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A framework to measure competences for digital transformation in the public sector: evidence from a pilot survey in Italy

MASTER'S THESIS IN
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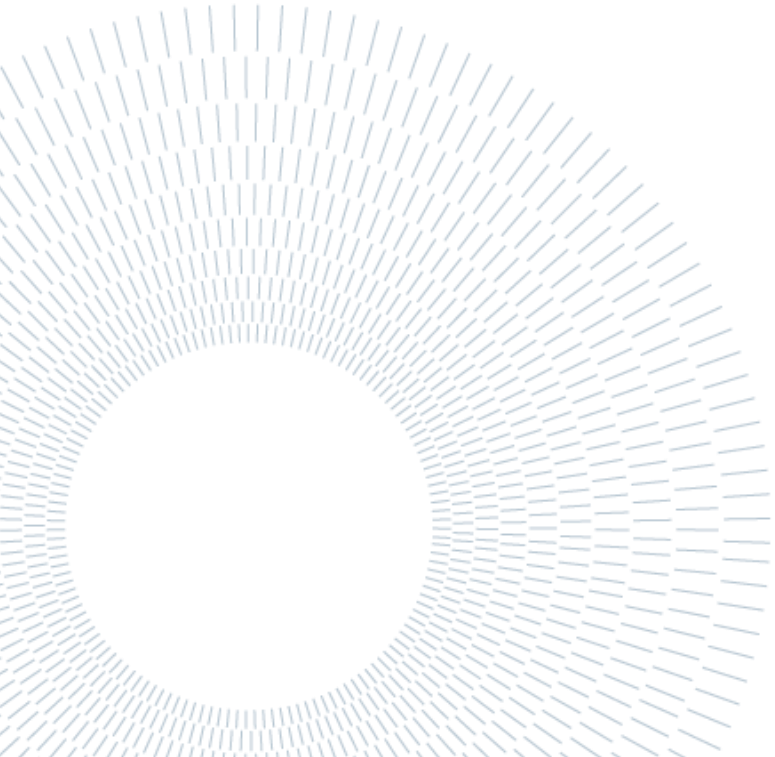


Abstract

Digital transformation is not a novelty anymore, but many of its impacts have not been assessed yet, particularly in regard to Public Administration (PA). Several elements hinder the digitalization of the public sector, and one of the preeminent is the shortage of digital competences among public employees.

A literature review on this topic highlights two main setbacks: firstly, the frameworks that define the digital competences of PA employees are fragmented and incomplete; secondly, few attempts to measure such competences have been made.

The purpose of my thesis is twofold: to build a framework that contains all the relevant digital competences that a civil servant should possess, and to refine and analyze a survey questionnaire to measure those competences – with the support of the Digital Agenda Observatory of Politecnico di Milano. To create the model, I qualitatively analyzed the models already present in the literature, with the aim of understanding how to integrate and extend them. To study the questionnaire, I carried out a quantitative analysis, mainly through factor analysis.

The results of my thesis have both academic and practical relevance. I developed a thorough model that contains all the relevant competences that a civil servant should possess, which I called DigCompPA. Furthermore, I propose a new extended model for assessing these competences, called KAS-O (Knowledge, Attitude, Skills, plus *Outcomes*), which adds the concept of achieving social and professional online and offline objectives to the traditional KSA model. The questionnaire, based on DigComp 2.2, was issued to a sample of 152 employees of the Piedmont region. My analysis validated the items present in the survey and suggested some modifications.

Keywords: Digital competences, strategic competences, eGovernment, DigComp.

Abstract in italiano

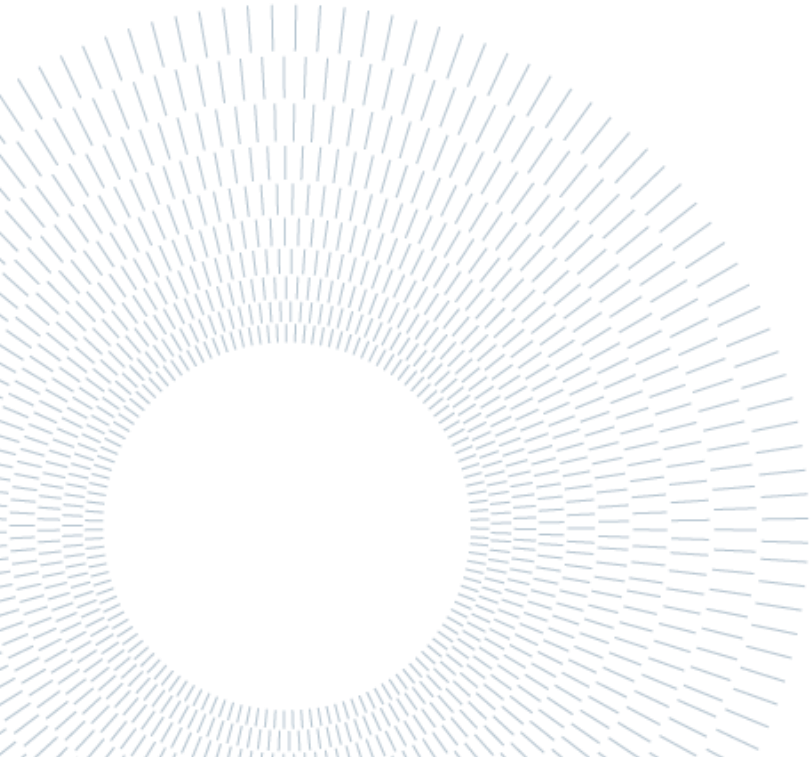
La trasformazione digitale non è più una novità, ma molti dei suoi impatti non sono ancora stati valutati, in particolare quelli sulla pubblica amministrazione (PA). Diversi elementi ostacolano la digitalizzazione del settore pubblico e uno dei principali è la carenza di competenze digitali tra i dipendenti pubblici.

Una revisione della letteratura su questo argomento evidenzia due risultati principali: in primo luogo, i framework che definiscono le competenze digitali dei dipendenti della PA sono frammentati e incompleti; in secondo luogo, finora sono stati fatti pochi tentativi di misurare tali competenze.

L'obiettivo della mia tesi è duplice: da un lato, costruire un framework che contenga tutte le competenze digitali rilevanti che un dipendente pubblico dovrebbe possedere; dall'altro, affinare e analizzare un questionario di indagine per misurare queste competenze – con il supporto dell'Osservatorio di Innovazione Digitale del Politecnico di Milano. Per creare il modello, ho analizzato qualitativamente i modelli già presenti in letteratura, con l'obiettivo di capire come integrarli ed estenderli. Per l'analisi del questionario, ho svolto un'analisi quantitativa, basata principalmente sull'analisi fattoriale.

I risultati della mia tesi hanno rilevanza sia accademica che pratica. In primo luogo, ho proposto un modello completo che contiene tutte le competenze digitali rilevanti che un dipendente pubblico dovrebbe possedere, che ho chiamato DigCompPA. Inoltre, ho proposto un nuovo modello per la valutazione di queste competenze, denominato KAS-O (Knowledge, Attitude, Skills, plus *Outcomes*), che aggiunge al tradizionale modello KSA il concetto di raggiungimento di obiettivi sociali e professionali online e offline. Il questionario, basato su DigComp 2.2, è stato somministrato a un campione di 152 dipendenti della regione Piemonte. La mia analisi ha convalidato la struttura delle domande presenti nel sondaggio oltre che proporre alcune modifiche.

Parole chiave: Competenze digitali, competenze strategiche, governo digitale, DigComp.



Contents

1 Introduction

Digitalization has had an impact on most areas of modern society, ranging from employability to leisure (Reis et al., 2018). Regarding Public Administration (PA), digitalization is not a new concept since most developed countries started this process decades ago. There is also another major trend that affects PAs: digital transformation: "A fundamental change process, enabled by the innovative use of digital technologies accompanied by the strategic leverage of key resources and capabilities, aiming to radically improve an entity and redefine its value proposition for its stakeholders." (Cheng Gong & Vincent Ribiere, 2021).

The implementation of digital technologies in PA can provide a wide variety of benefits. These include greater efficiency for governments and businesses and increased transparency. Those are mechanisms for the co-creation and participation of citizens in the public sector (Belyakova, 2021; European Commission, 2022a). The potential cost savings are massive. In Denmark, electronic invoicing saves taxpayers €150 million a year and businesses €50 million a year and, if introduced across the EU, annual savings could exceed €50 billion; meanwhile, in Italy e-procurement systems cut over €3 billion in costs (European Commission, 2022a). Nevertheless, under certain conditions, there can be hurdles to obtaining those benefits. According to the literature, one of the main ones is the lack of qualified personnel, who possess a certain level of digital competences (Belyakova, 2021). Governments are already measuring them in order to guarantee a baseline level for all citizens and the opportunity to acquire new specialized digital competences for the workforce. These are prerequisites to participate actively in the Digital Decade and to reinforce our resilience as a society

(European Commission, 2021b). In addition to the target on basic digital competences (80% of people) established in the Digital Education Action Plan and the European Pillar of Social Rights Action Plan, Digital Compass proposes to reach by 2030 a target of 20 million employed ICT specialists in the EU, with convergence between women and men (European Commission, 2016, 2021a). Digital competences range from basic usage competences that enable individuals to take part in the digital society and consume digital goods and services, to advanced competences that empower them to acquire new specialized digital competences and better compete in the market. The European Commission is measuring the level of digital competences of citizens through the Digital Economy and Society Index (DESI) (European Commission, 2022b). A significant issue is the lack of a single measurement of digital competences in the public sector. Furthermore, there is a need for a comprehensive and complete framework in order to do so.

The objective of my thesis is twofold: the proposal of a thorough framework to define and measure the digital competences for civil servants, and a survey tool to implement such framework – developed in collaboration with the Digital Agenda Observatory of Politecnico di Milano. These two additions could prove useful for PAs and decision-makers, but also academics. If the level of digital competences for civil servants is measured, then it would be possible to structure training programs customized to fill their knowledge gaps. This would lead to civil servants obtaining a sufficient level of digital competences if that were the case, not only they would benefit from it, but also the PAs would incur significant improvements. To reach the aforementioned objectives I applied a qualitative analysis of the literature and a quantitative analysis of the survey to derive my findings.

This dissertation is structured as follows:

- Chapter 2 is dedicated to the literature review, providing a detailed description of the state of the art on the research topic and explaining why the topic is relevant. Lastly, I discuss the research gaps and present the research questions;
- Chapter 3 outlines the methodology applied to my research and the data I used. It describes the qualitative research that I carried out to structure my framework, DigCompPA, and it describes the structure of the survey. Then, it presents a detailed description of the analysis that I applied to the survey, an Exploratory Factor Analysis (EFA). It also presents an analysis of the results produced by the EFA analysis;
- Chapter 4 contains the analysis of my findings. It presents DigCompPA, my proposal for a framework for digital competences for civil servants. Then, it outlines the results of the EFA analysis, with explanations of the factors I obtained and their meaning. Lastly, it describes how I validated the results of my analysis;
- Chapter 5 outlines the theoretical and practical implications of my work;
- Chapter 6 concludes, underlining the limitations of my study and some recommendations for future developments.

2 Literature review

This chapter is divided into two main sections. The first one describes the methodology used to search and review the academic literature. The second section provides a summary of the literature, starting with a description of the context, moving to a definition of digital competences, and then with a description of the problem of the lack of digital competences. To conclude, I present the literature gaps with the related research questions.

2.1. Methodology of the literature review

The literature search was carried out by adopting a mixed approach. Initially, I started my research through a systematic approach, adopting a funnel-shaped approach (Tranfield et al., 2003). Then, I complemented it with a snowball approach in order to include all the papers related to the themes of this thesis. The structured search phase is then followed by a conceptual review of the documents I have identified.

2.1.1. Research query definition

The analysis of the scientific literature was performed on Scopus. The topic that was investigated is the level of digital competences in Public Administrations (PAs). To identify the papers connected to that topic, I defined a query that includes specific keywords, to identify all the papers that may be relevant to my research.

The query was defined following a strategy that is going to be clarified in Table 1.

Table 1: Query strategy definition

First level	Definition of the empirical context
	TITLE-ABS-KEY (government OR "public administration" OR "public sector" OR municipalit* OR "regional government" OR "local government" OR "pa")
Second level	Definition of the subject under analysis
	AND TITLE-ABS-KEY ((digital* OR internet OR ict OR it OR computer OR tech) W/2 (competenc* OR skill* OR literac* OR training OR upskilling OR reskilling OR coaching))
	AND TITLE-ABS-KEY (EXCLUDE (SUBJAREA , "comp") OR EXCLUDE (SUBJAREA , "engi") OR EXCLUDE (SUBJAREA , "medi") OR EXCLUDE (SUBJAREA , "arts") OR EXCLUDE (SUBJAREA , "envi") OR EXCLUDE (SUBJAREA , "math") OR EXCLUDE (SUBJAREA , "nurs") OR EXCLUDE (SUBJAREA , "eart") OR EXCLUDE (SUBJAREA , "ener") OR EXCLUDE (SUBJAREA , "agri") OR EXCLUDE (SUBJAREA , "heal") OR EXCLUDE (SUBJAREA , "mate") OR EXCLUDE (SUBJAREA , "phys") OR EXCLUDE (SUBJAREA , "bioc") OR EXCLUDE (SUBJAREA , "ceng") OR EXCLUDE (SUBJAREA ,"immu") OR EXCLUDE (SUBJAREA , "phar") OR EXCLUDE (SUBJAREA , "neur") OR EXCLUDE(SUBJAREA , "chem") OR EXCLUDE (SUBJAREA , "dent") OR EXCLUDE (SUBJAREA , "vete")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "bk") OR LIMIT-TO (DOCTYPE , "ed")) AND (LIMIT-TO (LANGUAGE , "english"))

The strategy I adopted was to include all the possible papers related to the world of the measurement of digital competences to create a structured analysis, to ensure replicability.

In the first level, I identified PAs as empirical context. I employed different synonyms as keywords to be certain to include all the papers relevant to that area, excluding the citizens, at least in this preliminary stage. Many papers explain the measurement of the digital competences of citizens, but this is not the focus of my work.

In the second level, I specified the topic under analysis, the measurement of digital competences. This level is comprised of two different sections: in the first one, I defined all the main elements related to digital competences, including all the important keywords; in the second one, I narrowed my analysis, since I am interested in the way those competences are developed. In the last part of the query, I excluded the papers

that belong to subareas uncorrelated with public administrations, like healthcare or the arts, but I also specified that I am only interested in some typologies of documents. Lastly, I considered only the papers that are written in English.

To complete this list, I identified additional records through scoping review and snowball sampling from some very particularly relevant articles.

