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Toward a Sustainable Industry 4.0 Engineer

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Abstract:	In the last decade, a shift toward sustainable development in engineering, both in the educational and occupational framework, has started. Therefore, the need to rethink professional figures of engineer has become a necessity. Unfortunately, neither a formal methodology to define standard engineer profile (hereinafter archetype) nor procedural methods to evaluate the impact of such archetypes on sustainability are investigated. This paper bridges these two gaps by proposing a methodology to define engineering archetype as a set of Industry 4.0 (I4.0) engineering competences and a procedural method to evaluate its sustainability. Toward educational and occupational frameworks, I4.0 competences are defined respectively from educational Semi Structured Intended Learning Outcomes (SS-ILOs) and professional skills. The sustainability evaluation is based on indirect mapping of the archetypes onto United Nations Sustainable Development Goals (UN-SDGs) through I4.0. To illustrate the proposed approach, an industrial engineer archetype is defined, and its sustainability is assessed. The result shows that significant limitations toward sustainability remain open challenges. The intrinsic nature of the industrial engineer is confined to some specific goals and a characteristic signature on sustainability clearly emerged.

HIGHLIGHTS

- Define standard professional archetypes: integration both academic and occupational I4.0 skills
- Quantify the sustainability of standard professional archetypes into 2030 SDGs
- Realign educational and occupational engineer frameworks to Sustainable Agenda of the United Nations
- Provide holistic approach, integrating sustainability and I4.0 engineering contents
- Industrial engineer archetype sustainability signature

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Abstract

In the last decade, a shift toward sustainable development in engineering, both in the educational and occupational framework, has started. Therefore, the need to rethink professional figures of engineer has become a necessity. Unfortunately, neither a formal methodology to define standard engineer profile (hereinafter archetype) nor procedural methods to evaluate the impact of such archetypes on sustainability are investigated. This paper bridges these two gaps by proposing a methodology to define engineering archetype as a set of Industry 4.0 (I4.0) engineering competences and a procedural method to evaluate its sustainability. Toward educational and occupational frameworks, I4.0 competences are defined respectively from educational Semi Structured Intended Learning Outcomes (SS-ILOs) and professional skills. The sustainability evaluation is based on indirect mapping of the archetypes onto United Nations Sustainable Development Goals (UN-SDGs) through I4.0. To illustrate the proposed approach, an industrial engineer archetype is defined, and its sustainability is assessed. The result shows that significant limitations toward sustainability remain open challenges. The intrinsic nature of the industrial engineer is confined to some specific goals and a characteristic signature on sustainability clearly emerged.

Keywords: *industry 4.0, engineer profile, sustainability, professional archetype, industrial engineering*

1 Introduction

Worldwide sustainable development is one of the most challenging as well as exciting problems that humanity has ever faced. In the last decades, the uncontrolled anthropogenic impact on the three pillars of sustainability (economic, social, and environmental) caused and worsened many problems within and among countries [1]. It is most probably the major cause for environmental degradation, climate change, and more frequent and intense natural disasters. It also exacerbates majority of the problems that challenge having a fair life in this planet with dignity and tranquility. War, poverty, humanitarian crises, terrorism, migrations, enormous disparities of opportunities, and fragility and inequality of our healthcare systems are examples of these unresolved problems [2]–[4].

On the other side, this era has immense opportunities as well as responsibilities. The 17 Sustainable Development Goals (SDGs) outlined by the United Nations (UN) call on contributions from all the society stakeholders, including local and national governments, organization types, and individuals. This universally shared model finally offers the opportunity to address and face such urgent global issues by an integrated view. Engaging with sustainability-related issues, as described in the SDGs, requires possessing a full set of knowledge, skills, values, and attitudes that empower individuals with the purpose of "*meeting currents needs without affecting the ability of the future generations"* [5]. In the last decades, a shift toward sustainable development affects policies, educational and occupational scenarios. The redefinition of the relevant learning objectives and learning contents as well as introduction of pedagogies that empower learners in the construction of sustainability related skills are moving toward the "right" direction [6]. Among many areas, engineering education has a potential role in generating a fundamental group of possible change agents that could highly and quickly impact the SDGs fulfillment by informed decisions and responsible actions [7], [8]. In parallel, the practical occupational framework can empower new engineer profiles that gain more responsibility in the sustainability trend transition.

As highlighted by Boucher et al. [9], the topical requirements for industrial systems have progressively reintroduced human skills, competences, or know-how as the main source of industrial performance. However, a significant restriction to the latter aspect is the usual association of soft skills (instead of hard competences) concerning sustainability [10], [11]. Unfortunately, we are not aware of a methodology that can help to define these engineering competences, which will be called herein engineer archetypes. The definition of a *standard* engineer archetype or at least a European engineer could help in the redefinition of the engineer profile both from an educational and occupational perspective and opens numerous applications. Moreover, a method to evaluate the sustainability of such archetypes is also missing; therefore, it is not possible to measure the progress in the transition toward sustainability, neither from an educational nor from an occupational perspective.

In this context, the ongoing research under the Erasmus+ Programme of the European Commission called "Manufacturing Education for a Sustainable Fourth Industrial Revolution" (MAESTRO) project [12], offers a fertilization environment of academic experts from diverse engineering disciplines such as industrial, mechanical, electrical, management and production as well sustainable education. The consortium was formed by seven teams from seven European higher education organizations from six European countries (Sweden, United Kingdom, Italy, Portugal, Poland, and Slovenia). They are putting efforts to define and deliver competences to prepare engineers to work in the I4.0 revolution and in a harmony with SDGs. In this challenging context, this paper aims to answer the following research questions:

RQ1: How to define the engineering archetypes?

RQ2: How much of the sustainability aspects are addressed in these archetypes?

For the first question, also interpretable as "does a *standard* engineer exist? or at least a European engineer has been defined?", a methodology to define engineer archetypes as a set of I4.0 competences is proposed. Both educational and occupational competences are considered to define comprehensive archetypes, providing a ground to define educational units for academic and occupational learning.

To answer the second question, we took advantage of our previous work, which proposed a systematic investigation on the influence of the I4.0 technologies onto the UN-SDGs [13]. As shown in Figure 1, the defined engineer archetype sustainability is evaluated by mapping the engineering (*educational* and *occupational*) *competences onto the 17 SDGs* indirectly by *I4.0 mapping*.

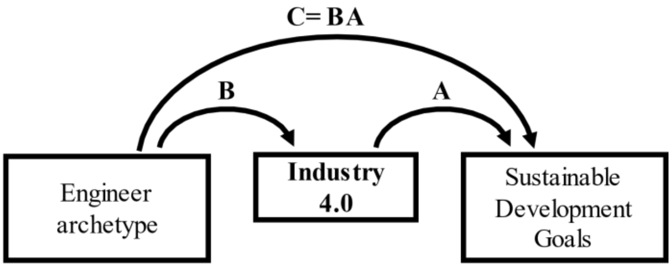

Figure 1: Arrow A represents our previous work [13] where I4.0 has been mapped onto SDGs and resulting in the matrix **A**. Mapping engineer archetype onto SDGs (arrow and matrix **C**) is therefore allowed using a preliminary mapping of the engineer archetype onto I4.0 (arrow and matrix **B**).

This paper is structured as follows: a background along with relevant literature is presented in Section 2. Section 3 describes the methodology for defining engineering archetypes (**RQ1**) and the proposed method to evaluate the sustainability of the archetypes (**RQ2**). In Section 4, an illustrative application of the proposed method is presented for *industrial* engineers, addressing the two questions, and providing a deep analysis and interpretation of the results. The discussion and conclusion are presented in Sections 5 and 6, respectively.

2 Background

This section discusses the research background of this work. It starts by providing an overview of UN-SDGs in section 2.1 and continue with a discussion of sustainability in engineering education in section 2.2 as well as in the occupational framework in section 2.3. Engineering is a major driver in industry and has a substantial effect on sustainability [13]. Section 2.4. discusses this influence, focusing on I4.0 as the dominant industrial future.

2.1 Sustainable Development Goals (SDGs)

After the development of prior Millennium Development Goals (MDGs), 193 worldwide governments met at the historic United Nations Summit in September 2015 and agreed to the 17 SDGs and corresponding 169 targets (Figure 2) to draw the 2030 Agenda for Sustainable Development [14]. "*The Goals and targets are the result of over two years of intensive public consultation and engagement with civil society and other stakeholders around the world, which paid particular attention to the voices of the poorest and most vulnerable. The SDGs and relatives' targets are integrated and indivisible, global in nature and universally applicable, considering different national realities and respecting national policies and priorities*" [2].

