project Model Canvas - Gerenciamento de Projetos Sem Burocracia. Elsevier – Campus. ISBN: 978-85-352-7456-1. http://www.livrariasaraiva.com.br/produto/4967937/project-model-canvas-gerenciamento-de-projetos-sem-burocracia/

**Journals and Magazines:**

International Journal of Project Management, Elsevier Ltd.

Project Management Journal, Wiley-Blackwell

International Journal of Project Organisation and Management, Inderscience Publishers

International Journal of Information Systems and Project Management, Scika

Journal of Modern Project Management, Mundo Press

**Teaching and Learning Methods:** This is a project-based learning course, where teams of students will solve an open ended problem related to the Industry 4.0. During lecture sessions, concepts will be discussed as much as possible in an inductive manner, using student-centered methodologies (e.g. simulations, think-pair-share, gamification and project-based learning). During workshop sessions, teams of students will develop their projects with the supervision of the instructors, developing different competences related to technical parts of Project Management, and including, but not limited to, project planning, execution and controlling, time management, team management, decision making, problem-solving, critical thinking, written communication, oral communication, presentation, communication and teamwork.

**Time Distribution and Study Load:**

Lectures: 30 hours

Workshop / project: 30 hours

Self-study: 45 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Individual weekly portfolio entries (10%); overall global portfolio (40%); project presentation and discussion (50%). These will be divided in Oral communication (40%); Written communication (20%); Presentation (10%); Peer Assessment (10%) and Personal Development (20%).

An "A" would be awarded if a student can demonstrate clearly effective project management competences for industry 4.0.

A "B" would be awarded if a student can show good progress on project management competences for industry 4.0.

A "C" would be given if a student can show reasonable progress on project management competences for industry 4.0.

A "D" would be given if a student shows a lack of improvement in project management competences for industry 4.0.

**Course Developers:** Rui Lima (rml@dps.uminho.pt) (UMinho), Anna Wiśniewska-Sałek (anna.wisniewska-salek@wz.pcz.pl) (CUT)

## Course 3: Smart Operations Management (2-2-0)

**Course Objective:** The objective of this course is to develop competences on design and implementation of continuous and efficient operations while creating a digital copy of the end-to-end process. The Internet of Thing (IoT) system to collect real time data need to be discovered. Real-time data analytics can help to evaluate, and simulate the end-to-end operation to improve and manage all operations efficiently. Emphasis is on cross-enterprise integration of the physical and virtual systems among various functions including operation strategy, process design, capacity planning, facility location and design, forecasting, production scheduling and inventory control.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. apply knowledge and methods from the advanced science of industrial engineering to model, evaluate and improve industrial processes and systems in relation with company operating efficiency and customer service.
CLO2. create smart production and co-created product development concepts in planning and controlling company's operations.
CLO3. design real time data analytics and software systems to support planning, scheduling and control of smart production processes and systems.
CLO4. design smart production processes and systems to efficiently respond to changes in operating conditions.

**Prerequisite:** None

**Course Outline:**

Module I: Advanced science of industrial engineering to model, evaluate and improve industrial processes and systems and co-created product development concepts

1. Operation management strategy in industry 4.0 context
   1.1 Industry 4.0 framework, concept, theories, tools and techniques
   1.2 Impact of industry 4.0 on modern operation management in strategic level
2. Smart product and co-created design concept
   2.1 Smart product and co-created design concept and tools
3. Smart manufacturing concept
   3.1 Introduction of traditional manufacturing concept
   3.2 Smart manufacturing definitions
   3.3 Architecture model for smart manufacturing
   3.4 Characteristics of smart manufacturing and assessment
4. Smart operation concept
   4.1 The enterprise-wide and cross-enterprise integration of the physical and virtual world
   4.2 The design of smart production planning system and supply chain model

Module II: Smart production in planning and controlling company's operations integrated production planning and shop-flow control system concept

1. Implementation forecasting model under real-time situation:
   1.1 Tracking accuracy of forecasting model when data are updated and real-time.
   1.2 Adjusting forecasting model to match with the real-time demand.
   1.3 Advanced techniques to utilize real-time demand for demand forecasting.
2. Inventory management under real-time situation:
   2.1 Utilizing real-time data for inventory management and control.
   2.2 Control system and advanced technology in inventory management
3. Advanced integrated production planning
   3.1 Intelligent ERP and integration of IoT, massive data analytics. Cognitive and process automation.
   3.2 Integrated planning system including aggregated planning, master production schedule (MPS), material requirement planning (MRP), and capacity planning (CRP) by utilizing real-time data.
4. Advanced shop floor control
   4.1 Advanced scheduling techniques when real-time data are updated.
   4.2 Automated shop floor control system and technology.

Module III: Real time data analytics and software systems to support planning, scheduling and control of smart production processes and systems

1. Real-time monitoring system
   1.1 Example
   1.2 How to design the system
2. IoT system
   2.1 Smart sensor
   2.2 Smart device
   2.3 Cloud service
   2.4 Telemetry service
3. Real-time data analytics
   3.1 Logistic regression models
   3.2 Time series analysis
   3.3 Decision trees
4. Big data for predictive analytics, predictive modeling, and forecasting
   4.1 Identify trends in supply chain sales
   4.2 Monitor status of manufacturing process
   4.3 Forecast when maintenance and repair work should be done in order to prevent problems

**Workshop Sessions:**

1. Impact of industry 4.0 on modern operation management
2. Product design tools for designing smart product
3. Design smart manufacturing and smart operations for local industry

4. IoT system for automatic data retrieval

Case Study:

1. Integrated production planning and controlling
2. Real-time manufacturing process monitoring system

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Ibrahim Garbie, Sustainability in Manufacturing Enterprises: Concepts, Analyses and Assessments for Industry 4.0, Springer International Publishing, 2016

Klaus Schwab and Nicholas Davis, Shaping the Future of the Fourth Industrial Revolution, Crown Publishing Group, 2018

Guilherme Frederico, Operations and Supply Chain Strategy in the Industry 4.0 Era, Independently Published, 2018

Diego Galar Pascual, Pasquale Daponte and Uday Kumar, Handbook of Industry 4.0 and SMART Systems, CRC Press, 2018

Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress, 2016

**Journals and Magazines:**

Computers and Industrial Engineering

Computers in Industry

Engineering Science and Technology

International Journal of Distributed Sensor Networks

International Journal of Industrial Engineering Computations

International Journal of Production Economics

International Journal of Production Research

Journal of Industrial and Production Engineering

Journal of Manufacturing Systems

Journal of Productivity Analysis

Nature

Smart and Sustainable Manufacturing Systems

**Teaching and Learning Methods:** This is an activity-based course. During lecture sessions, class discussion and case study will be conducted. During workshop sessions, active learning will be used. Students will practice several skills including, but not limited to, decision making, problem-solving, critical thinking, written communication, oral communication, presentation, debate, and teamwork.

**Time Distribution and Study Load:**

Lectures: 30 hours

Workshop: 30 hours

Self-study: 30 hours

**Evaluation Scheme**: The final grade will be given according to the following weight evaluation:

Assessment (CLO1): 25%

- Workshop 15%
- Open Exam 10%

Assessment (CLO2): 25%

- Case study 10%
- Class Project 10%
- Oral Presentation 5%

Assessment (CLO3): 25%

- Class Project 15%
- Workshop 10%

Assessment (CLO4): 25%

- Case Study 10%
- Oral Presentation 5%
- Open Exam 10%

**Course Developers:** Uttapol Smutkupt (uttapol@eng.cmu.ac.th) (CMU), Madalin Catana (mg_catana@yahoo.com) (UPB), Tritos Laosirihongthong (ltritos@engr.tu.ac.th) (TU)

## Course 4: Quality Management for Extended Enterprise (2-2-0)

**Course Objective:** The extended enterprise concept has been adopted to collaborate in the entire supply chain. Quality and efficiency issues, therefore, extend well beyond the traditional enterprise. This course constructs student competencies of management skills, particularly on how to define, develop, implement and manage the strategy to improve and build the quality system to align with the digital domains. Students will be trained on the modern quality management methods used in product design, product development,and production planning, as well as, the quality management methods focused on statistical quality control methods and data analytics, under the context of the extended enterprise. This course will also develop a technical skill for students to implement quality control and monitoring system that covers both process operation and supply chain operations.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Understand the impact of digitalization on quality management system, particularly on processes and people.
CLO2. Identify the strategy to assess the need and define the suitable technologies in order to transform the production system and organization, quality culture and processes to maximize value
CLO3. Analyze operational quality-related data for sustaining the process and Enterprise as well as identify the improvement by using quality monitoring tools such as SPC and modern data analytic technique and be able to embed quality management principles and tools in the value chain of operations and integrate with business operation strategy.
CLO4. Design a data visualization platform and Create its system components based on operational data such as quality and productivity output characteristics as well as Enterprise data (Enterprise Quality Metrics visualization).
CLO5. Design the proper quality management system for smart factories that can integrate the production and quality operations under the digital quality management concept

**Prerequisite:** None

**Course Outline:**

Module 1: Strategic Digital Quality Management System

1. Quality Management Concept under the Digital Era
2. Organization Performances and Quality System Strategy for I4.0
3. Quality Strategy for Digital Quality Management System
4. Quality System Structures for I4.0

Module 2: Automated Quality Control and Monitoring System

1. Quality Control Concept under Digital Data Collection
2. Automated SPC Strategy

3. Multivariate SPC Strategy
4. Data Analytic for Quality Monitoring

Module 3: Automated Quality Report System

1. Automated Quality Report Concept
2. Strategic Quality Improvement under I4.0
3. Real-Time Quality Control
4. Quality System Transformation

**Workshop Sessions:**

Module 1

1) Review, criticize, discuss and present the concept of quality management under the Industry 4.0 era. Individual presentation of the conceptual design of a case-based quality management concept.

2) Report, discuss, and present the key performance indexes (KPI) and key results indexes (KRI)of the organization that supports quality management under the Industry 4.0 era. Design and construct the KPI and KRI of the quality domain that is the basis for the digital quality management strategy.

3) Identify the strategy to (i) assess the need and (ii) define the suitable technologies and (iii) transform the production system and organization, quality culture and processes to maximize value

4) Criticize and select the quality system structure among the existing standard-based quality structure to improve or design the new quality system structure for the organization that matches the chosen quality management strategy.

Module 2

5) Select and define the quality control concepts and tools that coherences with the automated data collection processes under the Industry 4.0 structure. Group project presentation of case-based vision technology quality control concept at the shop floor will be used for demonstration and learning.

6) Design and implement the automated SPC that supports automated quality control and consistent with Digital quality management.

7) Understand the multivariate SPC for aggregated data from different quality characteristics collected from different machines and processes. Apply the multivariate data analytics to analyze the effectiveness of the processes. Cased-based learning will be used for demonstration and learning

8) Understand the different quality data analytic tools used to monitor the univariate and multivariate quality characteristics of product and process. Apply the data analytic and data mining techniques to analyze quality status.

Module 3

9) Discuss and present the concept of the automated quality report that coherences with the KRI, KPI generated from the digital quality management structure. Individual project presentation of the conceptual design of digital quality report concept

10) Understand the strategy of quality improvement of the Industry 4.0 quality management. Identify the quality improvement initiative and its strategy from the automated quality report system.

11) Identify the structure, components of the quality control tools and devices and their schematic relations for real-time process management.

12) Develop and identify the project of the quality system transformation. The contents of project initiation, project implementation, and project evaluation must be presented along with the scope, project schedule, project resources, and budgets, and project implementation plan and evaluation scheme.

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Germany Trade & Invest, "Smart manufacturing for the future," http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Brochures/Industries/industrie4.0-smart-manufacturing-for-the-future-en.pdf; National Academy of Science and Engineering, "Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative of Industry 4.0"

Forces of change: Industry 4.0

A Deloitte series on Industry 4.0

Juran's Quality Handbook: The Complete Guide to Performance Excellence

Case study: FANUC, the Japanese robotics company, https://www.cbinsights.com/research/future-factory-manufacturing-tech-trends/#quality

8 different steps of the manufacturing process to Future Factory, https://www.cbinsights.com/research/future-factory-manufacturing-tech-trends/#quality

Nikon Strategic Focus on Quality 4.0, https://metrology.news/nikon-strategic-focus-on-quality-4-0/

A strategist's guide to Industry 4.0, https://www.strategy-business.com/article/A-Strategists-Guide-to-Industry-4.0?gko=a2260

Suggested Indicators to Measure the Impact of Industry 4.0 on Total Quality Management, International Scientific Conference on Industry 4.0, At 3-16. DECEMBER 2017, BOROVETS, BULGARIA

Developing a Kano-Based Evaluation Model for Innovation Design, Mathematical

Problems in Engineering 2015(2):1-8 · October 2015

The Complete Guide to the Kano Model: Prioritizing Customer Satisfaction and Delight https://foldingburritos.com/kano-model/

Perdikis, Theodoros, and Stelios Psarakis. "A survey on multivariate adaptive control charts: Recent developments and extensions." Quality and Reliability Engineering International 35.5 (2019): 1342-1362.

Mason, Robert L., and John C. Young. Multivariate statistical process control with industrial applications . Vol. 9. Siam, 2002.

Montgomery, Douglas C. Introduction to statistical quality control . John Wiley & Sons, 2012.

Luis Rocha-Lona, Jose A. Garza-Reyes, and Vikas Kumar. Building Quality Management Systems . CRC Press, 2013

J.D.T. Tannock. Automating Quality Systems . Chapman & Hall, 1992.

Chen-Burger, Yun-Heh, and Dave Robertson. Automating Business Modelling . Springer, 2005.

**Journals and Magazines:**

**Teaching and Learning Methods:** This is an activity-based course. During lecture sessions, class discussion will be conducted.

During workshop sessions, the students, to be active learners, will practice several skills

including, but not limited to, decision making, problem-solving, critical thinking, written

communication, oral communication, presentation, debate, and teamwork.

**Time Distribution and Study Load:**

Lectures: 30 hours

Workshop: 30 hours

Self-study: 45 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight

distribution:

Assessment (CLO1): (20%)

- LogBook/Journal + Cases Study (5%)
- Oral Presentation (Individual Work Presentation & Report) (5%)
- Open Exam (10%)

Assessment (CLO2): 20%

- Role Play + Cases Study (5%)
- Extended Response Question (5%)

- Report of Strategy Plan and Analysis (10%)

Assessment (CLO3): (30%)

- Professional Discussion (5%)
- Cases Study +Simulation (10%)
- Assignment (15%)

Assessment (CLOs 4&5): (30%)

- Project (20%)
- Oral Presentation (5%)
- Oral Question (5%)

An "A" would be awarded if a student can design the proper quality management system for smart factories.

A "B" would be awarded if a student can evaluate the proper quality management system for smart factories.

A "C" would be given if a student can analyze the proper quality management system for smart factories.

A "D" would be given if a student can only remember some criteria for designing the proper quality management system for smart factories.