2.1.2. Screening process

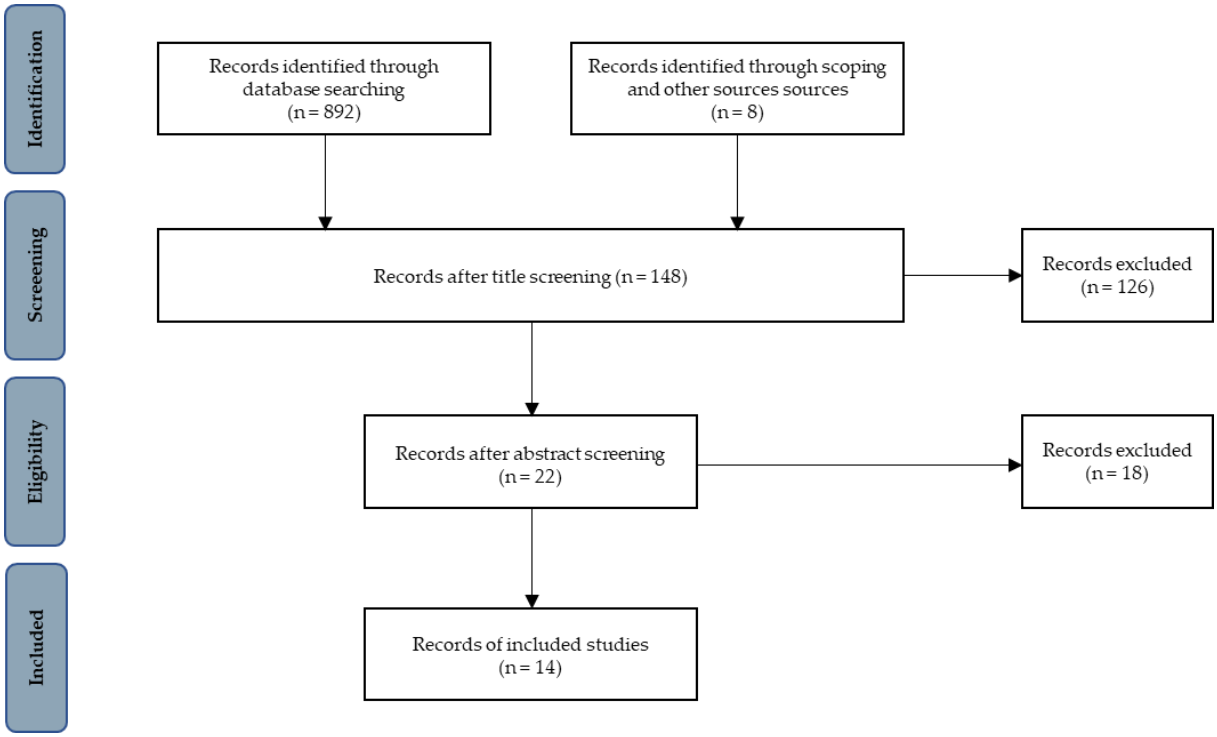
Once extracted, the list obtained underwent a screening process aimed at collecting the relevant articles strictly inherent to the topic.

The selection was performed according to a three-step procedure:

- In the first step, I discarded the results that were not aligned with the research objective based on their title (*title screening*);
- In the second step, I filtered the records that were out of focus based on their abstract (*abstract screening*) ;
- In the third step, the remaining documents were subjected to a full-text reading for an eligibility assessment (*full-text review*).

The screening process was supported by considerations about the relevance of each article, assessed by looking at indicators measuring the relevance of the journal (H-index2 and AiIG3 class) and the specific study in terms of citations (Field-Weighted Citation Impact from Scopus and Highly-Influential Citations from Semantic Scholar). Figure 1 illustrates the process using the PRISMA Flow Diagram (Deeks et al., 2019).

Figure 1: PRISMA Flow Diagram



The process started with a high number of records, but in the end, I included only 14 of them. There are different explanations for this result. The topic of digital competences is broad and some words are related to a multitude of results, like ICT, digital, IT, and so on. Due to the generality of these words, the query captured many records that are completely unrelated to the topic of my thesis. Nevertheless, I included them in order to guarantee a comprehensive approach. During the title screening phase, I discarded 752 records because they were out of focus. Most of those papers could be grouped into these categories: education system, private sector, competences in general, use of the internet, teaching methods, and ICT competences. With the abstract screening, I discarded 126 records because they were related to the following categories: eGovernment in general, competences in education (higher education, universities, masters), ICT gap, and training in the public sector.

I decided to reformulate the query, excluding some recurring keywords which were present in the papers I discarded, but it did not prove successful. The reason for that

was the scarce number of keywords recurring in the papers I discarded. A majority of the time, those papers were unrelated to my research. In addition, this process was structured with a bottom-up approach and was not replicable.

My choice was to maintain the original query to increase the value to the readers in terms of replicability. Since the number of papers from the scientific literature was not exhaustive to my research, I preferred to apply a snowball sampling, to enlarge the number of documents under analysis. By looking at the references of relevant documents for my research, I found eight additional documents; in total, the amount of documents is fourteen.

I reported all the documents that I used for the literature review in Table 2.

Table 2: Literature review records

Title	Digital competence development of state civil servants in the Russian Federation	Interoperability skills and competencies-the drivers for digital growth in Public Administrations	Digital Business Transformation Organizing, Managing and Controlling in the Information Age	Governments' Need for Digitization Skills: Understanding and Shaping Vocational Training in the Public Sector	How to Foster e-Competence in the Public Sector? A Mixed-Method Study Using the Case of BPM	Managing IT Skills Transfer in an Outsourcing Partnership within the Namibian Ministries Computing Environment	The OECD Framework for digital talent and skills in the public sector	Digital Skills: Unlocking the Information Society	Competency Requirements for Transformational E-Government	Towards Efficient EGovernment: Identifying Important Competencies for EGovernment in European Public Administrations	DigComp 2.2: The Digital Competence Framework for Citizens	Development and validation of the Internet Skills Scale (ISS)	Syllabus "Competenze digitali per la PA"
Author, Year	(Elena Vasilieva et al., 2018)	(Kyriakopoulou et al., 2021)	(Rocco Agrifoglio et al., 2020)	(Ogonek, 2018)	(Halsbenning et al., 2021)	(Shaanika & Nehemia, 2017)	(OECD, 2021)	(Van Dijk & Deursen, 2014)	(Hunnius & Schuppan, 2013)	(Krimmer et al., 2016)	(Vuorikari et al., 2022)	(Deursen et al., 2016)	
Source title	Journal - Business Informatics	ACM International Conference Proceeding Series	Springer	International Journal of Public Administration in the Digital Age	Palgrave Macmillan	IST-Africa	OECD Working Papers on Public Governance No. 45	Palgrave Macmillan	Hawaii International Conference	Dual EGOV 2016 and ePart 2016 conference	JRC	London School of Economics and Political Science	Dipartimento della Funzione Pubblica
Document type	Article	Conference Paper	Book	Article	Conference paper	Conference Paper	Working Paper	Book	Conference Paper	Conference Paper	Government document	Article	Government document
Focus	Measurement of digital competences of civil servants	Framework on a specific skill (interoperability)	Analysis of Digital Competences in PA	Vocational training for Digital Competences	Framework on internet skills	Outsourcing of skills	Framework on Digital competences for civil servants	Framework on Digital competences	Competences for e-Government	Measurement of competences for e-Government	Framework on Digital Competences for citizens	Framework on internet skills	Framework on Digital Competences for civil servants

2.2. State of the art

2.2.1. Digital transformation of Public Administrations

Digital transformation is "A fundamental change process, enabled by the innovative use of digital technologies accompanied by the strategic leverage of key resources and capabilities, aiming to radically improve an entity and redefine its value proposition for its stakeholders." (Cheng Gong & Vincent Ribiere, 2021). This phenomenon impacts all spheres of life since digital technologies provide many opportunities previously unavailable. I intended to focus on the digital transformation of public administrations (DTPA). Specifically, for Public Administrations (hereinafter referred to as PAs), this DT is partially based on dematerialization (Casalino Nunzio et al., 2021). The dematerialization of documents, i.e., the progressive increase of digital and the computerized management of documents and processes, are key drivers of organizational digital transformation. To implement these actions, a new digital technology strategy is required, alongside a new organizational business model (Armenia et al., 2008). The effective implementation of DTPA will lead to outstanding advantages, that may be summarized in increasing employee productivity; decreasing decision-making time; creating new work opportunities; accumulating experience and improvement activities through the integrated use of databases, information portals, corporate search systems; improving the flexibility of management decisions; reducing the number of errors in decision-making; minimizing the time for providing public services by consolidating operations and functions (Armenia et al., 2008). Of course, the process to achieve these benefits is not linear, instead, some major problems slow down, and sometimes grind to a halt, the implementation of DTPA. The main obstacles may be summarized in limited budget funding, insufficient regulatory norms, inadequate technological standards, and lack of qualified personnel (Belyakova, 2021; Casalino et al., 2020).

My thesis will consider this last element: the lack of digital competences for civil servants, which represents an obstacle for PAs to achieve most of the benefits of digital transformation.

2.2.2. eGovernment

For years now, public administrations have been at the centre of an impressive series of digital changes aimed at creating structures oriented towards a culture of effectiveness and efficiency. These changes are part of the DTPA and they have led to e-Government (Casalino Nunzio et al., 2021). "E-government is defined as a way for governments to use the most innovative information and communication technologies, particularly web-based Internet applications, to provide citizens and businesses with more convenient access to government information and services, to improve the quality of the services, and to provide greater opportunities to participate in democratic institutions and processes." (Guo, 2010), which means using ICT and the internet as tools to achieve better governments (OECD, 2003). The resulting benefits can be less corruption, increased transparency, greater convenience, revenue growth, and/or cost reductions (Foley & Alfonso, 2009). Those benefits could only be achieved through the effective implementation of the e-government and, to do so, civil servants need some specific *e-competences* (Krimmer et al., 2016). These include different categories of competences, as reported in Table 3.

Table 3: eGovernment competences

Category of Competencies	Competencies
Technical	IT competencies
	Expertise in Information Systems design
	Information Systems competencies
	Expertise in eGovernment impact
Socio-technical	Expertise in technology and eGovernment adoption
	Expertise in politics of eGovernment
	Expertise in eGovernment structures
Organizational	Expertise in organizational design
	Process management competencies
	Business/Public management competencies
	Project management competencies
Managerial	Financial management competencies
	Performance management competencies
	Change management competencies
	E-Policy competencies
Political-administrative	Expertise in legal framework
	Expertise in administrative workflows
	Expertise in public policy

These e-competences represent a success factor for e-government endeavours (Müller & Skau, 2015; Stefanović et al., 2016). To achieve the required level of competences in those fields, and be able to meet the customers' expectations, civil servants need proper training (Janowski et al., 2012).

E-competences are relevant for the implementation of eGovernment, but there is a difference between e-competences and digital competences. E-competences are specific for the e-government, while digital competences have a broader meaning, they refer to the capability of civil servants to be able to operate in a digitalized world. Creating a digitally enabled state requires going beyond the concept of "eGovernment", which focuses on technology to improve efficiency in response to government needs. To successfully perform this transition, the government requires new digital government practices that focus on designing services and policies to meet not only the current users' needs but also future ones (Jonathan, 2020; OECD, 2014). For example, looking at Table 3, Financial management competences and Expertise in

legal framework are competences that are relevant for eGovernment but not for digital competences. Since my focus is on digital competences, the policy- and legal-related competences do not have a primary role.

Nevertheless, during my analysis I included some papers that explore the e-competences for eGovernment, to have a broader perspective and to enlarge the concept of digital competences.

2.2.3. Digital Competences

It is fundamental to clarify the concept of digital competences for civil servants. The most complete definition of digital competence 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; manage information; collaborate; create and share content; and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, reflectively for work, leisure, participation, learning and socializing" (European Commission, 2012).

During the last few years, research on this theme has increased and new elements have emerged. Nevertheless, it appears that the number of studies related to public servants is much lower compared to the ones related to citizens. A rather small amount of studies focus on civil servants and most of them focus on eGovernment implementation. Some of the latter documents that analyze digital competences from the citizen and eGovernment point of view have been included since they provided some relevant information also for my research question.

The output of my analysis is the matrix in Table 4.

Table 4: Classification of the record from the literature review.

	Document name	DigComp 2.2	Syllabus "Competenze digitali per la pa"	The OECD Framework for digital talent and skills in the public sector	Digital skills, unlocking the Information society	Digital competence development of state civil servants in the Russian Federation
	Document type	Government document	Government document	Government document	Government document	Article
Target group	**Citizens**	x			x	
	Civil servants		x	x		
	e-Government					x
Type of Competences	**Information and data literacy**	x	x	x	x	x
	Communication and Collaboration	x	x	x	x	x
	Digital content creation	x	x	x	x	x
	Safety	x	x	x		x
	Problem Solving	x		x	x	x
	Online services		x			
	Digital Transformation		x			
	Digital Government leadership			x		
	Digital government professional			x		
	Digital government socio-emotional			x		
	Strategic				x	

The most complete and precise documents related to digital competences are governmental documents since they provide a precise framework for the topic. In regards to the articles and the papers, they usually adopted a less structured approach and they mostly focus on a specific set of competences. To classify the typology of competences, I used DigComp 2.2 as a base because its classification is quite thorough, and it can capture most of the required digital competences that civil servants need to compete in the new digital job market (Vuorikari et al., 2022). The DigComp includes many of the prerequisites that are needed to compete in a digitalized world. It starts with Information and data literacy, which is the capability to articulate information needs, retrieve digital data, judge relevant sources, and organize them. These are the most basic competences to navigate the internet. Then comes Communication and collaboration, which is the ability to interact, communicate and collaborate through digital technologies. The next step is Digital content creation, which requires the capability to create and edit digital content. Lastly, Safety refers to the protection of devices, content, personal data, and privacy in the digital environment. Even though these competences could be sufficient to measure the digital competences of citizens, for my purpose I need to extend the DigComp since public employees have specific competences requirements that are additional to the ones of citizens.

In this regard, the Italian *Syllabus "Competenze Digitali per la PA"* – which was derived from DigComp - is specifically related to public employees. Its framework is comprised of five different competences, which include most of the competences presented by DigComp, apart from the Problem-solving one. Instead, it introduces two additional areas, that are specific to the public sector: Online services and Digital transformation. Online services refer to the knowledge of digital identity and the capability to supply online services. The public employee is called upon to know and guarantee the right to use the online services, as well as to get to know the main enabling platforms to support the provision of such services by public administrations

in favour of citizens and businesses. Regarding Digital transformation, it is necessary for the public employee involved in the processes and services to know the objectives that characterize the national strategy for the digital transformation of public administration and how it has structured digital governance in its country. It is also necessary that the civil servants possess a basic "digital culture" regarding trends and technologies that are developing at the moment and can recognize their application potential in the public sphere (Presidenza del Consiglio dei Ministri - Dipartimento della Funzione Pubblica, 2019).