The extreme degree of complexity resulting from the integration and indivisibility of the 17 SDGs and relatives' targets can be justified by the nature of these goals. As highlighted in the pyramid of UN sustainability objectives in Figure 2, the SDGs and targets have been derived using a top-down approach by focusing on sustainability as the highest target for people, planet, and prosperity, reflecting what the 2030 Agenda for Sustainable Development is looking for. A holistic perspective sees the concept of sustainability as a dynamic and evolving combination of contextual interconnected variables (social, economic, and environmental) with temporal considerations (short, medium, and long-term) [15]. The integration and indivisibility of these three pillars reflects in the second level characterized by a set of interconnected challenging visions (i.e., goals) whose achievement can lead to sustainability. Each goal typically has 8–12 targets and each target has 1–4 indicators to measure the progress toward reaching the targets. Therefore, the third level represents the deployment of 169 specific targets for 17 goals, which inherits the integration and indivisibility defined at the root.

Figure 2: The pyramid of UN sustainability objectives deployment [14].

Table 1 provides a short description of the 17 SDGs, along with the goals' acronyms and graph legend, which will be referred to in the paper remainder. Huge opportunities could be gained based on the SDGs synergies and benefits, cutting down their trade-off. Since the announcement of the SDGs, a growing interest is dedicated to investigate SDGs related aspects, including indicators for goals integrations [16], achievement assessment [17], energy-related targets [18], planet impacts [16], Artificial Intelligence (AI) role [19]–[21], coping with the consequences of economic systems [22], and the influence of the I4.0 on the goals [13].

Table 1: Description of the Sustainable Development Goals (Adapted from [14]).

Sustainable Development Goal (SDG)	Short Description	Graph legend
SDG1: No Poverty	End poverty in all its forms everywhere	

SDG2: Zero Hunger	End hunger, achieve food security and improved nutrition as well as promote sustainable agriculture
SDG3: Good Health and Well-being	Ensure healthy live and promote well-being for all at all ages
SDG4: Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG5: Gender Equality	Achieve gender equality by providing equal opportunities for both genders
SDG6: Clean Water and Sanitation	Ensure availability and efficient management of water and sanitation for all
SDG7: Affordable and Clean Energy	Ensure access to affordable, reliable, and ecofriendly energy for all
SDG8: Decent Work and Economic Growth	Promote inclusive economic growth, full and productive employment, and decent work for all
SDG9: Industry, Innovation, and Infrastructure	Build resilient infrastructure, promote inclusive and eco-friendly industrialization and foster innovation
SDG10: Reduced Inequality	Reduce inequality within and among countries
SDG11: Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient, and eco-friendly
SDG12: Responsible Consumption and Production	Ensure reasonable and efficient consumption and production patterns
SDG13: Climate Action	Take urgent action to combat climate change and its impacts
SDG14: Life Below Water	Considerable consumption and usage of oceans, seas, and marine resources that preserve the for future generations
SDG15: Life on Land	Protect, restore, and promote responsible use of terrestrial ecosystems and forests, combat desertification, and halt and reverse land degradation and biodiversity losses
SDG16: Peace and Justice Strong Institutions	Promote peaceful and inclusive societies, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels
SDG17: Partnerships to achieve the Goal	Strengthen the means to implement and revitalize the global partnership for sustainable development

2.2 Sustainability in the engineering educational framework

The Sustainable Agenda dedicates SDG4: Quality Education as a standalone goal to achieve sustainable education and at the same time as a key enabler in the pursuit of all the remaining 16 SDGs. In this manner, education is viewed as an engine for change by means of a lifelong learning ranging from formal (preschool to tertiary and adult education) to informal education (online courses and self-education) [6]. Education for SDGs (ESD) promoted by the United Nations Educational, Scientific and Cultural Organization (UNESCO) guides education professionals to contribute toward the SDGs achievement [6]. Within the past generation, hundreds of millions of people have emerged from extreme poverty and the access to education has greatly increased [2]. However unfortunately, industrialized countries often prepare students for their competitive participation in the global economy rather than becoming critical and responsible members of society [15].

In the evolution of the classical paradigm of the engineer profile, a considerable efforts have been dedicated to the realignment of the educational provision to the modern challenges toward a "Sustainable

Engineer" [23]–[25]. As for the course design, teachers have been challenged to comply with Constructive Alignment (CA) approach that focuses on the alignment of Intended Learning Outcome (ILO) to the Teaching and Learning Activities (TLA) as well as Assessment Task (AT) [26]. By focusing into the ILOs, they use sentences providing acting verbs, contents, and contexts that mainly cover what the students should be able to do at the end of the course. Interpret SDGs in defining these educational units is a complicated process. Leifler et al. [8] concluded in their recent study that, according to Swedish engineering universities and directors of engineering colleges, deep integration of sustainability into the core subjects are lacking and the progression of sustainability through programs is often weak. The lack of impact of the engineering curricula on specific SDGs, e.g., SDG10, SDG16 and SDG17 have been also highlighted [8]. Such limitations call for studies and approaches that facilitate the design and implementation of educational unit that comply with SDGs [27].

Accreditation bodies (i.e., The Engineering Accreditation Board (EAB) in the UK [28], the European Network for Accreditation of Engineering Education (ENAEE) in Europe [29], and the Accreditation Board for Engineering and Technology (ABET) in the US [30]) have developed their own standards and sustainability has been covered to some extent. As highlighted by recent initiatives, these accreditation bodies together with UNESCO are still pushing toward the establishment of a new paradigms for the professional figure of engineer as a true enabler, equalizer, and accelerator to deliver the SDGs [31]. However, despite numerous guidelines and standards on teaching the SDGs (e.g., [32]–[34]) and the above mentioned initiatives, an objective understanding on how much a specific engineering professional is aligned with the SDGs is missing.

2.3 Sustainability in the engineering occupational framework

As the main result from the education process, the practice of making everyday decisions in occupational scenarios defines the real impact on economic, social, and environmental issues [22], [23]. The peculiar huge set of hard skills owned by engineers define the related responsibilities in making such decisions [35]. This aspect of the relationship between technology and qualification development trends determines the role of educational organizations into innovative ecosystems.

The influence of technological revolutions toward sustainability highlights the need for professional skills transformation, especially in engineering occupations, which are the ground to foster and realize revolutions [35]. Indeed, the multilingual classification of European Skills, Competences, Occupations and Qualifications (ESCO) database deserves significant attention when describing, identifying, and classifying professional occupations and skills that should be gained by the end of a specific qualification (e.g., *industrial* engineer) [36]. The European Commission developed ESCO to map the existing "occupational profiles" in Europe for 27 sectors of the economy in July 2017. These diverse sectors are taken from the statistical classification of economic activities in the European Community or NACE [37]. In August 2020, a new version had been published, which remains a trending tool for both employers and education programs designers, in academia and in lifelong learning, offering updated information on the new trending skills, and it systematically shows the semantic relationships between different skills [36].

From the industrial organizations side, numerous aspects are highly important in Health, Safety and Environment (HSE) as well as sustainable systems [38], [39]. However, managing change toward sustainability is far from being simple and a clear and compact definition of what an engineer is and how it could be associated with sustainability are missing. Therefore, define engineer archetypes are helpful to be a ground to design practical skills and pedagogical units and harmonize it with the SDGs. To define archetypes, designers of occupational and academic programs must consider overwhelming requirements, spanning from governmental and accreditation body standards to technologies advancements and sustainable agenda. A systematic approach for meeting these multidimensional requirements in defining archetypes is needed.

2.4 Industry 4.0 and engineering

Industry 4.0 (I4.0) is a well-known vision that describes the introduction and implementation of new technological concepts to fully interconnect production elements by bridging the physical and digital world

[40], [41]. The integration of Information Communication Technologies (ICT) and industrial technology lead to the creation of a cyber-physical system to realize an intelligent factory promoting more digital, highly flexible, and green production model [42], [43]. Another important purpose of this new vision is to build systems with real-time interactions between people, products and devices [44]. Classical engineering domains such as manufacturing, informatics, and process technologies deserve significant attention in the rethinking of merging interdisciplinary knowledge together with industry 4.0 enabling technologies [41], [45].