**Course Developers:** Wichai Chattinnawat (chattinw@gmail.com) (CMU), Runchana Sinthavalai (runchana.s@psu.ac.th), Suriya Jirasatitsin (suriya.j@psu.ac.th)(PSU), Anintaya Khamkanya (kanintay@engr.tu.ac.th) (TU)

## Course 5: Sustainable Supply Chain Management (1-4-0)

**Course Objective:** The main goal of the course is to acquire the ability to create an effective value chain (the ability to work and manage a team in the process of design/redesign structure of modern sustainable supply chain in Industry 4.0 environment), functioning in a sustainable environment with the use of intelligent and flexible production technologies and modern communication as part of the interaction network between its participants.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. apply the knowledge and competences related to Industrial Engineering in order to improve the supply chain functions
CLO2. indicate entrepreneurial activities and implement solutions in the field of Industrial Engineering to improve SSCM
CLO3. redesign the supply chain in accordance to the requirements of the Industry 4.0
CLO4. analyze and select scientific solutions in the field of Industrial Engineering in building a network of connections in SSCM
CLO5. manage a group (interdisciplinary, intercultural and distributed) in order to identify and evaluate trans strategies for the supply chain network functioning in a sustainable development economy

**Prerequisite:** Basic knowledge in the field: engineering sciences, logistics science including the supply chain and management sciences

**Course Outline:**

MODULE 1: Supply Chain Management in sustainability environment

1. Role of sustainability in supply chain management (4.5 hours): Lecture: AC + RO (Discussion, Assignment)
   - Key factors for sustainable development
   - Key economical solutions in sustainable supply chain management
   - The impact of sustainable development on supply chain management
2. Supply chain redesigning and cooperation in a sustainable interorganizational network (6 hours): Lecture: AC + RO (Discussion, Assignment, Group project)
   - Transformation and design of cluster supply chains
   - Framework for network structures in a sustainable supply chain
   - Engineering assessing the effectiveness of networks in a sustainable supply chain
3. Application of network solutions in sustainable supply chain management (4.5 hours): Lecture: AC + RO (Discussion, Group project)
   - Development of the supply chain management concept: Application of network as a method of sustainable supply chain management
   - Case study presentation

MODULE 2: Supply Chain Modeling

1. Inventory Management and Risk Pooling (4 hours): Lecture: AC + RO (Discussion, Assignment)

- The Role of Inventory
- Inventory Control Policies
- Continuous Review Policy
- Periodic Review Policy
- Risk Pooling
- Centralized vs. Decentralized Systems
- Echelon Inventory

2. Supply Contracts (6 hours): Lecture: AC + RO (Discussion, Assignment)

- Buy-Back Contract
- Revenue Sharing Contract
- Other Types of Contracts
- Global Optimization and Supply Contracts
- Contracts for Make-to-Order Supply Chains: Pay-Back, Cost Sharing
- Contracts with Asymmetric Information
- Portfolio Contracts and Risk Trade-Off

3. Bullwhip Effect and Distribution Strategies (5 hours): Lecture: AC + RO (Discussion, Assignment)

- Bullwhip Effect
- Impact of Centralized Information
- How to Relieve the Bullwhip Effect?
- Direct Shipment
- Intermediate Inventory Storage Point Strategy
- Central vs. Local Facilities
- Cross-Docking
- Nash Equilibrium
- Critical Search Level
- Transshipment Strategy

MODULE 3: Applications of Supply Chains in Different Industry Sectors in this Disruptive Era

1. Role of Supply Chain in Industry 4.0 (4.5 hours): Lecture: AC + RO (Discussion, Assignment)

- Key technologies in the 4th Industrial Revolution
- Impact of the 4th Industrial revolution on supply chain
- Key elements and digital technologies in smart supply chains

2. Supply Chain Redesign and new Collaboration Models (6 hours): Lecture: AC + RO (Discussion, Assignment, Group project)

- Transformation and design into a digital supply chains and logistics
- Creating collaboration framework in a digital supply chain
- Creating information visibility, a new data-driven vision, and exploiting the power of data in smart supply chains

3. Applications of Supply Chains in this disruptive era (4.5 hours): Lecture: AC + RO (Discussion, Group project)

- Applications of Supply Chains in this disruptive era: Smart supply chains in industry, agriculture, and tourism

- Case study presentation

**Workshop Sessions:**

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Bruno S. Sergi, Elena G. Popkova, Aleksei V. Bogoviz, Tatiana N. Litvinova, Understanding Industry 4.0: AI, the Internet of Things, and the Future of Work, Emerald Group Publishing, 2019

Joseph Sarkis, Handbook on the Sustainable Supply Chain, Edward Elgar Publishing, 2019

Yui-yip Lau, Adolf K.Y. Ng, Jorge Acevedo, Principles of Global Supply Chain Management, Anthem Press, 2019

Anjali Awasthi, Katarzyna Grzybowska, Handbook of Research on Interdisciplinary Approaches to Decision Making for Sustainable Supply Chain, IGI Global, 2019

D. Simchi-Levi, P. Kaminsky, and E. Simchi-Levi: Designing and Managing the Supply Chain (3rd edition), McGraw-Hill, 2008.

S. Chopra, and P. Meindl: Supply Chain Management, Pearson, 2013

M. Watson, S. Lewis, P. Cacioppi, and J. Jayaraman: Supply Chain Network Design, FT Press, 2013

**Journals and Magazines:**

European Journal of Operational Research, Elsevier

International Journal of Production Research, Taylor and Francis

Management Science, Informs

Journal of Supply Chain Management, Wiley

**Teaching and Learning Methods:** The course is focused on personal activity and group work. The workshop is a project classes and assignments. The project task concerns work in a group (about 10 people), during which each participant will actively use their own knowledge to write a joint project work. The project group will be create the supply chain in the industry chosen by the group. Presentation the project, discussion and activity at workshop will allow to implement the assumed learning outcomes for the course.

**Time Distribution and Study Load:**

Lectures: 15 hours

Workshop: 60 hours

Self-study: 75 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Individual reflections (20%); Class discussions (10%); Project outcome (30%); Powerful Public Speaking (20%) and Personal Development (20%).

An "A" would be awarded if a student can demonstrate the use of transferred and self-acquired knowledge in creating a sustainable supply chain.

A "B" would be awarded if a student can show the use of transferred and self-acquired knowledge in the field of sustainable supply chain management.

A "C" would be given if a student can show the use of the knowledge provided in the field of sustainable supply chain management.

A "D" would be given if a student shows the inability to use the transferred knowledge in the field of sustainable supply chain management.

**Course Developers:** Anna Wiśniewska-Sałek (anna.wisniewska-salek@wz.pcz.pl) (CUT), Kanchana Sethanan (KKU), Huynh Trung Luong (luong@ait.ac.th) (AIT), Bogdan Abaza bogdan@ctanm.pub.ro (UPB)

## Course 6: Digital Factory (2-0-3)

**Course Objective:** Today's factories are challenged by increasingly aggressive competition to satisfy customer demands. As information and communication technologies connects the world into one, a global market opens up vast opportunities for manufacturers. However, globalization does not only lead to a larger number of potential customers, who nowadays express their demand as an individual, looking for products customizedly fabricated for them. Manufacturers must as well take on a growing number of relentless competitors. It is therefore very arduous to tackle all those challenges while keeping the production economical. To stay competitive in the market needs strategies. One is digital transformation. Wisely implementing the technologies, manufacturers will gain competitive edges through improved productivity and an ability to respond to customer needs in realtime.

The objective of this course is to introduce concepts of digital factory that will soon take over a traditional one in the era of Industry 4.0. Practice on digital transformation of a case study factory is scheduled after students are trained on digital technologies and production data analysis.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Understand strategic differences between traditional factory and digital factory (Understand, Module I)
CLO2. Understand capacities and limitations of digital technologies available nowadays (Understand, Module I)
CLO3. Formulate a data model representing data streamlining in a production line of an existing traditional factory using a data flow diagram (Develop, Module II)
CLO4. Simulate a dynamic behavior of a production line and identify locations which must be closely monitored to keep productivity in control, as well as to prevent work defects and machine breakdowns (Analysis, Module II)
CLO5. Propose a digital factory platform of a case study factory in a virtual environment upon what have been learned (Design, Module III)

**Prerequisite:** Background in manufacturing processes, manufacturing systems and production planning and control is recommended.

**Course Outline:**

Module 1: Introduction to digital factory: Road to digital transformation

1. Lean product lifecycle management
2. Technologies for digital transformation
3. Integration of technologies for digital factory

Module 2: Digital Factory Modeling: How to formulate a virtual world

1. A cyber-physical system and data security
2. Data flow model concept and construction
3. Simulation of a production line

Module 3: Digital factory analysis: From analysis to factory solutions

1. Factory digitalization
2. Factory critical points identification and suggestions for improvement

3. Future trends of digital factory

**Workshop Sessions:**

None

**Laboratory Sessions:**

Laboratory on establishment of a digital twin

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Barrenechea, Mark J. Jenkins, Tom Digital Manufacturing, First Published, Published in Canada 2018.

Milan Gregor and Stefan Medvecky (2010). Digital Factory – Theory and Practice, Engineering the Future, Laszlo Dudas (Ed.), InTech, Available from: http://www.intechopen.com/books/engineering-the-future/digital-factory-theory-and-practice

Stephan Richter Dr. Steffen Wischmann, Additive manufacturing methods – state of development, market prospects for industrial use and ICT-specific challenges in research and development, Available from: www.autonomik40.de

Zude Zhou, Shane (Shengquan) Xie, and Dejun Chen, Fundamentals of Digital Manufacturing Science, Springer London Dordrecht Heidelberg New York, 2012.

Zongwei Luo, Robotics, Automation, and Control in Industrial and Service Settings, Published in the United States of America by Engineering Science Reference (an imprint of IGI Global), Available from: http://www.igi-global.com

2016 Global Industry 4.0 Survey, Industry 4.0: Building the digital enterprise, Available from: https://www.pwc.com/gx/en/industries/industry-4.0.html

**Journals and Magazines:**

Not declared

**Teaching and Learning Methods:**

1. Every week students will participate in in-class activities along with practical training in a PLM software laboratory.
2. Visiting case study factories will be scheduled every month for students to observe digital technologies being implemented in reality and for data collection.
3. Student presentation will be regularly scheduled for students to practice presentation skills.
4. Students design a virtual digital factory out of a real traditional one as a class final project.

**Time Distribution and Study Load:**

In-class activities: 30 hours

Laboratory sessions and practical training: 45 hours (including visiting a factory at a minimum of 12 hours)

Self-studying: 45 hours

**Evaluation Scheme**: Class participation (10%)

Peer assessment in class activities (10%)

Individual assignments and presentations (10%)

Progress presentation (25%)

Final group project presentation (25%)

Final Examination (20%)

An "A" would be awarded if a student shows a deep understanding of the knowledge learned through home assignments, project works, and exam results.

A "B" would be awarded if a student shows an overall understanding of all topics.

A "C" would be given if a student meets below average expectation in understanding and application of basic knowledge.

A "D" would be given if a student does not meet expectations in both understanding and application of the given knowledge.

**Course Developers:** Athakorn Kengpol (athakorn.kengpol@gmail.com) (KMUTNB), Supapan Chaiprapat(supapan.s@psu.ac.th) (PSU)

## Course 7: Advanced Optimization: Techniques and Industrial Applications (3-0-0)

**Course Objective:** The objective of this course is to provide the students with knowledge on the application of various optimization techniques which can help making decisions for practical problems in industries. Modeling concepts and applications of linear, integer, nonlinear, and dynamic programming as well as network models are addressed. Meta-heuristic techniques are also discussed to obtain good solutions for large scale practical problems in a reasonable computational time. Optimization model and its applications are demonstrated for solving problems in Industry 4 era.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Formulate mathematical programs for practical problems in production and supply chain systems (Create).
CLO2. Apply appropriate optimization techniques and write codes of optimization models using professional optimization software (i.e., MATLAB, LINGO, or MPL software) to solve single-objective practical problems in production systems, supply chain systems and specific operational problems (Create).
CLO3. Find appropriate trade-off solutions for multiobjective decision making problems in production systems, supply chain systems and specific operational problems (Create).
CLO4. Use meta-heuristic techniques to solve large scale NP-hard combinatorial problems for both single and multiple objective decision making problems where analytical methods cannot be used (Create)
CLO5. Conduct sensitivity analysis to examine the robustness of the solutions resulting from optimization models in order to ensure that appropriate solutions will be deployed in real world situations where input parameters are uncertain and cannot be estimated precisely (Evaluate).
CLO6. Understand how to apply digital technology for automated data-driven and in real-world optimization model. (Apply).

**Prerequisite:** Operations Research

**Course Outline:**

Modules

Module 1: Theory of mathematical programming for convex optimization

Module 2 : Heuristics and Metaheuristics

Module 3: Optimization and Its Applications in Industry 4 Era

Contents (45 hrs. in total)

Module 1: Theory of mathematical programming for convex optimization (19 hrs.)

1. Basic Modeling Concepts (1 hr.): Lecture: AC
2. Linear Programming (6 hrs.): Lecture: AC + RO (Discussion, Home Assignment, Group project)
3. Integer Programming, Mixed Integer Programming, and Combinatorial Optimization (5 hrs.): Lecture: AC + RO (Discussion, Home Assignment, Group project)
4. Non-linear Optimization (3 hrs.) Lecture: AC + RO (Discussion, Home Assignment)
5. Dynamic Programming (4 hrs.) Lecture: AC + RO (Discussion, Home Assignment)

Module 2: Heuristics and Metaheuristics (16 hrs.)

1. Concept of Heuristics and Metaheuristics (1 hr.) Lecture: AC + RO (Discussion)
2. Population-based algorithms: GA, PSO, DE) (9 hrs.) Lecture: AC + RO (Discussion, Group project)
3. Local Search Methods: ALNS and Tabu Search (3 hrs.) Lecture: AC + RO (Discussion, Group project)
4. Multiobjective optimization (3 hrs.) Lecture: AC (Discussion)

Module 3: Optimization and Its Applications in Industry 4 Era (10 hrs.)

1. An Overview of Digital Technologies (1 hr.)

This topic aims to give overview information of the tools (digital technology) used in optimization problems in Industry 4.0 era. Lecture: AC + RO (Discussion, Home Assignment)

1.1 Digital technology concept

1.2 Digital technology hardware & software

1.3 Digital technology applications

2. Optimization (Opt) concept and Its Applications in Industry 4.0 Era (2 hr.)

This topic aims to give a basic idea of how to apply optimization to the real-world problem in Industry 4.0. Lecture: AC + RO (Discussion, Home Assignment, Group project)

2.1 Optimization concept in Industry 4.0 era

2.2 Optimization applications in Industry 4.0 and mobile support

- Opt in Warehouse and Inventory Management
- Opt in Transportation problems
    1) Smart Pickup and Delivery system (i.e., customized and real time pick up scheduling)
    2) Real time fleet management, tracking service and transportation condition
- Opt in Scheduling problems

3. Optimization (Opt) Design in Industry 4.0 (2 hr.)

This topic aim to enhance student capability to analyze the problem, design, implement and measuring to use the optimization problems in Industry 4.0. Lecture: AC + RO (Discussion, Home Assignment, Group project)

3.1 System analysis concept

3.2 System architecture, module and component design

3.3 Data input/output user interface design

3.4 Optimization programming, modeling, and simulation

3.5 Evaluating the designed system

4. Real-Time Optimization (2 hr.)

This topic aims to deal with practical optimization problems for automated input data. Lecture: AC + RO (Discussion, Home Assignment, Group project)

4.1 Checking optimality conditions when input data change

4.2 Setting initial solution when input data change

5. Case Study (3 hr.)

This topic aims to enable students to apply optimization concept in an Industry 4.0 real-world problem. Lecture: AC + RO (Discussion, Group project )

**Workshop Sessions:**

**Laboratory Sessions:**

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Operations Research: An Introduction, 9th Edition, Hamdy A. Taha, Pearson Education, 2013.

