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SHYFTE 4.0

WP1: Preparation

D1.1: Literature review of Industry 4.0

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This document is a literature review on industry 4.0.

The objective of this deliverable is to analyze current teaching and learning curricula in Asia, for the four application domains

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Further Information

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1. The existing curricula in Asia

The main objective of this document is to present a comprehensive study of the existing curricula that are practiced predominantly in the academia of Asian countries. The curricula cover four major domains entail “Industrial Engineering and Management”, “Software Engineering and Big Data Analysis”, “Wireless Networks Analytics”, and “Artificial Intelligence” that are integral parts of Industry 4.0 and the key interests of the SHYFTE project. .

This deliverable is the result of deep and wide investigations conducted by the Asian partners of the project in the HEIs of their respective countries. It is supported by a document in which the curricula are listed by the partners by taking into account the following attributes: curriculum name, program description, targeted level, addressed SHYFTE domain, content, teaching and learning methods, and developed skills.

1.1 Domain 1: Industrial Engineering and Management

In Thailand, there are 75 engineering faculties in both public (32 institutes) and private (43 institutes) higher education institutes. More than 40 institutes provide an industrial engineering bachelor’s degree. The number of credit hours required for the Bachelor Engineer (Industrial Engineering) degree is in the approximate range 130-150 with some variation between universities. The curriculum structure consists of general courses (30 credits), specific courses (between 100 to 114 credits), and free elective courses (6 credits).

The analysis of the existing curriculum focuses on the courses of industrial engineering. The specific courses are composed of two groups i.e. core courses and major courses. The core courses are mathematics, sciences and engineering knowledge for an engineer. The major courses are specific knowledge in industrial engineering. The major courses are divided into two groups i.e. the required courses and the major elective courses. The required courses are mandatory courses for all industrial engineering students whereas, the major elective courses are selected by the students according to their interest in minimum credit requirement.

The primary focus of the study is to analyse the existing curriculum of industrial engineering taught by the six top rank universities include Chiang Mai University (CMU), Chulalongkorn University (CU), Mahidol University (MU), Prince Songkla University (PSU), King Mongkut's University of Technology North Bangkok, and Kasetsart University (KU). Students are required to enroll in the required courses around 14 – 20 courses and to select the major elective courses at least 1 – 7 courses with the variation between universities (see Figure 1).

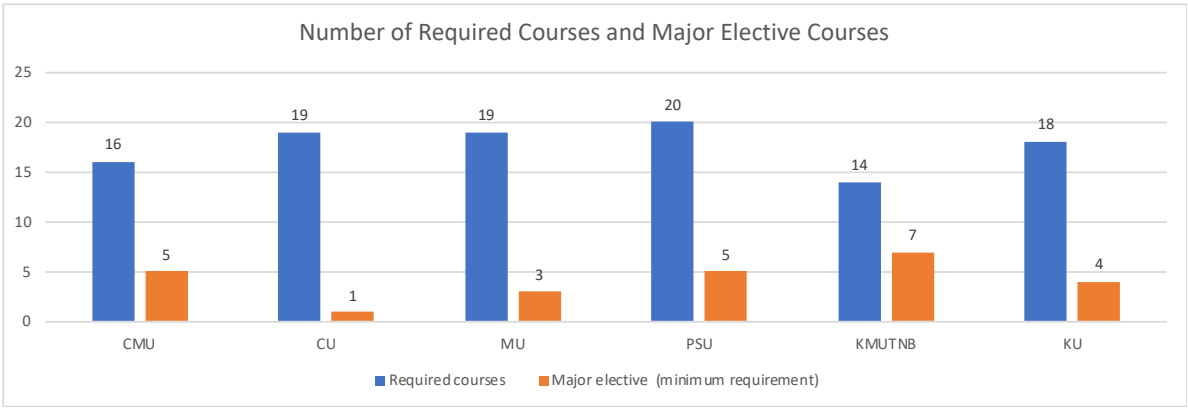

Figure 1. Comparing required and major elective courses in industrial engineering studies

This figure shows that the institutes provide the required industrial engineering knowledge for 80%. For the remaining 20%, the students choose other topics of interest.

