UNIVERSITY OF THE AEGEAN
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Digital Governance Science Base: Analysis and Visualization of Structure and Neighboring Domains

DIPLOMA THESIS

by

PANAGIOTIS KERAMIDIS

Supervisor: Professor Ioannis Charalampidis

Members of the Examination Committee: Professor Ioannis Charalampidis, Professor Euripides Loukis, Professor Spyros Kokolakis

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To my family...

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Acronyms

DGSB	Digital Governance Science Base
DGRL	Digital Governance Reference Library
DGRC	Digital Governance Research Center
AI	Artificial Intelligence
IoT	Internet of Things
AR	Augmented Reality
VR	Virtual Reality
OWL	Web Ontology Language
ID	Identity
API	Application Programming Interface
DLT	Distributed Ledger Technology

Επιστημονική Βάση της Ψηφιακής Διακυβέρνησης: Ανάλυση και Οπτικοποίηση της Δομής και των Συναφών Επιστημονικών Πεδίων

Περίληψη

Η παρούσα Διπλωματική Εργασία μελετά την Επιστημονική Θεμελίωση της Ψηφιακής Διακυβέρνησης στο πλαίσιο της ανάπτυξης της Επιστημονικής της Βάσης. Έχοντας τη σχετική βιβλιογραφία σα βάση γνώσης και τη διοργάνωση ερωτηματολογίου με συμμετοχή ειδικών στον κλάδο για αντιπροσωπευτική αποδοχή της επιστημονικής κοινότητας, η Διπλωματική Εργασία παρέχει την Επιστημονική Βάση της Ψηφιακής Διακυβέρνησης στο επίπεδο των πτυχών που την ορίζουν, εννοώντας τα συστατικά της που καθορίζουν τη δομή της, τους γειτονικούς επιστημονικούς της κλάδους, την επιστημονική χαρτογράφησή της και τα εκπαιδευτικά προγράμματα σχετικά με αυτήν. Επίσης παρέχει μοντελοποίηση και οπτικοποίηση της οντολογίας που εγείρεται από την έρευνα χρησιμοποιώντας το ανοιχτού λογισμικού πρόγραμμα – επεξεργαστή οντοτήτων Protégé. Τέλος, η Διπλωματική Εργασία συζητά τα αποτελέσματα στο επίπεδο της αποδοχής, της βαρύτητας, των σχεσιακών συνδέσεων μεταξύ τους και στοχεύει στο να θέσει τα θεμέλια για μελλοντικές διαδικασίες αναγνώρισης των προβλημάτων και λύσεων, με τρόπο επιστημονικά εμπεριστατωμένο, και να καταστήσει την οντολογική προσέγγιση της απεικόνισης της Ψηφιακής Διακυβέρνησης δημοφιλή για το ερευνητικό και όχι μόνο κοινό.

Λέξεις Κλειδιά: *ψηφιακή διακυβέρνηση, ηλεκτρονική διακυβέρνηση, έξυπνη διακυβέρνηση, ψηφιακός μετασχηματισμός, επιστημονική θεμελίωση, οντολογία, επιστημονική βάση*

Abstract

This Diploma Thesis studies the Scientific Foundations of Digital Governance on the context of the development of the Digital Governance Science Base. Having the relevant literature as a knowledge base and the experts' questionnaire conduction for the representative approval of the scientific community, the Thesis provides the Digital Governance Science Base on the level of its definitional aspects, meaning the components of the Science Base that identify the structure, neighboring scientific domains, research roadmap and training curricula. It also provides modelling and visualization of the ontology emerged from the research using the open source ontology editor Protégé. Finally, the Thesis discuss the findings on the context of the acceptance, importance, relational connections amongst them and aims to set the groundwork for future problem – solution identification processes that are scientifically solid and to popularize the ontological approach of representation of Digital Governance.

Keywords: *digital governance, digital government, smart governance, digital transformation, scientific foundations, ontology, science base*

1

Introduction

1.1 Context and Necessity of Diploma Thesis

As the research initiatives that are related with Digital Governance increase, the necessity of its structuralization on the context of components, of interaction between the components, of rules and principles and of the self-existing scientific establishment increases proportionally. That is due to the fact that strong scientific foundations enhance a domain's efficiency, since the actions will be executed with a systematic approach, research solidity, since the stable research domain will be more attractive for research endeavors, accuracy, since the homogeneity on the solutions, as they were defined, will reduce omissions, collaboration, since all the stakeholders of the ecosystem will be able to cocreate on a common basis, and popularization, since a well-defined sector is more clearly promoted to the stakeholders outside the domain.

That scientific establishment should include a conceptual model in a form of an ontology in order to define the individual components with a relational and visually presentable way. It is desirable to provide an ontology with different levels of abstraction and hierarchical categorization, since that is an aspect of the real-life examples of the Digital Governance. The interconnectivity between the components should be presented alongside with the semantic representation of that interconnections. Lastly, there is a certain need for the right documentation, in order to make the scientific establishment more well-defined and understandable.

1.2 Aims of the Diploma Thesis - To whom it is addressed

This Diploma Thesis aims to provide exactly that scientific foundation for the Digital Governance Science Base. It provides the modelling and the visualization of a significant proportion of the Digital Governance Science Base, alongside with the appropriate documentation that evidences that modelling.

The Digital Governance Science Base modelling and visualization will assist the scientific foundations of the Digital Governance providing an ontology of its structure, its components, its related scientific domains and its research and education aspects. The ontology is result of a well-defined research methodology whose results are variously visualized.

This Thesis can be useful for researchers of Digital Governance but also to researchers of a various set of scientific domains, who aim to study the newly emerged Digital Governance scientific domain on a centralized basis. It can also be useful for public officials and practitioners who need a well-structed model of scientific foundations concerning Digital Governance, which is a domain of great influence in the public administration.

1.3 Subject and Limits of the Diploma Thesis

The dominant subject of this Diploma Thesis concerns a region of the Digital Governance Science Base, as it is presented. That region of components is the one that concerns the definition of the Digital Governance as a scientific domain. More specifically, this Thesis provides the Domain Structure elements, more specifically the ones derived from literature analysis, relevant conference tracks and Digital Government Reference Library analysis. Those elements are presented as key-words in table format and some of them, more specifically the ones that have emerged from the traditional literature review are presented in a form of an ontology. This ontology also includes the Neighboring Domains of Digital Governance. Those have emerged from the different deliberations of the scientific domain as eleven elements and could be confirmed by scientific classifications in a future research initiative. The ontology also provides the Research Roadmap of the Digital Governance and the structural elements of the Training Curricula, based on the “Gov 3.0” project. The ontology is presented using the Protégé editor. The research methodology that was followed includes literature research, questionnaire conduction, for the Neighboring Domains, modeling and a basic statistical analysis and discussion over the results.

This Thesis does not focus on the problem-solution related components of the Science Base and it does not focus on the Ethics or the Rationale of the Science Base. It might seem as an introductory to the fundamental aspects of the research entity of Digital Governance, but that region is the cornerstone for everything related to Digital Governance. The rest of the Digital Governance Science Base elements are planned to be examined in another research initiative, with the problem and solution space definitions and the assessment methods being of paramount importance for those future research initiatives.

1.4 Structure of the Diploma Thesis

This Diploma Thesis is structured as following: The Scientific Analysis, meaning the stat of the art in the scientific domain of Digital Governance is presented in Chapter 2, the Methodology that this Thesis followed in order to extract the results is presented in Chapter 3, the Results of the research are presented in Chapter 4, the Discussion on the results and the proposition in the scientific community are presented in Chapter 5 and the Conclusion and the future steps are presented in Chapter 6. The last Chapter includes the literature references.

2

Scientific Field Analysis - Current Situation

2.1 Basic Concepts - Definitions

Starting the scientific analysis of the subject proposed, it is important to clarify the basic concepts that compose this analysis. Those are the fundamentals of the scientific perspective of Digital Governance and henceforward convoy its theoretical enhancement.

Since the approach of the scientific analysis combines the inspection of both the theoretical elements of a dominant scientific field and the wide assortment of the aspects of Digital Governance as a research and an industry domain, the analysis should provide separate investigation for both of these contexts. After the provision of the separate analysis of the basic concepts in these two contexts, namely the Digital Governance and the emblematic science base, the presentation of the combination of the aforementioned contexts should be provided.

The combination of the fundamentals mentioned, namely the scientific base of the Digital Governance, is the linchpin of the analysis and consequently of the visualization of the Digital Governance's systematic structure and neighboring domains. The overall scientific analysis is based on literature research.

2.1.1 Digital Governance

Initially, the context of Digital Governance is the first one in the scientific analysis. As a research term has different definitions. Conventionally, Governance is the term that pertains an ecosystem's entities, more specifically citizens, government and stakeholders and their betwixt related processes [1]. Digital Governance (or initially Electronic Governance) is referred as term that is consisted of initiatives implemented by government and public institutions with the goal of utilizing the Information and Communication Technologies (ICT) in their processes and interaction with the entities inside the ecosystems they are applied [2].

As a research domain, Digital Governance appears to aim to increase efficiency and effectiveness inside the public sector through the usage of ICTs, for both the internal and the external processes [3]. It is essential to clarify the difference between the literature terms of Digital Governance and Digital Government; the former is relevant with a wider increase in organizational efficiency through the usage of ICT in public sector, while the latter specifically focuses in delivering better services in citizens through the usage of ICT in public sector [4]. This differentiation is explicit in literature, videlicet, Digital Government is related to the structure of relevant topics and Digital Governance is related to the overall purpose and range of capabilities of the relevant topics [5].

Regarding the Government term, the research community states its evolution in form of different generations. Government 1.0 is the first generation of Government and it mainly concerns optimization of processes and increase in efficiency in existing services within public sector [6]. Government 2.0 focuses on e-participation and citizens' involvement on the context of values such as transparency and accountability [7]. Government 3.0 mobilizes the inclusion of disruptive technologies, such as Artificial Intelligence (AI), Blockchain, Internet of Things (IoT) on the context of data-driven decision making [8]. Digital Governance researchers and practitioners could benefit by studying this representational model of evolution of the different government focus topics, since Digital Governance functionalities and goals could be derived by those topics.

Literature suggests that there is increasing demand for relevant applications in the discussed field and that demand shall include the contribution of a wide variety of domains and professions [9]. Consequently, the endeavors that subject to this field of research are expected to encompass increasing collective intelligence, as a result of the plethora of stakeholders and research domains that they include. The economic demonstration of this status is the funding in Digital Governance and Digital Government projects by the European Commission through programs like "Horizon 2020", which is estimated around 80 billion euros between 2014 and 2020 [3].

Implemented initiatives and projects are not the only ones that are increasing in number in these years. Academia is equally leading into the establishment of a prominent scientific field, the suggested Digital Governance. Since 2000 the number of scientific conferences and published papers related to Digital Governance and Digital Transformation for the public sector has significantly increased; collecting a knowledge of more than 5500 peer-reviewed contributions in English language alone, to be precise [10]. The multi-year average of peer-reviewed publications exceeds the number of 400 publications and it is mostly comprised of conference and journal publications and to a lesser degree book chapters and other forms of publications [10]. Another determinant of the expansion of the knowledge base of the Digital Governance is the existence of The Digital Government Reference Library (DGRL, previously named EGRL - Electronic Government Reference Library), which was developed in 2005 by the University of Washington and was publicly released in 2006 and consists of at least 13,532 references of predominantly English-language, peer-reviewed work in the study domains of the field [11].

It is visible that the Digital Governance term has attained a considerable stature in the past years in both the industrial and the research communities. To all appearances Digital Governance could help contemporary societies to face their complex problems, since it provides a variety of disciplines and stakeholders from both the industry and academia cooperating towards the solution of problems of this societies with the assistance of the ICT developments [12]. However, the orchestration of the collaboration and the relevant actions, research initiatives and implementations in general is of paramount importance.

2.1.2 Science

After exploring the conceptualization of Digital Governance, the next step towards its scientific foundation is the actual scientific conceptualization as a broad term. Initially, it is notion of Science that should be clarified. Bohm identified Science as the only way of extracting useful information, using an empirical mechanism in which perception extends into new forms and contexts [13]. This mechanism acts gradually in order to bring to light novel effects, collecting intimations of something that operates differently than what expected [14]. Science, as a formalized way of extracting knowledge through observation has been expressed by three standpoints; Empiricism, which is the view that observations, senses and experiences are the only or the most important way of extracting knowledge, Rationalism, which is the view that rational intuition is the most important way of extracting knowledge, and Positivism, which combines aspects of both the previous views [15]. Though, the observations are not the only component of Science. Taking as an example Galileo, Douglas suggested that the scientific observations need to be accompanied by a theory, existing one or newly emerged by the observation results, even if it means opposing existing traditional theories [16]. Examining another aspect of Science and its research methodology, Chalmers claims that the facts, meaning the results related to the observation, should be examined having in mind three propositions in order to be deemed as the basis for Scientific process; a) they are given to careful, unprejudiced observers via their senses, b) they are prior to and independent of theory and c) they constitute a firm and reliable foundation for scientific knowledge [17]. There are more Science definitions, some of them do not emphasize only the structural elements or the principles of Science. For instance, the study of science is considered to be an intellectual and social endeavor, since it is the application of human intelligence to figure out how the world works [18]. The societal aspect of the Scientific conceptualization is significant and it is visible in a variety of ways. For instance, Whorf suggested that the linguistic determination of science intervenes in the conceptualization and he also suggested that no individual is free to describe nature with absolute impartiality but is constrained to certain modes of interpretation [19].

Science is a term that consists of a vast number of subdomains and disciplines. Those subdomains and disciplines are interconnected and collaborating. The extend and the connectivity of the different fields is presented widely in literature. A comprehensive visualization is presented in Figure 1, where Boyack et. al shorted roughly 800,000 published papers into 776 different scientific paradigms [20]. Different mappings indicate different aspects of the scientific development, connectivity between fields and researchers and the dominant subdomains. Some of those mappings indicate that interdisciplinarity of Science is gently increasing in the last decades, especially concerning neighboring domains, meaning the close cognitive areas [21]. This interdisciplinarity is discussed to revolve around factors like scientific motivation, political factors, socio-economic factors, resource accessibility or social networking [22]. The interdisciplinarity discussed is also reinforced by the usage of ICT [23]. This interdisciplinarity is achieved by research collaboration, which is described as individuals who differ in notable ways sharing information and working toward a particular scientific purpose [24].

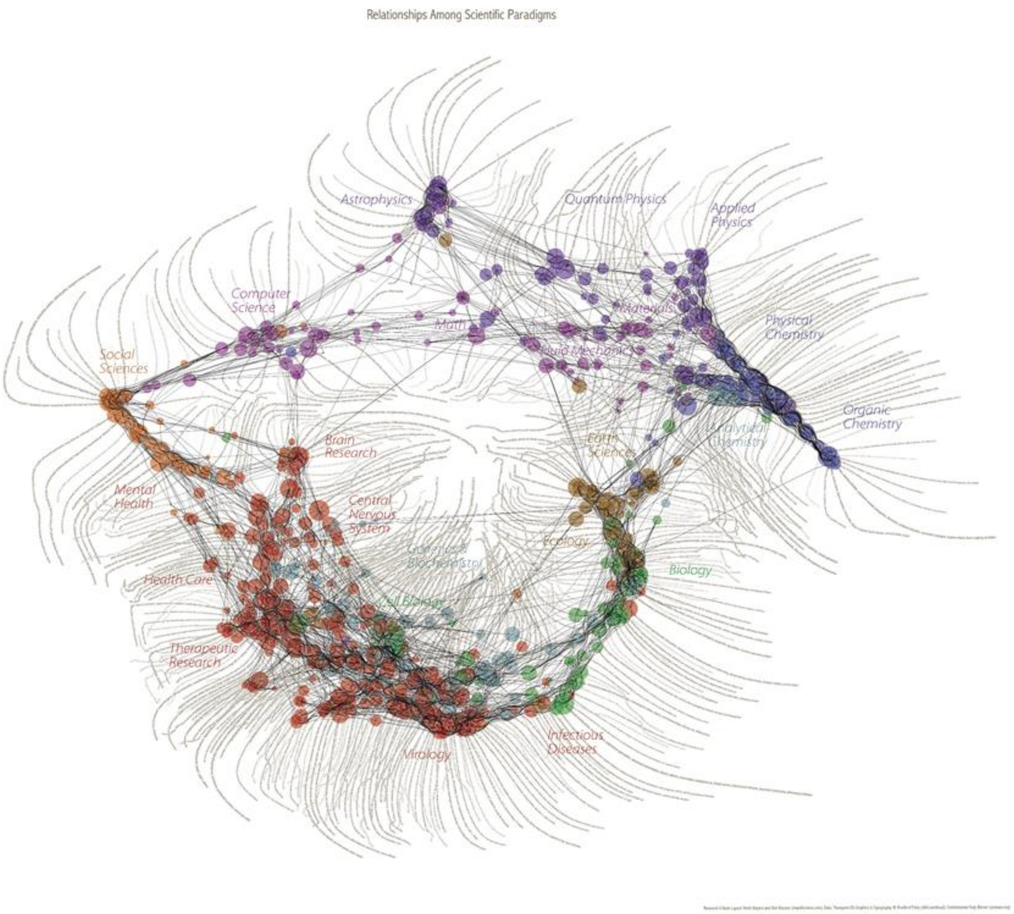

Figure 1. Scientific Method: Relationships Among Scientific Paradigms [20]

Having the multilevel nature of Science being established with several disciplines it is appropriate to clarify the way of implementing a novel scientific discipline. A scientific discipline could emerge into a dominant Science if it presented evolution over time [25]. Aside from this there is necessity for two customs: adequate progression through the years comparing with other scientific domains – progression covers the increase of the number and the novelty of the challenges that this domain faces – and active community that provides competing scientific theory, for the particular field, that should be evaluated regularly on a multilevel basis – taking into consideration the other fields involvement [26].

Digital Governance may seem as a predominantly technologically enabled discipline, by virtue of including a vast number of ICT initiatives as a mechanism of facing challenges. Various research initiatives underline the importance of scientific foundations in technological disciplines [27]. Even though that varies depending on the economic factors [28] and the technological factors included [29], it is safe to assume that Digital Governance - both as a scientific domain and as a technologically enabled field - should be tested taking into consideration the characteristics of both technology and science, since they both seem to mature in ways that have similar outlines [30]. That being mentioned, it is important to clarify that Science and Technology may be interdepended but they should not be treated as exactly the same notion [31]. And the scientific foundation of Digital Governance provides just that complementary representation of the maturity.

On this context, a Science Base should be defined. The Science Base would provide concepts, theories, and principles emerged from dominant existing sciences that could provide long-term problem-solving frameworks [26]. A Science Base is a structed, ordered and semantically searchable collection that consists of the knowledge concerning the principles and applications of a domains and the knowledge emerge from other related domains [3]. In other words, a Science Base is consisted of empirical data, findings that have emerged from the scientific process. The purpose of the Science Base is to justify the existence of a scientific domain, describe its structure elements, preferably in a semantically correlated way, and assist the community in order to lead the scientific domain into implementation. Alongside with the abovementioned, there are the rules and the principles that are being followed in every relevant research initiative. The establishment of a Science Base for Digital Governance would provide certain possibilities towards the formalization of the knowledge concerning the field of research [3].

2.2 Current Situation

The separate examination of Digital Governance and Science demonstrated the structural elements as well as the reasoning behind the Digital Governance Science Base. However, constructing this novel approach of order concerning Digital Governance is a procedure more complicated than just implementing general rules of scientific foundations in Digital Governance. The procedure should include the consideration of the particularities of this domain, the steady approach of the Science Base and that should answer some of the key questions that every Science Base should answer. Additionally, the Science Base should provide the visual representation and the interconnectivity internally and with other Bases.

The gradual construction is referred in literature as a three-wave process [3]. The foundations of this three-wave process have been set through another similar investigation, that of Interoperability Scientific Foundation [32]. The activities within each wave differ in scope and deliverables.

The first wave of activities provides the key elements of the scientific foundation. It provides the definitions on what problems and solutions are included in this scientific field. It clarifies the main issues of this domain while stating the basic concepts of the domain, for instance terminology, structure, neighboring domains and others. It is the wave that sets the ground in order to provide the research community the fundamental elements of their future initiatives.

Having those fundamentals established in the first wave, the second one provides stability over the research process. The goal is to promote sustainability, reusability and expansion of the research community. This is the step of experimentation that will lead to the scientific consensus about the findings of the first wave.

The third wave is the one that opens Digital Governance to fields other than scientific ones. The popularization of the domain will start in this wave. One of the most intriguing parts of this wave is the emphasis in the industrialization of the initiatives concerning Digital Governance. The success of the activities within the third wave will bring enhancement to Science Base of Digital Governance through its widen understanding, the adoption by the industry and the collaboration with external scientific domains.

Other Science Bases recently occurred could assist the formulation of the one of Digital Governance. Examples of well-established and widely implemented fields of research, for example Software Engineering [33], interdisciplinary examples, like Enterprise Interoperability Science Base [26], or more recent attempts of Science Base construction, for instance Renewable Energy Technologies [34], have been studied in order to accomplish the definition of the Science Base of Digital Governance, taking into consideration the particularities of this specific field. All the existing examples emphasize to the value of clearly and systematically studying the subdomains of the field given.