Linear Programming and Extensions, George Dantzig, Princeton University Press, 2016.

Model Building in Mathematical Programming, 4th Edition, H. Paul Williams, Wiley, 1999.

Operations Research: A Practical Introduction (Operations Research Series) 1st Edition, Michael W. Carter, Camille C. Price, CRC press, 2000.

**Journals and Magazines:**

European Journal of Operational Research, Elsevier

International Journal of Production Research, Taylor and Francis

International Journal of Production Economics, Elsevier

Journal of the Operational Research Society, Palgrave Macmillan

Management Science, Informs

**Teaching and Learning Methods:** This is a project-based learning (PBL). During lecture sessions, class discussions and group projects will be conducted. Group projects are included in all modules in order to make students are able to solve the real-world optimization models. Students will practice various skills included developing mathematical programming, heuristics, and metaheuristics. Most importantly, students will be able to apply digital technology for automated data-driven used in the real-world optimization models.

**Time Distribution and Study Load:**

Lectures: 45 hours

Self-Study: 30 hours

Group Project: 15 hours

Discussion: 10 hours

**Evaluation Scheme**: An "A" would be awarded if a student can demonstrate clearly skills in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student can show clearly understanding how to apply digital technology for automated data-driven used in real-world optimization models.

An "B" would be awarded if a student can show good progress in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student can show good understanding how to apply digital technology for automated data-driven used in real-world optimization models.

An "C" would be awarded if a student can show reasonable progress in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student

can show reasonable understanding how to apply digital technology for automated data-driven used in real-world optimization models.

An "D" would be awarded if a student shows lack of improvement in developing mathematical programming, heuristics and metaheuristics to solve real-world optimization models. Additionally, a student shows lack of improvement how to apply digital technology for automated data-driven used in real-world optimization models.

**Course Developers:** Kanchana Sethanan (KKU), Huynh Trung Luong (luong@ait.ac.th) (AIT), Warisa Wisittipanich (warisa.o@gmail.com) (CMU), Teresa Monteiro(tm@dps.uminho.pt) (UMinho)

## Course 8: Intelligent Decision Support Systems (1-4-0)

**Course Objective:** The objective of this course is to give students the up-to-date of decision-making concepts, process, strategies, and technologies that are often used to support decision making in real-world issues coupled with agile approach and industry 4.0 specification. Students will know how to analyse, to design, to implement and to validate an Intelligent Decision Support System (IDSS). The integration of Artificial Intelligence models and Statistical models, and the knowledge discovery from data step will be emphasized. The course consists of foundations and developments of IDSS, software tools for IDSS development, IDSS for Digital Manufacturing Systems, and IDSS applications

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Explain concepts of a decision support system in term of an interactive system providing information, tools and models and its effects on Industry 4.0.
CLO2. Apply techniques of IDSS (e.g. artificial neural networks, machine learning, rule-based systems, etc.) and validate IDSS techniques to solve a complex industrial problem.
CLO3. Identify decision factors, models, and analysis of intelligent decision support systems (IDSS) to support a smart production system.
CLO4. Appraise the frameworks of IDSS.
CLO5. Design a knowledge-based system for a smart production system.

**Prerequisite:** None

**Course Outline:**

Module 1: IDSS Foundation and Development

1. The needs of decision support tools
2. Modelling of Decision Process
3. IDSS Architecture, Analysis, Design, Requirements, and Validation
4. Impact of IDSS in Industrial Performance
5. Economic Impact of IDSS in industry
6. Agile Approach for Smart Production

Module 2: Software Tools for IDSS Development

1. The analytic hierarchy process (AHP)
2. R-software
3. RapidMiner
4. WEKA
5. Deep Learning for Smart Production

Module 3: IDSS for Digital Manufacturing Systems

1. Artificial Intelligence and DSS
2. Knowledge Acquisition and Representation
3. Predictive Models

4. Uncertainty Models
5. Industrial Applications
6. Knowledge-based Systems for Smart Production

**Workshop Sessions:**

1. Analyzing the needs for decision support tools
2. Modelling of Intelligent Decision Process
3. IDSS design and validation
4. IDSS impacts to Industry
5. Creating a smart production by agile approach
6. IDSS Development by AHP
7. Multi-objective decision analysis in R
8. RapidMiner & Data Mining
9. Simple Classifiers with WEKA
10. Deep Learning for smart production
11. Knowledge acquisition and representation
12. IDSS combining predictive models
13. IDSS combining uncertainty models
14. IDSS applications in real-world
15. Creating knowledge-based systems for smart production

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Gupta, J.N.D., Forgionne, G.A., and Manuel, M.T., Intelligent Decision-making Support Systems: Foundations, Applications and Challenges, Springer, 2006

Iantovics, B., and Kountchev, R., Advanced Intelligent Computational Technologies and Decision Support Systems, Springer, 2014

Kumer. K., Zindani, D. and Davim, J.P., Digital Manufacturing and Assembly Systems in Industry 4.0, CRC Press, 2019

Tweedale, J.W., Neves-Silva, R., Jain, L.C., Phillips-Wren, G., Watada, J., and Howlett, R.J., Intelligent Decision Technology Support in Practice, Springer, 2016

Valencia-Garcia, R, Paredes-Valverde, M.A., Salas-Zarate, M.P. and Alor-Hernandez, Giner., Exploring Intelligent Decision Support Systems, Springer, 2018

**Journals and Magazines:**

Decision Support Systems, Elsevier

Journal of Decision Systems, Taylor & Francis LTD

International Journal of Decision Support System Technology, IGI Global

International Journal of Intelligent Systems, Wiley-Blackwell

IEEE Intelligent Systems, IEEE

Expert Systems, Wiley

**Teaching and Learning Methods:** The Collaboration is the main idea of teaching. Students are actively participated in the class by talking with each other and listening to other opinions. The learning methods include case study, group discussion, individual assignment, practical exercises, simulation, field class, and group project.

**Time Distribution and Study Load:**

Lectures: 15 hours

Workshops: 60 hours

Self-study/Group project: 75 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Case Studies 20%, Practical Exercises 10%, Assignments 10%, Portfolio 5%, Peer Assessment 5%, Oral Presentation 10%, Project 20%, and Open Exam 20%. In final grading,

An "A" would be awarded if a student shows a deep understanding of the knowledge learned through assignments, project works, and exam results.

A "B" would be awarded if a student shows an overall understanding of all topics.

A "C" would be given if a student meets below average expectation in understanding and application of basic knowledge.

A "D" would be given if a student does not meet expectations in both understanding and application of the given knowledge.

**Course Developers:** Suriya Jirasatitsin (suriya.j@psu.ac.th) (PSU), Warapoj Meethom (warapoj.m@eng.kmutnb.ac.th) (KMUTNB), Thitipong Jamrus (thitja@kku.ac.th) (KKU)

## Course 9: Applied Data Analytics (2-2-0)

**Course Objective:** The objective of this course is to help students develop competences on statistical techniques needed for data analysis, and various data mining techniques and algorithms used in practical problems that require processing big data for decision making purpose.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Apply various inferential statistical analysis techniques to describe data sets and withdraw useful conclusions from the data sets (e.g., confidence interval, hypothesis testing)
CLO2. Apply data visualization techniques and key data mining techniques (e.g., classification analysis, associate rule learning, anomaly/outlier detection, clustering analysis, regression analysis) in dealing with big data sets
CLO3. Implement the analytic algorithms for practical data sets
CLO4. Perform large scale analytic projects in various industrial sectors
CLO5. Work and communicate effectively in teamwork

**Prerequisite:** None

**Course Outline:**

Module 1: Basic Data Analysis

I. Basic Concepts
   1. Descriptive Statistics
   2. Statistical Inferences
   3. Data Measurement
   4. Measures of Central Tendency and Dispersion
   5. Common Statistical Graphs
   6. Determination of Outliers

II. Statistical Inferences
   1. Point Estimation and Required Properties of Point Estimators
   2. Interval Estimations for Mean, Proportion and Variance of Population
   3. Sample Size Determination

III. Hypothesis Testing
   1. Hypothesis Testing for Mean, Proportion and Variance of Population – Single Sample Test
   2. Hypothesis Testing for Mean, Proportion and Variance of Population – Two Samples Test
   3. Type I and Type II Errors – Power of the Test

4. Observed Significance Level

Module 2: Data Visualization

IV. Data Visualization

1. Introduction to Data Visualization
2. Basic Charts for Numerical Data and Categorical Data
3. Distribution Plots
4. Multivariate Charts: Combo Chart, Combination Chart, Stacked Column Chart

V. Data Dashboard

1. What is a Data Dashboard?
2. Applications and Benefits of Data Dashboard
3. Design and Construct a Data Dashboard

Module 3: Key Data Mining Techniques

VI. Regression Analysis

1. Linear Regression and Least Square Method
2. Residual Analysis
3. Multiple Regression
4. Goodness of Fit Tests

VII. Data Classification

1. k-Nearest Neighbor Algorithm for Estimation and Prediction
2. Distance Functions: Euclidian, Manhattan, Minkowski, Min-Max Normalization, Z-Score Standardization
3. Logistics Regression
4. Bayesian Networks
5. Model Evaluation Measures for Classification Task

VIII. Data Clustering

1. Hierarchical Clustering Method
2. k-Means Clustering
3. Measuring Cluster Goodness: The Silhouette Method and The Pseudo-F Statistic

IX. Association Rules

1. Affinity Analysis

2. The a Priori Algorithm – Generating Frequent Itemsets
3. The a Priori Algorithm – Generating Association Rules
4. Measure the Usefulness of Associate Rules

X. Case Studies/Group Projects

**Workshop Sessions:**

Tutorial 1: Basic Statistical Analyses using R and R Studio

Tutorial 2: Importing Data in R Studio

Tutorial 3: Percentiles & Distributions Functions; Probability Plots

Tutorial 4: Confidence Intervals & Test of Hypotheses

Tutorial 5: Constructing Data Dashboards using Microsoft Power BI

Tutorial 6: Linear & Multiple Linear Regression

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Larose, D.T. and Larose, C.D., Data Mining and Predictive Analytics, 2nd edition, Wiley, 2015

Shmueli, G., Bruce, P.C., Yahav, I., Patel, N.R. and Lichtendahl Jr., K.C., Data Mining for Business Analytics – Concepts, Techniques, and Application in R, Wiley, 2018

Ankam, V., Big Data Analytics, Packt, 2016

Walkowiak, S., Big Data Analytics with R, Packt, 2016

Grolemund, G., Hands-on Programming with R, O'Reilly, 2014

Wickham, H. and Grolemund, G., R for Data Science, O'Reilly, 2017

Wexler, S., Shaffer, J. and Cotgreave, A., The Big Book of Dashboards: Visualizing Your Data Using Real-World Business Scenarios, Wiley, 2017

O'Cornor, E., Microsoft Power BI Dashboards Step by Step, Practice Files, 2019

**Journals and Magazines:**

Management Science, Informs

Journal of Supply Chain Management, Wiley

Computational Statistics & Data Analysis, Elsevier

Advances in Data Analysis and Classification, Springer

**Teaching and Learning Methods:** The teaching is done via lectures by the instructor. Tutorial sessions are conducted on the use of tools in each subject. The learning methods include group discussion, individual/group assignment and group project/case study.

**Time Distribution and Study Load:**

Lectures: 30 hours

Tutorials/Group Discussions: 30 hours

Self-study: 45 hours

Group project: 40 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Mid-semester examination 20%, assignments and group projects 50%, final examination 30%. In final grading,

An "A" would be awarded if a student shows a deep understanding of the knowledge learned through home assignments, project works, and exam results.

A "B" would be awarded if a student shows an overall understanding of all topics.

A "C" would be given if a student meets below average expectation in understanding and application of basic knowledge.

A "D" would be given if a student does not meet expectations in both understanding and application of the given knowledge.

**Course Developers:** Huynh Trung Luong

(luong@ait.ac.th) (AIT), Sirorat Pattanapairoj (siropa@kku.ac.th); Komkrit Pitituek(komkri@kku.ac.th) (KKU), Wimalin Laosiritaworn (wimalin@hotmail.com) (CMU)

## Course 10: Cyber-Physical Industrial Systems (2-0-3)

**Course Objective:** Gaining knowledge about: the main types and characteristics of the Cyber-Physical Systems, their application areas, components selection rules, programming methodology, specific aspects related to different measured physical parameters, data storage, reporting and communications.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Identify links between industrial engineering knowledge and methods, on one side, and the design, modeling and management activities related to CPIS, on the other side (Analyze)
CLO2. Implement smart production and co-created product design & development concepts in CPIS related activities (Create)
CLO3. Identify use cases of big data and real time data analytics applied for CPIS, for supporting smart production, product design & development and advanced manufacturing process (Evaluate)
CLO4. Exploit the CPIS online connectivity for strengthening business capability (Apply)
CLO5. Applying CPIS related knowledge and competences for improving sustainability (Apply)

**Prerequisite:** None

**Course Outline:**

Introduction - concept of standard CPS, basics, model

Establishing the projects' subjects and forming the teams

Identify the physical quantities to be measured or the datasets to be acquired and computed

Types of transducers, characteristics, application fields, selection criteria

Choose or design the sensors and/or the transducers for measuring or for data collection

Signal conditioning basics

Data acquisition basics

Choose or design the needed electronics (power supplies, signal conditioning, analog to digital converters, multiplexers, communication subsystems)

Connect the CPS components

Test the CPS assembly

Data acquisition programming basics

Develop the CPS data acquisition software components

Data processing basics

Develop the CPS data processing software components

Data communication basics

IoT communication protocols basics

Develop the CPS data communication software components

Cloud computing and artificial intelligence basics

Feed artificial intelligence component with experimental data

Final project presentation

**Workshop Sessions:**

**Laboratory Sessions:**

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Wang, L. and Wang, X.V. (2018). Cloud-Based Cyber-Physical Systems in Manufacturing. Springer

Markwedel, P. (2018). Embedded System Design: Embedded Systems, Foundations of Cyber-Physical Systems, and the Internet of Things. Springer.

Brown, P. (Ed.) (2016). Sensors and Actuators: Technology and Applications. Library Press.