As highlighted by Ramirez-Mendoza et. al. [44], several efforts have been detonated in the world trying to better understand the evolution in the engineering education toward the I4.0 and numerous frameworks for the definition of new curricula for I4.0 in engineering education have been proposed. Example of such work are reported in the following papers: [41], [44], [46]. However, the lack of a systematic and comprehensive procedure for the definition of standard engineer that encompasses both old and new I4.0 competences focusing on sustainability impact is still an open issue.

To revolutionize engineering contents with I4.0 technologies, a clear definition of these technologies at a lower granularity level is essential, which facilitates the interpretation of the technologies and include it in such contents. Toward this end, our recent paper [13] systematically defined I4.0 elements technologies at a sufficient granularity level. Table 2 shows the defined technologies at two levels: called enablers (i.e., E1) and element technologies (i.e., E1.1). The paper also is the first attempts to comprehensively quantify the influence of I4.0 technologies on the 17 sustainability goals. It shows the technologies that are believed to have a substantial effect toward the SDGs achievement. Such promising technologies should be prioritized and considered in teaching future engineers. However, an effort is needed to transform the emerging I4.0 technologies into engineering competences. Also harmonizing such transformation with SDGs is still an open challenge.

Table 2*:* I4.0 enablers and the element technologies (subenablers) [13].

Enablers	Element technologies
E1 Industrial Internet of Things	E1.1 General Identification E1.2 Ubiquitous Sensing E1.3 Seamless and Real-Time Communication E1.4 Embedded & Edge Computation E1.5 Services Oriented Architecture (SOA) E1.6 Interoperable Semantics Communication
E2 Big Data & analytics	E2.1 Sensors E2.2 Data collecting E2.3 Data processing E2.4 Data querying E2.5 Data access E2.6 Data analytics E2.7 Decision-making support E2.8 Data management techniques and methods
E3 Cloud Computing	E3.1 Computing E3.2 Interoperability E3.3 Servicelisation (on the Cloud) E3.4 Cloud Manufacturing
E4 Simulation	E4.1 Products and processes E4.2 Production lines, workstations, and internal logistics E4.3 Enterprise and its operational environment
E5 Augmented Reality	E5.1 Machine interaction E5.2 Human interaction E5.3 Training E5.4 Communication E5.5 Simulation
E6 Additive Manufacturing (AM)	E6.1 Processes for polymers E6.2 Processes for metals E6.3 Processes for ceramics E6.4 Materials E6.5 Design for AM

		E6.6 Software
E7 Horizontal & Vertical System Integration		E7.1 Reference Architecture E7.2 RAMI 4.0 E7.3 Systems Integration E7.4 Digital Twins E7.5 Cyber Physical System E7.6 System of Systems E7.7 Collaborative Networks
E8 Autonomous Robots		E8.1 Perception E8.2 Deliberation E8.3 Autonomy
E9 Cybersecurity		E9.1 Threat identification and detection E9.2 Data loss prevention

3 Methodology

This section provides a detailed description of the suggested methodology to address the two research questions: **RQ1** and **RQ2**. Figure 3 depicts this methodology. To address **RQ1,** a procedural method to define archetypes is suggested. The raw information for educational learning outcomes and occupational skills are retrieved from university programs and from the ESCO database, respectively, as discussed in section 3.1 (Figure 3, left). Once the archetype has been defined, assessing the sustainability of the defined archetypes (**RQ2)** is the next step. As the direct relation between archetypes and SDGs are difficult to be investigated, an indirect quantification of the relation of the archetypes and SDGs through the I4.0 technology is proposed in section 3.2 (Figure 3, right).

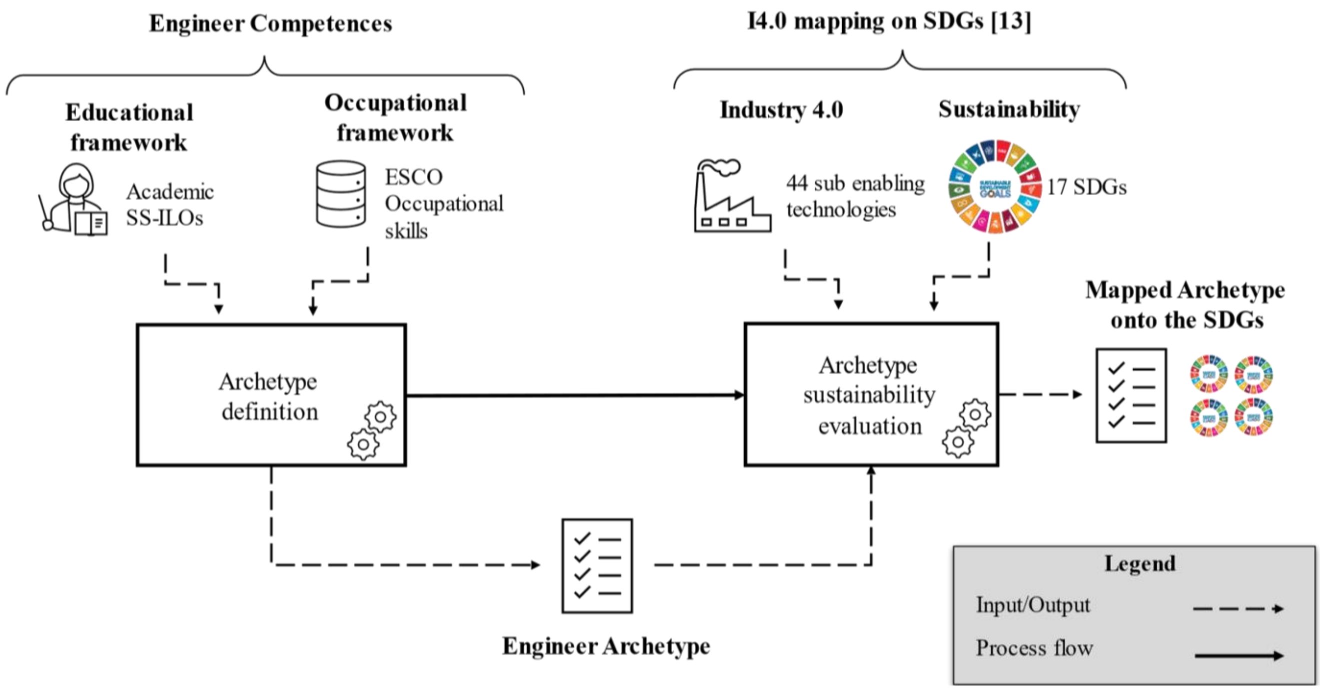

Figure 3: Flowchart of the proposed methodology to define a standard engineer profile (archetype) and assess its sustainability, through the I4.0 subenablers.

3.1 Archetype definition

As anticipated in the background section 2., standard engineer archetypes have not yet been defined nor in the educational (section 2.2) neither in the occupational (section 2.3) frameworks. To answer **RQ1,** a method to provide the procedural steps for designers of learning frameworks is detailed. This guidance method helps define standard engineer archetypes in a systematic way. The following two types of engineering competences are used (Figure 3, left) as input raw data:

I. ***Academic SS-ILOs*** are sets of Semi Structured Intended Learning Outcome derived from the related courses in the university program under interest. Semi Structured ILOs are a less formal version of the well-established ILOs that are used to overcome different degrees of formalization from diverse academic institutions. From a practical side, the SS-ILOs represent a set of sentences (from two to five, depending on the number of topics, recappable with the number of credits). They are a sort of abstract with the main purposes and intended outcomes that a course should achieve.

II. ***ESCO Occupational skills*** are a set of skills that characterize the engineering profile under interest obtained from the ESCO database. As highlighted in section 2.3, this database offers a formal and multilingual classification for the main professions' skills.

The elements of the two sets of competences are clustered through a consensus-based approach by groups of academic experts. The aim is to define the final archetypes. The consensus-based approach is carried out following structured techniques to guide the working group. The main task of this activity is the synthesis of the input list to a final set of 5-10 clusters of competences that cover all the identified aspects. The engineer archetype is defined by the respective clusters of competences. The output is therefore a consensus archetype made by a number (e.g., 5<x<10) of competence clusters denoted as CL1-CLx. An example for the *industrial* engineering case study will be presented in section 4 and is available in Table 3.