Industrial engineering is related to six sub-domains: (1) material and manufacturing process, (2) work-study and safety, (3) quality system, (4) economics and finance, (5), production and operations management, and (6) Integration of IE Techniques. As shown in Figure 2, the analysis of a required course shows that most of the universities provide courses related to production and operation management and integration of industrial engineering techniques more than the other sub-domains. This means that the industrial engineering curriculum in Thailand tends to develop management skills of the students.

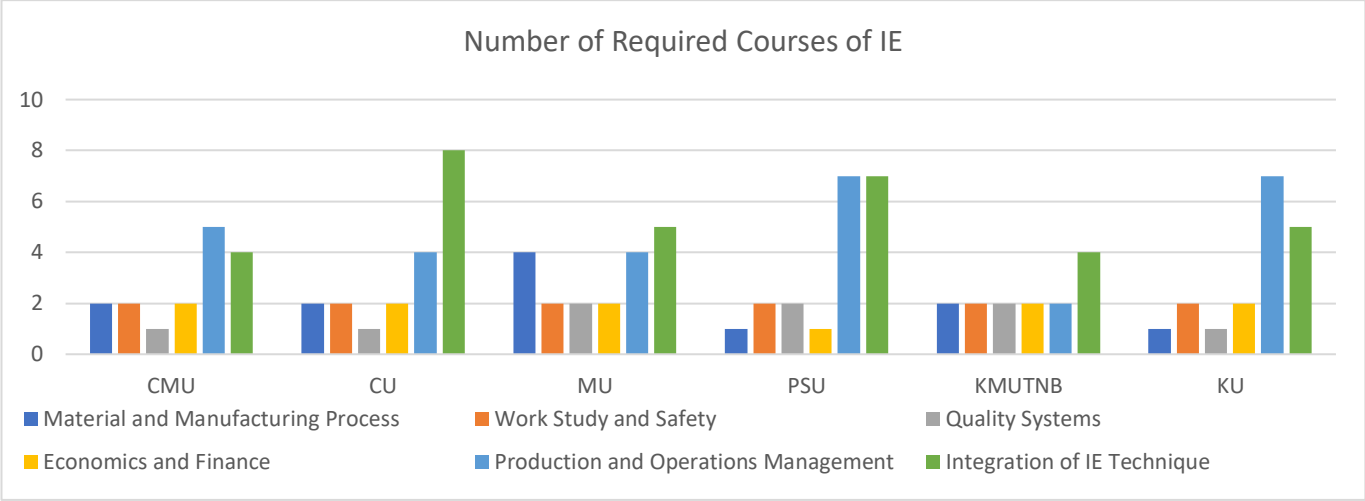

Figure 2. Comparing industrial engineering courses in each sub-domain

The effect of Industry 4.0 on production systems is the flexibility and ability to produce many versions of products in low batch sizes which leads to greater efficiencies and a revolution of relationships in the supply chain. CPS, IoT, Internet of Services, and Smart Factory turn the production system into flexible, reconfigurable manufacturing systems, offering interactive and collaborative decision-making approaches. These changes are affecting the role of industrial engineers in the manufacturing system. Industrial engineers need competencies in deploying and optimizing augmented-reality systems and information technology skills in advanced analytics for simulation.

Besides, Soft skills such as critical thinking skills, collaboration skills, and communication skills, are becoming more critical than ever. The job functions of industrial engineers (IEs) changed from primarily with work simplification and methods improvement to a flexible manufacturing system. They have to work with a complex system, production based on information technology, new manufacturing technology, and human-robot collaboration. Thus, they will have to be open to change, possess the flexibility to new roles and work environments. The set of technical skills in some knowledge areas was pointed out [1] as follows:

- **Technical skills for production management** such as analyze, mode and simulate the production system based on big data from sensors, use of digital devices to monitor and control system, design production system and use of collaborative robots, use of additive

manufacturing technologies, managing human resources, interconnected through digital devices, etc.

- **Technical skills for logistics and supply chain management** such as developing or use of Information Technology (IT) system to support supply chain management (e.g. collaboration platform on the cloud), analyze big data to design, implement, control and monitor logistics and supply chain activities, use of real-time management, monitoring, and tracking technologies, etc.