To further extend the set of digital competences, the OECD proposed a pyramid framework of digital competences based on five levels (OECD, 2021). The first two categories, "21st century skills in society" and "Digital government user skills", contain competences that could be grouped into the aforementioned dimensions. Instead, this framework introduces another set of competences that ought to be considered. "Digital government socio-emotional skills" aims at finding a balance between vision, analysis, diplomacy, agility, and protection, because they are crucial to delivering a trustworthy and proactive public body. "Digital government professional skills" defines the characteristics required by a digital professional, in terms of knowledge, competences, and attitude to support digital government maturity, but also the roles that may be covered by that person. Civil servants that have this level of competences may cover the following roles inside a PA:

- User-centred design professionals

  They are specialized in terms of service design, interaction design, content design, and user design. At the most senior level, they include the Head of Design and Research. Their responsibility is to embed a user-centred culture in the PA and, at the highest level of proficiency, to ensure a collective recognition of the problems to address in transforming government services.

- Service professionals

  These professionals have the responsibility to control the user experience across products, services, and organization boundaries. They are used to work in proximity to the ministries and their activities are measured against user-driven, citizen-centric metrics and government outcomes.

- Product professional roles

  They work at the intersection between different disciplines in a team, to ensure that the user needs are understood and provided for, and to respect the technical feasibility of the solution, considering a broader organizational context. At the most senior level, they could be the Head of Product, considering the perspective across multiple products and services.

- Delivery professionals

  The objective of these professionals is to ensure that digital government teams work in the best possible manner, guaranteeing the health of the team and protecting it from external distractions. The main activities that are performed are financial management and recruiting, and generally, they apply agile or lean practices. At the most senior level, they are the Head of Delivery.

- Data professional roles

  They are responsible for an effective data governance model and ensuring the use of data builds to increase trust. It is crucial to embed a data-driven approach in PAs and to underline the importance of the roles of data analyst and data scientist. The operational activities include managing the data collected, monitoring the performance of public services, and keeping track of the new policy development. At the most senior level, they could be Chief Data Officers.

- Technology professionals

  They contribute, with different disciplines, to effective multi-disciplinary teams. At the operational level, there are different roles, such as technical architects and developers. Technical architects work in a team to ensure the

resilience, scalability, and security of work. Developers are in charge of ensuring that the software is accessible, to solve possible problems by maintaining and documenting the code. At the most senior level, they are Chief Technology Officers.

Lastly, this framework introduces a crucial competence, that cannot be neglected: leadership. Civil servants need the leadership to establish a digitally enabled state and to model digital government user competences, to actively shape an environment that fosters digital transformation.

The book "*Digital skills: unlocking the information society*"(Van Dijk & Deursen, 2014) provides further insights to extend the framework for individual, social, and professional purposes. The authors divide digital competences into six different categories. Five of them can be mapped into the five areas of DigComp, but they add a new dimension that adopts a different perspective: *strategic* internet competences. These refer to the capabilities of individuals to take advantage of the internet by developing an orientation towards a specific goal and putting in place all the required actions and decisions to benefit from the result. This strategy perspective is crucial – in the professional realm and the public sector, in particular – because it allows public employees to enhance their careers and provide a significant contribution to the digitalization of PAs. This is why the dimension of strategy is mentioned in the definition of digital competences that I proposed at the beginning of this chapter.

Another interesting article, "Digital competence development of state civil servants in the Russian Federation", tries to assess the digital competencies of Russia's civil servants through a survey, issued to more than 100 public employees (Elena Vasilieva et al., 2018). They did not base the survey on a specific theoretical framework, although their questions touched almost all five areas of DigComp, neglecting Safety competences. The survey is structured in the following way: the authors created a list of qualification requirements in terms of knowledge and competences, in the field of

ICT, that public servants must possess. They subdivided these requirements into three levels: base, advanced and special. Even though this survey does not refer to any specific framework, it could be used to integrate some examples of questions into the ones proposed by DigComp.

Based on my research, the aforementioned were the most interesting frameworks related to digital competences. They are complementary to each other and can provide solid grounds to extend DigComp in the direction of a comprehensive framework to define the competences needed for the digital transformation of public administrations.

2.2.4. Measurement of Digital Competences

Based on the results of my query, only one study has tried to determine the most relevant digital competences for PA, while two papers focus on the competences required to implement an e-government system. Considering the findings from the snowball sampling, I found six documents that propose a framework for digital competences, but only two of them are related to civil servants. According to these documents, the methodologies adopted to perform the measurements are mostly surveys and interviews, although they do not follow any standardized framework.

The main outcome of my analysis is that there is no single document that provides the level of digital competences for public administrations. Nevertheless, digital competences are currently measured at a global level, but almost all of the studies focus either on citizens or on workers in general rather than public employees. There are two big measurements in terms of digital competences, one related to citizens and one concerning workers. The first one is the Digital Economy and Society Index (DESI) is an annual report, published by the European Commission, which monitors Europe's overall digital performance, including the digital competences of its citizens. The results of this index suggest that there is huge potential to improve the digital competences of citizens.

The second important measurement of digital competences, in this case for workers, is the Digital Skills Index, computed by Salesforce (Salesforce, 2022). This index is based on a survey, which received answers from over 23,000 workers in 19 countries, including over 1,300 from Italy, and measures the level of digital competences of workers. Even though this index is generic for all workers, it includes public employees, and it underlines the lack of digital competences of workers.

However, Eurostat measures the individuals' level of digital competences (Eurostat, 2019). In Table 5 I reported the data from 2019, which are useful for my analysis because I can isolate the public employees from the other workers. Eurostat provides aggregated data which includes "working in public administration, defence, education, human, health or social work activities". Even though it does not only consider civil servants, this is the best information regarding the digital competences of public employees that I found and it allows me to derive some considerations. The following considerations are valid both for the Italian context and also at the European level, but I considered the Italian context. Compared to individuals, public employees have a greater level of digital competences (64% vs. 42%). This is the consequence of a greater percentage of public employees with high formal education compared to all individuals. If I compare public employees with individuals with high formal education, the result is the opposite of the previous one (64% vs. 76%). The level of digital competences of public employees is lower than the ones of workers in business services (64% vs 76%), and the result is even worse if I compare them with workers in financial or insurance activities (64% vs 81%). In general, I conclude that there is a lack of digital competences, especially in the public sector, and this situation is worse in Italy than in the average European countries.

Table 5: Eurostat measurement of individual level of digital competences

IND_TYPE/GEO	European Union - 27 countries (from 2020)	Italy
Working in public administration, defence, education, human health, or social work activities	77	64
All Individuals	56	42
Individuals with high formal education	84	76
Employees, self-employed, family workers	66	52
Employees working full time	67	-
Working in financial or insurance activities	88	81
Working in business services	79	76[1]

Based on my search, the only paper that describes the assessment of the digital competences of civil servants is related to a survey conducted in Russia, in 2017 (Elena Vasilieva et al., 2018). The survey was issued to more than 100 experts and civil servants from various entities of the Russian Federation and state authorities. The experts were formed from representatives of various categories and groups of positions in the state civil service of three constituent entities of the Russian Federation (Penza, Moscow, and Leningrad regions), with experts from five groups of four categories of positions.

The survey aimed at finding the actual level of digital competences to update the job regulations qualification requirements. Inside the paper, they defined digital competences as a part of ICT competences, but with many additional components, like PC competences and digital information processing competences. They divided the digital components of ICT competences into three different levels, namely basic, advanced, and special ones. To be more precise, inside each level, they made a distinction between knowledge and competences. Then, they formulated a list of qualification requirements for professional knowledge and competences in the field of ICT which a public civil servant must possess. Then, they identified those competences

[1] Data extracted from Eurostat the 29/11/2022. The data refers to individuals who have basic or above overall digital competences. The time of the measurement was 2019 and the unit of measure is a percentage of individuals.

that are crucial for the leaders and the most important people in the civil service, and the ones relevant for most civil servants. The final ranking on information and communication competences was determined based on the weighting of expert assessments taking into account the significance (on a scale from -3 to 3). Looking at the qualification requirements present in the report, it is possible to note that they are divided into proficiency levels, instead, the frameworks present in the literature provide a classification of digital competences. The questions of the survey are an updated version of the qualification requirements that are present in Russia. The problem with this approach is that they do not refer to a theoretical and recognized framework of digital competences. Thus, different PAs may have different qualifications and requirements and may structure the survey in different ways.

Hence, the value added of my thesis is to provide a structured, evidence-based framework to measure digital competences, that could be used as a reference by PAs. In addition, I also propose an example of the measurement of digital competences on a sample of civil servants of a specific PA – Piedmont region – that volunteered to pilot this approach. The analysis of the pilot survey is useful to understand if the items present in the survey managed to measure digital competences and if they could be improved.

There are several reasons behind this lack of digital competences. One reason is the lack of education opportunities for the employee, concerning both IT systems and available digital content (Lönn & Uppström, 2013), given that many PAs lack the capacity to upskill their employees through specific education programs (Casalino et al., 2020). An explanation is that PAs have difficulties in determining the right employees 'competences requirements, and they also struggle to measure them (Bannykh & Kostina, 2021). As a result, they fail to structure customized and effective training. Nevertheless, PAs offer training to upskill their employee, but they focus on high-level competences that have little chance to enhance digital competences levels. For example, in Russia, Russian civil servants have prioritized their competences as

focusing on results, discipline, and stress resistance rather than digital competences (Elena Vasilieva et al., 2018). An example of an initiative to improve digital competences in the public sector is the Interoperability Academy Solution (ISA), offered by the European Commission. This project aims to improve the level of advanced digital competences in the public sector with a focus on interoperability, which is an important competence for civil employees, through a comprehensive cursus and different learning paths according to the user status (Kyriakopoulou et al., 2021).

In addition, PAs still have to adapt their job descriptions according to the new requirements of the new digitalized era. As emerged from a study conducted on ten job regulations in Russia, half of them contain only the most general descriptions of the professional competences that an applicant for those positions must possess. As a result of that study, they presented an extensive list of knowledge and competences that applicants need to have to work in the investigated positions. Some requisites are about information security, (including not only work with official information, but also personal mail and accounts on social networks), personal data, document management systems, electronic signature, as well as work with a personal computer (creating texts, tables, and presentations, working with network resources, and much more) (Elena Vasilieva et al., 2018).

Then, the great complexity of the public sector domain and its slowness to adapt to the external context are additional causes of the lack of the required competences. A study conducted in Germany showed that the reasons for the shortage of digital competences, with a focus on the Business Process Management (BPM) competences, are manyfold, like slow uptake in adapting the training according to the newly identified competence requirements; lack of a clear image of the required competences for the roles that have to be digitalized (Ogonek & Becker, 2018).

Another reason is the great demand for skilled workers with IT competences, thus, the competition in the job market for those employees is very high. Here, the problem for public agencies is that they cannot pay comparable salaries as happens in the private sector (Halsbenning et al., 2021).

2.2.5. Limitations and Research gaps

Based on the literature review that I conducted, some literature gaps emerge. The most important one is the need for a unique and thorough framework that can *define* digital competences for civil servants. In the literature, there are some frameworks on digital competences, and some of them are focused on civil servants, but there is the opportunity to define a new framework, that integrates all the important elements of the frameworks already existing.

Furthermore, few studies aim at *measuring* digital competences for civil servants. As a result, there is no consensus on how to structure a survey to measure those competences, which are the items that should be included and if those items work. Thus, it would be interesting to analyze additional surveys, to understand if their questions are effective and understandable. It would be useful to develop a tool, in this case, a survey, that all the PAs could issue to their employee to measure their digital competences. Having a unique tool would standardize the understanding of digital competences and the way by which the results of the survey are analyzed.

Based on these two main literature gaps, I focused my thesis on the following research questions:

RQ.1 How to build a complete framework to define digital competences for civil servants?

RQ.2 How to measure digital competences among public servants?

RQ.2.1 What are the fundamental items that should be measured?

RQ.2.2 Do different measurement approaches yield different results?

The following chapter illustrates the methodology and the data I have employed to answer these questions.

3 Methodology and Data

3.1. Development of the framework

To answer the first research question, I applied qualitative research. Based on the literature gaps that emerged from the literature review, I made additional research to determine which were the opportunities to create a new framework. My proposal of the framework will be mainly based on the DigComp, but I expanded it to create a tool that is capable of measuring the digital competences of civil servants. To come up with my proposal, I collected information from both academic research but also government documents. The results of this analysis will be presented later, in the paragraph "A proposed framework to measure the digital competences of civil servants".

3.2. Survey structure

The process that I followed during my thesis is the following: based on the main output of my work, that is my proposal of a framework, the Digital Agenda Observatory of Politecnico di Milano had a primary role in the development of a pilot survey, and I gave my contribution in this phase; after the survey was issued to the respondents, I had the role of analysing the results of that questionnaire.

The pilot survey represents my case study, and it was conceived together with the Piedmont region, to measure the digital competences of their civil servants. The questionnaire was the result of a journey made up of a series of focus groups with some selected employees of the Piedmont region. These people work either on the

subject of training and digital competences or on the digital procedure of the PA. In any case, they are insiders on the subject of the digital transformation of the PA within the Piedmont region. During these focus groups, we illustrated to them what are the main frameworks that are available for measuring digital competences for public employees; we identified their priorities, and we built the survey, which was first tested on them during focus groups.

The questionnaire was based on DigComp 2.2, thus it includes items from the five dimensions of that framework. This pilot survey does not include any of the new elements of my framework. The reason is that it was not possible to test everything from the first pilot. I and the Observatory had to meet the requirements of the Piedmont region, which wanted to test this structure of the survey to expand it in the future. The questionnaire is made of six main blocks, and the total number of items is 131. You can find a detailed description of all the items of the survey, their description and their classification in Table 20.

The questionnaire is structured in the following way:

1. The first block aims at gathering socio-economic information about the respondents through 12 items.
2. Access to digital measures how often and through which devices the respondents browse online through 6 items.
3. Test contains items that measure the specific digital competences of the respondents. These items are meant to measure the competences for each area of competence and were built either during the focus groups or based on the ECDL (ICDL, 2022). This section is made of 8 variables and 19 items, which are multiple-choice questions, and the respondents were asked to select the right choice out of four alternatives.
4. Online activities measures the confidence with the online of the respondents. The items in this section are based on some guidelines of Istat and are integrated

with some specific tools that are used by the employee of the Piedmont region (Istat, 2022). This section is made up of 8 variables and 36 items, which allowed three types of replies: "Yes", "No", and "I don't know what you mean".

5. Self-assessment is the section where the respondents are asked to self-evaluate their competences concerning some tasks, and it is based on an article from the literature (Deursen et al., 2016). This section is made of 7 variables and 39 items. The respondents were required to indicate how much they agree with the question, choosing a value from "-2" to "+2". In addition to this option, there was the "I don't know what you mean", but it was codified as a "-2", thus, in the end, there are 5 options.
6. Engagement aims at measuring the feelings of respondents when they perform some tasks, and it is based on an article from the literature (Seppälä et al., 2009). This section is made of 3 variables and 20 items, which measure the engagement of civil servants from 3 different perspectives, namely: force, dedication, and focus. The respondents were required to indicate how much they agree with the question, choosing a value from "-2" to "+2".