3.2 Archetype sustainability evaluation

This section describes the suggested method to assess the sustainability of an archetype as defined in section 3.1 and answers the second research question (**RQ2**). The relation between the archetypes and SDGs is complicated and cannot be assessed in a straightforward way. As anticipated, the suggested method indirectly exploits the result of mapping the I4.0 technology into the SDGs in [13]. As shown in Figure 4, once the archetype has been defined, the assessment is done in two consecutive steps:

I. The ***team scoring*** activity involves in the assessment of the I4.0 technologies consideration in the archetypes (Figure 4, left). The representation of the I4.0 subenablers (Table 2) in the archetype has been evaluated by a panel of experts. Each member of the panel has assigned a score for each cluster of competences (CLx), identified in the previous step, into the 44 element technologies (E1.1-E9.2). A four ordinal correlation measure is used: no correlation, weak, high, and very high correlation. The four possible correlation scores are 0, 1, 3 and 9; the average values from the panel of experts are computed.

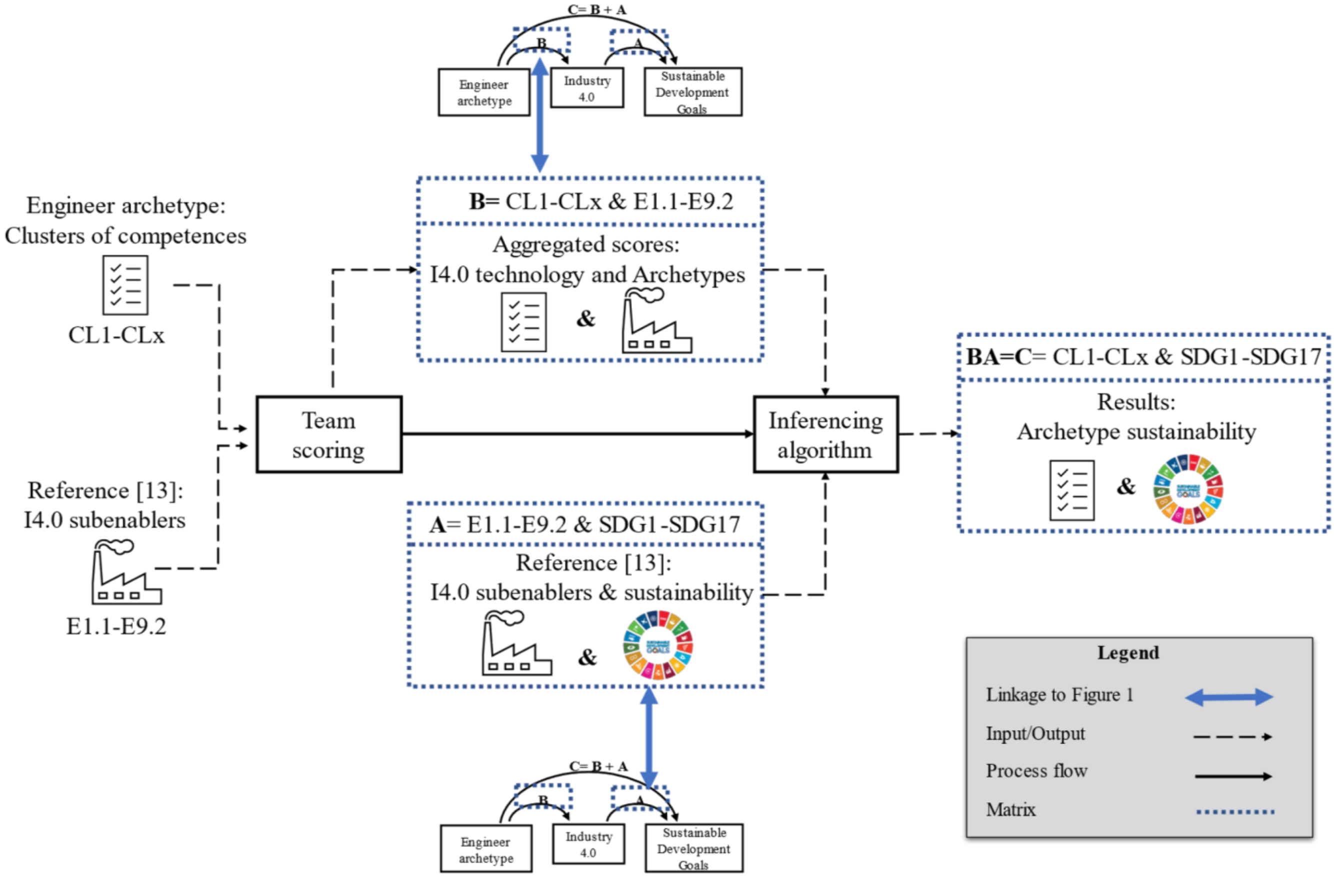

Figure 4: Outline of the proposed method for the sustainability evaluation of the engineer archetype.

II. The ***inferencing algorithm*** is based on the matrix product **BA**. As introduced in Figure 1, also represented as graphical item in Figure 4, the bridge that links archetype and sustainability is I4.0. Since the two matrices **B** = CL1-CLx & E1.1.-E9.2 and **A** = E1.1- E9.2 & SDG1-SDG12 share the I4.0 subenablers dimension, E1.1-E9.2, an algebraic product operator can be used. The inferencing algorithm used the team scoring result (matrix **B** in Figure 4) to deduce the sustainability relation via the mapping result in [13] (matrix **A** in Figure 4) and obtaining the final matrix **C=BA** that bridges the CLx (archetype) to each of the 17 SDGs (sustainability), where each element **C(***i*,*j***)** is the weighted average of the products as recalled in Algorithm 1.

Algorithm 1: Pseudocode of the inferencing algorithm that indirectly deduce the sustainability of archetypes.

```
for each column_j where j=1 to X [or CL1-CLx]
      for each column_k where k=1 to 17 [or SDG1-SDG17]
           for each row_i where i=1 to 44 [or E1.1-E9.2]
                 sum1=sum1 + (cell_j,i * cell_k,i)
                 sum2= sum2 + (cell_j,i)
           end
           The CLj impact onto SDG_k-8 is computed as the
           weighted mean= sum1/sum2
      end
     plot the radar diagrams
end
```

4 *Industrial* engineer archetype case study

This section illustrates the suggested approach to a specific engineer archetype by defining an *industrial* engineer archetype and evaluating its sustainability. *Industrial* engineering can be dated back after the second Word-War II and can be positioned among mechanical, management and production engineering. The application of the two steps of the methodology described in section 3.1 and 3.2 is described in section 4.1 and

4.2, respectively. Section 4.3 discusses the resulting sustainability evaluation and addresses improvement proposals.

4.1 *Industrial* engineer archetype definition

An *industrial* engineer archetype has been defined from educational and occupational competences as follows:

I. A set of more than 100 SS-ILOs has been collected from more than 50 courses from master's degree programs in *industrial* engineering. The list of the SS-ILOs has been derived from the seven universities involved in the MAESTRO Project [12]. Basic knowledge such as math, physics, and bachelor *industrial* engineering competencies are implicitly embedded.

II. A set of more than 200 occupational skills from the ESCO database for the "*industrial* engineer" profile (ESCO Code 2141.3.) has been built.

This listing of more than 300 competences has been further processed by the team members individually and collectively by virtual meetings. About 50 duplicate entries have been removed. The remaining competences have been merged to the compact set in the second column of Table 3. A further merging iteration has achieved a manageable number of clusters of competences: CL1-CL6 in the first column of Table 3. Table 3 represents a first attempt in the definition of a standard *industrial* engineer profile: CL1 is related to both conventional and non-conventional manufacturing processes, including assembly, as well as shop floor design and operations. CL2 is related to structures, machines, and products design, including software, simulations, analyses, experiments, and product data. CL3 focuses on software tools for digital manufacturing. CL4 is related to robotics and automation in general, including sensors, control theory and electronics. CL5 includes production planning and control, maintenance, HSE standards, statistical tools, and system optimization. CL6 is related to the supply chain/network management including mathematical modelling and managerial topics, financial and economic aspects.

Table 3: The *industrial* engineer archetype and its clusters of competences.