- **Technical skills for robotics and automation production** such as the implementation of human-robot collaboration, and design multi-machine worker assistance systems.

- **Technical skills for production technology** such as evaluating alternatives and identifying, selecting, and implementing manufacturing technologies, use of CAD/CAM process design and concurrent engineering.

- **Technical skills for work-study and ergonomics** such as design friendliness work station or manufacturing system for optimizing human-robot collaboration with ergonomically-convenient jobs.

According to our analysis of the course contents offered in six Bachelor of Industrial Engineering curricula, the topics of production management, supply chain management, automation production, production technology, and workstudy, are being taught at least at the basic level. However, the advanced subjects such as big data analytics, real-time simulation production system, collaborative robots, human-robot collaboration, etc. areyet to be included in the courses. Thus, industrial engineering departments should increase the number of interdisciplinary courses that integrate information technology and industrial engineering. They should focus on building specific capabilities required for the new information technology tools by adapting their curricula to meet companies' expectations.

Regarding the management area, Figure 3 shows the distribution of credits among course types for the top 5 universities in Thailand namely Chulalongkorn University (CU), Mahidol University (MU), Chiang Mai University (CMU), Thammasat University (TU) and Kasetsart University (KU) [2-6].

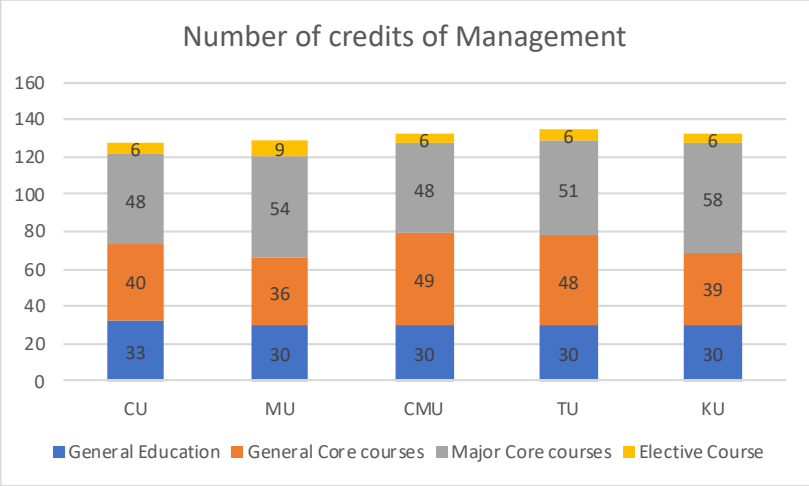

Figure 3. Comparisons of the number of credits in the management area

The topics of the management studies [2-6] are listed below:

Mathematics and Economics with Fundamental Mathematics, Business Mathematics, Business Statistics, Financial Management, Applicable Basic Mathematics and Statistics, Managerial Economics, Microeconomics, and Macroeconomics.

Information and Data system with Introduction to Information Technology, Information System Analysis, Applications of ERP in Organizations, Information System Design, Intelligent Information Systems, and Data Analysis for Decision Making.

Language and Communication with Thai Usage, English Course, English for Organizational Communications, Creativity and Communication, English Skill Development and Thai Language for Communication.

Social Science and Art with Social Science, Humanities, Integrated Social Sciences, Arts and Sciences for Human Developments, Man and the Modern World, Art in Everyday Life and Social Life Skills.

Figure 4 shows the number of credits related to those topics across the different universities.