Morris, A.S. and Langari, R. (2017). Measurement and Instrumentation: Theory and Application (Second Edition). Elsevier.

Boyer, S.A. (2009). SCADA: Supervisory Control and Data Acquisition. ISA The Instrumentation, Systems and Automation Society

Buyya, R. and Dastjerdi, A.V. (Eds.) (2016). Internet of Things: Principles and Paradigms. Morgan Kaufmann

**Journals and Magazines:**

**Teaching and Learning Methods:** The teaching / learning methodology is mainly student-centered (active learning) rather than teacher-centered. The course comprises lectures and laboratory sessions (for projects' development). The lectures, besides the expositive part (teacher-centered), incorporate elements of active learning (e.g. small tasks to be solved individually or by teams in 5-10 minutes). The laboratory sessions adopt the project-based learning (PBL) approach. The projects are developed by teams and incorporate project management skills (e.g. time management and tasks' distribution), problem solving, hands-on work (learning by doing), communications skills (project presentation and discussion) and peer assessment.

**Time Distribution and Study Load:**

Lectures: 15 hours

Laboratory sessions: 45 hours

Autonomous work (self-study): 60 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution:

- Assessment during lectures: 10 %
- Assessment during teamwork lab activities:
    - Individuall student grade: 50 %
    - Peer assessment by teammates: 10 %
    - Team grading: 10 %
- Assessment during final project presentation:

- Individually: 10 %
- Team assessment: 10 %

Assessment During lectures:

- Presence is compulsory
- Students are graded according to their answers to questions addressed during the lecture

During teamwork lab activities

- Each student continuously assessed during the lab works, individually graded every week regarding:
  - solutions correctness
  - volume of needed support
  - adopted approach
  - innovative solutions
- Each student peer assessed, by the teammates, regarding:
  - contribution to the overall project objective achievement
  - Innovative solutions
- Team graded every week regarding the alignment to the project plan and milestones achievement

During the final project presentation:

- Each student individually graded regarding:
  - Solutions
  - Presentation skills (also peer assessed by other teams)
- Team graded regarding:
  - Technical solutions (also peer assessed by questions from other teams)
  - Quality of the technical report
  - Quality of teamwork
  - Questions asked to other teams

**Course Developers:** Tom Savu (savu@ctanm.pub.ro) (UPB), Rui Sousa (rms@dps.uminho.pt, ruibe2008@gmail.com) (UMinho), Sawat Pararach(psawat@engr.tu.ac.th) (TU)

## Course 11: Collaborative Manufacturing Systems (2-0-3)

**Course Objective:** Collaboration among partners to form a value network has become necessary as up-to-date information is so critical in a competitive market. Sharing of information among a network of physical units on the shop floor and connecting internal manufacturing processes and business processes with external business processes allow a company to offer a core competence with flexible, responsive operations meeting the expectations of customers and the value network partners. This course aims to build students' competence in collaboration in manufacturing from the board picture of collaborative manufacturing management down to collaboration on a shop floor. The students will learn from concepts, applications, and hands-on experience.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Recognize a potential collaborative manufacturing in a factory (understand)
CLO2. Identify a value network for collaborative manufacturing for a business (apply)
CLO3. Apply collaborative manufacturing management in practice (apply)
CLO4. Manipulate collaborative robots for collaborative tasks (apply)
CLO5. Manage manufacturing collaboration on a shop floor (apply)

**Prerequisite:** none

**Course Outline:**

Module 1: Collaborative Manufacturing Management

1. Evolution of Manufacturing Systems
2. Collaborative Manufacturing Management Model
3. Collaborative Manufacturing Management Fundamentals and Infrastructure
4. Ontology for Collaborative Manufacturing

Module 2: Machines Collaboration on a Shop Floor

1. Distributed Manufacturing
2. Distributed Arrival Time Control for Real-Time Scheduling
3. Collaborative Material Handling System
4. Collaborative Manufacturing Processes

Module 3: Man-Machine Collaboration on a Shop Floor

1. Evolution of Man-Machine Collaboration
2. Industrial human augmentation systems
3. Flexible Human-Robot Collaboration
4. Cyber-Human System

**Workshop Sessions:**

**Laboratory Sessions:**

- Laboratory on plant simulation: Simulate a manufacturing process based on local industries, identify a value network for collaborative manufacturing and apply collaborative manufacturing management.
- Laboratory on collaborative machines: Manipulate collaborative machines e.g. communication between 3D-printing machine and CNC milling machine
- Laboratory on collaborative robots: Manipulate collaborative robots e.g. machine-robot communication, human-robot collaboration
- Laboratory on collaborative material handling system: Manipulate collaborative material handling system on a shop floor e.g. automatic guided vehicle (AGV) and Automated storage and retrieval system (AS/RS)

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Andre P. Calitz, Paul Poisat and Margaret Cullen, 2017, The future African workplace: The use of collaborative robots in manufacturing, SA Journal of Human Resource Management,pp. 1-11.

ARC Advisory group, 2001, Collaborative Manufacturing Management Strategies, ARCweb.com, pp.1-28

Eloise Matheson, Riccardo Minto, Emanuele G. G. Zampieri, Maurizio Faccio and Giulio Rosati, 2019, Human–Robot Collaboration in Manufacturing Applications: A Review, Robotics, Vol.8(100), pp. 1-25

Koomsap, P., Shaikh, I., Prabhu, V.V., 2005, Integrated process control and condition-based maintenance scheduler for distributed manufacturing control system, International Journal of Production Research, Vol. 43, No. 8, pp. 1625-1624.

Li, W. D., Ong, S. K., Nee, A. Y.C., McMahon, C. A. (Eds.), 2007, Collaborative Product design and manufacturing methodologies and applications. Springer Science & Business Media.

Luis M. Camarinha-Matos , Rosanna Fornasiero and Hamideh Afsarmanesh, 2017, Collaborative Networks as a Core Enabler of Industry 4.0 in Collaboration in a Data-Rich World. PRO-VE 2017. IFIP Advances in Information and Communication Technology, vol 506, pp 3-17.

Matthew Krugh and Laine Mears, 2018, A complementary Cyber-Human Systems framework for Industry 4.0 Cyber-Physical Systems, Manufacturing Letters, vol 15, pp. 89-92.

Melo, J. G., Fattori, C. C., Junqueira, F., & Miyagi, P. E., 2009,. Framework for collaborative manufacturing systems based in services. 20th International Congress of Mechanical Engineering (COBEM), Gramado, Brazil.

Mohammad Rizal Firmansyah and Yousef Amer, 2013, A Review of Collaborative Manufacturing Network Models, International Journal of Materials, Mechanics and Manufacturing, Vol. 1, No.1 pp. 6-12.

Roope Raisamo, Ismo Rakkolainen, Päivi Majaranta, Katri Salminen, Jussi Rantala and Ahmed Farooq, 2019, Human augmentation: Past, present and future, International Journal of Human-Computer Studies, Vol. 131, pp. 131-143.

Shirine El Zaatari, Mohamed Marei, Weidong Li and Zahid Usman, 2019, Cobot programming for collaborative industrial tasks: An overview, Robotics and Autonomous Systems, Vol. 116, pp.162–180.

Wit Grzesik, Hybrid additive and subtractive manufacturing processes and systems: A review (2018), Journal of Machine Engineering, Vol. 18, No. 4, pp. 5–24.

**Journals and Magazines:**

Journal of Machine Engineering

Robotics and Autonomous Systems

International Journal of Human-Computer Studies

International Journal of Materials, Mechanics and Manufacturing

Manufacturing Letters

**Teaching and Learning Methods:** Each major topic of this course is approached using a three steps process: lecture together with class discussion and in-class group assignments, including case studies and practical exercises that students will work on and present at the end of the sessions. The students are expected to involve actively in-class activities. The students will also apply knowledge learned from class in laboratory sessions, which have been designed to match the learning topics. Besides, there will be a group project for the students to practice their knowledge, critical thinking, problem-solving, and decision-making skills as well as team management.

**Time Distribution and Study Load:**

| | |
|---|---|
| Lectures: | 30 hours |
| Laboratory sessions: | 45 hours |
| Self-study/Projects: | 45 hours |

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution:

Class discussion and participation 5%, Peer assessment in class activities 5%, Assignments 10%

Practical exercises 20%, Presentation 10% and Group project 50%.

The mark ("A", "B" ... 1 - 10) obtained by student will be given according to the rules of each university, based on the total number of points accumulated.

An "A" would be awarded if a student shows a deep understanding of the knowledge learned through assignments, project works, and exam results.

A "B" would be awarded if a student shows an overall understanding of all topics.

A "C" would be given if a student meets below average expectation in understanding and application of basic knowledge.

A "D" would be given if a student does not meet expectations in both understanding and application of the given knowledge.

**Course Developers:** Kunlapat Thongkaew(kunlapat.t@psu.ac.th) (PSU), Wasawat Nakkiew

(wasawat@gmail.com) (CMU), Pisut Koomsap (pisut@ait.asia)(AIT)

## Course 12: Additive Manufacturing for Industry 4.0 (1-2-3)

**Course Objective:** Additive Manufacturing (AM) is a technology supporting the sustainable rapid development of personalized complex design in various disruptive applications, especially in manufacturing and medical.

This course aims to build student competence in AM and related technology. The students will learn fundamental knowledge of Additive Manufacturing and Reverse Engineering (RE) and their applications in manufacturing, medical and other sectors. Besides, the students will be proficient in practice design for additive manufacturing.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Apply knowledge on additive manufacturing, and reverse engineering in a variety of domains (apply);
CLO2. Investigate process parameters for effective additive manufacturing (create);
CLO3. Differentiate principles behind additive manufacturing and reverse engineering technologies available in the market (analyze);
CLO4. Select an appropriate AM technology based on preset optimisation criteria (eg. cost, quality, time/ available resources) (evaluate);
CLO5. Apply design for additive manufacturing (DfAM) in practice for the development of new products (apply);
CLO6. Communicate effectively and work in a team environment (apply).

**Prerequisite:** Computer Aided Design

**Course Outline:**

Module 1: Additive Manufacturing Technologies – Principles and Applications

I. Additive Manufacturing Basic Concepts and processes

1. Additive Manufacturing workflow
2. Benefits & Limitations of Additive Manufacturing
3. Applications of 3D printing (Aerospace, Automotive, Robotics, Tooling, Healthcare, Design, Education etc.)
4. Main technologies (ISO/ ASTM DIS 52900:2018)

II. Solid- Based Additive Manufacturing Technologies

1. Material Extrusion

   1.1 Fused Deposition Modelling (FDM)

   1.2 Fused Filament Fabrication (FFF)

   1.3 Freeform Fabrication (FF)

2. Sheet lamination

   2.1 Laminated Object Manufacturing (LOM)

III. Powder-Based Additive Manufacturing Technologies

1. Powder Bed Fusion
   - 1.1 Multi Jet Fusion (MJF)
   - 1.2 Selective Laser Sintering (SLS)
   - 1.3 Direct Metal Laser Sintering (DMLS)
   - 1.4 Selective Laser Sintering (SLS)
   - 1.5 Electron Beam Melting (EBM)
2. Direct Energy Deposition
   - 2.1 Laser Engineering Net Shape (LENS)
   - 2.2 Electron Beam Additive Manufacturing (EBAM)

IV. Liquid-Based Additive Manufacturing Technologies

1. Vat photopolymerization
   - 1.1 Stereolithography (SLA)
   - 1.2 Digital Light Processing (DLP)
   - 1.3 Continuous Digital Light Processing (CDLP)
2. Material Jetting
   - 2.1 Material Jetting (MJ)
   - 2.2 NanoParticle Jetting (NPJ)
   - 2.3 Drop on Demand (DOD)
3. Binder Jetting

Module 2: Data Interfacing for Additive Manufacturing

V. STereoLithography (STL) Models

1. ASCII STL
2. Binary STL
3. Color in binary STL
4. Facet normal
5. Use in 3D printing
6. Use in other fields
7. STL processing software

VI. Slicing Techniques

1. STL-based Slicing
2. Direct Slicing
3. Slicing Software

VII. Reverse Engineering for Additive Manufacturing Applications

1. Reverse Engineering Technologies
2. Reverse Engineering Workflow
3. From Physical to Digital: Meshes and Solids

Module 3: Design for Additive Manufacturing

VIII. Optimization of 3D printing process parameters

1. Machine preparation and settings
2. Design rules for 3D printing
3. Part quality (layer height, line width etc.)
4. Part shell (wall thickness, top/bottom thickness, bottom pattern initial layer etc.)
5. Part infill (infill density, infill pattern, infill support etc.)
6. Material characteristics (printing temperature, flow rate, diameter etc)
7. Printing speed and travel
8. Post-processing
9. Technology specific parameters

IX. Influences, complementarity and Synergy in AM and conventional technologies

1. CNC manufacturing
2. Injection molding
3. Laser cutting & engraving
4. Stamping & cold plastic deformation

X. Macro environment of AM

1. Workforce of the future
2. Intellectual property issues
3. Standards
4. Quality assurance
5. Manufacturing and Supply chain
6. Product design
7. Digital thread & Industry 4.0
8. European policies

XI. AM Business models and reshaping production

1. Cloud manufacturing

2. SHAPEWAYS (www.shapeways.com)
3. 3D HUBS (www.3dhubs.com/)
4. SCULPTEO (www.sculpteo.com)
5. MATERIALISE (www.materialise.com/)
6. 3D PRINT (www.3dprint.com)
7. 3 x 3D – 3DPBM (https://www.3dpbm.com/),
8 PULSE (www.3dprintingmedia.network/),
9. INDEX (https://www.3dprintingbusiness.directory/)
11. FAB LAB (www.fablabconnect.com)

XII. Case Studies/Group Projects

**Workshop Sessions:**

Topic/ Chapter 1. State of the art in product design and development of .... (name of individual selected product)

Note: Each student/ student team is given a PRODUCT to study and develop during the workshop sessions/ group project. It is mandatory that the PRODUCT is considered a complex assembly with three main subsystems: mechanical, electrical (mechatronics) and software. The selected PRODUCT should have at least 8 mechanical components.

Topic/ Chapter 2. Product description of .... (name of individual selected product)

- Function of the assembly
- Objective of the assembly
- Main components description (Bill of Materials)

For each component you should mention: manufacturing technology (AM/ stamping, injection moulding/ CNC machined etc.) or if it is purchased.

Characteristics of the manufacturing technology, materials, equipment used etc.

Characteristics of the purchased part and web link.

- Working hypothesis of the assembly (Stress scenario, environment conditions which might influence the development process, any other process and product restrictions or special requirements)
- Calculus
- etc.

Topic/ Chapter 3. Computer Aided Design of components and Assembly procedures

- Description of all design stages for all individual parts of the assembly
- Description of all assembly conditions
- Description of Motion studies
- Description of FEA studies
- Description of Topological optimisation studies
- etc.

Note: Make sure the description for all redesigns of the parts and all concepts of your product are covered in this topic/ chapter.