Clusters of competences	Summary of Competences
CL1: Manufacturing Processes	- Design and analyze a plan or specification for the design of conventional industrial production systems (e.g., cutting, molding, deformation, welding etc.). - Design and analyze nonconventional processes (e.g., advanced additive manufacturing, water jet, laser cutting, industrial adhesive bonding etc.). - Design and analyze the best-suited assembly technology, applying technical and economic criteria. - Use specific software for event-driven flow simulation to develop a balanced manufacturing flow within a factory. - Use specific software to develop factory layouts with buildings, manufacturing/assembly systems and factory assets.
CL2: Structures, Machines, and Products Design	- Research on and design of machines and mechanical installations, components, or testing prototypes using CAE tools. - Prepare drawing and technical documentation by applying standards and engineering principles. - Analyze materials' ability to endure stress imposed by temperature, loads, motion, vibration, and other factors using mathematical formulae and simulations. - Conduct research and experiments.
CL3: Production IT Tools Infrastructure	- Practical skills in using CAE software for integrated manufacturing systems (e.g., CAD-CAPP-CAM). - Evaluate and Select optimal IT solutions to integrate with hardware systems. - Compare and assess ICT products and service in terms of quality, costs, and compliance to specifications. - Design/Select of an optimal PLM system for product data control.
CL4: Manufacturing Automation and Robotics	- Apply robot modelling and control theory in robotic stations as well as design and build manufacturing systems.

	- Select suitable components, control systems and communication technology for automation of material handling and automated assembly. - Assemble robotic machines, devices, and components according to engineering drawings. - Program and install the necessary components of robotic systems, such as robot controllers, conveyors, and end-of-arm tools.
CL5: Production Planning and Control	- Design and optimization of production planning and adjust work schedules to maintain efficient shift operation. - Plan maintenance processes to ensure satisfactory performance and compliance with specifications and regulations. - Use of statistical methods and tools for process monitoring and product measurements. - Apply integrated HSE systems (ISO 9001, 14001, 45001 and other standards). - Improve production rates, efficiencies, yields, costs, and changeovers of products and processes. - Plan, monitor and report on the budget.
CL6: Logistics and Supply Chain Management	- Apply mathematical models for anticipating demand, solving/optimization problems in aggregate planning, inventory management and resource exploitation. - Monitor and control the flow of supplies that includes the purchase, storage, and movement of the required quality of raw materials and work-in-progress inventory. - Manage supply chain activities and synchronize supply with demand of production and customers.

4.2 *Industrial* engineer archetype sustainability evaluation

Five independent sets of scores have been provided by five different teams. Each team has blindly assigned a correlation score on how each of the identified six competence clusters (CL1-CL6) is aligned to I4.0 subenablers (E1.1-E9.2). Table 4 in appendix shows the inferenced scores. The right side of Table 4 recalls the correlation between I4.0 and SDGs from [13]. The values have been normalized to the maximum value of 3 (light blue header) to provide a 0-100 range. For each column CL1-CL6, the weighted mean of the scores on each SDGs column (SDG1-SDG17) has been calculated using the Algorithm 1. A Visual representation that highlights a typical "signature" of the *industrial* engineer is provided as radar plots shown and discussed in section 4.3.

4.3 Results

An evidence emerged from the *industrial* engineer case study. The graphical representation for the six clusters (CL1 to CL6) is shown in Figure 5: the radar plots display the weighted mean values obtained by the computation Algorithm 1, normalized in the 0-100 range for the 17 SDGs. Each cluster of competences CLx presents the same shape, which can be clearly observed for all the six clusters of competences of an *industrial* engineer. This proves that and *industrial* engineer archetype shows the same I4.0 signature on sustainability that was observed in [13]. Only some of the SDGs are aligned to the competences of an *industrial* engineer. Despite the different technological imprinting that characterizes the identified clusters of competences, a one-to-one comparison between each cluster highlights an evident recurrent and confined pattern.

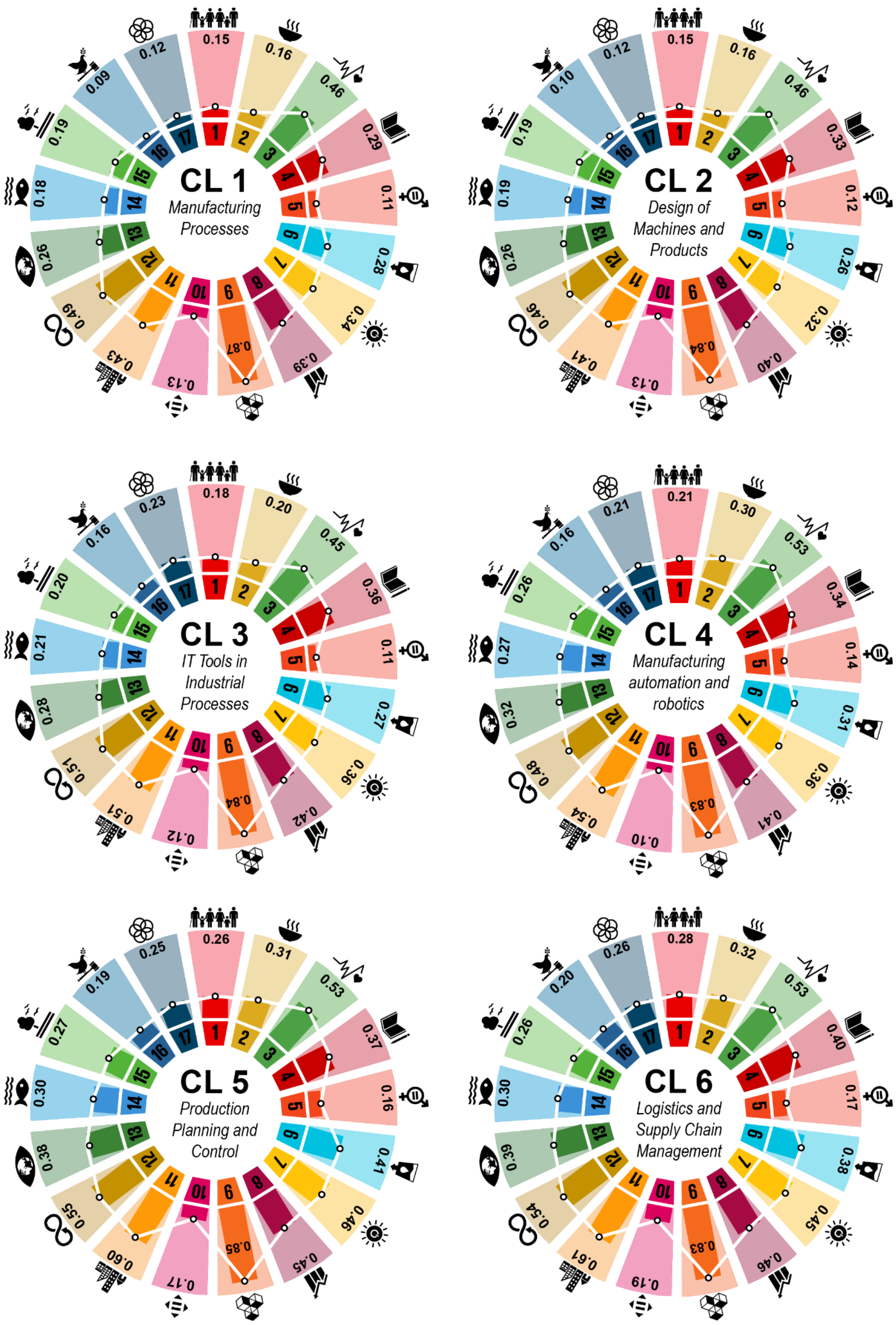

Figure 5: Sustainability mapping on the 17 SDGs of the proposed *industrial* engineer archetype.

For a deeper understanding of the results in Figure 5, the score distribution is further investigated. Figure 6 shows the variability of the weighted average of each SDG score, given by the teams of experts, output from the inferencing algorithm. The boxplots are based on the values of the radar diagrams of Figure 5 considering each team separately. At a glance, SDG9 is the goal that presents the lowest variability and the highest weighted mean. After all, the intrinsic relation with I4.0 and *SDG9: Industry, Innovation, and Infrastructure* is quite intuitive and is demonstrated by the unanimous scores. Conversely, *SDG 11: Make cities and human settlements inclusive, safe, resilient, and eco-friendly* presents the highest variability showing the different perspectives related to this goal. *SDG5: Gender Equality* and *SDG10: Reduced Inequality* present the lowest weighted means with a low variability, thus demonstrating the limited impact that an *industrial* engineer can have on those aspects.