One of the purposes of the survey is to understand whether different measurement approaches lead to comparable results and how these results are linked to each other. Indeed, the sections of the questionnaire are based on three approaches: literature-based, institutional-statistical based, and a micro-approach, where items designed for the local context are scalable and valid for a greater sample size.

The observations of the survey come from a variegated sample size, with the respondents that belong to all the departments of the region, randomly selected by their directors. The pilot was first issued to 10 people, then 152, with the objective of extending it to the entire population of the Piedmont region, which is made up of 2800 employees. The survey received 119 complete responses (78% of the participants), and

it is made up of 26 variables and 132 items; the average time to fill it out was 29'; the average age of the respondents was 54.1 (69% female, 31% men).

3.3. Exploratory Factor Analysis

The first step in my quantitative analysis of the survey was an Exploratory Factor Analysis (EFA). The EFA "is an analytic technique that permits the reduction of a large number of interrelated variables to a smaller number of latent or hidden dimensions." (Tinsley & Tinsley, 1987). The goal is to explain the maximum amount of common variance in a correlation matrix by using the smallest number of explanatory factors. The main reason why I chose the EFA is that, according to many authors (Briggs & Cheek, 1986; Canivez, Gary L. et al., 2016; Fadia Nasser-Abu Alhija, 1998; Watkins et al., 2002), EFA could be used to assess the validity of a survey. In addition, EFA can reduce a large number of items from a survey instrument to a smaller number of components and examine which items have the strongest association with a given factor (DiStefano et al., 2009). The EFA analysis is made of 9 steps.

Step 1 consists of the choice of the variables that are included in the EFA. I selected all the variables that are related to the measurement of digital competences. Thus, I decided not to include the items that are related to either socio-economic or Access to digital sections of the survey. This choice will positively benefit the communalities among the measured variables. Another critical choice is the number of variables per factor. I set at three the minimum number of variables per each factor to reduce the risk of construct underrepresentation"(Thomas A. Schmitt et al., 2018).

Step 2 regards the choice of the participants that are included in the survey. My pilot survey is made of a variegated sample, with people with different jobs, responsibilities, and socio-economic characteristics. The number of participants to include in an EFA have a significant impact on the results because correlation coefficients tend to be more stable when estimated from big samples. Comrey and Lee (1992) suggested some guidelines: 100 participants are poor, 200 are fair, 300 are good,

500 are very good, and 1,000 or more are excellent (Comrey & Lee, 1992). In my case, the survey was issued to 152 people; thus, this result could be considered almost fair.

Step 3 consists of a data screening. The main choice is the decision between a Pearson and a Polychoric correlation matrix. In Table 6 I reported the criteria I followed to choose between the two correlation matrixes.

The main problems related to data that may affect an EFA analysis might be: the presence of a restricted score of range; non-linearity among variables; the presence of outliers, and the presence of missing data. Regarding missing data, I applied a listwise deletion for 32 observations because these people did not respond to the survey at all.

Table 6: Selection criteria for the correlation matrix

Correlation matrix	**Condition**	
	Univariate	Multivariate
Pearson	$Skewness < 2.0$ $Kurtosis < 7.0$	$Kurtosis < 5.0$
Polychoric	$Skewness < 5.0$ $Kurtosis < 50.0$	Mardia's multivariate normality test

In Step 4 I conducted some tests to ascertain the appropriateness of EFA.

The conditions that have to be verified are:

- Many correlation coefficients >=.30 (Hair et al., 2019);
- Absence of a multicollinearity problem (Marjorie A. Pett et al., 2003);
- Bartlett's test of sphericity (Williams et al., 2010);
- Kaiser-Meyer-Olkin measure of sampling adequacy (Kaiser, 1974).

Step 5 requires choosing a factor analysis method. There are two major models for factor extraction: the Principal Component Analysis (PCA) and the Common Factor Analysis (CFA). The objective of my analysis is to uncover the latent structure

underlying my measured variables, and the direction of influence from factor to measured variables. Thus, I applied the CFA method rather than the PCA one.

In Step 6 I chose which factor extraction method to apply. There are different factor extraction methods, but I chose the principal factor extraction with initial communalities estimated by squared multiple correlations (Barbara G. Tabachnick & Linda S. Fidell, 2019) because it ensures greater computational robustness and reduced sensitivity to nonnormality compared to other methods (Barendse et al., 2015; Lee et al., 2012).

Step 7 deals with one of the biggest issues with EFA, which is the determination of the exact number of factors to retain for interpretation. Choosing a number of factors that is either too small or big has serious consequences on the results of the EFA (Hoelzle & Meyer, 2013). Nevertheless, research proved that underextraction is more dangerous than overextraction (Kline, 2013). Because of this issue, I applied more than one method, to increase the accuracy in terms of the choice of the number of factors. The three methods that I applied are scree plot, Parallel Analysis, and the Minimum Average Partial (MAP).

In Step 8 I had to choose the rotation method of the factor axes. There are two typologies of rotations available: orthogonal and oblique rotation. I chose the oblique rotation because, based on the pilot survey structure, I expect that factors are correlated and it is more accurate (Bandalos & Boehm-Kaufman, 2008; Bandalos & Finney, 2018). Regarding the oblique analytic rotation method, I choose the promax rotation because "promax rotation is almost always a good choice" (Thompson, 2004).

In Figure 2, I reported the Stata do-file that I used during my analysis.

Figure 2: Stata do-file for the EFA

```
*Step 3: Data Screening
*Data Distribution
**Review of the univariate descriptive statistics
tabstat $varlist, statistics (count mean sd min max skewness kurtosis) columns ( statistics)
*Mardia's test to check multivariate normality
mvtest normality $varlist, stats(all)
* Correlation matrix
corr $varlist
*To produce a Polychronic correlation matrix (if violation of multivariate normality)
search polychoric
polychoric $varlist
*Step 4: Is EFA appropriate?
*Verify the appropriateness of the correlation matrix for EFA
ssc install factortest
factortest $varlist
*Run of EFA Analysis
factor $varlist
factor $varlist, factor(#factors) blanks(0.31)
*Computation and printing of communalities
matrix M = J(1,colsof(e(Psi)),1) - e(Psi)
matrix list M
*Parallel Analysis method
findit fapara
fapara, pca reps(500)
*Minimum Average Partial Correlation method
ssc install minap
minap $varlist
**Scree Plot method
screeplot, yline(1)
*Step 8: Factor Rotation
*Start with an oblique rotation
rotate, promax blanks(.3)
*Determine the best number of factors lokking at the BIC value (ML extraction)
estat factors
* KMO measure of sampling adequacy
estat kmo
* Barlett's test for sphericity
factortest $varlist
*Check the Alpha reliability of each set of variables identified in EFA
alpha #factor1
alpha #factor2...
**Repeat lines 31-41 for each model
```

In the end, in Step 9, I reported the guidelines that I followed to come up with a significant interpretation of the results.

1. It is relevant to set a threshold at which factor loadings will be considered meaningful (Worthington & Whittaker, 2006). The salient values provided by the literature are .30, .32, and .40 (Hair et al., 2019). My choice was an intermediate value, .31, and this value implies that variables have around 9.6% (loading squared) of their variance explained by the factor.
2. To create a structure that is as simple as possible, I excluded variables for which there were salient loadings on more than one factor (Pituch & Stevens, 2015).
3. The alpha reliability of each factor should exceed a certain threshold. In my case, since I am dealing with a group of experimental research, the coefficients should be greater than .70 (Kline, 2013).

4. It is important to measure the model fit in terms of residuals. The smaller the RMSR value the better, with desired values below .08 (Brown, 2015). In addition, the proportion of non-redundant residual correlations greater than .05 should be small (Watkins, 2018), while absolute residuals greater than .10 suggest the presence of another factor (Cudeck, 2000).

3.4. Interpretation and Validation of the EFA results

After the computation of the factors, I studied them to understand how they relate to the items of the survey, and whether different measurement approaches lead to different results. To start, I computed three types of indexes, based on the observations of the survey, to measure the digital competences of civil servants.

The computation of the first index was carried out for all four sections of the survey, namely: Test, Online services, Self-assessment, and Engagement. Per each of the four areas of the survey and each observation, I computed the arithmetic average over all the variables of that specific area. Thus, I started from a database with a dimension of $[nxk]$ and I obtained an index, that is a vector of $[nx1]$. I reported the formula below.

Equation 1: Index – arithmetic average

$$name\_avg_i = \frac{\sum_{j=1}^{k} x_{i,j}}{k} \quad (1)$$

Where:

- k = number of measured variables inside the specific area of the survey
- n = number of observations

The second type of index is a weighted average between the scores of the survey and the factor loadings that the selected items had on the respective factors. In other words, the EFA analysis has produced 3 different models for the respective areas of the survey, made of 5,7, and 3 factors respectively. Those factors are formed by a group of items, and I reported the factor loadings between variables and factors. Those factor

loadings represented the weights in the computation of the index. I started from a database with a dimension of [nxz] and I obtained an index, that is a vector of [$nx1$]. I reported the formula below.

Equation 2: Index – factor loadings

$$name\_EFA_i = \sum_{j=1}^{k} x_{i,j} * f_j \quad (2)$$

Where:

- $x_{i,j}$ is the score x that the *i-th* respondent gave to the *j-th* variable
- f_j is factor loading f that the *j-th* variable had on the respective factor
- z is the number of variables for each model selected during the EFA

Then, I computed an index based on all the indexes that I previously obtained. I computed a weighted average between the score of each index and weight. To determine the weight, I adopted the same criteria that is applied by DigComp 2.2 with the computation of the DigComp Index: I assigned to each index the same weight, thus, $1/U$. Again, this index is a [$nx1$] vector. I reported the formula below.

Equation 3: Index – final

$$index = \sum_{t=1}^{U} s_{i,j} * w_j \quad (3)$$

Where:

- U is the number of indexes, thus, 7
- $s_{i,j}$ is the score s that the *i-th* respondent gave to the *j-th* variable
- w_j is the weight w of the *j-th* variable

Finally, I normalized this index, with a score between 0 and 1. By doing so, the results of this index could be interpreted as the percentage of correct replies. To compute the index, I applied the formula below to all the values of the previous index.

In the end, I computed the pairwise correlation among the indexes, which allowed me to answer the second research question.

Equation 4: Index – final normalized

$$index\_norm_i = \frac{index_i - \min\,(index_i)}{\max(index_i) - min(index_i)} \quad (4)$$

4 Results

4.1. A proposed framework to measure the digital competences of civil servants

To answer the first research question, I developed a new framework. Based on my analysis, I took DigComp as the starting reference, because it is the most complete and assesses digital competences from different perspectives. Nevertheless, there is a huge potential to extend and improve it. My objective is to design a framework that could be adopted by PAs to measure digital competences for civil servants, while DigComp was designed for citizens. Thus, it is important to extend the DigComp, to include competences that are specific to the PAs. This extension will be explained in the next four paragraphs:

1. Number of proficiency levels;
2. Additional competence areas;
3. Additional competences;
4. Addition of a new area of assessment.

4.1.1. Number of proficiency levels

DigComp 1.0 only includes 3 different proficiency levels (foundation, intermediate and advanced), while the update to DigComp 2.1 proposes a classification based on eight different levels. The progression of competences acquisition is defined by three different areas, which are: the complexity of the tasks, the autonomy and guidance needed for accomplishing them, and the cognitive domain. This structure is still present in the last version of DigComp, 2.2, and it is based on Bloom's taxonomy and the European Qualification Framework (EQF) (Vuorikari et al., 2022). The EQF is a competence framework that is adopted internationally, so it is useful to provide

comparability to the different measurements performed by different Public Administrations in different geographical areas (Europäische Kommission, 2018).

To produce a synthesis, I differentiate between 6 basic levels (foundation 1 and 2, intermediate 3 and 4, and advanced 5 and 6) and then 2 highly specialized levels, that require a significant level of autonomy and professional competences.

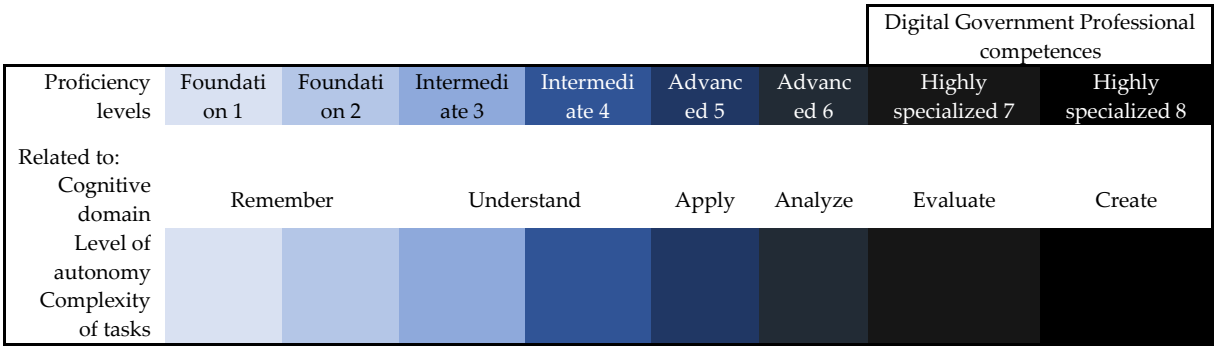
The last 2 levels can be integrated with the characteristics required by a digital professional, as proposed by OCED with its framework, as reported in the paragraph Digital Competences (OECD, 2021). In that paragraph I also detailed the responsibilities and tasks for the new roles that I proposed to add, namely:

- User-centred design professionals;
- Service professional;
- Product professional roles;
- Delivery professionals;
- Data professional roles;
- Technology professionals.

These levels of expertise require an additional competence: the capability to foster and manage innovation. As it emerges from the European e-Competence Framework, ICT specialists need the capacity to challenge the status quo and the right leadership to promote innovative solutions, especially in PAs (European Commission, 2017). This choice enables to design of a comprehensive framework that can describe the digital competences of both basic users and experts.

Figure 3 illustrates the structure of the different proficiency levels. The different colours are meant to highlight the increasing level of autonomy and complexity of the tasks.

Figure 3: Proficiency levels structure



4.1.2. Additional competence areas

The second decision concerns the opportunity to extend the DigComp by adding new areas of competence. DigComp, in fact, completely neglects two relevant aspects: Socio-emotional competences and Leadership competences.

Socio-emotional competences are the third level of the framework proposed by the OECD (OECD, 2021). I propose to add a new area of competence, called "Socio-emotional competences", and to consider each of the 5 Socio-emotional competences proposed by OECD as a new competence of my framework. In Table 7 I reported my proposal for the introduction of this new area of competence.