There are some studies that attempt to standardize the approximate time needed in order to have a technological sector mature. For instance, Graham states that there has been a 50-year cycle in the popularization of technology [35]. However, there are more optimistic approaches. According to Redwine and Riddle [33], the development and propagation of technologically enabled domains lasted not more than 20 years, meaning that it takes on the order of 15 to 20 years to mature a technology to the point that it can be popularized and disseminated to the technical community at large.

Literature suggests that there are eleven components of Digital Governance Science Base [3]. Generally, these components answer the three fundamental questions of Metamodeling, namely “Why?”, “What?” and “How?” [36]. Those three questions are not randomly selected. They are three questions on which the scientific fields are based. The “Why?” goals to reveal the necessity of each scientific domain existence. The “What?” reveals the structure, the components of the scientific domain, its neighboring domains and other elements that form the domain. The “How?” is related with the problem-solution relation and the methods and tools that are used in order to implement the scientific domain in the real-life applications. These components as well as the Metamodeling question that each of them answers to are the following:

- Rationale - “Why?”
- Domain Structure (Areas) - “What?”
- Research Roadmap - “What?”
- Neighboring Domains - “What?”
- Training Curricula - “What?”
- Problem Space - “How?”
- Assessment Methods & Tools - “How?”
- Solution Paths - “How?”
- Solution Methods and Tools - “How?”
- Generic Laws, or Rules or Theories
- Code of Ethics

Figure 2. The Digital Governance Science Base

Rationale clarifies the importance of the existence of the DGSB as it offers a thorough overview, analysis, and interpretation of the science base's objectives covering, also, the aspects of its development and maintenance.

The Domain Structures and more specifically the Scientific Areas that comprise the Digital Governance domain provide in-depth and comprehensive knowledge and understanding of the field, a decomposition of the domain.

The link between the past and future research can be illustrated in a Research Roadmap. A Research Roadmap acknowledges the state of the art and future research challenges/issues of Digital Governance.

The notion that Science is interconnected with other domains is abovementioned with the Science mappings, but also discussed in a plethora of research initiatives who suggest that Science is not a standalone entity in our societies [37]. "Neighboring Domains" refers to the Recognized interdependencies among Digital Governance and other Scientific Disciplines.

Training Curriculum in the era of Digital Governance and Transformation is of major importance since it consists the groundwork for a young generation of practitioners and researchers, which will advance the practical contribution and the knowledge in the domain.

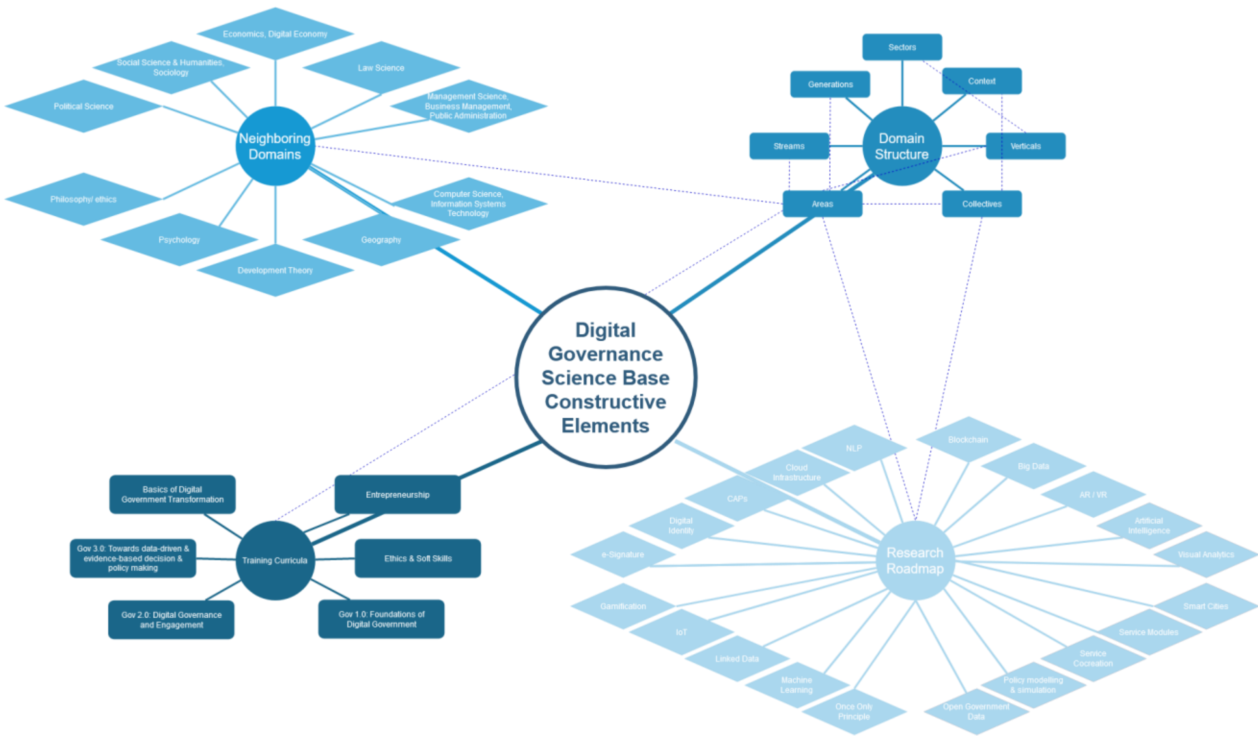

Figure 3. The "What?" components

As for the components that are related to the "How?" question, meaning the Problem – Solution components, they start with the identification of the problem as is. "Problem Space" represents the as is situation. The "Assessment Methods and Tools" find problems inside government and public institutions concerning the exploitation of ICTs. Conversely with the "Problem Space", the "Solution Path" component provides a taxonomy of knowledge available that allows the identification of paths– directions for the solution. The "Solution Methods and Tools" component is a typology of methods and tools capable of solving any issue and aims at providing solutions to an identified problem. A visual representation of the abovementioned components is provided in Figure 4 and in Figure 5.

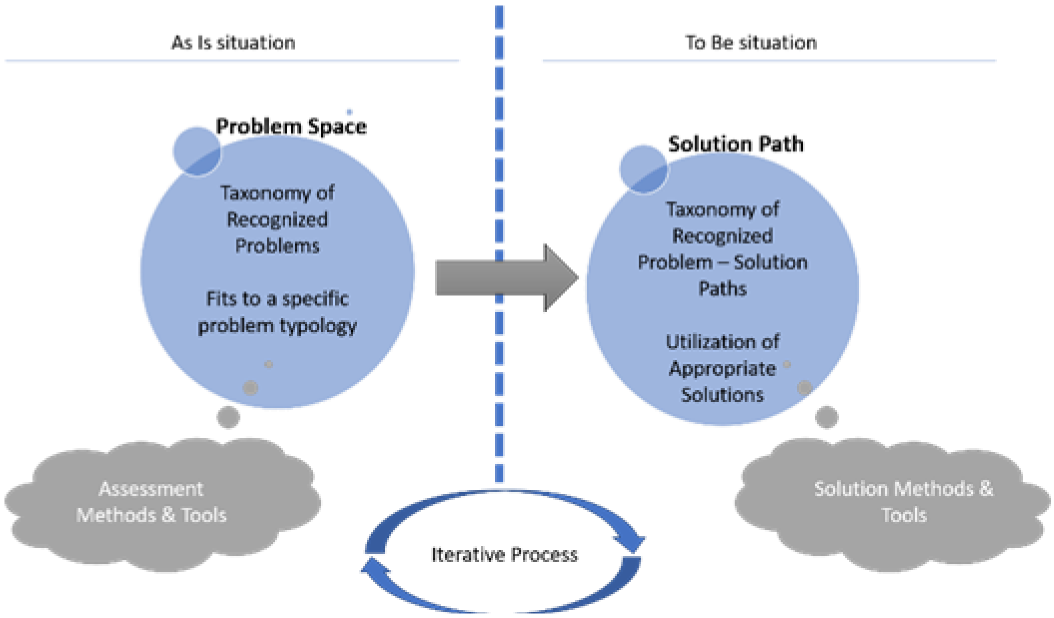

Figure 4. From the Problem Space to the Solution Path [3]

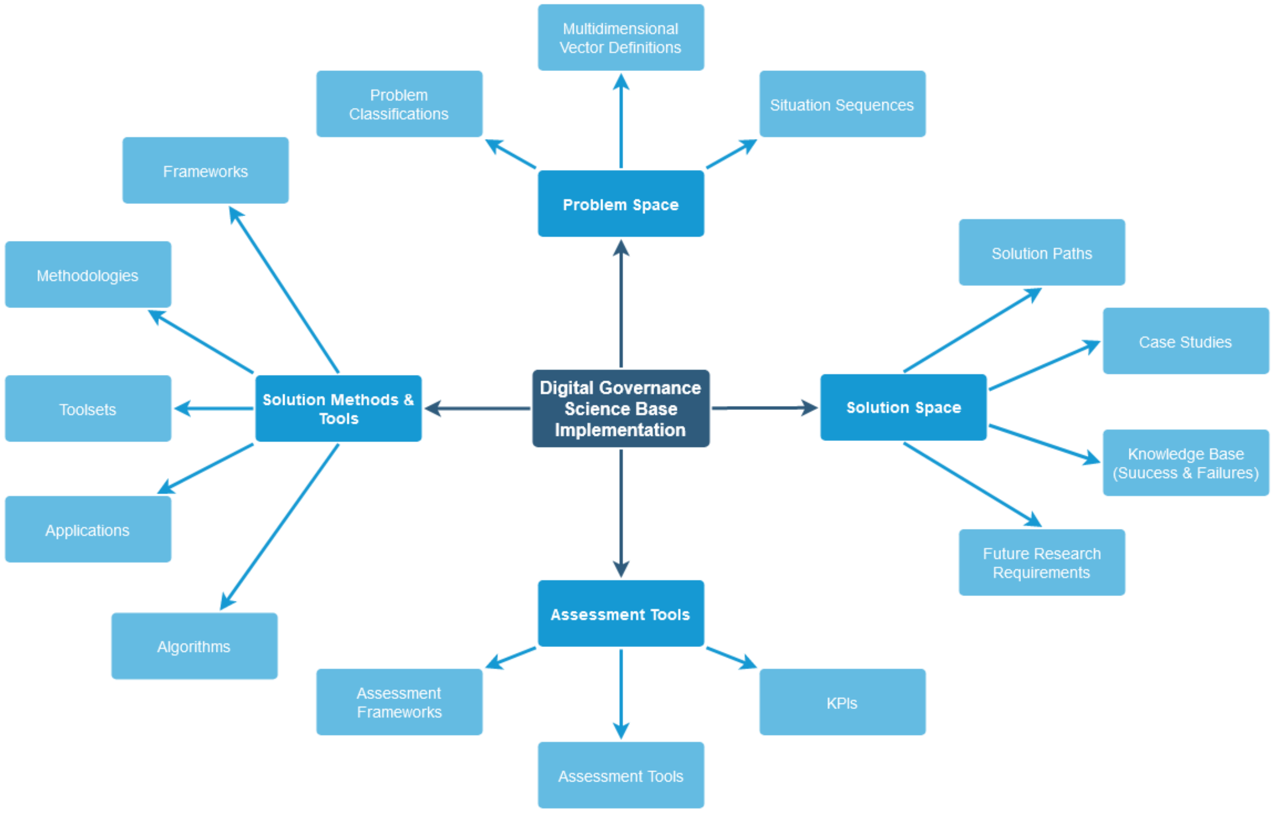

Figure 5. The "How?" components

As for the Laws, Rules and Theories, they are generally applicable observations or guidelines ("do's and don'ts"), which are grounded in observation and rationalization from cases. Finally, the Code of Ethics stands for the correct application for all the elements in order to provide the right ethical context.

The abovementioned components should be examined, discussed, evolved, if necessary, by the research community. The structure of the Digital Governance Science Base is the linchpin of the establishment of the domain as an independent scientific field that reacts with other fields in order to provide government institutions, public organizations, researchers, professionals and stakeholders the structured and well documented set of practices and fundamentals they need in order to support their initiatives.

2.3 Conclusions on the Current Situation (and Research Needs)

In the previous section, the Digital Governance Science Base is presented as a structural model of organizing the reasoning, the goals, the fundamentals, the tools and methods and the rules of the Science Base. Although that is the starting point of the establishment of the research practices and fundamentals that would emerge into a Science, the objective is to maintain the structure while progressing towards the extroversion to the whole ecosystem. The research community has to follow well defined steps towards the establishment, taking into consideration the particularities of this domain, which would define the research needs. These steps may emerge from already established scientific fields, as they would provide the Digital Governance research community some best practices and some obstacles to be considered in order to establish and evolve the Digital Governance Science Base.

Other scientific paradigms might prove useful on the context of guiding the research community towards the definition of the Science Base and the procedure of its evolution in order to be established. Their contribution might differ, just as the paradigms' efforts to establish a Science Base differ on account of the particularities of each paradigm. These differences might be visible through the research initiatives and their perspective of introducing a new scientific domain. One perspective could be the proposal of a Science Base and afterwards its comparison to other well-established Science Bases. Such an example is presented at Figure 6, where Charalabidis and Lachana classified the basic components of Digital Governance Science Base and compared them with the Medical Science Base on the level of every component and element. This perspective provides an overview that might prove useful both in intuitively understanding the divisions inside the novel Science Base and in deciding the evolutionary steps towards its establishment. Another perspective is that that is presented in Figure 7, where Persoon et al. proposed a Science Base for the Renewable Energy Technologies in contrary of some indicators the Fossil Fuel based Energy Technologies. In this case the Science Base emerges through the different scores in some indicators comparing to other Science Bases. One of those indicators is the Web of Science Research Categories that signifies the scientific predominance of Renewable Energy Technologies, hence proving that literature supports the existence of such Science Base. That is another useful method of examination of literature, since it focuses on relevant fields of Science. Consequently, it provides quantitative comparison with contrasting or antagonizing fields of Science with a direct approach, making it well-suited for establishing more measurable technological or scientific paradigms.

COMPONENT	DIGITAL GOVERNANCE SCIENCE BASE Element	MEDICAL SCIENCE Element
Structure of the Domain	Government 1.0, 2.0, Government 3.0	Pathology, Surgery
Neighboring domains	Management Science, Computer Science	Biology, Pharmacology
Training curricula and material	AI-based decision Making, Security and Legal Implications	Medical School curricula
Research Roadmap	Blockchain, Virtual Reality	Cancer, AIDS, etc
Problem space	Taxonomy of problems (e.g. Interoperability issues)	The book of diagnoses (DSM)
Assessment tools and methods	Established Indicators (e.g. DESI), Maturity Models	Blood tests, MRI's, psychology tests
Solution paths	Matrix of Solutions (e.g. best practices, cases knowledge)	The book of drastic substances
Solution methods and tools	DCAT, URI, Twitter	The various treatment protocols and the myriads of medical methods and tools

Figure 6. Comparison of different scientific domains, Digital Governance Science Base, and Medical Science [3]

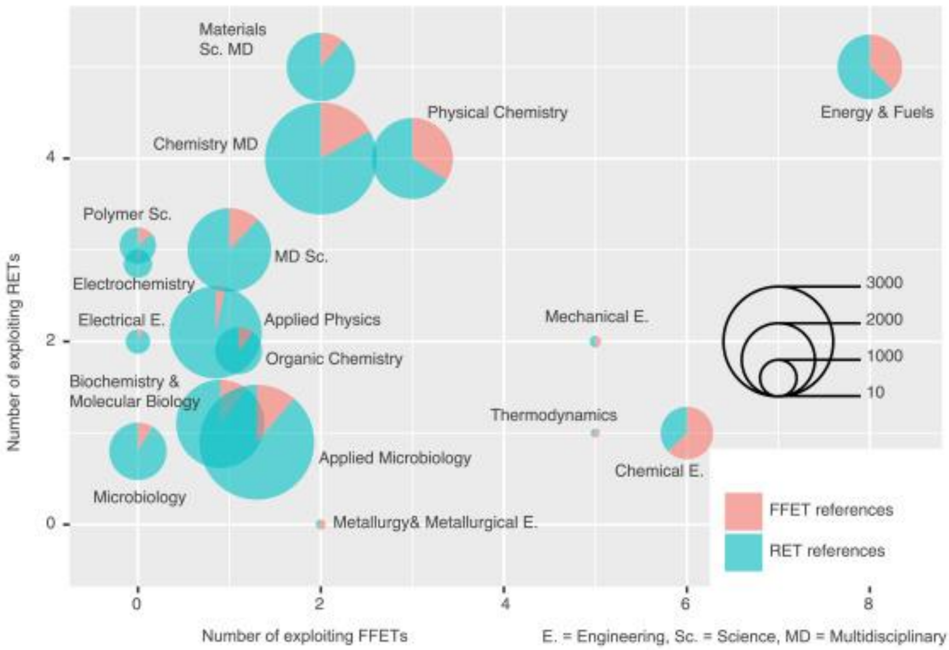

Figure 7. Most important WOS Research Categories [34]

There is a plethora of methodologies to be followed in order to provide the Scientific Base and the fundamentals. After deciding the one to follow, or the combination of those which are advantageous in the effort, the next phase is to implement a set of actions in order to expand the Science Base and the entities of the research community that comprises it. The sequences of actions that could be followed in order to popularize the Science Base and involve as many professionals, researchers, stakeholders, policy makers and public administrative officials could vary depending on the nature of the field, its role on the public and private sector's sustainability and economy, the technological factors that advance it, the social groups that it involves and ultimately the research initiatives that have already been accomplished.

One of the most well-defined, established and accepted amongst the scientists and the researchers is the one of Software Technology maturation process, provided by Redwine and Riddle [33]. The sequence of actions they proposed is based on a six-phase set that describes the maturation process of Software Technology based on observation of different cases. Starting with the basic research, the research community will search for fundamentals and ideas that would be useful for the problem-solution investigation. When the appropriate elements are found, the concept formulation is the phase that should take place, where the research community should clearly define the problem and the solution prototypes. Then, they should trial those findings and that is the development phase, where the theoretical foundations are put to test. This will provide the user capabilities and will lead to the next step, which is the internal enhancement of the domain. In this step the solutions and methodologies will be tested in a wider variety of domain problems in order to stabilize the capabilities. The next phase is the external enhancement, where the solutions and tools are tested in a wider set of domains outside the development group, forming the real-world structure of the Science. After this step is finished, the popularization of the domain is the last phase. There, the solutions are ready for the production, the problems are involving not only researchers but a wider variety of stakeholders, creating a wide community that supports the efforts of this scientific domain.

Figure 8. Software Technology Maturity Process [33]

The Scientific Base's components, its comparison with other Science Bases and the maturity process are the key elements in order to form the overall strategy in order to structure the Digital Governance and to secure the standardize the future solutions and initiatives both in academic and in production level. The research needs concerning the definition of the mentioned above elements concern both the academic stakeholders but also public and private institutions that contribute to the knowledge base. Especially in the Digital Governance Science domain, which is multidisciplinary on its entities' categories. Since the scientific analysis defines the dominant research findings, the methodology of identifying the individual characteristics and components should be stated.

3

Methodology

3.1 Research Questions – Research Issues

The fundamental components of Digital Governance Science Base have been stated and defended in the literature of the domain. However, the overall transition to the implementation of the Science Base in the current societal, business and academic environment is not yet well defined. There are still certain units of the transition to be clarified based on the research initiatives that are available.

The first research issue that needs to be clarified is the exact entities that the Digital Governance Science Base's Domain Structure is comprised of. Those divisions of the Domain Structure and the objects of every division should be investigated extensively in order to provide the exact structural components and relations between them.

The second research issue is the Neighboring Domains of the Digital Governance Science Base. That term is the scientific domains that collaborate and are strongly connected with Digital Governance. The Neighboring Domains' clarification could provide advantageous insights for the enhancement of the domain.

Another important issue is that of the modelling and the visualization of the relations and the elements. The data that describe the Digital Governance Science Base should be modelled and visualized in a relational way, meaning it should provide the elements and the relations between them. That is a major step towards the understanding and the popularization of the scientific domain.

Different research questions could emerge from different perspectives and even if the academic literature has space for every observation and examination of the field, it is the systematic analysis and visualization that could provide the benchmark for future research initiatives, that would provide different perspectives to the field. That means that this research, as a systematic review of the findings of literature provides the core elements and their visualization, mainly focusing on the "What?" question that was mentioned above concerning the Scientific foundations of Digital Governance.

More specifically, the goal is to identify the Domain Structure, the Neighboring Domains, the Research Roadmap components, the Training Curricula and their visual representations. That is the key elements in order to identify the Digital Governance Science Base and its core characteristics.

3.2 The Methodological Steps and Aids

This thesis is not the introductory study into the Digital Governance Science Base, as it is already mentioned in previous chapter. There are some studies that either focus specifically on that scope, or have influenced its establishment with a more indirect way, meaning that they might focus on subjects related to the scope. This thesis focuses on enhancing the Digital Governance Science Base on the context of studying its Domain Structure, Neighboring Domains, Research Roadmap, Training Curricula, which are significantly complex components. It also emphasizes in visualizing the findings using advanced visualization tools that provide the semantic representation of the components.

The methodological approach of the analysis of the scientific domain and the relevant research initiatives is structured and while it follows diverse steps in order to enhance the components, those steps follow two major research techniques. Those techniques are common and well established in the literature; namely the literature analysis technique and the questionnaire technique.