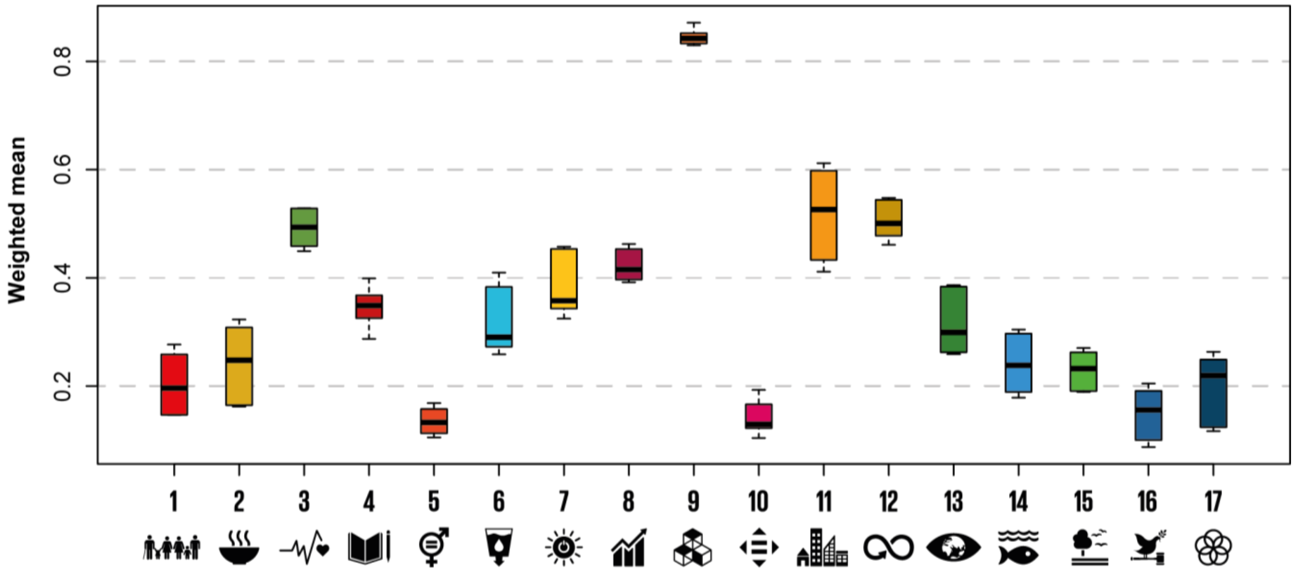

Figure 6: Boxplots of the distribution of the weighted mean of each SDG score, given by the teams of experts, output from the inferencing algorithm.

Based on the values of the weighted average, five groups are identified by hierarchical clustering the 17 SDGs as shown in the dendrogram in Figure 7 and have been characterized as follows:

- ***Red SDG-Group:*** *SDG9: Industry, Innovation, and Infrastructure*. As previously highlighted this SDG is highly addressed by the *industrial* engineer archetype since it is the core of I4.0.
- ***Light blue SDG-Group:*** *SDG3: Good Health and Well-being*, *SDG11: Sustainable Cities and Communities*, *SDG12: Responsible Consumption and Production*. This group includes technical aspects that combine policy making and cultural habits. As an example, for the SDG12 engineers might play a major role in responsible production, but on the other end, responsible consumption depends on the consumer attitude or regulations imposed by central or local governments, outside of the *industrial* engineer field of work.
- ***Purple SDG-Group:*** *SDG4: Quality Education*, *SDG6: Clean Water and Sanitation*, *SDG7: Affordable and Clean Energy*, *SDG8: Decent Work and Economic Growth*, *SDG13: Climate Action*. Similarly, to above Group, these SDGs require a combination of technical actions with policies and culture. For example, engineers may affect the production system efficiency or water treatment plants. Nevertheless, pushing on the achievement of the SDGs of these groups also requires a fundamental contribution from policy makers.
- ***Green SDG-Group:*** *SDG1: No Poverty*, *SDG2: Zero Hunger*, *SDG14: Life Below Water*, *SDG15: Life on Land*, *SDG17: Partnerships to achieve the Goal*. In this group of SDGs, policy making, and economical factors play a predominant role over technical aspects.
- ***Gold SDG-Group:*** *SDG5: Gender Equality*, *SDG10: Reduced Inequality*, *SDG16: Peace and Justice Strong Institutions.* These SDGs are more related to humanities and social disciplines, far from engineering profiles. Additional and interdisciplinary expertise is needed to deliver these topics in cooperation with I4.0 engineers.

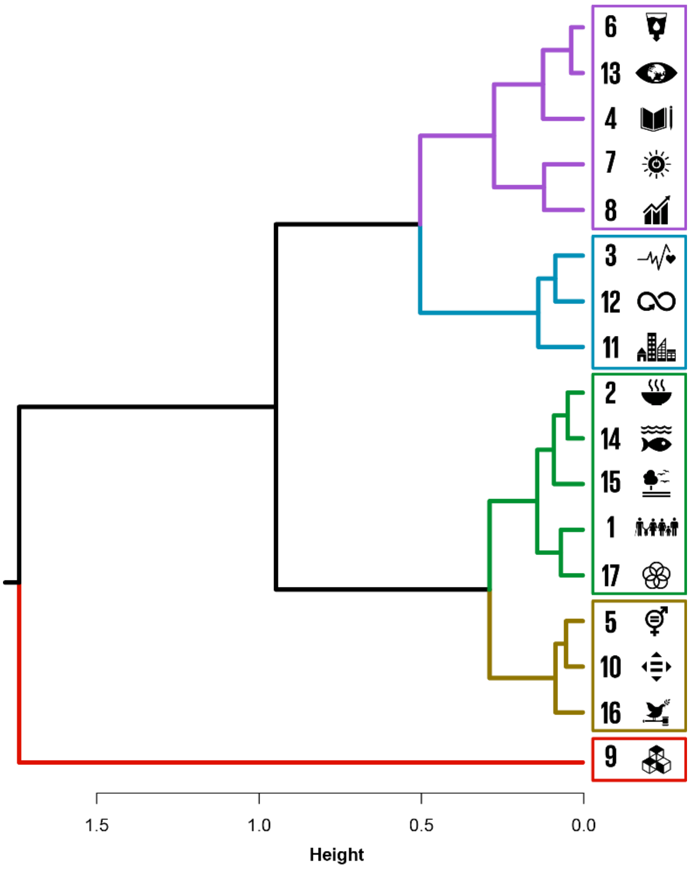

Figure 7: Hierarchical clustering of the SDGs

These analyses reinforce our idea that, for a significant coverage of the SDGs, the gap should be filled through the support of experts on the related topics in a contamination framework. A multidisciplinary team is likely to possess a broader range of sustainability abilities, knowledge and skills, and members with different perspectives give a larger pool of resources. Such a diversified team may be helpful in dealing with non-routine issues for more creative and innovative problem-solving approaches that could encounter success in a sustainable manner [47]. This concept stays true also if reversed: different professional profiles may require support from (industrial) engineers for an integrated action toward sustainability.

A similar clustering analysis on the resulting data has been carried out. Three main groups have been identified by hierarchical clustering of the six clusters of competences of the *industrial* engineer as shown in the dendogram of Figure 8 and have been characterized as follows:

- ***Light blue CL-Group:*** it includes the profiles of IT Tools in Industrial Processes (CL3) and Manufacturing Automation and Robotics (CL4). This group is distinguished by a predominant use of IT tools, digital technologies, and computer related disciplines in I4.0.
- ***Green CL-Group:*** it includes the profiles of Manufacturing Processes (CL1) and Design of Machines and Products (CL2). This group includes more traditional engineer profiles for the design and development of the process and of the product. Although nowadays digital data and Computer Aided Engineering (CAE) software packages are used in these disciplines, theoretical knowledge and the experimental approach are of paramount importance.
- ***Red CL-Group:*** it includes the profiles of Production Planning and Control (CL5) and Logistics and Supply Chain Management (CL6). These profiles are primarily involved in managerial activities and take advantage of the cyber-physical integration of data in I4.0. For decision-making, a comprehensive overview of the production state or delivery state of a product with real-time information is required.