Table 7: Socio-emotional competences

Area of competence	Competence	Description	Tasks
6. Socio-emotional competences	6.1 Vision	It is important to have visionary people inside the digital government teams, to rethink and redesign the citizen-government experience. Those people have the role to inspire change and build momentum for the digital government agenda. The objective is to turn the imagined vision into a deliverable reality.	• Big-picture thinking • Spotting patterns and trends • Looking at the future
	6.2 Analysis	It is the capacity to collect information, weigh the evidence and respond to the needs that have been found. These competences are needed to provide a solid test for testing assumptions to the visionary.	• Impartially • Rationality
	6.3 Diplomacy	It is the ability to build a relationship, understand how they work and create consensus.	• Connecting with others • Empathy
	6.4 Agility	It represents the capability to ask questions and promptly react to the fast-changing environment around us.	• Adaptability • Quick thinking • Spontaneity
	6.5 Protection	It stresses the importance of the trustworthy use of data and technology, providing trusted, reliable and secure digital government efforts.	• Seeking order • Providing stability • Ensuring security

The second area of competence that I propose to add is "Leadership", the upper competence in the framework proposed by OECD in its framework (OECD, 2021). Leadership is put at the top of the pyramid because, if a civil worker has all the other competences, then being a leader allows a person to actively shape an environment to encourage digital transformation. To define the competences required to be competent in terms of leadership, I choose to base my reasoning on a framework made by OECD (Daniel Gerson, 2020). The result of my analysis is provided in Table 8.

Table 8: Leadership competences

Area of competence	Competence	Description	Tasks
7. Leadership competences	7.1 Values-based leadership	Capability to negotiate multiple and urgent values to guide their decisions making toward the public interest.	• Create value for the society • Embodying and sharing public services values • Managing tensions and trade-offs
	7.2 Open inclusion	Capacity to listen to new and different perspectives, without judging them and ensuring psychological safety.	• Actively seeking out different perspectives and opinions • Create a psychologically safe environment • Managing diversity to achieve better outcomes
	7.3 Organisational stewardship	Capacity to reinforce trust- and value-based culture and equip the workforce with the right competences, tools and working environments.	• Orientation towards future • Guarantee a distributed leadership
	7.4 Networked collaboration	Capacity to collaborate through networks with other government actors.	• Connecting with the actors of the network • Reframing common goals • Decision-making process through collaboration

4.1.3. Additional competences

The DigComp could be further extended through the introduction of competences that are specific for civil servants of PAs, i.e., do not apply to citizens in general. To do so, I analysed the "*Syllabus Competenze digitali per la PA*" (Presidenza del Consiglio dei Ministri - Dipartimento della Funzione Pubblica, 2019). This document is based on DigComp 2.1 but, instead than focuses on citizens, it was specifically designed for civil servants. The Syllabus introduces two elements that were neglected by DigComp, which are the "Online services" and the "Digital transformation". I have included these two elements, to make the DigComp a tool that could be used to measure digital competences for civil servants.

To add these competences to my framework, I assigned competences to the area of competence based on the principle of coherence to the actual structure of DigComp. Table 9 describes my suggestions in terms of new competences that should be added to the DigComp.

Table 9: New competences to the DigComp

Competence Area	Competence	Description
2. Communication and collaboration	2.7 Activate Open Government processes	Practice transparency (access to information and open data), participation (listening and consultation), collaboration and accountability using technology as an enabling factor for the relationship with citizens and the effectiveness of internal innovation processes.
3. Digital Content Creation	3.5 Provide information and content through digital technologies	PAs are obliged to publish online all the modules and forms adopted for the provision of services. Thus, these documents have to be identified and drafted.
	3.6 Responsive design of the PA services	Build the service with responsive design methods using common design patterns within a style guide
	3.7 Ensure a satisfactory Omnichannel Customer Experience	Citizens interact with PAs through many different channels (e-mail, live chat, online forms, …). Civil servants have to ensure a satisfactory customer experience throughout these channels.
4. Safety	4.5 Protecting transactions	PAs have to ensure that citizens can perform digital payments in a safe and easy way
	4.6 Protecting digital citizenship	Ensure inclusive adherence to the ideals of digital citizenship by launching all the necessary activities to make these rights genuinely attainable.
5. Problem Solving	5.5 Managing digital content analytics	It is important to measure the level of satisfaction of citizens with online services offered by PAs
	5.6 Identifying and solving procedural gaps	The process that digitalizes PAs is not simple and linear, it may have many problems. Thus, it is important to find and solve procedural gaps.
	5.7 Management of risk during the digitalization of a PA	The digitalization process of a PA takes a lot of time, involves a lot of resources and is featured a high level of risk. It is crucial to managing that risk.
7. Leadership	7.4 Fostering digital transformation through leadership	Capacity to foster digital transformation inside the PA.

4.1.4. Addition of a new area of assessment

Per each area of competence, the DigComp defines how competent a person is based on three traditional elements, namely: knowledge, skill, and attitude. However, there is also another relevant component: strategies (Horst & Prendergast, 2020). Two people, for example, might have the same level of knowledge, competences, and attitudes, but differ in the capability to achieve some outcomes, either online or offline. Hence, I extend the KSA model, transforming it into the KAS-O (Knowledge, Skill, Attitude, *Outcomes*). To include this level of strategy inside the model, I analyzed the related literature to understand how this element is related to digital competences and determine how to define it for each proficiency level.

A further document that stresses the importance of strategic competences is the book "Digital skills: unlocking the information society" (Van Dijk & Deursen, 2014). Van Dijk defined strategic internet competences as "the capacity to use computer and network sources as the means of reaching particular goals and for the general goal of improving one's position in society". They are believed to be the most advanced internet competences and represent the last, but most important element, to determine the competence level of an individual.

In Table 11, I reported the final version of the extended DigComp framework, called DigCompPA. I underlined the areas of competence and the competences that I proposed to add, but also my proposal in terms of strategic outcome. For each area of competence, I identify a strategic outcome that could be achieved if a civil servant masters the competences of the respective area of competence. I grouped the strategic outcomes into three main categories, and I assigned them a colour code, as displayed in Table 10.

Table 10: Colour code strategic outcomes

Colour code	Description
Relational	The outcome is to improve the relational capabilities of a person
Transversal	The outcome is transversal to all spheres of the life of a person
Professional	The outcome is to obtain benefits at work

Table 11: DigCompPA

Area of competence	Competence	Strategic outcome
1. Information and data literacy	1.1 Browsing, searching and filtering data, information and digital content	Benefits in terms of consciousness of choices both in personal and professional life.
	1.2 Evaluating data, information and digital content	
	1.3 Managing data, information and digital content	
2. Communication and collaboration	2.1 Interacting through digital technologies	Better relationships with the people in your network, in terms of better friendship and relationships with colleagues and parents.
	2.2 Sharing through digital technologies	
	2.3 Engaging citizenship through digital technologies	
	2.4 Collaborating through digital technologies	
	2.5 Netiquette	
	2.6 Managing digital identity	
	2.8 Activate open-government processes	
3. Digital content creation	3.1 Developing digital content	Allows a specialization in a certain professional domain, which leads to better professional opportunities.
	3.2 Integrating and re-elaborating digital content	
	3.3 Copyright and licences	
	3.4 Programming	
	3.5 Ensuring information and content through digital technologies	
	3.6 Responsive design of the pa services	
	3.7 Ensure a satisfactory omnichannel customer experience	
4. Safety	4.1 Protecting devices	More safety for all the domains of the personal life. It has a different polarity compared to 1. And 5. It does not improve your capabilities; instead, it protects you from harm. The result is an increased sense of security during your daily life. Thus, for example, you can better manage your money without the risk of losing them.
	4.2 Protecting personal data and privacy	
	4.3 Protecting health and well-being	
	4.4 Protecting the environment	
	4.5 Protecting transactions	
	4.6 Protecting digital citizenship	
5. Problem-solving	5.1 Solving technical problems	Benefits in terms of the autonomy of choices both in personal and professional life.
	5.2 Identifying needs and technological responses	
	5.3 Creatively using digital technology	
	5.4 Identifying digital competence gaps	
	5.5 Managing digital content analytics	
	5.6 Identify and solve procedural gaps	
6. Leadership competences	6.1 Values-based leadership	Greater capacity to move inside the organization, with increased organizational dynamics. It allows them to reach better professional positions.
	6.2 Open inclusion	
	6.3 Organisational stewardship	
	6.4 Networked collaboration	
	6.5 Digital transformation	
7. Socio-Emotional Competences	7.1 Vision	Greater soft competences in all spheres of individual life. It allows having a better relationship with people, together with benefits for psychological health.
	7.2 Analysis	
	7.3 Diplomacy	
	7.4 Agility	
	7.5 Protection	

4.2. Analysis of the survey

To answer the second research question, my findings commence with the results of the EFA. As already explained, the EFA analysis is an iterative process. Nevertheless, some general considerations could be made which are valid for all the EFA analyses and I reported them at the beginning of this chapter. To clarify, I performed one EFA analysis, subdivided into four parts, for sections 3 to 6 of the survey. There are different reasons why I opted for this approach. An EFA conducted on more than 100 variables would likely produce results with not enough significance for them to be relevant. A greater number of variables would increase the complexity of the results and their interpretability. The correlations among various items belonging to different sections are so insignificant that the results of an EFA would be unsatisfactory. I will now report a detailed description of the EFA analysis on the different modules of the survey. I decided not to report the analysis for the Engagement section because this module has been included for further investigations that do not concern this study.

4.2.1. Test

Initially, the factorability of the 19 items was examined. Several well-recognised criteria for the factorability of a correlation were employed.

Only 5 of the 19 items had a correlation of .3 or greater with at least one other item, suggesting unreasonable factorability. In addition, the correlation matrix outlines that variable *testpa_sic3* has a standard deviation equal to 0, it is therefore a constant. It represents the most extreme case of a restricted score range, which is the reason why I removed it (Bollen & Long, 1993; Lorenzo-Seva & Ferrando, 2021).

Based on the descriptive statistics that I computed in Table 21, there is evidence of univariate non-normality because 9 items out of 19 have either a $skewness > 2.0$ or $kurtosis > 7.0$, which outlines the need for a Polychoric correlation matrix. In addition, there are 3 items with a $kurtosis > 50.0$. To ascertain the multivariate

normality, I applied Mardia's kurtosis test. The expected kurtosis is 1224 and Mardia's multivariate kurtosis was 1426.804 ($\chi 2\ (1)\ =\ 499.838, p\ <\ .001$). As a result, data are not multivariate normal. This is an additional element that suggests that the EFA is unfeasible.

The Kaiser-Meyer-Olkin measure of sampling adequacy was .5151, below the recommended value of .7. The determinant is reported to be .000 but this figure is specious. Stata only reported these results to three decimal places, meaning that the determinant is less than .001. So, it was important to check whether it was actually equal to 0 or not. Bartlett's test of sphericity also tests whether the determinant of the matrix is zero. In this case, it statistically rejected the hypothesis that the correlation matrix was an identity matrix ($\chi 2(91) = 132.59, p < .03$). Thus, the determinant was not zero. It is therefore not possible to run an EFA analysis in this section of the pilot survey considering that items could not be grouped into factors.

4.2.2. Online activities

The data was screened for univariate outliers, but no outliers were found. The minimum amount of data for factor analysis was satisfied, with a final sample size of 119 (using listwise deletion), with over 3 cases per variable.

Initially, I excluded the variable *att_ecom* because it was the only multiple-choice question, and it would have altered the analysis of this module and it was not relevant to the EFA. The factorability of the 35 items was examined and several well-recognized criteria for the factorability of a correlation were used.

Only 17 of the 35 items had a correlation of .3 or greater with at least one other item, suggesting unreasonable factorability. In addition, the correlation matrix outlines that variable *att_com1* has a standard deviation equal to 0, it is therefore a constant. It represents the most extreme case of a restricted score range, which is the reason why I removed it (Bollen & Long, 1993; Lorenzo-Seva & Ferrando, 2021).

Based on the descriptive statistics that I computed in Table 22, there is evidence of univariate non-normality because 11 items out of 34 have either a $skewness > 2.0$ or $kurtosis > 7.0$. In addition, there is 1 item (*att_so6*) with a $kurtosis > 50.0$, which would make Polychoric correlation not robust; therefore I removed it. To ascertain the multivariate normality, I applied Mardia's kurtosis test. The expected kurtosis is 1224 and Mardia's multivariate kurtosis was 1506.804 ($\chi 2\ (1) = 515.838, p < .001$). As a result, data are not multivariate normal. These results outline the need for a Polychoric correlation matrix.

The Kaiser-Meyer-Olkin measure of sampling adequacy was .5849, below the recommended value of .7. The determinant is reported to be .000 but this figure is specious. Stata only reported these results to three decimal places, meaning the determinant is less than .001. So, it was important to check whether it was actually equal to 0 or not. Bartlett's test of sphericity also tests whether the determinant of the matrix is zero. In this case, it statistically rejected the hypothesis that the correlation matrix was an identity matrix ($\chi 2(561) = 1182.667,\ p < .001$). Given these overall indicators, factor analysis was conducted with all 34 items.

To proceed, I computed the number of factors that have to be retained. Since there is no infallible method to determine the exact number of factors, I chose to compare the results of three different methods. The first method was the scree plot with the $eingenvalues > 1$ criteria. I reported the result in Figure 4, which suggests retaining up to 7 factors. The second method is the Parallel Analysis, which suggests retaining up to 1 factor. As emerges from Figure 5, only the first random eigenvalue is greater than real eigenvalues. Lastly, I applied the Minimum Average Partials procedure, which suggests retaining up to 2 factors. As emerges from Table 12, the minimum value corresponds to the solution with 2 factors.

