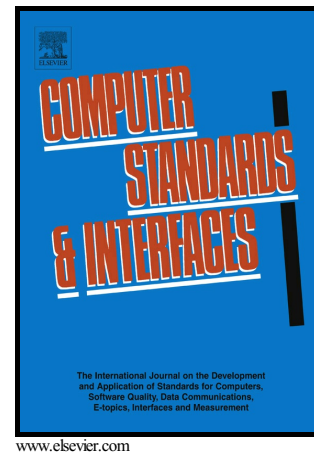


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## Abstract

Definition of skills, occupations, professional profiles and similar concepts have been explored in the ICT area since long ago. It has been only recently in Europe when new frameworks and standards have strived in getting a real systematic conceptual map to this challenging and fast evolving field. More precisely, three are the most important references which provide different aspects and approaches to the challenge of creating a common language in the area: e-Competence Framework e-CF (EN 16234-1:2016), ESCO (European Skills, Competences and Occupations classification) and the European ICT BOK. This paper addresses the challenge of studying them with the goal of providing a consistent model covering the different views of the area. This is an essential step to integrate ICT profiles, competences, skill, knowledges and qualifications, keeping both an interlink to the different already existing systems and the capability to acknowledge and integrate emerging areas in ICT profession in the future. The resulting framework, named as eSkills Match, will allow development of future support systems which may provide self-assessment functions for job candidates, recommender modules to guide their training to target occupations and the possibility of knowledge validation options aligned to the specific set of skills, knowledges and competences used as basic elements of the model.

Keywords: competences, skills, occupation, ICT, standard, framework

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modules to guide their training to target occupations and the possibility of knowledge validation options aligned to the specific set of skills, knowledges and competences used as basic elements of the model.

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## 1. INTRODUCTION

As part of the construction process of a real European Union, cross-country mobility of professionals and workers is one of the key inspiring pillars of this political union. This cannot be achieved unless there is a coordination in the information and language used by recruiters, employers and candidates not just related to the problem of using different languages (Spanish, English, German, etc.) both unifying concepts and expressions. Although the European Union has launched different initiatives (e.g. "eSkills for Jobs", "Digital Agenda for Europe", etc.) to help more people to get jobs across Europe, current analysis has shown that the level interoperability in ICT (Information and Communication Technology) labour market in Europe is still low. One of the identified barriers for that is the above mentioned lack of standardization and use of a common language for ICT jobs descriptions, demands, etc.

The first conflict appears when referring to the appropriate term for skills for ICT profiles as several have been proposed to name this idea. It is true that many common terms on education and qualification have been officially defined in [1] to use a common language in the European Union. The term e-skills is the concept used by DG Enterprise and Industry and ICT industry [2] to refer to the ICT professional skills connected to description of occupations. The term e-skills aim to reflect the different levels of ICT skills needs from basics towards ICT professionals and entrepreneurs. The European e-Skills Forum adopted in 2004 [3] a definition of the term "e-skills" covering the following three main categories: ICT user skills, ICT practitioner skills and e-Business skills. Another term as digital competence (which could be assumed by some people as a synonym of e-skill) is the set of knowledge, skills, attitudes, abilities, strategies, and awareness that are required when using ICT and digital media to perform tasks, solve problems, communicate, build knowledge or even socializing. It is more connected to the so-called ICT users. That is the reason why we prefer using e-skills in this work as we focus on the ICT professional world.

It is not a novelty to realize that standards have been defining roles (or even occupations) of professionals in many areas of ICT. A typical example is the field of software engineering where different frameworks and standards have included interesting descriptions of roles mainly while defining software processes and life cycles. One example comparing the definitions and descriptions of profiles in several software engineering can be found in [4], where several standards such as [5-7] are mentioned and the information on the work profiles and roles involved in software projects is compared and analysed.

Apart from the world of technical standards, some governmental agencies and mainly the labour authorities were always very interested in categorizing and describing the occupations for different reasons: statistics and control, immigration regulation, etc. Some countries and supranational organizations have created frameworks, classifications and other instruments for the above mentioned purposes such as the Australian and New Zealand

Standard Classification of Occupations (ANZSCO) [8] or the North American Industry Classification System (NAICS) [9]. Of course, one primary reference is the standard classification from the International Labour Organizations ISCO-08 [10], the International Standard Classification of Occupations which was adopted in many European countries. However, these references tend to suffer from several drawbacks: the process for the creation and for their maintenance and update is not agile and is usually too long, maybe because public entities are not agile themselves but also due to the possible legal implications of the documents and the effort and time consuming process of their implementation. The result is that these classifications and frameworks tend to be out of date in short time especially in those fields where technical and professional evolution is impacted by a fast pace of innovations like e.g. ICT.

In the academia and in the research world, the work in ICT profiles and occupations has not been one of the fields which has cumulated more effort and interest during the last 15 years: searches in literature databases provide scarce results. Of course, there are some general studies on ICT profiles and their connection with labour market and ICT education but there is still large room for improvement. Interesting and relevant studies like [11-12] and the ones from Leithbridge [13-15] have contributed to explore the complexity of the standardization, classification, analysis and description of ICT profiles and occupations. However, these interesting works have been more concentrated in surveys and analysis to characterize which are the real demands of labour market (and then making proposals for e.g. education) than in creating exhaustive and complete descriptions of positions, occupations and profiles. Other studies that must be taken into account are related to the problems of adaptation of the competences developed through the engineering education to the current labour market [16-18].

Some related works are based on the existing standards/frameworks such as the European e-Competence Framework (e-CF), the European Classification of Skills/Competences, Qualification and Occupation (ESCO), the Information Technology Infrastructure Library (ITIL), etc. For instance, an approach to structure and unify skills, competencies, and qualifications in the field of renewable energies was presented in [19]. The classification was done using the European standard ESCO pillars: skills/competencies, qualifications, and occupations. [20] presents the ESCO framework as the solution to achieve semantic interoperability throughout Europe. This work highlights how ESCO tries to remove communication obstacles, increase transparency, and enable stakeholders to accurately understand exchanged information. The ESCO classification is exploited in [21] where a novel approach and proof of concept application to enable automatically matching MOOCs learning outcomes with learners' needs related to specific skills and competencies is presented. [22] is also based on ESCO and concludes that there is an urgent need for those developing the ESCO taxonomy to establish a framework capable of transcending sector and national specificities, as well as reconciling the worlds of education and work.

On the other hand, in [23] authors focus on the development of a competence-mapping model and specific validation of the IT pillar based on e-CF. The research approach consisted of a literature study and one expert workshop with participants from a range of for-profit educational organizations to develop the model. Similarly, [24] reviews need for digital competence, different concepts used to describe and understand it, and related policy approaches and measurements. Based on these, it suggests a conceptual model to highlight the various knowledge, skill and attitude areas that should be considered when developing

digital competences. The purpose of [25] is the evaluation of a method for measuring work activities and skill requirements of occupations for international comparisons. Like ESCO and e-CF, its objective is to facilitate labour mobility and related training across EU member states.

Regarding other standards/frameworks, one option is focusing on frameworks linked to certifications where process approaches or syllabus and exams description try to describe best practices for a specific area in ICT profession. An example is a well known certification universe like ITIL which has served (together with other certifications and references) for a recent competence scheme under the organization of Axelos (see section 2.4). References like [26] have described how the ITIL and TOGAF frameworks have evolved, and the key areas of overlap and differentiation between them while the work in [27] tries to build a framework to understand the adoption of ITIL and to depict the relationship between major ITIL critical success factors on Technology Acceptance Model. The technical side and the description of roles are not enough to be comparable to the competence models mentioned above but the supplement created by Axelos (section 2.4) could be an example to check if the world of personal ICT certification could be relevant for our purpose of unifying views of main standards and frameworks related to ICT occupations.