Topic/ Chapter 4. Additive manufacturing of .... (name of individual selected product)

- AM principles which were used in the design of the parts
- Description of each part function in accordance with the general function of the assembly
- Description of optimisation process for 3D printing parameters in Cura or ZSuite for all individual parts of the assembly (including the redesigned parts)
- Justification for each 3D printing parameter chosen in accordance with the part function and the assembly function

Note: Make sure the 3D printing parameter description for all redesigns of the parts and all concepts of your product are covered in this topic/ chapter.

Topic/ Chapter 5. Conclusions and future development

Topic/ Chapter 6. Annexes - Development and constructions

6.1 Annex 1 – CAD Models for part 1, ...n (names of individual components)

6.2 Annex 2 – Assembly CAD file for product .... (name of individual selected product)

6.3 Annex 3 – *.STL files for part 1, 2, ....n (names of individual components)

6.4 Annex 4 – *.gcode/ *.zcode/ *.zcodex files for part 1, ...n (names of individual components)

6.5 Annex 5 – *.3mf (Cura) / *.zprojx (Zsuite) files for part 1, ...n (names of individual components)

Notes:

1. One *.3mf (Cura) / *.zprojx (Zsuite) file can contain several *.stl files, according to the optimum build layout that you set.
2. The annexes folders will be uploaded on the Moodle platform together with the word document of the project.

**Laboratory Sessions:**

During each laboratory students undertake the following activities:

identify a need, design & develop a CAD model of a product, simulate the working movements in the CADA environment, optimize the 3D printing parameters for the function of the product, 3D

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

ISO/ ASTM DIS 52900:2018 (E), (2018), Additive manufacturing – General principles – Terminology, ISO/ ASTM International 2018.

Wohlers T., (2018), Wohlers Report 2018, 3D Printing and Additive Manufacturing State of the Industry: Annual Worldwide Progress Report, Wohlers Associates, ISBN ISBN 978-0-9913332-4-0.

Redwood B., Schöffer F., Garret B., (2017), The 3D Printing Handbook: Technologies, design and applications, Editura 3D Hubs, ISBN 978-90-827485-0-5.

Zhang J., Jung Y.G., (2018), Additive Manufacturing: Materials, Processes, Quantifications and Applications, Elsevier, ISBN 978-0-12-812155-9

Gibson I., Rosen D., Stucker B., (2015), Additive Manufacturing Technologies - 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, Editura Springer, ISBN 978-1-4939-2112-6.

Page T., (2012), Design for Additive Manufacturing: Guidelines for Cost Effective Manufacturing, LAP Lambert Academic Publishing, ISBN 384732294X.

Barnatt C., (2013), 3D Printing: The Next Industrial Revolution, CreateSpace Independent Publishing Platform, ISBN-13: 978-1484181768.

Marchese K., Gorham R., Joyce J., Sniderman B., Passaretti M., (2017), 3D opportunity for business capabilities - Additive manufacturing transforms the organization, Deloitte Insights, Available at: https://www2.deloitte.com/content/dam/insights/us/articles/3256_3D-opportunity_AM-capabilities/DUP_3D-opportunity_business-capabilities.pdf,

Öberg C., Shams T., Asnafi N., (2018), Additive Manufacturing and Business Models: Current Knowledge and Missing Perspectives, Technology Innovation Management Review, Available at: https://timreview.ca/sites/default/files/article_PDF/Öberg_et_al_TIMReview_June2018.pdf

Laboratory: PPT handouts, necessary equipment, tools and consumables

**Journals and Magazines:**

Rapid Prototyping Journal, Emerald

Additive Manufacturing, Elsevier

Virtual and Physical Prototyping, Taylor and Francis

Journal of Materials Processing Technology, Elsevier

Computer Aided Design, Elsevier

Computer and Industrial Engineering, Elsevier

International Journal of Advanced Manufacturing Technology, Springer

International Journal of Computer Integrated Manufacturing, Taylor and Francis

Robotics and Computer Integrated Manufacturing, Elsevier

**Teaching and Learning Methods:** The teaching is done via lectures, laboratories and project sessions by the instructor. Tutorial sessions are conducted on the use of tools in each subject. The learning methods include group discussion, individual/group assignment and group project/case study.

**Time Distribution and Study Load:**

Lectures: 15 hours

Laboratories: 45 hours

Group project/Tutorials/Assignments/Self-study: 70 hours

Workshops for Group project preparation: 30 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Mid-semester examination 20%, assignments and group projects 50%, final examination 30%. In final grading,

An "A" would be awarded if a student shows a deep understanding of the knowledge learned through home assignments, project works, and exam results.

A "B" would be awarded if a student shows an overall understanding of all topics.

A "C" would be given if a student meets below average expectation in understanding and application of basic knowledge.

A "D" would be given if a student does not meet expectations in both understanding and application of the given knowledge.

**Course Developers:** Mihaela ULMEANU (mihaela.lupeanu@yahoo.com) (UPB), Pisut Koomsap (pisut@ait.asia) (AIT)

## Course 13: Innovative Product Design and Development (1-4-0)

**Course Objective:** The subject of the course concerns the creative design of innovative products that are technological innovation or modification of existing technological solutions. As a result, designed products should find their application in Industry 4.0 related businesses and its problems. The implementation of the course subject is based on learning and training methods of effective implementation of innovation, identification and analysis of the strategic elements of new product innovation, e.g. the process, different functions, and individual roles. The goal of this course is to develop creative thinking of the graduates and discussion of issues related to development and marketing innovative products, including searching for ideas and creating a concept based on creative thinking techniques and methods of entrepreneurial problem solving, selecting ideas and development of prototypes, taking into account user needs and the latest scientific research.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. analyze the basic concepts related to innovations and the idea of implementing innovative products (apply),
CLO2. apply the basic techniques of creative thinking and creative problem solving for creating innovative product and marketing strategies (apply),
CLO3. identify the benefits of implementing innovations (analyze),
CLO4. identify the challenges and opportunities associated with the launch of a new product and propose suitable strategies depending on product and situation (analyze),
CLO5. prepare a conceptual product design taking into account user needs and the latest scientific research (create),
CLO6. valorization, capitalization and protection of the original solutions obtained from the creative activity (evaluate),
CLO7. create and co-ordinate cross-disciplinary teams to achieve a common objective (create),
CLO8. present entrepreneurial and creative attitude towards seeking various problem solutions (apply).

**Prerequisite:** None

**Course Outline:**

Module 1: Innovation and creativity (Lectures: 5 hours, Workshop: 15 hours, Self-study: 15 hours)

I. Innovation
   1. The innovation process and its source
   2. Methods of analysis and evaluation of innovations
   3. Examples of innovative products

II. Creative thinking and creative problem solving for creating innovative product
   1. The concept of creative thinking and creative problem solving
   2. Principles and stages of creative problem solving
   3. The benefits of creative thinking
   4. Difficulties blocking creative thinking, counteracting the suppression of creativity

5. Basic heuristic methods and techniques (mind mapping, brainstorming and its variants, reverse brainstorming, Edward de Bono Methods)

Module 2: Product Design and Development (Lectures: 5 hours, Workshop: 25 hours, Self-study: 25 hours)

III. Creation and development of new products including sustainable development

1. Characteristics of the innovative product
2. Impact of consumers on the design and implementation of innovative products
3. Eco product design

IV. Creating a product design concept based on the design thinking methodology

1. Stages and tools in the design thinking method
   - Stage 1 - Empathy
   - Stage 2 - Defining problems
   - Stage 3 - Generating ideas
   - Stage 4 - Prototyping
   - Stage 5 - Testing
2. Examples of using the design thinking method in the design of innovative products

Module 3: Intellectual Property (Lectures: 5 hours, Workshop: 20 hours, Self-study: 20 hours)

V. Intellectual property

1. The role and importance of intellectual property in business development
2. National, regional and international authorities

VI. Knowledge management techniques

1. Copyrights
2. Related rights
3. Patents
4. Trademarks
5. Industrial design
6. Appellation of origin (Geographical Indications), protection of new varieties of plants, protection of integrated circuits, unfair competition

**Workshop Sessions:**

Module 1: Innovation and creativity (15 hours)

I. Innovation

The process of innovation - stages, methods of analysis and evaluation

II. Creative thinking and creative problem solving for creating innovative product

The concept of creative thinking and creative problem solving - basic heuristic methods and techniques

Module 2: Product Design and Development (25 hours)

III. Creation and development of new products including sustainable development

Eco-designing - characteristics, benefits and barriers

IV. Creating a product design concept based on the design thinking methodology

Stages and tools in the design thinking method

Stage 1 - Empathy

Stage 2 - Defining problems

Stage 3 - Generating ideas

Stage 4 - Prototyping

Stage 5 - Testing

Module 3: Intellectual Property (20 hours)

V. Intellectual property

The role and importance of intellectual property in business development

VI. Knowledge management techniques

Practical aspects of issues related to knowledge, explaining the essence and process of knowledge management in an organization and perceiving the need and importance of knowledge management in contemporary organizations

**Laboratory Sessions:**

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Curedale R.A., Design Thinking Process & Methods 4th Edition, Publisher: Design Community College Inc., 2017.

Justice L., The Future of Design: Global Product Innovation for a Complex World, Publisher Nicholas Brealey, 2019.

Chesbrough H.W., Open innovation. The New imperative for creating and profiting from technology, Harvard Business School Press, Boston 2003.

Liu C. Innovative Product Design Practice, CYPI Press, 2007.

Cooper R.G., Edgett S.J., Product Innovation and Technology Strategy, Booksurge Publishing, 2009.

Gessinger G.H., Materials and Innovative Product Development, Publisher Butterworth-Heinemann, 2009.

Patton J., Economy P., User Story Mapping: Discover the Whole Story, Build the Right Product Published O'Reilly Media, 2014.

Alves R., Nunes, N.J., Towards a Taxonomy of Service Design Methods and Tools, (in:) Falcão e Cunha J., Snene M., Nóvoa H. (eds.), Exploring Services Science. Lecture Notes in Business Information Processing, 2013, 215-229, Springer, Berlin, Heidelberg.

Zawadzki P., Żywicki K., Smart product design and production control for effective mass customization in the Industry 4.0 concept, „Management and Production Engineering Review", 2016, 7, 3, 105- 112.

**Journals and Magazines:**

Management and Production Engineering Review

**Teaching and Learning Methods:** This course will be implemented through the lectures, workshops and self-studies. The teaching and learning methods during workshops and self- studies include class discussion, analysis of examples, identification of customer needs, individual/ group generation of the product concept and its critical assessment, as well as simple prototyping of a product. Workshops will be conducted among others by the Design Thinking method. Students will gain the ability to moderate according to the Design Thinking methodology, which creates innovative solutions, products, services and processes. They will acquire the ability to search and recognize challenges that can be conducted according to the Design Thinking methodology. They will learn the rules for selecting project teams. Students will acquire ability to use teamwork to achieve the group's intended goal and result.

**Time Distribution and Study Load:**

Lectures: 15 hours

Workshop: 60 hours

Self-study: 60 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Class discussions (15%); Individual presentation of assignments (15%); Individual tasks for a group project (15%); Progress a group project (10%); Project outcome (10%); Final presentation of group project (20%); Test (15%).

An "A" would be awarded if a student shows a deep understanding of the knowledge about innovative product design and development.

A "B" would be awarded if a student shows an overall understanding of all topics about innovative product design and development.

A "C" would be given if a student meets below average expectation in understanding and application of basic knowledge about innovative product design and development.

A "D" would be given if a student does not meet expectations in both understanding and application of the given knowledge about innovative product design and development.

During lectures:

- Class discussions
- Test

During workshops and self-studies:

- Class discussions
- Individual presentation of assignments
- Individual tasks for a group project
- Progress a group project
- Project outcome

- Final presentation of group project

**Course Developers:** Agnieszka Ociepa-Kubicka (Agnieszka.Ociepa-Kubicka@wz.pcz.pl), Katarzyna Rozpondek (Katarzyna.Rozpondek@wz.pcz.pl) (CUT), Naritsak Tuntitipawan (supernst88@gmail.com) (KMUTNB), Nicolae Ionescu (ionescu_upb@yahoo.com) (UPB), Montalee Sasananan (nmontale@engr.tu.ac.th)

## Course 14: Human-Centric Design for Operator 4.0 (1-4-0)

**Course Objective:** Human-centric design is a unique approach to solve problems ofproducts, process, environments, and other human operations challenging withincompatibilities of human needs, abilities and limitations. The objective of this course is tounderstand the interactions among humans and other elements of a system, evaluate anddesign tasks, equipment, products, processes, jobs, environments and other elements inworking systems including work organization in order to optimize human well-being andoverall system performance.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Apply human abilities, limitations, needs and other important human characteristics for designing tasks, jobs, equipment, products, environments, processes and other element in working systems.
CLO2. Evaluate occupational health and safety (OHS) risks to accidents, injuries, and ill health in a working system.
CLO3. Create solutions and opportunities for reducing OHS risks, enhancing operators' performance and preference.
CLO4. Design tasks, equipment, workstation, workspace, environment, and other elements in working systems compatible with needs, abilities and limitations of operators for better well-being and performance.
CLO5. Analyze work organization affecting on human behavior and performance, e.g. policy, work schedule, motivation, satisfaction, communication and participatory.