3.2.1 Method of Literature Analysis

The method of literature analysis is the one that comprises the lion's share of the research findings to be presented in this thesis. It is the one that provides the current stage concerning the Digital Government Science Base Domain Structure. It also acts as a base in order to find the Neighboring Domains, the Research Roadmap components and the Training Curricula. Lastly, it is the literature analysis findings that are visually presented.

Literature findings are not used for a single purpose in this research initiative, but they rather influence the majority, if not the absolute majority, of the divisions of this research initiative. That happens in a different quota in each division. Yet, the literature that was analyzed does not originate from a single source of information.

Traditional forms of research initiatives in literature, meaning journal papers, conference papers and book chapters are a major share of the sources of information that came together in order to form the knowledge base for this thesis. More specifically, they are used in order to identify the basic structure of the Domain Structure of Digital Governance Science Base. That is one of the major uses but it is not the only one. The Neighboring Domains' basic form has also been constructed after research in traditional literature. Basically, the existence and the primary structure of every one of the components of Digital Governance Science Base is based on the analysis that has been conducted to traditional research sources.

Another source of information was the Digital Government Reference Library (DGRL) [11]. Using EndNote (https://endnote.com/) in order to search the Library, the enhancement of the Domain Structure was made possible. Examining the title, the abstract and the key-words of every published paper that was part of Digital Government Reference Library the existing elements of the Domain Structure increased on various subcategories.

Those elements increased not only using the Digital Government Reference Library, but they also increased by the research into the tracks and mini-tracks of the dominant conferences related to Digital Governance. The dominant conferences of the field or even those that have neighboring domains as a subject, meaning not only Digital Governance or Digital Government but also Computer Science, Software Engineering etc., were found through the classification of the Digital Governance Research Center (DGRC - http://www.dgrc.gr/research_el/conferences_el/). The tracks and mini-tracks were studied on the level of title, description and key-words, if existed. Similarly to the Digital Government Reference Library, if a title, a description or a key-word provided a term that was not overlapped by another term in the Domain Structure it was added to the cluster.

The conferences and the relevant deliberations provided the Digital Governance related Neighboring Domains. Those scientific domains are the ones that the applications of Digital Governance are closely related with, meaning they collaborate with them in order to succeed. Those domains are used in the questionnaire phase.

The project "Gov 3.0" (https://www.gov30.eu/) is a research project that provided useful insights concerning the Research Roadmap and the Training Curriculum (https://moodle.gov30.eu/). The research initiative aims to establish Government 3.0 as a scientific domain. It provided comprehensive knowledge towards the current research situation, the needs for the future of Digital Governance research and training.

The methodology of both the "Gov 3.0" Research Roadmap and Training Curriculum is being provided on the context of the project deliverables. As for the Research Roadmap methodology, it is flexible and it evolves overtime, taking into account the newest technological developments. The sources of information about the research and training needs concerning the Research Roadmap are two: a) analysis of existing research projects concerning ICT in public service provision, most of them funded by the European Commission, b) experts' opinions extracted by several workshops concerning the future situation in the public sector, the private sector and the academia on the context of Digital Governance.

As for the Training Curriculum methodology, it is also provided by the "Gov 3.0" project. It is divided into three phases:

- Phase 1: The study and research plans were discussed amongst the partners. The search keywords, the search metadata concerning e-Government training programs and the workshops and the questionnaires design were defined in this phase.
- Phase 2: In this phase the data concerning the training programs of e-Government were collected. The questionnaires and workshops were also conducted in this phase.
- Phase 3: In this phase the future training needs in e-Government were emerged. They emerged from the data analysis of the search, the questionnaires and the workshops conducted. A comparison between the future needs and the current situation took place here to uncover the existing training gaps.

The research methodology was designed to be implemented taking into consideration several categories in every phase. For instance, the keywords were classified by subject (e.g. Digital Governance, Digital Government, Electronic Governance etc.) or by institutional/educational degree (e.g. Bachelor, Capacity Building, Certificate etc.). The research for data conducted was after the partners divided the search process into regions, for instance PwC searched for USA and Canada data, University of the Aegean for African data etc. The metadata that emerged from the research process were classified in terms of four identifiers: The Program Description, the Program Content, the Program Administration and the Institution of the training program. Similar systematic approach was followed in the workshops and questionnaires design.

The Training Curriculum methodology, its structure, its target group, its courses were influenced by the findings of the research on the current situation in the academic field of the Digital Government. The existing programs' level, orientation, learning goals, specialization, Institutions' countries, and its ECTs were some of the identifiers that influenced the final Training Curriculum.

Lastly, the visualization of the overall Domain Structure was accomplished using the visualization tool named Protégé (https://protege.stanford.edu/). It is a free, open-source ontology editor and framework for building intelligent systems.

3.2.2 Questionnaire Description

The second research technique that was used is the one of the questionnaire's conduction. The questionnaire is a form of survey that provides the participants a set of questions that they should answer in order to identify the qualitative and quantitative measurements of a phenomenon or a proposition. Typically, those questions are relative with the contextual study and they should adequately reflect the issues being studied [38].

Figure 9. The Neighboring Domains

This questionnaire matched the theme of the thesis on the context of exploring the participants' views on Digital Governance Science Base, particularly on the Neighboring Domains. The overall questionnaire had a broad scope but the highpoint was either the rating of the existing Neighboring Domains based on the relevance or their contribution to some aspects of Digital Governance.

The methodology that was followed in order to form the questionnaire was based on two fundamental aspects, the Digital Governance Science Base elements in general and the Neighboring Domains. Thus, the main questions were classified into two categories, the ones concerning Digital

Governance Science Bas elements and the ones concerning Neighboring Domains. The first category questions are the following:

- "Please rate the 10 elements according to the importance you think they have". The purpose of this question is to measure the participants' stance on the Digital Governance Science Base in terms of their importance. The importance of the elements might signify the research needs and the cruciality of every one of them, for the research community to observe.
- "Rate the difficulty you think the community will face in defining and progressing the 10 elements". This question is similar with the previous, only this time it is the difficulty that is the concept that is being measured. The difficulty results might be advantageous in the risk assessment of the research of each element.
- "In which of the 10 elements you think you are capable to contribute to?". This question aims to signify the research community's readiness in some elements and its need for expansion in others.
- "Can you identify any other element we are missing?". This one is an open question, aiming to extract additional Science Base elements.

Moving forward to the second category of questions, the focus shifts into the Neighboring Domains. The questions in this category aim to reveal the context of the Neighboring Domains and their relation with the other Science Base elements. The questions are the following:

- "Please rate the 10 neighboring domains according to the importance and potential you think they have for Digital Governance". This question aims to reveal the importance of every Domain. It is essential to understand that in order to cooperate with the appropriate research community in order to achieve the collaborative nature of Digital Governance.
- "Can you identify any other Neighboring Domain we are missing?". One of the main objectives of the questionnaire conduction is to provide the conducting team some Domain propositions that might be missing, and this question provides just that.
- "Please match the neighboring domains with the elements they contribute". One of the most complicated tasks is to correlate the Neighboring Domains with the rest of the Digital Governance Science Base elements. The correlation needs to be done on in terms of the enhancement that every Domain provides in every aspect of Digital Governance, which is expressed in every element.
- "In which of the 10 Neighboring Domain(s) you think you are capable to contribute to?". Another question concerning the participants' collaboration in the Neighboring Domains.
- "Do you have any other idea / issue that you think would help us in defining Digital Governance Science Base, its Structure and Neighboring Domains?". An open, wider question in order to give the participants the chance to provide their insights in a broader context. Their insights could assist the definition of the Science Base itself, its Structure and its Neighboring Domains in particular.

Generally, all the questions are planned to be easy to understand, to be answered in less than 20 minutes and to enhance the diversity of the answers given by the participants. The aim is to extract the insights that the participants might possess without targeting in certain response trends. That is the reason of the existence of both open and closed types of questions in the questionnaire.

3.3 Methodological Objectives

The objective of the methodological approach is to present the exact elements of the Domain Structure, the Neighboring Domains, the Research Roadmap Components, the Training Curricula, the relations between them and their contribution to Digital Governance Science Base. The complementary part of the research is the appropriate visual representation in order to assist the popularization of the Science Base.

There is a specific number of studies and a specific range of subjects to be analyzed. Additionally, the participants of the questionnaire are relevant to the research, administrative and enterprise initiatives that support Digital Governance.

3.3.1 Number of Studies to Be Analyzed

The literature research needed is not easy to be quantified. There are exemplary studies that have introduced the Scientific Base of Digital Governance and have set its structure based on literature and broad scientific initiatives, for instance EU-funded projects, such as the "Gov 3.0". Those studies could be the resource for the identification of the fundamentals that should be analyzed in this study.

As for the nontraditional literature review, meaning the DGRL and the conference terms, the estimated number of elements to be examined is less fluid. The DGRL provides access to 13,532 references to literature assets, while the list of the conferences related to Digital Governance, as presented in DGRC, are 19, with the dominant ones be listed around 5.

3.3.2 Number and Type of Questionnaires to Be Completed

The number of questionnaires to be completed is also fluid. It depends on the objective of the conduct. If the conduction intends to gather views of general population about the Digital Governance Science Base, then the number of participants needs to be large in order to simulate the diversity of public opinion, having as a given that in that case the participants would be selected from a wide variety of ethnical, political, professional, educational, cultural and economic background.

In this case, where the goal is not to collect the public opinion but rather the experts' opinion, the target group should be limited. The questions should be more specific, with larger choice sets in the closed-ended questions type and more opportunities for open-ended questions. The views, the insights, the experience of the experts on the field are not subjects that could easily be quantified. As a result, they should have the opportunity to express themselves with as many ways as possible.

The experts and practitioners were participating in the Samos Summit 2020 (https://www.samos-summit.com/). There was a number of Graduate Students of relevant Digital Governance Program, researchers, professors, public administrative officers, policy makers, professionals of the private sector and other stakeholders. Those were the target group, that provided answers based on their experience, and their insights on the context of the Neighboring Domains.

3.3.3 Possible Problems That May Arise and Ways of Prevention and Treatment

The methodology constructed provides the precognition of the potential obstacles that may occur during the research process. A potential limitation concerns the non-inclusion of a number of research initiatives, since they are not included to the research sources, namely the DGRL. A solution for that issue is the separate inspection of the research initiatives published after the update of the DGRL. Another obstacle might occur in the exact opposite time spectrum, meaning the inclusion of research initiatives that are obsolete, conversely to the modern, technologically up-to-date research initiatives found in literature. The solution of this problem requires a time threshold in the acceptance of the research initiatives, for instance accept papers published only after 2005, except they are published before but they have been updated after 2005.

A set of challenges concern the visualization, generally the presentation, of the information emerged. The information should be presented with accuracy and integrity without making it incomprehensible for some people, since the goal is the popularization of the Science Base. The programs used in order to present or classify the information are specifically selected to attain that exact challenges.

Generally, when establishing a novel subject in literature the threats are not instantly visible, since there is no previous knowledge on that. Henceforward, the obscurity of both the structural particularities and the results' orientation could be considered a threat towards the overall extraction of knowledge from that procedure.

4

Results

4.1 Results of Literature and Questionnaire Analysis

The results of the research conducted provide enhancement into multiple levels of the Digital Governance Science Base. More specifically, they provide complementary elements in the Domain Structure, the Neighboring Domains, the Research Roadmap and in the Training Curricula. Those components had already been defined, so their basic anatomy is given, meaning the categories and some areas for the Domain Structure, the Neighboring Domains, the primary list of Research Roadmap components and the Training Curricula courses. However, this study provides enlargement to the Domain Structure in several categories based on the literature review and also provides determination of a set of Neighboring Domains based on the questionnaire answers. It also provides the semantic visualization that displays the Domain Structure, the Neighboring Domains, the Research Roadmap and the Training Curricula entities as well as the relations between them.

The results of this study could be presented in a number of ways. Tables, images, axes, xml documents, Web Ontology Language (OWL) documents or other graphic representations. This thesis presents the findings in most of the abovementioned ways, while providing access to the rest of them.

4.1.1 Results Based on Studies

As it is mentioned before, the literature review was implemented on different levels. The basic categorization of those levels could involve traditional literature review, where conference papers, journals, book chapters were thoroughly studied in order to form the basic structure as well as some starting elements, Digital Government Reference Library exploration, where all 13,532 references were examined on the basis of title, abstract and key words in order to extract more elements for the Domain Structure, and relevant conference tracks and mini tracks for the same purpose.

The fundamental elements of the Domain Structure were determined by Charalabidis and Lachana [3]. The Domain Structure is a taxonomy. More specifically, a system of axes that correspond to different elements, categories and relations between them that concern Digital Governance.

The Domain Structure is not a standard ontology. It is expected to evolve over time, with the appropriate usage of the collaborative tools. That it inter alia due to the diversity of the academic views on some of the relevant issues that subject under the Domain Structure. It is also expected to be easily understandable, to the most convenient extent. On this context it is possible the information to be presented on different layers depending the abstraction needed for the user.

One of the major components of the Domain Structure is the Areas. Areas are specific topics of the Digital Governance. They might be academic topics, technological solutions, processes, techniques, business orientations and other subjects that comprise Digital Governance field of application. The Areas are not standalone entities. They interconnect with other Areas and with other components of Domain Structure. That happens with multifaceted ways. Each Area could also contain some sub-areas (for instance Interoperability could be divided into Legal, Organizational, Semantic, Technical). Those sub-areas could also be divided themselves. From a certain standpoint, it might be reasonable to consider the Areas to be the epicenter of the Domain Structure.

The next component of the Domain Structure that interacts actively with the Areas is that of the Streams. Generally, Streams are thematic classifications of Areas. Consequently, Areas and Streams are orthogonal, mutually exclusive. The Areas might involve one or more Streams. The involvement might be characterized as "involvement" or "strong involvement" of Streams into Areas of the Domain Structure. There are five basic streams that correspond to the basic aspects of Information Systems inside the Areas. Namely, "Process & Regulation", "Data", "People", "Infrastructure" and "Intelligence". The proportion of the involvement of each Stream reveals differing interpretations of the usage, the extension, the versatility, even the feasibility and the adequacy of an Area. That is reasonable considering the Streams as factors of influence in every Area, where every Stream indicate different aspects.

The difference between the aspects that the Streams indicate is significant. Process & Regulation is the first one. It represents the series of activities, the rules or the regulations controlling the efforts to achieve a desired outcome or goal of the implementation of a certain Area. Data is the second. It represents the evidences. Either in the form of semantic elements or in the form of information (structed or not). The data might differ on the form and type; however, the indication of this stream concerns the information on the context of the findings. The third stream is named "People" and it represents the human element. This involves the roles inside the ecosystem where the Area is implemented and their importance. Users, citizens, employees and a plethora of variations. Next, the Infrastructure Stream includes the physical and intangible structures that could be used in order to extract knowledge or public value on the context of Digital Governance. This Stream combines a range of technologies, systems, devices and applications, consisting a synthesis of software, hardware, networks and other information related components. The last Stream is the Intelligence. It includes specific combinations of processes, data, people and infrastructure that simulates properties of the human mind. It is the one that is abstract on its interpretation. It might have common elements with the "Data", but the distinction between the findings and their transformation into knowledge and cognition is decisive.

The existing taxonomy, based on literature research, includes 28 Areas that are correlated with the 5 Streams with two possible variables, namely "includes" and "strongly includes". That taxonomy could be presented in the next table:

Table 1.The Taxonomy of Areas and Streams and their correlations

	Streams				
Areas	**Process (& Regulation)**	**Data**	**People**	**Infrastructure**	**Intelligence**
Digital Public Services Transformation	XX				
Business Process Reengineering	XX				
Dynamic Workflow Automation	XX			X	
Organizational Interoperability	XX				
Semantic Interoperability	X	XX			
Technical Interoperability	X			XX	
Digital Identity (e-ID)	X		X	XX	
Digital Security	X	X		XX	
Service Portals				XX	
Mobile applications in Digital Governance			X	XX	
Digital Governance Assessment Methods	X	XX			
Cloud Infrastructures	X	X		XX	
e-Participation			XX	X	
e-Voting	X		XX	X	
Open Governmental Data		XX	X	X	
Linked Data		XX	X	X	X
e-Collaboration	X		XX	X	
Big Data Processing		XX		X	X
Visual Analytics		X		XX	X
Social Media in Governance		X	XX	X	
Artificial Intelligence	X	X		X	XX
Blockchain / DLT's	X	XX		X	

Internet of Things			X	XX	X
Policy modelling & simulation		X			XX
Opinion Mining & Sentiment Analysis		X	XX		XX
Service API-fication	X			XX	
Text Mining		X		X	XX
Evidence-based decision making		XX	X	X	XX

The previous table indicates that there is a diversity between the influence of the Streams over the Areas of the Domain Structure. “Infrastructure”, for instance, is the most influential Stream with 12 correlations and 9 strong correlations, while “Intelligence” is the least influential Stream with 4 correlations and 5 strong correlations. The next table provides useful data concerning the correlations of the Streams and Areas:

Table 2. Streams and Correlations

	Process (& Regulation)	**Data**	**People**	**Infrastructure**	**Intelligence**
Correlations	11	8	6	12	4
Strong Correlations	4	7	5	9	5
Correlations – Strong Correlations Ratio	2.75	1.14	1.2	1.33	0.8
Percentage of Strong Correlations	0.26	0.46	0.45	0.42	0.55
Overall Correlations	15	15	11	21	9
Association	Infrastructure	Infrastructure	Infrastructure	Data	Data

The previous table presents the scores of each Stream concerning its involvement in the Areas set. "Infrastructure" is included in the most correlations. It is also the most associated Stream with the other Streams, meaning when a Stream is included on the same Area with another. “Process & Regulation”, “Data” and “People” are most associated with "Infrastructure". The “Data” is the second most influential Stream, with the same overall correlations with “Process & Regulation” but being the second most commonly associated Stream with the other Streams, with “Infrastructure” and “Intelligence” having it as the most associated Stream. Another useful element is that of the

Correlations – Strong Correlations Ratio. It is roughly interpreted as the number of Correlations for each Strong Correlation in the same Stream. "Process & Regulation" has the greatest number, for every one Strongly Correlated Areas there are 2.75 Correlated ones, while "Intelligence" has the lowest ratio, for every one Strongly Correlated Areas there are 0.8 Correlated ones. That ratio's purpose is slightly more obvious in the next element, the percentage of Strong Correlations within the Stream, where the percentage acts conversely. "Intelligence" has a 0.55 ratio and that is the greatest one, while "Process & Regulation" possess the lowest, of only 0.26. That might be an indicator of the importance of the inclusion of this Stream in the Areas applied to. In other words, the number of Areas that involve "Intelligence" might be the lower, but those that do, they involve it more actively. That is not a definite proposition. For instance, the comparison between "Process & Regulation" and "Intelligence" on this ratio does not definitely signify that either of them is more important. Because the percentage of the Strong Correlations might favor the "Intelligence" but the overall Correlation number is significantly greater in the Stream of "Process & Regulation". The apparent observation on this reasoning would be that given that the number of the correlations is equal, then the percentage of Strong Correlations would definitely indicate the necessity of the one Stream against the other. Yet, this is still not a deterministically solid presupposition. Because the objective necessity of each Stream is not easily quantified. Furthermore, the importance, the complexity, the obscurity, the innovation and the organizational particularities of the given Area are major variables in the importance equation, henceforward making it delicate to determine the general Stream's importance. The research community can only speculate by examining the elements of every Stream and composing a projection based on the overall table. Nonetheless, the Area – Streams correlations are not the only ones that characterize an Area.

The same research source indicates several other aspects that characterize a given Area. One of the literature's most commonly referred taxonomy is the Generations. As also mentioned in a previous chapter, Digital Government terms in literature fall into 3 generations, which evolutionary focus on different applications and goals [39]. The Areas also are categorized in Government Generations, as it is shown in the next table:

Table 3. Areas and Generations

	Generations		
Areas	**Gov 1.0**	**Gov 2.0**	**Gov 3.0**
Digital Public Services Transformation	X		
Business Process Reengineering	X		
Dynamic Workflow Automation	X		
Organizational Interoperability	X		
Semantic Interoperability	X		
Technical Interoperability	X		
Digital Identity (e-ID)	X		
Digital Security	X		
Service Portals	X		
Mobile applications in Digital Governance	X		

Digital Governance Assessment Methods		X	
Cloud Infrastructures		X	
e-Participation		X	
e-Voting		X	
Open Governmental Data		X	
Linked Data		X	
e-Collaboration		X	
Big Data Processing		X	
Visual Analytics		X	
Social Media in Governance		X	
Artificial Intelligence			X
Blockchain / DLT's			X
Internet of Things			X
Policy modelling & simulation			X
Opinion Mining & Sentiment Analysis			X
Service API-fication			X
Text Mining			X
Evidence-based decision making			X

The areas are almost equally distributed, with Gov 1.0 and Gov 2.0 having 10 Areas each and Gov 3.0 having 8. This table is in line with the literature. It is visible that Gov 1.0 Generation includes more Areas related to Interoperability, Processes, Business and Service Digital Transformation etc. Those Areas signify the first attempts to adopt the fundamentals of the Digital Governance. Gov 2.0 is mostly about e-Collaboration, e-Participation, e-Voting, Social Media, so it is visible that the communal aspect of the Digital Governance possesses a more dominant role. Finally, Gov 3.0 is more technologically enabled, including Artificial Intelligence, Blockchain, Internet of Things, Opinion Mining and generally Disruptive Technologies. This is the attempt of the initiatives to insert Intelligence and Data handling into the policy making and the decision-making process.