The aim of this work is to develop a comprehensive matching framework in order to benefit jobseekers and employers. The developed framework will be dynamically adapted to changes occurring in job labour market classifications that supports training for acquiring the necessary e-skills and to access the desirable jobs within ICT or non ICT sectors. That adaptation will be achieved by updating the information provided by e-CF, ESCO and BoK when they will be subjected to the regular updates which their underlying supporting entities have promised to perform in the forthcoming years.

This paper is organised as follows. Section 2 describes the existing ICT related competence frameworks on which basis the matching model has been developed. The matching procedure is detailed in section 3. Validation and discussion are included in section 4. Finally, section 5 presents the conclusions as well as further lines of action.

## 2. EXISTING FRAMEWORKS

Facing the challenge of developing a really complete and integrated competence-mapping model requires considering the most important frameworks at European level: e-CF and ESCO. However, these are not the only frameworks incorporated to the competence-mapping process as other very relevant references as the BOK (Body of Knowledge) have to be obviously considered. Of course, the work has not only to cover those frameworks but it also has to analyse the possible contributions of other references which play an important role in today's labour market: ICT personal certifications. There is a huge almost unmanageable number of certifications and certifications providers (some informal catalogues already lists more than 2300 certifications and 161 providers) but only some of them have been complemented or transformed into a competence scheme which may contribute to our purpose of competence mapping. The other remain as a lean pair of syllabus plus description of evaluation instruments. As a solid representative of the contribution of a certification scheme we included the Axelos framework intimately connected to two well known certifications like ITIL and Prince. Following subsections describe each of these frameworks/schemes as a first step for understanding their similarities and differences.

It is worth to note that a recent survey with 97 respondents in 8 different European countries carried out in another EU funded project e-CF Council ([www.ecfalliance.org](http://www.ecfalliance.org)) where University of Alcalá is also participating revealed that the knowledge of existence of frameworks like e-CF or ESCO by ICT professionals is rather low: 25,7% and 12,3% respectively. So there is still time to work in an integrated view of the different models before separated views of them may make more difficult the convergence.

## 2.1. The European e-Competence Framework (e-CF)

e-CF is a reference framework of competences applied within the ICT sector that can be used and understood by ICT user and supply companies, ICT practitioners, managers and human resources departments, the public sector, educational and social partners across Europe. The framework was established due to the need of supporting mutual understanding and provide transparency of language through the articulation of competences required and deployed by ICT professionals, including both practitioners and managers.

In 2005, further to the recommendations of the European e-Skills Forum, the CEN ICT Skills Workshop members agreed that national ICT framework stakeholders as well as European ICT industry representatives should consider developing a European e-Competence Framework (e-CF). Encouraged and accompanied by the European Commission, ICT framework stakeholders met with representatives from European larger companies to put this intention into practice.

The e-CF version 1.0 was published in 2008 from the outcome of two years e-Skills multi-stakeholder, ICT and human resources experts' work from multiple organization levels. The e-CF version 2.0 was published in 2010, now also with dimension 4 fully developed, and it was accompanied by an updated user guide and a newly developed methodology documentation. The e-CF framework has recently become a European standard for the ICT competences [28].

This framework considers a set of 40 different competences categorised into 5 competence areas (Plan, Build, Run, Enable and Manage). It adopts a competence based approach where the competences are characterised by a specific set of knowledges and skills, useful to achieve observable results in the context where the competences are acted. Similarly, knowledges and skills can be attributed to job profiles. 23 ICT profiles have already been described in terms of the e-CF competences and a framework to create new ones has been provided [29]. Job profiles are categorised into six main families. Proficiency levels are reference level specifications on competences, which are related to the European Qualification Framework (EQF) [30] levels 3 to 8 (although how this correspondence was created is not well explained in the documents). The structure of e-CF is summarised in Fig. 1 and in Table 1.

Competences	40
Competence Areas	5
Profiles	23
Proficiency levels	5
Knowledges	209
Skills	203
Profile families	6

Table 1 e-CF structure

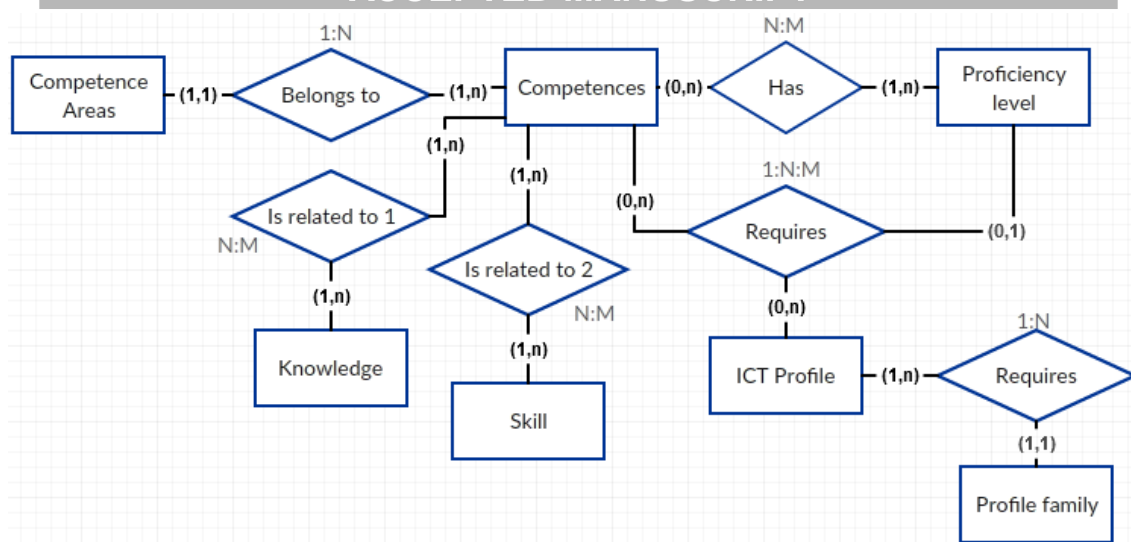


Figure 1 Entity relationship diagram of the e-CF framework

e-CF is the most popular competence framework as big effort from European Commission DG Industry supported its development and testing through a variety of projects. As a consequence of its development, different organizations developed several online tools [31-33] mainly focused on the functionality of self-assessment of ICT user competences. However, they do not provide any link to training institutions to recommend training paths for the identified gaps between the candidate's profile and the target professional profile he/she chose. The connection to competence certifications is also missed as well as the correspondence to other frameworks or references (as the ones e.g. we analyse in this work).

## 2.2 European Classification of Skills/Competences, Qualification and Occupation (ESCO)

ESCO [34] is an official labour classification promoted by European Commission to be adopted in the next future by the employment services of the European countries. The European Commission services launched the project in 2010, as part of the Europe 2020 strategy, with an open stakeholder consultation. Stakeholders are closely involved in the development and dissemination of ESCO.

Although the first version was published on 23 October 2013, ESCO is being gradually developed (addressing sets of sectors to work in occupations, skills and knowledge). It is continuously going to be updated to reflect changes on the European labour market and in education and training. The classification will be completely revised until end of 2016. ESCO v1, which is scheduled for 2017, will mark the first release after a complete revision carried out by the sectoral Reference Groups, groups of experts in each sector selected by the ESCO project secretariat after a public call for applications. It will be available free of charge to all stakeholders through the ESCO portal.

The ESCO framework has been mainly developed to help bridge the gap between the world of education and training and the labour market. Thus, it would be possible to fight the detected mismatch between unemployed workers' skills and companies' needs.