**Prerequisite:** None

**Course Outline:**

Module 1: Basic of Human Factors Knowledge for Human-Centric Design

1. Introduction to Human-Centric Design (HCD)
   1.1 Meaning, scope and applications of human-centric design
   1.2 Basic concepts of HCD for engineering
   1.3 Professional in HCD
2. Human characteristics: Limitation, Ability, and Fatigue
   2.1 Physical / Physiological / Psychological and Cognitive /Behavioral Characteristics
   2.2 Stress and strain in human
   2.3 Human fatigue and human errors and their effect to health, accident and efficiency
3. Human System Interaction: Manual working system, Semi-automation working system, and Automation
   3.1 HCD for product design
   3.2 HCD for process and physical environmental design
   3.3 HCD for work organization design
4. Human System Interaction: Situation Awareness and Usability Testing
   4.1 HCD for product design

4.2 HCD for process and physical environmental design

4.3 HCD for work organization design

Module II: Problem Identification for Human-Centric Design

1. Human factors evaluation tools for identifying risk factors effecting on health, incident, accident and efficiency such as Posture Evaluation, Task Analysis, Usability Testing, Human Error Risk Assessment et.al.
2. Each student selects a problem of interest related to HCD
3. Identify human factors elements related to the selected problem
4. Analysis the problem of Human-Centric Design

Module III: Intervention and Design

1. Workstation and Workspace Design
   1.1 Measurement of human dimensions and motion.
   1.2 Application of human anthropometry for workstation and workspace designs
   1.3 International standards related to HCD
2. Design for Human Control/System Interaction (HCI/HSI)
   2.1 Visual/Display Control Design
   2.2 HCD for control centers
   2.3 Accessible design for special people
   2.4 Physical environment design for HCI/HIS
3. Man-machine system and interaction and cognitive designs
   3.1 Human perception, information and sensory receptors
   3.2 Human fallibility: human information processing / memory
   3.3 Visual display of static and dynamic information /designs
   3.4 Human decision
4. Design of physical environment: Light, Temperature, Pressure, Noise/Auditory, and Vibration

Module IV: Evaluation, Test, and Recommendation

1. Evaluation of manual work
   1.1 Size and dimension evaluation
   1.2 Posture and strength evaluation
   1.3 Space and movement evaluation
2. Evaluation of physical environment in design: Light, Temperature, Pressure, Noise/Auditory, and Vibration
3. Evaluation of HCI/HIS and Cognitive

3.1 Usability testing of human compatibility

3.2 Spatial compatibility evaluation

3.3 capacity and limitation

3.4 Usability testing of human performance

3.5 Usability testing of human error in controlling system

**Workshop Sessions:**

1. HCD showcase on usability test and discussion ….
2. Human characteristics measurement…..
3. Human system interaction and response
4. Situation Awareness and human error in decision
5. Human factors evaluation tools for identifying risk factors I: Practice
6. Human factors evaluation tools for identifying risk factors II: Practice
7. Human factors problem identifications: Presentation & Discussion
8. Workstation and workspace design
9. Design for human control/system interaction
10. Human decisions and cognitive designs
11. Design of physical environment
12. Evaluation of manual work
13. Evaluation of physical environment
14. Evaluation of HCI/HIS and cognitive
15. User experience design: usability, accessibility, and desirability

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Sanders, M. S. and McCormick, E. J. Human Factors in Engineering and Design, 7th Edition, McGraw Hill, 1993

Kroemer, K. H. E., and Grandjean, E. Fitting the Task to the Human. CRC Press, 1997

Stanton, N., Hedge, A, Brookhuis, K, Salas, E., and Hendrick, H. Handbook of Human Factors and Ergonomics Methods. CRC Press, 2005

Karwowski W., and W. S. Marras. Occupational Ergonomics: Principles of Work Design. CRC Press, 2003

Willson, J. R., and Corlett, E. Evaluation of Human Work: A practical ergonomics methodology, 3rd Ed. Taylor & Francis, 1995

Marras, S. M., and Karwowski, W. The Occupational Ergonomics Handbook: Fundamentals and assessment tools for occupational ergonomics, 2nd Ed. Taylor & Francis, 2006

**Journals and Magazines:**

Not declared

**Teaching and Learning Methods:** This course is problem-based learning. It is designed for more practical by dividing into 4 modules (1) Basic, (2) Problem Identification, (3) Design and Intervention, and (4) Evaluation. Students will be educated all the basic knowledge of human factors related to work elements and human interaction system designs via lectures and case study discussions at the first module. During the second module, they will learn how to identify the problems related to human in several work systems by practical workshops and case studies. Individual assignments will be assigned to the students to gain their understanding. The third module will provide more skill of human-centric design in practice via workshop, laboratories and self-learning based on a project of interest. To complete the project, the students will be able to discuss and get recommendations from instructors and share their learning with other students in the class during the workshops in the third module. At the last module, the students will learn and practice more and more in evaluation tools of human-centric design techniques to increase their skill for optimizing human well-begin and system performance in their project.

**Time Distribution and Study Load:**

Lectures: 15 hours

Workshop: 60 hours (includes 9 hours of lab session)

Project and Self-study: 60 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Paper examination of basic knowledge (20%), Peer assessment in class activities (10%), Individual assignments and presentations (20%), Group project progress presentation (20%), Group project final report and presentation (30%)

"A" would be awarded if a student shows a deep understanding of the basic knowledge based on exam results and home assignments, and an excellent in applying the knowledge to project works.

"B+" would be awarded if a student shows a mature understanding of the knowledge learned through home assignments, project works, and exam results.

"B" would be awarded if a student shows an overall understanding of all topics.

"C+" would be given if a student meets above average expectation in understanding and application of basic knowledge.

"C" would be given if a student meets average expectation in understanding and application of basic knowledge.

"D+" would be given if a student meets below average expectation in understanding and application of basic knowledge.

"D" would be given if a student does not meet expectations in both understanding and application of the given knowledge.

**Course Developers:** Naris Charoenporn (cnaris@engr.tu.ac.th) (TU), Suriya Jirasatitsin (suriya.j@psu.ac.th) (PSU), Nélson Costa (ncosta@dps.uminho.pt) (UMinho)

## Course 15: Customer Experience-Driven Design (2-0-3)

**Course Objective:** Economic offerings have progressed to the fourth evolution when products and services are used as props and stages for creating memorable experiences for customers. It is important for students to be able to support an industry with this change. This course aims to build student competence in design customer experience with knowledge on a concept of customer experience management (CEM) and on a systematic approach for an experience design process. In this course, the students will learn customer perception, customer involvement, and customer experience. Besides, they will learn and practice how to design a customer journey and to prevent failure of offering in a team environment.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Present entrepreneurial and creative attitude towards seeking various problem solutions (Apply)
CLO2. Identify customer needs (Analyze)
CLO3. Identify potential failure of offerings (Analyze)
CLO4. Manage customer experience journey (Create)
CLO5. Communicate effectively and work in an interdisciplinary team environment (Apply)
CLO6. Design a pain point-free, memorable customer experience journey (Create)
CLO7. Utilize Industry 4.0 technologies/applications to support the creation of a memorable customer experience journey (Apply)

**Prerequisite:** None

**Course Outline:**

Module 1: Pain Point-Free Customer Experience Journey

1. Introduction to Experience Economy
2. Customer Journey
3. Experience Clues
4. Customer Oriented-Failure Prevention

Module 2: Customer Experience Value Creation

1. Understanding Customers
2. Customer Perceived Value Model
3. Product-Service Systems
4. Co-Creation

Module 3: Memorable Customer Experience Design

1. Customer Experience Journey Design
2. Embedding Memorable Experience into Customer Experience Journey
3. Customer Experience Co-Creation
4. Industry 4.0 Technologies/Applications for the Creation of Customer Experience

**Workshop Sessions:**

**Laboratory Sessions:**

1. Customer Journey Creation
2. Embedding Clues into Customer Journey
3. Assessing Potential Failure in Customer Journey
4. Customers Need Identification
5. Customer Perception
6. Applying Product Service System for Customer Journe

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Chavez, T., O'Hara, C. and Vaidya, V. Data Driven: Harnessing Data and AI to Reinvent Customer Engagement, McGraw-Hill Education, 2018

Goodman, J. Customer experience 3.0: High-profit strategies in the age of techno service, Amacom, 2014

Kalbach, J. Mapping experiences: A complete guide to creating value through journeys, blueprints, and diagrams, O'Reilly Media, Inc., 2016

Loeffler, B. and Church, B. The experience: The 5 principles of Disney service and relationship excellence, John Wiley & Son, 2015

Shaw, C. The DNA of Customer Experience, Palgrave Macmillan, 2007

Shep, H. The Cult of the Customer: Create an Amazing Customer Experience That Turns Satisfied Customers into Customer Evangelists, Wiley, 2009

Walters, D. Behavioral Marketing: Delivering Personalized Experiences at Scale, John Wiley & Sons, 2015

Weinschenk, S. 100 Things Every Designer Needs to Know About People, Pearson Education, 2011

**Journals and Magazines:**

European Management Journal, Elsevier

Journal of Business Research, Elsevier

Journal of Engineering Design, Taylor and Francis

Journal of Hospitality Management, Elsevier

Journal of Interactive Marketing, Elsevier

Journal of Services Marketing, Emerald Insight

Journal of Service Theory and Practice, Emerald Insight

Harvard Business Review

MIT Sloan Management Review

**Teaching and Learning Methods:** This is a participant-centered learning course that the students actively involve. Lecture materials include, but not limited to, slides, case study, games, interesting animations, and videos. Most of the lecture sessions contain discussion and students are encouraged to participate actively

in the discussion. To increase understanding of the subject, the students are required to do literature reviews, group project, and presentations. The literature reviews are the individual assignments. The group project is for the students to develop and practice several skills including, but not limited to, decision making, problem-solving, communication, critical thinking, negotiation, conflict resolution, and teamwork. Presentations are a part of the project and assignments for personal development and knowledge sharing.

**Time Distribution and Study Load:**

Lectures and discussion: 30 hours

Presentations: 10 hours

Laboratory sessions: 35 hours

Group meeting outside classroom: 40 hours

Self-study: 20 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Class discussions and participation (20%); Peer Assessment in-class activities (10%); Individual assignments and presentations (10%); Project (40%); and Final Examination (20%)

An "A" would be awarded if a student can demonstrate a clear understanding of the knowledge learned in class as well as from literature reviews, can apply the knowledge appropriately in the project, and involve actively in class discussion.

A "B" would be awarded if a student can understand the basic principles of the knowledge learned in class and from literature reviews, can apply the knowledge in the project, and participate in class discussion.

A "C" would be given if a student shows partial understanding of the basic principles of the knowledge learned in class and from literature reviews, needs much guidance to apply the knowledge in the project, and is quiet during class discussion.

A "D" would be given if a student shows lack of understanding of the knowledge learned in class and from literature reviews, cannot apply the knowledge properly in the project and does not participate in class discussion.

**Course Developers:** Pisut Koomsap (pisut@ait.asia) (AIT), Duangthida Hussadintorn Na Ayutthaya (duangthidahna@gmail.com) (AIT), Tomasz Nitkiewicz (Tomasz.Nitkiewicz@wz.pcz.pl), Agnieszka.Ociepa-Kubicka@wz.pcz.pl (CUT), Apiwat Muttamara (mapiwat@engr.tu.ac.th) (TU)

## Course 16: Communication and People Skills Development for Engineering Leaders (1-4-0)

**Course Objective:** Technical excellence is always a trademark for engineering graduates, but their lacks of collaborative communication skills, people skills and understanding holistic picture, which are essential characteristics of a leader, often hinder their career success. This course aims to build engineering student competence in leadership communication skills and people skills. This course will train the engineering students on how to be a leader who can communicate effectively to facilitate the achievement of organizational goals and to motivate other members along the way.

**Learning Outcomes:**

The students on the completion of this course would be able to:

CLO1. Explain their works, thoughts, and ideas effectively
CLO2. Do both technical and non-technical written communication that ease understanding of audiences
CLO3. Make presentation professionally
CLO4. Develop emotional intelligence domains and competencies in different professional situations
CLO5. Work in a team environment in a complex workplace
CLO6. Apply people skills to support, lead, persuade, motivate and inspire others to achieve goals.

**Prerequisite:** None

**Course Outline:**

Module 1: Essential Communication Skills Development for Self Expression

1. Effective oral communications
   1.1 Knowing your intention and audience
   1.2 Get your audience attention
   1.3 Deliver your presentation professionally
2. Effective written communications
   2.1 Plotting your idea
   2.2 Filling up your story
   2.3 Polishing your story

Module II: Collaborative Communication Skills Development

1. Personality, character, and Cultural barrier in communication
2. Emotional intelligence
3. Strategic persuasive communication
4. Conflict management strategies
5. Effective managerial communication in a meeting

Module III: Leadership Communication Skills Development

1. Knowing your leadership style

2. Cultivating your leadership and communication style
3. Nonverbal communication
4. Adapting your communication to different situations and audiences
5. Making your message powerful, motivating and inspiring

**Workshop Sessions:**

Effective oral communication I

Effective oral communication II

Effective oral communication III

Effective written communication I

Effective written communication II

Personality

Emotional intelligence

Persuasive communication

Conflict management

Communication in a meeting

Leadership

Leadership communication I

Leadership communication II

Communication to different situations and audiences

Powerful Speech

**Laboratory Sessions:**

None

**Learning Resources:**

**Textbooks**: No designated textbook, but class notes and handouts will be provided.

**Reference Books:**

Anderson, C. TED Talks: The Official TED Guide to Public Speaking, Headline Publishing Group, 2016

Goleman, D. What Makes a Leader: Why Emotional Intelligence Matters, More Than Sound, 2014

Kerpen, D. The Art of People: 11 Simple People Skills that will Get You Everything You Want, Penguin Random House, 2016

Murray, K. The Language of Leaders: How Top CEOs Communicate to Inspire, Influence and Achieve Results, Second Edition, Kogan Page, 2013

Shall G. R. and Moussa M. The Art of Woo: Using Strategic Persuasion to Sell Your Ideas, Penguin Books, 2008

**Journals and Magazines:**

Journal of Engineering Education, Wiley

Journal of Management in Engineering, American Society of Civil Engineers

Research in Higher Education, Springer

**Teaching and Learning Methods:** This is an activity-based course. During lecture sessions, class discussion will be conducted. During workshop sessions, the students, to be active learners, will practice several skills including, but not limited to, decision making, problem-solving, critical thinking, written communication, oral communication, presentation, debate, and teamwork.

**Time Distribution and Study Load:**

Lectures: 15 hours

Workshop: 60 hours

Self-study: 45 hours

**Evaluation Scheme**: The final grade will be computed according to the following weight distribution: Class discussions and participation (15%); Oral communication (15%); Written communication (10%); Presentation (10%); Simulation/Scenario (10%); Peer Assessment (10%); Powerful Public Speaking (10%) and Personal Development (20%).

An "A" would be awarded if a student can demonstrate clearly effective communications, people skills, and leadership.

A "B" would be awarded if a student can show good progress on communications, people skills and/or leadership.

A "C" would be given if a student can show reasonable progress on communications, people skills, and leadership.

A "D" would be given if a student shows a lack of improvement in communications, people skills and leadership.