The next taxonomy of the Areas is that the one of the Collectives. Collectives are arbitrary, well-coined and recognized, identifiers that act as sets of Digital Governance Areas. The existing literature initiative contains three exemplary Collectives. One Area might be included in more than one Collective. The next table provides the relevant taxonomy:

Table 4. Areas and Collectives

	Collectives		
Areas	**Smart Cities**	**Data-driven Entrepreneurship**	**Service Automation**

Digital Public Services Transformation			X
Business Process Reengineering			X
Dynamic Workflow Automation			X
Organizational Interoperability			X
Semantic Interoperability			X
Technical Interoperability	X		X
Digital Identity (e-ID)	X		X
Digital Security			X
Service Portals	X		X
Mobile applications in Digital Governance	X		
Digital Governance Assessment Methods			
Cloud Infrastructures	X		
e-Participation			
e-Voting			
Open Governmental Data	X	X	
Linked Data		X	
e-Collaboration		X	
Big Data Processing	X	X	
Visual Analytics			
Social Media in Governance			
Artificial Intelligence	X		
Blockchain / DLT's	X		
Internet of Things	X		
Policy modelling & simulation			
Opinion Mining & Sentiment Analysis			
Service API-fication	X	X	
Text Mining			
Evidence-based decision making			

There are a few key elements to observe in this table. Firstly, it is visible that "Smart Cities" Collective is more widely influential than the other Collectives, listing the number of its correlations with the Areas. Another aspect is the fact that some Collectives are more widespread across the Areas matrix. For instance, "Smart Cities" has correlations in the whole spectrum of Areas, while

“Data-driven Entrepreneurship” and “Service Automation” are more or less accumulated in specific subsets of Areas. That could signify the association of the Collectives with the Government Generations. More notably, it is visible that “Service Automation” correlations set almost coincides with the one of the Gov 1.0. That signifies the importance of “Service Automation” as a concept in the first generation of Digital Government. There are plenty of other observations that could be conducted in order to associate the Collectives with the Generations or even with the Streams. For example, almost every “Service Automation” implies the involvement of “Process & Regulation”, or that all “Smart Cities” correlations coexist with the “Infrastructure” ones. The analysis could be exhaustive until every element of the Domain Structure is connected with all the others.

The last category that involves Areas is that of the Verticals. Verticals are sets of Areas in the same sector of the economy or society. The research initiative that was used as a basis signifies three exemplary Verticals, as shown in the next table:

Table 5. Areas and Verticals

	Verticals		
Areas	**eHealth /Health Informatics**	**eJustice /Legal Informatics**	**eFinance**
Digital Public Services Transformation			
Business Process Reengineering			
Dynamic Workflow Automation			
Organizational Interoperability			
Semantic Interoperability			
Technical Interoperability			
Digital Identity (e-ID)			
Digital Security			
Service Portals	X	X	
Mobile applications in Digital Governance	X	X	
Digital Governance Assessment Methods			
Cloud Infrastructures			
e-Participation			
e-Voting			
Open Governmental Data			
Linked Data			
e-Collaboration			
Big Data Processing	X	X	
Visual Analytics			

Social Media in Governance			
Artificial Intelligence			
Blockchain / DLT's			
Internet of Things	X	X	
Policy modelling & simulation			
Opinion Mining & Sentiment Analysis			
Service API-fication			
Text Mining	X	X	
Evidence-based decision making			

The taxonomy does not fully explore the potential of the Areas on the contexts of each Vertical, but is signifies the most dominant interconnections between those two categories of the Domain Structure. It presents the most obvious and dominant Verticals, which are eHealth and eJustice. There is still the eFinance, which still plays a significant role. However, the taxonomy does not seem to link it with the Areas, but with something different.

The Verticals are not connected with Areas. They are also connected with another set of elements called Sectors. Sectors are well-known economy or society sectors, where Verticals are classified. In order to understand the difference, suppose the Sector of "Law and Justice", one of the most important parts in our societies and one of most involved with governmental institutions. That includes "eFinance" as a Vertical in order to enhance its efficiency and its effectiveness. The whole taxonomy is presented in the following table:

Table 6. Sectors and Verticals

	Verticals		
Sectors	**eHealth /Health Informatics**	**eJustice /Legal Informatics**	**eFinance**
Law and Justice		X	
Health	X		
Education and Research			
Entrepreneurship & Development			
Labor & Social Security			
Economy & Finance			X
Internal Affairs			
Transportation			
Culture and Tourism			
Environment and Natural Resources			

External Affairs			
Public Safety			

The results are plausible. One might argue that the table could list more Sectors or more Verticals and Sectors. Still, the existing ones give an overview in the Domain Structure of the Digital Governance Science Base.

There is also another element. That is the Context. That is the spatial – organizational field of implementation of every Collective. For instance, the "Smart Cities" collective is implemented on "Local" Context. The Contexts that the existing Domain Structure includes are the obvious, meaning "International", "National", "Local".

The overview of the whole Domain Structure based on the existing framework and research initiative is presented in the next figure:

	Streams					Generations			Collectives			Verticals		
Areas	**Process (& Regulation)**	**Data**	**People**	**Infrastructure**	**Intelligence**	**Gov 1.0**	**Gov 2.0**	**Gov 3.0**	**Smart Cities**	**Data-driven Entrepreneurship**	**Service Automation**	**eHealth /Health Informatics**	**eJustice /Legal Informatics**	**eFinance**
Digital Public Services Transformation	XX					X					X			
Business Process Reengineering	XX					X					X			
Dynamic Workflow Automation	XX			X		X					X			
Organisational Interoperability	XX					X					X			
Semantic Interoperability	X	XX				X					X			
Technical Interoperability	X			XX		X			X		X			
Digital Identity (e-ID)	X		X	XX		X			X		X			
Digital Security	X	X		XX		X					X			
Service Portals				XX		X			X		X	X	X	
Mobile applications in Digital Governance			X	XX		X			X			X	X	
Digital Governance Assessment Methods	X	XX					X							
Cloud Infrastructures	X	X		XX			X		X					
e-Participation			XX	X			X							
e-Voting	X		XX	X			X							
Open Governmental Data		XX	X	X			X		X	X				
Linked Data		XX	X	X	X		X			X				
e-Collaboration	X		XX	X			X			X				
Big Data Processing		XX		X	X		X		X	X		X	X	
Visual Analytics		X		XX	X		X							
Social Media in Governance		X	XX	X			X							
Artificial Intelligence	X	X		X	XX			X	X					
Blockchain / DLT's	X	XX		X				X	X					
Internet of Things			X	XX	X			X	X			X	X	
Policy modelling & simulation		X			XX			X						
Opinion Mining & Sentiment Analysis		X	XX		XX			X						
Service API-fication	X			XX				X	X	X				
Text Mining		X		X	XX			X				X	X	
Evidence-based decision making		XX	X	X	XX			X						
Sectors														
Law and Justice													X	
Health												X		
Education and Research														
Entrepreneurship & Development														
Labor & Social Security														
Economy & Finance														X
Internal Affairs														
Transportation														
Culture and Tourism														
Environment and Natural Resources														
External Affairs														
Public Safety														
Context														
International														
National														
Local									X					

Figure 10. The Domain Structure of Digital Governance Science Base

It is visible that there are multiple axes in the taxonomy. The elements are interconnected. The taxonomy is incredibly useful and helpful on the context of the expansion. Meaning, there definitions and the structural choices of the formation assist the expansion of the Domain Structure without significant modification to the Structure itself. For instance, an Area, which is the part of the largest group in the Structure is conveniently described by the correlations with the several elements. This is fitting, since the Areas are the fundamental element of inspection.

The expansion of the Domain Structure was accomplished by the two sources mentioned in previous chapter, the Digital Government Reference Library and the dominant conferences in the field. The expansion did not concern only the Areas, which might seem as the centric element, but in also all the others. For every new object found, its source was noted in order to examine the context of the new object if needs. The Digital Government Reference Library was searched first. The results are presented in the following table:

Table 7. Newly Proposed Elements for the Domain Structure based on the DGRL

New Area – Sub-Area	New Sector	New Collective	New Vertical	New Context	Reference
			E-Inclusion		UN Global E-government Readiness Report 2005: From E-government to E-inclusion
		Citizen-Centricity			Service delivery in transformational government: model and scenarios
		Transformational Government			Service delivery in transformational government: model and scenarios
User-Friendly Information Systems					Envisioning e-Justice for Criminal Justice Chain in Finland
Cross-border data flows					Data is different, and that's why the world needs a new approach to governing cross-border data flows
	Transparency				Dimensions of Open Government Data Web Portals: A Case of Asian Countries
			E-Residency		Integrating Digital Migrants: Solutions for Cross-Border Identification from E-Residency to eIDAS. A Case Study from Estonia

	Welfare				Is Government Welfare Able to Change? Analyzing Efforts to Co-create an Improved Social Welfare System through Taking Advantage of a Collaborative Economy
Open Source Software					Secure National Electronic Voting System
Smart Cards					Secure National Electronic Voting System
Biometrics					Secure National Electronic Voting System
Accessibility					e-Government Website Accessibility: In-Depth Evaluation of Saudi Arabia and Oman
		Mobile Government			Security frameworks in contemporary electronic government
		Contemporary Government			Security frameworks in contemporary electronic government
Privacy					Privacy preservation in a pattern-aware authentication scheme for

					vehicular ad hoc networks
Geospatial Data					Towards a Linked Geospatial Data Infrastructure
Maturity Model					Framework for e-government assessment in developing countries: case study from Sudan
			E-Democracy		The Roadmap to e-Democracy in Arab Spring Countries via Social Networks
Standardization					Preserving privacy in web services
E-Government Training					Developing an E-Government Training Program: A Stakeholder Approach
	Insurance				Blockchain-Based Insurance
Personalized Services					m-Government: Benefits and its Key Attributes for Personalized Services
Immigration					ICT-enabled Refugee Integration: A Research Agenda
			E-Transactions		Instrument development and contextualization for perceived characteristics of e-transactions

			E-Learning		Users' perspective on the adoption of e-learning in developing countries: The case of Nepal with a conjoint-based discrete choice approach
				Community	Connected Kids: Community Information System Design and Development
			E-Procurement		Utilization of Electronic Procurement Solutions in Curbing Public Sector Corruption: Analysis from Nigeria
	Agriculture				A Geo-Decisional Tool for the Management of the Agricultural Development Fund Under the Green Morocco Plan
	Emergency Response				Supporting Efficient Multinational Disaster Response through a Web-Based System
E-Transformation					A New E-Transformation Metric System
3D City Model					Smart Geo-Spatial Analytical Tool for Urban

					Development and Management
Human Resource Information Systems					Examining the Role of Social Influence, Usefulness and Ease of Use for Determining the Mandatory Use of a Human Resource Information System in the Context of Saudi Ministries
			E-Diplomacy		Factors influencing e-diplomacy implementation: Exploring causal relationships using interpretive structural modelling
	Trust				Building Trust in E-Government Adoption through an Intermediary Channel
Gamification					Gamification of e-Government Services: A Discussion of Potential Transformation
	Politics				Who votes for mayor? Evidence from midsized American cities
	Urban Planning				Transparent Urban Planning Measures for Citizens' E-Participation
Unmanned Aerial Vehicle					Survey on Collaborative Smart Drones and

					Internet of Things for Improving Smartness of Smart Cities
Electronic Records					A framework for electronic records management in support of e-government in Kenya
Chatbots					Transforming the communication between citizens and government through AI-guided chatbots
	Gender Equality				Women's political representation and transparency in local governance
Threat Intelligence					Towards an Evaluation Framework for Threat Intelligence Sharing Platforms
Digital Preservation					Modeling digital preservation capabilities in enterprise architecture
Shared Services					Shared Services Strategies and Their Determinants: A Multiple Case Study Analysis in the Public Sector
Data Integration					Exploring Data Integration Strategies for

					Public Sector Cloud Solutions
Internet Content					Internet Content Regulation in France and Germany: Regulatory Paths, Actor Constellations, and Policies
	Digital Divide				G-8 Collaborative Initiatives and the Digital Divide: Readiness for E-government
Smart Contracts					Smart Contracts: Coding the Transaction, Decoding the Legal Debates
Visualization					Legal Design and e-Government: Visualizations of Cost & Efficiency Accounting in the e-Learning Environment of the Canton of Zurich (Switzerland)
	Citizen Satisfaction/ Acceptance				Modeling Citizen Satisfaction with Mandatory Adoption of an E-Government Technology
	Volunteerism				Digital Volunteer Networks and Humanitarian Crisis Reporting

	Social Activism/Social Movement				Financing Social Activism: Crowdfunding and Advocatory Social Movement in Spain in Times of Crisis
			E-Rulemaking		Legal Issues in E-Rulemaking
	Smart Mobility				Are You Responsible for Traffic Congestion? A Systematic Review of the Socio-technical Perspective of Smart Mobility Services
			E-Activities		E-Identity, E-Activities and EPolitical Participation: How are College Students Embracing the Promise of the Internet?
	Digital Rights				The Right to Know and Digital Technology: Proactive and Reactive Transparency in the Italian Legal System
Smart Grid					Investment uncertainty analysis for smart grid adoption: A real options approach
			E-Audit		The Intention to use E-Audit

					Technology: An Integration of the Theory of Planned Behavior (TPB) and Technology Acceptance Model (TAM)
	Consumers' Awareness				Consumers' Awareness of the Value of E-Government in Zambia: Empirical Evidence
			E-Parliament		Role of E-Parliament in Hungary, The
Crowdsourcing					Depression Index Service Using Knowledge Based Crowdsourcing in Smart Health
	Military				Military electronic governance as a proxy of Armed Forces' integrity: a model and an example
Marine Observing Systems					Australia's Integrated Marine Observing System (IMOS): Data Impacts and Lessons Learned
			E-Assistance		eAssistance
	Surveillance				Video Surveillance in Public Libraries: A Case of Unintended Consequences?

Agent Based Modeling					Agent Based Modeling of Smart Grids in Smart Cities
Parliamentary Information Visualization					An Overview of Parliamentary Information Visualization (PIV) Initiatives: Assessing Their Completeness and Contribution to Parliamentary Openness
Social Robots					New Channels, New Possibilities: A Typology and Classification of Social Robots and Their Role in Multi-channel Public Service Delivery
			E-Cognocracy		Enhancing the Trust and Perceived Security in e-Cognocracy
			E-Signatures		e-Signatures for Delivery in e-Government
	Urban Sprawl Monitoring				Urban Sprawl Monitoring Using Remote Sensing and GIS Techniques of the City Jaipur, India
Remote Sensing					Urban Sprawl Monitoring Using Remote Sensing and GIS Techniques of the City Jaipur, India

	Social Solidarity				The evolution of Self-organized Social Solidarity (SoSS) initiatives in Greece and their relationship to online media: A longitudinal research
	Social Value				Information Production and Social Value for Public Policy: A Conceptual Modeling Perspective
	Participatory Budgeting				Participatory Budgeting: Findings from Germany
Search Engines					Search Engines, Social Media, and the Editorial Analogy

The overall objects are 76 in number and are proposed with the purpose of the enhancement of the Domain Structure as new object elements (or sub-elements). All the reference sources of these findings are research items found in Digital Government Reference Library using EndNote as a tool for searching the Library elements. It is important to clarify that the newly proposed elements are falsifiable. That means there are different views on the inclusion or non-inclusion of an element. Some might argue that an Area is not wide enough to stand alone and it is included in another already established one. The same principle applies to the other proposed elements of the Domain Structure.

The same structure of the taxonomy of the newly propose elements is followed for the ones emerged from the dominant conferences of the field. The next table provides the results:

Table 8. Newly Proposed Elements for the Domain Structure based on the dominant conferences

New Area – Sub-Area	**New Sector**	**New Collective**	**Reference**
Cyber Deception			https://hicss.hawaii.edu/tracks-54/digital-government/#cyber-deception-and-cyber-psychology-for-defense-minitrack

Supervisory Control and Data Acquisition			https://hicss.hawaii.edu/tracks-54/digital-government/#cybersecurity-and-privacy-in-government-minitrack
Adaptive Case Management			https://hicss.hawaii.edu/tracks-54/digital-government/#digital-government-and-business-process-management-bpm-minitrack
Metamodeling (BPM)			https://hicss.hawaii.edu/tracks-54/digital-government/#digital-government-and-business-process-management-bpm-minitrack
		Digital Government Theory Development	https://hicss.hawaii.edu/tracks-54/digital-government/#digital-government-theory-development-and-application-minitrack
	Digital Journalism		https://hicss.hawaii.edu/tracks-54/digital-government/#digital-society-minitrack
Mobile ad-hoc networks			https://hicss.hawaii.edu/tracks-54/digital-government/#disaster-information-resilience-for-emergency-and-crisis-technologies-minitrack
		Ethics of Digital Government	https://hicss.hawaii.edu/tracks-54/digital-government/#emerging-topics-in-digital-government-minitrack
Motivational technology			https://hicss.hawaii.edu/tracks-54/digital-government/#engaging-governance-minitrack
Digital storytelling			https://hicss.hawaii.edu/tracks-54/digital-government/#engaging-governance-minitrack
AR, VR, MR, XR			https://hicss.hawaii.edu/tracks-54/digital-government/#engaging-governance-minitrack
Digital twin			https://hicss.hawaii.edu/tracks-54/digital-government/#engaging-governance-minitrack
Crowdsensing			https://hicss.hawaii.edu/tracks-54/digital-government/#engaging-governance-minitrack
		Smart partnerships	https://hicss.hawaii.edu/tracks-54/digital-government/#smart-and-connected-cities-and-communities-minitrack
Collective intelligence			https://hicss.hawaii.edu/tracks-54/digital-government/#smart-and-connected-cities-and-communities-minitrack

Internet of Everything			https://hicss.hawaii.edu/tracks-54/decision-analytics-and-service-science/#internet-of-everything-and-the-power-of-where-minitrack
Learning Analytics			https://hicss.hawaii.edu/tracks-54/decision-analytics-and-service-science/#learning-analytics-minitrack
		Industry 4.0	https://hicss.hawaii.edu/tracks-54/decision-analytics-and-service-science/#modeling-and-decision-making-in-manufacturing-and-logistics-in-the-age-of-industry-4-0-minitrack
Health Behavior Change Support Systems			https://hicss.hawaii.edu/tracks-54/information-technology-in-healthcare/#health-behavior-change-support-systems-hbcss-minitrack
Body Sensor Systems			https://hicss.hawaii.edu/tracks-54/information-technology-in-healthcare/#implementation-of-body-sensor-systems-in-healthcare-practice-minitrack
	Digital Nudging		https://hicss.hawaii.edu/tracks-54/internet-and-the-digital-economy/#behavioral-economics-in-the-digital-economy-digital-nudging-and-interface-design-minitrack
Internet of Nano Things			https://hicss.hawaii.edu/tracks-54/internet-and-the-digital-economy/#internet-of-nano-things-iont-minitrack
Internet of People			https://hicss.hawaii.edu/tracks-54/internet-and-the-digital-economy/#the-internet-of-everything-converging-the-internet-of-people-iop-and-the-internet-of-things-iot-minitrack
	Digital literacy		http://dgsociety.org/egov-2020/conference-tracks/#1545136690087-16b2d9ce-d7de
Legal XML standards			http://www.icegov.org/wp-content/uploads/ICEGOV2020_Call_for_Papers.pdf
Collaboration support systems			http://www.dexa.org/egovis2020
Cybernetics policies			http://www.dexa.org/egovis2020

E-government enterprise architectures			http://www.dexa.org/egovis2020
		Ubiquitous and pervasive computing	http://www.dexa.org/egovis2020

The previous table does not contain the additions to the Collectives and the Verticals, since there were not new objects obtained. The dominant conferences that provided the supplementary objects were the following: Hawaii International Conference on System Sciences (HICSS), Annual International Conference on Digital Government Research (DG.O), ICEGOV, DEXA. They are some of the most prominent conferences in Digital Governance and they also have a significant academic influence in several other domains, for instance Computer Science, Engineering, Political Science and others. Since those are well established conferences and are organized for a long time, there was chosen not to include tracks and mini-tracks that might be outdated today. As a result, the editions of the conferences that were investigated were only those of 2020 or 2019 if the conference was not available for 2020. Yet again, as with the DGRL findings, the findings based on the conferences are falsifiable. That means that the academic community is welcome to discuss the inclusion or not of those findings in the Domain Structure.

As it is visible in both the Table 7 and Table 8, the investigation in the DGRL and the conferences was fruitful in providing new objects. Not only it provided over 100 new objects, those objects number amongst all the spectrums of the Domain Structure of the Digital Governance Science Base, and not just the Areas.

The overall schema of the Domain Structure is presented to possess the following schema:

Figure 11. The Domain Structure schema

That schema represents the basic Structure of the Domain and it signifies the fundamental positions of the proposed Domain Structure. Firstly, that the Areas play a leading role in the Structure's delineation, since they are the ones that are connect everything else. Secondly, that even if some of the elements focus on different aspects of Digital Governance comparing with some others, they all are equally paramount in order to provide a crystal-clear overview of the academic context of Digital Governance. Lastly, it shows that one Area, at this example "Service Portals" might correlate with more than one objects, for instance assist both "eHealth" and "eJustice". Of course, that is not always attainable, because some elements are mutually exclusive, for instance Generations, where it cannot belong in both "Gov 1.0" and Gov 2.0.