ESCO is structured on the basis of three pillars (occupations, skills/competences and qualifications) representing a searchable database in 25 languages to facilitate the dialogue between the labour market and the education/training sector. The pillars have their own hierarchical structure and are interlinked to show the relationships between them. Occupational profiles show whether skills and competences are essential or optional and what qualifications are relevant for each occupation. Alternatively, one can identify a specific skill and see which occupation or qualification this skill is relevant to. However, the allocation of skills, knowledges and competences to occupations does not allow to specify a qualification level, only the information of being essential or optional.

The ESCO framework provides a highly rich description of essential and optional knowledges / skills related to each occupation profile included. It identifies and categorizes skills, competences, qualifications and occupations in a standard way, using standard terminology in all EU languages and an open format that can be used by third parties' software. Its structure is summarised in Fig. 2 and in Table 2.

Profiles/occupations	111
Optional Skills/Knowledges	467
Essential Skills/Knowledges	631
Occupation groups	4
Occupation subgroups	15
Qualifications	TBD

Table 2 ESCO structure

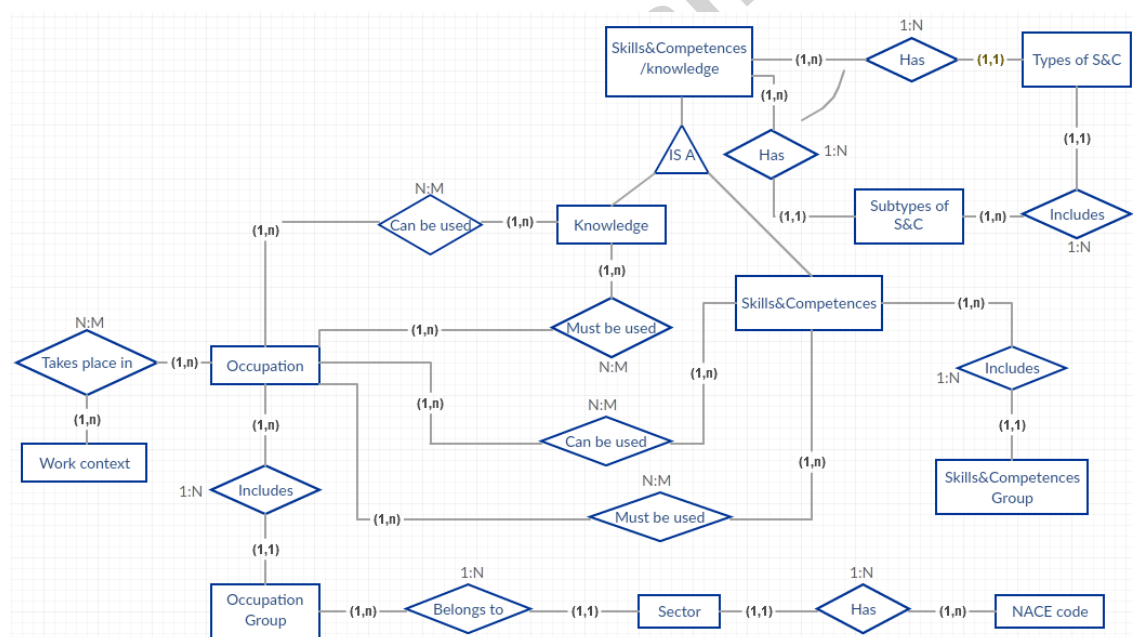


Figure 2 Entity relationship diagram of the ESCO framework

ESCO is linked to relevant international classifications and frameworks, such as NACE [35], ISCO [10] and EQF [30] as some primary inspirational sources or references. However, specificity of some sectors like the one of ICT Services has led to decisions which have adjusted the initial common structure and procedures of creation. As an example, NACE



classification of economic activity was suggested as guideline for the sectoral breakdown of occupations in all sectors but in the one of ICT Services was not considered as a good inspiration as ICT occupations are transversal by nature and this classification would be not meaningful. The final adopted scheme was the sectoral breakdown that is shown in Fig. 3. The first level is structured into four categories: governance, management, development and operations. A second level is established under each category except for ICT Governance because it involves a reduced number of occupations (Chief Information Officer, Chief Technology Officer, ICT Market Strategist, etc.)

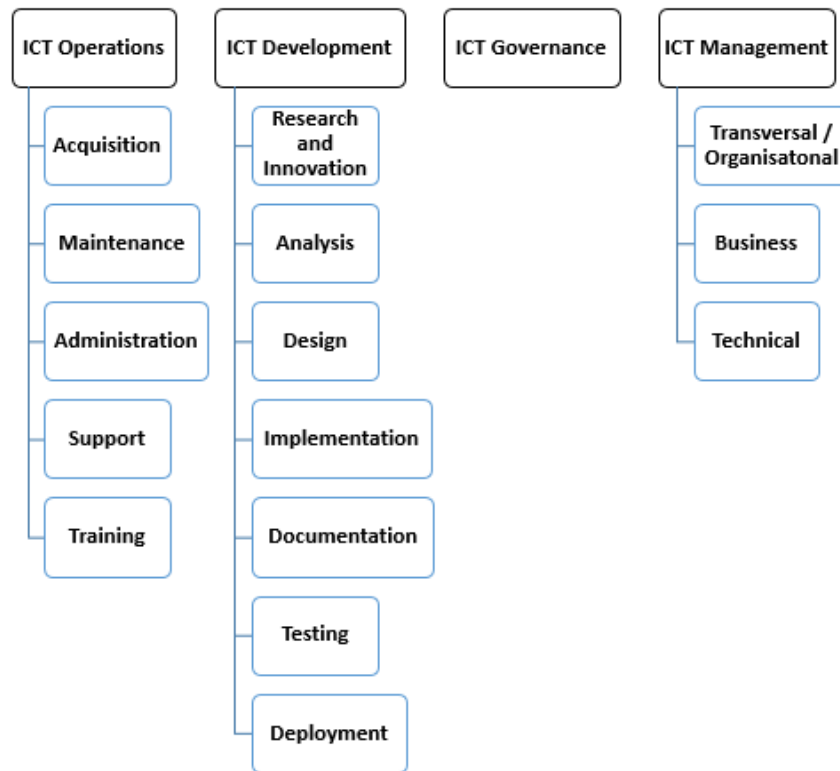


Figure 3 Sectoral breakdown of ICT services

Another characteristic of the work in the ICT Services sector of ESCO was that the qualification pillar has not been developed in the first stages due to the difficulties of dealing with the huge number of existing certifications in this field.

### 2.3 Body of Knowledge (BOK)

The Body of Knowledge (known as BOK) is the complete set of concepts, terms and activities that compose a professional domain, known by the relevant learned society or professional association [36]. The BOK often forms the basis for curricula for most professional programs, setting the essential competencies to get accredited before applying these principles in practice.

There are a vast number of Bodies of Knowledge in each area of professional specialization and the ICT field is not an exception. However, despite its high acceptance, there is currently no global or European Body of Knowledge that is all encompassing and which addresses all the ICT knowledge areas required by the industry. This situation is due to, in some cases, several countries have a national ICT BOK adapted to their national context. Besides it is possible to

find different BOK on ICT field as outcome from different research projects, as happens with SWEBOK created by the IEEE Computer Society [37] and related to the software engineering discipline [38]; with another shape, also the Computing Curricula, created by the ACM IEEE-CS joint committee is a well-known proposal of a set a curricular guidelines on computer sciences [39].

These Bodies of Knowledge usually either structure the content adopting an industry point of view with the future employability of students in mind or take a purely educational point of view. The European Foundational ICT Body of Knowledge [40] claims to be the base level knowledge required to enter the ICT profession and acts as the first point of reference for anyone interested in working in ICT. This BOK has been selected as a reference to be followed as a framework of reference in the proposed e-Skills Match framework (eSKM). It is linked to e-CF, since it was created after e-CF was well structured in version 3.0 [28].