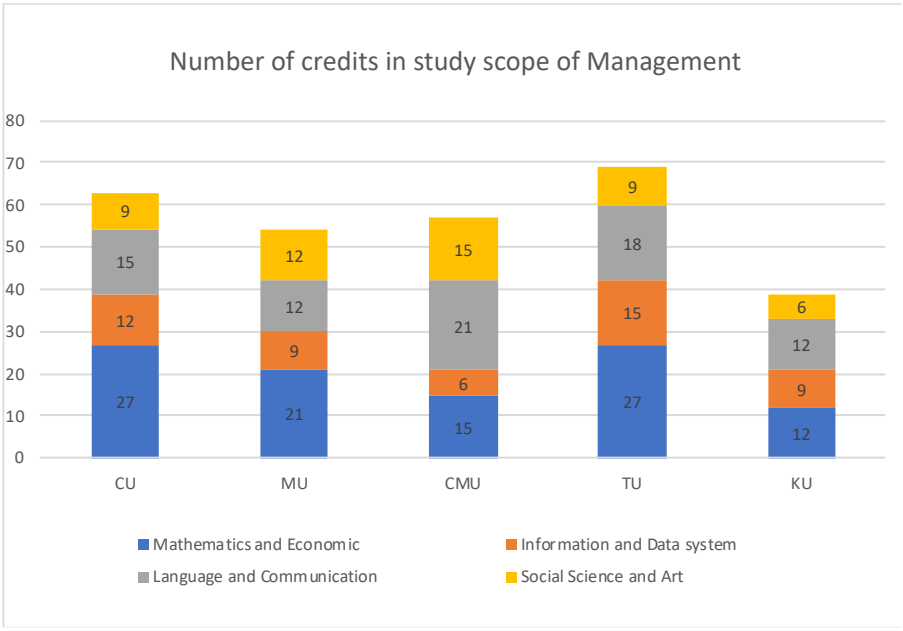

Figure 4. Number of credits in the study for the management area

In current curricula, the topics needed for the Skills 4.0 that will be used when graduating are only a few of the topics in the core courses, which is not enough for students who will apply to work in Industry 4.0. Therefore, Skills 4.0 for SMEs should be set the first year and taught deeper every year until graduation to give students knowledge on hard skills, soft skills, and meta-skills.

1.2 Domain 2: Software Engineering and Big data analysis

In China, there are 2956 Universities, includes 2688 general institutes of higher education (817 public Universities, 417 private Universities) and 268 adult colleges in 2019 [7]. 256 institutes provide software engineering bachelor's degree since 2002 [8]. 283 institutes provide big data bachelor's degree since 2016 [9]. The number of credit hours required for the Bachelor's degree

is in the approximate range 160-170 with some variation between universities. The curriculum structure consists of general courses (around 48 credits), major courses (between 100 to 110 credits), and free elective courses (around 16 credits).

This analysis gives three Universities which can represent the current situation of China include University of Electronic Science and Technology of China [10], Chengdu University of Information Technology [11], Chengdu University [12]. The UEST can represent the top education level of China, CUIT and CDU can represent the normal education level in China.

In Table 1 and Table 2, the main courses provided by these Universities are listed.

Table 1. Mapping of the program offered by the universities to the Software Engineering principle

Name of the University / Principal of Software Engineering	University of Electronic Science and Technology of China (UEST) [13]	Chengdu University of Information Technology (CUIT)	Chengdu University (CDU)
Calculus	+	+	+
Linear Algebra and Space Analytic Geometry	+	+	+
Physics	+	+	+
Probability and Mathematical Statistics	+	+	+
Discrete Mathematics	+	+	+
Introduction to IE	+	+	+
Software Engineering	+	+	+
Object-oriented Programming	+	+	+
Program Design and Algorithm	+	+	+
Principles of Computer Organization and Architecture	+	+	+
Computer Networks System	+	+	+
Digital Logic Design	+		
Principles of Database and Application	+	+	+
Principles of Computer Operating System	+	+	+
System Analysis and Design	+	+	
Cloud Computing	+		
Software Architecture and Design Mode	+		
Software Test Technology and Quality Assurance	+	+	+
Software Security Design	+	+	
Big Data Analysis and Computing Paradigm	+		
Java EE Framework		+	+
Java Web Programming		+	+

Table 2. Mapping of the program offered by the universities to the Big Data principle

Name of the University / Principal of Big Data	University of Electronic Science and Technology of China (UEST) [13]	Chengdu University of Information Technology (CUIT)	Chengdu University (CDU)
Calculus	+	+	+
Linear Algebra and Space Analytic Geometry	+	+	+
Physics	+	+	+
Probability and Mathematical Statistics	+	+	+
Discrete Mathematics	+	+	+
Introduction to Computer	+	+	+
Principles of Database and Application	+	+	+
Computer Architecture	+	+	
Computer Vision and Pattern Recognition	+	+	+
Information Retrieval	+	+	+
Statistical Analysis and Machine Learning	+	+	+
Distributed and Parallel Computing	+		
Big Data Storage and Management	+	+	+
Social Media Analysis	+		
Big Data Application Techniques	+	+	+
Data Mining and Big Data Analysis	+	+	+
Artificial Intelligence	+	+	+
Security Technology of Computer System and Network	+		
Big Data Security	+		