**Course Developers:** Pisut Koomsap (pisut@ait.asia) (AIT), Duangthida Hussadintorn Na Ayutthaya (duangthidahna@gmail.com) (AIT), Diana Mesquita (diana@dps.uminho.pt) (UMinho), Athakorn Kengpol (athakorn.kengpol@gmail.com) (KMUTNB)

# WP 2 - Curriculum Development I: Curriculum Structure and Courses

# Outcome 2.2 - Syllabuses for all courses in the curriculum

# ANNEX II – First Reviews of 16 Syllabuses

| | |
|---|---|
| **Project Acronym:** | MSIE 4.0 |
| **Project full title:** | Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry |
| **Project No.:** | 586137-EPP-I-2017-I-TH-EPPKA2-CBHE-JP |
| **Funding Scheme:** | Erasmus + KA2 - Capacity Building in the field of Higher Education |
| **Coordinator:** | AIT |
| **Work Package:** | WP2 – Curriculum Development I: Curriculum Structure and Courses |
| **WP Leaders:** | Tomasz Nitkiewicz (CUT) and Pisut Koomsap (AIT) |
| **Task Title:** | Task 2.2. Developing courses and course learning outcomes based on a matrix that maps course learning outcomes with program learning |
| **Task Leader:** | Tomasz Nitkiewicz (CUT) |
| **Last version date:** | 05/08/2020 |
| **Status:** | Final draft |
| **Dissemination Level:** | Department / Faculty - Institutional - National -International |

**List of course reviews**

Enterprise Management in Digital Economy

Project Management for Industry 4.0

Smart Operations Management

Quality Management for Extended Enterprise

Sustainable Supply Chain Management

Digital Factory

Advanced Optimization: Techniques and Industrial Applications

Intelligent Decision Support Systems

Applied Data Analytics

Cyber-Physical Industrial Systems

Collaborative Manufacturing Systems

Additive Manufacturing for Industry 4.0

Innovative Product Design and Development

Human-Centric Design for Operator 4.0

Customer Experience-Driven Design

Communications and People Skills Development for Engineering Leaders

# Reviews of Course 1. Enterprise Management in Digital Economy

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Yes but not in Thailand | Yes |
| **1.1 Quality of the content for the objective** | Minor revision is required | Minor revision is required |
| **1.2 Quality of writing for the objective** | Minor revision is required | Minor revision is required |
| **1.3 Suggestion for revision for objective** | This is a very interesting course, with a focus on strategy for the digital economy.<br>In my opinion, the objective could be more clear. It does not make a clear link with the outline of the course.<br>As an example, it was not clear for me the relation of the last sentence of the objective, with the topics and with the CLOs. Maybe this last sentence could be removed.<br>This course is in my opinion aligned with the MSIE4. project objectives and PLOs.<br>I am not sure if the following example is helpful, but it seems to be a good simple description found in a business school:<br>Managing the Digital Economy<br>Christian Peukert / 3.5 ECTs / Trimester / English<br>This course examines the economic forces of digitization that shape and transform markets and strategy in various industries, including entertainment goods, software, banking, and health. The course will apply standard tools of microeconomic analysis to describe important features of these markets, capturing common and diverging elements of those various industries. We will use these microeconomic tools to make predictions about the impact of technology on future outcomes, to discuss strategic reactions and management, evaluate policy, and to understand the value derived by customers. | English proof is required. |
| **1.4 Quality of the content for the CLOs** | Minor revision is required | Minor revision is required |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 4-5 CLOs with level of analyze, evaluate or create | all of CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Minor revision is required | Minor revision is required |
| **1.7 Suggestion for revision for CLOs** | The description of LO1 uses the term"use" two times and the term "usability" once. Please review and clarify.<br>Regarding LO3, consider:<br>- Select and apply the appropriate management roles for the implementation of the defined strategy.<br>The description of LO5 is too complex. Please clarify it. | Some LOs included more than one level of Bloom's Taxonomy (e.g., LOs 1 and 2). Please revise. |

| | | |
|---|---|---|
| | The description of LO6 is not clear and does not seem to be from the "evaluate" level of complexity. | |
| **1.8 Does the syllabus has a prerequisite section?** | Yes | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Minor revision is required | Minor revision is required |
| **2.3 Quality of writing for course content** | Minor revision is required | Minor revision is required |
| **2.4 The originality of the course content relative to existing IE courses** | One fourth is new | Half is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | No |
| **2.8 How likely will the course be delivered to cover all topics?** | Only some topics can be delivered with depth to cover all topics | Only some topics can be delivered with depth to cover all topics |
| **2.9 Does the course has workshop or laboratory sessions?** | No | No |
| **2.10 Quality of the workshop or laboratory sessions** | Not applicable | Not applicable |
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | The course content description could be more aligned with the digital economy without many changes. | Course content contains less info to review. |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Individual presentation, Group presentation, Group project | Lecture, Homework, Class discussion, Individual presentation, Group presentation, Group project |
| **3.3 Suggestion for additional teaching and learning methods** | It seems that the suggestions are appropriate, with a project approach. Nevertheless, I would suggest to make the description of problem to be addresses by PBL more specific. At this point it does not seem aligned with the I4..<br>Individual assignments are not clear. Maybe this are too much elements to be evaluated. Just for you to reflect on it.<br>Peer assessment: will it be among team members or between teams?<br>In first case, I would suggest Peer Team Assessment | Cannot add any comment |

| | | |
|---|---|---|
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 5 | 3 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 3 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 5 | 3 |
| **4.5 Overall assessment for this course** | Minor revision is required | Minor revision is required |
| **4.6 How confident are you with your answers?** | confident | I am not sure |
| **Additional comments** | | |

Reviews of Course 2. Project Management for Industry 4.

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Don't know | Yes |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | | |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 4-5 CLOs with level of analyze, evaluate or create | all of CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | | |
| **1.8 Does the syllabus has a prerequisite section?** | Yes | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Partially | Yes |
| **2.2 Quality of the course content** | Major revision is required | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Major revision is required | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | One fourth is new | Three fourth is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | No |
| **2.6 How many modules are in this course?** | 2 | 2 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | Only some topics can be delivered with depth to cover all topics | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Not applicable | Minor revision is required |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | The subtopics in each module should be elaborated more. Also, in module 2, the concept "Industry 4." is not there in all subtopics. The laboratory sessions are in fact "workshop" because the students will not attend any lab sessions there | A better link between the content of the course modules and laboratory sessions may be designed. |
| **3.1 Have references been written properly and consistently?** | Minor revision is required | Minor revision is required |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Group presentation, Group project | Lecture, Class discussion, Individual project |
| **3.3 Suggestion for additional teaching and learning methods** | | Not clear if there are teams during the project |
| **3.4 Time distribution and study load** | Improper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Somewhat strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Teacher-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 3 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 4 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 4 | 4 |
| **4.5 Overall assessment for this course** | Minor revision is required | Minor revision is required |
| **4.6 How confident are you with your answers?** | confident | Very confident |
| **Additional comments** | | |

# Reviews of Course 3. Smart Operations Management

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | No | Yes |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Minor revision is required |
| **1.2 Quality of writing for the objective** | Minor revision is required | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | The second statement in this session should be revised | No comment |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Minor revision is required |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 2-3 CLOs with level of analyze, evaluate or create | 4-5 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Minor revision is required |
| **1.7 Suggestion for revision for CLOs** | | The CLOs should include levels of Bloom's Taxonomy. |
| **1.8 Does the syllabus has a prerequisite section?** | Yes | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Minor revision is required |
| **2.3 Quality of writing for course content** | Major revision is required | Minor revision is required |
| **2.4 The originality of the course content relative to existing IE courses** | Half is new | Half is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | No |
| **2.8 How likely will the course be delivered to cover all topics?** | Only some topics can be delivered with depth to cover all topics | Only some topics can be delivered with depth to cover all topics |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Appropriate | Minor revision is required |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | The format should be revised. For example, the sessions should be 1.,2., and the subsessions should be numbered 1.1, 1.2,... | It is not enough information to comment. |
| **3.1 Have references been written properly and consistently?** | Major revision is required | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Group presentation, Case study | Lecture, Homework, Class discussion, Group presentation, Group project, Case study |
| **3.3 Suggestion for additional teaching and learning methods** | Case study should be referred to in teaching & leaning methods | Not clear this time |
| **3.4 Time distribution and study load** | Improper allocation | Minor adjustment is required |
| **3.5 Relationships between course assessment and CLOs** | Somewhat strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 3 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 3 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 4 | 4 |
| **4.5 Overall assessment for this course** | Major revision is required | Minor revision is required |
| **4.6 How confident are you with your answers?** | confident | I am not sure |
| **Additional comments** | The evaluation scheme session should be rewritten following the required structure. Some reference books should be incorporated. In Journals & Magazines session: List only the journals & Magazines, should not put specific papers there | |

# Reviews of Course 4. Quality Management for Extended Enterprise

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Yes but not in Thailand | Yes |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Minor revision is required |
| **1.3 Suggestion for revision for objective** | | Please do English proof. |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | all of CLOs with level of analyze, evaluate or create | all of CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Minor revision is required |
| **1.7 Suggestion for revision for CLOs** | | Please do English proof. |
| **1.8 Does the syllabus has a prerequisite section?** | No | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Minor revision is required |
| **2.4 The originality of the course content relative to existing IE courses** | Half is new | Three fourth is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | No |
| **2.10 Quality of the workshop or laboratory sessions** | Appropriate | Not applicable |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | The content was selected in an exemplary manner. | Not clear between management skill and managerial skill of modules 1 and 3, respectively |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Minor revision is required |
| **3.2 Teaching and learning methods to be applied in the course** | Class discussion, Individual presentation, Case study, Role play, Simulation, Report, Extended Response Question | Lecture, Homework, Class discussion, Individual presentation, Group presentation, Individual project, Group project, Case study |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 4 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 4 | 4 |
| **4.5 Overall assessment for this course** | Accept in current form | Accept in current form |
| **4.6 How confident are you with your answers?** | confident | confident |
| **Additional comments** | | Not sure how many LOs included for this class. They stated that only 5 LOs included at the beginning, but there are 7 of them in the last part (i.e., Assessment part). |

## Reviews of Course 5. Sustainable Supply Chain Management

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | No | Don't know |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Major revision is required |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Major revision is required |
| **1.3 Suggestion for revision for objective** | Supply chain structure can be addressed as well | The current version emphasises on applying intelligent technologies. "Sustainability" is not well addressed as an ultimate goal of this course. |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Major revision is required |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 4-5 CLOs with level of analyze, evaluate or create | 2-3 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Major revision is required |
| **1.7 Suggestion for revision for CLOs** | Standard types of SC can be adhered to | 1. The current revision describes the outputs of this course, outcomes to students in a context of sustainable supply chain are still missing. After this course, students may understand how those advanced technologies work, but what is sustainability for them and how can they take a benefit of those technologies to create a sustainable supply chain.<br>2. CLO1 is too broad<br>3. CLO2 is not relevant to the course content<br>4. CLOs 3 & 4 are relevant but (see 1.)<br>5. CLO5 the course design does not show how this competence will be developed. Students work in group does not guarantee that team management skill has been developed. |
| **1.8 Does the syllabus has a prerequisite section?** | No | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | No |
| **2.2 Quality of the course content** | Acceptable in the current form | Major revision is required |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Major revision is required |
| **2.4 The originality of the course content relative to existing IE courses** | Totally new | Totally new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |

| | | |
|---|---|---|
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | Only touch and go to cover all topics |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Appropriate | Major revision is required |
| **2.11 Is there any topic or subtopic that should belong to another course?** | Yes | Yes |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | The transportation in SC has cause lots of Envi problem. The course content on logistics activities may be mentioned a bit more. | Most of the content and workshop are about tools (DF, BD, ISC), this course shall ensure that students really get to explore & learn about the relationship between sustainability (triple bottom line), supply chain, and SCM. |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Minor revision is required |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Homework, Class discussion, Individual presentation, Group presentation, Group project, Case study | Lecture, Individual project, Group project |
| **3.3 Suggestion for additional teaching and learning methods** | Additional field assessment of real industrial environment may also be good option | Field trip, meeting with practitioners in SSCM, or some hands on experience would allow students to understand context and challenges in SSCM so that they can identify opportunities to use intelligent technologies. |
| **3.4 Time distribution and study load** | Proper allocation | Minor adjustment is required |
| **3.5 Relationships between course assessment and CLOs** | Strong | Quite weak |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 5 | 3 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 3 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 5 | 3 |

| | | |
|---|---|---|
| **4.5 Overall assessment for this course** | Accept in current form | Major revision is required |
| **4.6 How confident are you with your answers?** | Very confident | Very confident |
| **Additional comments** | Supply chain design is very important for sustainability. Hence supply chain structure and supply chain redesign with logistics context also help students to aware more. | 1. This course does not provide the fundamental of sustainability and SCM. If there is no SCM course provided in the program, how do we ensure that they have capacity to integrate new knowledge.<br>2. The use of intelligent technologies nowadays is undeniable. We (academician) need to be aware that students understand the context and needs of stakeholders so that appropriate technology level is recommended. Students should propose solution that meet the needs (demand pull) rather than technology push. |

## Reviews of Course 6. Digital Factory

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Yes | Yes but not in Thailand |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Minor revision is required | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | Please review the writing in "…technology for modeling, and communications to…" | |
| **1.4 Quality of the content for the CLOs** | Minor revision is required | Minor revision is required |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 0-1 CLOs with level of analyze, evaluate or create | 0-1 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Minor revision is required | Minor revision is required |
| **1.7 Suggestion for revision for CLOs** | More high-level CLOs should be defined (namely analysis and evaluation of existing systems). Also one or two more CLOs (from lower levels of Bloom's Taxonomy) related to technology might be included (e.g. related to additive manufacturing* and CNC equipment). In fact, in general terms, CLOs might be more aligned with the contents described in the course outline (which mentions cyber-physical systems, VR/AR, robotics, etc.).<br>* Course 12 is totally dedicated to additive manufacturing. | There are now Bloom levels mentioned. Only a few LOs seem related to the course title |
| **1.8 Does the syllabus has a prerequisite section?** | No | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Partially | Partially |
| **2.2 Quality of the course content** | Minor revision is required | Minor revision is required |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Similar to existing IE course | Half is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | No |
| **2.6 How many modules are in this course?** | More than 3 modules | More than 3 modules |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |

| | | |
|---|---|---|
| **2.8 How likely will the course be delivered to cover all topics?** | Only some topics can be delivered with depth to cover all topics | Only some topics can be delivered with depth to cover all topics |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Minor revision is required | Minor revision is required |
| **2.11 Is there any topic or subtopic that should belong to another course?** | Yes | Yes |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | The course outline includes many topics (CBS, VR/AR, cyber-security, additive manufacturing, robotics, AGVs, etc.) and it is not viable to work all those aspects in detail. Thus, it might be advisable to remove some topics (e.g. cyber security). Regarding the modules' sequencing, module V could be addressed before module IV. The CBS laboratory session is only about product lifecycle management. | Some of the modules seem similar with modules from other courses |
| **3.1 Have references been written properly and consistently?** | Minor revision is required | Minor revision is required |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Homework, Class discussion, Group presentation, Group project, Case study, Field trip | Lecture, Homework, Class discussion, Group presentation, Group project, Case study, Field trip |
| **3.3 Suggestion for additional teaching and learning methods** | About references: please consider reviewing the referencing style. | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Somewhat strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Teacher-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 4 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 3 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 3 | 4 |
| **4.5 Overall assessment for this course** | Minor revision is required | Minor revision is required |
| **4.6 How confident are you with your answers?** | confident | Very confident |

| | | |
|---|---|---|
| **Additional comments** | n.a. | Difficult to evaluate the originality of the course content relative to existing IE courses |