The structure of the Foundational ICT Body of Knowledge could be described as an 'inverted T-model'. In this structure the horizontal axis shows the knowledge areas of the ICT domain, while the vertical axis corresponds to specific knowledge and skills to specialise in one domain. Its structure is summarised in Fig. 4 and in Table 3.

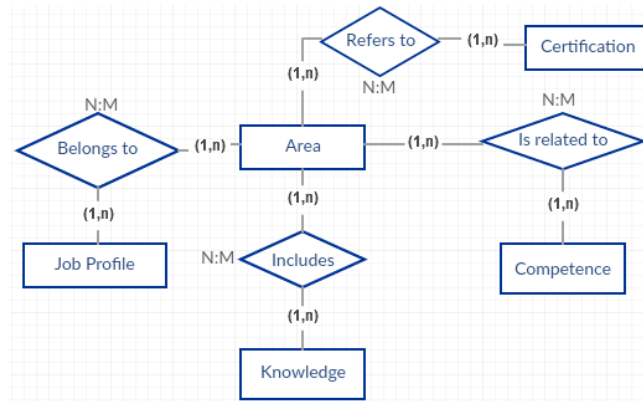


Figure 4 Entity relationship diagram of the BOK framework

Job Profiles	28
Knowledge	91
Areas	12
Competences	33

Table 3 BOK structure

As can be observed, the ICT BOK considers 12 areas and each area includes a:

- List of items required as foundational knowledge necessary under this Knowledge Area
- List of references to the e-Competence Framework
- List of possible job profiles that require having an understanding of the Knowledge Area
- List of examples of specific Bodies of Knowledge, certification and training possibilities

## 2.4 AXELOS framework

Axelos is a joint venture company, created in 2013 by the Cabinet Office on behalf of United Kingdom Government and Capita plc, to manage, develop and grow the Global Best Practice portfolio. This portfolio includes well known certifications such as ITIL, PRINCE2 and others. ITIL (Information Technology Infrastructure Library) was produced in UK by the CCTA (Central Computer and Telecommunications Agency) in the late '80s and is a trusted and well-established framework based on best practices which represents the collective experience of experts at global level [41]. Its main strength is that provides guidance to service providers on the provision of quality IT services. This characteristic makes of it a reference used by hundreds of organizations around the world. However, ITIL has not been designed as to be followed, but it is a guidance to create value for the service provider and its customers [42]. Within the ITIL there are two main areas of IT service management: service support and service delivery [43] although the guidance provided is currently focused on covering the entire service lifecycle. Some contributions claim that these practices lead to benefits and a strong positive influence on the business [44]. Regarding the project management methodology PRINCE2 (Projects In Controlled Environments, version 2), it encompasses quality management, control and organization of a project with consistency and review to align with project objectives. PRINCE2 is based on seven principles, seven themes and seven processes [45].

Axelos created the AXELOS Skills Framework [46] working with the sources like e-CF version 3.0, ICB3 from the Institute of Project Management Association (IPMA), Syllabus documents for PPM (specifically building on the themes and principles), ITIL syllabus documents and manuals and RESILIA manuals. Each skill represents a unique dimension of work, such as risk management or leadership, and provides recognizable descriptions of the main behaviors that an individual demonstrates when operating effectively. Each skill is defined at up to five different levels which represent the full range of responsibility/autonomy, very similar to e-CF levels [47]:

1. Intern/Entry: Works primarily under supervision with responsibility for carrying out routine work.
2. Practitioner: Works independently, primarily in non-complex situations, and may take some responsibility for the evaluation and improvement of work activities.
3. Professional/Manager: Works independently where there is unpredictable change; may manage others and be responsible for reviewing and developing performance of themselves and others.
4. Lead Professional/Senior Manager: Manages complex technical or professional activities or projects, taking responsibility for decision-making in complex and unpredictable work; takes responsibility for managing professional development of individuals and groups.
5. Executive: Manages and transforms work contexts that are complex, unpredictable and require new strategic approaches; takes responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams. Recognised as an expert by other professionals.

Axelos considers 50 job profiles or occupations, 2 occupation groups, 9 occupation subgroups and 5 qualifications in the IT service management area.

It is important to point out that certifications like ITIL are not competence frameworks. In the case of ITIL it is just a model which defines the best practices for IT management. Moreover, the structure is not equivalent to the rest of the frameworks. It is only a proposal

for a certification in a very specific area in the universe of occupations in ICT. Certifications are always relevant as sources of information for competences frameworks but they are usually very specific and restricted to the documentation of syllabus and evaluation methods. Moreover, as can be seen in a non exhaustive non formal catalogue of ICT certifications [48], there are 2313 different IT certifications from 161 vendors/entities. This represents a huge number where there is a broad range of rigor and quality of design and justification from the worst to the best level something already identified in [4].

### 3. A FRAMEWORK FOR MATCHING THE EXISTING ONES

As commented above, the existence of different standards and frameworks for mapping the concepts of occupations, skills..., represents a challenge for providing consistent foundation for an appropriate connection among recruiters, candidates and other stakeholders such as training and education institutions and certification bodies. Our proposal for a matching framework aims at describing the digital competences for ICT professional, considering the already existing frameworks. We have chosen to use the term framework in order to be conceptually consistent to the definition of the term provided in [1]: an instrument for the development and classification of skills , competences and knowledges.

In the end, the goal is integrating ICT profiles, competences, skills-knowledges and qualifications, keeping both an interlink with the different already existing systems and the capability to acknowledge and integrate emerging areas in ICT based and hybrid areas where the evolution of technology and labour market is incredibly fast. The model will be flexible enough include all such contributions as well as evolution along time while making explicit the cross references or mappings to all the existing standards and models. Therefore, the matching framework includes the possibility that new competences can be detected onwards and the related content shall find place in it.

Figure 5 shows a diagram that summarizes the matching process:

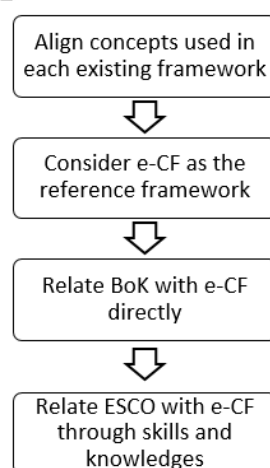


Figure 5 Steps of the matching process

Figure 6 shows the entity relationship diagram of the proposed eSKM model.