From Table 1 and Table 2, it is evident that the Universities in China are focusing more on teaching mathematics than the other courses. To explain further, the top-ranked universities offer courses to help the students to deepen their understanding of computer architecture, theory of computing, and secure programming. The average ranked universities, on the other hand, offer courses that enrich students' knowledge in software implementation.

The bachelor's degree in Software Engineering was started by Chienese universities in 2002; in the last 18 years, the program has reached at maturity level[14]. Nevertheless, the bachelor's degree in Big Data is a very recent program started in 2016, which is essentially a new program in China [15]. The students enrolled in this program are yet to be graduated. Until today, the software engineering students are working in companies for building Big Data solutions. According to our investigation, the companies are not satisfied with the skills of Software

Engineering students. Therefore, the Chinese government is urging the universities to provide more courses in Big Data areas. It is worth noting that our study found a huge shortage of Big Data experts in the Chinese industry, although the Chinese IT sector is a fast growing sector.

From the curricula of the three Univerisities, we can see that the curricula focus more on theoretical knowledge, many mathematic lessons are provided. However, Industry 4.0 needs students to have more practices to implement novel ideas into application. The current curricula can not satisfy this requirement enough. We need to provide more real cases which come from industry, combine these cases with theoretical lessons, in order to push students to apply theory into practice.

1.3 Domain 3: Wireless Networks Analytics

In Malaysia, several public universities namely Universiti Putra Malaysia (UPM), University of Malaya (UM) and Universiti Teknologi Malaysia (UTM) have offered programs related to Wireless Networks. They are also Research Universities under Malaysian Research University Networks (MRUN).

In UPM, Master in Communications Engineering (Taught Courses) [16] is offering a program suitable for experienced wireless networks and communications engineers from the industry as well as undergraduate students who would like to extend their studies. The program addresses the national needs on new wireless technologies such as 5G and beyond, focusing on real problems faced by the industry, especially on wireless networks and communications. Some data analytics courses can be added to the program, in order to equip the students with a comprehensive and end-to-end wireless system, such as IoT.

In UM, Bachelor of Computer Science (Computer System and Network) [17] offers courses in networking and the theory of computer systems. The program aims to produce critical thinking students with advanced scientific techniques in solving computer-based problems in line with the rapidly changing computer systems and technology. Currently, there are no data analytics or data science courses available in the program. However, the program will include wireless network related courses, especially in covering issues related to 5G and beyond.

In UTM, Master of Engineering (Electronics & Telecommunication) (Taught Courses) [18] offers cutting-edge technology and techniques in electronics and telecommunication for its students. The program is heavily on antenna and propagation and can be enhanced with Wireless network-related and data analytics courses to increase its students' competency and knowledge.

The related programs to Domain 3 offered by Malaysian Universities are as follow:

Name of University	Program	Remark
University Malaya (UM)	Bachelor of Computer Science (Computer System and Network)	- Only Machine Learning - No data analytics or data science courses available - Wireless Network should also be included, especially in covering issues related to 5G and beyond

Universiti Teknologi Malaysia (UTM)	Master of Engineering (Electronics & Telecommunication) (Taught Courses)	- Program is heavily on antenna and propagation - Wireless network-related and data analytics courses can be introduced to increase its strength
Universiti Teknikal Malaysia (UTM)	Master of Technology (Data Science and Analytics) (Data Science and Analytics)	The program is designed to equip the students with Data Science and Analytics. Includes: - the fundamental principles of data science, - the capability to analyse a diversity of big data, - the skills of using data science tools and applying the data analytics techniques to various domain - the capability to present the analytics results
Universiti Putra Malaysia (UPM)	Master in Communications Engineering (Taught Courses)	The program addresses the national needsof new technologies and real problems faced by the industry, especially on wireless networks and communications.