Figure 4: Scree plot – Online activities

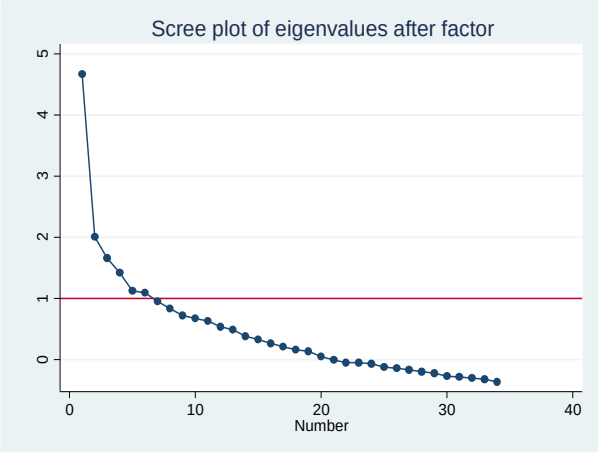


Figure 5: PA – Online activities

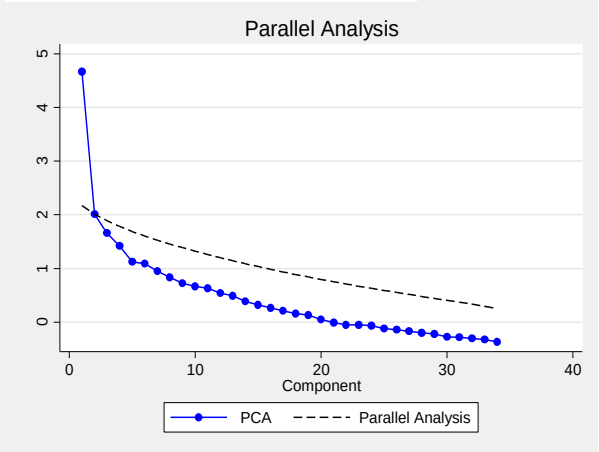


Table 12: MAP – Online activities

m	0	1	2	3	…….	33
f	.02675	.01536	.01532	.01556	…….	1

I examined solutions from seven to one factors. It was hypothesized that the seven-factors model would have been the best option since this module of the survey is made up of seven groups of questions. In reality, there was an additional module of this section, the one composed by the item *att_ecom*, but since I did not consider that variable, I did not expect to have eight factors. This hypothesis was not confirmed because the best model appeared to be the one with five factors, as you can see from Table 13. All the models converged properly and produced reasonable parameter estimates. Nevertheless, the first two models, the ones with 7 and 6 variables, were discarded since their last factor was composed of only 2 variables. The choice was made between the model with 5 and 4 factors since they had similar results. The final choice was to retain 5 factors because it was the model with the highest percentage of variance explained (31.99%); it had the highest number of items with significant communalities (9.09%) and it had the lowest RMSR value (.041). A further reason that led to this choice was that "underextraction is more dangerous than overextraction, so

it may not be a bad strategy to risk the overextraction of one or two factors" (Kline, 2013).

Table 13: Model comparison – Online Activities

Name of the model	% of variance explained	% of communalities >.50	RMSR	Min Alpha coefficient
Model 5	31.99%	9.09%	.041	.4524
Model 4	28.68%	8.00%	.048	.5654
Model 3	24.51%	0%	.056	.5039
Model 2	19.63%	0%	.065	.4625
Model 1	13.73%	0%	.079	.8218

Considering the five-factors model, during several steps, a total of 12 items were eliminated because they did not contribute to a simple factor structure and failed to meet a minimum criterion of having a primary factor loading of .31 or above, and no cross-loading of .3 or above. In Table 23 I reported, for all the models I evaluated, which items I discarded, in which stage, and the reason for their exclusion.

I conducted a principle-components factor analysis of the remaining 22 items, using promax rotation. All items had primary loadings over .31 and there were no cross-loadings among factors. The factor loading matrix for this final solution is presented in Table 14.

During the selection process, I considered as a parameter the RSMR. For the five-factors model, the RMSR value is .041, which is below the threshold that is suggested in the literature. In addition, the 4.71% of absolute residuals were greater than .10, which is not an alarming result. Overall, these results do not suggest a model misfit.

Then, I examined the internal consistency for each of the scales using Cronbach's alpha. The alpha was moderate -- .74, for Factor 1 (6 items), and low for Factor 2 (5 items), .66; Factor 3 (3 items), .45; Factor 4 (5 items), .51; Factor 5 (3 items), .58.

Last, I provided a qualitative interpretation of the factors. I will now define the factor names, while in Table 14 I specified which items are associated with each factor. Software confidence (Factor 1) describes the capability to customize and use the software according to the specific person's needs. Data manipulation (Factor 2) describes the capability to use the software to modify texts, run advanced computations and make presentations. Privacy management (Factor 3) describes the capability of a person to safely browse online, to actively decide which information to share and how to limit the sharing of some information. PA tools (Factor 4) describes the capability of a civil servant of the Piedmont region to use the specific tools of its PA, alongside the coding ability. PA document management (Factor 5) describes the capability of a civil servant to manage digital documents inside the Piedmont region.

Table 14: Pattern matrix, Communalities, and Cronbach's Alphas – Online Activities

	Factor					
Variable	1	2	3	4	5	Communalities
att_pc2	.750					.569
att_pc1	.705					.468
att_pc3	.642					.417
att_com2	.595					.364
att_se3	.506					.383
att_pa2	.355					.341
att_so3		.732				.479
att_so1		.537				.401
att_so4		.502				.359
libreoffice		.457				.312
att_so2		.310				.312
att_sic4			.669			.561
att_se5			.614			.428
att_sic3			.311			.157
att_so6				-.609		.354
comunica				.505		.327
intranet				.493		.353
procirisweb				.437		.283
forma				.329		.256
stilo					.708	.495
contabilia					.584	.394
doquiacta					.365	.266
Eigenvalues	3.425	1.649	1.228	1.113	.863	
% of Total Variance	15.57%	7.50%	5.58%	5.06%	3.92%	
Total Variance	37.64%					
Number of items	6	5	3	5	3	
Cronbach's Alpha	.743	.661	.452	.501	.575	

4.2.3. Self-assessment

The data was screened for univariate outliers, but no outliers were found. The minimum amount of data for factor analysis was satisfied, with a final sample size of 119 (using listwise deletion), with over 3 cases per variable.

Initially, the factorability of the 39 items was examined. Several well-recognised criteria for the factorability of a correlation were used.

37 of the 39 items had a correlation of .3 or greater with at least one other item, suggesting unreasonable factorability.

Based on the descriptive statistics that I computed in Table 24, there is evidence of univariate non-normality because 6 items out of 39 have a $kurtosis > 7.0$. The expected kurtosis is 1559 and Mardia's multivariate kurtosis was 1755.777 ($\chi 2\ (1) = 228.651, p < .001$). As a result, data are not multivariate normal. These results outline the need for a Polychoric correlation matrix.

The Kaiser-Meyer-Olkin measure of sampling adequacy was .877, well above the recommended value of .7. The determinant is reported to be .000 but this figure is specious. Stata only reported these results to three decimal places, meaning that the determinant is less than .001. So, it was important to check whether it was actually equal to 0 or not. Bartlett's test of sphericity also tests whether the determinant of the matrix is zero. In this case, it statistically rejected the hypothesis that the correlation matrix was an identity matrix ($\chi 2(741) = 3035.460,\ p < .001$). Given these overall indicators, factor analysis was conducted with all 39 items.

To proceed, I computed the number of factors that has to be retained. Since there is no infallible method to determine the exact number of factors, I chose to compare the results of three different methods. The first method was the scree plot with the $eingenvalues > 1$ criteria. I reported the result in Figure 6, which suggests retaining up to 7 factors. The second method is the Parallel Analysis, which suggests retaining up to 2 factors. As emerges from Figure 7, the first two random eigenvalues are greater

than real eigenvalues. Lastly, I applied the Minimum Average Partials procedure, which suggests retaining up to 7 factors. As emerges from Table 15, the minimum value corresponds to the solution with 7 factors.

Figure 6: Scree plot – Self-assessment

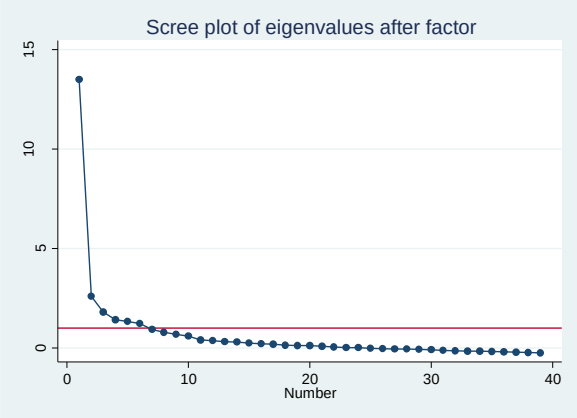


Figure 7: PA – Self-assessment

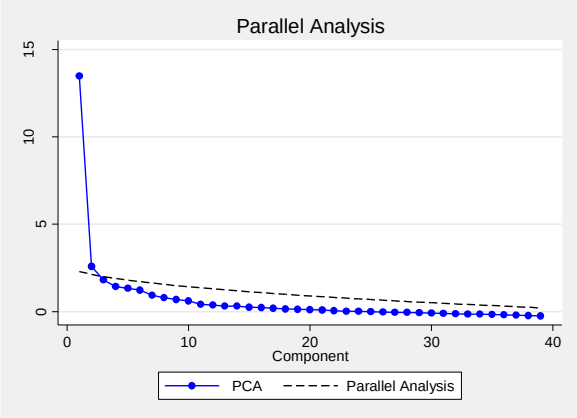


Table 15: MAP – Self-assessment

m	0	1	2	3	4	5	6	7	8	.....	38
f	.12355	.02512	.02086	.02088	.02049	.02010	.01948	.01941	.01958	.....	1

I examined solutions from seven to two factors. It was hypothesized that the seven-factor model would have been the best option since this module of the survey consists of seven groups of questions. This hypothesis was confirmed, because that model showed better performance compared to the other two, as you can see from Table 16. All the models converged properly and produced reasonable parameter estimates. Nevertheless, the choice was made between the model with 7 and 6 factors since they had similar results. The final choice was to retain 7 factors because it was the model with the highest percentage of variance explained (58.60%); it had the highest number of items with significant communalities (64.86%), and it had the lowest RMSR value (.025). A further reason that led to this choice was that "underextraction is more dangerous than overextraction, so it may not be a bad strategy to risk the overextraction of one or two factors" (Kline, 2013).

Table 16: Model comparison – Self-assessment

Name of the model	% of variance explained	% of communalities >.50	RMSR	Min Alpha coefficient
Model 7	58.60%	64.86%	.025	.6185
Model 6	56.19%	63.16%	.029	.6185
Model 5	53.01%	57.89%	.034	.6389
Model 4	49.57%	52.78%	.036	.6389
Model 3	45.91%	48.57%	.035	.7551
Model 2	41.25%	40.00%	.051	.9849

Considering the seven-factors model, during several steps, a total of two items (*self_communication_6, self_operational_1)* were eliminated because they did not contribute to a simple factor structure and failed to meet a minimum criterion of having a primary factor loading of .31. In Table 25 I reported, for all the models I evaluated, which items I discarded, in which stage, and the reason of their exclusion.

I conducted a principle-components factor analysis of the remaining 37 items, using promax rotation. All items had primary loadings over .31 and there were no cross-loadings among factors. The factor loading matrix for this final solution is presented in Table 17.

During the selection process, I considered as a parameter the RSMR. For the seven-factors model, the RMSR value is .025, which is below the threshold that is suggested in the literature. In addition, only .6% of absolute residuals were greater than .10, which is a fantastic result. Overall, these results do not suggest a model misfit.

Then, I examined the internal consistency for each of the scales using Cronbach's alpha. The alpha was high -- .86, for Factor 1 (7 items); Factor 2 (8 items), .91; Factor 3

(4 items), .89; Factor 4 (5 items), .87; Factor 5 (5 items), .82; moderate -- .74, for Factor 6 (4 items); low -- .62, for Factor 7 (4 items).

Last, I provided a qualitative interpretation of the factors. I will now define the factor names, while in Table 17 I specified which items are associated with each factor. Online search easiness (Factor 1) describes the capability of a person to find the right tool, and the right shortcuts to browse online, but also the easiness to find the information needed. Digital content manipulation (Factor 2) represents the capability of a person to create and manipulate digital content, like images, videos, audio, presentations, or digital identity. Smartphone confidence (Factor 3) describes the employee confidence and awareness when using a smartphone, in terms of finding and installing a new app, but also tracking the costs and the permissions to apps. File management (Factor 4) describes the capability of an employee to download and open a file from the web thanks to the correct shortcuts. Network communication (Factor 5) describes an employee's capability to interact with other people, by choosing which information can be exchanged and by which means. Digital means exploitation (Factor 6) describes the capability to get the most out of digital technologies, like finding projects and opportunities, achieving better results, and enlarging the social network. Information search awareness (Factor 7) describes the awareness of an employee when searching for information online. This, in turn, allows him to find the right information without getting tired.

Table 17: Pattern matrix, Communalities, and Cronbach's Alphas – Self-assessment

	Factor							
Variable	1	2	3	4	5	6	7	Communalities
self_infor~2	.863							.763
self_infor~1	.849							.770
self_forma~6	.685							.530
self_infor~4	.648							.409
self_forma~3	.599							.627
self_forma~5	.489							.403
self_forma~7	.403							.412
self_conte~5		.893						.749
self_conte~3		.840						.645
self_conte~2		.813						.642
self_conte~1		.780						.728
self_conte~4		.763						.685
self_conte~6		.557						.568
self_strat~4		.459						.486
self_commu~7		.442						.490
self_mobil~2			.930					.845
self_mobil~1			.891					.850
self_mobil~4			.728					.634
self_mobil~3			.693					.692
self_opera~4				.819				.695
self_opera~5				.706				.722
self_opera~2				.591				.681
self_forma~1				.499				.663
self_opera~3				.408				.462
self_commu~2					.792			.616
self_commu~1					.777			.634
self_commu~5					.736			.613
self_commu~4					.619			.522
self_commu~3					.438			.431
self_strat~5						.806		.630
self_strat~2						.794		.678
self_strat~3						.517		.424
self_strat~1						.445		.438
self_forma~4							.611	.412
self_forma~8							.566	.333
self_forma~2							.492	.348
self_infor~3							.471	.335
Eigenvalues	12.465	2.544	1.748	1.372	1.325	1.182	.921	
% of Total Variance	33.69%	6.88%	4.72%	3.71%	3.58%	3.20%	2.49%	
Total Variance	58.27%							
Number of items	7	8	4	5	5	4	4	
Cronbach's Alpha	.855	.906	.891	.867	.823	.736	.618	

4.2.4. Interpretation and Validation of the EFA results

Based on the factors computed during the EFA analysis, I calculated nine indexes. Then, to answer the second research question, I computed the pairwise correlation among them, and I reported the result in Table 18.

To answer the RQ.2.1, I considered the correlation between the due indexes that belong to the same section of the pilot survey, which is: .905 for Online activities; .996 for Self-assessment; .975 for Engagement. The three correlation coefficients are all greater than .9, and two of them are almost 1.0. This result means that measuring digital competences through either the items of the survey or the factors (thus, the items that are related to those factors), returns almost the same result.

To answer the RQ.2.2, I considered the correlation between different sections of the survey. The Test index has low scores ($< .40$) with the other indexes. This means that it measures different competences, thus, this section of the survey has to be retained. Nevertheless, it is important to add some items to obtain results that are closer to the ones of the other sections of the survey. The Online activities and the Self-assessment indexes have a moderate correlation ($\approx .50$) among them. Thus, my conclusion is that they measure the same digital competences, utilizing different approaches. As a result, either section 4 or section 5 could be removed from the survey, if time constraints require a more synthetic tool.

I propose to remove the Self-assessment section because the Online activities section is based on the recommendations and the items proposed by Istat. Therefore, the items that belong to Online activities can be used as a benchmark with those used by Istat.