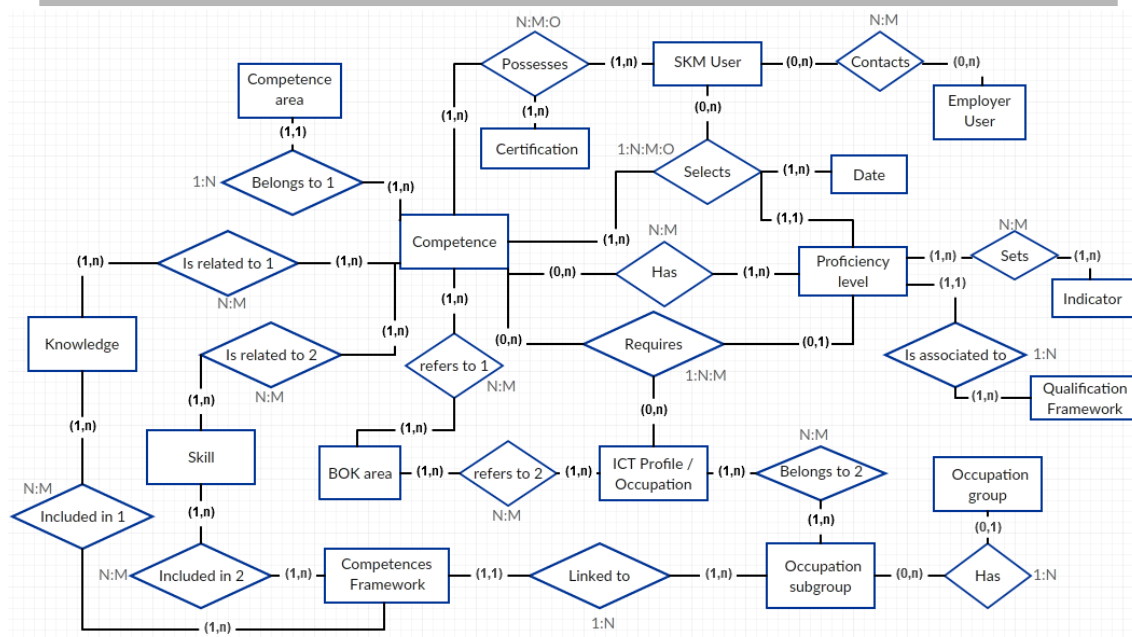


Figure 6 Entity relationship diagram of the matching model

Before explaining the matching process, it is important to remark that a previous study to link/align the different concepts that are used in each framework was necessary (for example, an ESCO occupation and an e-CF profile refer to similar concepts). Table 4 shows the correspondence of terms among the different standards and frameworks according to the recommendation of the European Parliament and of the Council of 23 April 2008.

Concept	ESCO	e-CF	Axelos	BOK	Comments
Occupation	Grouping of jobs involving similar tasks and which require a similar skills set.	A job profile provides a comprehensive description written and formal of a job	Defines the roles, responsibilities, skills and knowledge required by a particular person. One job description can include multiple roles.	Same as e-CF	They refer to similar concepts
Competence	Proven ability to use knowledge, skills and personal, social and/or methodological abilities, in work or study situations and in professional and personal	Demonstrated ability to apply knowledge, skills and attitudes for achieving observable results.	Is a collection of knowledge, personal attributes, skills and relevant experience needed to be successful in a certain function	Same as e-CF	They refer to similar concepts

	development.				
Skill	Ability to apply knowledge and use know-how to complete tasks and solve problems	It is related to competences through some examples.	Represents a unique dimension of work, and provides recognizable descriptions of the main behaviors that an individual demonstrates when operating effectively.		They refer to similar concepts. BOK does not consider this concept
Qualification	Formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards		(ITIL Service Transition) An activity that ensures that the IT infrastructure is appropriate and correctly configured to support an application or IT service.		e-CF and BOK do not consider this concept. ESCO and Axelos refer to similar concept
Knowledge	Outcome of the assimilation of information through learning	It is related to competences through some examples.	Knowledge requires an understanding of relationships, knowing how to apply project management in practical situations as well as interpreting methods	High-level areas of knowledge that represent the base level starting ICT professionals should understand. Each knowledge area includes a list of items required as foundational knowledge necessary under that knowledge area.	They refer to similar concepts.

Area	Occupation Group	Occupation families			ESCO and e-CF refer to similar concepts. Axelos and BOK do not consider this concept.
Proficiency level		Reference level specifications on competences		Responsibility autonomy levels	Axelos and e-CF refer to similar concepts. ESCO and BOK do not consider this concept.

Table 4 Terms comparison

Regarding the existing frameworks considered in the matching framework, the e-CF 3.0 represents the underpinning structure as it is also the one published as a standard. Therefore, e-CF will be the one taken as the reference for matching to the others (ESCO, Axelos and BOK) to perform the matching between the different frameworks. The reference [47] will be the one for collecting all the information about a profile in e-CF, where is detailed the information about 23 different example profiles. Once collected all the information about a profile according to e-CF specifications, the next step is to perform the matching with the other frameworks as ESCO, Axelos and BOK. The matching is made considering the e-CF competences as the main reference, then proceeding with an incremental approach.

### 3.1. Matching criteria

Firstly, the work has focused on a deep analysis of the above mentioned existing frameworks in order to highlight the strengths and the weaknesses as well as the overlapping areas where mutual links are possible.

The comparison of the information provided by the ESCO and the ICT profiles allows to highlight and merge the content concerning knowledge and skills by following a series of steps:

- detecting the essential and optional skills and knowledge within the referred ESCO profile
- mapping the applicable set of knowledge and skills from ESCO to those e-CF competences where they fit in terms of semantic representation
- analysing the direct correspondence between the applicable set of knowledge and skills from ESCO to the skills and knowledges included in the description of the corresponding e-CF competence
- referring the knowledge and skills to the most appropriate proficiency levels.

The correspondence has been done between respectively knowledge and skills, ensuring that they are homogeneous elements. In other words, the knowledges in e-CF will only be matched to ESCO knowledges, and the e-CF skills to ESCO skills.

Duplicated e-CF skills/knowledges were detected before doing the mapping. Therefore, a filtering process was conducted to remove the duplicated items, as shown in Table 5. This previous result that has been necessary before applying the matching process to ensure consistency and avoid confusion.

Item 1	Item 2
New emerging technologies	New emerging technologies (e.g., distributed systems, virtualisation models, datasets, mobile systems)
Organisation processes and structures	Organisation processes including, decision making, budgets and management structure
Manage and guarantee high levels of cohesion and quality	Manage and guarantee high levels of cohesion and quality in complex software developments

Table 5 Example of duplicated e-CF skills/knowledges

As mentioned above, the matching mainly follows an incremental approach: where the matching highlights two items (knowledge or skills) with similar meanings then an additional analysis determines if they have to be merged; otherwise, the ESCO items are mapped into the e-CF competence structure by following some criteria of significance. At first, the matching between ESCO skills and knowledge and e-CF competences are carried out looking for matching keywords in the definition of the e-CF competences from the CWA's document of 23 ICT Professional profiles [47], the knowledges and skills examples (Dimension 4) from [28] and the description of the ESCO skills and knowledges.

Enabling an easy correspondence between e-CF and ESCO elements requires the identification of a list of keywords of ESCO elements (knowledge and skills). For example, the ESCO skill "define technical requirements" is initially considered as related to the e-CF competence "A.5. Architecture design" because the keyword "requirements" appears in the definition of the e-CF competence. The first draft proposal created by this matching based on keywords needs then to be evaluated and validated by content experts who can confirm or not the real link between the two elements.

The keywords searching process has been automatised so that indicating any word, the system automatically provides the number of coincidences with each e-CF and ESCO item. The searching process has been implemented looking for: (1) the number of coincidences between a certain keyword and the e-CF skills/knowledges, and (2) the number of coincidences between a certain keyword and the ESCO skills/knowledges. In the first case, the analyzed items are the names of the e-CF competences and the names of the e-CF skills/knowledges. In the second case, the analyzed items are the names and the descriptions of the skills/knowledges.

In case of profiles not included in the e-CF documentation [47], the framework referenced will be ESCO and it will be necessary to find the correspondence of those profiles with similar competencies of e-CF. Analyzing the correspondence is easier if the keywords of ESCO knowledges and skills are used to find possible correspondences to elements in e-CF documentation.



It is possible that some ESCO skills/knowledge do not match with an e-CF competence. If this does happen then a new competence category "miscellaneous" has to be used.