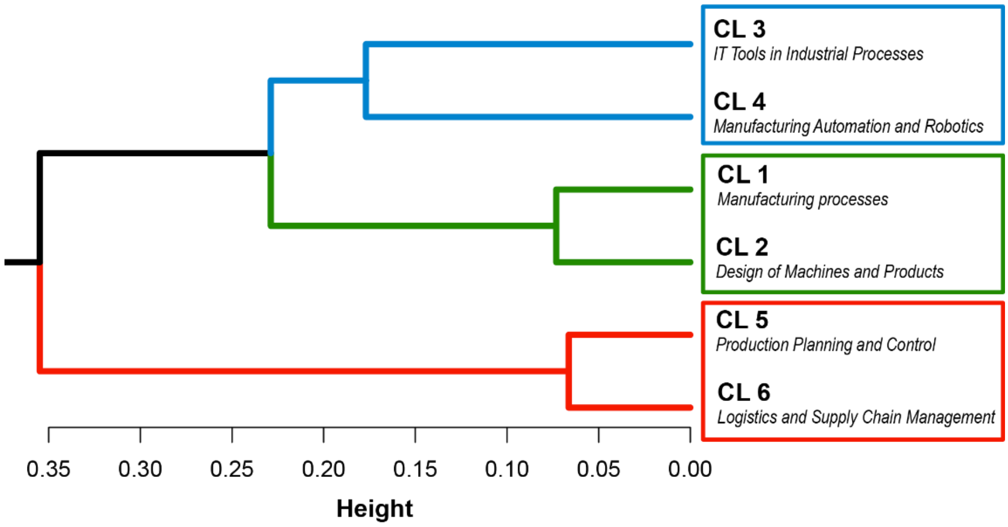

Figure 8: Hierarchical clustering of the six clusters of competences of the *industrial* engineer profile.

The dendrogram in Figure 8 also shows that a further clustering reduces to two groups only: the technical profiles from CL1 to CL4 can be grouped separately from the managerial profiles CL5 and CL6. From all the previous highlighted analysis on the *industrial* engineer archetype sustainability, MAESTRO partners are currently investigating methods to improve these educational SS-ILOs. We still believe that lots of studies, implementation cases, and dissemination events are needed toward sustainable curricula in engineering.

5 Discussion

As for the interpretation of the *industrial* engineer case study the evidence in Figure 5 could be justified by the argument that I4.0 technologies will have un-equal influence on the goals. As it can be seen the effect of I4.0 is mostly covering SDG3, SDG9, SDG11 and SDG12 in all the six CLx. Taking CL6 and CL1 as an example of the highest absolute difference (still relatively very low) observed in the pairwise comparison among clusters of competences, additional observations follow. CL6 presents a better overall impact on all the 17 goals except SDG9. This could be justified by the fact that logistic and supply chain disciplines are a set of topics embedded in the management scenario that could have broad impact on the sustainability aspects. On the other hand, CL1 is quite confined to heavy technical disciplines related to manufacturing processes, therefore, the highest impact on SDG9 can be reached by focusing less on the other goals.

The following consideration apply to the engineer archetype. A general engineer archetype includes both technical and managerial skills, which are required by an integrated view according to the 17 UN-SDGs. However, the next generation engineer archetype should include more social and environmental aspects in order to encompass a holistic approach [23]. The proposed archetype definition methodology is virtually applicable to engineering and non-engineering. A critically may arise in non-engineering programs such as social, mathematical and arts programs, where weaker association exist with industry and technologies.

As for engineering, this methodology allows the harmonization of profiles and their sustainability quantitative monitoring and improvement.

As stated by Tejedor et al. [48], a sustainable engineer requires creating new long-term, participatory, solution-oriented programs as platforms to recognize and engage with the macro-ethical, adaptive, and cross-disciplinary challenges embedded in professional issues that are quite far from being reached. Despite the provided answers to the two-research questions of the paper, this work opens more research questions, such as:

- ***Improve the archetype and the definition method:*** The proposed sustainable engineering archetypes can be improved by a more systematic and automated input of competences: SS-ILOs and occupational skills. Procedural approaches are needed to harmonize existing contents with sustainability and to add new contents that could speed the transition toward sustainability.

- ***Multi-disciplinary collaboration for defining the archetypes:*** Defining a collaborative framework of experts from academia, research, and industry for specific curricula from different countries to define archetypes and evaluate sustainability. Does a more sustainable global engineer exist with respect to the one depicted in this paper? What are the constraints to “extend” the identified engineer sustainability signature? What can remove the “inertia effect” that frequently freezes the improvement dynamics due to lack of communication between different disciplines bureaucracy, and competition. Other kinds of issues can be found in external barriers: e.g., lack of incentives [8].
- ***Alternative assessments of the archetype’s sustainability:*** Extend mapping of the SDGs to a general archetype without passing through the I4.0 technologies requires investigation, particularly involving profiles from different fields e.g., economics, mathematics, life, and social sciences etc.

6 Conclusion

This paper has investigated the extent for an industrial or I4.0 engineer to realize the 2030 Sustainable Agenda of the United Nations strategic objectives. It has started by defining a standardized professional archetype, integrating academic and occupational skills. A method to quantify its sustainability has been proposed: indirectly through a mapping of I4.0 on the SDGs. This method initiates and promotes the culture of defining and measuring the progress and transition toward the sustainability path.

The proposed method has been applied to define an *industrial* engineer archetype; its main competences CLx are clustered on six areas. The 44 I4.0 subenablers Ex.x have been mapped on these clusters and on the UN-SDGs. The SDGs standardized view provides a holistic approach, integrating sustainability and I4.0 contents. Observing the intersection between sustainability and *industrial* engineer archetype it is no surprise that a high degree of sustainability is present. Both I4.0 enablers and sustainability principles have been present in engineering profiles for a long time. However, a confined impact on certain SDGs has been clearly observed. While there may be an evolution of current *industrial* engineer archetype, there is no certainty that it will provide a significant impact on the trilobate-shaped SDG signature.

As far as sustainability can be pushed, engineers will always have a deep but specific focus coming from their educational paths and professional careers. These characteristics show the need for an integrated approach to sustainability by experts from different fields with matching signatures.

As a final conclusion, we, argue that (industrial and I4.0) engineers, but also no single discipline on its own, can present a solution for achieving all the SDGs. This is mainly due to the intrinsic integrated and indivisible balancing on the three economic, social, and environmental dimensions of sustainable development. These dimensions need support from specialists with different backgrounds to achieve a real integrated coverage of SDGs through interdisciplinary approaches, which can be objectively identified by the method proposed in this paper.

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Appendix

Table 4: The competences mapping table deduced from MAESTRO team average scoring.