Table 18: Correlation coefficients among Indexes

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) test_avg	1.000								
(2) att_avg	.381	1.000							
(3) att_efa	.402	.905	1.000						
(4) self_avg	.278	.552	.493	1.000					
(5) self_efa	.273	.554	.499	.996	1.000				
(6) eng_avg	.076	.181	.177	.285	.295	1.000			
(7) eng_efa	.067	.155	.156	.293	.302	.975	1.000		
(8) index	.264	.546	.505	.939	.945	.581	.594	1.000	
(9) index_norm	.264	.546	.505	.939	.945	.581	.594	1.000	1.000

4.2.5. Problems of the survey

A thorough analysis of the pilot survey outlined some questions with some "I do not know what you mean" as a response (13 questions, from 2.5% to 8.4% of the total responses). I studied these responses to determine whether they were related to a problem with the questions. My conclusion is that, in some cases, the questions were affected by some issues, and I report the major ones:

- The question is too long (2 items);
- The question contains unknown terms (3 items);
- The questions were too general, without providing a concrete example (7 items).

5 Discussion

5.1. Contribution to the academic scientific literature

My study contributes to academic scientific literature in several respects. I carried out a comprehensive literature review on the actual frameworks available on digital competences and I classified them. Based on that, I highlighted the main literature gaps that emerged, and I proposed a framework that aims at filling those gaps: the DigCompPA. DigCompPA is based on DigComp 2.2, but I extended it with new areas of competence, new competences, and better clarification of the highly specialized roles. In addition, I proposed a new model to assess competences. In the literature there is the KSA (Knowledge, Skills, and Attitude) model but, as I explained, this framework is not comprehensive in measuring digital competences. My model is called KSA-O (Knowledge, Skills, Attitudes, and *Outcomes*), and it considers the capability to achieve some outcomes, either online or offline. With this addition, the framework can distinguish the digital competences possessed by an individual on a strategic level, and this is a novelty.

I also crafted and analyzed a pilot survey based on quantitative analysis. As it emerged from the literature review, there are no examples of surveys that aim at measuring the level of digital competences of a civil servant. Thus, the creation of this survey is already a contribution to the literature. In addition, as a result of the EFA analysis, I provided a list of factors that could be used instead of the items that are present in the survey. Furthermore, the qualitative analysis and interpretation of the factors could be useful from an academic standpoint to define new determinants of digital competences for public employees. Additionally, I determined which relevant sections of the survey should be kept to measure digital competences effectively.

5.2. Policy and Managerial implications

Based on the results of the literature review, I am confident that the output of my thesis will be useful for the PAs. So far, the information regarding digital competences and how to measure them were contained in many different frameworks, and this process was overly time-consuming. Now, thanks to my DigCompPA, all those information is contained in a single document, and this improves the process. Having all the information readily available in a single framework will bring relief to the PAs' bureaucratic work. It also helps them to achieve a common understanding of how to measure digital competences for public employees. In turn, this would lead to increased comparability of results among PAs because they could all use the same framework. The introduction of new areas of competence, new competences specific to the PA, the definition of highly specialized roles and a new driver to measure digital competences – through the KSA-O model – will increase the completeness of the measurements. Furthermore, DigCompPA lists many practical tasks that could be easily monitored by PAs.

In regard to the survey, it could be considered a starting point for PAs and it will help them to will enable them to cut costs and be time-efficient. If different PAs used the same survey to measure the digital competences of their employees, there would be comparable results. As a result, common actions could be taken, like a unified strategy at a national level that aims at measuring and improving digital competences for public employees. If PAs knew how to measure the level of digital competences of their employees, they could upskill their employees based on their competences gap. The customization of the employees' training programs will increase their effectiveness, but also efficiency, with consequent improvements.

5.3. Summary of research results

In Table 19 I summarize the answers to my research questions:

Table 19: Answers to Research Questions

Research Questions	Answers
RQ.1 How to build a complete framework to define digital competences for civil servants?	By performing a qualitative analysis of the literature, to detect the frameworks that are already available. Then, selecting a framework that could be considered as a reference (DigComp 2.2), and then extending it with the relevant elements of the other frameworks. I followed this process, and the result is my DigCompPA.
RQ.2 How to measure digital competences among public servants?	Based on my analysis, a survey questionnaire is a valid solution because it provided insightful results.
RQ.2.1 What are the fundamental items that should be measured?	Items that belong to the Test section have to be retained since they measure digital competences differently compared to the other modules of the survey. Regarding the sections of Online activities and Self-assessment, they measure almost the same competences. Thus, I propose to delete the Self-assessment section.
RQ.2.2 Do different measurement approaches yield different results?	I concluded from the correlation coefficients among the different sections of the survey, reported in Table 18, that they have a remarkable impact.

6 Conclusions

I structured my analysis of the measurement of digital competences around the two main areas of interest. The first one considered the current frameworks available on digital competences, with a focus on those on public employees. The aim was to understand if the literature already proposed a thorough framework, specifically for the public sector. To answer my first research question, I applied a qualitative analysis of the academic literature, and my findings show that the available frameworks lack a comprehensive approach. Every framework proposes to measure digital competences differently and according to different evaluation measures. I proposed a framework to take into account all the relevant elements that emerged from the literature, which I called DigCompPA. In addition, I proposed a new model, called KSA-O, which is an extension of the KSA model that is already present in the literature.

The second focal point was the quantitative analysis of a pilot survey. In collaboration with the Digital Agenda Observatory of Politecnico di Milano, we developed a survey to measure the digital competences of the civil servants of the Piedmont region. This survey allowed me to offer a valid answer to my second research question; we developed it to effectively measure digital competences. In addition, my analysis of the survey highlighted which are the most important elements that should be taken into consideration and which portions of the survey could be removed.

6.1. Limitations

However, this dissertation is not without limitations. This study presents three main areas that could benefit from further research.

Firstly, DigComp does not provide any objective and defined criteria to assign competences to areas of competence. My decision about that choice was based on my analysis of the DigComp, but since there are no guidelines, they could be questioned.

Secondly, among the 152 participants, 32 did not respond to the survey, thus, the significance of the results achieved could be biased due to the sample size. While the respondents to the survey were purposely selected to represent a variegated population, I could not exclude a bias. All the respondents belong to the Piedmont region, and they may have different socio-cultural characteristics compared to civil servants from other regions or nations. Lastly, the participation in the survey was not based on a voluntary initiative. Thus, the respondents may have lacked motivation which could have led to biases in their responses.

The last limitation regards the EFA analysis. I based the qualitative interpretation of the factors on the knowledge I obtained through my analysis, leading to the possibility of misinterpreting the factors. Different researchers may choose to name the factors differently since there is no unique way to correctly label them.

6.2. Future development

Starting from those limitations, I offer some outlooks for future research to extend and refine this study. Since limitations are mainly due to the lack of data availability, future research may replicate this study using a more comprehensive and better-refined dataset as input. In order to make conclusions more generalizable, the geographical scope of the analysis can be extended. It could be done by looking at a broader but similar context, such as the national or European one. The best outcome would be to

issue the same survey to several PAs, to increase the comparability of the results. This outcome could be achieved if different PAs agreed on a common strategy in terms of digital competences.

An important opportunity for future research would be to improve and enlarge this pilot survey. To do so, it would be important to integrate it with the DigCompPA, but also to modify the current items based on the problems I found.

My thesis aimed at designing a tool to measure digital competences, and not measuring the actual level of digital competences that emerged from the survey. This analysis could be carried out in future research. For example, since I already computed the factors, they could be used for additional analysis, such as cluster analysis to create clusters of respondents.

Regarding the assignment of competences to the respective areas of competence, I suggest organizing events where stakeholders and policymakers to replicate the process that led to the creation of the DigComp.

Given the limitations listed above, the framework presented is not supposed to be considered a finish line rather, it is intended as a preliminary starting point that sets the stage for new avenues of research.

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8 Appendix

Table 20: Description of the items of the survey

Area of survey	Variable	Description	Codification
1. Socio-economic data	1. gender	Gender	
	2. anno_nascita	Year of birth	
	3. provincia	Province of residence	
	4. popolazione	Number of habitants in the location of residence	
	5. citt	Citizenship	
	6. studio	Highest qualification achieved	
	7. iscrizione	Current enrolment in schools, courses or institutes	
	8. reddito	Monthly net income of the household	
	9. Residenza	Home ownership	
	10. cohabitation	Do you currently live with other people?	
	11. categ	Contractual category	
	12. fam_prof	Professional family	
2. Access to digital	1. smartp	Do you have a smartphone?	
	2. pc	Do you have a pc?	
	3. internet_accesso	Do you have internet access at home?	
	4. internet_uso	In the past 3 months, have you ever used the internet at home, at work or elsewhere?	
	5. rds	Have you ever used the RDS mobile app in the past 3 months?	
3. Test	1. test_operat	What key combination is used to cut content?	1 if correct, 0 otherwise
	2. test_form	Which key allows you to move between entry fields in a form?	
	3. test_inform	Which formulation allows you to find pages that report an exact phrase?	
	4. test_comm	What audience is a site with online games and pop forums aimed at?	
	5. test_contcre	What term does not identify a type of license?	
	6. test_strat	Which social network is suitable for the search for job opportunities?	
	7. testpa_info1	On which portal do I compare an original text of the law with the current text?	
	8. testpa_op1	Which key allows you to move between entry fields in a form?	
	9. testpa_probsolv1	What activities can I not do with pagopa?	
	10. testpa_probsolv2	What type of software is best suited for editing data tables?	
	11. test_probsolv3	With which digital signature can a native digital document be signed?	
	12. testpa_com1	Which expression is best suited for an email addressed to a new executive?	
	13. testpa_com2	As a citizen, how can I access the online services of Piedmont region?	

	14. testpa_cont1	Which of the following files is a media file?	
	15. testpa_sic1	Which option is certainly an invasion of privacy?	
	16. testpa_sic2	Which of the following behaviors causes a risk of virus infection?	
	17. testpa_sic3	Which of the following is a characteristic of a "strong" password?	
	18. testpa_trasfd1	Which of these is not an advantage of using open data in pas?	
	19. testpa_trasfd2	Which of the following statements best represents the role of the RTD?	
4. Online activities	1. att_com1	Sending or receiving e-mails	0="No" or "I do not know what you mean", 1="Yes"
	2. att_com2	Make calls or video calls	
	3. att_com3	Participate in social networks	
	4. att_ecom	In the last month, what tools have you used for your work?	1="Never", 2="1-2 times", 3="3-5 times", 4="6-10 times", 5="More than 10 times"
	5. att_pa1	Find information on PA websites or apps	0="No" or "I do not know what you means", 1="Yes"
	6. att_pa2	Submit completed forms online	
	7. att_pc1	Copy or move files between folders or between devices	
	8. att_pc2	Download or install software or apps	
	9. att_pc3	Change software, app, or device settings	
	10. att_se1	Look for health information	
	11. att_se2	Book a doctor's visit, a swab, or a vaccine	
	12. att_se3	Use banking services	
	13. att_se4	Sell goods or services	
	14. att_se5	Search for information on goods or services	
	15. att_se6	Take an online course	
	16. att_sic1	Read the privacy policies before providing your data	
	17. att_sic2	Limit or deny access to your geographical location	
	18. att_sic3	Restrict access to social networks or sharing services	
	19. att_sic4	Deny the use of your personal data for advertising purposes	
	20. att_sic5	Check the security of websites before providing data	
	21. att_sic6	Require admins to access the data they hold	
	22. att_so1	Word processing software	
	23. att_so2	Create presentations	
	24. att_so3	Use spreadsheets for calculations	
	25. att_so4	Advanced functions of spreadsheets	
	26. att_so5	Software to edit photos, videos, or audio	
	27. att_so6	Write a computer program	
	28. doquiacta	It is a specific tool of Piedmont region	1 if select, 0 otherwise
	29. comunica		
	30. libreoffice		
	31. intranet		
	32. forma		
	33. procirisweb		
	34. stilo		

	35. apro		
	36. contabilia		
5. Self-assessment	1. self_operational_1	I know how to open files downloaded from the web	-2="Not at all" or "I do not know what you mean", -1, 0, +1, +2="Totally"
	2. self_operational_2	I know how to download / save a photo found online	
	3. self_operational_3	I know how to use keyboard shortcuts	
	4. self_operational_4	I know how to open a new tab in a browser	
	5. self_operational_5	I know how to bookmark a site	
	6. self_mobile_1	I know how to download and install apps on a smartphone	
	7. self_mobile_2	I know where I can find a new app for my smartphone	
	8. self_mobile_3	I know how to deny permissions to apps on my smartphone	
	9. self_mobile_4	I know how to track smartphone app costs	
	10. self_formal_1	It is easy for me to find a site that I have already visited	
	11. self_formal_2	I often get tired when I search for information online	
	12. self_formal_3	I easily find the links to pages, texts, images, menus	
	13. self_formal_4	Sometimes I end up on a site not knowing how I got there	
	14. self_formal_5	I feel comfortable using work applications	
	15. self_formal_6	The way websites are designed puts me at ease	
	16. self_formal_7	I am comfortable managing my digital identity	
	17. self_formal_8	I feel more comfortable editing paper documents	
	18. self_information_1	I find it easy to decide which keywords to use for an online search	
	19. self_information_2	I easily locate the tool for my online searches	
	20. self_information_3	I should take a course on how to find information online	
	21. self_information_4	I rarely find it difficult to verify information online	
	22. self_communication_1	I know what information I can share online	
	23. self_communication_2	I am attentive to appropriate comments and behaviour	
	24. self_communication_3	I find it easy to interact and exchange information online	
	25. self_communication_4	I'm comfortable figuring out who to send an email to	
	26. self_communication_5	I know how to choose who I share my content with online	
	27. self_communication_6	I know how to remove people from my contact list	
	28. self_communication_7	I am comfortable creating an online profile or an avatar	
	29. self_contentcreation_1	I know how to create something from images, audio, or video	
	30. self_contentcreation_2	I know how to make simple edits to other people's content	
	31. self_contentcreation_3	I know how to create a digital form	
	32. self_contentcreation_4	I can create a presentation	
	33. self_contentcreation_5	I am confident in the quality of my video content	
	34. self_contentcreation_6	I feel confident writing comments	
	35. self_strategic_1	The internet helped me to find projects and opportunities	
	36. self_strategic_2	Digital allows me to achieve better results	
	37. self_strategic_3	Social media helps me make friends and build relationships	
	38. self_strategic_4	Applications and software help me manage savings	
	39. self_strategic_5	Work applications make me more productive	
6. Engagement	1. engage_vigore_1	When I wake up, I want to go to work	-2="Not at all", -1, 0, +1, +2="Totally"
	2. engage_vigore_2	When I'm at work, I feel full of energy	
	3. engage_vigore_3	I hold on even when things don't go well	