In summary, the critical points of the matching algorithm are the following ones:

1. The difficulty of determining levels for competences when the occupations have not equivalent in the already described 23 e-CF profiles: there is not supporting procedure except the analysis by experts analyzing descriptions and other information.
2. In general, only allocating levels is done with competences and we are not trying to do the same for skills and knowledges in an individual pattern. Then the adopted general rule: when the level of a competence has been determined, it applies to all the lower level of skills and knowledges (unless any special analysis by experts is required, eg. when the competence could be linked to several proficiency levels, etc.).
3. Each e-CF competence will be documented through the merge of skills and knowledges coming from e-CF and ESCO (avoiding duplicates, i.e. the same S/K in both models will appear only once).
4. As the general rule is to avoid changing the description in terms of competences of an existing already described e-CF profile in [47], there is a problem with S/K which do not match the corresponding competences of the profile. There are two cases here:
  - a. If a S/K does not match any e-CF competence, it will be allocated to a general miscellaneous competence.
  - b. If a S/K match an e-CF competence which it is not in the description of the e-CF profile, what to do?. The option adopted in the eSKM has been including that e-CF competence in an "extended description" of the e-CF profile. This particular case will be explained in detail in the validation section.

Figures 7 and 8 represent the whole mapping process in the case that the analysed job profile is considered in both frameworks, and in the case that it is considered only in the ESCO framework, respectively.

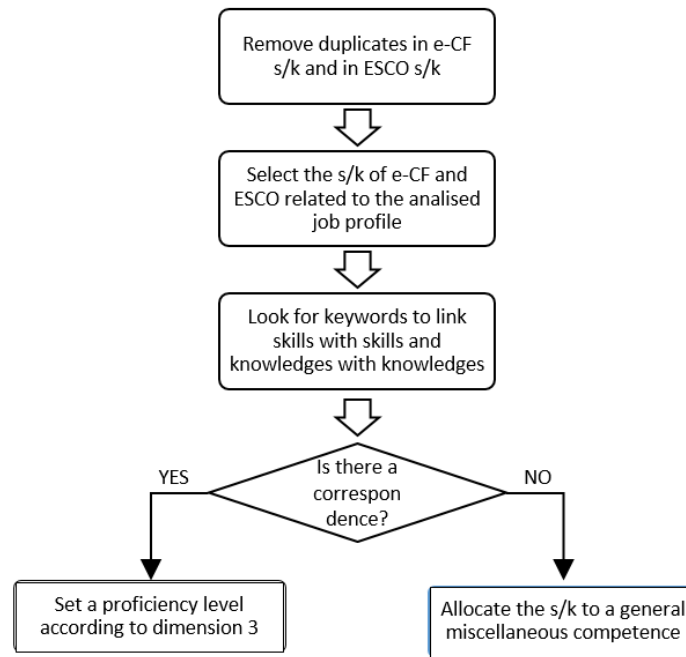


Figure 7 Diagram of the mapping process when the profile is included in ESCO and in e-CF.

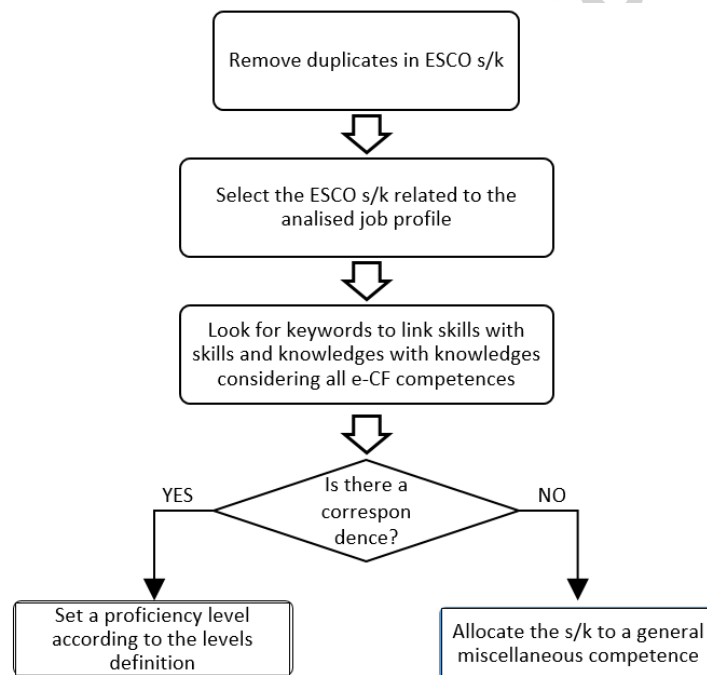


Figure 8 Diagram of the mapping process when the profile is included only in ESCO.

Regarding BOK, the correspondence between e-CF and BOK is done according to the competences. To perform this matching the BOK's area of knowledge that fits better to e-CF competence description must be found, and to do so it is necessary to find the keywords of the e-CF competence. It is important to highlight that an e-CF competence could be matched with one or more BOK knowledge areas. The BOK literature already provides a matrix that links the e-CF 3.0 competences with the Knowledge Areas as well as a table that shows the correspondence between the European ICT Professional Profiles and the European Foundational ICT Body of Knowledge Area. The reason is clear as BOK was created when the

version 3.0 of e-CF was already published as CWA document of the CEN Workshop on ICT Skills [28].

#### 4. VALIDATION

The eSKM framework resulted from our research during the eSKM project [49], aimed at providing integrated services for self-assessment of e-Skills and digital competences and further training recommended to reach the target profile as well as market certifications offered by the developed e-Skills platform. The goal of this section is to validate the developed framework to ensure that the resulting scheme of competences, skills and knowledges is consistent to the existing reference frameworks.

The matching procedure has been validated by a group of experts from the project with additional participation of external consultants and everything has been done by consensus among the partners. The consortium is composed of more than 20 experts and researchers from 4 different countries in 5 organizations:

- Stockholm University, from Sweden.
- Fondazione Politecnico di Milano, from Italy.
- ADFOR S.p.A., from Italy.
- Government to You, from Greece.
- University of Alcalá, from Spain.

The final framework has been properly validated through different rounds of review by project's experts and the authors have also participated in the peer review of every document involved in the project. In fact, the project progress has been continuously reviewed by additional experts from several professional fields such as engineers, consultants, higher education teachers, researchers, developers, etc.

Apart from this validation, real cases were considered. Matching ESCO and e-CF ICT profile opens to different situations when analyzing existing job profiles for testing real examples:

- The analysed profile is already present in both frameworks
- The analysed profile is included only in one of the considered frameworks

The eSKM framework has been tested according these representative situations which can exemplify how the framework can be deployed. As shown in Table 6, the members of the project chose four main profiles: System Analyst, Chief Information Officer and Service Manager, which are profiles included in both frameworks; and Data Scientist, that is only present in ESCO.

These different situations have allowed to experiment the merging process among the information provided by both frameworks and to find out general rules and procedures that can be reproduced as well as critical points and the limitations.