# Reviews of Course 7. Advanced Optimization: Techniques and Industrial Applications

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Yes but not in Thailand | Yes |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Minor revision is required |
| **1.2 Quality of writing for the objective** | Minor revision is required | Minor revision is required |
| **1.3 Suggestion for revision for objective** | The English grammar should be improved. | They did not say anything about IE4.. |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Minor revision is required |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 4-5 CLOs with level of analyze, evaluate or create | 4-5 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Minor revision is required | Minor revision is required |
| **1.7 Suggestion for revision for CLOs** | The English grammar should be improved. | Online and offline control devices may not related to Optimization. |
| **1.8 Does the syllabus has a prerequisite section?** | Yes | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Partially |
| **2.2 Quality of the course content** | Acceptable in the current form | Minor revision is required |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Minor revision is required |
| **2.4 The originality of the course content relative to existing IE courses** | One fourth is new | One fourth is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | No |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | No | No |
| **2.10 Quality of the workshop or laboratory sessions** | Not applicable | Not applicable |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | Yes |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | | Digital Optimization (DOpt) should be defined more clearly. |
| **3.1 Have references been written properly and consistently?** | Major revision is required | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Homework, Class discussion, Group project, Case study | Lecture, Homework, Class discussion, Group presentation, Group project, Case study |
| **3.3 Suggestion for additional teaching and learning methods** | Please add information under this topic. | |
| **3.4 Time distribution and study load** | Proper allocation | Minor adjustment is required |
| **3.5 Relationships between course assessment and CLOs** | Strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Teacher-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 5 | 5 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 3 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 5 | 3 |
| **4.5 Overall assessment for this course** | Accept in current form | Minor revision is required |
| **4.6 How confident are you with your answers?** | Very confident | I am not sure |
| **Additional comments** | Please add references and grading criteria. | |

# Reviews of Course 8. Intelligent Decision Support Systems

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | No | Yes but not in Thailand |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Minor revision is required |
| **1.3 Suggestion for revision for objective** | | I suggest a revision of the first part of the objective. In the way that it is written it may include "human" decisions and it seems to me that in this case it should be focused in AI, ML, RBS...<br>I found another description at UPC that may be helpful. I am not an expert so, please consider it if you find it useful.<br>"…main goal is to know how to analyse, to design, to implement and to validate an Intelligent Decision Support Systems (IDSS), for this kind of domains. Particularly, the integration of Artificial Intelligence models and Statistical models, and the knowledge discovery from data step, will be emphasised."<br>https://www.fib.upc.edu/en/studies/masters/master-artificial-intelligence/curriculum/syllabus/IDSS-MAI |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Minor revision is required |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 4-5 CLOs with level of analyze, evaluate or create | 2-3 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Minor revision is required |
| **1.7 Suggestion for revision for CLOs** | | LO3 and LO5 – please review the last part of the text. For a "smart production" is not clear. Could it be "smart production system"?<br>LO5 – could "using a programming language" be removed? |
| **1.8 Does the syllabus has a prerequisite section?** | No | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Three fourth is new | Half is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |

| | | |
|---|---|---|
| **2.6 How many modules are in this course?** | More than 3 modules | More than 3 modules |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | Only some topics can be delivered with depth to cover all topics | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | No | No |
| **2.10 Quality of the workshop or laboratory sessions** | Not applicable | Not applicable |
| **2.11 Is there any topic or subtopic that should belong to another course?** | Yes | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | Some tools are similar to data mining. | It seems that this course should have Laboratory Sessions to support software tools. |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Individual project, Group project, Simulation,field class | Lecture, Group project, Case study, group discussion, individual assignment, practical exercises, simulation, field class |
| **3.3 Suggestion for additional teaching and learning methods** | | The “Teaching and Learning Method” should be revised in order to make it clear that it is not just lectures. If other activities exist (project, field class, assignments,…) than the methods are active and this should be more clear, because the first sentence says “The teaching is done via lectures by the instructor”. |
| **3.4 Time distribution and study load** | Proper allocation | Minor adjustment is required |
| **3.5 Relationships between course assessment and CLOs** | Somewhat strong | Strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Teacher-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 3 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 3 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 3 | 4 |
| **4.5 Overall assessment for this course** | Accept in current form | Minor revision is required |

| | | |
|---|---|---|
| **4.6 How confident are you with your answers?** | confident | confident |
| **Additional comments** | | I am not an expert in the this field, but find this a very appealing and important part of the program. Nevertheless, it seems that it will require very technical background from the students to be successful. |

# Reviews of Course 9. Applied Data Analytics

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Yes but not in Thailand | No |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Minor revision is required |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | | Change "Practical Problems" to "Smart Production" |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Minor revision is required |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 4-5 CLOs with level of analyze, evaluate or create | 2-3 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | | |
| **1.8 Does the syllabus has a prerequisite section?** | No | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Half is new | Three fourth is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | No |
| **2.6 How many modules are in this course?** | 3 | |
| **2.7 Has the content been designed with the logical flow?** | Yes | No |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | No | No |
| **2.10 Quality of the workshop or laboratory sessions** | Not applicable | Major revision is required |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | A short description may be added under a module name, to provide an overview of each module. | The course is not a moludar. It should be re-design to be a moludar course. |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Group project | Lecture, Homework, Class discussion, Group presentation, Group project, Case study |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Strong | Somewhat weak |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Teacher-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 5 | 5 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 3 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 5 | 3 |
| **4.5 Overall assessment for this course** | Accept in current form | Minor revision is required |
| **4.6 How confident are you with your answers?** | Very confident | confident |
| **Additional comments** | | |

# Reviews of Course 10. Cyber-Physical Industrial Systems

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | No | No |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | | Different types of industry and service structure may need different CPIS. May be specific definition can be mentioned. |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 2-3 CLOs with level of analyze, evaluate or create | all of CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | | |
| **1.8 Does the syllabus has a prerequisite section?** | No | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | No | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Totally new | Totally new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | More than 3 modules |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | Only some topics can be delivered with depth to cover all topics | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | No | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Not applicable | Appropriate |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | Yes |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | | Standard type of CPIS |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Group presentation, Group project | Lecture, Homework, Class discussion, Individual presentation, Group presentation, Individual project, Group project |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Somewhat strong | Strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 4 | 5 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 4 | 5 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 4 | 4 |
| **4.5 Overall assessment for this course** | Accept in current form | Accept in current form |
| **4.6 How confident are you with your answers?** | confident | confident |
| **Additional comments** | | |

# Reviews of Course 11. Collaborative Manufacturing Systems

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Yes | Yes |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Minor revision is required |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Minor revision is required |
| **1.3 Suggestion for revision for objective** | n.a. | please reconsider "... developing understanding of manufacturing processes...,<br>...products and ways of working |
| **1.4 Quality of the content for the CLOs** | Minor revision is required | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 2-3 CLOs with level of analyze, evaluate or create | 4-5 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Minor revision is required | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | The “CLO1: identify the proper manufacturing process… ( analyse )” does not seems to be an “analysis CLO” (high level) but rather a low level CLO. Similarly, the “CLO4: manage advanced production systems (synthesis)” should not be classified as “synthesis CLO” (highest level) but rather as “apply CLO”. | |
| **1.8 Does the syllabus has a prerequisite section?** | No | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Partially | Yes |
| **2.2 Quality of the course content** | Minor revision is required | Minor revision is required |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Similar to existing IE course | Half is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | Only some topics can be delivered with depth to cover all topics |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |

| | | |
|---|---|---|
| **2.10 Quality of the workshop or laboratory sessions** | Minor revision is required | Appropriate |
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | In terms of course contents, the "Collaborative manufacturing systems" module should be more elaborated (e.g. with some contents about collaborative models). There is no mention to laboratory sessions. Although "discussions" might be interpreted as "workshops", this aspect might be clarified (e.g. describing workshop sessions). | please add more workshop and laboratory |
| **3.1 Have references been written properly and consistently?** | Major revision is required | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Group presentation, Group project, Case study | Lecture, Class discussion, Individual presentation, Group presentation, Individual project, Group project, Case study |
| **3.3 Suggestion for additional teaching and learning methods** | About references: Only one reference book (from 23) about collaborative manufacturing is indicated, along with two edited books (27 and 29). A list of three journals is provided but no specific papers are indicated. The number of references should increase and they should be more recent. | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Somewhat strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 4 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 3 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 3 | 4 |
| **4.5 Overall assessment for this course** | Minor revision is required | Minor revision is required |
| **4.6 How confident are you with your answers?** | confident | confident |
| **Additional comments** | | please add summative assessment method |

Reviews of Course 12. Additive Manufacturing for Industry 4.

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | No | Yes but not in Thailand |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Minor revision is required |
| **1.3 Suggestion for revision for objective** | | Should be added with the students will be proficient for evaluation for AM versus conventional manufacturing |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | all of CLOs with level of analyze, evaluate or create | 4-5 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Minor revision is required | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | Seem to have a missing item such as "understand" | |
| **1.8 Does the syllabus has a prerequisite section?** | Yes | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Minor revision is required | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Three fourth is new | Totally new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 2 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | Only some topics can be delivered with depth to cover all topics | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Appropriate | Minor revision is required |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | Yes |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | Product-cost analysis might be included in the AM Business models section. | Should be added lab for the design creativity of AM & reference : https://learn-xpro.mit.edu/additive-manufacturing |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Minor revision is required |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Homework, Class discussion, Group project, Case study | Lecture, Homework, Class discussion, Individual presentation, Group presentation, Individual project, Case study |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Strong | Strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 4 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 4 | 5 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 4 | 5 |
| **4.5 Overall assessment for this course** | Minor revision is required | Accept in current form |
| **4.6 How confident are you with your answers?** | confident | confident |
| **Additional comments** | | |

## Reviews of Course 13. Innovative Product Design and Development

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | No | Yes |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | | |
| **1.4 Quality of the content for the CLOs** | Minor revision is required | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | all of CLOs with level of analyze, evaluate or create | 4-5 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Minor revision is required | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | The first item "identify thebasicconcept" is more related to "ubderstand" rather than "apply" | |
| **1.8 Does the syllabus has a prerequisite section?** | No | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Three fourth is new | Three fourth is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Not applicable | Appropriate |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | It is not quite clear how workshop will be conducted. | |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, workshop | Lecture, Class discussion, Individual presentation, Group presentation, Individual project, Group project |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Minor adjustment is required |
| **3.5 Relationships between course assessment and CLOs** | Somewhat strong | Somewhat strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 3 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 3 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 3 | 4 |
| **4.5 Overall assessment for this course** | Minor revision is required | Minor revision is required |
| **4.6 How confident are you with your answers?** | confident | confident |
| **Additional comments** | The course evaluation is more precise if "table of time allocation" is provided. | please add assessment scheme |

# Reviews of Course 14. Human-Centric Design for Operator 4.

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Don't know | Yes but not in Thailand |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | | Considerable - expanding the content with the assumptions of the Industry 5. concept. Note that this does not affect the high rating of the course. |
| **1.4 Quality of the content for the CLOs** | Minor revision is required | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | 2-3 CLOs with level of analyze, evaluate or create | all of CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Minor revision is required | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | Replace "Understand" from CLO 1 and CLO 5 with "Analyze and evaluate" | |
| **1.8 Does the syllabus has a prerequisite section?** | No | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Half is new | Half is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | More than 3 modules | More than 3 modules |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | Only some topics can be delivered with depth to cover all topics |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Appropriate | Appropriate |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | - | |
| **3.1 Have references been written properly and consistently?** | Minor revision is required | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Class discussion, Individual presentation, Group presentation, Group project, Case study, Workshop | Lecture, Case study, Self-study, PBL, Workshop |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Strong | Strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 5 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 5 | 4 |
| **4.5 Overall assessment for this course** | Minor revision is required | Accept in current form |
| **4.6 How confident are you with your answers?** | Very confident | confident |
| **Additional comments** | | |

# Reviews of Course 15. Customer Experience-Driven Design

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | No | No |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | | |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | all of CLOs with level of analyze, evaluate or create | 4-5 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.7 Suggestion for revision for CLOs** | | |
| **1.8 Does the syllabus has a prerequisite section?** | No | No |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Three fourth is new | Totally new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Appropriate | Appropriate |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | | |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Homework, Class discussion, Individual presentation, Group presentation, Individual project, Group project, Case study, Game | Lecture, Class discussion, Individual presentation, Individual project, Case study, Field trip |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Strong | Strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 5 | 4 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 4 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 4 | 5 |
| **4.5 Overall assessment for this course** | Accept in current form | Accept in current form |
| **4.6 How confident are you with your answers?** | Very confident | confident |
| **Additional comments** | | |

# Reviews of Course 16. Communications and People Skills Development for Engineering Leaders

| | Reviewer 1 | Reviewer 2 |
|---|---|---|
| **Are they similar IE courses being offered?** | Don't know | No |
| **1.1 Quality of the content for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.2 Quality of writing for the objective** | Acceptable in the current form | Acceptable in the current form |
| **1.3 Suggestion for revision for objective** | | |
| **1.4 Quality of the content for the CLOs** | Acceptable in the current form | Acceptable in the current form |
| **1.5 Do the CLOs show high levels of learning outcome attainment according to Bloom's Taxonomy?** | all of CLOs with level of analyze, evaluate or create | 0-1 CLOs with level of analyze, evaluate or create |
| **1.6 Quality of writing for CLOs** | Acceptable in the current form | Minor revision is required |
| **1.7 Suggestion for revision for CLOs** | | Since Bloom's taxonomy is not directly referred in the CLOs I suggest to add attainment level in parentheses at the end. |
| **1.8 Does the syllabus has a prerequisite section?** | No | Yes |
| **2.1 Does the course content relate directly to the title, objective, and CLOs?** | Yes | Yes |
| **2.2 Quality of the course content** | Acceptable in the current form | Acceptable in the current form |
| **2.3 Quality of writing for course content** | Acceptable in the current form | Acceptable in the current form |
| **2.4 The originality of the course content relative to existing IE courses** | Totally new | Three fourth is new |
| **2.5 Has the course been designed with modular architecture?** | Yes | Yes |
| **2.6 How many modules are in this course?** | 3 | 3 |
| **2.7 Has the content been designed with the logical flow?** | Yes | Yes |
| **2.8 How likely will the course be delivered to cover all topics?** | All topics can be delivered with depth | All topics can be delivered with depth |
| **2.9 Does the course has workshop or laboratory sessions?** | Yes | Yes |
| **2.10 Quality of the workshop or laboratory sessions** | Appropriate | Appropriate |

| | | |
|---|---|---|
| **2.11 Is there any topic or subtopic that should belong to another course?** | No | No |
| **2.12 Suggestion for revision for course content, workshop and laboratory sessions** | | |
| **3.1 Have references been written properly and consistently?** | Proper and consistent | Proper and consistent |
| **3.2 Teaching and learning methods to be applied in the course** | Lecture, Homework, Class discussion, Individual presentation, Group presentation, Role play, Game | Lecture, Class discussion, Individual presentation, Group presentation, Role play |
| **3.3 Suggestion for additional teaching and learning methods** | | |
| **3.4 Time distribution and study load** | Proper allocation | Proper allocation |
| **3.5 Relationships between course assessment and CLOs** | Strong | Strong |
| **4.1 Based on the information provided in the syllabus, what type of course is this course?** | Student-centered Learning | Student-centered Learning |
| **4.2 Based on the information provided in the syllabus, how likely the knowledge will be transferred effectively?** | 5 | 5 |
| **4.3 Based on the information provided in the syllabus, how likely the skills will be built effectively?** | 5 | 5 |
| **4.4 Based on the information provided in the syllabus, how likely competence will be built?** | 4 | 5 |
| **4.5 Overall assessment for this course** | Accept in current form | Accept in current form |
| **4.6 How confident are you with your answers?** | Very confident | Very confident |
| **Additional comments** | | |