The last step towards establishing the Domain Structure based on the literature analysis is selecting the appropriate way of presenting and modelling the information occurred. The previous figure could stand a primary representation of the Domain Structure. However, it might not be suitable in representing all the Areas and the different type of correlations with the other elements. Also, it does not provide any quantitative type of information.

As for the latter, there are some more visual representation ways of presenting the quantitative information that emerges from the initial taxonomy of the Domain Structure. The first Tables, meaning the ones that concern the existing Domain Structure, could be of great use.

Starting with the Areas – Streams correlations, as it could be visible from Table 2, one intriguing visual representation would be the overall allocation of the correlations between them.

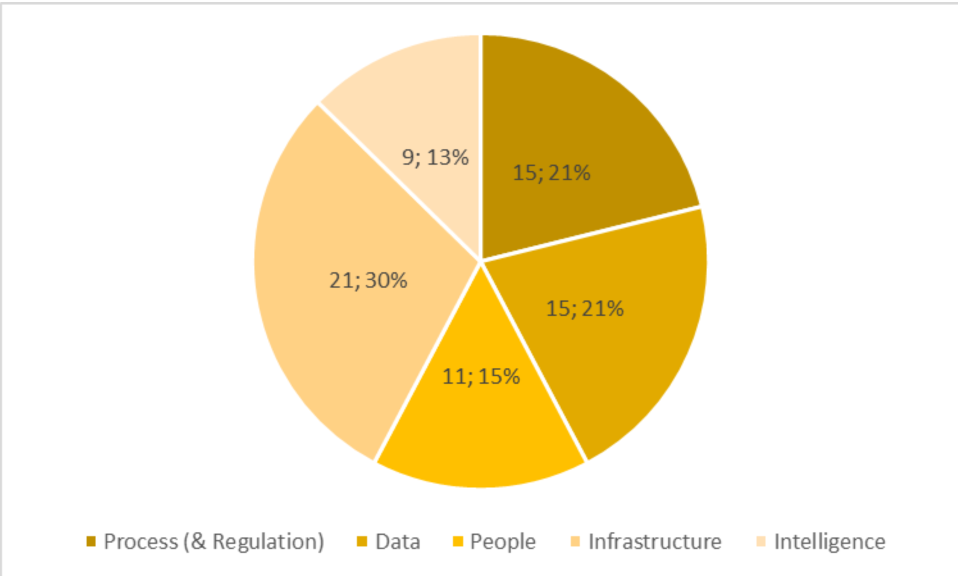

Figure 12. The distribution of the Areas - Streams correlations

That graph shows that of all Streams, the Infrastructure is the most influential, with both the absolute numbers and the percentage of the correlations to prove it.

Based on the same Table, the influence is also determined by the ratio of the Correlations – Strong Correlations that this Stream possesses. If the ratio is heavier on the Strong Correlations that means that even if the absolute number of correlations do not favor this particular Stream, it is strongly correlated with the existing Areas that involves. The next graph indicates that exact ratio.

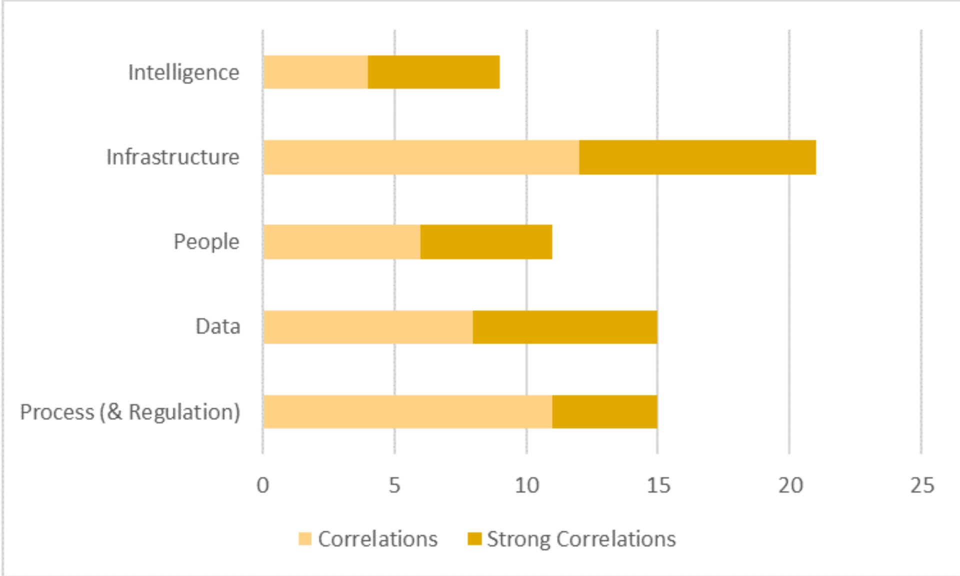

Figure 13. The Correlation - Strong Correlation ratios

This graph proves that even if the absolute numbers favor Streams like “Infrastructure”, it is “Intelligence” that has a greater ratio of Strong Correlations over the Correlations. And that could be quantified with the next graph:

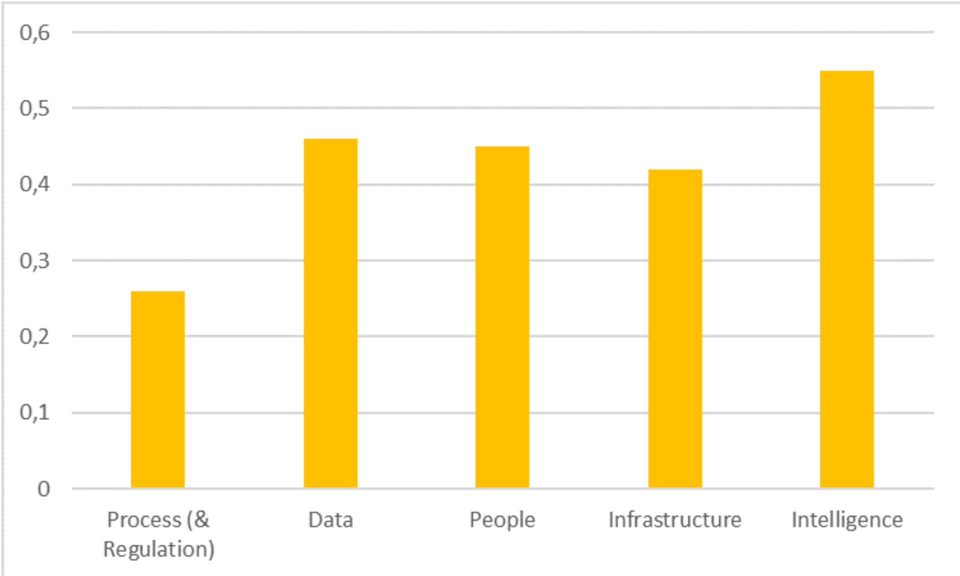

Figure 14. The comparison of the Correlations - Strong Correlations ratios

The last piece of information that could be visualized from this Table is the Streams association, meaning with which Stream, each Stream has the greatest number of common Areas included. That could be particularly useful, since the contextual research or organizational team could take into consideration some of the Streams that are commonly associated with the main Stream of implementation of their initiative. The following graph presents each Stream’s association with the other Streams:

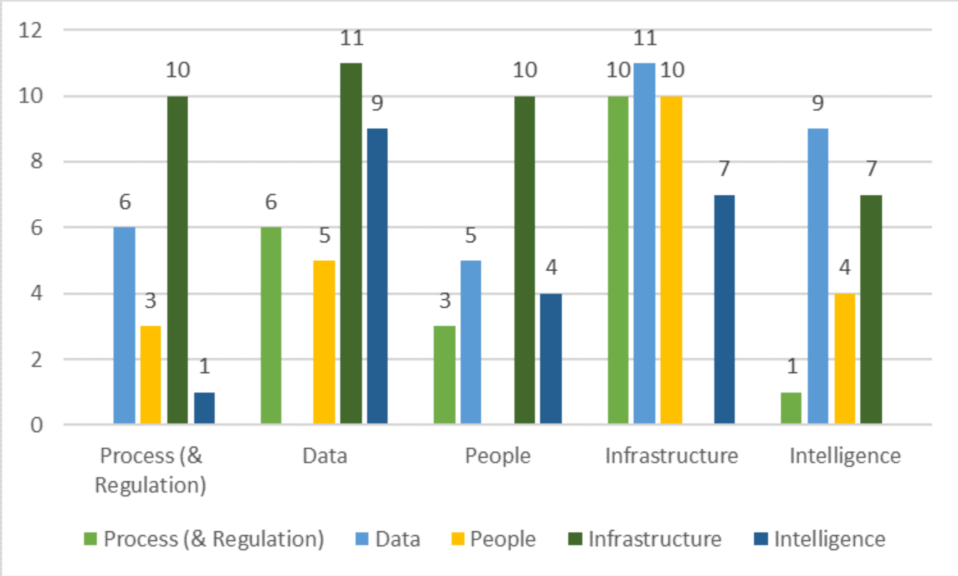

Figure 15. The Streams' associations with other Streams

It is visible that in the first three ones the "Infrastructure" Stream is the most associated with them, while in the last two the "Data" is the one. That could lead, for instance, into the decision to focus on the Data-related aspect of an initiative, given that the latter would have primary focus on Infrastructure aspects.

Moving forward to the correlations between the rest of the Streams, the visualization techniques do not change dramatically. For instance, just like in Table 5, where the distribution of the correlations to the streams was presented, the next figure presents the overall correlations between the Areas and the Collectives:

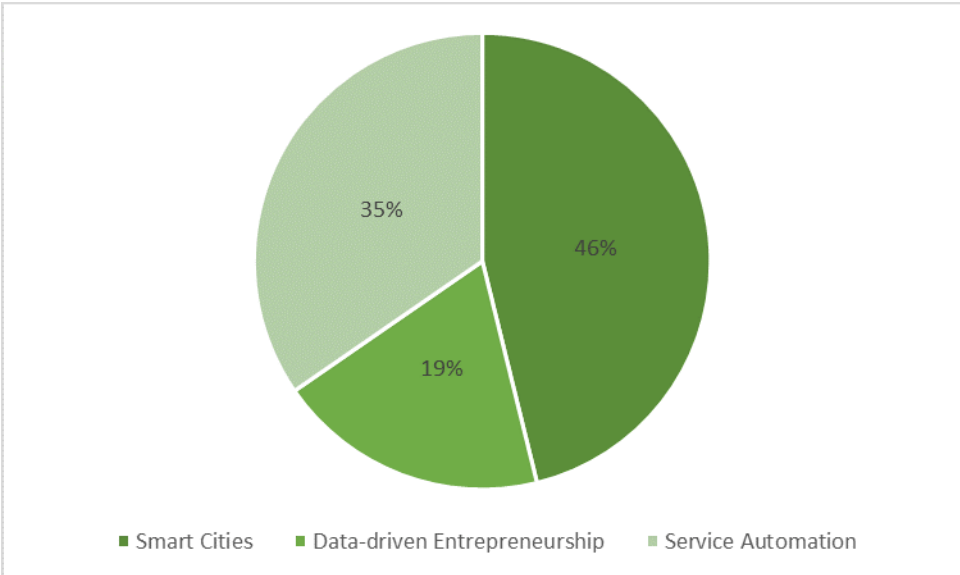

Figure 16. Correlations distribution between Areas and Collectives

It is visible that "Smart Cities" is the dominant Collective. The next and more interesting graph, is the one that presents the association of each Stream with every Collective. That happens with the same technique that provided Figure 15.

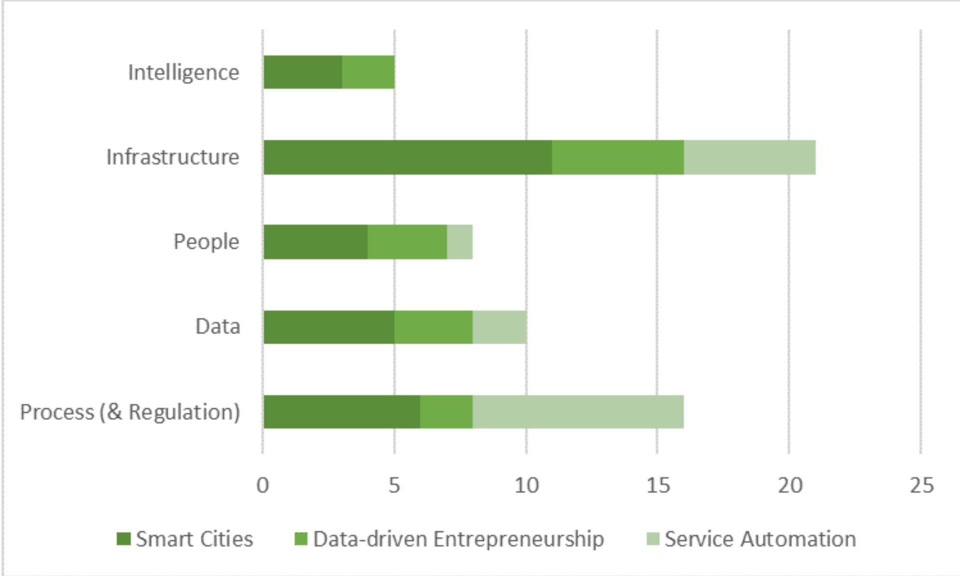

Figure 17. The Streams - Collectives associations

This graph indicates that mostly every Stream is associated with "Smart City" on a wide scale, while just "Process & Regulation" is the only one that is associated more with "Service Automation" than "Smart Cities". The results are plausible, and they generally reflect the current situation with the academic references', the projects' and initiatives' orientation.

There are plenty of combinations of the elements of Digital Governance Science Base Domain Structure to be associated and correlated with each other. Still, those visual representations, those graphs and plots are just quantifying the information needed, which is indeed impactful. However, those graphs, or the taxonomy presented in Figure 3 do not provide an ontology for the proposed Domain Structure. The interconnectivity is not fully evinced, the multidimensional nature of the taxonomy is narrowed down, the information does not include semantic representation of the correlations and the overall objects are limited up to a certain point, since if the number of objects is extended enough the taxonomy would be quite inconvenient to be studied.

On this basis, the need to create a more ontologically-enabled visualization emerges. This way the investigation of the elements is not one-dimensional, but it rather approximates the connectivity of a network, where all the relevant nodes and objects are interconnected with each other, providing the semantic identifying characteristics of the links between them. Additionally, the modelling of the ontology does not include only the Domain Structure Elements, even though they are the most crucial for the implementation of the Digital Governance Science Base. It also provides space for the rest of the "What?" components of the Digital Governance Science Base, meaning the Neighboring Domains, the Research Roadmap components and the Training Curricula.

The Neighboring Domains have emerged from the deliberations and the conferences related to Digital Governance and they are ten. They are the related scientific domains with the Digital Governance. The Research Roadmap components are extracted by the Gov 3.0 research roadmap report, where the scopes that the future research initiatives should focus on are presented, based on projections. Those research components connect the state of the art and the future research initiatives. The Training Curriculum is the training programme concerning Digital Governance by the Gov 3.0 project. It provides 6 thematic categories of courses and each one of them assists different aspects of Digital Governance. All those categories as well as their elements are included to the ontology. In addition, their associations with the Domain Structure's Areas is also included. The Areas are the epicenter of the Domain Structure and hence they are connected with the rest of the elements.

The appropriate solution on this scope came from Stanford Center for Biomedical Informatics Research (BMIR). The research team provided the academic community a free and open source platform that includes a suite of tools to construct domain models and knowledge-based applications with ontologies. The name of the platform is Protégé (https://protege.stanford.edu) and it is provided in both Desktop application and Web application (https://webprotege.stanford.edu/). In the case of the conduction of this Thesis the Desktop application was used.

The Protégé assisted the formation of the Digital Governance Science Base as it is presented in Figure 3. The aim was to represent the ontological graph of the entities and elements inside the Science Base, providing the semantic relations amongst them, some comments and their categorization. The result of the creation of the ontology are in the form of Web Ontology Language (OWL) documents.

Starting the modeling, the first step was to define the classes of the Science Base. Those are the categories of the elements that include the objects and their relations.

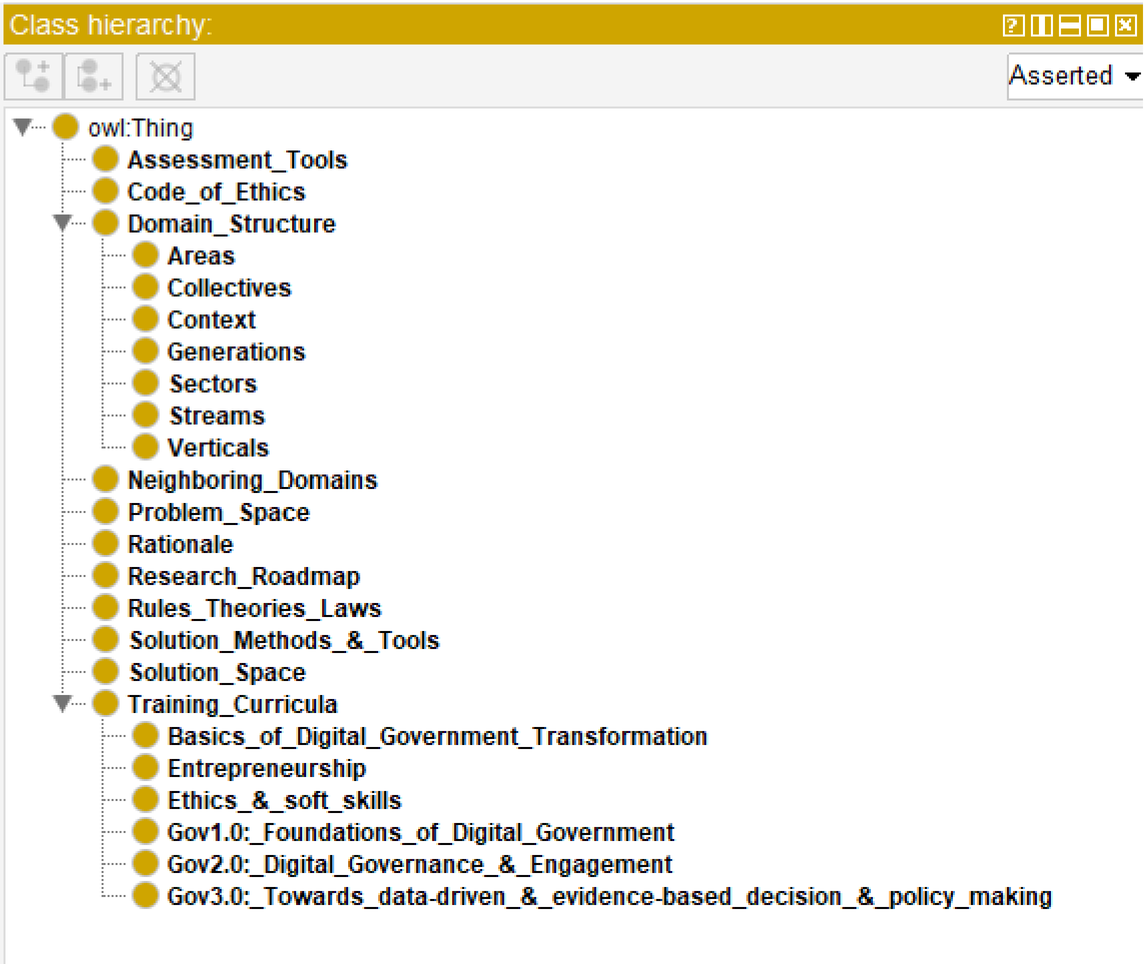

Figure 18. The classes of the Science Base

Examining Figure 18, it is obvious that the spatial recesses indicate the sub-classes. That is due to the tree-form of the final ontology. The components of the "What?" are the ones that are analyzed in this Thesis, and some of them are being divided into sub-classes.

One of the functionalities that complements the Class definition is that the one of the commenting, in order to clarify some key characteristics of the Class and to make the ontology easier to understand to observers.

Figure 19. The Class comments

The next fundamental aspect of the ontology is the relations between the entities, namely the Object Properties. Thanks to them, the semantic representation of the correlations between elements is enhanced. A convenient way of presenting one Property is the one of an arrow, meaning an implication symbol (→). Just like in the case of a sentence that has three parts, meaning subject, verb, object, the Property signifies the verb that characterizes the correlation between the two elements that connects. For instance, the next Figure presents the Property of "involves". That is the Property that connects an Area with a Stream. The Areas involve Streams in a way that a Stream, which is a set of factors in the implementation of an initiative, plays a role in the implementation of an Area, which is an entity that concerns the application that enhances Digital Governance.