Profile	e-CF	ESCO	BOK	Axelos
System Analyst	System Analyst	System Analyst	System Analyst	-
CIO	Chief Information	Chief Information	Chief Information	IT Manager

	Officer	Officer	Officer	
Service Manager	Service Manager	ICT Operations manager	Service Manager	Service Manager
Data Scientist	-	Data Scientist	-	-

Table 6 ICT Profiles that have been analysed

A clear example of matching between ESCO elements (knowledges and skills) and competences from e-CF is one related to the ESCO knowledge “software architecture models”. It is related to the e-CF competence “A.5. Architecture design” because the keyword “architecture” appears in the definition of the e-CF competence and in its own name as is shown in table 7.

e-CF Competence	e-CF Competence Description	ESCO knowledge
A.5. Architecture Design	Specifies, refines, updates and makes available a formal approach to implement solutions, necessary to develop and operate the IS architecture. Identifies change requirements and the components involved: hardware, software, applications, processes, information and technology platform. Takes into account interoperability, scalability, usability and security. Maintains alignment between business evolution and technology developments.	Software architecture models

Table 7 Matching between an ESCO knowledge and an e-CF competence using keywords

In addition, as can be seen in table 8, the e-CF competence “A.5. Architecture design” includes four examples of knowledges and four examples of skills that also include the keyword “architecture”:

Examples of Knowledges	Examples of Skills
K1: Architecture frameworks, methodologies and systems design tools	S1: Provide expertise to help solve complex technical problems and ensure best architecture solutions are implemented
K2: Systems architecture requirements: performance, maintainability	S2: Use knowledge in various technology areas to build and deliver the enterprise architecture
K3: Costs, benefits and risks of a system architecture	S3: Understand the business objectives / drivers that impact the architecture component (data, application, security, development, etc.)
K4: The company’s enterprise architecture and internal standards	S4: Assist in communication of the enterprise architecture and standards, principles and objectives to the application teams
K5: New emerging technologies (e.g., distributed systems, virtualisation models, datasets, mobile systems)	S5: Develop design patterns and models to assist system analysts in designing consistent applications

Table 8 Examples of Knowledges and Skills of the e-CF competence “A.5 Architecture Design”

As mentioned before, the first outcome by keywords needs to be refined by some semantic criteria that could be provided by the content experts themselves. In fact, this may help in ensuring precision and consistency of the final outcome.

Table 9 shows a summary of the four studied profiles. The competences, skills and knowledges that have been linked among the different frameworks are summarised in each column. For example, in the case of System Analyst, 10 ESCO skills and 5 ESCO knowledges have been linked to the A.5 e-CF competence. Moreover, from the BOK mapping available in [40], is easy to get the BOK area that is related to each e-CF competence independently of the job profile. It is important to highlight that the BOK mapping only links an e-CF competence with one or more BOK areas, but this does not mean that achieving the e-CF competence implies achieving all the foundational knowledges of every BOK area related to that competence, basically because BOK areas are very large. For example, the A.5 e-CF competence (Architecture design) is related to two BOK areas: 'Architecture' and to 'Human-Computer Interaction'. However, as shown in Table 10, the relation with the first one is much stronger than the relation with the second one.

Regarding Axelos, it does not provide a comprehensive classification of job profiles. It mainly covers the IT service management and the project management areas. Therefore, there are not any Axelos skill linked to the System Analyst.

Profile	e-CF competences	ESCO skills / knowledges	BOK Areas	Axelos skills
System Analyst	A.5	10 skills 5 knowledges	2	-
	E.5	1 skill 8 knowledges	1	-
	B.1	11 skills 4 knowledges	6	-
CIO	A.1	5 skills 0 knowledges	3	7 skills
	A.3	3 skills 0 knowledges	2	
	E.2	7 skills 4 knowledges	2	
	E.4	1 skill 0 knowledges	0	
	E.9	6 skills 8 knowledges	1	
Service Manager	A.2	3 skills 1 knowledge	2	4 skills
	C.3	1 skill 0 knowledges	2	
	C.4	3 skills 1 knowledge	3	
	D.8	1 skill 0 knowledges	1	
	D.9	3 skills 0 knowledges	0	
Data	A.5	1 skill	2	-

Scientist		0 knowledges		
	A.6	1 skill 0 knowledges	4	-
	B.1	2 skills 2 knowledges	6	-
	B.5	2 skills 1 knowledge	0	-
	C.1	skills knowledges	2	-
	D.2	3 skills 1 knowledge	2	-
	D.10	12 skills 6 knowledges	1	-

Table 9 Summary of the matching process for the four selected profiles

Figure 9 shows a sample of the detailed information that has been summarized in Table 9. It includes a section of the matching between the ESCO skills/knowledges and the e-CF competence D.10 Information and knowledge management for the case of the Data Scientist. Note that the matching is done in terms of knowledges (highlighted in yellow color) and skills (highlighted in blue color). Note that some items (statistics, information extraction, etc.) have not any correspondence in the other framework. However, they are related to the competence itself.

PROFILE	ECF			
Profile	ECF COMPETENCES	ECF Competence Description	ECF - KSC PT	ESCO - KSC PT
Data Scientist	D.10. Information and knowledge management	Identifies and manages structured and unstructured information and considers information distribution policies. Creates information structure to enable exploitation and optimisation of information. Understands appropriate tools to be deployed to create, extract, maintain, renew and propagate business knowledge in order to capitalise from the information asset.	K1 methods to analyse information and business processes	business intelligence
			K2 ICT devices and tools applicable for the storage and retrieval of data	data mining
			K3 challenges related to the size of data sets (e.g. big data)	information categorisation
			K4 challenges related to unstructured data (e.g. data analytics)	unstructured data
				statistics
				information extraction
			S1 gather internal and external knowledge and information needs	
			S2 formalise customer requirements	
			S3 translate /reflect business behaviour into structured information	interpret current data
			S4 make information available	
			S5 ensure that IPR and privacy issues are respected	
			S6 capture, storage, analyse, data sets, that are complex and large, not structured and in different formats	normalise data
			S7 apply data mining methods	perform data mining
				execute analytical mathematical calculations
				handle data samples
				establish data processes
				collect ICT data

Figure 9 Detail of the matching between e-CF and ESCO

BOK area	Foundational knowledge required
Architecture	<ul style="list-style-type: none"> <li>• Computer systems architecture</li> <li>• Business architecture</li> </ul>

	<ul style="list-style-type: none"> <li>• Data architecture</li> <li>• Applications architecture</li> <li>• Technical architecture</li> <li>• Enterprise architecture</li> </ul>
Human-Computer Interaction	<ul style="list-style-type: none"> <li>• Models and theories of human-computer interaction (HCI)</li> <li>• Interaction design basics</li> <li>• HCI in the software process</li> <li>• Modelling rich interaction</li> <li>• Groupware, ubiquitous computing and augmented realities</li> <li>• Hypertext, multimedia, and the world wide web</li> </ul>

Table 10 Description of the BOK areas related to the A.5 e-CF competence.

A more detailed summary of the System Analyst is shown in Table 11, where the correspondence between e-CF and ESCO is done in terms of skills and knowledges. It contains the result of applying the merging procedure that link knowledges and skills from ESCO with e-CF competences taking into account its dimension 4.

e-CF competence	e-CF skill / knowledge	ESCO skill / knowledge	Proficiency level
A.5	K1	Software architecture models	3
	K2	ICT infrastructure	3
	S1	Solve ICT system problems	3
	S3	Interact with users to gather requirements	3
	S4	Analyse the context of an organisation	3
E.5	K2	Computer programming	3
	S3	Manage system testing	3
B.1	S2	Analyse business processes	3, 4
	S6	Service-oriented modelling	3, 4

Table 11 Detailed summary of the System Analyst profile

When trying to link the ESCO skills and knowledges to the e-CF competences, some exceptions can occur:

- ESCO skills and knowledges can be logically referred to one of the existing 40 e-CF competences, but the competence is not included in the ICT CWA Profile examined.
- ESCO skills and knowledges cannot be logically referred to any of the existing 40 e-CF competences.

In the former case, the eSKM framework propose to include the identified competence in the ICT profile. An external validation by experts has been required in order to assure this proposal. Table 11 shows such competences in brackets. In the latter case, the elements are inserted in an additional category named “Miscellaneous”. It identifies potential new competences, not already included in the e-CF framework.

Once the ESCO element is attributed to the related e-CF competence, the following step requires to identify the appropriate proficiency level. In case the matching concerns an ICT profile already exists in the e-CF set, then the profile itself provides for the information as it already specifies the e-CF level for the analysed profile. However, eSKM considers as a general rule that the skills and knowledge contained in the lower proficiency levels are also contained in the higher ones, unless any special analysis specifies differently. That is, there is a minimum set of knowledge and skills that reasonably regard any proficiency level for a determined competence. The higher the proficiency becomes, the higher is the chance to outline additional knowledge and skills referring to further abilities for acting the competence with more strategic, systemic and managerial proposals.