	4. engage_vigore_4	I could continue to work for hours without taking a break	
	5. engage_vigore_5	At work, I am mentally resilient	
	6. engage_vigore_6	When I am at work, I feel strong and vigorous	
	7. engage_dedizione_1	For me, my job is challenging	
	8. engage_dedizione_2	My work is a source of inspiration for me	
	9. engage_dedizione_3	I am enthusiastic about my job	
	10. engage_dedizione_4	I am proud of the work I do	
	11. engage_dedizione_5	I believe the work is full of meaning and value	
	12. engage_dedizione_6	I have goals suited to my professionalism	
	13. engage_dedizione_7	I have a strong sense of belonging to the organization	
	14. engage_focus_1	When I work, I forget everything around me	
	15. engage_focus_2	Time flies when I'm at work	
	16. engage_focus_3	When I work, I often let myself be carried away by thoughts	
	17. engage_focus_4	I find it difficult to detach myself from my work	
	18. engage_focus_5	I feel immersed in my work	
	19. engage_focus_6	I feel happy when i work hard	
	20. engage_focus_7	I feel fatigued because I jump from one activity to another	

8.1. Exploratory Factor Analysis

8.1.1. Test

Table 21: Descriptive statistics –Test section

Variable	N	mean	sd	min	max	skewness	kurtosis
test_operat	120	3.6333	.7326	1	4	-2.0138	6.2573
test_form	120	3.9250	.4331	1	4	-6.0156	38.7311
test_inform	120	1.7250	1.1520	1	4	1.1469	2.5944
test_comm	120	1.0083	.0913	1	2	10.8170	118.0084
test_contcre	120	3.3583	1.0595	1	4	-1.3915	3.3971
test_strat	120	1.0250	.1568	1	2	6.0849	38.0256
testpa_info1	120	2.5667	.5611	1	4	.0225	2.2545
testpa_op1	120	2.7583	.5500	1	3	-2.1923	6.6889
testpa_pro~1	120	2.9583	1.3559	1	4	.6148	1.4902
testpa_pro~2	120	1.0250	.2034	1	3	8.6483	79.7437
test_probs~3	120	3.0750	.7796	1	4	-1.0922	4.5182
testpa_com1	120	1.8667	.3414	1	2	-2.1573	5.6538
testpa_com2	120	2.1333	.4662	1	4	1.4463	7.1631
testpa_cont1	120	1.2667	.6316	1	4	2.5374	9.0723
testpa_sic1	120	2.9083	.4490	1	4	-3.1983	14.8440
testpa_sic2	120	2.9500	.2855	1	3	-5.9939	38.9598
testpa_sic3	120	1.0000	.0000	1	1	.	.
testpa_tra~1	120	2.3667	1.0919	1	4	.1813	1.5646
testpa_tra~2	120	2.0917	.5185	1	4	2.6704	11.6316

8.1.2. Online activities

Table 22: Descriptive statistics – Online activities

Variable	N	mean	sd	min	max	skewness	kurtosis
att_com2	119	.8908	.3133	0	1	-2.5053	7.2765
att_com3	119	.5882	.4942	0	1	-.3586	1.1286
att_se1	119	.8403	.3678	0	1	-1.8583	4.4532
att_se2	119	.7983	.4030	0	1	-1.4869	3.2110
att_se3	119	.7479	.4361	0	1	-1.1418	2.3037
att_se4	119	.2101	.4091	0	1	1.4234	3.0260
att_se5	119	.9496	.2197	0	1	-4.1093	17.8864
att_se6	119	.7647	.4260	0	1	-1.2481	2.5577
att_pc1	119	.9496	.2197	0	1	-4.1093	17.8864
att_pc2	119	.7059	.4576	0	1	-.9037	1.8167
att_pc3	119	.7983	.4030	0	1	-1.4869	3.2110
att_so1	119	.9244	.2655	0	1	-3.2100	11.3040
att_so2	119	.4202	.4957	0	1	.3235	1.1046
att_so3	119	.8992	.3024	0	1	-2.6512	8.0288
att_so4	119	.5630	.4981	0	1	-.2541	1.0646
att_so5	119	.4286	.4970	0	1	.2887	1.0833
att_so6	119	.0168	.1291	0	1	7.5178	57.5171
att_sic1	119	.8571	.3514	0	1	-2.0412	5.1667
att_sic2	119	.8824	.3236	0	1	-2.3735	6.6333
att_sic3	119	.7899	.4091	0	1	-1.4234	3.0260
att_sic4	119	.9412	.2363	0	1	-3.7500	15.0625
att_sic5	119	.8067	.3965	0	1	-1.5535	3.4135
att_sic6	119	.2773	.4496	0	1	.9949	1.9898
att_pa1	119	.8151	.3898	0	1	-1.6235	3.6359
att_pa2	119	.5630	.4981	0	1	-.2541	1.0646
doquiacta	119	.6807	.4682	0	1	-.7751	1.6007
comunica	119	.9664	.1810	0	1	-5.1754	27.7848
libreoffice	119	.8487	.3598	0	1	-1.9466	4.7893
intranet	119	.9580	.2015	0	1	-4.5655	21.8439
forma	119	.7647	.4260	0	1	-1.2481	2.5577
procirisweb	119	.9160	.2786	0	1	-2.9986	9.9917
stilo	119	.3866	.4890	0	1	.4659	1.2171
apro	119	.4538	.5000	0	1	.1857	1.0345
contabilia	119	.2857	.4537	0	1	.9487	1.9000

Table 23: Variables deletion – Online activities

Model	Number of iterations	Variables excluded	Reason of exclusion
7	1	att_sic1, att_se4, att_sic5, apro	Low factor loading
	2	forma, att_sic4	Low factor loading
	3	att_pa1	Cross-loading
6	1	att_pa2, att_se6, att_sic1, att_se4, att_com3, att_so3, att_so1, libreoffice, att_so4, att_so2, att_se2, att_se5, att_se1, att_pa1, att_so5, att_so6, intranet, comunica, forma, att_sic6, procirisweb, att_sic5, att_sic2, att_sic4, att_sic3, apro	Low factor loading
	2	att_pa1	Low factor loading
5	1	att_se6, att_se4, att_sic1, att_so3, att_so1, libreoffice, att_so4, att_so2, att_pa1, att_se5, att_sic4, att_se1, att_se2, att_sic3, att_com3, att_so5, stilo, contabilia, doquiacta, apro, att_so6, intranet, comunica, att_sic6, forma, procirisweb, att_sic5	Low factor loading
4	1	att_sic1, att_com3, att_pa1, att_sic5, att_se4	Low factor loading
	2	att_so6,apro	Low factor loading
3	1	att_se4, att_se5, att_se2, att_pa2, att_se1, att_so5, att_sic3, att_sic4, doquiacta, att_sic5, att_sic1, intranet, procirisweb, forma, comunica, stilo, contabilia, att_so6, apro, att_se6, att_sic6	Low factor loading
	2	att_sic3, apro	Low factor loading
2	1	att_se1, att_sic5, att_se2, att_sic6, doquiacta, att_sic1	Low factor loading
	2	apro, stilo, contabilia	Low factor loading
1	1	att_se4, att_se1, intranet, att_sic5, att_se2, att_so6, forma, stilo, procirisweb, contabilia, att_sic6, doquiacta, apro, att_sic1, comunica	Low factor loading
	2	att_se6, att_sic3	Low factor loading

8.1.3. Self-assessment

Table 24: Descriptive statistics – Self-assessment

Variable	N	mean	sd	min	max	skewness	kurtosis
self_opera~1	119	1.5042	.8623	-2	2	-2.0436	7.2178
self_opera~2	119	1.5966	.7401	-2	2	-2.0985	7.8737
self_opera~3	119	1.1345	1.0964	-2	2	-1.1591	3.5315
self_opera~4	119	1.5126	.8623	-2	2	-2.0702	7.3010
self_opera~5	119	1.6471	.6838	-2	2	-2.4579	10.4967
self_mobil~1	119	1.4286	1.0216	-2	2	-2.0332	6.5753
self_mobil~2	119	1.4874	.9643	-2	2	-2.3557	8.3295
self_mobil~3	119	1.2605	1.0453	-2	2	-1.5639	5.0018
self_mobil~4	119	.6471	1.2927	-2	2	-.7643	2.5494
self_forma~1	119	1.4622	.7455	-2	2	-1.5956	6.3398
self_forma~2	119	-.0588	1.2164	-2	2	-.1710	2.1350
self_forma~3	119	1.2773	.8918	-2	2	-1.2192	4.1034
self_forma~4	119	-.7143	1.2013	-2	2	.4677	2.1624
self_forma~5	119	1.4286	.8190	-2	2	-1.6752	5.9869
self_forma~6	119	.4622	.9897	-2	2	-.2371	2.7914
self_forma~7	119	.7479	1.2366	-2	2	-.7815	2.5572
self_forma~8	119	-.2605	1.3683	-2	2	.0391	1.7134
self_infor~1	119	1.1261	.9616	-2	2	-1.0002	3.5711
self_infor~2	119	1.1176	.9930	-2	2	-1.1235	3.9128
self_infor~3	119	-.6891	1.3388	-2	2	.4829	1.9205
self_infor~4	119	.5714	1.2043	-2	2	-.4170	2.2331
self_commu~1	119	1.3025	.8592	-2	2	-1.1855	4.1415
self_commu~2	119	1.6807	.6630	-2	2	-2.5244	10.8214
self_commu~3	119	1.2017	1.0299	-2	2	-1.4857	4.9310
self_commu~4	119	1.6387	.5928	0	2	-1.4072	3.9257
self_commu~5	119	1.4706	.7792	-2	2	-1.6828	6.2373
self_commu~6	119	1.4706	.8618	-2	2	-1.7035	5.4668
self_commu~7	119	.0924	1.4555	-2	2	-.1944	1.7371
self_conte~1	119	-.1681	1.3233	-2	2	.0468	1.8490
self_conte~2	119	.3782	1.4613	-2	2	-.4290	1.8222
self_conte~3	119	-.6891	1.4306	-2	2	.7330	2.1347
self_conte~4	119	.2605	1.4870	-2	2	-.3443	1.6794
self_conte~5	119	-.3109	1.3132	-2	2	.0691	1.8240
self_conte~6	119	.0924	1.4142	-2	2	-.0558	1.7774
self_strat~1	119	-.0756	1.2899	-2	2	-.1682	1.9928
self_strat~2	119	1.2689	.9361	-2	2	-1.4913	5.2664
self_strat~3	119	.1176	1.2900	-2	2	-.3628	2.0270
self_strat~4	119	.0252	1.2245	-2	2	-.2428	2.1959
self_strat~5	119	1.2017	.9350	-2	2	-1.4721	5.2857

Table 25: Variable deletion – Self-assessment

Model	Number of iterations	Variables excluded	Reason of exclusion
7	1	self_communication_6, self_operational_1	Low factor loading
6	1	self_operation_3	Low factor loading
5	1	self_operation_4	Low factor loading
4	1	self_information 4	Low factor loading
		self_strategic_2	Cross-loading
	2	self_formal_3	Cross-loading
3	1	self_formal_8	Low factor loading
	1	self_formal_3, self_information_1	Cross-loading
	2	self_information_4	Low factor loading
2	1	self_formal_2, self_formal_4, self_formal_8	Low factor loading
	2	self_communication_7	Cross-loading

8.1.4. Engagement

Table 26: Descriptive statistics – Engagement

Variable	N	mean	sd	min	max	skewness	kurtosis
self_opera~1	119	1.5042	.8623	-2	2	-2.0436	7.2178
self_opera~2	119	1.5966	.7401	-2	2	-2.0985	7.8737
self_opera~3	119	1.1345	1.0964	-2	2	-1.1591	3.5315
self_opera~4	119	1.5126	.8623	-2	2	-2.0702	7.3010
self_opera~5	119	1.6471	.6838	-2	2	-2.4579	10.4967
self_mobil~1	119	1.4286	1.0216	-2	2	-2.0332	6.5753
self_mobil~2	119	1.4874	.9643	-2	2	-2.3557	8.3295
self_mobil~3	119	1.2605	1.0453	-2	2	-1.5639	5.0018
self_mobil~4	119	.6471	1.2927	-2	2	-.7643	2.5494
self_forma~1	119	1.4622	.7455	-2	2	-1.5956	6.3398
self_forma~2	119	-.0588	1.2164	-2	2	-.1710	2.1350
self_forma~3	119	1.2773	.8918	-2	2	-1.2192	4.1034
self_forma~4	119	-.7143	1.2013	-2	2	.4677	2.1624
self_forma~5	119	1.4286	.8190	-2	2	-1.6752	5.9869
self_forma~6	119	.4622	.9897	-2	2	-.2371	2.7914
self_forma~7	119	.7479	1.2366	-2	2	-.7815	2.5572
self_forma~8	119	-.2605	1.3683	-2	2	.0391	1.7134
self_infor~1	119	1.1261	.9616	-2	2	-1.0002	3.5711
self_infor~2	119	1.1176	.9930	-2	2	-1.1235	3.9128
self_infor~3	119	-.6891	1.3388	-2	2	.4829	1.9205
self_infor~4	119	.5714	1.2043	-2	2	-.4170	2.2331
self_commu~1	119	1.3025	.8592	-2	2	-1.1855	4.1415
self_commu~2	119	1.6807	.6630	-2	2	-2.5244	10.8214
self_commu~3	119	1.2017	1.0299	-2	2	-1.4857	4.9310
self_commu~4	119	1.6387	.5928	0	2	-1.4072	3.9257
self_commu~5	119	1.4706	.7792	-2	2	-1.6828	6.2373
self_commu~6	119	1.4706	.8618	-2	2	-1.7035	5.4668
self_commu~7	119	.0924	1.4555	-2	2	-.1944	1.7371
self_conte~1	119	-.1681	1.3233	-2	2	.0468	1.8490
self_conte~2	119	.3782	1.4613	-2	2	-.4290	1.8222
self_conte~3	119	-.6891	1.4306	-2	2	.7330	2.1347
self_conte~4	119	.2605	1.4870	-2	2	-.3443	1.6794
self_conte~5	119	-.3109	1.3132	-2	2	.0691	1.8240
self_conte~6	119	.0924	1.4142	-2	2	-.0558	1.7774
self_strat~1	119	-.0756	1.2899	-2	2	-.1682	1.9928
self_strat~2	119	1.2689	.9361	-2	2	-1.4913	5.2664
self_strat~3	119	.1176	1.2900	-2	2	-.3628	2.0270
self_strat~4	119	.0252	1.2245	-2	2	-.2428	2.1959
self_strat~5	119	1.2017	.9350	-2	2	-1.4721	5.2857

Table 27: Variable deletion – Engagement

Model	Number of iterations	Variables excluded	Reason of exclusion
2	1	engage_foc_7	Low factor scoring
	2	engage_dedizione_2, and engage_focus_5	Cross loading

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List of abbreviations

Variable	Description
PA	Public Administration
DT	Digital Transformation
DTPA	Digital Transformation of Public Administration
EFA	Exploratory Factor Analysis
MAP	Minimum Average Partial

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