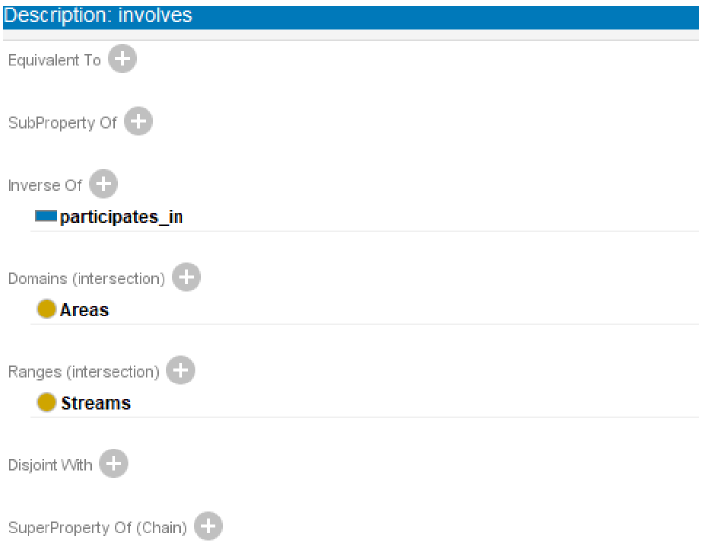

Figure 20. Object Property example

In this Figure the fields of the Description are visible and each of them represent a separate part in the semantic analogy of the correlation. The Domains are the elements that could play the role of the subject in the semantic analogy. It is the node where the correlation begins. The Ranges are the ones that represent the object. It is the "target" node of the arrow. Another part that it is intriguing is the one of the Inverse. There the inverse, or the arrow with the exact opposite direction, is defined. In this example, the "involves" Property has the "participates_in" Property. That means that if the Domains – Ranges reverse each other the appropriate Property that connects them in that order would be the "participates_in". It is plausible that the inverse Properties, in the most cases, have inverse meaning. In this case the involves is the inverse verb of the participates, since the first one is used by the wider group for the sub-groups, while the other is used by the smaller entities that lead to the bigger ones. In other examples, the inverse entity is described by the same verb, just used in the contrary voice, meaning in the passive voice if the initial is used in the active voice or in the active voice if the initial is used in the passive voice. For instance, a "Sector" is "augmented_by" a "Vertical", while a "Vertical" "augments" a "Sector". That underlines the clausal nature of the semantic representation.

Moving forward, the next step is the definition of the exact objects, meaning the records that are not Classes or Properties, but they are the actual examples of the Classes that the Properties apply to. They are called Individuals. They belong to Classes, are described by the Properties and are presented organized by their Class. The Individuals are the ones that comprise the essence of the Domain Structure ontology, inheriting their Classes' characteristics and following the rules, meaning the Properties that the relevant Classes follow.

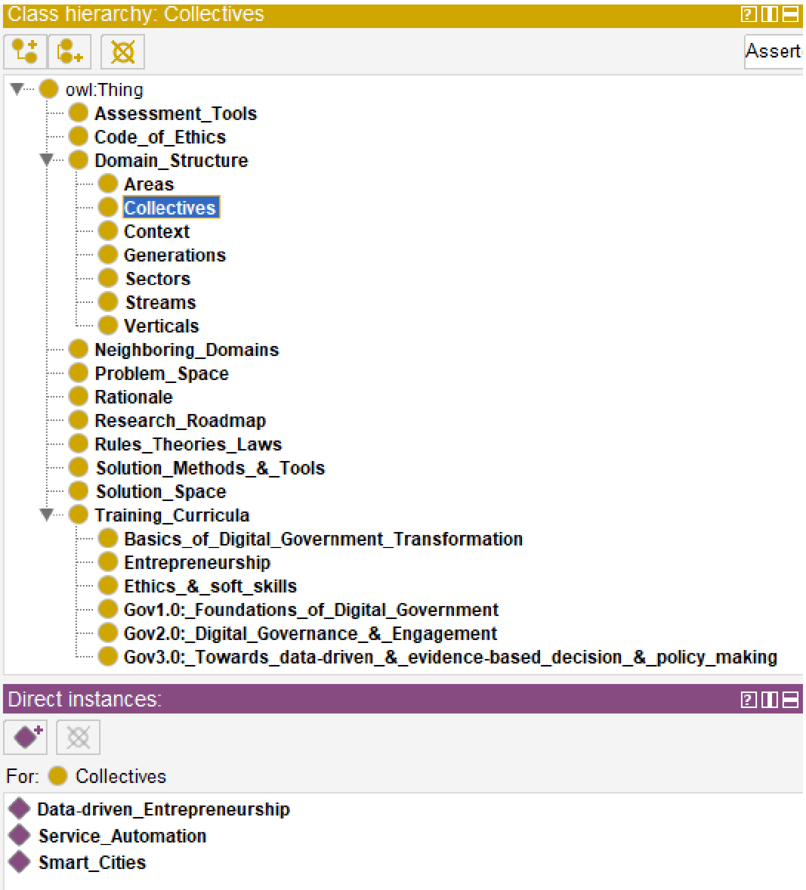

Figure 21. Individuals presented based on their Class

The Properties that they have depend on their Class. That happens because some Classes connect with only one other Class, while others might have multiple types of Properties for different connections with Classes. In this case, the Collectives as a Class interacts only with the Areas. Consequently, the Properties of the Collectives Individuals will be consisted only by "group" (Area).

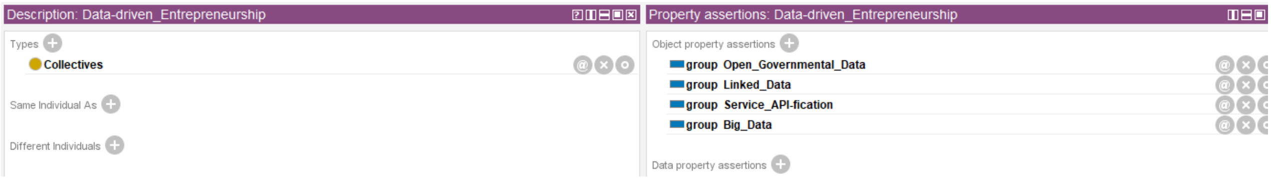

Figure 22. Individuals' characteristics

Another, more complex example of Individuals might be that of an Area.

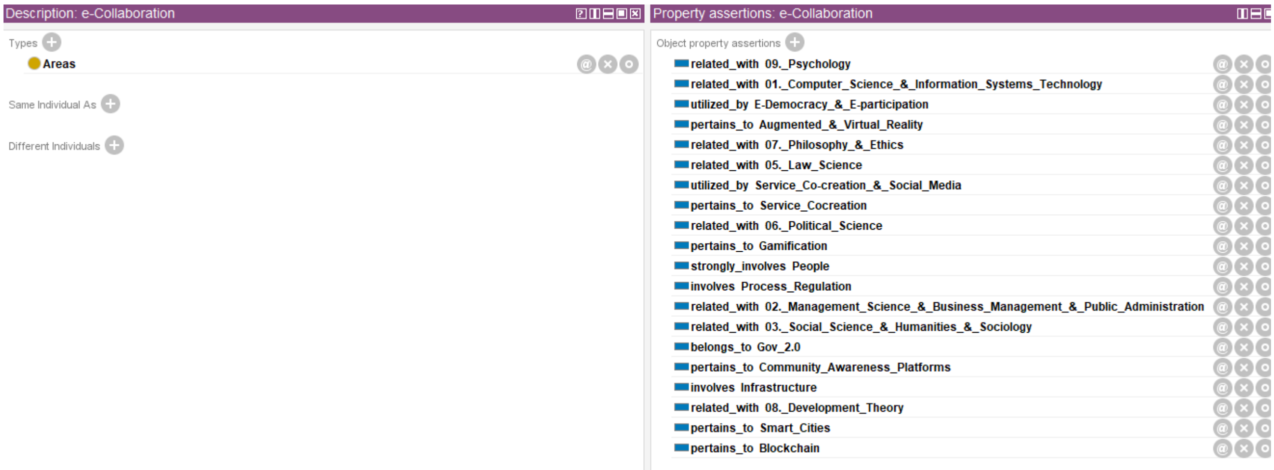

Figure 23. More complex Individuals' characteristics

Another important aspect that needs to be clarified is that even if the Domains and Ranges might be the same in an Object Property, the correlations' semantics might differ, depending on the

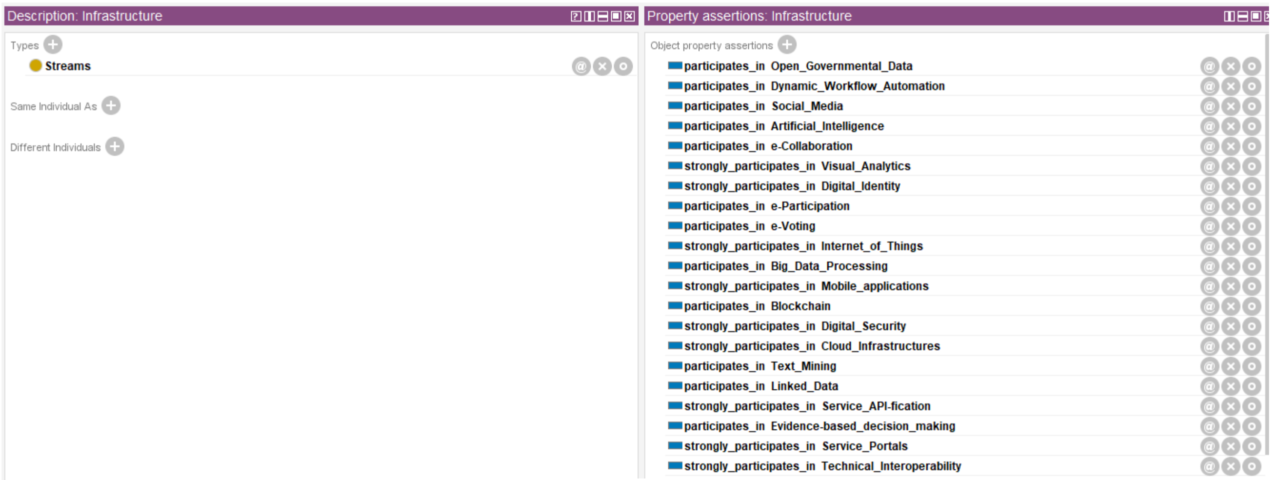

Figure 24. Semantic differences between Properties

name itself. For instance, a Stream can either "participate" in an Area or it can "strongly_participate" in an Area.

Finally, with the usage of the OntoGraf (https://protegewiki.stanford.edu/wiki/OntoGraf), which is a Protégé plugin, the ontological visualization was made possible. The final view provides the user with the ability to open the exact Classes needed, to visualize the ontology in a plethora of schemas (horizontal tree, vertical tree, spiral, network etc.) providing the exact Individuals and their correlations. The correlations are presented as arrows between the nodes and one could see the name of the correlation, as well as the types of Classes it connects. Hovering over an Individual one could also see its Class and all the Properties of this particular Individual. The exploration of the ontology is accomplished through careful examination of the objects, since the overall number of Individuals and Properties is quite extensive and increases the visual complexity of the schema. Luckily, the visual representation is dynamic and the observer can move objects in order to make the schema more appealing. The OWL code of the schema created with the Protégé is free and open source and it is available at Github (https://github.com/panos-keramidis/DGSB_OWL).

The next Figures present the OntoGraf ontologies. They are presented in different modes in order to simulate the variance of appearances that could emerge using OntoGraf. More conveniently, the user could experiment the ontology if it would be uploaded in the Web application of Protégé.

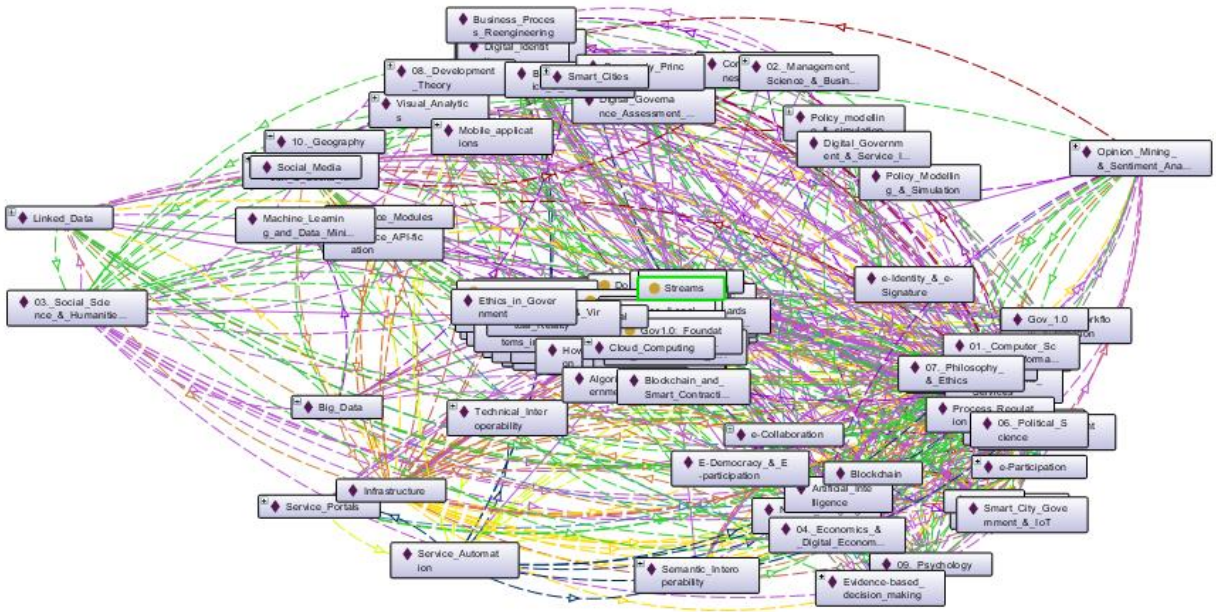

Figure 25. Network Overview of the Digital Governance Science Base using OntoGraf.

As it is visible, the purple diamonds are the Individuals, the yellow circles are the Classes and the multicolor arrows are the Properties between them.

The number of objects in the ontology does not allow them to be readable if the ontology possesses the whole canvas presented as a horizontal or vertical tree, which are structured by Class level hierarchies. Fortunately, using Protégé with OntoGraf plugin or a Web application that is capable of visualizing OWL documents the user is able to zoom in and out in order to specify the canvas in any point. Another useful functionality of Protégé is the ability to search specific objects and entities in Ontograf.

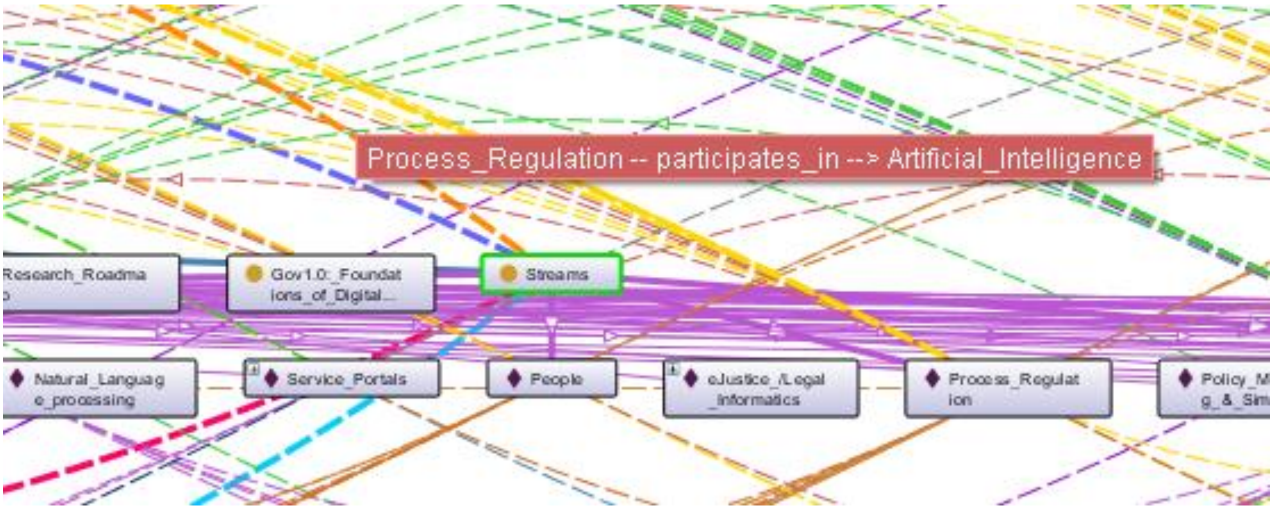

Figure 26. The Properties presented as arrows

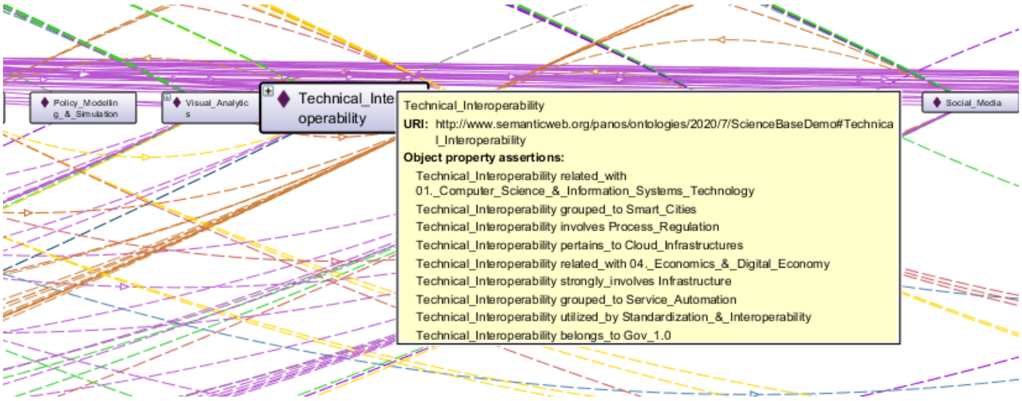

Figure 27. The Individual properties

Generally, the ontology presents the components of Digital Governance Science Base, their objects and correlations with semantic representation. Protégé provides a Reasoner, meaning a tool that checks the logical correctness of the ontology created, and that Reasoner indicates that this ontology does not include any logical inaccuracy.

The objects that build the presented ontology are the ones before the DGRL and conferences research, since the objection was to provide the ontology on a steady basis, with the objects inside it already studied and discussed in literature, conferences and summits. The ontology will be reinforced with the newly emerged objects that this Thesis proposes, when those objects are approved by the relevant academic community. Still, the existing ones provide more than enough evidence for the usefulness of the Digital Governance Science Base and set the ground for future research initiatives. One impactful addition would be the ontology of the other components of the Science Base, since this focuses only on the "What?" components.

4.1.2 Results Based on Questionnaires

As mentioned in a previous chapter, the questionnaire was meant to be completed by experts, or at least students and practitioners of the Digital Governance field. On that context, the questions were not bounded to be introductory to the subject, or to aim solely at the instinctive views of the participants on the subject. The specialization of the target group provided the conducting team with the opportunity to focus on a higher level of intricacy concerning both the quality of the questions and the aptness of the recommendations of the expected answers.

The questionnaires were completed after a lecture at Samos Summit 2020, where Professors, researchers, students, public administration officials and private stakeholders were participating. All of them had an overview of the domain, which only was enhanced by the lecture on the Digital Governance Science Base.

As usual, the first questions were the demographic ones. Name, surname and email addresses were the first ones. Overall, the questionnaire was completed by 38 people, from various countries and backgrounds. The majority was Greek participants, with the rest being from a plethora of countries, Germany, Austria, the Netherlands, Slovenia, Poland, Lithuania, Italy, Norway and Denmark. The next questions concerned the academic level of the participants as well as their current occupation. The results are presented in the next Figures.

Academic Level

Sector of Economy you work in

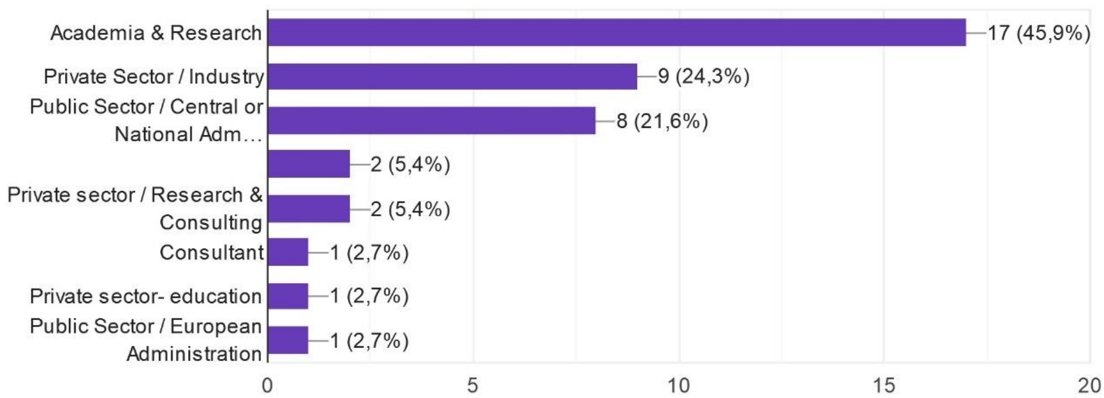

Figure 28. Sector of Economy where the participants work in

The results indicate that the vast majority of the participants are rather on the most educated end of the population, having at least a Bachelor’s degree, with the majority possessing a Master’s degree. There was a set of participants that was even more high on the education scale, holding a PhD, being Post-Doctoral researchers or even Professors. That only adds on the reliability of the answers they provided and indicates that their opinions on the subject might be the ones that shape-shift the academic and public sphere concerning Digital Governance.

Their occupation is also quite relevant on the subject, meaning the Scientific Foundations of Digital Governance, since the majority is working on the Academia, while other strong percentages are related with public administrations, the industry etc.