A general view of the mapping at a competence level can be observed in Table 12 for the analysed job profiles. Symbols 'X' represent e-CF competences that are included in each profile definition according to [47]. Symbols '(X)' represent e-CF competences that are not included in the profile definition, but are related to the ESCO skills and knowledges associated to that profile.

e-CF COMPETENCE	SYSTEM ANALYST	DATA SCIENTIST	CIO	SERVICE MANAGER
A.1			X	
A.2	(X)		X	(X)
A.3			X	(X)
A.5	X	X	(X)	
A.6		X		
B.1	X	X	(X)	(X)
B.5		X		
C.1		X		
C.3				X
C.4			(X)	X
D.2		X		
D.8				X
D.9	(X)		(X)	X
D.10	(X)	X		
E.2	(X)		X	(X)
E.4			X	
E.5	X	X	(X)	(X)
E.9	(X)		X	(X)

Table 12 e-CF competences analysed for the four ICT job profiles considered

#### 4.1. DISCUSSION



The adaptation of the framework will be achieved by updating the model once the information provided by e-CF, ESCO and BoK is updated. e-CF as a standard will be subjected to a regular process of reviews and updates during the next years as it happens with similar standards. It is quite probable that new profiles based on e-CF (beyond the 23 profiles described in the document CWA 16458) could be added in the future. EC has committed to regularly maintain and update ESCO during next years. Once the updates are published, our mechanism for matching will be again performed to update e-Skills Match.

The first outcome of this work shows that merging of both frameworks is possible, even if some critical points require additional assistance. In particular, some of them occur when the ICT profile is not already included in the set indicated by the CWA 16458 [47] so different decisions have to be made with the help of further validation by external experts as well as public consultations. Moreover, some critical points arise when there is not a univocal or clear correspondence between the ESCO items and the e-CF ones. For example, it can happen that a knowledge or skill from ESCO can't be easily matched with anyone of the e-CF competences or it can match one of these, but the matched e-competence is not indicated within the CWA ICT Professional Profile.

The critical points that have been identified are the following ones:

- The initial set of validated profiles for the eSKM framework includes 10 ICT profiles. Although this may seem a limitation (as e.g. e-CF includes 23 profiles and ESCO describes 111), it is relevant to note that the eSKM framework does work with the different possible types of cases of matching.
- ESCO has not been published yet. Although its publication is scheduled for 2017, real information has been taken into account to develop the e-Skills framework since one of the authors, Dr. Fernández Sanz, was one of the experts that were involved in the development of ESCO and the ESCO Secretariat conceded a permission for working with such information (although a non-disclosure agreement is still applicable) keeping the global set of information still undisclosed until official publication. This is another reason why the initial set of profiles was limited.
- Another limitation could be the understanding or the practical use of the framework by the users. There are several self assessment tools based on the e-CF framework already available [31-33]. However, none of them provides comprehensive information about profiles, competences and qualifications, because those tools are just focused on e-CF official definitions. The novelty of the eSKM framework is that every competence framework has been analysed before implementing the final developed framework. The authors' concern is that users may not fully understand the matching between the different frameworks. For that reason, a pilot plan is scheduled to be deployed in order to test the framework using a sample of potential users.

The eSKM framework is aimed at serving as basis for a personal recommender system (following initial experiences, e.g. [50]). The system recommends learning resources to improve personal competence development plans after a self assessment. Like [51] and [52], the system supports users in deciding what learning activities are of value to achieve a needed competence or to reach the required profile for a target occupation.

As mentioned in Section 2, the framework is complete because we were able to set the links to the most important frameworks in Europe. The integration is also shown by the fact that the main elements of all the reference frameworks are reflected in our proposal. It also allows to detect and relate the new competences and skills arising as part of the new emerging professions and jobs in the labour market as well. Despite its limitations, experts think that there will not be any problem to launch the pilot platform. Based on the Italian experience, where new job profiles have been defined in local setting by using these models, we suggest that the framework is flexible enough and can be easily adapted.

The cost-benefit analysis of applying the proposed solution suggests that eSKM allows a fast response to all the stakeholders who need to address the activities related to the use of the reference frameworks. These activities may involve the (self-) assessment of competence profile and the comparison to qualification profiles of identified occupations, the design of qualification profiles, the training and career development recommendation to meet a qualification profile of a target occupation, the testing procedures of competences, etc. As reference model like e-CF is fast gaining relevance in the training and certification market while ESCO will be compulsory in the public employment services as well as in many activities related to employment, labour statistics, training for job seekers, etc., the work done for eSKM and the future supporting system has required a big effort by experts specifically trained for managing the frameworks and their elements as well as the development of supporting tools and procedures. Any stakeholder wanting to be aligned to e-CF and ESCO will be benefited of having the matching done, something which could not be afforded by almost none of them. Moreover, eSKM will be easy updated once the developed matching procedures have been implemented and tuned. The adaptation will be achieved by updating the model once the information provided by e-CF, ESCO and BoK is updated. e-CF as a standard will be subjected to a regular process of reviews and updates during the next years as it happens with similar standards. It is quite probable that new profiles based on e-CF (beyond the 23 profiles described in the document CWA 16458) could be added in the future. The European Commission has committed to regularly maintain and update ESCO during next years. Once the updates are published, our mechanism for matching will be again performed to update eSKM with relatively small effort unless a dramatic foundational change is decided in any of the reference frameworks.

## 5. CONCLUSIONS

This paper has provided a consistent framework, the eSKM framework, which integrates the existing ICT related reference schemes and standards: namely ESCO, e-CF and BOK. This matching framework has been developed as part of the eSKM project funded by European Commission. The final framework has highlighted the linkable parts of the existing frameworks while generating a method to create an evident and operative interaction among competences, job profiles, skills and knowledges.

A first set of 10 ICT job profiles was analysed as contextual application in order to test the matching method and a set of four (System Analyst, Data Scientist, CIO, and Service Manager) has been presented in this article. The application to a few job profiles has highlighted some critical parts. On one hand, we found some issues in the merging procedures that link

knowledge and skills from ESCO to e-CF competences and its dimension 4 of levels of proficiency. In these cases, the framework has required a validation from experts and a wider consultation in order to be shared and approved. On the other hand, the testing work should be enlarged and the framework applied to more ICT profiles besides the initial 10 considered in this work.

The eSKM framework has some limitations which can be solved in further investigation but as a conceptual mechanism the matching framework is opened to next updating of data and profiles. Future development will also allow to add in the model the new competences and skills potentially coming out of the description of new emerging professions and occupations as they are included in new versions of the source models or as a maintenance effort of the model. In fact, authors have already developed prototype tools to help in working with the high numbers of elements from the three frameworks (ESCO, e-CF and BOK) providing analysis methods to detect duplicates, inconsistencies and similarities.

Future work will refine details of the eSKM framework while working in the implementation of a support system for candidates and employers where they can find self assessment functions for job candidates and matching procedures between candidate profile and job openings descriptions, recommender modules to guide professionals' training to target occupations and the possibility of knowledge validation tests and methods. This last part will benefit from a previous experience in online tests based on e-CF [53] and the standard ISO/IEC 17024: 2012 [54]. In fact, one of the goals of the eSKM project is the development of such a system and its implementation with a relevant sample of real cases.

## 6. ACKNOWLEDGMENT

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#### HIGHLIGHTS

- The proposed framework provides a useful system for job candidates and employers.
- It integrates the ICT related reference schemes and standards: ESCO, e-CF and BOK.
- It includes ICT profiles, competences, skill, knowledges and qualifications.

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