It can be seen that in Malaysia, the IR 4.0 is still at its infancy both at the industry as well as in the university. The universities in Malaysia are slowly incorporating IR 4.0 elements such as data science, big data, network analytics into their study programmes. It is hoped that in 2-3 years down the line we will see IR 4.0 skills visible among Malaysian graduates.

1.4 Domain 4: Artificial Intelligence

In Malaysia, Artificial Intelligence (AI) is one of the hot areas for research and taught courses. Some universities offer AI as a program and some consider AI as part of the courses in a program (embedded in the curriculum).

University of Malaya, Universiti Teknikal Malaysia Melaka, University of Nottingham-Malaysia campus and Multimedia University offer a program of computer science or information technology with specialisation or minor in Artificial Intelligence [19-22]. These programs address the deeper knowledge in AI principles such as Machine Learning, Robotics, Natural Learning Processing, Artificial Neural Network, and Data Mining. Table 1 shows a mapping of the program offered by the respective universities in Malaysia with the AI principle addressed in the program.

Table 1. Mapping of programs offered by the universities in Malaysia to the Artificial Intelligence principles

	Public Universities		Private Universities	
	Univ. Teknikal Malaysia Melaka (UTM)	University of Malaya (UM)	Nottingham, Malaysia campus	Multimedia University (MMU)
Name of the Program / Principles of Artificial Intelligence	Bachelor of Computer Science (Artificial Intelligence)	Bachelor of Computer Science (Artificial Intelligence)	Bachelor of Computer Science with Artificial Intelligence	Bachelor of Information Technology (Artificial Intelligence)
Machine Learning	+		+	
Robotics	+			
Natural Language Processing	+			+
Artificial Neural Network	+	+	+	
Data Mining	+	+	+	+

Other than that, Artificial Intelligence can be offered as part of courses/subjects to be embedded in a program curriculum. Some engineering programs offer applications of Artificial Intelligence in a certain area, especially in Mechatronics and Robotics [23-28]. Besides that, AI applications in non-engineering programs include business intelligence systems and business analytics [29-32]. Table 2 and Table 3 show local universities in Malaysia that offer AI embedded courses in the engineering-based and non-engineering based programs respectively.

Table 2. Local universities offering AI embedded courses in engineering-based programs

University	Program Name
Universiti Malaysia Perlis (UniMAP)	Bachelor of Electrical Engineering Technology (Robotic and Automation Technology
Universiti Teknikal Malaysia Melaka (UTM)	Bachelor of Electrical Engineering Technology (Industrial Automation and Robotics)
Multimedia University	Bachelor of Eng. Electronic in Robotics and Automation
Swinburne University of Technology, Malaysia campus	Bachelor of Eng. (Robotics and Mechatronics)
Univ. Kuala Lumpur – Malaysia France Institute (UniKL-MFI)	Bachelor of Engineering Technology in Industrial Automation and Robotics
Universiti Teknologi Malaysia	Bachelor of Electrical Engineering (Mechatronics)

Table 3. Local universities offering AI embedded courses in non-engineering based programs

University	Program Name
Limkokwing University of Creative Technology	Bachelor of Science in Business Intelligence System
Asia Pacific University of Technology and Innovation	Master in Science in Data Science and Business Analytics
University of Malaya	Master of Data Science
Universiti Teknologi Malaysia	Master of Business Administration (Concentration approach – Data Analytics)

Industry 4.0 is characterised by advances in technologies such as Artificial Intelligence. For readiness towards the future workplace, several AI related academic programme offerings have been carried out by some universities in Malaysia. These offerings are through academic programme with specialisation on AI principles and academic programme that embeds AI application course/courses.

1.5 Conclusion

From the Asian curricula data gathered in the "Shyfte4.0_Curriculum_Review.xlsx" appendix on the one hand, and from this analysis of the curricula landscape on another hand, the AS-IS situation shows the real need for new training offers in the four domains to better meet the needs of companies, in order to reach digitalisation. This training program must cover both theoretical and practical aspects, based on the real case study to allow students to acquire knowledge and skills that are quickly transferable within companies.

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