Moving forward to the actual questions related to the subject, they start with the rating of the 10 elements of the Digital Governance Science Base. The rating system was comprised of four choices, that progressively increased in importance value, meaning the first choice was the indication of the Least important while the fourth was that of the Most important. The goal was to specify which components had to have the greatest academic focus in order to quantify the need for further research on those components. The question does not come without challenge, since the rating system could not represent the overall importance equation, since the latter is too complex to be projected linearly.

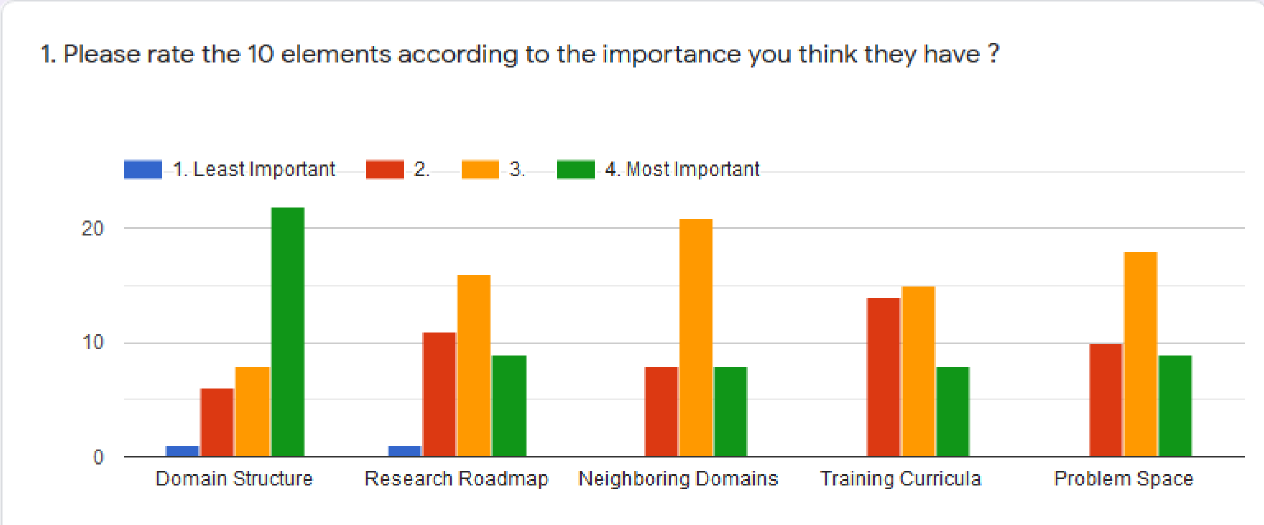

Figure 29. Importance of the DGSB elements (1/2)

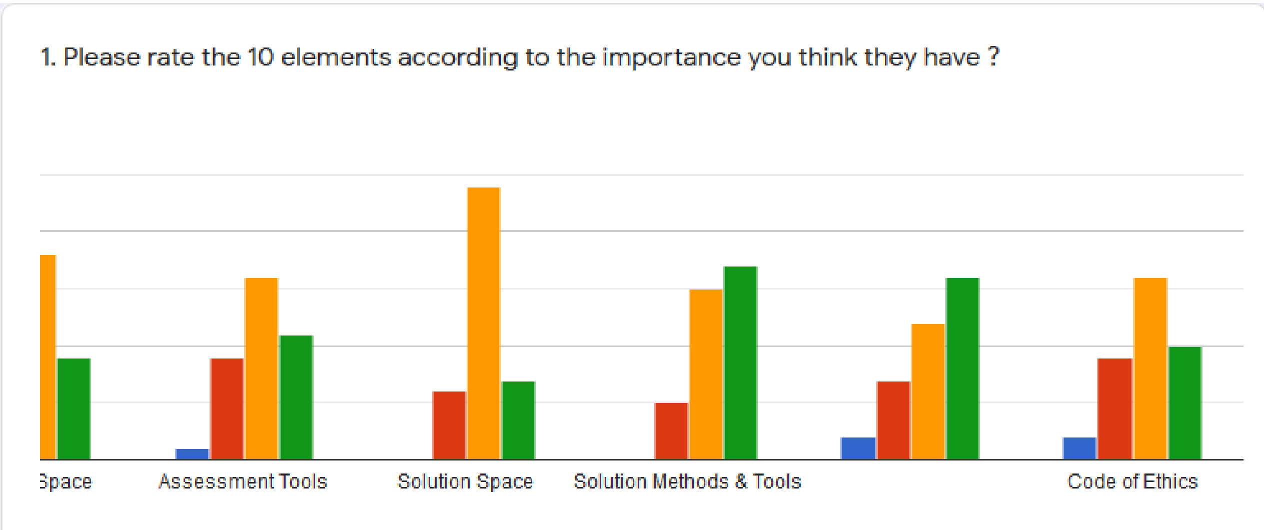

Figure 30. Importance of the DGSB elements (2/2)

The next question was on similar context, meaning the Digital Governance Science Base components. This time it concerned the difficulty of the academic community to deal with them.

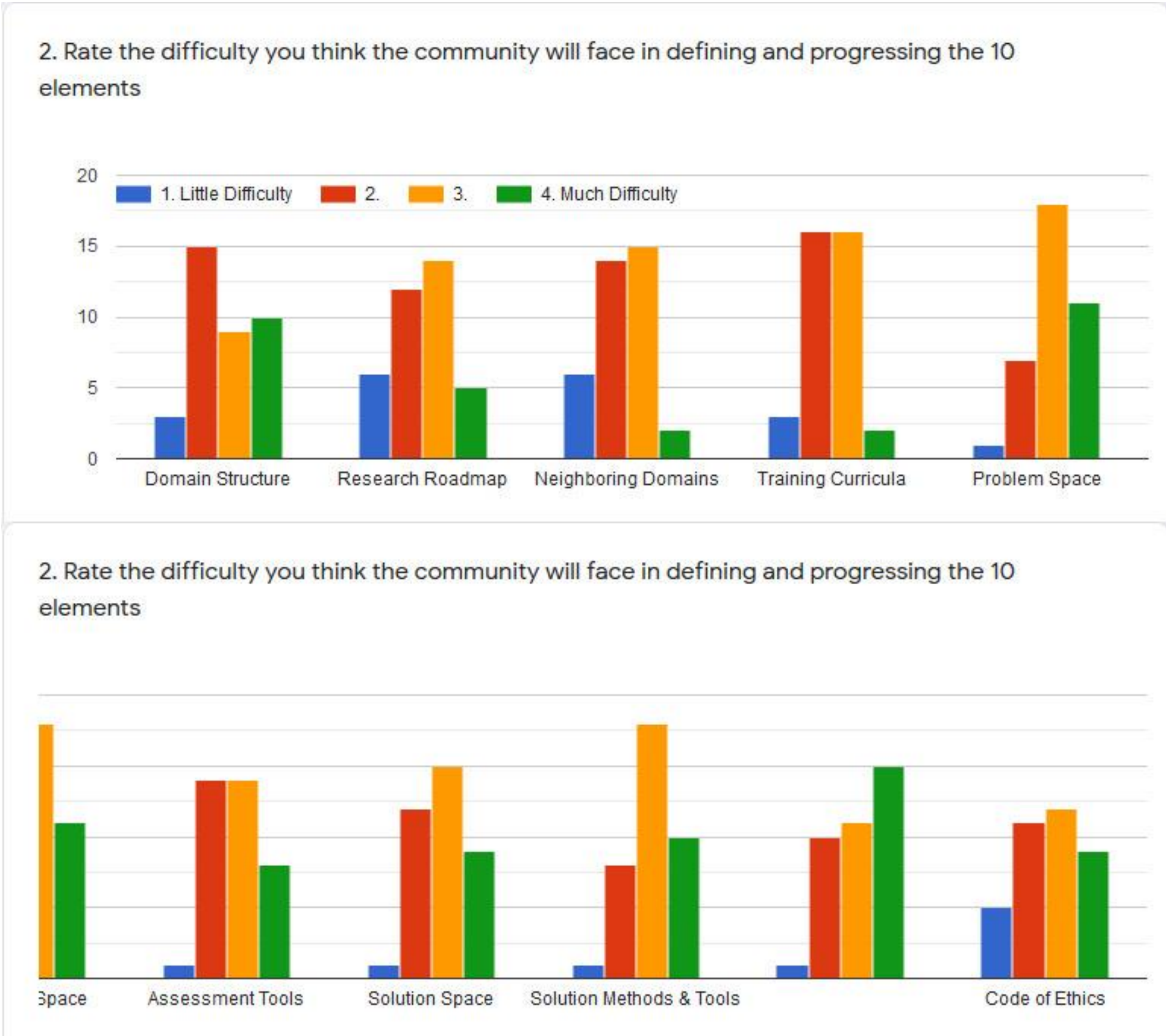

Figure 31. The difficulty that the academic community will face dealing with those components

The third and last closed-type question of this part of the questionnaire, that where the questions concern the Digital Governance Science Base components, is that of the participants' involvement and contribution to some of those components. The results are presented in the next Figure.

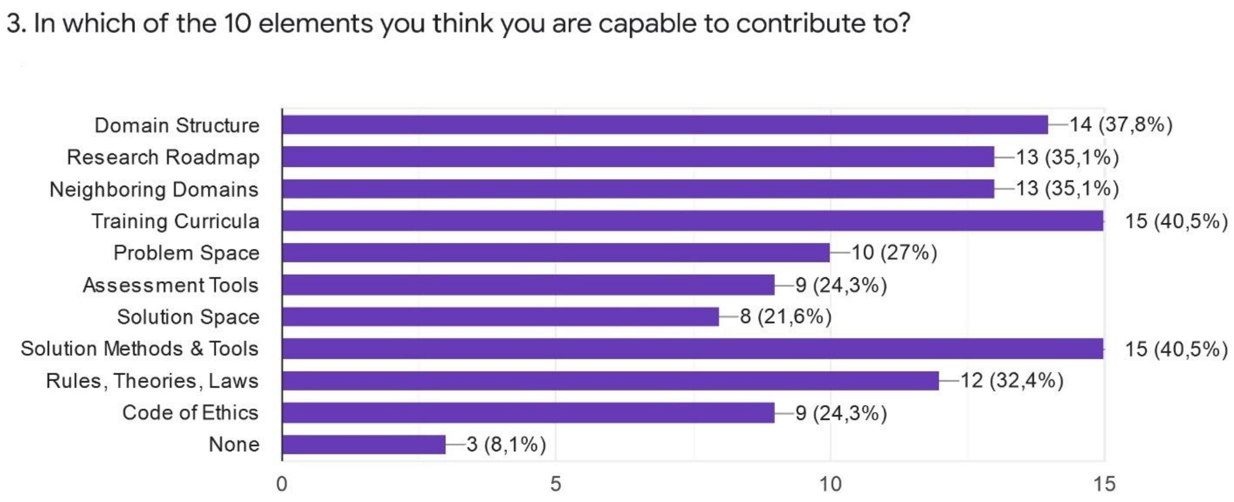

Figure 32. The Participants' potential contribution to the components of the Science Base

The last question of the section is an open question where participants propose new components that might not be included in the existing form.

The results in this section were intriguing. Regarding the importance ratings, overall, the participants agree that the "Domain Structure" is the most important component. The "Solution Space" and the "Neighboring Domains" follow in importance. The participants' distributed the importance indications evenly, with the "Training Curricula", the "Research Roadmap", the "Solution Methods & Tools" and the "Rules, Theories and Laws" (it is the one that is not visible in the diagrams because of its length) being characterized with indications from all the spectrum of importance. The results concerning the difficulty of the definition and expansion of the Science Base are also interesting. The majority of the participants agree that the most difficult component to define is that of the "Rules, Theories and Laws". The great majority of the participants agree that the next most difficult components are the "Problem Space" and the "Solution Methods & Tools". Just like the previous question, this question's answers are also distributed in the median difficulty ratings. As for the third question, the most popular components for the participants' contribution are the "Solution Methods & Tools", "Training Curricula" and the "Domain Structure". Some exemplary results of the open question of this question are presented in the "Discussion" chapter.

The next section of the questionnaire focuses solely on the "Neighboring Domains". The domains proposed as options were the followings: "Computer Science, Information Systems Technology", "Management Science, Business Management and public administration", "Economics, Digital Economy", "Psychology", "Social Science & Humanities, Sociology", "Philosophy/ ethics", "Political Science", "Development Theory", "Law Science", "Geography" and the open option for something else.

The first question concerns the importance of each "Neighboring Domain" with the same scaling option that was used in the previous section of the questionnaire. The results were the following:

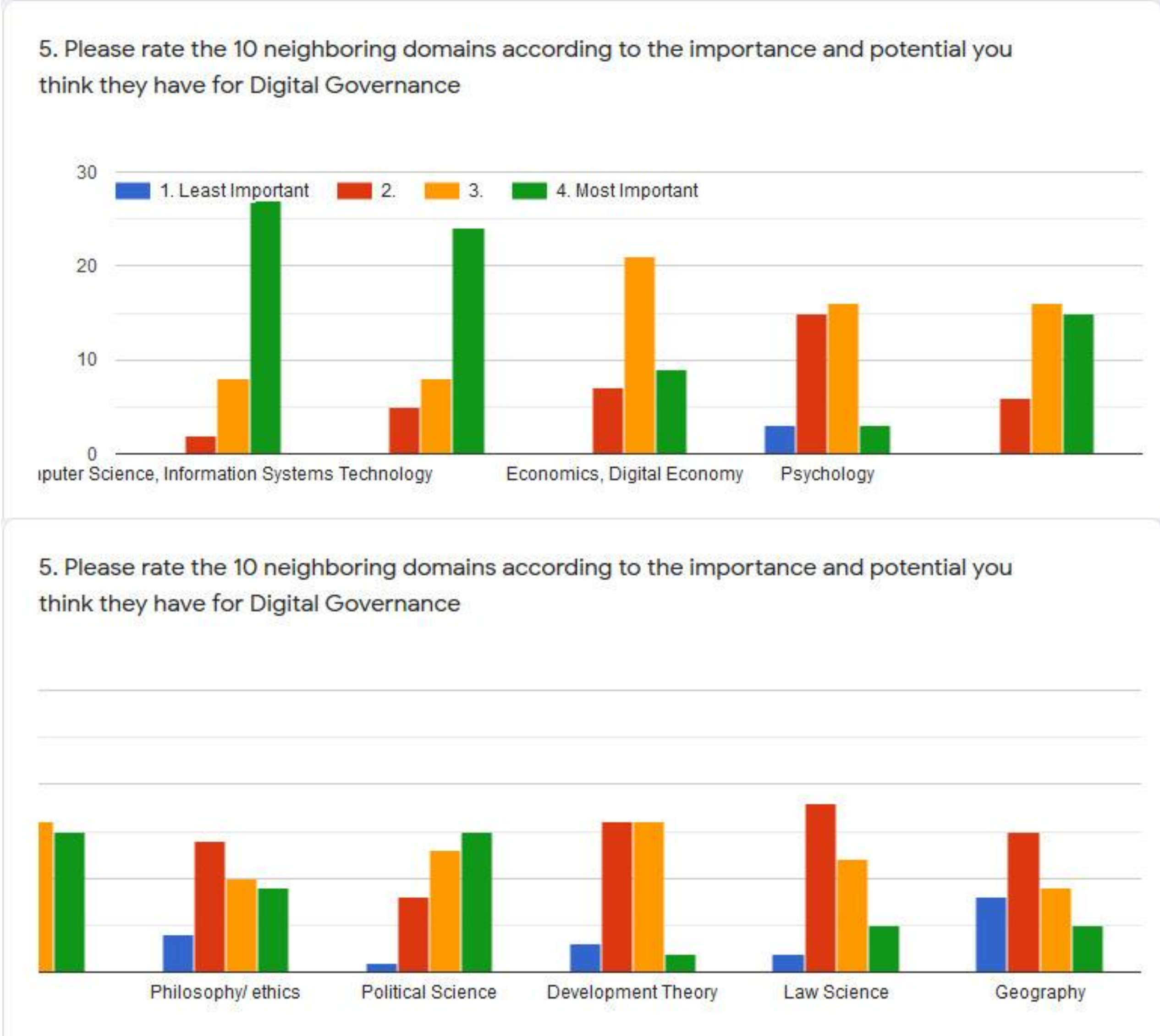

Figure 33. The Neighboring Domains rating based on the importance

The next question was an open one. The participants were called to propose any additional Neighboring Domain that might not be included in this set of options. The results were absorbing and will be discussed in the "Discuss" chapter.

The next question was a more complicated one. On the vertical axis, there were the Neighboring Domains. On the horizontal one there were the basic components of the Digital Governance Science Base. The question was about the contribution of each Neighboring Domain to the Digital Governance Science Base. That was not the full representation of the contribution or the influence of each domain in the components of the Science Base, since there was not a particular way to rate how much each domain contributes to each component, it was just the existence or the non-existence of the influence that the domain has over the component. Still, it is a remarkable question because it follows the notion of the association, as it was mentioned in a previous section, between two components of the Science Base. The results are presented below:

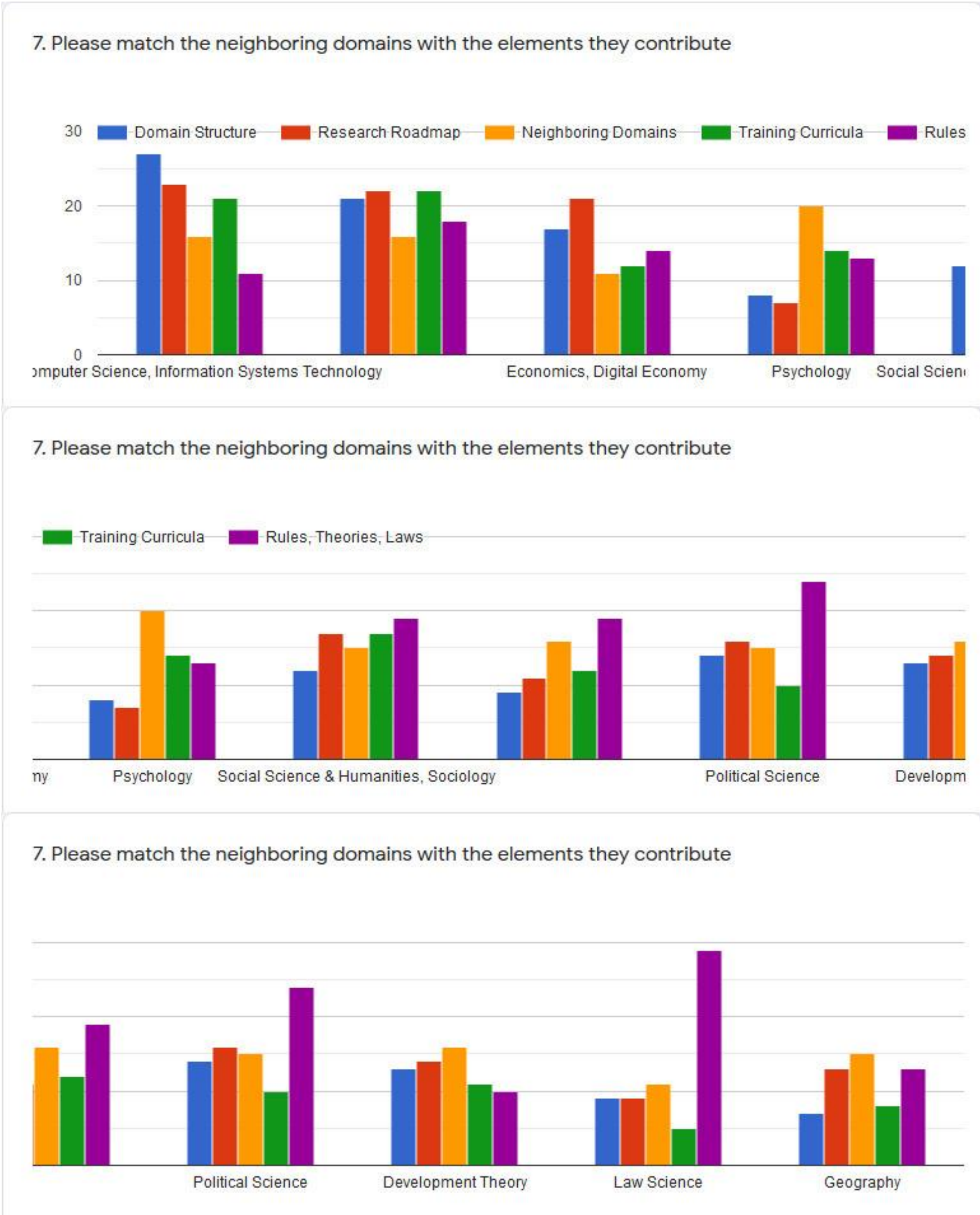

Figure 34. The contribution of the Neighboring Domains to the DGSB components (1/2)

Since the components were too many to be presented in a single graph, the question was split in two. The first covered the "Domain Structure", "Research Roadmap", "Neighboring Domains", "Training Curricula" and the "Rules, Theories, Laws", while the second one covered the "Problem Space", "Assessment Tools", "Solution Space", "Solution Methods and Tools" and the "Code of Ethics". The results of the second part of the question are presented below:

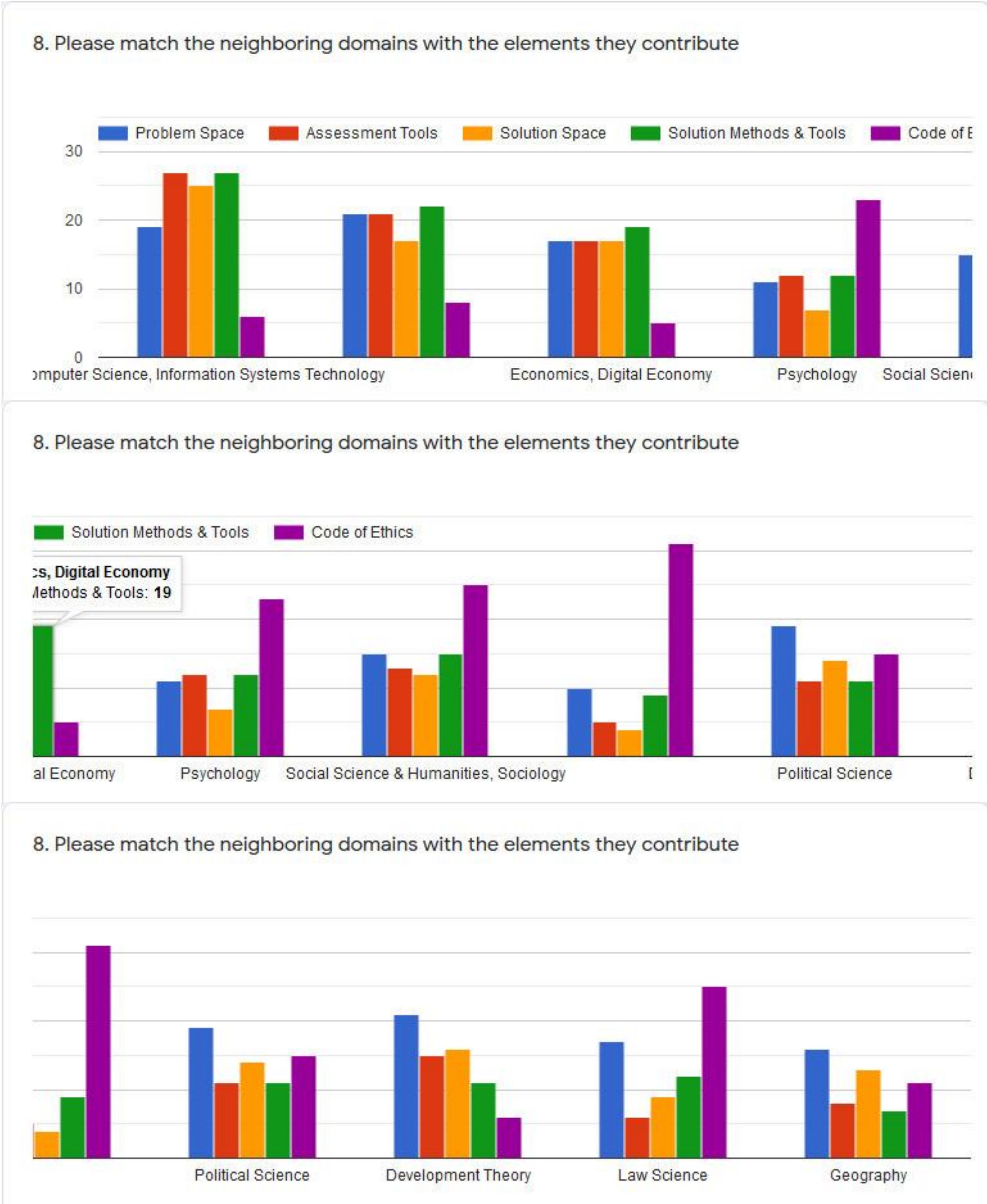

Figure 35. The contribution of the Neighboring Domains to the DGSB components (2/2)

The results are quite detailed and provided an overview on the context of the association of the Neighboring Domains with the rest of the components. That assisted the mapping of the Neighboring Domains in the Digital Governance as a scientific field.

The next question was similar with the one that is presented in Figure 32. This time, they respond to which Neighboring Domains they can contribute.

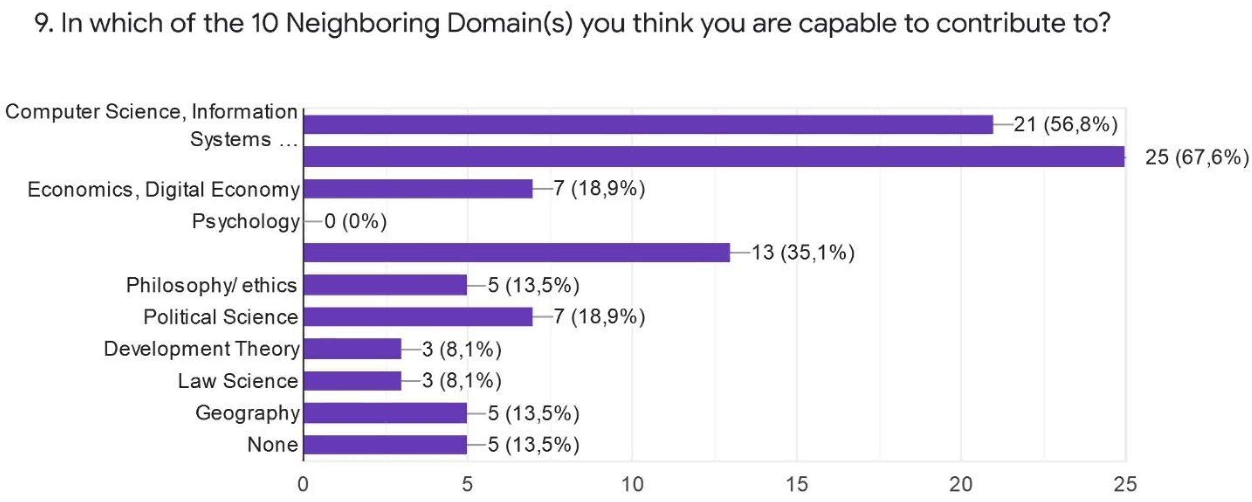

Figure 36. The participants' contribution to the Neighboring Domains

The last question of the questionnaire was an open question about additional comments, propositions that could help define the Digital Governance Science Base, its Domain Structure and its Neighboring Domains. The participation in this question proved distinctively advantageous since it provided the organizing team with some insights that the participants might possess through their practice on the field.

This section of the questionnaire was critical for the development of the Digital Governance Science Base and more specifically for the definition of the Neighboring Domains. Most participants agree that “Computer Science, Information Systems Technology” is the most important Neighboring Domain, closely followed by “Management Science, Business Management and public administration”. “Economics, Digital Economy” is considered important, while it is generally observable that the order of appearance of the options is inversely proportional to their importance, as stated by the participants. That means that, generally, the most important were the ones in the first positions and as the order progressed the importance seemed less significant. As for the association of the Neighboring Domains with the components of the Science Base, the components that each Domain influenced the most were the following:

Table 9. The Neighboring Domains and their most influential component of the DGSB

Neighboring Domains	Component of DGSB
Computer Science, Information Systems Technology	Domain Structure, Assessment Tools, Solution Methods & Tools
Management Science, Business Management and public administration	Research Roadmap, Training Curricula, Solution Methods & Tools
Economics, Digital Economy	Research Roadmap
Psychology	Code of Ethics
Social Science & Humanities, Sociology	Code of Ethics
Philosophy/ ethics	Code of Ethics

Political Science	Rules, Theories, Laws
Development Theory	Problem Space
Law Science	Rules, Theories, Laws
Geography	Problem Space

Finally, the decisive majority can contribute to the Neighboring Domains at the "Management Science, Business Management and public administration" one. The next most prominent Domain is that of the "Computer Science, Information Systems Technology".

Generally, the questionnaire's results, both the quantitative and the qualitative, provided beneficial comparisons between the Science Base components and the Neighboring Domains, proving that the difficulty, the importance and the participation in some of the abovementioned aspects are relevant and variable. It also pointed out the exact aspects that should concentrate the academic focus and be the cynosure of the future research initiatives. Furthermore, it signified the ambiguity of some terms, based on their assigned difficulty and academic contribution. One singular part of the questionnaire, namely the associations between the Neighboring Domains and the rest of the Digital Governance Science Base components, proved that the ontological approach includes interconnected components and that some of the components are more auspicious, since they are enhanced by a lot of Neighboring Domains, for instance the "Code of Ethics", while others, for instance the "Solution Space", face less beneficial contribution from the Neighboring Domains. That is something that should be considered for the future research orientation. The last thing that also needs to be examined in future research activities, is the heterogeneity between the potential contributions, where also some of the components of the Domain Structure or the Neighboring Domains, face a similar situation as that of the associations, meaning there is polarization of the contribution in a few components while the rest remain stagnant.

The views of the experts of the field are a unique advantage towards the definition of the Digital Governance Science Base and this questionnaire conduction provided exactly that. Providing both quantitative and the qualitative results, based on both closed-ended and open-ended questions, the questionnaire was the key step towards specifying the research needs, the weaknesses and inhomogeneities of the existing Digital Governance Science Base and its conduct by the relevant academic community.

5

Discussion

5.1 Discussion on the Results

The results of both the literature analysis and the questionnaire conduction revealed the fundamental aspects of some of the most underlying components of the Digital Governance Science Base. Those components are the Domain Structure, the Neighboring Domains, the Research Roadmap and the Training Curricula. They are interconnected with each other. That interconnectivity is also visible through some of the questionnaire questions and answers, where one of the components and its objects, meaning the Neighboring Domains, contribute to the rest of the components of the Science Base. So, it is safe to assume, that the rest of the components are also associated with each other through some semantic reciprocity.

Having clarified that the results of this Thesis contribute to the whole Digital Governance Science Base establishment, even if the main focus is in the components that answer the question "What?" about the Digital Governance scientific domain, since the components are interconnected and studying one of them might provide useful insights concerning others, it is essential to study the qualitative findings of the research conducted. Those are the insights that emerge from the overall inspection of the quantitative results and their correlations, as well as the direct insights of the questionnaire conducted.

Starting with the latter, the open questions in the questionnaire conducted in the Samos Summit were three and they were related to the following aspects: a) Digital Governance Science Base elements missing, b) Neighboring Domains missing, c) Ideas and issues that could assist the definition of the Digital Governance Science Base, the Neighboring Domains and the Domain Structure. As for the first one, the proposed elements include "Implementation", meaning the ease of implementation of a solution, probably meaning to categorize it into the "How?" region of components, "Context" meaning the direction of the problem or the solution, also in the "How?" region and others that fall into the existing categories of the Digital Governance Science Base. As for the second one, the propositions were more diverse in terms of the scientific theme of the propositions. "History", in order to understand the cultural background, "Cultural Fit", for the ecosystems adopting the solutions, "Neuroscience, Cognitive Psychology", that could be useful in a number of aspects concerning the solutions and the ecosystems applied to, "Education", "Statistics" and others were proposed. There were also other experts that commented that the "Neighboring Domains" component is rather simplistic as a term, since the closest neighboring discipline may depend on the subject of study. Others propose the separation of some terms, for instance the management science and the public administration. Finally, there were some more applied propositions for the Neighboring Domains, for instance "Industry" since many industrial research projects are also including Digital Government issues, or even "Engineering", as a broad term of a Neighboring Domain. Lastly, concerning the more general last question, the input is consisted of subjects from broader thematic disciplines. Some experts emphasize the need for certain actions, for instance the visualization, the relations' representation and the description of the elements. Others, report some challenges that might occur during the expansion of the Digital Governance Science Base, for instance its multidisciplinary nature. There was also a comment doubting the very existence of the Digital Governance Science Base and considers it a non-independent scientific domain.

Overall, the results of the open questions signify the acceptance of the structural decisions that support the Digital Governance Science Base and enhance it with more elements, comments and aspects that might not have been visible at first. They also prove the diversity of the standpoints about the Digital Governance Science Base. That is due to the multidisciplinarity of the experts' interests, but also their opinions on the matter. The questionnaires served their purpose in enhancing the existing components and alerting the research team about the challenges and the particularities ahead.

As for the overall research results, the multidisciplinarity of the scientific field of Digital Governance is also visible. The Digital Government Reference Library, the relevant conferences as well as the traditional research sources reveal the various categories of key-words, thematic directions and research principles. The multidisciplinarity might lead to complexity, mishmash and fuzziness amongst the Digital Governance Science Base elements, both in terms of external correlations and the internal ones. Initially, the ontological approach of modelling might seem complicated, since it requires extensive analysis of the properties and the correlations between the components, but it is the necessary approach in order to define the structural model alongside with the semantic correlations inside and outside of it accurately.

The Digital Governance Science Base is not yet fully completed, since the parallel research's results found in the DGRL and the conferences are not included in the ontology. However, even with the existing structure of the ontology and the tables presented with the potential future additions it is easy to understand the expansion of the Digital Governance Science Base, not only by the starting research team but also from the broader scientific community when the ontology is provided for everyone to have access to.

5.2 Proposition to the Scientific Community

The role of the scientific community in the establishment of a new scientific domain is of paramount importance. There is a certain need for the construction of a specific community consisted of practitioners, researchers, public and private sector stakeholders and citizens. That community will monitor, update, deliberate and popularize the Digital Governance Science Base to the best of its interest. The heterogeneity inside this community is more than necessary. That community needs to include people from various disciplines and from different levels of the organizations' hierarchy, in order to accomplish the inclusion of all the different standpoints concerning the Science Base's future.

The scientific community can study the proposed ontology of the Science Base and the results of the research conducted in order to identify missing elements, structural adjustments and to debate on the advantages and challenges that this ontological approach provides to the scientific foundation of the Digital Governance. The Protégé and Ontograf visualization provides a comprehensible representation of the ontology, ready to be reused for other research initiatives, which is a desirable step towards the scientific acceptance.

Figure 37. The Digital Governance Science Base Community

This Thesis provides the scientific knowledge base the structured and well-defined way of modelling the Digital Governance as a scientific domain. That domain is independent as an entity but it does connect with others. That connection is presented within the section about the Neighboring Domains. The overall Digital Governance Science Base is hereby presented with both the quantitative data and the modeled ontology. The former provides the exact individuals that consist or are projected to consist the Digital Governance Science Base, along with some useful statistics to illustrate the different aspects that characterize each of the individuals or the categories. The latter, provides the visual representation of the categories, the individuals and the semantic correlations between the different components of the Digital Governance Science Base, emphasizing to those that answer the question “What?”, concerning Digital Governance. Consequently, the scientific community can contribute on a range of aspects of this domain. Quantitively or qualitatively, on a specific component or on the overall Science Base, on the ontology or the individuals, by enhancing the existing Science Base or proposing another the scientific community has the opportunity to set the foundations for a more scientifically structured Digital Governance.

6

Conclusions and Prospects

6.1 Conclusions on the Methodology

Reporting the results of the Methodological approach followed in order to accomplish the modelling and the visualization of the Digital Governance Science Base, the Methodology is the first aspect that subject to evaluation. The results accuracy and the success of the scientific foundation might not depend solely on the Methodology but it is a great indicator of the success.

The overall Methodology was successful. The research steps were concrete, the research investigation included several sources of information to achieve the least deviation possible and the timeline for these actions was reasonable. As always, the Methodology acted in different levels of abstraction for every aspect of Digital Governance Science Base, measuring the fundamentals and those that could be elaborated in future research initiatives.

The combination of literature analysis and the questionnaire conduction is a safe, well established and prudent decision when the subject is scientifically driven. The literature provided the appropriate foundations for the modelling and the visualization as well as for the documentation of the abovementioned and the questionnaire provided reinforcement for one of the components, namely the Neighboring Domains, and also provided insights, comments and propositions for that exact component. It would be desirable that the Methodology included the Case Studies analysis alongside with the tow mentioned above steps, but that is not necessary for the completion of this Thesis.

6.2 Conclusions on the Results - Potential for Reuse

As for the results, one could argue that they cover a noticeable proportion of the Digital Governance Science Base. They assist the definition of the Digital Governance scientific domain and they set the ground for the connection with the rest of the regions of Digital Governance Science Base.

The ontology, meaning the modelling, which is the most underscored result of this Thesis, provides an extensive view in the Domain Structure, the Neighboring Domains, the Research Roadmap and the Training Curricula of the Digital Governance Science Base. It includes the classes, the individuals of every class and their semantic correlations. It visualizes the ontology providing a schematic representation of the abovementioned elements and giving the opportunity to the user to interact with every one of them. It is a prominent step towards structuring, collaborating and popularizing the Digital Governance Science Base.

The rest of the literature review focuses on the establishment of the ontology. Research papers, articles, book chapters, elements of the Digital Government Research Library and the relevant conferences' tracks were studied in order to identify the structural model and the elements constructing it. Especially, the elements are classified into two categories, the ones used for this edition of the ontology and the ones that are going to be shorted and added to the ontology in the future. The second category is the one that emerged from the DGRL and conference tracks research.

The usage of statistics in order to present the results of the literature study in a more consolidative way proved effective in providing relational metrics concerning the elements of the Digital Governance Science Base. The statistics relied mostly in the literature findings concerning the Domain Structure, since it is the Domain Structure that has the most interconnected components, and hence the greatest interest concerning the relational metrics.

As for the results concerning the questionnaires, the statistics provided useful quantitative metrics concerning the consensus about the Digital Governance Science Base elements, their classification and their correlations. The open questions' results provided insightful comments, opinions and additions to the Science Base on the context of several of its components.

Generally, the results provided abundant quantitative and qualitative additions to the Digital Governance Science Base They are presented in a plethora of ways, tables, statistics, ontology and others more comprehensive ways and even if they are not in their final version, they stand as a rewarding outcome of the research conducted.

6.3 Limitations of the Research

There are certain limitations that occurred during this research. At first, this research does not include the "Rationale", the "Problem Space", the "Solution Space", the "Assessment Tools", the "Solution Methods & Tools", the "Code of Ethics" or the "Rules, Theories & Laws" of the Digital Governance Science Base. Although there are hints of correlations with the abovementioned components, the findings of this study do not define or establish any individuals from those categories.

As it is mentioned in previous chapter, the literature research is not wholly included in the ontology, the DGRL and the conference findings are not included. They need to be shorted, in order to exclude the ones that are already overlapped by others. Also, the relations between those and the existing ones in the ontology might differ.

Another part of the ontology that is not included concerns the Data attributes of the individuals in each category. Those are specific measures of the individuals' properties that can be expressed with a plethora of ways, for instance alphanumerics, object types, encodings etc. Since the Data attributes are not used for the ontology implemented, there is no way to express a polysemous semantic connection between two entities. Consequently, for the same semantic property that has different extent there is need for separate object property. For instance, the object properties that include the word “strongly” would not be included if the Data attributes were used. There would be a homogeneous object property, for instance just “involves” instead of that and “strongly_invloves”, and it would fall onto the Data attributes to define the strength of the correlation.

A similar principle is applied if the annotations were used. Further semantic limitations and categorizations of the individuals would be possible if those functionalities were used in the ontology construction.

As the Protégé ontology is being examined, it is safe to present a completion table concerning the ontology provided in this Thesis. Having the abovementioned in mind, it is obvious that the ontology is not fully completed. In fact, in certain aspects the ontology is still on early stage. For instance, the components of the Domain Structure of Digital Governance Science Base still need examination and expansion, even if the structural form of the Domain Structure is almost defined. The Neighboring Domains are completed in a significant part. The Research Roadmap components need more examination and shorting, even if they are predefined in number, due to the “Gov 3.0” project deliverable. The Training Curriculum elements are almost defined.

Table 10. The Modelled Ontology Completion Table

Component	**Percentage of completion**
Domain Structure (Structural Model)	85%
Domain Structure (Components)	50%
Neighboring Domains	80%
Research Roadmap	60%
Training Curriculum	85%

It is also safe to assume that the literature research did not include every single one research initiative and it did not search in every conference that might be connected with the Digital Governance. That exactly is the reason of constructing a research community that supervises the Digital Governance Science Base further development, to expand the Science Base studying novel research initiatives and conferences.

The last limitation concerns a factor that is not directly linked with the research process followed. It is not possible to come up with an ontology and a definition of the Science Base and to accomplish to make it absolutely agreed and comprehensible for the rest of the scientific community. The structure, the elements and the ontology resulted should be debated and cross examined by experts on the field.

6.4 Prospects - Next Steps

Concerning the literature findings, the goal is to include the findings of the DGRL and the conference tracks after a classification comparing the existing individuals. That needs deliberation and careful examination. The next version of the ontology will include those alongside with their semantic relations. Also, the next version should include the Data attributes and as a result there will be a reevaluation of the object properties.

One important step is to popularize the ontology. The usage of Github for sharing the owl code, the WebVOWL for making the ontology available for everyone online and of course the documentation of the ontology are necessary steps towards the popularization of the ontology and its cross examination by the wider community.

Finally, having the findings of the “What?” region of components of the Digital Governance Science Base it is crucial for them to be used in order to identify the “How?” region of components, meaning the “Problem Space”, the “Solution Space”, the “Assessment Tools” and the “Solution Methods & Tools”. Those components are related with the more pragmatic aspects of the problem-solution factors in the Digital Governance. Yet, it is essential to have the research foundations been clarified in order to move on to the problem definitions, the solutions, the tools available and the methods. So, the results of this study need to be cross examined with a more practical approach in order to identify the structural factors that lead to the problems and the solutions concerning Digital Governance.

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Appendix I