Industrial Engineer Archetype						Industry 4.0		Sustainable Development Goals																
CL1	CL2	CL3	CL4	CL5	CL6			SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
1.00	0.75	4.00	7.00	1.75	3.25	E1	E1.1	0.24	0.29	0.57	0.24	0.10	0.29	0.33	0.38	0.90	0.19	0.52	0.48	0.33	0.29	0.33	0.10	0.24
3.00	0.25	1.50	2.25	1.00	1.00		E1.2	0.24	0.38	0.62	0.10	0.10	0.38	0.33	0.29	0.81	0.10	0.71	0.57	0.33	0.33	0.43	0.10	0.14
2.25	0.75	5.25	3.75	0.25	1.00		E1.3	0.24	0.38	0.57	0.43	0.05	0.33	0.43	0.43	0.90	0.05	0.81	0.62	0.14	0.10	0.19	0.10	0.19
2.25	1.00	5.25	3.25	0.75	0.25		E1.4	0.19	0.14	0.67	0.48	0.05	0.48	0.48	0.33	0.90	0.00	0.57	0.52	0.38	0.38	0.38	0.24	0.19
0.75	0.25	1.00	1.75	0.25	1.00		E1.5	0.33	0.33	0.67	0.43	0.14	0.38	0.48	0.48	0.90	0.19	0.81	0.57	0.33	0.29	0.29	0.33	0.33
0.75	0.25	0.75	1.75	0.75	0.25		E1.6	0.14	0.14	0.43	0.24	0.05	0.29	0.33	0.29	0.71	0.05	0.67	0.38	0.24	0.14	0.19	0.14	0.24
1.50	2.75	3.25	3.75	3.00	1.00	E2	E2.1	0.24	0.33	0.76	0.10	0.14	0.62	0.48	0.38	0.81	0.10	0.71	0.57	0.62	0.52	0.52	0.19	0.10
0.75	1.00	3.75	3.25	3.25	4.75		E2.2	0.43	0.52	0.67	0.52	0.24	0.62	0.62	0.52	0.71	0.29	0.81	0.48	0.71	0.52	0.38	0.33	0.29
0.75	0.75	1.50	1.50	5.50	5.00		E2.3	0.38	0.48	0.67	0.48	0.33	0.62	0.62	0.48	0.71	0.33	0.81	0.57	0.67	0.57	0.43	0.43	0.48
0.25	0.75	3.75	1.00	0.75	0.25		E2.4	0.38	0.48	0.57	0.48	0.24	0.48	0.38	0.33	0.62	0.19	0.52	0.52	0.48	0.38	0.33	0.33	0.33
0.25	0.75	3.25	1.00	0.75	0.25		E2.5	0.33	0.24	0.67	0.62	0.29	0.62	0.43	0.52	0.81	0.24	0.62	0.52	0.57	0.48	0.33	0.33	0.33
0.75	2.25	3.00	2.25	6.00	3.00		E2.6	0.38	0.57	0.67	0.52	0.33	0.71	0.62	0.19	0.81	0.19	0.81	0.57	0.62	0.52	0.38	0.33	0.38
4.50	2.25	3.00	4.75	7.00	4.75		E2.7	0.71	0.81	0.76	0.62	0.33	0.81	0.71	0.52	0.90	0.38	1.00	0.57	0.71	0.62	0.48	0.43	0.48
0.75	2.50	3.25	1.00	1.50	2.75		E2.8	0.38	0.48	0.57	0.43	0.29	0.62	0.62	0.52	0.81	0.48	0.71	0.48	0.52	0.38	0.38	0.33	0.33
0.75	2.50	4.00	2.25	0.25	0.75	E3	E3.1	0.33	0.29	0.33	0.38	0.05	0.14	0.29	0.05	0.90	0.10	0.67	0.52	0.14	0.10	0.10	0.19	0.38
0.25	0.75	5.25	0.75	0.25	0.25		E3.2	0.14	0.24	0.29	0.19	0.05	0.24	0.38	0.33	0.90	0.00	0.76	0.43	0.14	0.10	0.10	0.33	0.52
0.75	0.25	5.00	0.75	0.25	1.50		E3.3	0.10	0.10	0.24	0.48	0.05	0.10	0.48	0.52	0.90	0.29	0.62	0.57	0.24	0.05	0.05	0.19	0.38
0.75	0.75	3.50	1.00	0.25	0.75		E3.4	0.14	0.05	0.05	0.24	0.00	0.05	0.33	0.33	1.00	0.10	0.33	0.43	0.19	0.00	0.00	0.14	0.29
7.00	6.00	6.00	3.00	5.50	2.00	E4	E4.1	0.14	0.05	0.33	0.43	0.05	0.33	0.38	0.62	0.90	0.10	0.43	0.62	0.24	0.19	0.14	0.05	0.05
6.00	3.75	4.50	3.00	4.00	7.00		E4.2	0.14	0.10	0.43	0.29	0.05	0.14	0.38	0.57	0.81	0.10	0.38	0.71	0.14	0.00	0.05	0.00	0.00
3.50	1.75	3.25	3.00	4.00	1.75		E4.3	0.05	0.10	0.48	0.29	0.05	0.29	0.43	0.62	0.81	0.05	0.43	0.57	0.19	0.10	0.10	0.00	0.10
0.75	3.00	1.50	1.00	0.25	0.25	E5	E5.1	0.05	0.10	0.48	0.81	0.24	0.05	0.14	0.62	0.90	0.14	0.14	0.24	0.24	0.14	0.14	0.00	0.00
0.50	1.00	1.75	0.75	0.25	1.00		E5.2	0.14	0.10	0.52	0.81	0.38	0.05	0.10	0.71	0.90	0.19	0.43	0.48	0.29	0.29	0.29	0.14	0.29
2.50	0.50	3.25	0.75	1.00	0.50		E5.3	0.24	0.10	0.52	0.90	0.33	0.05	0.29	0.71	0.81	0.24	0.43	0.43	0.29	0.19	0.19	0.05	0.19
0.75	1.00	5.25	2.25	0.25	1.00		E5.4	0.10	0.05	0.52	0.71	0.19	0.10	0.19	0.52	0.81	0.19	0.48	0.57	0.38	0.33	0.33	0.19	0.24
2.50	5.25	5.25	2.25	0.25	1.00		E5.5	0.05	0.05	0.48	0.71	0.24	0.05	0.19	0.52	0.81	0.14	0.29	0.38	0.29	0.24	0.29	0.05	0.00
7.00	2.75	1.75	0.25	1.00	0.25	E6	E6.1	0.00	0.00	0.38	0.10	0.05	0.24	0.24	0.19	1.00	0.14	0.24	0.43	0.24	0.14	0.19	0.00	0.00
7.50	2.75	1.25	0.25	1.00	0.25		E6.2	0.00	0.00	0.38	0.05	0.05	0.24	0.24	0.19	1.00	0.14	0.24	0.48	0.24	0.05	0.10	0.00	0.00
5.50	2.75	1.25	0.25	1.00	0.25		E6.3	0.00	0.00	0.38	0.05	0.05	0.24	0.33	0.19	0.90	0.14	0.29	0.43	0.10	0.00	0.05	0.00	0.00
4.00	5.00	0.25	0.25	1.00	0.25		E6.4	0.10	0.10	0.48	0.10	0.10	0.29	0.33	0.29	0.90	0.14	0.29	0.43	0.19	0.14	0.19	0.00	0.00
3.50	7.50	4.50	1.00	1.00	0.25		E6.5	0.00	0.00	0.38	0.10	0.05	0.05	0.14	0.29	0.71	0.05	0.14	0.29	0.05	0.00	0.05	0.00	0.00
3.00	4.50	3.75	1.00	0.25	0.25		E6.6	0.00	0.00	0.29	0.10	0.05	0.05	0.14	0.29	0.71	0.05	0.10	0.29	0.05	0.00	0.00	0.00	0.00
0.25	0.25	5.50	2.50	1.00	1.00	E7	E7.1	0.05	0.10	0.10	0.05	0.00	0.19	0.24	0.19	0.71	0.05	0.29	0.52	0.05	0.00	0.05	0.00	0.19
0.25	0.25	3.00	0.50	0.50	0.50		E7.2	0.10	0.10	0.19	0.14	0.00	0.14	0.24	0.38	0.81	0.00	0.14	0.48	0.05	0.05	0.05	0.00	0.05
0.75	0.25	7.50	1.50	5.50	1.25		E7.3	0.14	0.19	0.48	0.24	0.05	0.19	0.38	0.57	1.00	0.10	0.57	0.62	0.24	0.19	0.24	0.14	0.33
1.00	0.50	5.50	1.00	4.75	0.25		E7.4	0.14	0.19	0.33	0.29	0.05	0.24	0.43	0.48	1.00	0.05	0.48	0.57	0.14	0.14	0.19	0.14	0.29
0.25	0.75	4.00	3.00	0.75	1.00		E7.5	0.14	0.14	0.48	0.38	0.10	0.24	0.38	0.52	1.00	0.05	0.48	0.57	0.33	0.19	0.19	0.14	0.38
0.75	0.75	4.50	1.50	1.00	1.00		E7.6	0.10	0.10	0.38	0.24	0.05	0.19	0.33	0.43	0.81	0.05	0.38	0.52	0.24	0.19	0.19	0.05	0.29
0.75	0.75	1.50	0.50	0.75	2.25		E7.7	0.48	0.52	0.43	0.38	0.14	0.29	0.52	0.43	0.90	0.24	0.71	0.52	0.24	0.29	0.19	0.33	0.57
1.00	0.75	0.75	6.00	0.25	0.50	E8	E8.1	0.14	0.48	0.52	0.14	0.19	0.14	0.19	0.33	0.81	0.00	0.38	0.33	0.29	0.33	0.29	0.14	0.14
1.00	0.75	0.75	6.00	0.25	0.50		E8.2	0.14	0.38	0.52	0.24	0.29	0.24	0.29	0.33	0.81	0.00	0.38	0.33	0.29	0.33	0.29	0.14	0.14
1.00	0.75	0.75	7.50	0.75	0.33		E8.3	0.19	0.43	0.62	0.24	0.10	0.10	0.14	0.33	0.76	-0.1	0.43	0.24	0.24	0.24	0.24	0.05	0.05
0.33	0.25	3.50	1.00	0.25	0.50	E9	E9.1	0.10	0.10	0.43	0.24	0.05	0.24	0.19	0.29	0.62	0.05	0.62	0.38	0.05	0.05	0.05	0.33	0.33
0.25	0.25	3.50	1.00	0.25	0.50		E9.2	0.10	0.10	0.43	0.19	0.05	0.29	0.24	0.29	0.62	0.05	0.62	0.43	0.19	0.14	0.14	0.33	0.33

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: