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IMPLEMENTATION OF A RESEARCH NETWORKING SYSTEM IN THE INSTITUTE OF SYSTEMS AND COMPUTER ENGINEERING, PORTO (INESC TEC): AN EXPLORATORY STUDY TO SPECIFY INSTITUTIONAL REQUIREMENTS

Sharon Okori

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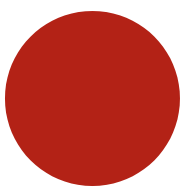

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Dissertation submitted in partial fulfillment of the requirements for the Degree Master of Information Science under the supervision of Associate Professor António Lucas Soares

Faculty of Engineering and Faculty of Arts

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*“Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.”- **Winston Churchill***

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Resumo

Instituições e investigadores enfrentam hoje em dia dificuldades em apresentar uma imagem clara das suas competências de investigação, seja ao nível interno, ou face ao respetivo ambiente externo. Apesar dessas instituições procurarem incentivar o trabalho-em-rede e a interdisciplinaridade, tem-se afigurado difícil implementar os mecanismos adequados para apoiar e fomentar a colaboração entre investigadores. Não é raro encontrar uma separação entre as áreas funcionais num ambiente de investigação, dando-se mais atenção e recursos para cobrir necessidades administrativas, de formação e tecnológicas, do que ao desenvolvimento de um modelos de investigação em rede. Tudo se torna ainda mais desafiante quando se pretende compreender padrões de investigação ou identificar competências específicas em cenários incluíndo mais do que uma instituição. A informação científica é difundida com pouca consistência, exceto quando confinada às disciplinas individualmente. É importante que as instituições de investigação e os seus investigadores divulguem as suas atividades, conhecimentos, resultados e recursos de maneira a que possam ser compreendidos e reutilizados, não só dentro dos seus limites institucionais, mas também ao nível nacional e internacional.

Para se superar esta situação, é crucial desenvolver formas fidedignas de reunir informação a partir de contextos institucionais locais, para ir ao encontro das necessidades dos investigadores, das suas equipas e instituições, e assim promover Redes de Investigação (RI). A RI é um conceito aqui definido como a utilização de ferramentas que servem para descobrir e utilizar a informação académica e de investigação em favor da organização. A literatura mostra que, ao longo das últimas

décadas, os Sistemas de Redes de Investigação (SRI) constituem uma solução que permite aos investigadores e instituições apresentar as suas competências de investigação, atividades e realizações, de modo a favorecer a descoberta de pessoas com interesses comuns, ao mesmo tempo que propicia o trabalho em equipa. Além disso, facilitam o trabalho-em-rede dos especialistas, quer dentro, quer entre instituições. É com base neste pressuposto que esta Dissertação especifica os requisitos do INESC TEC para a implementação de um Sistema de Redes de Investigação (SRI). Na sequência da avaliação qualitativa da literatura na área dos SRPs, foi realizado no INESC TEC um estudo experimental em duas fases.

Este estudo, de natureza qualitativa, empregou um modelo de investigação que recorre a um estudo-de-caso, visando explorar o fenómeno dos SRPs no INESC TEC. Na primeira fase, foram realizadas entrevistas exploratórias a investigadores séniores e administradores do INESC TEC, no sentido de se obter uma visão aproximada acerca da situação da Rede de Pesquisa nesta instituição. De seguida foram analisados os dados qualitativos, cujo resultado divide os requisitos do INESC TEC para implementar um SRI em duas categorias: a melhoria da gestão de competências e a promoção de Redes de Pesquisa, seja dentro do instituto, seja para além das suas fronteiras. Foram igualmente identificados alguns problemas fundamentais das RIs, tais como a falta de um sistema global, o cariz das suas atividades e cultura organizacional, isto para mencionar apenas alguns. Foi também nesta fase que foi selecionado o modelo de investigação adequado para a fase seguinte. A segunda fase foi realizada no contexto do Centro de Engenharia de Sistemas Empresariais (CESE), que constitui um dos centros de investigação do INESC TEC. Foi selecionado, dentre vários outros, um protótipo de SRP *open source*

designado por VIVO, que foi instalado e configurado para gerar presença na Web. Foram apresentados, através de um *focus group*, a plataforma VIVO e as suas características funcionais, com o objetivo de estimular uma discussão. Os participantes deste *focus group* eram pessoas-chave (investigadores séniores) no CESE, os quais já haviam participado na primeira fase. Os resultados indicaram um feedback geral positivo relativamente à VIVO, bem como uma série de recomendações destinadas a melhorar as respetivas funcionalidades, por forma a melhor atender aos requisitos do CESE.

Concluindo, o presente estudo propôs uma série de recomendações para a aplicação da VIVO no contexto do CESE. As sugestões para trabalhos futuros incluem a automatização da recolha de dados e manutenção da VIVO, assim como a realização de testes ao sistema VIVO INESC TEC. A um nível mais avançado, apontam-se a implementação de uma VIVO multi-institucional e, dependendo do seu êxito, um ensaio de VIVO que facilite o trabalho em rede dos investigadores nacionais.

Palavras-chave: Gestão do Conhecimento, Redes Colaborativas, Sistemas de Redes de Pesquisa, Investigação e Desenvolvimento, Gestão de Competências

Abstract

Institutions as well as researchers face challenges in presenting a clear picture of their research capabilities both internally and to the outside world. And even though these institutions seek to encourage networking and cross-disciplinary collaborations, some of them have not put the right mechanisms in place to support and nurture networking among researchers. It is not uncommon to find a disconnect between the functional areas in a research environment with more attention and resources going into the administrative, instructional and research computing needs rather than the evolving nature of research. It is even more challenging when considering scenarios beyond one institution to try and understand research patterns or identify specific expertise. Scientific information is hardly delivered with consistency except within the confines of some narrow disciplines. It is important for research institutions and researchers to communicate their activities, expertise, results and resources in a way that can be understood and reused not only within their institutional boundaries but also nationally and internationally.

Key to overcoming this predicament is devising a way to bring together authoritative information from local institutional contexts to meet the needs of researchers, their teams, and institutions, and promote Research Networking (RN). RN is the use of Research Networking tools to discover and use research and scholarly information for the Research Enterprise (Wikipedia). Relevant literature shows that over the past few decades, Research Networking Systems (RNSs) have provided a remedy for researchers and institutions to showcase their research competences, activities and accomplishments to enable discovery of persons with common interests and facilitate team work. Besides this, they facilitate networking among experts within and across institutions. It is upon this basis that this Dissertation specified the requirements of INESC TEC for implementing a Research Networking System (RNS). Following a qualitative review of literature in the area of RNSs, a two phase empirical study was conducted at INESC TEC.

The empirical study was qualitative in nature and employed a case study research design to explore the phenomenon of RNSs in INESC TEC. In the first phase, exploratory interviews were conducted with senior researchers and managers of INESC TEC to get insight about the state of research networking in the institution.

This was followed by qualitative data analysis, whose outcome categorized INESC TEC's requirements for implementing an RNS into two, which are, enhancing competency management and promoting research networking within the institute and beyond its borders. Some key concerns of RN were also revealed to include a lack of a comprehensive system, nature of activities, organizational culture, to mention but a few. It was also in this phase that an appropriate research method for the next phase was selected. The second phase was conducted in the context of Center for Enterprise Systems Engineering (CESE) which is one of the research centers in INESC TEC. An open source RNS prototype called VIVO was purposely selected among several others, installed, and configured to generate web presence. Through a focus group meeting, the VIVO platform and functional features were presented with the aim of stimulating a discussion. The participants of the focus group were key persons (senior researchers) in CESE and they also happened to have participated in the first phase. The results of this phase indicated general positive feedback towards VIVO and a number of recommendations towards improving the VIVO functionalities to better serve the requirements of CESE.

Conclusively, this study proposed a number of recommendations towards the implementation of VIVO in the context of CESE. Going forward, recommendations for future work include automatic ingest of data and maintenance for VIVO and testing VIVO INESC TEC. At an advanced level, suggestions for future work included a multi –institutional VIVO and depending on the success, a VIVO effort to facilitate national networking of researchers.

Keywords:

Knowledge Management, Collaborative Networks, Research Networking Systems, Research and Development, Competency Management

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Acronyms

API – application Programming Interface

APRU - Asia-Pacific Rim Universities

CERIF - Common European Research Information Format

CMMI (excerpt) - Capability Maturity Model Integration

CRIS – Current Research Information Systems

CSTA - Clinical and Translational Science Awards

CUSP - Columbia University Scientist Profiles

FDIs – Foreign Direct Investments

INESC TEC – Institute of Systems and Computer Engineering, Technology and Science

KM – Knowledge Management

LOP – Linked Open Data

MNEs – Multi-National Enterprises

NGOs – Non Governmental Organizations

NIH – National Institute of Health

R & D – Research and Development

RN – Research Networking

RNSs – Research Networking Systems

SAGE – Searchable Answer Generating Environment

SGC 3 – Strategic Goal Committee 3

Glossary of words

Applied Research - systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met (Glossary, Chapter 6, *Science and Engineering Indicators 2008,* 6–56).

Basic Research - as systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind (Glossary, Chapter 6, *Science and Engineering Indicators 2008,* 6–56).

Collaborative Networks – A collaborative network is a collection of businesses, individuals and other organizational entities that possess the capabilities and resources needed to achieve a specific outcome (Drucker P, 2001)

Knowledge - the mental processes of comprehension, understanding and learning that go on in the mind and only in the mind (Wilson 2002)

Knowledge Management –"Knowledge management is a discipline that promotes an integrated approach to identifying, capturing, evaluating, retrieving, and sharing all of an enterprise's information assets. These assets may include databases, documents, policies, procedures, and previously un-captured expertise and experience in individual workers" (Duhon, 1998)

Linked Data - Linked Data is about using the Web to connect related data that was not previously linked, or using the Web to lower the barriers to linking data currently linked using other methods. More specifically, Wikipedia defines Linked Data as "a term used to describe a recommended best practice for exposing, sharing, and connecting pieces of data, information, and knowledge on the Semantic Web using URIs and RDF" http://linkeddata.org/

R&D - also called research and development, comprises creative work undertaken on a systematic basis to increase the stock of knowledge—including knowledge of man, culture, and society—and its use to devise new applications (Glossary, Chapter 6, *Science and Engineering Indicators 2008,* 6–56).

Research – a systematic study directed toward fuller scientific knowledge or understanding of the subject studied. Research is classified as either basic or applied

according to the objectives of the sponsoring agency. (Glossary, Chapter 6, *Science and Engineering Indicators 2008,* 6–56).

Research Information - "Any information that describes the research output as well as the context in which research is being conducted" (Jeffery et al. 2014)

Research Networking – is about using web-based tools to discover and use research and scholarly information about people and resources (Wikipedia)

Research Networking Systems/ Tools – serve as knowledge management systems for the research enterprise (Wikipedia). "Research Networking Systems (RNS) are systems which support individual researchers' efforts to form and maintain optimal collaborative relationships for conducting productive research within a specific context" (Schleyer T. et al. 2012)

Researcher Institution - is an establishment endowed for doing research. Research institutes may specialize in basic research or may be oriented to applied research (Wikipedia)

Semantic Web – is an extension of the Web through standards by the World Wide Web Consortium (W3C) – (XML and Semantic Web W3C Standards Timeline, 2012). The standards promote common data formats and exchange protocols on the Web, most fundamentally the Resource Description Framework (RDF). "The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries" (W3C, 2011)

Technology Transfer – is the translation of research discoveries into commercializable products. It is an important component of any region's innovation economy and therefore a priority focus for a region's leaders. It is a marker not only of a region's productivity as a knowledge center but also of its capacity for and receptivity to innovation (CEO Council for Growth Report, 2014)

Web – based Applications – "...or **web app** is any computer program that runs in a web browser. It is created in a browser-supported programming language (such as the combination of JavaScript, HTML and CSS) and relies on a web browser to render the application" (Nations, 2014)

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INTRODUCTION

This part of the dissertation explains the background, motivation of the study through to the goals and research question, theoretical and conceptual framework and finally the dissertation structure.

1. Background and Motivation

Modern Universities and research institutions strive to capitalize their competences or capabilities on individual researchers and their teams in order to keep up with the growing trends in the advancement of research. Processes of conducting research have significantly become interdisciplinary and collaborative making the need for researchers to work with other experts outside their institutions inevitable (Weng, et al., 2008). This trend is evident in the increase in the number of international collaborations, co-authorship of papers and multidisciplinary research activities and proposals (Olson et al., 2008). However, the predicament institutions and even individual researchers face is the difficulty in providing a clear representation of their research competences or capabilities in a way that communicates to other experts inside their institutions as well as the outside world. This is mostly because, describing a researcher's profile is no longer a dimensional task as it involves attaching a set of core scientific or technical specializations. The capabilities of a researcher are characterized by other information sources like publications, networking activities, participation in projects, committees, teaching etc. Besides, the evolution of this information over time is very crucial to the advancement of an institution's research. This makes the construction and exploration of researchers' profiles a complex task as it involves some sort of automated data collection (Wikipedia).

Furthermore, it is important to note that, there are various kinds of social networking tools like Facebook and LinkedIn that support person-to-person connections by facilitating, local, institutional, national and even international platforms to create and link profiles, posts, images and comments. Nevertheless, these tools are closed domains that do not facilitate communication with other systems and support only active and not passive networking. More recent

commercial research information systems like Research Gate have attempted to compensate for where social and professional networks fall short but even they provide little or no system integration and limited user input (Obeid et al, 2014). Without a mechanism to support Research Networking (RN) – which is the use of Research Networking Systems (RNSs) or tools to discover and use research and scholarly information for the Research Enterprise (Wikipedia), it is up to the individual researchers to maneuver their ways to discover up-to-date research activities, resources and active experts in their fields of interests and beyond. This usually involves relying on a combination of personal contacts, disciplinary knowledge, and chance or casual meetings through search engines and social networks or events. This implies that those who have not yet amassed professional connections especially junior researchers are left at a major disadvantage (Conlon, M. 2007). And while Research Networking Systems (RNSs) have significantly remedied the situation, most RNSs implementations, regardless of platform, focus only on harvesting and displaying expertise from a single institution or university system.

Relevant literature on RNSs has grown considerably especially over the past two decades alongside technological advancements under the influence of globalization. To pin-point the roles of RNSs, Schleyer, T. et al. (2012) defined Research Networking Systems (RNS) as "systems which support individual researchers' efforts to form and maintain optimal collaborative relationships for conducting productive research within a specific context. Schleyer T. et al. (2012) also emphasizes that even though RNSs can be employed to manage faculty or human resources portfolio, its intended user whose needs must be satisfied is the individual researcher. RNSs use data-mining and social networking to facilitate discovery of expertise, connecting people with common interests and collaborations, which are crucial factors in team science and translational research. Several commercial and open source platforms have been developed and implemented in a number of institutions (Weber, et al. 2011).

Literature has also indicated that institutions can benefit immensely from RNSs as the information obtained from them is required for a variety of reasons. Strategically, it informs an institution of its performance and competitiveness and

allows it to take decisions accordingly. Operationally, it provides support for day-to-day administration of research and helps fulfil the needs of external stakeholders. This is important in focusing institutional strategies on research quality, raising the profile of an institution's research nationally and internationally, managing talent, and building a high-quality research environment (Green & Langley, 2009).

It is also evident in literature that a substantial portion of proposed technical innovations especially related to the field of biomedical research is about facilitating the sharing of information and resources while enhancing collaborations or team science amongst researchers across disciplines (Conlon, M. 2007). However, in the recent past, the lack of a standard data-exchange model coupled with the resistance from universities to share their faculty data posed significant hindrances in establishing an institutionally supported national network. In August 2010, the Clinical and Translational Science Award (CTSA) Research Networking Affinity Group in the USA, launched an initiative to develop a pilot network, called Direct2Experts. This Network was to enable users search and discover researchers in the field of biomedical sciences across various institutions. This initiative was meant to provide a more rapid and precise way of searching and retrieving information compared to search engines like Google, Facebook or LinkedIn (Weber, et al. 2011). Meanwhile, as institutions are invest tremendously in developing RNSs, some previous studies have indicated that researchers “are not really interested in networking as an end itself” but rather “they need to boost productivity” (Barabási A. L. et al., 2002). So regardless of the frantic growth of RNSs, there is still a great need to understand how scientific professionals adopt and interact with RNSs (Boland et al., 2012). A substantial amount of previous literature on RNSs has focused on improving RNSs functionality to enhance search and discovery of collaborators. Studies by (Schleyer T. et al, 2008; Boland et al, 2012; Borromeo, et al, 2014) have dealt with specifying RNS requirements for the enhancement of ‘discovery of collaborators and increasing the visibility of researchers both locally and globally.’

Even then, what an RNS accomplishes mostly depends upon the requirements of a particular institution. CTSA Research Networking Affinity Group proposed an Evaluation Guide for RNSs implementation in institutions. One of the main emphases of this guide is the significance of understanding and specifying of

institutional requirements prior to RNS implementation. The guide also indicated that these requirements vary from institution to institution usually depending on the workflows of their user classes. Lastly, there is an evident gap in literature concerning initial implementation of RNSs in institutions. Not much was found documented about studies or experiences of institutions that have already adopted RNSs and what lessons should be picked by institutions planning to adopt these systems.

This study was conducted at the Institute of Systems and Computer Engineering, Porto (INESC TEC) for a period of six (6) months. INESC TEC is a major Portuguese Research Institute engaged in Research and Development activities executed through projects and consultancy work in a variety of engineering and science disciplines. INESC TEC is located at the Faculty of Engineering, University of Porto where the researcher is a final year student of Master of Information Science. It is significant to mention that INESC TEC just like many other research institutions faces the challenges mentioned earlier related to providing a clear representation of competences. There have already been efforts towards implementing information systems especially to manage or map the competencies of INESC TEC but most of them unsuccessful. Several initiatives towards RN have equally not yielded much fruit either. The idea of RNSs was therefore, conceived upon the basis that they could facilitate these two components that were found crucial for the research environment at INESC TEC. For this reason, it was important to explore this idea further to determine how INESC TEC can benefit from it.

Also the activities of INESC TEC are generally characterized by projects which end after a given life cycle and others start almost immediately. This was found to negatively affect the management of research information and competencies. Furthermore, most partnerships or collaborators from other institutions are dictated by the funding agencies like the European Union (EU) or the State or the Consortia that do the lobbying for funds. This was also found to pose a limitation to RN as people do not really see the necessity of looking for partnerships elsewhere. We found these to be interesting scenarios to explore in relation to the main subject of this dissertation.

That said, the subject of Research Networking Systems (RNSs) and their implementation was found to be very relevant for this Dissertation for a number of reasons. Considering that this area is still relatively recent and therefore under explored in terms of literature, this dissertation will make a significant contribution to the body of knowledge in the area of Information Systems specifically initial implementation of RNSs in research institutions. It is also our expectation that the findings of this dissertation will provide the necessary input for empowering researchers and research institutions as they plan and embark on initial RNS implementation. Through this knowledge, institutions and researchers can begin to have a better understanding of what is involved when determining to adopt an RNS and identifying one that can best serve their institutional needs. It is also upon the basis of this dissertation that further work towards the eventual implementation of a RNS in the INESC TEC, across institutions and even nationally is envisaged.

2. Goals and Research Question

The overall goal of this dissertation is to understand and specify the requirements of INESC TEC for implementing a Research Networking System (RNS). The rationale behind this goal is that different institutions have different user classes, and these user classes have different workflows. These workflows are the drivers behind the requirements of each user class for the using given information system especially in an academic and/ or research environment. It is therefore significant for research institutions such as INESC TEC to understand and specify its requirements for implementation of an RNS based upon the knowledge of the workflows of its user classes. This is important in ensuring that the system implemented is suitable and can efficiently and effectively serve the purposes of the institution.

In light of this goal, a number of pertinent issues are addressed: the contribution of this dissertation to the body of knowledge both in Information Systems and RNSs implementation research. Secondly, the empowerment of research institutions and researchers on initial RNS implementation. And finally, providing a foundation upon which the eventual implementation of a RNS in INESC

TEC is envisaged. With all this said, below is the research question of this dissertation and the specific goals linked to its development.

Research Question: How can INESC TEC benefit from implementing a Research Networking System (RNS)?

Specific goals included:

i) Characterizing the research networking information and competencies in INESC TEC;
ii) Identifying the research networking tools/ platforms used in INESC TEC;
iii) Installing, configuring and examining an open source RNS prototype in INESC TEC;
iv) Developing recommendations towards the implementation of a suitable RNS in INESC TEC.

3. Theoretical and Conceptual Framework

As earlier mentioned, the overall goal of this dissertation is to understand and specify the requirements of INESC TEC for implementing an RNS. Figure 1 below provides an interactive map of how this research will unfold. First, it was imperative to explore what has already been done and what is going on in this domain RNSs implementation. To do this, there was a need to explore relevant literature and given that the area of Research Networking Systems (RNSs) is relatively recent, literature related to initial implementations is still underexplored. In exploring literature, areas found relevant in providing a better understanding and perspective were captured and investigated. It was important to capture the subject of 'Management of Research and Development' given that this is the directly related to the core of this study as it provides the contextual aspect.

Additionally, the areas of 'Globalization, Technological Innovation and Networks' were also tackled in representation of a growing trend in globalization of world processes in general and specifically research. Emphasis was directed to the role of technological innovations and networks in furthering the process of

knowledge generation and technological transfer. Finally, the phenomenon of Research Networking Systems (RNSs) was dealt with. The review delved into the various definitions of RNSs, the various types available on the market and finally, a considerable part of this section tackled a number of studies related to RNS implementation in specific of institutions. This was important in providing a representation of the current state of RNS implementation. This initial inductive probing of literature provided the researcher with a much better understanding of the subject in question. With this knowledge, the researcher was able to draw knowledge, theories, insight and observations that guided the subsequent stages of the investigation.

The Literature Review was then followed by a study that was divided into two independent but complementary phases. The study was exploratory in nature and employed a case study design with a number of research methods in each phase.

Phase 1: Involved conducting exploratory interviews with key persons at INESC TEC. This method was supplemented by documentation to corroborate and look for any discrepancies from the interviews. This phase was instrumental in gathering insight on the state of Research Networking in INESC TEC and also provided a better understanding of the institution. It was also in this phase of the study that the feasibility of the next phase was determined and a suitable research method selected.

Phase 2: Initial preparation involved study of literature and documentation on VIVO - an open source prototype of RNS that was purposely selected for this study. It was then installed and configured at the Center for Enterprise Systems Engineering (CESE), one of the research centers in INESC TEC. By entering sample data from the Curriculum Vitae (CVs) of a number of employees of this center into VIVO, the researcher was able to study and get acquainted with the functionalities of the application. This was followed by a presentation of the of VIVO platform to key persons in CESE (who also participated in the previous phase) with the aim of stimulating a discussion. The outcome of both phases was significant in developing the final recommendations towards the possible implementation of RNS in INESC TEC.

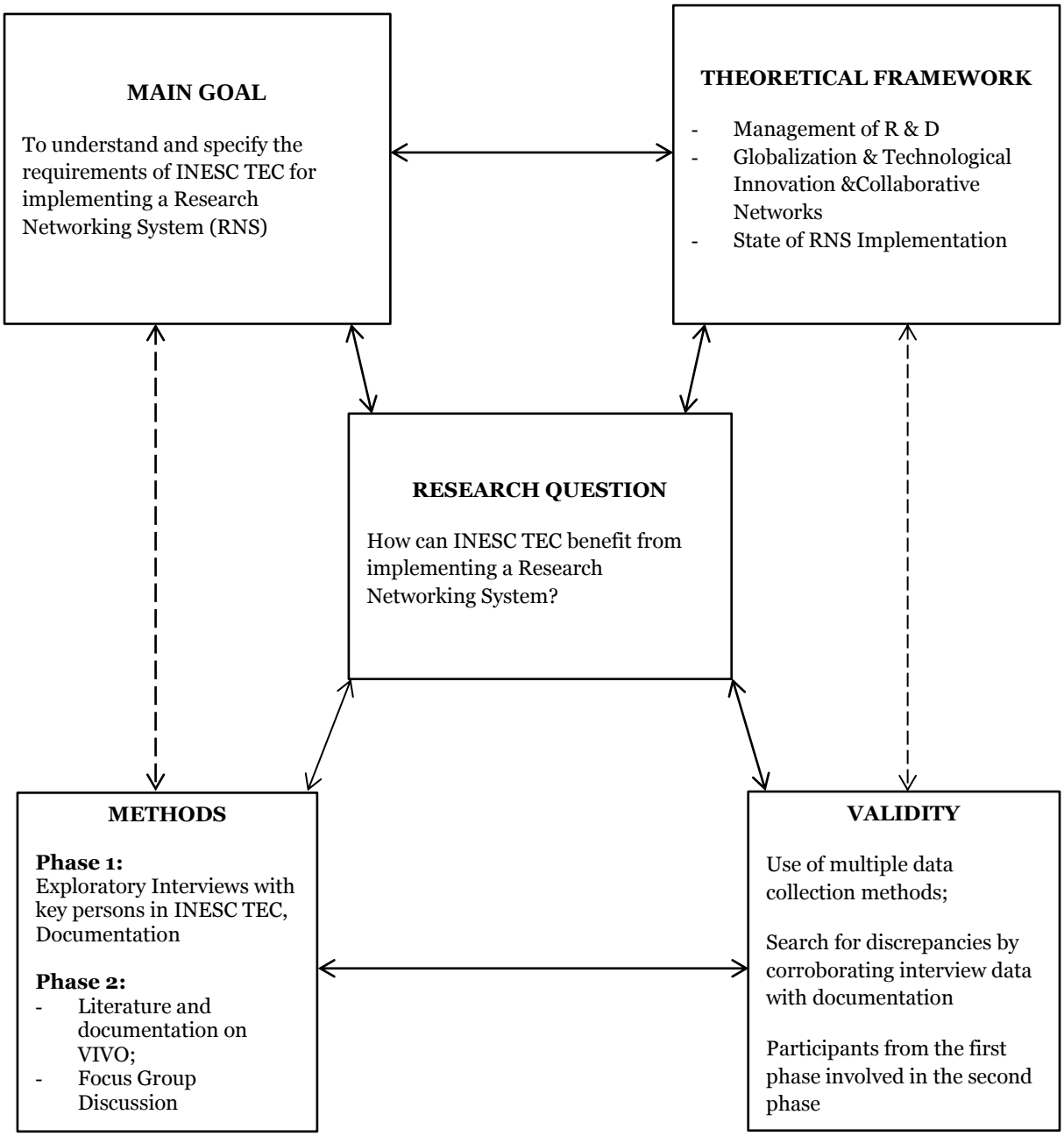

Figure 1: A Design Map of this Dissertation Research. Based on Maxwell, J. A. (2012)

4. Structure of the Dissertation

This dissertation is divided and organized in 4 chapters. Following the Introduction is chapter 1 which tackles the Literature Review. The Review followed an inductive approach focusing on three main areas of the study, namely, Management of Research and Development; Globalization, Technological Transfer and Networks and Research Networking Systems and the state of their

implementation. Chapter 2 then follows with the Research Design which describes the research approach and methods used in the two phases of the study. In both phases, the research approach was qualitative and exploratory in nature. This is then followed by Chapter 3 which presents the results of the two phases of the study conducted. The results of phase I are geared towards providing a better understanding of the institution in question – INESC TEC with special emphasis on its state of research networking. The study characterizes the research information and competences in INESC TEC, identifies the research networking tools/ platforms in use at INESC TEC and specifies the requirements of INESC TEC for implementing a Research Networking System (RNS). Additionally, an open source system was selected, installed, configured and examined in CESE, one of the centers of INESC TEC resulting into a proposal of action. Results emanating from both phases of the study are discussed and analyzed in chapter 4 in order to reach meaningful conclusions and subsequently develop appropriate recommendations. The last part of the Dissertation is then devoted to generating major conclusions including pointing out the achievements and contribution of this dissertation both to the CESE, INESC TEC and to science as a whole. It also presents the limitations of the study and identifies areas for future work.

1.0. LITERATURE REVIEW - IMPLEMENTATION OF RESEARCH NETWORKING SYSTEMS

This chapter presents the literature review with the purpose of illuminating the major concepts related to the topic of this dissertation and the project as a whole. The literature review specifically tackles the concepts of Research Networking Systems in relation to the phenomenon of Globalization and Management of Research and Development. Considering that the concept of Research Networking Systems (RNSs) is relatively recent, literature about it is progressing steadily alongside technological advancement and innovations. And since RNS implementation is also the core area for the development of this dissertation, special focus has been given to it.

The literature review draws from a qualitative selection of published information material from diverse sources dated mostly within the last 15 years. These include; journal articles, web pages, book pages and chapters specifically from the areas of interest to this dissertation that is, Research Networking Systems, Globalization and Management of Research and Development. A section was presented on the state-of-the-art review of the implementation of Research Networking Systems to represent the work that has already been done in this area and where the situation is currently at. In essence, the researcher approaches all these concepts based upon previous literature.

1.1. Management of Research and Development (R &D)

1.1.1. Research Information Management

While much has been written on management of Research and Development in general, relatively little has quite focused specifically on management of research information or data and their evolutionary tendencies. However, with the development in research, research information and its management is attracting more and more attention. Due to rapid advances in technology, methods of data collection, networking, storage and management of research took a turn towards data intensive science models consequently impacting worldwide conduct of research

(Hey, Tansley and Tolle, 2009). More crucial characteristics of research activities are data infrastructures as they facilitate virtual science and the management of research information (Hey and Trefethen, 2005). It is expected that a typical research environment should deliver a comprehensive information management system to serve the research needs of its patrons. The systems should be proficient enough to facilitate data processing, reproduction and communication through collaborative working environments, providing instruments for publicizing and an e-infrastructure of detectors. That said, management of research information is paramount as it binds other information and communication systems including their information, processes and resources under one context. It is therefore, imperative for researchers to have access to all research information by way of research proposals, generation of publications, collection of data from detectors, performance of statistical analysis, carrying out reproductions, producing reports on output, to mention but a few. All these tasks should be performed within a workflow and within a single research environment.

To have a clearer understanding of what research information is, Jeffery et al. (2014) defines it as "*any information that describes the research output as well as the context in which research is being conducted.*" In their work, they provide a description of the main elements of research information which include:

a) Research output like scientific publications, data sets, patents, software, devices, designs, artistic works and performances to mention but a few;
b) Information pertaining to research processes, workflows and methods like observations, experiments and several others;
c) The Research Personnel of various categories including researchers, research administrators/managers, technical and support staff participating in research projects;
d) Organizations involved in research activities like R & D institutions, funder to mention but a few;
e) Research projects
f) The research funders including public agencies both national and international, Non-Governmental Organizations (NGOs) and other research supporting bodies;

g) Research Infrastructure like buildings, software systems, telescopes and so forth;
h) Information pertaining to research related services and services provided through the research infrastructure. Some of these include workshops, conferences, observation or experiments periods.
i) Also measurements and indicators of research activities like impact, output, inputs

According to CIBER (2010), Kroll & Forsman (2010) and McColl & Jubb (2011), Research information serves a number of purposes;

1. Research Information is used by researchers to review their work, identify competitors and potential collaborators for future research activities. Researchers also utilize research outputs such as databases to cross-check works of other researchers and validate corresponding results for a possible reuse.

2. As it is with companies, research institutions use research information for business intelligence to enable effective management of resources, research planning, monitoring of income and expenditure, intellectual property management and for the performance of benchmarks against competitors.

3. In Funding Agencies, research managers use research information to justify funding and monitor research productivity, research the funding expended, particularly to evaluate the outputs of the research, results and later, the impact of research.

4. Research Information is fundamental in policy and decision making as it facilitates monitoring of research activities, identification of strengths and weaknesses, setting priorities and taking decisions regarding funding.

5. Innovators take advantage of research information to acquire research prototypes, designs and ideas for to enable them gain profits especially in global markets.

6. The media use research information for validation of research reports and to communicate to the lay people. This enables participatory democracies as citizens are well informed about the developments in research.

Research Information of several types are preserved and interconnected by unique information systems called Current Research Information Systems (CRIS). A classical model of the CRIS is the "Common European Research Information Format (CERIF)." It is a model for representation of the core concepts of research information. It is also known as a "property-centric ontology" (Doerr, 2003) or "enterprise model" (Calvanese, 1998). Apart from its capability to represent core concepts of research information applications, it also clearly demonstrates their emerging semantic connections (Doerr, 2003 and Calvanese, 2009). The CERIF is able to pick up search results together with the objects in a research lifecycle and establishing a research context. It harvests concepts like; publications, funding, persons, indicators, measures, organizations, projects and proceeds to facilitate their connection with geolocation information. The CERIF is operational in various production systems across Europe like national or institutional research information systems), plus in European FP7 e-infrastructure projects such as OpenAIREplus, EuroRIs-Net+ and ENGAGE (Jeffery et al., 2014). Figure 1 below shows the major objects in the CERIF with the exception of the connections that demonstrate the relationship between objects (Jörg et al., 2013).

Key of the Figure 1:

The color **orange** illustrates objects representing research results, **green**; important objects of the research environment, **purple**; research infrastructure objects, **brown**; indicator and measurement objects and **blue**; 2nd-level supporting objects.

1. *Base Objects: Project, Person, Organization Unit.*
2. *Result Objects: Publication, Patent, Product. Product covers datasets, software and other research output*
3. *Infrastructure Objects: Facility, Equipment, Service.*
4. *Indicator and Measurement Objects: Indicator and Measurement.*
5. *2nd level Objects: Funding, Event and Medium are some of the most often used object in research information. Funding refers to an amount of money or an in kind equivalent value allocated to a purpose (e.g. a funding programme). Medium refers to a means for storing information, essentially digital files.*

6. *Geographic Bounding Box, enabling specification of geographic areas through the specific coordinates of their boundaries.*

1.1.2. Strategic Management of R &D Competencies

Earlier definitions by Nordhaug (1993) refer to a competency as a work-related capability and goes ahead to define it as a combination of personal knowledge, skills, behaviors, aptitude that one possesses to be productive in an organization. In essence, competencies may positively relate to an individual's performance. It may also be regarded as the capacity to execute a number of tasks relatively easily with a great chance of achieving quality and promptness (Spencer, 1993). Similarly, King (1997) defined a *"competency as an explicit and quantifiable performance with regard to quality, quantity, time, cost or all the above, for which action focused verbs, are used in writing competency statements."* A later definition by Dranganidis and Mentazas (2006) labelled a competency as a *"blend of tacit and explicit knowledge, behavior, and skills that give an individual potential ability to effectively perform."* Competencies in organizations may be widely categorized at employee and organizational levels (Cardy and Selvarajan, 2006). At the organizational level, competencies are rooted in employee-level competencies.

Literature presents a number of models for defining and mining competencies of an organization. Mansfield (1996) described a competency model as *"a comprehensive characterization of conducts expected of employees to ensure that they are effective on a job."* It therefore, goes without saying that excellent performers of these conducts on job show them more consistently than mediocre or poor performers (Schoonover et al., 2000). Although many kinds of competency models have been developed, there are few specific competency models that have been deemed appropriate for technical professionals. Spencer and Spencer (1993) presented a general competency model for technical professionals comprising twelve essential competencies, namely; *achievement orientation, impact and influence, conceptual thinking, analytical thinking, initiative, self-confidence, interpersonal understanding, concern for order, information-seeking, teamwork and cooperation, expertise, and customer service orientation.*

To Research and Development (R & D), a competency application built on a competency model is crucial to R&D management. This is because it prepares organizations to deal with current developments and facilitates the implementation of R & D management.

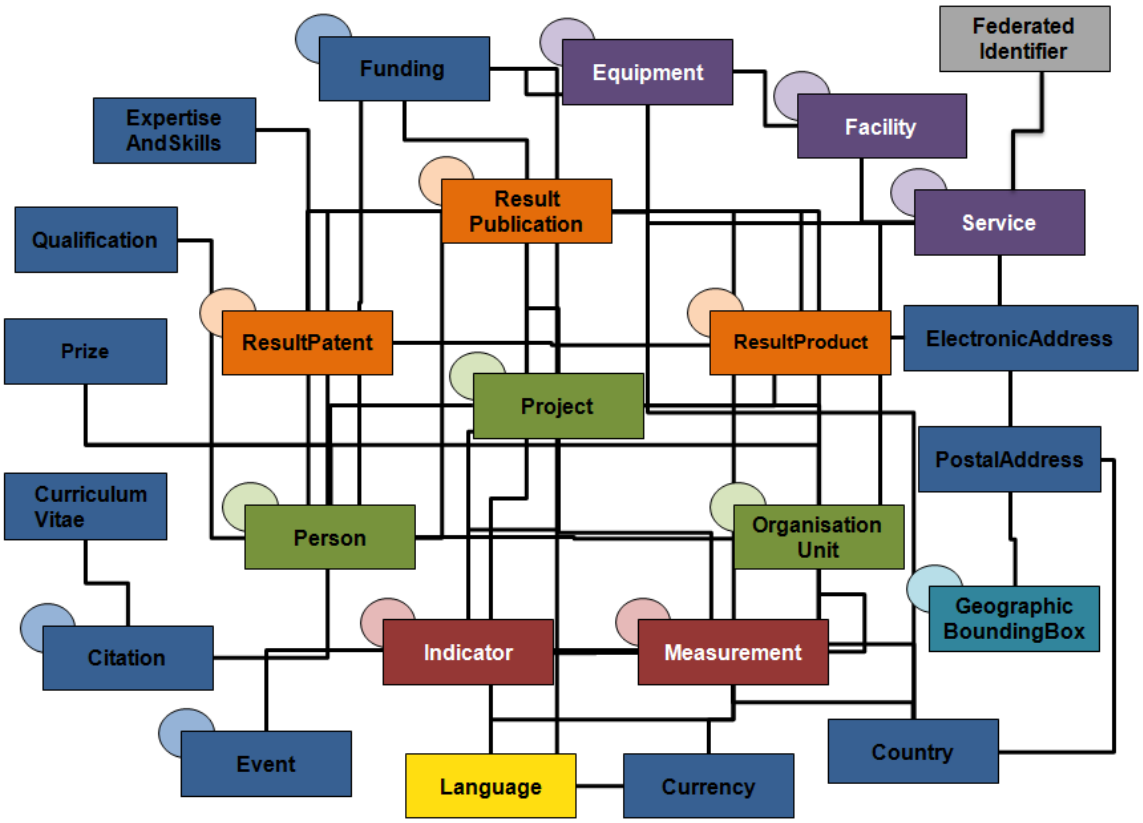

Figure 2: Major Objects in the CERIF (Jörg et al., 2013)

Nevertheless, it has been argued by some authors that competencies presented by competency models are often too many to be adopted pragmatically (Dive, 2004; Works Institute, 2003). The Works Institute (2003) proposed a gradual implementation of these models involving not more than eight competencies at ago while Dive (2004) recommends a maximum of six competencies only.

While paying great attention to the role of competencies and resources, institutions' strategic management professionals are increasingly showing interest in discovering effective means for managing the competencies that characterize them. Institutions that employ high-tech management systems, competencies have a direct

effect on the institutions' competitive advantages and future positioning. Technological competencies regulate the renewal of product lines and establish collaborative relationships with other institutions. Since Research and Development (R & D) programs strive to produce results, analysts continuously look out for major success factors like time-to-market, lowering of R & D costs, and to be more certain of the future of R & D activities (Burgelman et al., 1996; Brown and Eisenhardt, 1998). Therefore, in order to face the current challenges in R & D, institutions are trying to devise techniques for managing technological competencies like compiling skills directories, managing the range of the competence base, and monitoring the competencies that accrue in the business units. *(Figure 2 demonstrates a typical application of technological competences in an R &D setting).* Executing the mentioned efforts encompasses the development of internal structures of horizontal nature like project management, virtual R & D workgroups as well as the creation of collaborative relationships with interested players from surrounding work environments like academic institutions, R & D laboratories, suppliers, companies, and suppliers. It must be pointed out that, uncertainty is a major concern in managing technological competencies and R & D cycles mostly because it impacts institutional activities in various ways. It impacts the attempt to assemble basic technological competencies and the efforts towards regulating internal interactions between institutional competencies and their capacity to assemble other vital competencies, external ones inclusive (Que´Lin, 2000).

In regard to strategic management of R & D, much attention has been paid to the role of competencies and resources that are accumulated over time by institutions (Dierickx & Cool, 1989; Barney, 1991; Que´lin and Arre`gle, 2000). Institutions are constantly striving to develop competencies that are aligned and supportive of the institutional strategy. In doing so, they are looking to implement horizontal and sometimes cross-division structures proficient for amassing competencies and resources, regulating strategic activities and encouraging innovation. Additionally, decisions regarding policies to diversify, to develop new products and partnerships depend significantly on the institutions' awareness of the appropriate role of the business unit (the repository for the several types of knowledge, know-how, expertise and competence that the firm possesses (Que´Lin,

2000). Table 1 illustrates the basis upon which innovations and new products should be developed.

Adaptation: *a competence, whether individual or collective, must enhance the firm's flexibility*
It increases the company's added value: a firm's clients assess its ability to generate added value from its products, processes and organization
A firm's ***performance*** *is determined by its competence*
Competencies are a new source of ***capital growth***
Individual and organizational competencies need time to develop
The mobilization of competencies infers the existence of a ***structured approach, methods and tools***

Table 1: Basis for Innovation in Institutions (Que´Lin, 2000)

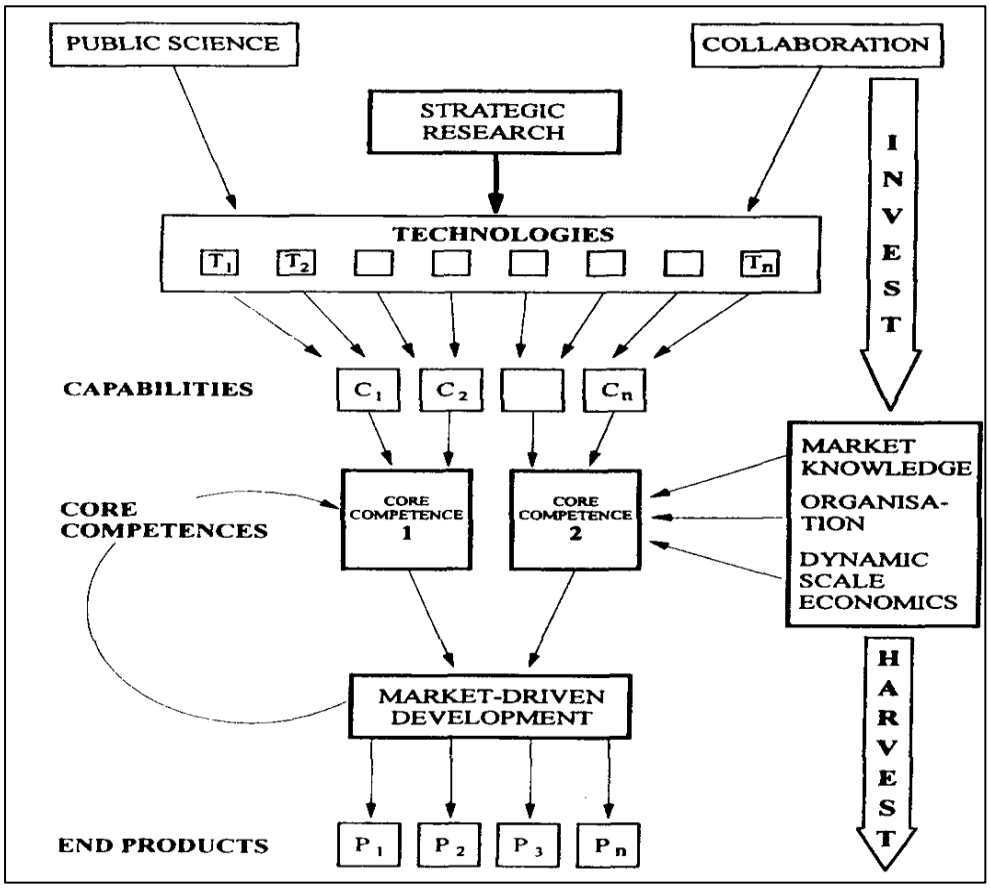

Figure 3: A typical application of technological competences in an R &D setting (Coombs, 1996)

1.2. Globalization, Technology and Collaborative Networks

1.2.1. The Phenomenon of Globalization

There has been conflicting interpretations of 'globalization' both in public debates and specialized studies right from the beginning a few decades ago. Several authors have labelled it an inevitable characteristic of the modern world and yet have still failed to arrive at a single perspective to look at the phenomenon (Ohmae 1990). However, if the amount of relevant literature on globalization is anything to go by, then it is indeed undeniable that this phenomenon has caught the attention of many. Globalization as a term is [1]often used by many across the world in an attempt to characterize social perceptions of the late twentieth century. It is incredible though that its meaning still remains ambiguous even among those who evoke it. In fact, earlier authors like Jan Aart Scholte (1995) remarked that *"globalization stands out for quite a large public spread across the world as one of the defining terms of late twentieth century social consciousness."* Paul Steeten (1996) referred to the concept of Globalization as contextual, and defined it as *"the intensification of world-wide social relations which link distant localities in such a way that local happenings are shaped by events occurring many miles away and vice versa."* This definition suggests that geographical boundaries have been defied by the increasing relation and dependence between and among diverse actors.

Similarly, the definition by Held et al. (1999) and Tomlinson (1992) referred to Globalization as *"the process whereby a global network of interconnections and interdependences uniting different countries and regions is becoming increasingly dense, so that we create an ever stronger sense of the world as one place"* (Held et al., 1999: 16; Tomlinson, 1999). This definition was made in the context of qualitative research and methodologies with the implication that despite our individual physical and professional locations, we use the same knowledge, methods and ideas for

[1] "The central feature of the idea of globalization is that many contemporary problems cannot be adequately studied at the level of nation-states that is, in terms of each country and its inter-national relations, but instead need to be seen in terms of global processes." (Sklair, 1999)

conducting qualitative research to explain social situations based on empirical qualitative data (Alasuutari, 2004). Furthermore, Globalization in the context of Economics, also known as *"Economic Globalization"* is not only the movement of people, money, goods and services, but also the flow of information and ideas (Storper, 2000). Indeed, because there is an increase in the intensity of global competition for new ideas and innovative technologies, information and knowledge resources required to conduct cutting edge Research and Development (R&D) can be collected from diverse sources (Tijssen, 2012)

1.2.2. Global Technological Innovation

'Globalization' has been intimately associated with the rapid and persistent technological innovation (Nelson, 1994) leading to a modern world which is characterized by the emergence of a "global village" or better yet, a "borderless state" (Ohmae, 1993). This modern world is a knowledge based society (Archibugi & Iammarino, 2002) in which the advancement of technology seems to have accelerated the creation of global markets, political and economic institutions and other world systems. Most significant in the simultaneous advancement of 'globalization' and technological innovations is Networks. Networks involving a sophisticated web of relationships between and among firms, universities, government agencies, and other institutions for producing and sharing knowledge relevant to technological innovation (Rycroft, 2003). It is for this reason that authors like Cornali & Tirocchi, (2012) pointed out that *"Globalization is based on a network of interconnections, interactions and interdependencies between remote actors who make it possible and within which causative actions, information, knowledge and influences are propagated almost instantaneously. The general consensus is that without the impetus provided by the development of new information and communication technologies, globalization whose first signs began to appear a couple of centuries ago would have stopped short at a very basic level."*

A similar but earlier school of thought based on Castells work described by Frank Webster (2006) explained that the so-called 'modern world' is "*a transformation towards an information age, the chief characteristic of which is the spread of networks linking people, institutions and countries."* The internet plays a

fundamental role in the information age by reinforcing the power of technology through its inbuilt features that promote interaction between electronic communities. Frank Webster (2006) also remarked that *"Castells in his book the Information Age, restates his distinction between the 'space of places' and the 'space of flows', and places the emphasis in the 'network society' on the latter. With information flows becoming central to the organisation of today's society, disparate and far-flung places can become 'integrated in international networks that link up their most dynamic sectors' (Castells, 1996, p. 381). Castells emphasises his argument that regions and localities do matter, but suggests that we are experiencing now a 'geographical discontinuity' (p. 393) which throws established relations out of kilter.*

That said, it is imperative to define the link between globalization and technological innovations by indicating their simultaneous advancement. Over the years, multi-national Enterprises (MNEs) have taken center stage in globalization among other players but that is changing due to the emergence of new forms of network organizations. And this was explained by (Daniele Archibugi and Jonathan Michie, 1995) in a typology (see Table 1) they developed for categorizing the technologically-related indicators linked to globalization as described below:

i) Technological Exploitation: This aspect of globalization was characterized by innovators, usually Multi-National Companies (MNEs) selling their technological competences on the international market for profit. This was actually more of an internationalization of competences rather than globalization considering that the players involved keep their national identities even though their innovations have been sold in other countries or the knowledge used was outsourced from another country. This in itself became one of the most commonly engaged in international activities hence the escalation of globalization of the market. It suffices to point out that usually, changes in technology were associated with compliance in facilitating function and reducing cost of operation. However, in this case, changes in technology served only to make money for MNEs, hence the analogy of technological exploitation.

ii) Technological Generation: This second aspect of globalization of innovation included innovations considered global as soon as they were generated. It was characteristic of MNEs to efficiently manage units of their innovative Networks located in various countries. These units included; Research and Development (R & D) and technical departments which gave inputs to the production units. A number of Foreign Direct Investments (FDIs) indicated that the generation of technology was expanding but at a modest level outside their own home countries. Research and Development (R & D) facilities were being moved to MNEs' host countries and patents being generated by their foreign branches. That said, the process of globalizing technological generation had noticeably stretched amongst the very large MNEs in major industrialized countries in North America, Europe and East Asia (Patel, 1995).

iii) Technological Collaboration: This one falls in-between the first two categories. Technological collaborations came into play involving two or more firms or institutions coming together to start a joint project with the goal of developing technical knowledge and products. The collaboration was usually defined by three factors; i) the joint project that had to be formal and distinctive ii) the institutions involved had to keep their identities and ownership iii) the biggest part of the project had to be about sharing knowledge and/or producing new products (Mowery, 1992). These collaborations could also involve institutions and firms within the same country but usually involved firms and institutions within two or more countries hence the aspect of globalization. It goes without saying that these kinds of collaborations in technological advancements developed tools to enable cost effective operations and results. Organizations and firms implemented new ways of managing their industrial and ownership structure to facilitate reduction in costs of innovation while making more compliant products to serve the ever changing market. Such collaborations enlarged their borders not only technologically but otherwise too (Dodgson, 1993). It is very important to note that this know-how and how to transmit it was something that the academic world introduced. This is so because the academia was always operated beyond

national borders through the transfer of knowledge from one colleague to another.

1.2.3. Research Networks in the Modern World

The labor market for the academia and competence development has become internationalized as institutions especially universities are devising new research approaches to position themselves to benefit from research opportunities available globally. The motivation of these new research approaches are spread all over various sources and practices. While, some institutions just want to enhance and maintain their mark in the globalization of new opportunities and challenges (Olds, 2012), others want to establish themselves as 'global institutions' that are able to defy geographical or national borders to match the others that are considered elite institutions elsewhere. Others also want to exploit the opportunities to access resources and large scale resource support. And the rest may just want to exploit 'globalization' as a way to enlarge their research capabilities by establishing relationships with identified partners or countries that are considered 'emerging powers.'[2] That said, it is becoming increasingly apparent that international research collaborations or relationships are responsible for the emergence of new systems or approaches of working or getting things done and achieving maximum results (Larner, 2013).

International Consortia have continued to grow and receive attention from the academia (Teather, 2004 and Higgitt et al., 2008) hence providing a demonstration of how the environment of 'globalization' comes into practice (Tadaki & Tremewan, 2013). According to Olds (2012), some of these Consortia include mission-specific consortia like the Worldwide Universities Network, regional consortia like the Asia-Pacific Rim Universities (APRU), and project-specific international consortia which develop experiments in higher education, as well as defacto consortia related to

[2] Frank Webster (2006) was quoted to have suggested that the so-called 'modern world' "is transforming into an information age characterized by knowledge networks that connect people, institutions and countries."

building programs in selected cities. Greater emphasis has recently been put on collaborations that bring universities in partnerships amongst themselves and with other think-tanks like industry, government, MNEs to promote even more rigorous collaborative works to enhance international research opportunities.

Globalizing research networks also has a lot to do with the discipline or field of the activity. There is more acceleration going towards formation of networks based on scholarly practice rather than networks based on the institutions involved. Models of networks based on scholarly practice are developed for a range of disciplines like; biomedical sciences, physical and natural sciences to social sciences and humanities. Formation of these Networks are conscious efforts by researchers to develop multi-disciplinary partnerships that go beyond national boundaries to take advantage of intellectual and resource opportunities. In the same way, research councils are investing in the establishment of global networks like the PhD Partnering Program created by the UK Economic and Social Research Council to build institutional partnerships between the United Kingdom and non-European, non-Anglo institutions. Additionally, funding bodies at both national and international levels have played a big part in promoting the globalization of research networks particularly by focusing on globally challenging areas like energy, health, environment, to mention but a few (Larner, 2013). As expected, research in these globally challenging areas require big teams of professionals from across disciplines and so are usually sourced from all over the world.

Furthermore, even though academic and research institutions are at the center of research and globalization of research networks, other research providers like MNEs, Public bodies, industry, Non-Governmental Organizations (NGOs) and other think tanks are playing alongside. This has given rise to new research partnerships and contact between the academia, policy and practice. Additionally, there are new networks forming among industry, scientific and public institutions (Slaughter & Rhoades, 2004; Shore, 2011). Nevertheless, it should not be ignored that, this acceleration in the globalization of research networks comes along with a number of questions. Some of them are related to standards and formats of the knowledge shared, cultures and norms of the different players, for example, the ethics of conducting clinical trials especially in developing countries (Cooper, 2008)

and the influence of the new emphasis on experimentation in some social science areas like social policy and behavioral economics (Pykett, 2013).

Categories	*Actors*	*Forms*
International exploitation of nationally produced innovations	Profit-seeking firms and individuals	Exports of innovative goods Cession of licenses and patents Foreign production of innovative goods internally designed and developed
Global generation of innovations	Multinational firms	R&D and innovative activities both in the home and the host countries Acquisitions of existing R&D laboratories or green-field R&D investment in host countries
Global techno-scientific collaborations	Universities and public research centres	Joint scientific projects Scientific exchanges, sabbatical years International flows of students
	National and multinational firms	Joint-ventures for specific innovative projects Productive agreements with exchange of technical information and/or equipment

Table 2: Categories of Global Technological Innovation (Archibugi and Michie, 1995)

It is therefore, important for research players in a global environment to work towards harmonizing these questions in order to achieve universal outcomes in their collaborations. Also, the academic institutions should recognize the fact that the other research players like the Multi-National Enterprises (MNEs) have greater global goals and may be better placed to generate the much needed knowledge that is

required to respond to the globally challenging issues. Therefore, collaborations with these categories of research players may create such profound results.

Finally, while Literature shows that much has been covered regarding academic and research institutions becoming global, less attention has been paid to how these institutions can globalize the important issues about research like research itself and the research professionals. Research and Academic Institutions have recently become proactive in identifying the challenges related to the globalization of their research competences to enhance academic practice and career growth by recognizing that the element of going international facilitates collaboration. This has been considered necessary for the enhancement of their visibility and reputation to the rest of the world and to position them for future success (Larner and Le Heron, 2005). That said, 'globalization' has become an important phenomenon especially in the transfer and flow of research knowledge among institutions. This has led to international and multi-disciplinary or inter-disciplinary collaborations by academic and research experts. One very noticeable result of these global partnerships is that academic institutions (universities) have become a central part of this enormous knowledge network (Faist, 2008 and Obamba, 2013). [3]

1.3. Research Networking Systems (RNSs)

1.3.1. Understanding RNSs

Research Networking has become a global undertaking through which individuals, teams and institutions in research are seeking to work together towards the advancements of scientific endeavors. However, without subsequent ways of

[3] Certain issues like standards/ formats, ethics, research management infrastructure and institutional factors are consequently changing as institutions adapt to global activities involving other institutions, countries, MNEs and even the civil society across borders. These issues must be addressed to ensure smooth sailing for the benefit of all parties involved.

exposure to the 'global arena', it gets increasingly unlikely that some researchers or research institutions will be able to exploit the research resources and opportunities within and beyond their own institutional or national boundaries. Research Networking Systems (RNSs) appear to have provided a solution to this dilemma and have been accepted world over for providing a platform for research that defies both disciplinary and geographical boundaries. Precisely because Research Networking is a digital activity, the ubiquity of RNSs has facilitated team work amongst researchers beyond time-zones and continents. This trend is evident in the increased number of international collaborations, co-authored papers, and multi-investigator grant proposals (Olson et al. 2008). There is also a significant indication that there are more researchers/ scientists working in teams rather than solo to produce high impact and highly cited works from across boundaries of their institutions.

Authors of relevant literature like; Schleyer T. et al. (2012) propose the definition that *"Research Networking Systems (RNSs) are systems which support individual researchers' efforts to form and maintain optimal collaborative relationships for conducting productive research within a specific context."* This definition is also adopted by Eichmann (2012). On the hand, Kahlon (2014) refers to them as *"Web-based applications that mine a variety of data sources to automatically generate searchable profiles and expose existing networks of collaborators."* These pieces of literature suggests that even though researchers can be located by searching webpages using search engines like Google, the need to create an institutional researcher population, maintenance of publication and enhancement of inter-linkage of the represented researcher population justifies the implementation of the RNSs in Institutions.

Research Networking Systems (RNSs) as a topic has attracted a lot of attention especially within the Research and Academic Community. In fact, National Center for Research Resources (2009) observed that the term *"Research Networking System"* was used in place of *"research collaborator discovery system," "expertise location system,"* and other terms after the Center awarded a $12m grant to the University of Florida to develop a national prototype system. These unique systems are designed with special features to enhance researchers' experience in locating research resource information within and amongst institutions as well as across the

globe. Research resource information mostly searched for include; researchers' or investigators' profiles, collaborators, funding, publications, and mentors for upcoming researchers or students, to mention but a few. Implementation of commonly adopted architecture (see Figure 3) is usually massive because of the influence of the institution in its design and layout. For this reason, researchers may not have much influence or ownership in the data managed by the implemented RNS. Nevertheless, RNSs like Profile RNS and VIVO have registered successes in the institutions where they have been implemented (Eichmann, 2012).

Clinical and Translational Science Awards (CTSA) Research Networking Affinity Group in the USA considers very crucial the *"elements of access to sufficient institutional and linked open data, data that are semantically structured and made publicly available."* This is known to be one of the major characteristics of good RNSs. The CTSA Research Networking Affinity Group disclosed that adoption of an RNS can solve a number of challenges that come along with research changes in ways such as; identifying collaborators or complementary partners especially in multi-disciplinary research, creation of issue specific research teams beyond institutional or relationship barriers, identifying and establishing prospects for funding and keeping truck of funding trends, participation in virtual team science to accomplish research goals and support for creation and editing of digital Curriculum Vitae (CV). Similarly, Weber, et al. (2011), in their paper *Direct2Experts, a brief communication concerning the establishment of a National Research Network to promote formation of multi-university science* explained that, a national RNS can harvest both linked and open data from various sources ranging from institutional, national and enterprises research networking systems and match them with the researcher or investigator profiles generated by academic and scientific institutions. [4]

[4] A good RNS should enable to facilitate identification and establishment of collaborations, research teams and funding to address existing and new scientific challenges. The systems should also enable generation and editing of Curriculum Vitae (CV) and facilitate evaluation research information resources over time.

1.3.2. Types of Current Research Networking Systems (RNSs)

While a relatively large amount of literature on RNSs exists (Ackerman et al., 2003; Becerra-Fernandez, 2006), a comprehensive list with detailed description of the various types of RNSs available in the market are not many. One source of information on the types of RNSs available in the market is Wikipedia which provides list of RNSs both commercial and open-source. We will look at a few of them but it should be noted that at this point that, it is quite beyond scope of this literature review to describe all of the RSNs on the market. For this reason, after a focused literature search, five RNSs that have been tested and implemented by various institutions all over the world were selected and will be briefly discussed below.

- **Digital Vita**

Digital Vita is the RNS for the University of Pittsburg, Pitt Health Sciences Center - also previously called the Faculty Research Information Software. Developments on the former were discontinued and focus has been committed to the establishment and functionality of Digital Vita. This RNS is open source and is characterized by functions such as maintenance, creation of online profiles and Curriculum Vitae (CV), importation and update of bibliographic data specifically from MEDLINE, formatting and semi-automated updating of bibliographic information, finding researchers and identifying collaborators, building and maintenance of social networks, and Electronic Document Management Digital Vita is designed to revolve around the researcher's profile and Curriculum Vitae (CV) which is regularly updated to provide the most comprehensive representation of the researcher and his/ her activities and accomplishments. Due to this special focus on CV integration, barriers for the adoption of Digital Vita are minimized especially for research institutions seeking to expose their competences within and beyond their boundaries and achieving maximum system utilization (Schleyer et al., 2012).

- **Elsevier's SciVal Experts**

SciVal Experts is a commercial RNS that has recently become a part of a bigger Information System at Elsevier to form the profiling and networking tool

called the Pure Experts Portal. This tool is *" a fully integrated research information system allowing you to build reports, carry out performance assessments, manage researcher profiles and more, all while reducing administrative burden for researchers, faculty and staff"* SciVal Experts allows interoperability with PubMed, and some Human Resource Systems mostly for purposes of importation of investigator profile data. The system also allows access to investigators/ researchers, which enables them to input and edit information after feeding in user authentication details. Additionally, the RNS works with the Human Resource Systems to regularly update information pertaining to grants and proposals. Publications that are manually entered are automatically forwarded to co-authors or collaborators.

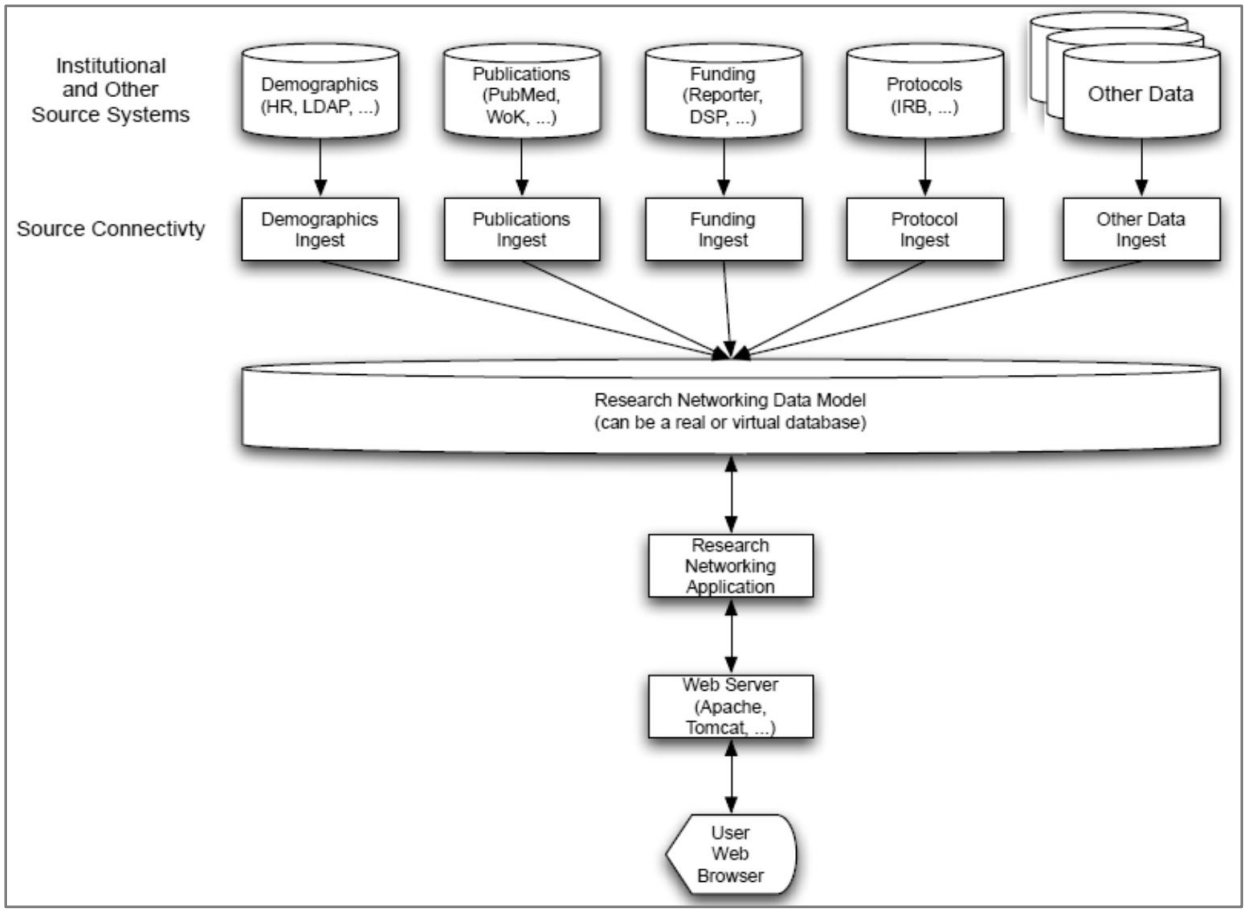

Figure 4: A Generic Architecture for Research Networking Systems (Eichmann, 2012)

According to the SciVal Experts Client List, the SciVal Experts RNS has so far been adopted and implemented by more than 45 institutions worldwide not

mentioning profile registration of researchers at more than 65 institutions. Some of the client institutions include; Johns Hopkins University, Memorial Sloan-Kettering, Northwestern University, REACH NC, University of Michigan, University of Texas MD Anderson Cancer Center, and several institutions in Asia-Pacific, Europe and Latin America. The fact that this RNS has already been largely implemented worldwide proves its credibility to serve the purposes of globalizing research and uncovering researcher capabilities especially for medical institutions. It is also an advantage that researchers/ investigators can access the system to input relevant information as it gives them some form of identity.

- **Profiles Research Networking Software**

Profiles RNS is able to extract data and information about every single researcher or investigator in an institution. It self-populates a database with information regarding the publications history, research interests, funding/ grant opportunities and professional relationships of the researcher.

> Profiles Research Networking Software is an NIH-funded open source tool to speed the process of finding researchers with specific areas of expertise for collaboration and professional networking. Profiles RNS imports and analyzes "white pages" information, publications, and other data sources to create and maintain a complete searchable library of web-based electronic CV's. Built-in network analysis and data visualization tools allow administrators to generate research portfolios of their institution, discover connections between parts of their organization, and understand what factors influence collaboration.

Due to its user-friendly visual and search functionality, its appearance can be customized or integrated into an existing website or operated as a stand-alone information system. Profile RNS can be accessed through an Application Programming Interface (API) to other power applications. With the introduction of *"passive"* and *"active"* networking, Profiles RNS is proficient to make the website both a useful and exciting experience for users. This RNS allows users to add information, contribute to other users' information and even edit what already exists on the system. Passive networks are automatically created based on current or past co-authorship history, organizational relationships and geographic proximity. It

extends the research network by discovering new connections, such as identifying people with similar interests and providing opportunities for collaboration.

This RNS also facilitates both online and facilitates physical identification of collaborators, advisors, mentors and colleagues with similar interests. This may well end up into physically functioning networks that will increase research productivity. Information from their website indicates that, in the near future, Profiles RNS will provide support to the Open Social standard to allow the use of plug-in collaborations such as those used by professional social networks like Google and LinkedIn. The adoption of the Profile RNS seems quite feasible because its characteristics fit almost any institution that is looking to maximize the utilization of an RNS. The fact that it gives access to researchers to provide input or edit is very crucial. It also has a user-friendly and customizable interface is an added advantage especially for users that will be interacting with a RNS for the very first time. Also, engaging the social networks tools will certainly enhance the users' interaction experience through a wider platform for networking and consequently advancing research. Profiles RNS has been adopted by Harvard University and the University of California, San Francisco among others (See reference for client institution list)

- **VIVO**

This is an open source semantic web application that was originally developed and implemented at Cornell. Upon installation and population with data describing researchers like their interests, activities, accomplishments, this RNS facilitates the identification of multi-disciplinary research opportunities worldwide. The browsing and searching capabilities of VIVO enable easy and fast retrieval of desired results. Maintenance of a local installation of VIVO can be manual or automatically integrated with other information systems such as Human Resources, Grant or Faculty databases or from database providers such as publication aggregators and funding agencies.

VIVO RNS supports and facilitates research recovery because of the semantically structured nature of its data. Applications such as visualizations, enhanced multi-site search consume the rich data from VIVO RNS. Other applications such as VIVO Searchlight, a browser bookmark-let uses text content of

any webpage to enable discovery of VIVO profiles; the Inter-Institutional Collaboration Explorer, shows collaborations among institutions, researchers and partners, to mention but a few. More than 100 institutions and agencies across more than 30 countries have or are implementing VIVO or producing VIVO-compatible data. VIVO Participant List

VIVO is a very comprehensive and multi-resourceful RNS considering its proficiency to facilitate and advance not just research but multi-disciplinary-research within, among and beyond institutions. The aspect of taking research out of the confinements of a single institution is currently a very significant feature of RNSs and institutions must bare that in mind before adoption. The wide coverage of VIVO in terms of implementation is no longer a hidden fact, making it one of the most popular RNSs available.

- **Searchable Answer Generating Environment (SAGE)**

This RNS may best be described as a repository of information about funded inter-university research in Florida. Universities across Florida can search for funded research opportunities or collaborations (Becerra-Fernandez, 2006). SAGE implements a distributed database schema with a search criteria that involves entering either the; research topic, investigator name, funding agency, or name of university. Participating Institutions regularly update the repository with funding information, this increases opportunities for researchers across Florida to identify and locate potential collaborators from other universities, industry and even federal agencies. In fact, federal agencies like NASA and other companies have been using SAGE to identify university researchers to work with in various research activities (Schleyer, et al. 2012). SAGE RNS demonstrates potential to facilitate inter-institutional collaborations on diverse areas of research ranging from academic, scientific, industrial, business, public, to mention but a few. Institutions engaged in diverse fields of research with diverse research partners may consider adoption of similar RNSs.

At this point, it is imperative to note that the RNSs described above are characterized by different approaches for creating searchable functionalities and directories for researchers. This difference elicits a better understanding of how each

institution planning adoption of RNSs should consider issues concerning functionality and data management for researcher profiles. It is also worth noting that, the description of each of the RNSs above is not entirely complete. Some features may have been left out majorly because describing them exhaustively would stretch the purpose of this review beyond limit.

Another issue great importance is that adoption of an RNS largely depends on the institutional factors in play. Factors like institutional requirements, culture, policy, financial and human resources must be carefully considered in order to achieve feasibility of the implementation. This implies that there should be a "fit" between the requirements of a particular institution for implementing the RNS and the RNS itself. That said, the RNSs described above are just but a few of the many that are available on the market today and from which the institutions can choose. A more comprehensive and regularly updated list of Research Networking Systems and Tools can be found at Wikipedia: List of Research Networking Systems and Tools.

1.3.3. State of Research Networking Systems Implementation

Literature on RNS is growing considerably especially within the last decade. However, not much regarding their initial implementations was found. RNSs have generally become a global affair resulting into implementations by research and academic institutions in order to take advantage of big universe of information, expertise, opportunities and resources. As mentioned earlier, institutional factors such as i) financial, policy, and other obligations ii) technical foundations for implementing the system and of course iii) the new developments in RNS models must be carefully considered to ensure a successful implementation. It is therefore, important for institutions to understand and specify their requirements for implementing RNSs. Additionally, it is to the benefit of the institution to carry out RNS implementation in stages to determine feasibility of the exercise. The CTSA Research Networking Affinity Group - Evaluation Guide that proposed a typical procedure for implementing Research Networking Systems (RNS) in institutions (See Figure 5). Depending on the purpose, the urgency to implement and prevalent

institutional factors determine which stages to include in or exclude from an implementation initiative. [5]

Relevant Literature (Obeid J.S., et al., 2014) reveals that a survey was conducted by the CSTA Research Networking Affinity Group between July and October 2012 involving experts from 61 CSTA funded institutions. The main aim of this survey was to examine the state of RNSs adoption in the Consortium and the influence of the recommendations by Strategic Goal Committee 3 (SGC3) on collaborative tools and Linked Open Data (LOD). The outcome of the survey revealed that 51 had implemented RNSs (22% VIVO, 23% Harvard Profile, 22% Elsevier SciVal Experts8, and 25% other systems (including locally developed or commercial platforms) CSTA funded institutions had already adopted an RNS while the rest were planning adoption. Forty Seven (47) of the institutions also had plans to expose their research expertise data through LOD. Also, initial exploration of the publically-available data indicated promising value in assessing cross-institutional collaborations.

It is true that RNSs have received attention as it is evident in related literature but currently, very little has been documented regarding initial implementations. Most of the available relevant literature is geared towards improving existing RNSs implementation to facilitate rapid and easier discovery of collaborators. However, we shall delve into studies showing the current state of RNS implementations in a general sense. Also, relevant literature indicated that some of the current RNSs have been found to fall short in terms of detail in design and development. As a result, these RNSs implementations in some institutions have been considered to lack "critical mass" (Gewin, 2010). Studies focused on RNSs usage in certain research/ academic institutions provide insight on user behaviors of the different user classes of RNSs. A study that was done to show search and navigation patterns from a five month user log at the Columbia University revealed contrasts in usage patterns across user classes, with faculty performing more keyword searches than

[5] "The development of research information systems is primarily driven by the needs and wishes of governance bodies; system users' need to provide the required information in order to fulfill their part in the research process" (Bittner and Muller, 2011)

administrators (Boland, et al. 2014). The study suggested that faculty members were probably technically more equipped to effectively use RNSs compared to their counterparts in administration who may found RNSs non-user friendly. It is possible in this case, that there could have been a gap in knowledge of the needs and workflows of the different user classes. If this was the case then, it would not be uncommon that the disadvantaged user abandons using the RNS and moves on to use a more user friendly system but usually of less quality in terms of information discovery.

Additionally, an attempt to address the gaps in RNS implementations and use showed concerns regarding the limitations of restricting searches to single institutions. These concerns led to the development of extensive search tools standard application programming interface convention. This interface was used in a pilot study - Direct2Experts, to demonstrate how a federated multi-institutional search uses a standard application programming interface convention to provide a federated multi-institutional search interface (Weber, et al. 2011). Even though, this federated interface allows comparison of results count returned, each institution provides its own inherent results. This implied that there was still a lack of standard formats for presenting results on a general interface thus limiting the opportunity to compare and contrast results (Borromeo, et al. 2014). The VIVO RNS may be better placed to support multi-institutional searches because of the fact that it uses semantic Resource Description Framework (RDF) markup and linked open data. On the other hand, the VIVO Searchlight browser plugin promises a possible approach to maximize the use of RNS data as it helps link individual VIVO profiles from various institutions through commonly accessed online resources or databases like PubMed (Chen, et al. 2011).

Meanwhile, Kahlon et al. (2014) conducted a study at the University of California, San Francisco with the objective of describing the usage of an institutional RNS. This study involved investigating the visitor details such as; number of visits, visitor location and type, referral source etc., and click paths from two and a half years of Web analytics data were also studied. By the end of the study, results indicated that more than 2000 visits per month navigated five or more links into related researchers and topics. One third of the returning visitors showed a behavior

consistent with using the RNS to discover new collaborators and research topics. This trend suggested a number of benefits of a RNS usage towards supporting research and the mission of the institution.

Literature also identifies studies that have worked towards closing some of the gaps in RNS implementation. Most of these studies focus on enhancing the functionality of existing implementations to support faster and easier discovery of collaborators and also increasing the visibility of researchers. Schleyer et al. (2008) carried out a study of which one of the objectives was to specify the requirements which RNSs for finding collaborations had to fulfill.

Adopting Research Networking. Institutional evaluation and commitment is essential to successfully participating in research networking, however, one does not need to fully commit financially, administratively, and in terms of policy in order to begin to see some benefits from research networking. Institutions can participate a step at a time. The Capability Maturity Model Integration (CMMI), for example, lays out 5 maturity stages for an organization. Using the CMMI framework allows a particular institution to assess itself relative to the model, and establish an appropriate path forward.

Level 1: Identification. Evaluate and understand the needs driving research networking, champions in research and administrative areas. Evaluate where expertise profile data may be found (maybe incomplete or under several authorities). Extract some approved profile data sets and develop some initial pilot projects to evaluate value and institutional strategy for next steps. Evaluate existing research networking tools to determine the best solution (see 'Software Applications' below). Identify and procure the necessary resources (financial, management, FTEs, and hardware) for implementation and maintenance and a staged implementation plan.

Level 2: Initial. Installing an RN tool or portal to a research networking system and doing a one-time extraction of public faculty information from an institutional repository (such as a faculty annual report system) into that system, combined with NIH grants (RePORTER) and biomedical publications (PubMed). This will allow a local demonstration of the capabilities of research networking and participation in pilot projects such as direct2experts.org. This has fairly low cost and commitment, and can deliver short-term benefits.

Level 3: Managed. The above, with regular updates to the RN tool by faculty or administrators or that are 'pushed' from institutional repositories and public databases such as PubMed and RePORTER, thus providing periodically updated information.

Level 4: Defined. The exchange of data between the RN tool and institutional and external system(s) is regularized so that faculty members can update information at any point and it is updated centrally. This provides a sustainable and proactive process to maintain accurate and rich data. This is typically combined with adoption of tools that provide greater functionality for administrative and research support processes such as automatic CV and web page generation.

Level 5: Optimizing. This phase includes all of the above, but also now integrates institutional business processes for network analyses of team science activities,

Figure 5: Capability Maturity Model Integration (CMMI). Excerpt extracted from CSTA Research Networking Affinity Group - Evaluation Guide

The outcome of this study revealed five main requirements namely;

> 1) … compatibility with respect to personality, work style, productivity, and many other factors (compatibility); (2) … ability to effectively search in domains other than your own using information that is comprehensive and descriptive (communication); (3) social networks are important for finding potential collaborators, assessing their suitability and compatibility, and establishing contact with them (intermediation); (4) information profiles must be complete, correct, up-to-date, and comprehensive and allow fine-grained control over access to information by different audiences (information quality and access); (5) keeping online profiles up-to-date should require little or no effort and be integrated into the scientist's existing workflow (motivation).

The study was instrumental in the evaluation of a prototype, *Digital Vita* for the above named requirements which it seemed to meet but as with most systems, had its deficits (Schleyer T. et al, 2008).

In March, 2011, the Institute for Clinical and Translational Research of the Columbia University implemented an RNS called the Columbia University Scientist Profiles (CUSP) with the goal of facilitating collaboration across disciplines within the area of clinical and translational research. CUSP was specifically implemented to help researchers and academicians identify and establish collaborations, students find mentors and for administrators keep truck of progress in the science community. These are perceived to be the functional requirements of this institute for implementing CUSP and indeed, the system harvests and integrates information from other databases like the Human Resources, PubMed and financial accounts for grants. According to Boland et al, (2012), CUSP also "*performs person name disambiguation, word stemming for synonym identification for each queried term, and query expansion.*" The RNS is also required to enhance retrieval of grants and match them with the respective investigator/ co-investigator, publications and match them with all co-authors then linked to PubMed, contact data and demographic description researchers and faculty. Regular updates are performed especially for information pertaining to grants and publications to keep abreast with new developments (Boland et al, 2012).

Furthermore, a qualitative study to better understand the requirements for designing an RNS to help biomedical scientists easily identify and establish collaborators was carried out (Barromeo, et al, 2014). As noted, this study was majorly to enhance identification and establishment of collaborators and later develop a functional prototype to that effect. This study yielded very positive results pinpointing repetitive trends in information needs and workflows of users. These included a sequential display of publications and grant information, the need for conjunctive keyword and name searches and tools for trucking potential collaborators. These revelations provided positive ideas for evaluating and improving the prototype. The study concluded that an RNS that is proficient in providing an updated and interactive display of information that facilitates evaluation of researcher capabilities in relation to funding and publication was likely to effectively support discovery of collaborators. Borromeo and his colleagues also recommended further studies to better understand the impact of collaborator search tools on researcher workflows (Borromeo, et al., 2014). A somewhat similar qualitative study was carried out by Bhavnani et al. (2012) to identify researcher needs for tools to facilitate discovery of collaborators and resources. The study yielded the following outcome*;* the need to have federated information, capacity to handle large volumes of information, and refined and user friendly to enable researchers participate in managing their data *(*Bhavnani et al, 2012).

Another development in RNSs implementation is the VIVO project to establish an open and semantic web-based national network of institutional ontology-driven databases. This project was aimed at facilitating the discovery of collaborators, networking amongst researchers and institutions through sharing information about researchers and their activities. This project was funded by the National Center for Research Resources (NCRR) of the NIH (National Institute of Health) in the USA in 2009 with a grant of $12.2 million. The VIVO Project implementations kick-started at the University of Florida, Cornell University, and Indiana University Bloomington and four other partner institutions all in the USA. In conjunction with the Semantic Web/ Linked Open Data community, the VIVO Project piloted the building of common ontologies, integration and authentication of information sources from the different institutions involved and discovery and assessment of the networks of researchers (Krafft, Dean B. et al. 2010). The VIVO

Project was developed on the foundation of the technology that Cornell University built over the past decade. Major features of VIVO include supporting flexible description and linking of people in the research environment, organizations, publications, affiliations, activities, and other aspects and their properties. Krafft, Dean B. et al. (2010) defined VIVO as *"an open source Java application built on W3C Semantic Web standards, including RDF, OWL, and SPARQL.*[6] *While the NIH-funded project focuses on biomedical research, the current Cornell implementation of VIVO supports the full range of disciplines across the university, from music to mechanical engineering to management."*

At this point of the review, it is important to say that a substantial amount has been gathered from relevant literature and studies in the area of RNSs implementation. Nevertheless, the study that follows this review intends to undertake and focus on an initial implementation of an RNS in the Institute of Systems and Computer Engineering (INESC TEC). This study aims at understanding and specifying the requirements of the institute for implementing an RNS. As earlier mentioned, it is important for institutions planning to implement RNSs to conduct this step prior to implementation in order to enable the selection of a suitable RNS.

[6] http://www.w3.org/TR/owl-features/
http://www.w3.org/RDF/
http://www.w3.org/TR/rdf-sparql-query/
http://linkeddata.org

2.0. RESEARCH DESIGN

This chapter presents the research approach used to organize, collect and analyze data during the study that was conducted. This also includes the target population, the sample and sampling technique, data collection instruments and procedures and data analysis techniques. Figure 6 below shows a summary of the research methodology employed to conduct this investigation.

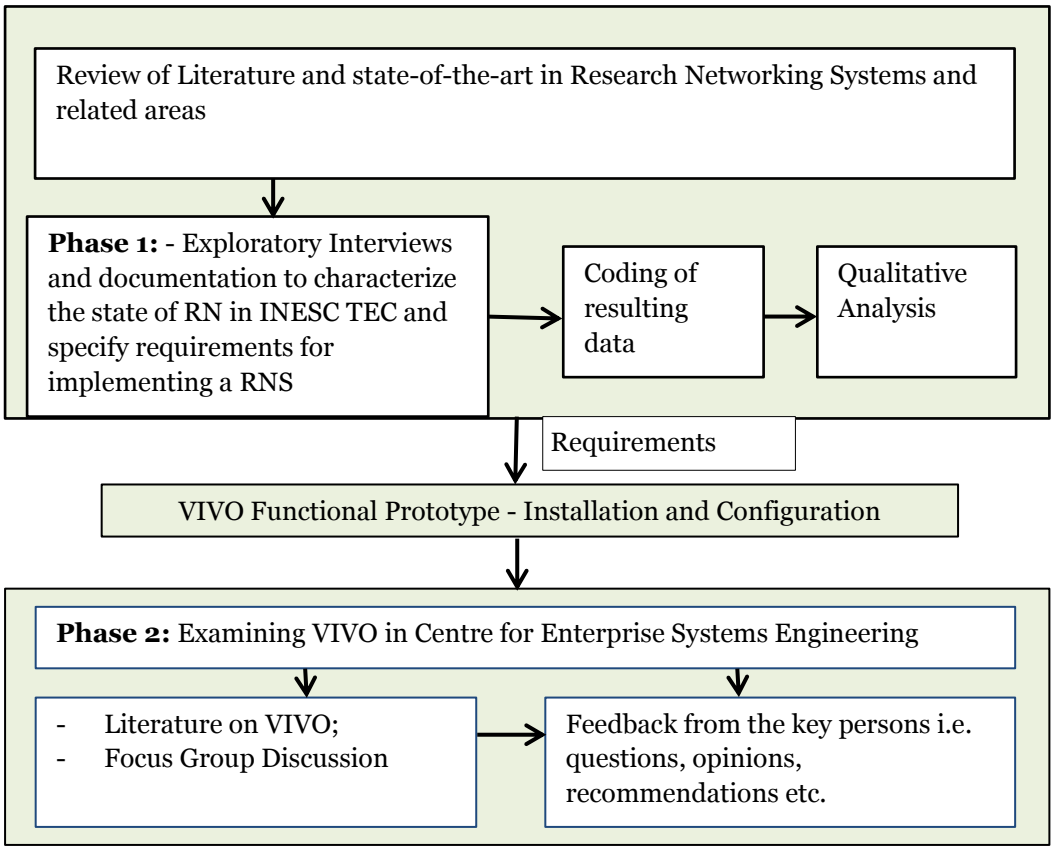

Figure 6: Summary of Research Methodology for Dissertation

This Dissertation employed a qualitative Case Study approach to facilitate the exploration of the phenomenon of Research Networking Systems implementation within the context of INESC TEC. This approach is known to enable the exploration of situations in which the intervention being assessed has no clear, single set of outcomes (Yin, 2003). Benbasat et al. (1987) also stated that the case study approach is particularly suitable in circumstances: (a) where research and theory are at their early, formative stages, and (b) where the experiences of the actors are important and

the context of action is critical. The Case Study approach is based on the Constructivism Paradigm (Stake, 1995; Yin, 2003) which is developed upon the foundation of the social construction of reality. The advantage of this approach is that it allows for the collaboration between the researcher and the participant whilst enabling the participants to communicate their stories (Crabtree & Miller, 1999). It is through these stories that the participants are able to express their perspective of the reality on ground allowing the researcher to have a better understanding of the participants' actions (Lather, 1992).

A variety of data collection methods were used to gather information that helped the researcher to understand the context better in relation to the phenomenon under study. The different methods were important in generating data from different lenses that enabled the study to reach logical conclusions that effectively contributed to the body of knowledge in the area of Research Networking Systems implementation. The study was divided and conducted in two complementary but independent phases, both of which were instrumental in developing recommendations towards the implementation of an RNS in INESC TEC.

2.2. Phase 1

This phase of the study was intended to gain insight on the state of Research Networking (RN) in INESC TEC, specify the requirements of INESC TEC to implement an RNS and identify key concerns of the RN. This phase also enabled the researcher to test the feasibility of phase 2 of the study and which research methods to employ. In this phase, exploratory one-on-one interviews were conducted with ten (10) key persons in INESC TEC consisting of center coordinators, project managers, senior researchers and members from the management of INESC TEC. Purposive sampling technique was used to identify the above mentioned groups because they were better placed to provide information relevant to the study. This method of sampling resonates with Marshall's (1996) assertion that *"Qualitative researchers recognize that some informants are 'richer' than others and that these people are more likely to provide insight and understanding for the researcher."*

Following a pre-designed interview guide, the researcher asked semi-structured questions and the participants were encouraged to speak freely, almost

like in an informal meeting. All interviews were audio recorded with the consent of the participant. The insight gathered from these interviews was valuable in achieving among other things, the main goal of the study which was; understanding and specifying the requirements of INESC TEC for implementing a Research Networking System (RNS). The following topics were instrumental in guiding the generation of questions and stimulating response from participants during the exploratory interview;

1. The State of Research Networking (RN);
2. Tools/ Platforms used for Research Networking;
3. Current trends in Research and Development;
4. Management of research information and competencies;
5. Expected benefits of implementing a Research Networking System (RNS).

The Exploratory Interviews were complemented by documentation to supplement, corroborate and identify discrepancies in the results from the interviews. Project documents studied include; the INESC TEC 2015 – 2020 which consists of an Evaluation Report for the years 2008 – 2012 and the INESC TEC Strategic Plan for 2015 – 2020 and the Institutional Presentation. The INESC TEC Website, the Bulletin and SACA (Sistema de Arquivo e Controlo de Artigos) – the repository for publications, were also explored to analyze their impact on Research Networking in INESC TEC. Resulting data from the interviews were transcribed, and together with documentation data, they were coded, analyzed under conceived categories to help identify emerging and recurrent patterns. With respect to the research question and goals, the researcher was able to make a number of theoretical conclusions especially in relation to the requirements of INESC TEC for implementing a Research Networking System.

2.2. Phase 2

This phase of the study was conducted in the context of the Centre for Enterprise Systems Engineering (CESE), one of the 12 research centers in INESC TEC and also the research station of the researcher for the period of the study. The aim of this phase was to; communicate the results from the first phase, empirically

present the platform and functionalities of an open source prototype and examine it against the requirements of INESC TEC specified in the earlier phase and consequently stimulate a discussion.

Firstly, the open source prototype called VIVO was installed, configured and a website generated to provide access to the functionalities of both the user and administrator interfaces. VIVO was purposefully selected from amongst a number of other RNS platforms after a study of literature and documentation on RNSs in general and VIVO in particular.

Through the Site Administrator Interface, the researcher was able to interact and get familiar with VIVO using its various functional features like the Data Input, Ontology Editor, Site Configuration, Advanced Data Tools and Site Maintenance. A sample of data from randomly selected Curriculum Vitae of CESE employees was manually entered into VIVO. The data included; name, address, position, publications, research activities, grant information, research areas, to mention but a few. The researcher then assessed the system's ability to successfully represent, integrate and retrieve this research networking information and competencies of CESE as well as demonstrate scenarios of research networking.

To examine VIVO, a focus group consisting of three (3) key persons from CESE (who also participated in the first phase) was converged where the researcher presented the VIVO platform and functionalities. In presenting the platform, the researcher's goal was to demonstrate how data is represented, integrated and retrieved as well as demonstrate some typical research networking scenarios. This presentation provided an entry point for participants to validate VIVO, identify areas for improvement and to stimulate further discussion. It is worth noting that this method was an effective way to solicit feedback from the right people in a single moment hence saving time.

At basic level, a focus group is an informal discussion among a group of particular persons about a specific topic. As a research method, a focus group, *'involves more than one participant per data collection session'* (Wilkinson, 2004). At a more broad level, a focus group represents a 'collective conversation', which may

be small, or large (Kamberelis and Dimitriadis, 2013) and enables examining a given set of subjects (Kitzinger, 2005). Focus groups involve a group of individuals with similar background, understanding or concern and a moderator in a setting comfortable enough to allow them engage in an active discussion for a given period of time (usually one or two hours). The individuals involved are selected purposely because their input is considered valuable to answering the overall research question.

Focus group discussions are not necessarily intended towards arriving at an agreement but rather encourage diversity in the feedback from the participants in order to gain a better understanding of their perceptions, attitudes, opinions, or concerns (Hennink, 2007). Additionally, the discussion among participants allows the researcher a chance to capture issues he/ she may not have heard from a discussion with just one participant at a time. Having the participants interact with each other provides more importance to their views rather than those of the researcher. Focus groups have been found to be advantageous in conducting research as they provide a great opportunity for researchers to appreciate the different lenses through which people view their own reality thus drawing closer to the data (Ivanoff and Hultberg 2006). The method therefore, allows the participants to be more involved in the research project and hence creating a possibility for it (the research project) to meet their needs.

In addition to all the above mentioned methods, it is important to mention that the researcher kept a journal to truck the whole process of research, jot down thoughts and contributions from participants and her own reflections. The study was carried out over a span of six months.

3.0. RESULTS OF EMPIRICAL STUDY

This chapter presents and discusses the results from the two independent but complementary phases of the study conducted. Table 3 below illustrates a summary of the goals and results from both phases of the study and how they led to the achievement of overall goal and consequently answer the research question of the Dissertation.

<table>
<tr><th colspan="3">Action Goals and Results</th><th colspan="2">Overall Research Goals and Results</th></tr>
<tr><th>Phase</th><th>Goals</th><th>Results</th><th>Goals</th><th>Results</th></tr>
<tr><td>Phase 1 – Characterizing the State of RN in INESC TEC</td><td>i. Characterizing the research information and competences in INESC TEC;
ii. Specifying requirements of INESC TEC for implementing a RNS.</td><td>- State of RN in INESC TEC;
- Requirements of INESC TEC for implementing an RNS;
- Key concerns/ issues surrounding RN in INESC TEC
- Recommendations towards the implementation of INESC TEC</td><td rowspan="2">Enhancing competency management and promoting research networking within INESC TEC and beyond</td><td rowspan="2">Recommendations towards the Implementation of VIVO to enhance competency management and promote research networking in INESC TEC</td></tr>
<tr><td>Phase 2 –The role of VIVO</td><td>i. Identifying, installing, configuring and examine VIVO;
ii. Presenting VIVO to key persons in CESE;
iii. Soliciting feedback from key persons in CESE</td><td>Feedback towards the implementation of VIVO in CESE</td></tr>
</table>

Table 3: Summary of the Goals and Results of the Study

3.1. Phase 1 – Overview of the State of Research Networking in INESC TEC

Phase 1 of the study intended to acquire a better understanding of the phenomenon being studied in this Dissertation. By conducting exploratory interviews with key persons in INESC TEC including senior researchers, project/ center coordinators, and management, we were able to gather clear insight about the state of Research Networking (RN) in INESC TEC. Research Networking (RN) is described as an activity that involves using web-based tools to discover and use research information and resources (Wikipedia). Following this definition, we were able to characterize the research networking information and competences, the research networking tools/ platforms in use, identify key concerns of research networking and understand and specify the requirements of INESC TEC for implementing a RNS.

3.1.1. Characterization of the Research Networking Components

Characterizing the state of Research Networking (RN) in INESC TEC was important in this phase of the study to help understand the reality on ground. It may be apparent that in most if not all research institutions, the research environment consists of a diversity of expertise from various areas, institutions and partnerships. This may imply that research networking is an inevitable exercise in such environments. Nevertheless, each institution has got its own workflows, processes, methods, priorities, culture and other dynamics that drive research networking.

To give a general overview of the findings of this phase, we found out that even though research networking is indeed a part of the research activities of INESC TEC, it is not really a prerequisite for any activity. One of the indicators of RN in INESC TEC is collaborative projects, which is mainly done within and among the clusters. Within these clusters, different research groups or centers participate mainly in the framework of European Union Projects. This is very common in solving complex problems in Engineering areas like developing; Transportation systems, Logistics systems, Energy Systems, Mobility systems, Telecommunication systems to mention but a few. In such cases, there is a clear need to involve different

competences to achieve a complete solution to a problem. An example of such a cluster is the Power and Energy Systems cluster which corresponds to the nuclear unit of Center for Power and Energy Systems. This cluster works in collaboration with the Center for Telecommunications and Multimedia, Laboratory for Artificial Intelligence and Decision Support (LIAAD) and High Assurance Software Laboratory (HASLAB).

Most of the respondents generally agreed that RN in INESC TEC is also important in conceiving new and original ideas for research and technology transfer. INESC TEC understands that by working together, more thrusting solutions could be offered to their partners and clients. Internal RN through collaborative activities has been very significant in bringing new business opportunities from companies which have greatly contributed to the income levels of INESC TEC. In fact, at present, the profile of INESC TEC is such that, 40% of its income is from direct contracts with industry. By helping companies develop solutions to different problems, INESC TEC enables these companies to provide better services and products to the society. For example, INESC TEC has helped the shoe sector in Portugal by adding automation, robotics and logistics to its production processes making shoes one of the major exports of Portugal. INESC TEC has also had a big influence in the creation of an industry for exporting equipment for shoe factories to several countries including China, Brazil and Italy. Networking with other researchers or institutions of the same interest has proved to be significant mainly due to the difference in cultural approaches to the same problems.

Furthermore, INESC TEC in partnership with international consortia which usually has a total membership of between 6 – 20 institutions is able to compete for funding and for projects especially those funded by the European Union. These Consortia are also important in bringing together complementary partners with different backgrounds and competences to achieve a given project. These partners may include; companies, universities or other research institutions both national and international.

Finally, publishing of papers in International Journals is a very important indicator of RN in INESC TEC. Researchers come together to publish papers in multi-disciplinary or inter-disciplinary areas. As a matter of fact, INESC TEC has

registered an increase in productivity in terms of papers published in international journals within the last strategic plan period (2008-2012) from 70 to 260. However it was pointed out that, this kind of collaborative work did not characterize the INESC TEC's activities until about 5 years or so ago. It is important to mention that in 2013, the Foundation for Science and Technology (FCT) produced a report entitled *"Diagnosis of the Research and Innovation Systems: challenges, strengths and weaknesses towards 2020"* that pinpointed INESC TEC as a;

- Major actor in knowledge transfer to industry (pg. 192-193)
- Major actor in networking with academic entities (pg. 199-200) within technology transfer projects
- Major gatekeeper among distinct cooperation sub-networks (pg. 202-203) in the cycle of the innovation process in Portugal.

3.1.1.1. Research Networking Information

Relevant Literature refers to research information as "Any information that describes the research output as well as the context in which research is being conducted" (Jeffery, et al., 2014). Research information in INESC TEC is produced and utilized during the process of conducting R & D. This information corresponds to the *"General indicators and research output"* described in section 5 of the document *'INESC TEC 2015-2020.'* It is important to emphasize that the figures from this document as presented in this section and in the corresponding tables, do not represent the current state of affairs in INESC TEC. These figures illustrate a representation of the most recently documented state of research in INESC TEC which was in the strategic period of period of 2008 – 2012. These indicators cover the achievements of INESC TEC from knowledge generation to valorization and they are broken down into two categories as explained below;

Productivity Indicators

Here, general productivity indicators are consistent with the traditional output of R & D. During the periods of 2008-2012, INESC TEC registered a remarkable increase in productivity compared to the previous equivalent period. These indicators include;

- Publications in journals, conferences, books and book chapters, theses; to mention but a few. Publication of papers journals increased between 2008-2012 from 76 to 258 and the other output items followed suit;
- Patents, Prototypes and Software: This research output is produced by the different research centers of INESC TEC.
- Research Projects and Funding

  The number of research projects implemented at both national and international levels has grown remarkably resulting into institutional sustainability. In the period of 2008-2012, 50 European Union (EU) research projects were conducted in addition to other international contracts.

39.835.268	2008	2009	2010	2011	2012	Total
Pluriannual Programme/Strategic project	**1.649.630**	**1.658.747**	**1.175.125**	**1.590.975**	**1.612.975**	**7.687.452**
FCT-funded projects	**1.174.815**	**682.274**	**1434.215**	**1.849.493**	**2.197.000**	**7.337.797**
European Commission-funded projects	**1.338.000**	**934.000**	**1.528.000**	**1.666.501**	**1.713.000**	**7.179.501**
Other international projects	**33.000**	**33.000**	**33.000**	**17.000**	**47.000**	**163.000**
Other national projects	**218.000**	**451.523**	**1.525.000**	**1.557.000**	**1.867.000**	**5.618.523**
National industry projects	**1.616.080**	**2.167.000**	**2.194.995**	**2.070.000**	**1.150.000**	**9.6380075**
International industry projects	**219.920**	**310.000**	**534.000**	**618.000**	**529.000**	**2.210.920**
Total	**6.249.445**	**6.236.544**	**8.424.335**	**9.368.969**	**9.555.975**	**39.835.268**

Table 4: INESC TEC List of Research Projects over the period of 2008 – 2012. Extracted from the *INESC TEC 2015 – 2020* (Document)

Impact Indicators

This category of indicators corresponds with the technological transfer and valorization process. These include;

- Direct Contracts with Companies

These contracts demonstrate the interest that the industry has in the technological solutions and know-how that INESC TEC has to provide. Over the period in question (2008-2012), the total number of direct contracts from companies was 230 valued at €12.5 million. Income from direct contracts represented 37% of the total project income of INESC TEC (with consideration of the effect of the national economic crisis).

- Number of Researchers

In the period of 2008-2012, 670 researchers worked at INESC TEC. According to the network CONNECT INESCTEC which was designed to track former employees, (see *http://connect.inescporto.pt/),* 184 former researchers have moved to the industry in 20 countries all over the world. Currently, INESC TEC employs about 800 people including PhD and Master Students.

- Licensed Technologies

Several licensed technologies produced by INESC TEC and in use world over and commercialized by international companies.

- PhD Programs

INESC TEC has provided a rich hosting work environment through its research laboratories to help PhD students form several Universities within Portugal, Brazil and other parts of the world accomplish their research aspirations. Through the supervision by integrated members of INESC TEC, students are able to acquire their masters and doctorates while making significant contributions through technological transfer. Additionally, contribution to higher education institutions: INESC TEC has been actively involved in the achievement of several PhD Programs within its area of expertise in partnership with American Universities (MIT, CMU and UTA).

- International Activity and Partners

INESC TEC has registered commendable impact on the international scene through a number of activities with indicators such as; *technologies exported (licensed) in the industrial manufacturing area, software for energy management systems included in industrial products and disseminated worldwide, contributions to international*

norms, presence at the highest level (board of Directors) in European industry platforms, strong presence in South America with INESC P&D Brazil in R&D contracts, etc. Details may be found in the reports from the research groups (INESC TEC 2015 - 2020).

- Spin-off Companies

These represent companies generated by or incubated within INESC TEC environment, those in which INESC TEC was/ is a shareholder, those in which INESC TEC actively participates and international players whose sales and activities are out of Portugal.

Table 5 below represents the research indicators corresponding to the research networking information in INESC TEC;

Note about the table below:

1. *The column TOTAL must be looked at with care because many activities extend to several years. E.g. the last number 501 in the last row is not the total of research contracts – it represents "contract.years" and is a measure of the actual effort put in place.*
2. *The 1st line of Table 5.1 does not refer only to researchers with a PhD degree, but of all kinds of profiles, including students.*

DESCRIPTION	2008	2009	2010	2011	2012	TOTAL
No. of researchers	**381**	**495**	**512**	**586**	**606**	**2580**
No. of integrated researchers	**135**	**158**	**170**	**189**	**224**	**876**
No. of technicians and administrative staff	**40**	**51**	**50**	**54**	**55**	**250**
PhD theses under the supervision of integrated members	**13**	**15**	**21**	**29**	**44**	**122**
Publications in international peer reviewed journals	**76**	**85**	**123**	**199**	**258**	**741**
Books and chapters of international distribution	**18**	**18**	**10**	**22**	**39**	**107**
Models						

Patents	**1**	**1**	**3**	**3**	**2**	**10**
Prototypes	**41**	**54**	**68**	**52**	**54**	**269**
Industry research contracts	**31**	**77**	**86**	**93**	**98**	**385**
Research contracts with national or international bodies	**57**	**61**	**111**	**139**	**133**	**501**

Table 5: INESC TEC Research indicators over the period of 2008 – 2012. Extracted from the *INESC TEC 2015 – 2020* (Document)

The impression we got from the interviews shows that INESC TEC is very concerned about the management of its competences more than information or knowledge it produced from its activities: *"information from one project is not usually useful for the next project and the knowledge produced from research is immediately disseminated through publications, conferences, books and so on. The main concern here is to find a better way to manage our competencies"* (Participant9).

3.1.1.2. Research Networking Competencies

INESC TEC - Institute of Systems and Computer Engineering, Technology and Science is a unit of the National Science and technology System, fully managed by INESC Porto. This institution was created as a private non-profit association and declared for public interest by the Portuguese Government. It is also an interface between the academic world, the world of industry, services and public administration (in Information Technologies, Telecommunications and Electronics) with the University. INESC TEC as a research unit is a network of Research Groups (RG) represented by centres or laboratories that conduct the management of the activities of the institute. These research centres share a common vision, mission and strategic view linked to the generation of knowledge and of value through technology transfer and the social relevance of science.

Through documentation, we were able to learn that INESC TEC provides support and management of R&D activities in association with public universities and other higher education institutions mainly the University of Porto. Other institutions partnering with INESC Porto include; the Polytechnic Institute of Porto (IPP), while, the University of Minho (UM) and the University of Trás-os-Montes e

Alto Douro (UTAD) have committed their support through the agreements set in protocols with INESC TEC/INESC Porto. INESC TEC is guided by the following strategic objectives;

- *<<Develop science and technology that is capable of competing on a national and international level.*
- *Participate in the technical and scientific training of high-quality human resources to enhance the nation's capacities and encourage modernization.*
- *Contribute to the development of the scientific and technological education system, modernizing it and helping it to adapt in order to meet the needs of society and the economy.*
- *Promote and incubate business initiatives in order to improve R&D activities and encourage young researchers to take risks and use their initiative.*
- *Create a modern Portugal, a well-established economy and a high caliber society by following the objectives that have been outlined>>*

We also found out that in the last strategic period (2008-2012), INESC TEC established the objectives to *"grow and consolidate; to improve in excellence and relevance and to assure sustainability."* INESC TEC was successful in achieving these objectives. According to the document *"INESC TEC 2015-2020"* these objectives were fully achieved. During this period (2008-2012), INESC TEC experienced an outstanding growth that was characterized by the following achievements;

- INESC TEC grew from 6 Research centers in 2007 to the 12 as at the end of 2012 and currently includes an associate R & D unit;
- INESC TEC consolidated its regional dimension with poles in the Polytechnic Institute of Porto, the University of Minho and the University of Trás os Montes e Alto Douro;
- INESC TEC established a private non-profit association in Brazil called INESC P&D Brazil together with several of the local top public universities, and launched R&D project activities in South America;

- INESC TEC signed cooperation agreements with a number of schools of the national polytechnic system;
- INESC TEC members were internationally recognized in several ways and achieved important positions in decision fora, namely in the European Union.

It was also demonstrated in the relevant documents that INESC TEC is driven by a double mission which ensures that it is not limited to scientific research alone but extends to the assistance of economic agents and public administration, through technology transfer and innovation as well as highly specialized consultancy. INESC TEC also promotes spin-off companies, hosting them during an early-stage pre-incubation phase, and often participates in their capital. The profiles of its researchers, therefore, reflect the large spectrum of responsibilities acquired. A fraction of the research body is devoted to contracts with industry and other forms of technological transfer. INESC TEC follows role models like Fraunhofer Institutes in Germany, TNO in Holland and others in Europe with which it shares a number of similarities.

INESC TEC was shown to symbolize the concept of knowledge-to-value production chain, that is, "From Knowledge Production to Science-based Innovation." The working organization follows the concept of smooth integration of knowledge producers (creating science) with developers (producing applications) and with appliers (transferring to industry, generating spin-off companies, etc.). The profile of a typical RG in INESC TEC tends towards the inclusion of all these components. Research projects generate new knowledge and excellence at international level. Theses and papers are published, projects in tandem move knowledge along the chain, prototypes are developed and relations with industry and services are strengthened. New projects are designed, materializing the value of innovation at the end of the chain: technology transfer, licensing. Ultimately, new spin-off companies may be incubated and launched. This is done with a careful blending of University scientists with full time contracted researchers and professionals like; engineers, mathematicians, economists, physicists.

In summary, the operations at INESC TEC are supported by highly qualified staff in project management, juridical, public relations, human resources. INESC

TEC currently employs more than 800 researchers distributed and organized in 12 Research Groups (RG) or centres, 01 Associate R &D unit and 4 fuzzy clusters defined at a higher level including; Computer Science, Communications and Devices, Industrial Systems and Innovation, Power and Energy Systems *(See Appendix 3 for details of the competencies of each research centre).*

It is important to clarify that currently, there is no competency management system in place at INESC TEC rather competencies are generally managed following an organizational approach. Through this approach, responsibilities are assigned to more integrated members to lead teams. These team leaders are supposed to capture the information pertaining to the competencies and activities of the members under their jurisdiction: *"I think that competences have been managed by creating several levels of responsibility and trying to promote people to those levels of responsibility like Project leaders, Center/ Unit leaders. The Board of Directors has tried to incorporate new people mixing with the more experienced ones. In fact it is a more informal strategy to keep the experienced people and promoting the younger people as soon as it is possible"* (Participant5). With this approach, employees are required to submit and update their CVs as and when required.

3.1.1.3. Research Networking Tools/ Platforms

There are a number of RNSs or tools in the global market and some of them have been adopted by various institutions especially academic and research institutions all over the world. Some of these systems or tools are open source and others are commercial, examples include; VIVO, Profiles, Digital Vita, SAGE among others.

However, it was discovered through the exploratory interviews that at the moment INESC TEC has not yet adopted any kind of RN system or tool. A number of efforts towards implementing a similar system to manage or map the competencies of the institute have been attempted a number of times without much success. INESC TEC therefore relies upon a number of Information and Communication Technology (ICTS) tools/ platforms to manage, discover and share information about research and researchers. *ICT tools/ platforms in general are systems which support information management, communication and publishing through projects,*

facilitate knowledge sharing across an organization. The INTRANET – a local network within INESC TEC, facilitates access, use and sharing of research information and resources across the institute. INESC TEC also depends on other non- technological forums to foster sharing and discovery of information about research expertise and resources. The ICT Tools/ Platforms include;

Bulletin of INESC TEC (BiP)[7] **:** This is a monthly e-magazine for INESC TEC prepared and managed by the Communications Department. The BiP has been in existence for a long time now and has been very instrumental in providing news about related to research and development from within INESC TEC and nationally. Through the BiP, information about projects, announcements, events, extra-curricular activities or social events, humor among others, is disseminated. Also, because it is an online/ electronic magazine, access is not restricted to only members of INESC TEC but to the rest of the world.

INESC TEC Website: The Website provides general information about the institution, the different research centers of INESC TEC, list of publications, projects, news and events. Nevertheless, it was stated by one of the participants that the website is still lacking in terms of content and presentation and may therefore not be the right place to go when seeking for more detailed information.[8]

Online Databases: For example; Google Scholar, Scopus, Web of Science are used to find information mainly about publications. There is no specific online database used by INESC TEC as an institution as the use of these information sources is purely based on individual preferences.

Collaborative Tools: For example; Wikis, Google Groups, Skype, Google Docs are used mainly to organize and manage research groups and activities. Again, different individual researchers and research groups have different mechanisms in place for managing research teams and activities.

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[7] Recent edition of the BiP: http://bipz.inescporto.pt/arquivo/60/en/paginas/noticia1.html

[8] INESC TEC Website: https://www.inesctec.pt

SACA (Sistema de Arquivo e Controlo de Artigos): This is a repository or system of records and archives for publications and articles for INESC TEC. This system provides information such as; list of research papers to be or already published in journals and those to be or already presented at conferences. It also stores other technical documents like project templates. It is regularly updated and provides options for searching and retrieval of desired results according to centers. SACA also provides information about upcoming conferences, dates and deadlines for paper or abstract submission, who submitted what and the status of the submission. It also provides statistical visualizations of the state of publishing in INESC TEC by center and by year based on the data in the system. It was mentioned by one of the participants that SACA needs improvement and a discussion about making it web-based and more systematic has already been conducted. There is also a similar tool for organizing and managing the lists of projects and activities. However, this one is not as well maintained as SACA due to the fact that most times project information is left to accumulate for a period of time which makes it difficult to be entered into the system.[9]

Server (CVS system): This is a simple file system which allows the responsible teams to share code for software being developed for a particular project, that is, it represents a repository for software source code. This file system is accessible to all team members through the coordinators during the life cycle of the project and when the project ends a summary of the activities is kept for the future.

Apart from the above mentioned tools and platforms, we found out that INESC TEC also uses other platforms to manage, access and share information about research and researchers. These include;

i. Individual CVs: Each Member of INESC TEC has an online CV (Curriculum Vitae) that can be accessed by anyone within the network. The CV displays the individual's competences, activities and accomplishments.

[9] SACA: http://saca.inesctec.pt/Login.php?from=index.php

They are also updated by the respective individual as and when it may be required.

ii. Annual Reports: These are generally prepared by each research center at the end of every year with the purpose of providing a representation and accountability of the activities, achievements, challenges and recommendations of a particular center. The reports are then consolidated into a single document to represent INESC TEC as an institute.

iii. Institutional Presentations: This document is a general representation of what INESC TEC is all about. At the central level, this document is regularly updated by the Board of Directors and used by members. Each center has its own presentation that *'steals'* one or two slides from the institutional presentation.

iv. Consortia: INESC TEC partners with consortia in order to compete for national and European Projects and other types of funding opportunities. These Consortia which are usually made up of between 6 – 20 institutions are also significant in establishing partnerships amongst institutions to work together on projects.

v. Professional gatherings, association and affiliations like Conferences, seminars, workshops, professional group meetings. These forums are usually meant for paper presentation, acquiring new knowledge and skills, identifying collaborators or partners, or simply social networking.

vi. Meetings: Formal meetings at INESC TEC include center coordinators meetings which take place once every week to report and share information on various topics. There are also informal meetings or social gatherings where members interact more freely such as; Christmas, Easter celebrations, celebrating birthdays, birth of new baby, among others.

vii. Networking Initiatives: These are activities intended to bring members together to achieve a common research or project goal. A good example is the Tech4Growth Plan which includes the Tech4s - Tech4Sea, Tech4Health, Tec4Media, Tech4Food and which brings together experts from different science areas.

It is important to note that while most of INESC TEC as an institution has established tools and platforms for information management, discovery and sharing,

the centers are also at liberty to have their own. For instance, the Center for Power and Energy Systems (CPES) have developed simple mechanisms to support information manage and share information about special events like international fares, funding partners like from European Union Projects. Some of these include; leaflets, dossiers, small working books that are carefully designed presentations and are printable

3.1.2. Institutional Requirements for RNS implementation

Relevant Literature proposes that institutions planning on implementing RNSs must be mindful of the institutional factors in play. These factors vary from institution to institution but may include; financial, administrative, cultural, institutional requirements for the system among others. Institutional requirements are particularly crucial because they enable institutions to select and implement suitable RNSs. These requirements vary from institution to institution depending on workflow of its user groups. Through the exploratory interviews with, the researcher was able to gather insight regarding the requirements of INESC TEC for implementing a RNS as presented in the following section.

From the participants, we learned that the envisioned RNS should have the ability to improve the duty of reporting and dissemination of research results by summarizing and making this information publically available. This phase of the study revealed that for INESC TEC to accomplish its reporting duties, it must receive results, publications, projects and several other indicators from its partners and associates. When INESC TEC receives these indicators, they are incorporated into a consolidated report which integrates information from within as well as the one it receives from these associate or partner institutions: *"the RNS should be able to convey the reports in an integrated manner and make it accessible to both INESC TEC, its partners and also allow individual researchers to update their research information individually when they have to compete for projects or funding" (Participant1).*

Another requirement of INESC TEC for an RNS is improving the management of competences that is, skills or capabilities, activities, accomplishments, resources and interest areas. We found out that a number of efforts towards implementing a

competency management or mapping system in INESC TEC have already been explored but with very little or no success. The idea of implementing a RNS was later conceived to not only support competency management but also promote creation of collaborative relationships among experts within and even beyond institutional boarders.

The study also indicated that the RNS should support the organization and management of research: "*Considering that INESC TEC is already so big, it needs some tools to organize research and development. When you are a small group, it is ok but when you have 100s of people, we have a problem. So to me it is clear that this system you are studying is a very good tool to organize research especially if it is organized on an Informatics Platform"* (Participant8). Emphasis was placed on the importance of accomplishing the double mission of conducting both basic research and technological transfer. Nevertheless, it was pointed that while INESC TEC strives to accomplish this double mission, it also desires to enhance its performance by ensuring that the information that describes its activities and competences is effectively and accurately integrated, and managed properly.

Showcasing the profile of INESC TEC, its research competencies, activities and accomplishments to mention a few, within the centers, the institution and to the outside world was found to be crucial requirement for implementing an RNS. The system would enhance the image passed around about INESC TEC by displaying a well-organized, well-designed platform where information is shared in a simple, professional and pleasant way: "*This clearly influences people to adhere to your activities and potentially want to be your partners"* (Participant4).

Cultural Integration was mentioned as another crucial requirement of INESC TEC for implementing an RNS. The system should support cultural integration within the centers of INESC TEC by making the profiles of researchers available to colleagues. This would not only allow new members to know more about the institution but also know who does what and where to find them when needed. This system should also help in bridging the geographical or departmental dispersion as the institution is big with a growing number of centers. This initiative should enable members to get to know each other and what they do not only as individuals, but also

at center and institutional level. This is because "*most people in INESC TEC, especially junior researchers are not informed of what the institution, or their colleagues do and more worrisome is that most of them do not even care"* (Participant7).

It was also stated that improving the management of research knowledge accumulated especially through publications was an important requirement if an RNS is to be implemented. The system should enhance searching or finding tools for faster and easier information retrieval. It is noteworthy to say that, INESC TEC has accumulated an enormous amount of knowledge but most of it has not yet been organized in a manner that makes its retrieval faster and easier: "*it is true that knowledge is there but how to find this it is the problem. Internally, this system would help us to avoid repetition work already done elsewhere by someone else and this is important in helping us be more innovative. And this may also apply to the institutions that we work with"* (Participant3). Systems like SACA have been helpful for managing publications but still require a lot of work to improve its functionalities.

Finally, the envisioned RNS is expected to enhance the discovery of collaborators or persons with common interests: *"I think that if each of us had an individual profile based on what we publish and other information provided surely that could help to summarize a project and help in finding the right partners inside INESC TEC" (Participant2).* Externally, INESC TEC would benefit very much from such a system in terms of identifying external partners. INESC TEC has informal partners like European entities, companies, institutions and organizations. However, "*it cannot be ignored that sometimes we are very limited and bound by these partners when the world is actually very broad and we may be presented with very interesting partners from all over the world* (Participant4).

From this phase, we were able to recognize and conclude that the requirements of INESC TEC can be summarized into two categories: enhance competency management and promoting research networking within INESC TEC and beyond its borders.

3.1.3. General Concerns about the State of RN

Based on the requirements specified in the previous section, it appears that even though there are a number of systems in place to support research, there is still a substantial gap in relation to competency management and research networking. It is important to note that, the participants in the exploratory interviews raised some concerns regarding the current state of RN in INESC TEC as discussed below;

It was pointed out that the nature of INESC TEC's activities, generally characterized by projects which are usually short lived, does not facilitate proper management of research information and competencies. Typically, project activities have a short life cycle and usually when they are concluded, new ones begin. This leaves little or no time to organize the information accumulated from the old one let alone manage or share it. On the other hand, the competencies are with the people who come and go. Additionally, people are pressured by other factors related to projects like deadlines and funding, that they generally do not give much attention to managing or even sharing information amongst themselves: *"We work so much for the future that we sometimes find it difficult to find material on things we have done previously"* (Participant3).

Furthermore, a concern about decision making on the part of INESC TEC management was raised. It appeared that even though management may regard RN as a crucial matter, it has not yet determined it as top priority in the performance and achievement of the mission and objectives of INESC TEC. INESC TEC's most immediate mission is to generate knowledge through basic research and add value to society through technology transfer. While the information pertaining to researchers, research activities and resources is very important and must be managed properly in an ideal context, this does not seem a matter of urgency compared to the achievement of the institutional mission.

There was also a question of institutional culture. It was revealed that in Portugal as a country and INESC TEC as an institution, the norm is often to "*have something done the easy way however minimal the results are rather than engage in something complex that may not be finished" (Participants3,10).* This scenario explained the case of INESC TEC whereby there are a number of simple systems in place that serve a basic purpose: "*The irony is that INESC TEC employs some of the*

best experts in Information Systems and Software Development and Design cannot be ignored (Partipant2).

The challenge of fostering cooperation among members was pointed out as a serious concern. This was evident by number of the failed initiatives put in place to bring people together. Though non-technological, these initiatives ('inter-unit activity lines') were intended to eliminate the 'culture of silos' or isolation. Incentives in monetary form were even offered to people that spearheaded activities in these initiatives. Nevertheless, after a few times, they failed. So it was concluded by some members that *"any model based on the romantic idea that people will come together to cooperate is doomed to fail"* (Participant7).

Based on these concerns, it was evident that the members recognized that INESC TEC faces a challenge when it comes to the management of its research information and competences. We were able to recognize that even though there is a general satisfaction with the different systems in place, there was a clear interest and curiosity about the idea of Research Networking Systems and what they can do for INESC TEC: *"any mechanism that has enough intelligence to cluster things and present things in different perspectives, disseminate knowledge, call attention for opportunities and stimulate cooperation across boarders or areas is a welcomed idea"* (Participant7).

It also appeared to us that most of the participants were not conversant with what Research Networking Systems (RNSs) are and what they do but openly declared that they wanted to learn more. This interest further confirms that there is a need for more comprehensive tool to accomplish more than just information management and sharing. The general lack of information about RNSs among participants resonates with what was expressed in the literature review that RNSs are quite a recent but growing area and therefore still less popular among some researchers and research institutions. Also, as it would be expected in any institution when a new idea especially related to information systems is introduced, there is always mixed feeling, between acceptance and skepticism. Nevertheless, we registered a general positive feedback towards RNS implementation.

3.2. Phase 2 – Implementation of a Research Networking System

The initial part of the second phase was conducted through a comprehensive study of relevant literature on RNSs in general and VIVO in particular. VIVO was then purposefully selected, installed, configured and examined. The major part of this phase of the study was conducted through a focus group with key persons in the context of the Center of Enterprise Systems Engineering (CESE). The VIVO platform and functionalities were presented to the group to stimulate a discussion and solicit feedback. Based on the conclusion drawn from Phase 1 of this study, the requirements of INESC TEC for implementing an RNS comprise the enhancement of Competency Management and promotion of Research Networking (RN) within INESC TEC and beyond institutional boarders. The main goal of this phase therefore, was to demonstrate that VIVO could effectively and efficiently serve these requirements. In essence, the results from this phase will help answer the following guiding questions;

1. How well does the RNS meet the requirements of INESC TEC to promote research networking within INESC TEC and beyond its borders?
2. How well does the RNS meet the requirements of INESC TEC to enhance the management of its competences?
3. How can the RNS be improved to better serve the requirements of INESC TEC?

It is important to mention that, the key persons that participated in this phase were also participants in the previous phase. These persons were invited back in this phase for a number of reasons. These persons hold key positions – senior researchers and managers in CESE (where this phase was conducted). Additionally, based on their expertise, they were considered potential super users of the RNS. And more important to the study was that these persons already acquired background knowledge of the study from the previous phase. This meant that their feedback would come from a sufficiently well informed point of view. This aspect was considered very important in ensuring validity of data. The following sections will

introduce the context of this phase of the study and the main findings regarding VIVO RNS in CESE.

3.2.1. Introducing the Context – Center for Enterprise and Systems Engineering (CESE)

This phase of the study was conducted in one of the research centers of INESC TEC; Center for Enterprise Systems Engineering (CESE). The main areas of activity at CESE are related to Operations Management and Enterprise Information Systems which are transferred and applied to industrial companies and enterprise collaborative networks.

CESE is committed to conducting high quality R & D with a strong focus on application in the following areas; Manufacturing (operations management, advanced information systems for industrial management, planning and control systems, rationalization and optimization of manufacturing processes, intelligent automation systems, decision support systems for production management), Logistics (supply-chain management systems, logistic systems, transportation, distribution and warehouse systems) and Operations Research (optimization methods, Decision Support Systems). In addition to its R & D activities, CESE provides consultancy services or projects tailored to specific clients including industrial companies. The research environment at CESE consists of various categories of employees ranging from researchers, PhD and Masters Students, and consultants. In accomplishing its duties, CESE is driven by a set of strategic objectives which include;

- *<<To strongly contribute for the performance improvement of industrial companies, through R&D projects, consultancy, technology transfer and training;*

- *To foster high quality research initiatives in specific areas where the elements of the group are internationally recognized, and start innovative research programs in new emerging topics;*

- *To transfer the resulting knowledge and technologies to software houses, equipment producers and industrial companies, through applied research, technology transfer and consulting projects. >>*[10]

3.2.2. Examining VIVO Research Networking System (RNS)

VIVO is an open source, semantic web-based application that facilitates research networking (RN) by sharing information about researchers and their activities. VIVO has provided the most successful means of promoting networking among researchers and enabling the discovery of researchers and research resources at individual, institutional, national and even international levels. This is possible when authoritative data about researchers and related institutional resources is represented in an open, integrated and consistent manner. VIVO harvests from and contributes data to other web accessible services, pages and applications. Through the semantic web, data is automatically navigated, represented and mined to facilitate interoperability and integration with other data sources (Berners-Lee, T. 1998).

3.2.2.1. Brief History of VIVO RNS

VIVO was initially designed by Cornell University Library to provide support for two funded initiatives in the Life Sciences (1997) and Social Sciences (2004). These initiatives were created to encourage inter-disciplinary collaboration and to facilitate recruitment of faculty and students in focused areas across departmental boarders. Nevertheless, discovery of collaborators across the many departments, colleges and four distantly located campuses of Cornell and effectively conveying a clear picture of its rich research landscape to other experts using available tools posed a challenge. For these reasons therefore, VIVO was developed as a remedy to provide an integrated view of the life sciences across disciplinary and administrative boarders and support research discovery. VIVO was first launched in 2004 after engaging key administrative and faculty members. This launch generated a fast

[10] Center for Enterprise Systems Engineering; https://www.inesctec.pt/cese-en/about-us

response with requests for the expansion of VIVO to cover other disciplines. Another request was to allow filtered views by the main academic priority disciplines for the College of Agriculture and Life Sciences, both requests were accomplished in 2005 (Devare, M., et al., 2007).

Additionally, with funding from the Office of the Provost, Cornell Library in 2007 was requested to expand the scope of VIVO to the cover the whole university. This funding provided support for building and expanding an interactive editing tool and web services to facilitate sharing of data from VIVO with other web applications and information consumers at Cornell. Developments to Web Ontology Language[11] (OWL) and Resource Description Framework[12] (RDF) tools, like; Java libraries to manage large RDF models, and SPARQL query language[13], proved that VIVO would not only be more flexible but more maintainable if converted to read and write OWL ontologies and RDF data. After the conversion was completed (Corson-Rikert, J., et al., 2009), VIVO was made more suitable for a much larger network of tools, and to facilitate the evolving nature of researcher data and consequently embrace the model of Linked Open Data.

Furthermore, due to the speedy expansion of content scope, it was necessary to surpass manual content acquisition and harvest from other information sources such as external publications databases and the administrative records at Cornell. Through a close collaboration among managers and IT staff, VIVO is currently able to integrate regular automated feeds from the human resources systems, research grants, course, publications databases and faculty reporting systems for the various colleges of Cornell. Hence, no additional effort is required to ensure that authoritative data from various sources is effectively exposed and mapped into VIVO. An informal network of departmental, research center, and core facilities staff offered to evaluate and update content. Also the individuals desiring to update their own information can log in via Cornell's single sign-on in addition to the information harvested from the systems of record. Apart from supporting a public search and view platform, VIVO also provides an integrated source of authoritative information

[11] http://www.w3.org/TR/owl-features/
[12] http://www.w3.org/RDF/
[13] http://www.w3.org/TR/rdf-sparql-query/

to complement Cornell website which is focused on promoting international activities, recruitment of graduate student, and entrepreneurship initiatives across the institution.

A later development indicates that the National Center for Research Resources (NCRR) and National Institute of Health (NIH) in the USA committed a $12.2 million in September 2009 to facilitate the development and implementation of a new version of VIVO to enable national networking of scientists. Also known as the VIVO project, this implementation effort was spear headed by the University of Florida and included other institutions like; Cornell University and Indiana University Bloomington as principal development partners. Other partners included; Weill Cornell Medical College, the Washington University at St. Louis School of Medicine, The Scripps Research Institute, and Ponce School of Medicine as implementation partners (Krafft, Dean B. et al., 2010). Other efforts towards VIVO implementation include; the Direct2Experts, cross-institutional federated search tool with 76 member institutions, over 150 VIVO efforts across almost 50 countries worldwide; open source, VIVO-compliant, collaboration systems like Harvard Profiles which currently reports a robust worldwide community; and a partnership in Europe (Hague, Netherlands) with the euroCRIS - a non-profit scientific association for the VIVO project.

The current VIVO Technology and platform provide unique features that characterize its functionality, such as; the ontology editing which enables creation or modifying of a data model, an intuitive user editor for managing data and the relationships among them and a simple content management system which provides an attractive web presence. Behind the VIVO platform is a Java servlet application that uses the Java Server Pages for page rendering; existing installations use the open-source Apache Tomcat servlet container and the Apache web server. VIVO's search function employs the Lucene library[14]. RDF data are managed through HP's Jena Semantic Web library[15], which permits direct access to various triple store implementations, as well as those based on familiar relational database systems.

[14] Apache Lucene Overview: http://lucene.apache.org/java/docs/

[15] Jena – A Semantic Web Framework for Java: http://jena.sourceforge.net

Existing VIVO installations use MySQL[16], which, similar to all the libraries used by VIVO, is open source. VIVO's default configuration caches RDF data in memory to support fast queries and web page rendering. Currently, VIVO is available under the terms and conditions of the Open Source Initiative BSD License[17].

3.2.2.2. The VIVO Ontology

Ontology is a key method in modelling knowledge to enhance organization, sharing and representation of information. It is important in enabling access to content-based data, interoperability, communication and delivers advanced levels of web services. Information in VIVO is identified by references to Uniform Resource Identifiers (URIs), which are used by other web pages and applications to locate and retrieve pieces of information. VIVO is able to capture information in such a way that it is able to represent complex relationships among data. VIVO web application is built on the RDF "triples" using classes and properties from OWL ontologies. That is, a subject (known as an individual, item, or entity), a predicate (an object property or a data property) and an object (any individual in VIVO). The Subject-predicate-object statements represent the relationships or properties among the individuals in VIVO through object properties and support attributes of individuals via data properties.

While local institutional installations share the core ontology, it is up to each institution to extend or specify additional ontologies as required. This enables the institution to reflect, model and display available data in ways that are important to the institution. This also helps in distinguishing between local ontology additions and VIVO core. VIVO core ontology is not a limiting schema that dictates which data can and which one cannot be fed into VIVO but provides a layer that allows all data from their different sources to be queried and represented in a consistent manner.

VIVO also provides a flexible and extensible data model which allows it to deliver a simple structure of people and their activities across an institution,

[16] MySQL 5.4 Home Page: http://dev.mysql.com

[17] VIVO Project: www.vivoweb.org

including the links and relationships among them and other people as well as their professional accomplishments. VIVO provides several options to enable the discovery of a person's expertise, these include; presentations/ talks, news releases, publications, research areas, teaching activities listed on their profiles. Also, the major information and knowledge assets digested by VIVO ontological approach is harvested from and requested by research networks (Y. Ding & D. Fensel, 2001).

This Ontological approach re-organizes the existing publicly available information from institutional systems such as the human resources, annual reports, publication repositories, funding records, teaching activities to mention but a few, in an ontological way to enable re-packaging and representation of this information to researchers to facilitate networking (Y. Ding & S. Foo, 2002). Maintaining a linked ontology structure enables ontology re-use, mapping and data integration. The VIVO core ontology for installations is built on the foundation of the Semantic Web Research Community (SWRC) ontology which was developed by the European Funded Network of Excellence Knowledge Web.

3.2.2.3. Opening and Freeing Institutional Data

The main aim of the Linked Open Data Movement is to *"extend the Web with a data commons by publishing various open data sets as RDF on the Web and by setting RDF links between data items from different data sources"*[18]. Under usual circumstances, data about research and researchers like competences, projects, affiliations, publications (to mention but a few) is at best disseminated in text across various web pages and web-based applications. At worst, this data is just closed up in institutional systems or databases. The established aim of VIVO is to expose this authoritative data from the institutional information systems and make it a part and parcel of the Open Data Universe. This enables information about researchers to be joined with other public authoritative sources of research information like publication, projects, funding, disciplinary information to provide support for

[18]http://esw.w3.org/SweoIG/TaskForces/CommunityProjects/LinkingOpenData#Project_Description

analysis not only within institutions but across institutions and beyond. Furthermore, with more research information becoming available in a linkable manner, VIVO is able to provide the "researcher context" which facilitates the discovery, retrieval and understanding of that data universe.

Additionally, data stored in institutional systems are not usually available purely because the systems do not enable human or machine accessible feeds of that data. Also it may be that the systems provide no support for monitoring private institutional data and allowing re-use for larger and public institutional purposes. Also, data from various silos may be missing common identifiers or be normalized to incompatible components (e.g., the definition of a department in a financial system may differ from the human resources system). One of VIVO's key elements therefore, is that it provides a mechanism for integrating publicly available data sets from various sources and presenting it in a suitable and useful format.

Opening and freeing institutional data constitutes two main components; presenting users with an integrated, web-based and accessible view on the platform of a website. This institutional data on the website may otherwise be complemented with direct entry by researchers with authentication and also from external sources like authoritative publications databases such as; Web of Science, Scopus, PubMed by licensed publications databases. Through the website, VIVO provides a one-stop for discovery of research information as well as facilitate Research Networking (RN). The second component of opening and freeing institutional data is to influence the integrated database to generate a basis for properly filtered data in standard formats like RDF, XML, or JSON) that can be used by other automated applications through web services or as linked data.

Establishing and sustaining a VIVO installation offers a significant return on investment across the institution through search interfaces and/or live feeds of selected content to additional websites. When data is fed into the VIVO installation, it is stored in various RDF formats and exposed as linked data. A request for linked data appears in VIVO as a standard HTTP request only improved to identify RDF/ XML or another RDF format. The additional advantage is that RDF offers machine-readable structure conveyed in the namespaces defined in the VIVO ontology which

link straight to a term in a vocabulary list or to the associated resources referenced with the requested page. VIVO will also join RDF to ensure that data is served to search engines that may not yet be ready to directly consume linked data.

3.2.2.4. Characterization of VIVO Information/ Data Sources

The main focus of this section is to identify and characterize the appropriate data or information sources for the VIVO installation in the context of CESE. This task is important in defining the kind of data available at a given source and which format it is in before it's ingested into VIVO. This is a significant step in the data ingest process as it will provide the basis upon which CESE's key data will be tested and demonstrated in VIVO . It will also facilitate future automated updating and removing of data.

General principles of identifying VIVO data sources caution to avoid any data that has any privacy issues, after all, most times (if not all) it is not even needed. Information such as; *age, sex, race, national origin, citizenship, leave status, termination dates, home phone number,* and most definitely not *Social Security numbers,* should for no reason be included in VIVO to avoid complicating an individual's and even institutional profile. For more up-to-date and correct data especially related to contact information it is best to have a link to the center or institutional directory. Additionally, it is recommended that, institutions implementing VIVO can extend or add their ontologies into VIVO in order to best represent their significant data sources. This ontology should be simple, but able to effectively reflect the structure of the data from a specific source. The semantic web approach facilitates mapping of data from the source ontology to the VIVO ontology which makes the work of data processing not only clearer but easily accomplished. VIVO – CESE Data Sources are divided into two categories which include; internal data sources – these are local or institutional sources of data that are publicly available in CESE. The other is external data sources – these are sources of data outside of CESE but publicly available for consumption based on certain requirements. It is important to note that, the list of information sources provided

here is not exhaustive as it was impossible to cover all of them in the scope of this dissertation.

VIVO - CESE Internal Data Sources are systems or mechanisms established for managing the different components of the research environment like publications, projects, reports, human resources to mention but a few.

- **SACA (SACA (Sistema de Arquivo e Controlo de Artigos)**

This is a repository or system of archives for publications and articles in INESC TEC. This system provides access to information such as; list of research papers to be or already published in journals or presented at conferences. Information in SACA is presented in simple plain text format and regularly updated. This provides basic functions for searching and retrieval of desired results including; menu bar and a drop down menu to retrieve results according to the "center" and another by "year." SACA also provides basic statistical representations and visualization of the state of publishing by center and by year. Even though SACA has web presence the information therein is not linked in anyway. Ingesting data from SACA into VIVO will require defining the SACA ontology. This will help to map both systems and facilitate automatic ingest, update and maintenance of data. There may be some challenges that are usually related to ingesting publication data such as; disambiguation of author names, research areas, keywords to mention a few. It may be helpful to use employee ID numbers or Research IDs for authors who have. The Researcher IDs especially show definite distinction between authors and the data related to them.

- **Human Resources Services**

This division manages and performs all duties related to human resources and the implementation of HR related policies in compliance with the Law and internal regulations as lay down by the Board. The Human Resources Services System provides both public and private information about the employees in CESE. Public information includes; name, activities, department to mention a few. While private information includes; sex, age, salary scale, employment terms, contact information, to mention but a few. For VIVO to consume this data, it has to be linked to the

human resources system by defining the ontology in VIVO. Attention must be paid to the issue of privacy by determining which data can or cannot be consumed by VIVO and which one can or cannot be made publicly visible.

- **Curriculum Vitae (CV)**

Similar to the previous data source, the CV provides a wide range of information, about an individual, some of which is public and others private. While the private information like sex, age, marital status, physical address, phone number, should be left out, the more public information that can be made visible in VIVO include; one's research areas, teaching activities, publications, and many others. Where manual data entry is possible, a VIVO Editor can manually enter CV data into VIVO. CV content and categories vary from individual to individual but VIVO employs a common shared ontology when referring to given pieces of information. It is therefore, possible for a VIVO Editor to map the CV information to the fields provided in a VIVO profile. The challenge may be the difference in the way different people represent the same data. For example, using different terms for a research area,

- **Project Financial/ Funding Administration System**

This one provides a record of projects reflecting their financial/ budgetary elements rather than the scientific side. This record also reflects the number of people and activities in a given project. This information is very relevant to represent funding or grants for CESE as a center and for the people involved in a particular activity. It is recommended that before data ingest to VIVO, the information to be ingested is determined in advance to avoid making public information that the center would rather keep private especially from competitors. Where the center prefers not to include comprehensive information on grants, individuals with authentication can manually feed in this information; delete it as they so wish or just modify it.

- **Reports**

Reports such as the annual report are used mainly as accountability tools in CESE and they show indicators of the various activities, the individuals involved, resources available, timeline, challenges and achievements. Some of the information

from the reports is public and can be consumed by VIVO to demonstrate a number of research indicators of CESE while other pieces of information are best left out of VIVO as may be determined by the Center. Individuals who have the duty to report and have authentication can use the self-editing feature of VIVO to make updates, delete or modify data on their profiles.

VIVO - CESE External Data Sources are systems or mechanisms outside CESE (and INESC TEC) from which CESE can consume publicly available information.

- **SIGARRA**

This is an online service that permits registration, retrieval and handling of information pertaining to the several faculties of the University of Porto, an associate of INESC TEC. Activities of users of this service who include students, staff or external users, are stored and maintained in SIGARRA under laid down terms and conditions. The users of this service are required to utilize their access or authentication credentials in order to make use of their desired component.

FEUP's SIGARA, also called SIFEUP enables registration, retrieval and handling of information about several faculty activities. SIGARRA has got three main components: *Management of Human Resources (GRH), Management of Students (GA) and the* aggregating *component*[19]. The last component consists of several interconnected units which are closely linked with the previous components. This component allows users access to a variety of information ranging from; news feeds and legislation related to control of content, FEUP services and departments, programs and courses by department, information about staff and students. SIGARRA also provides access to R & D information including; R & D Units, scientific production with indicators like projects and publications of faculty members which have links to collaborators, co-authors, online publication databases, organizations, and other web pages. Some of the information on SIGARRA is for public access while the rest is controlled and reserved for a certain type of users.[20]

[19] FEUP SIGARRA: http://www.fe.up.pt
[20] CICA: http://sigarra.up.pt/feup/en/WEB_BASE.GERA_PAGINA?p_pagina=21181

A great deal of information from SIGARRA is relevant for VIVO so interoperability can be ensured by adding SIGARRA ontology in VIVO to map the two systems and facilitate automated data ingest, update and maintenance. Challenges related to ingesting publication information like disambiguation of author names, research areas may arise. Nevertheless, the use of Faculty ID or employee number which is a common practice in Faculties may absolutely associate a certain piece of data with a faculty member in question. Also, many of the authors have a digital object identifier (DOI) which differentiates their data from others.

- **Authenticus - Authenticating Scientific Publications authored by researchers from Portuguese institutions**

Authenticus is largely a digital repository of scientific publications authored by researchers from Portuguese institutions[21]. The goals of Authenticus include to:

- *<<automatically associate publication authors to known researchers and institutions*
- *allow researchers to confirm their publications or dismiss wrong associations in a simple and effective way*
- *help researchers in propagating their publications to the information system of their Institution or to FCT, thus avoiding multiple manual insertions*
- *provide bibliometric indicators focusing on a researcher, a scientific area, or an institution*
- *provide specialized interfaces for researchers and institutions>>*

Authenticus also keeps a record of the publications indexed by major bibliographic databases, hence, access to the complete functionality of Authenticus is only permitted for users with b-On access. Additionally, these users should be able to validate using the Federated Authentication service provided by Fundação para a Computação Científica Nacional (FCCN). Today, Authenticus harvests publications data from Scopus, ISI Web of Science, DBLP (Computer Science Bibliography) and ORCID.

[21] Authenticus: https://authenticus.up.pt/

Authenticus is a very important source of data for VIVO-CESE as it is authoritative from licensed publication databases. Data coming from these databases are well curated and the challenges of data cleaning when ingested into VIVO are greatly reduced. Furthermore, the challenge of author name disambiguation is greatly improved because the databases use the special researcher IDs that distinguish one author's work from another's.

- **ORCID - Open Researcher and Contributor ID**

ORCID provides a solution for problems related to name ambiguity in scholarly research by assigning unique identifiers that can be linked to a researcher's output. ORCID also enables an open and transparent mechanism for linking ORCID and other ID schemes and research objects like publications, grants and patents. When ORCID is launched, researchers and scholars are able to register for an ORCID identifier, create ORCID records, and manage privacy settings. ORCID has the unique ability to cut across research disciplines, sectors and national boundaries. It connects researchers and research by embedding ORCID identifiers in key workflows, such as research profile maintenance, manuscript submissions, grant applications, and patent applications.

ORCID also enables researchers and scholars to register and acquire a unique identifier, manage a record of their activities, and also provides APIs that support system-to-system communication and authentication. ORCID records hold non-sensitive information such as name, email, organization and research activities. ORCID understands the fundamental need for individuals to control how their data are shared, and provides tools to manage data privacy. ORCID provides its code under the open source license and posts an annual public data file under a CCo waiver for free download. The ORCID Registry is available free of charge to individuals, who may want to obtain an ORCID identifier, manage their record of activities, and search for others in the Registry. Organizations may become members to link their records to ORCID identifiers, to update ORCID records, to receive

updates from ORCID, and to register their employees and students for ORCID identifiers[22] .

Membership is important because ORCID is a non-profit organization funded through organizational membership and subscription fees. To sustain the registry and ORCID mission of addressing the name ambiguity problem in scholarly communications, ORCID relies on membership and subscription (basic and premium) funding from the research community. ORCID is also in partnership with VIVO, the ORCID is one of the items provided for in a researcher's profile. Data from ORCID is well curated and poses few or no challenges related to data cleaning. Challenges of associated with publication data such as author name disambiguation are minimized.

- **SCOPUS:**

SCOPUS is the largest abstract and citation database of peer-reviewed literature: scientific journals, books and conference proceedings. SCOPUS delivers a comprehensive overview of the world's research output in the fields of science, technology, medicine, social sciences, and arts and humanities. SCOPUS features smart tools to track, analyze and visualize research. As research becomes increasingly global, interdisciplinary and collaborative, critical research from around the world is not missed in SCOPUS. Among other data sets, SCOPUS is updated daily to include:

- *<<22,000 titles from more than 5,000 international publishers 20,800 peer-reviewed journals (including 2,600 open access journals) 367 trade publications and over 400 book series*
- *6.4 million conference papers*
- *"Articles-in-Press" from more than 3,850 journals and publishers such as Cambridge University Press, Elsevier, Springer, Wiley-Blackwell, Nature Publishing Group.* [23]

SCOPUS is a subscription service typically available through an organization's library or information department. Researchers can link to their SCOPUS author

[22] ORCID: www.orcid.org
[23] SCOPUS: http://www.elsevier.com/online-tools/scopus/access

profiles from their ORCID records, saving them time when setting up their ORCID profile and allowing SCOPUS to automatically keep their ORCID bibliography up to date.[24] Just like ORCID, SCOPUS Author ID is one of the items provided for in the VIVO researcher's profile. Additionally, data from SCOPUS is also well curated and poses few or no challenges related to data cleaning and increases author name disambiguation which is crucial in representing VIVO data.

- **Web of Science**

By meticulously indexing one of the important literature sources in the world of Science as it has become the standard for research discovery and analytics. Web of Science connects publications and researchers through citations and controlled indexing in curated databases spanning every discipline[25]. Use of cited reference search to track prior research and monitor current developments in over 100 years' worth of content that is fully indexed, including 2.6 million records and back files dating back to 1898. Web of Science enables researchers to;

- Benefit from cover-to-cover indexing with objective evaluation processes to meet the highest standards of unmatched coverage of the sciences, social sciences, and arts & humanities. Journals, books, data and conference proceedings
- Get comprehensive and relevant coverage from a trusted standard in research coverage
- Identify hidden patterns, gaining insight into emerging research trends

Web of Science facilitates the exploration of the citation universe across a vast number of subjects. It also provides access to a reliable and integrated research connected through linked content citation metrics from multiple sources within a single interface. And since Web of Science adheres to a strict evaluation process, only the most influential, relevant, and credible information is included.

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[24] Scopus to ORCID: http://info.sciencedirect.com/scopus/scopus-in-detail/orcid

[25] Web of Science: http://wokinfo.com/

Collaboration with Google Scholar[26] facilitates the seamless movement between the open web to Web of Science and its trusted content through citations. Citation connections now meet the researcher where their search begins. Access to Web of Science through is subscription-based with a single sign in which also delivers access to two other powerful resources. EndNote online - a commercial reference management software package[27], and Researcher ID - unique identifier to enable researchers to manage their publication lists, track their times cited counts and h-index identify potential collaborators and avoid author misidentification.[28]

2.1.1. Feedback from CESE

The VIVO platform including its functional features was presented to key persons in a focus group with the aim of stimulating a discussion. The participants for this study are senior researchers and managers in CESE and therefore, considered potential users of VIVO.

The presentation stimulated a discussion where participants were able to voice their opinions, reflections and recommendations regarding the functionalities of VIVO. Below is a summary of matters that arose from the focus group meeting.

There was a general positive feedback towards the VIVO RNS platform. Participants disclosed that the platform seemed to provide a broad base of functionalities compared to the systems that were existent in CESE like SACA which has very basic functions. It was also mentioned that the user interface is generally easy to use, the presentation of information is clear and integrated, discovery of information is straight forward and the role of the semantic web through linked data demonstrated VIVO's ability to effectively represent and expose the profiles of

[26] Web of Science Collaboration with Google Scholar: http://wokinfo.com/googlescholar/

[27] EndNote: https://www.myendnoteweb.com/EndNoteWeb.html?

[28] Researcher ID: http://www.researcherid.com/

people. Figure 7 illustrates a profile of one of the researchers in CESE based on their data that was entered into VIVO.

There was a noticeable curiosity about the visualization display tools in VIVO and how they could be of use in representing data. For example, VIVO's Map of Science visualization (See Figure 8)[29] which illustrates the current expertise an institution, organization, or person and the Co-author Network of a person (See Figure 9)[30], both are based solely on past publications loaded into VIVO.

Concerns related to the privacy of CESE data arose, that is, there are pieces of information that the center may want to keep to itself and probably its members rather than make publicly visible on the web. It was clarified that CESE could determine which data should be ingested into VIVO and which one should. And once the data is already in VIVO, they are functionalities that can define the display of data to public or hidden from public.

Participants showed enthusiasm about the VIVO Ontology and how it facilitates representation and integration of data in people's profiles. From the Ontology Editor on the Site Administrator interface, participants were able to view and explore the VIVO ontology list and the different class and property groups. A recommendation was made to improve the representation of data to suit the needs of CESE.

There was a concern regarding the inconsistency or lack of standard pertaining to the terminologies and names used especially in defining research areas, author, organization to mention but a few. It was noticed on the VIVO platform that, there were different terms or names used to mean the same research thing, area or person or organization. It was pointed out though that, this concern may be a result of how different people understand and represent the same information in the CVs. The other factor could be the fact that CESE has no standard format or terminology for defining its data sets such as identifiers, common definitions that enable categorizing of research areas, professional areas, employment positions to mention but a few.

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[29] Figure 7: http://spurnix.inescporto.pt/vivo/vis/map-of-science/n6268

[30] http://spurnix.inescporto.pt/vivo/vis/author-network/n6268

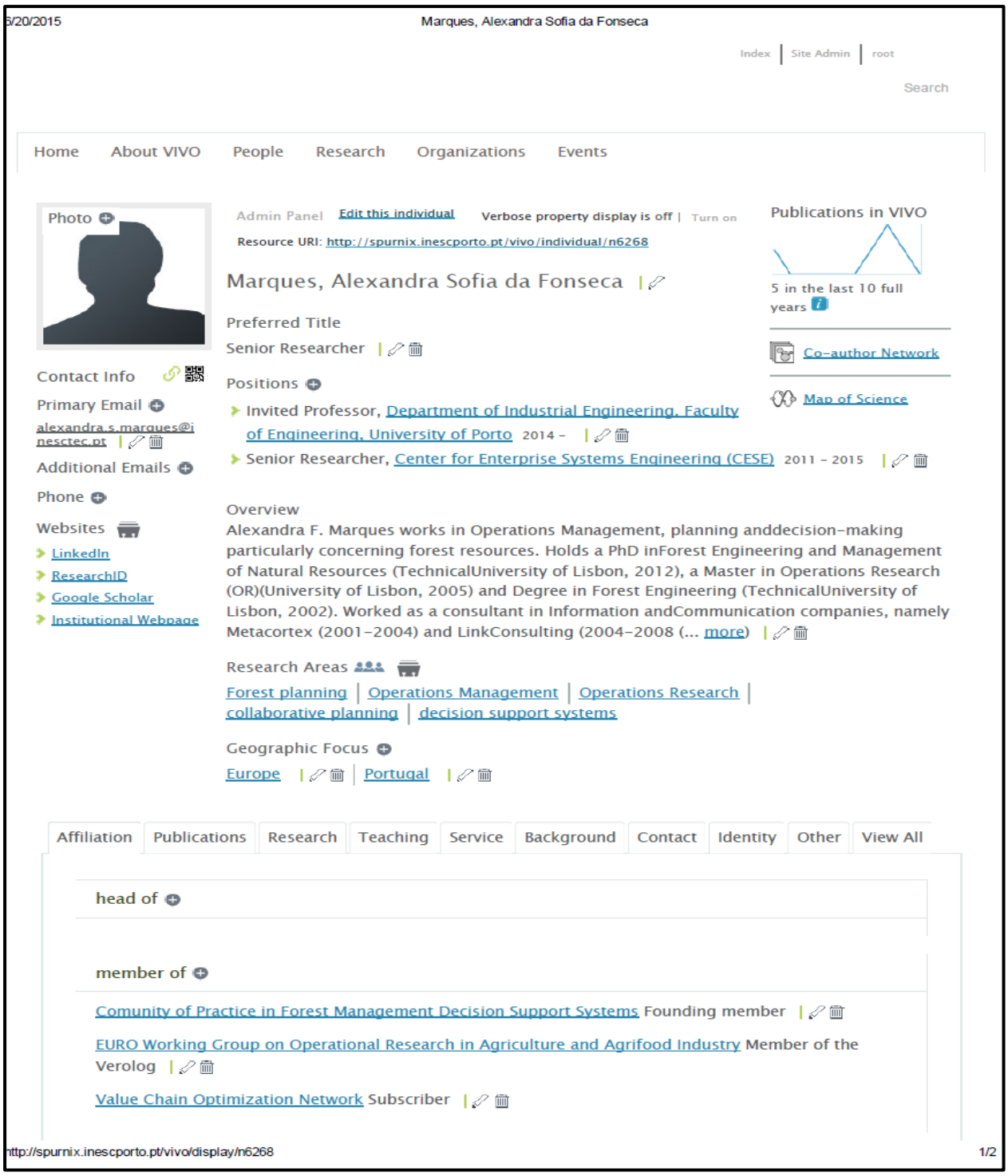

Figure 7: A researcher's profile as represented in VIVO

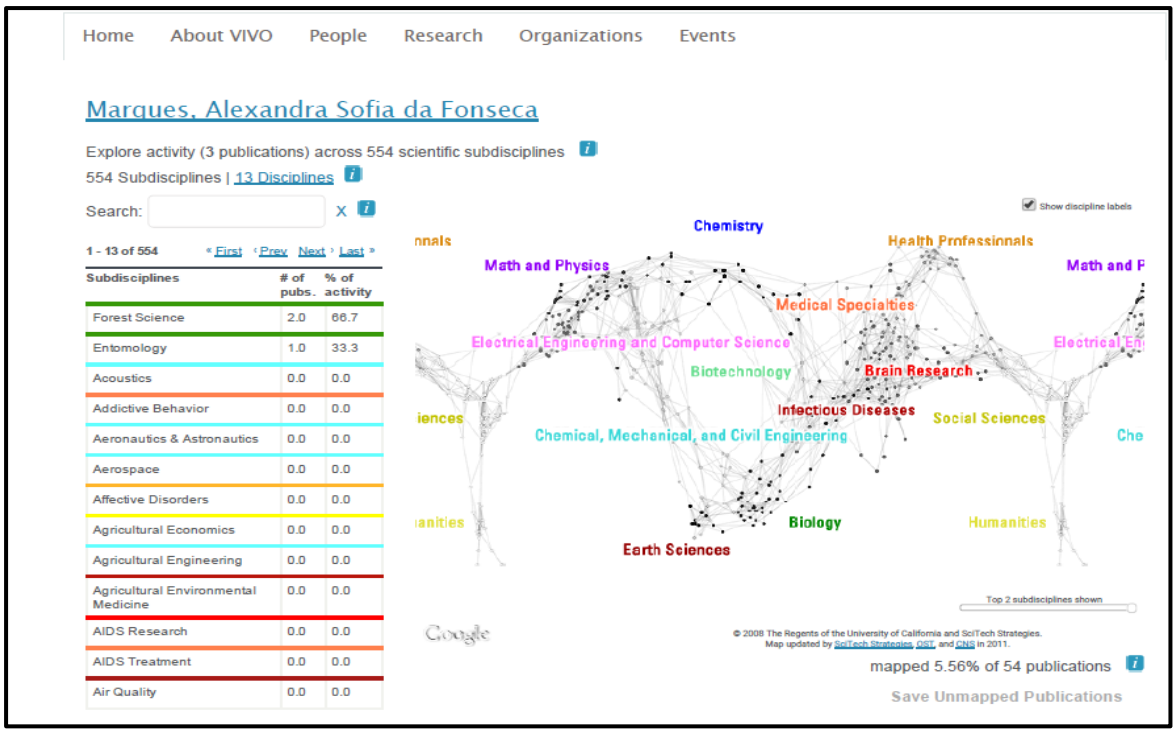

Figure 8: A researcher's Map of Science in VIVO

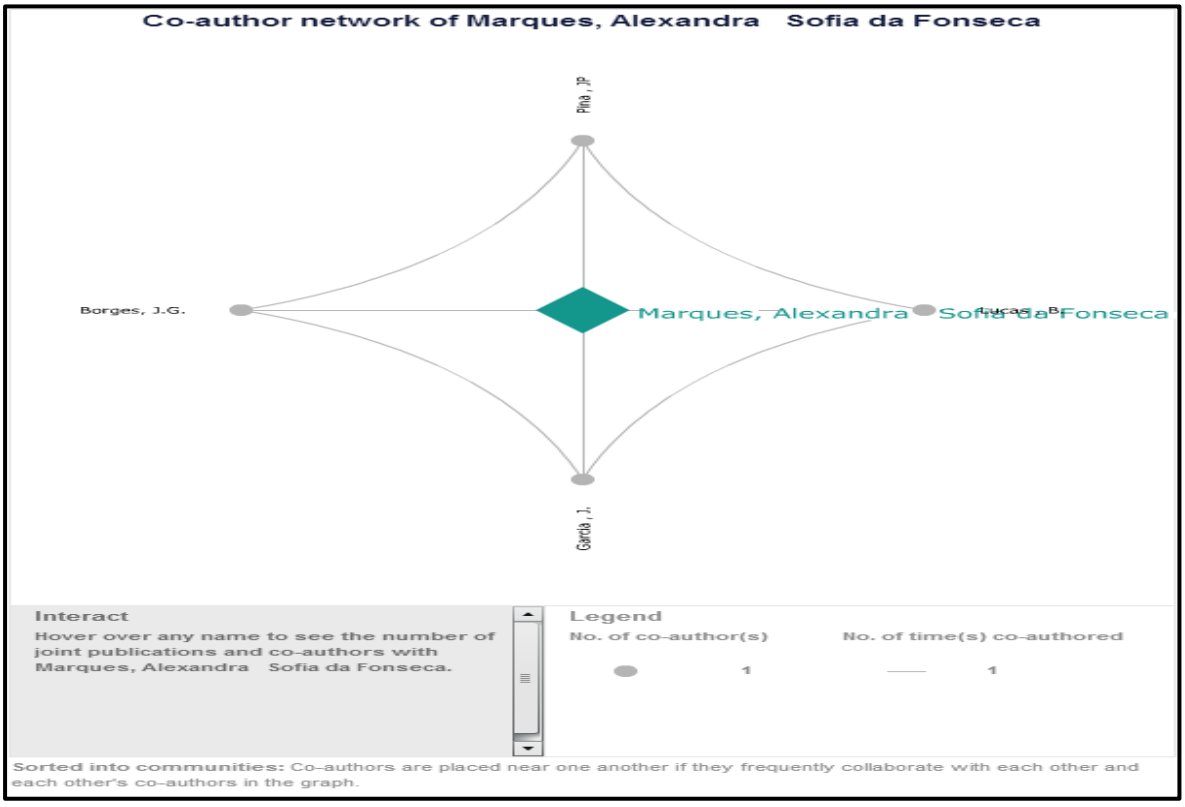

Figure 9: A researcher's Co-author Network in VIVO

Competency Management being one of the key requirements for RNS for CESE, it was pointed out that it would be important for VIVO to demonstrate its ability to effectively and efficiently represent CESE competences to include not only researchers but other professionals as well. It should, differentiate between research competency areas and professional competency areas and for where the same person is a both a researcher and professionally competent in another field, this information should be adequately represented.

It was also established in this focus group discussion that VIVO facilitates control and management of data pertaining to research and researchers at different levels of the institution as a whole. That is to say, at individual level, at center level and even at institutional (INESC TEC) level.

The fact that VIVO facilitates automated data ingest, update and maintenance from institutional and external sources into VIVO was considered a strong point. This would bring a total difference compared to the information systems that are currently in place where data has to be entered manually. Besides, people are often too busy that they may not have the time to manually enter, update and maintain data in the RNS. This is one of the key components that any RNS should have in order to effectively serve an institution otherwise its real purpose would be defeated.

Even though a discussion about the way forward regarding VIVO implementation in CESE was not conclusive, participants showed an interest in exploring the idea of implementation VIVO in CESE. They deliberated upon a number of issues including; whether to implement VIVO in CESE as a pilot study for the ultimate INESC TEC – wide implementation effort, involving other members of CESE to discuss the idea further, bringing on board or training someone with the right skills for VIVO to carry forward the work that has already started through this study and involving other centers, departments or individuals that are knowledgeable in the area or may have already developed similar.

4.0. DISCUSSION OF RESULTS

This chapter discusses the results of the study in order to arrive at meaningful conclusions to answer the research question and achieve the goals of the dissertation. The discussion is mostly based upon the results emanating from the final phase of the study conducted in CESE through a focus group discussion with key persons. Phase 1 of the study concluded that the requirements for implementing a Research Networking System (RNS) in CESE were to enhance competency management and promote research networking (RN) within the center and beyond.

The discussion aimed at establishing the significance of institutional requirements of CESE for implementing an RNS and establishing a link with relevant literature on RNS implementation. There was also a need to discuss the role of VIVO RNS – tackling how well its functional capabilities can serve the requirements of CESE. And finally, recommendations towards the implementation of VIVO to enhance competency management and promote research networking.

4.1. Significance of Institutional Requirements for an RNS in CESE

Best practice in the management of research and development today leans towards the use of collaborative networks and systems to perform the various processes that characterize the research environment. Additionally, establishing technological competencies in institutions have been known to improve the way R & D is conducted. Collaborative network technologies like RNSs have improved the performance of tasks such as managing the skills that accumulate in the different units of a research environment, effectively managing projects and teams, discovery of research resources, and development of collaborative and productive relationships to mention a few. However, for institutions to implement technologies like RNSs, they must understand their requirements first in order to be able to select a suitable tool. In this section, we intend to establish the link between the institutional requirements for implementing an RNS in CESE and the corresponding state of the requirements in CESE. The requirements are: enhancing competency management and promoting research networking. Previous relevant literature will also play an important role in helping us understand this link better.

In the context of CESE, research networking is evident in execution of research or project activities which require collaboration among persons with different competencies in order to develop solutions to clients' problems. This is especially true for areas related to complex engineering systems like transportation, manufacturing, to mention but a few. This demonstrates that researchers *"are not really interested in networking as an end itself"* but rather *"they need to boost productivity"* (Barabási AL et al., 2002). CESE therefore, employs basic ICT tools to support the performance of these activities by facilitating discovery, management and sharing of information pertaining to research expertise, resources and activities. We learnt from this study that even though these systems meet the needs of the researchers to a certain level, there is still a need for a more integrated system. This is evident by the fact that the idea of an RNS was received with significant interest.

Meanwhile, the advancement in technology and the processes of conducting research has stimulated the development of data intensive models which promote global conduct of research (Hey, Tansley, & Tolle, 2009). RNSs are a fine example of data intensive models as they aggregate data from various sources, model, integrate and accurately represent it across departmental, institutional or geographical borders. For RNSs like VIVO, the semantic web and linked open data enables data to be conveyed in ways that add value to the institution by facilitating rapid and easy access to authoritative information which may be inadequate or not present in other information sources (Schleyer T, et al., 2012). Also, these systems enable all user classes to accomplish their work flows or potential goals (Boland M. R., et al., 2012). We therefore, suggest that promoting research networking is a crucial issue in CESE given the current indicators and the perceived interest in RNSs exhibited by the participants.

Furthermore, while competency management is a very important part of the research environment at CESE, it has also been quite challenging to accomplish due to the absence of an integrated system to effectively manage and represent the competencies accumulated over a period of time. Previous efforts towards implementing a competency management system have been futile. Currently, competencies in CESE are managed using an organizational approach whereby responsibilities are assigned to the more integrated members to lead and coordinate

those with temporary tenures. However, this approach is challenged due to the nature of activities in CESE which is characterized by projects. Projects normally have a short life cycle implying that, once a project has ended, it is not guaranteed that the competencies will be retained. This is because competencies are with people who come and go as required. It is therefore, crucial to establish a more sophisticated way to capture and manage these competencies to reflect the true capabilities of CESE. Burgelman et al., (1996) Brown and Eisenhardt (1998) have shown that employing technological systems to enhance competency management has a significant influence on the competitive advantage and future positioning of an institution. It also facilitates the regulation of product renewal and promotes collaborative relations. Additionally, technological systems such as RNSs support connecting other basic technological tools and platforms to support networking among experts within an institution and beyond (Que´Lin, 2000). Additionally, RNSs like VIVO have capabilities to effectively integrate and represent researchers' profile to provide a clear picture of their competences. Based on this background, we can postulate that CESE recognizes the importance of enhancing competency management given its efforts towards implementing a suitable system for achieve that.

4.2. Competency Management and Research Networking: The Role of VIVO in CESE

In this sub – section, we would like to establish the similarity between VIVO and a suitable RNS mentioned in the previous section. We believe that the second one has a significant influence on the former. To do this, we shall demonstrate the role VIVO plays by tackling elements of its functionality. This is in alignment with technology acceptance theories which guided previous studies like Bhavnani, Suresh K, et al., (2012). This theoretical framework – the Technology Acceptance Models (TAMs) which assumes that for users to accept a particular technology, they must first of all understand its supposed usefulness and ease of use (Bhavnani, Suresh K, et al., 2012). Therefore, CESE's acceptance of VIVO does not depend only on having the infrastructure in place but understanding how well it serves the requirements of

center for implementing an RNS. Again, these requirements are; enhancing competency management and promoting research networking.

Having easy and fast access to authoritative research information and resources from a variety of sources is a huge benefit for any research environment. The semantic web has facilitated a continuous growth in the data universe and therefore, increasing the amount of authoritative information one can consume. This is clearly a very important component of CTSA Research Networking Affinity Group's Agenda as it considers the *"elements of access to sufficient institutional and linked open data, data that are semantically structured and made publicly available"* essential. For a busy work environment like CESE where researchers are constantly buried in project activities and deadlines, finding information should not be time consuming or tiring. Discovery of research information should be fast and easy but this depends more on the functionality of the tool being used. RNSs facilitate more rapid and precise means of information retrieval when compared to other platforms like Google, Facebook or LinkedIn (Weber, et al. 2011). VIVO provides efficient search and browsing mechanisms that facilitate the rapid discovery of people with similar interests, most searched research areas, research topics across disciplines, publications, departments, geographical location, authorship, to mention but a few. General positive feedback from participants in the second phase of the study makes us assume that the design of VIVO provided useful functionalities for representing and finding information.

Furthermore, CESE consists of several types of competencies categorized as – research and professional competencies. Under each of these categories are specific areas of expertise that characterize their duties that people perform. Currently, CESE uses the organizational approach of competency management whereby integrated members are given responsibilities to lead and coordinate teams of persons. These members are also charged with the responsibility to capture information that describes competencies of the people in their teams. Through the focus group discussion, we discovered that it is important to CESE that these areas of expertise are effectively represented and conveyed in VIVO. This should be done while being mindful of the distinction between the researcher and professional categories. It is therefore, important to say that, through the VIVO Ontology Editor, a person's

competencies and corresponding relationships can be effectively modelled, represented and conveyed. The VIVO Ontology is able to represent an accurate picture of a person's capabilities and display it in a desirable format based on the principles of the semantic web. We can propose here that, for these areas of expertise to be clearly and effectively represented, CESE needs a more comprehensive and integrated system like VIVO because of *"its capability to represent core concepts of research information applications, (…) clearly demonstrates their emerging semantic connections"* (Calvanese, 2009 & Doerr, 2003).

We also wanted to understand the usefulness of the visualization tools of VIVO to CESE given the interest from participants in the last phase of the study. The Visualization tools such as the Map of Science and the Co-author Networks comprised a calculation of the total counts of publications or of grants for of CESE and displaying by discipline. Visualization tools are characteristic of the collaborative networks (Newman, 2004, 2004b) and they are used to demonstrate the collaboration among authors, institutions, or even countries in producing scientific research. In such networks, an author is identified by certain attributes like research interests/ areas, experience levels, keywords, department, grants, country and more. Based on this, we can therefore assume the CESE's interest in visualization tools demonstrate that it has a need to understand the patterns of its research productivity.

Through this study, we found out that CESE has accumulated a lot of information pertaining to research and researchers over the period of its existence. However, this information has not been properly organized and managed in a manner consistent with competency management and research networking. Data entry is one of the biggest challenges of information management in CESE mostly because people do not have time to do it. As earlier mentioned, activities in CESE are project-based and therefore, characterized by a short life cycle. Activities have to be accomplished within given deadlines which leave very little or no time to organize data in a way that clearly represents the profile of CESE. RNS provide a remedy to this challenge because they have the capability to automatically aggregate information from both internal and external sources to generate profiles for individual researchers as well as the institution as a whole. This is aligned with Kahlon's (2014) definition that RNSs are *"Web-based applications that mine a*

variety of data sources to automatically generate searchable profiles and expose existing networks of collaborators." VIVO data ingest tools enable populating the ontology with data from a variety of local sources within CESE such as the human resources, financial, SACA (publication databases) to mention but a few and the external sources such as authoritative publication databases like SCOPUS, Web of Science. Also, the self-editing interface allows researchers with institutional authentication can modify data ingested into VIVO by adding, removing, editing, displaying or hiding pieces of data from public view. This gives these individuals a level of control of their data and deals with issues of privacy. For these reasons therefore, we strongly postulate that the element of automatic data ingest (especially) will ensure that data in VIVO is always up-to-date and maintained with very minimal efforts from the researchers or a responsible systems administrator.

4.3. Recommendations towards the implementation of VIVO in INESC TEC to enhance Competency Management and promote Research Networking

This sub-section presents recommendations towards the implementation of VIVO Research Networking System (RNS) in INESC TEC to enhance competency management and promote research networking (RN). It is important to point out the steps this dissertation has taken in developing key components towards implementing an RNS in INESC TEC. Initial steps were geared towards the characterization of the state of RN in INESC TEC and the key concerns therein, specifying the requirements of INESC TEC for implementing a RNS, identifying, installing and examining a prototype suitable to serve the requirements specified. The next part of this sub-section resulted mostly from the last phase of the study that was conducted through a focus group in CESE. The focus group intended to stimulate a discussion towards the implementation of VIVO to enhance competency management and promote research networking within CESE and beyond.

4.3.1. Proposal of action for CESE context

As it has already been earlier mentioned, INESC TEC has been around for about three decades and has therefore accumulated a large amount of research data/ information as well as competencies. A number of ICT tools and other informal platforms have been established to facilitate discovery of research information and

competencies. Competencies in INESC TEC are managed through an organizational approach which involves more integrated employees of CESE being responsible for those on temporary or short contractual basis. A number of efforts towards implementing a system to enhance competency management or mapping have already been explored but with very little or no success. Key concerns include the nature of activities in INESC TEC which is characterized by projects. Projects are generally short-lived, meaning that people come and go with the knowledge acquired as well as their competencies. Also, beyond their busy schedules and deadlines, researchers hardly have time to commit to managing information pertaining to their competencies and activities.

The major goal of this study was to understand based on the concrete contributions, which elements of RNS implementation are crucial in enhancing the management of competencies and promoting research networking in CESE. By elements, we mean the characteristics of the implementation process of an RNS and by RNS, we mean VIVO. VIVO was the prototype that was selected and examined as demonstrated in the previous parts of this dissertation and also considered appropriate for implementation in CESE. It has been demonstrated that VIVO has the capabilities and characteristics of an RNS that CESE would benefit from in the areas of competency management and research networking. It is therefore, our wish that CESE considers implementing VIVO. Some of the key elements of the recommendations towards the implementation of VIVO are presented in the following part of this sub-section.

An initial VIVO implementation in any institution should replicate the structure and priorities of that institution[31]. Questions regarding what kind of data is appropriate, where to find it and how to get it from the source into VIVO should be effectively answered. Additionally, there are other commitments that the institution has to make in order to see the implementation process through. To implement VIVO at CESE, these are some of the elements of VIVO implementation that should be considered in order to ensure that the center's needs are fully served.

[31] More information on local adoption of VIVO:
https://wiki.duraspace.org/display/VIVO/Planning+a+VIVO+Implementation

Ingesting and Maintaining Data in VIVO: this is usually dependent on the size of the organization in terms of the number of its employees and which information will be ingested into VIVO. For smaller organizations, data about people, activities, events and so on, can be entered and maintained manually through the interactive editing. This is easier when there is an available group of people, usually junior staff or students with the right data entry skills and willingness to learn and work in a research environment. Manual data entry also offers an opportunity for developing a functional prototype with institutional data as a pilot study for a wider coverage implementation. This allows for a familiarization with the structure and functionalities of the prototype. On the other hand, manual data entry may not be the thing for a bigger organization especially in situations where supplementary labor is unavailable. Automated data ingest and maintenance works best for this kind of organizations as it is more pragmatic and beneficial in ways such as ensuring consistency in data and rapid replacement of data over a predictable schedule. It is worth noting that, with the nature of work in CESE where people are very busy and barely have time to spare, automated data ingest and maintenance is the best option. Krafft, Dean B. et al (2010) advocated for both methods when he says that *"although much of the data in VIVO profiles is populated via automated feeds, initial data entry and testing to refine content categories in the VIVO interface tends to be manual, and managed by librarians."* Even then, it is advisable that even though CESE is one of the smaller centers of INESC TEC, automated data ingest and maintenance is highly recommended.

Consistency of Data: It is true that some institutions consider their data an asset and try their best to maintain it in a standard retrievable format based on the institutional stipulations. On the other hand, data in some institutions are stored in systems that struggle with misplaced or missing, inconsistencies with identifiers, lack of common terminology for organizing chunks of data like research areas, keywords, employment titles to mention but a few. It is recommended that inquiries be made with the responsible persons in order to establish what data sets are available to be entered into VIVO and which people should be allowed access to it. As earlier stated, information management is not one of CESE's strong points and therefore, inconsistencies and lack of standardized identifiers or common terms should not come as a surprise. However, it would be helpful for CESE to engage the services of

an information professional or specialist like librarians, information scientists or curators to organize information and categorize the various data sets. This recommendation resonates with Conlon, Michael's (2007) statement that a library is *"in its capacity as a generally impartial and trustworthy organization with a clear understanding of the needs of the research community and the proven capability of engaging with it, expertise in information management and dissemination, and an established liaison function—admirably performs this role"*

Representation of data using the VIVO Ontology: The VIVO Ontology conveys data about researchers based on their classes and relationships in order to represent the complete context of their work. It is therefore important for CESE to understand this ontology, how it can represent a clear picture of its data and how to it can be extended to serve the requirements of the different user groups. This will enable CESE data to me be represented accurately. An example of a scenario where the ontology will be important is distinguishing between the research and professional areas in CESE. It was pointed out in the focus group discussion that, the work environment at CESE does not only consist of researchers but other professionals as well. Therefore, VIVO ontology should clearly and accurately model and represent data pertaining to each of these user groups while being mindful of the distinction between them. Krafft, Dean B.et al., (2010) stated that, "t*he core ontology is not a constraining schema that prescribes the data that may be entered into VIVO"* therefore, achieving a true and complete representation of CESE's research data and competencies in VIVO is achievable.

Public or Private Data The concern about public or private data can be addressed consistently following the policies or legal provisions of a given institution regarding which information can be displayed on the Web and which one may not. Nevertheless, it is recommended that CESE not to display non-public information in the public VIVO. As pointed out in the focus group discussion, *"there is information that CESE prefers to keep within and away from the public eye"* (p2). This eliminates any chances of complicating the profile of an individual and probably that of the institution. CESE should be mindful of the fact that a number of semantic web tools have been built to facilitate data sharing by allowing its direct consumption by other applications as well as the human eye. And even though, the Vitro Software embedded in VIVO provides techniques to limit visibility of certain data from

websites, other web applications or tools can still read a complete export of a VIVO database directly without any form of filtering. It is therefore, recommended that CESE confidential data such; contract tenure, salary history, leave status, home address or phone number, demographic information (age, sex, marital status) are left out of VIVO. Alternatively, links to certain information such as contacts can be made to the institutional online directories or personal websites for more up-to-date information. Other data such as departmental identifiers or employee numbers may be entered into VIVO only for the purpose of aligning data of the particular individual but not made publicly visible. Other even more personal and sensitive data may include a person's photograph, political views, aspirations or activities. A person may also prefer not to have their older papers or publications included in their profiles as they may neither be relevant anymore nor represent their current interest areas. Also some researchers prefer to keep their funding information private in order to have an advantage over his competitors. All these are issues that CESE must consider carefully and determine which way to go. But as earlier mentioned it is ultimately best to keep any data that is considered private, confidential or sensitive out of the public VIVO.

VIVO as System of Records (SORs) or not?: VIVO may very well become an integrated SOR for information ranging from; research areas and keywords, publications to other information like; grants and appointments that is currently stored and maintained in other systems for administrative use. However, it is more practical for CESE to establish VIVO as a downstream consumer of information from existing SORs such as SACA, human resources, and not looking to displace these core systems. Ideally, it would be more advantageous for CESE to have a data mart - which in this case will be VIVO, that brings together all the information needed about the research environment such as; HR, grants, teaching activities, publications, events, organizations to mention but a few.

VIVO Data Reviews: Relying on individual researchers or employees to provide or review data for any information system may pose a challenge. In CESE, it is likely that there will be a gap between the need for individuals to control their data and the absence of time to review it. Within the VIVO effort, some universities have endeavored to reduce the frequency a faculty member is required to provide or review their information. Reporting is one of the most frequently conducted duties in

a research environment such as CESE's. Therefore, to reduce the number of times people review their data, CESE can rely on automated ingest and maintenance of data from the reporting systems such as annual reports. Nevertheless, the individual reviews are still important because when VIVO is not consuming data from the reporting system, it can still capture and display the modifications on a person's profile. The data reviews also reflect the aspects of the researcher's information to be included or excluded in an automated data ingest. This is especially possible for individuals who may have authentication as they will have rights to specify which of their data can be publicly visible and which one cannot. Data review also enables VIVO to reflect the larger information ecosystem at the institution while reducing the effort of the person in doing it.

Hierarchical control of VIVO Data: Implementing VIVO at CESE should demonstrate the level of hierarchy inherent in the structure of the center. This implies that all activities of defining data sources, private or public data, data entry or ingest, editing, updating, adding or removing data, specifying to mention a few, must be conducted at the center level. The profile of the center as a unit should be well represented and maintained and the data centrally controlled. This can be followed by adding user accounts of a particular set of individuals like project managers, senior researchers, team leaders and providing them with system authentication credentials. This way, they are able to log on and perform their various duties such as reporting, editing, adding, updating or removing dating from their profiles. This hierarchical approach can be beneficial when there is need to identify collaborators within the center or from another center. "*If I am the Head/ Director of a center, I have a project and I want someone to work related to Supply and Chains Management and I find a colleague in that area who is an expert, he has Post Doc. I cannot go to him and ask him to work in my project. I have to go through the Center Head"* (Participant, Phase 1).

User Education and Current Awareness: This is a significant part of any change especially when it has to do with introducing new information systems in an organization. It is recommended that CESE as a center engage all its stakeholders in their respective groups and educate them about VIVO and solicit feedback. *"This is one way to seek validation and establish acceptance of the system. It is important to be careful about the evolution. People must be educated about the system"*

(Participant, Phase 1). In the same light, there will be a need to train or bring someone knowledgeable about RDF and Ontologies on board to further the work that has already been started.

CONCLUSION AND FURTHER WORK

As we close in on the final part of this dissertation, we affirm that its main goals were achieved and the initial research question – *"How can INESC TEC benefit from implementing a Research Networking System?"* sufficiently answered. Through a two phased study, key issues, practices, challenges and solutions regarding implementation of a RNS in INESC TEC were demonstrated. The first phase of the study was important in providing an overview of the reality of research networking and specification of the INESC TEC's requirements for implementing a Research Networking System (RNS). In conjunction with the literature review, phase 1 of the study was very instrumental in providing the basis upon which the second phase of the study was developed. Phase 1 also helped us conclude that INESC TEC recognizes the need for an RNS to further support the achievement of its goals by enhancing competency management and promoting research networking within and beyond its borders. Nevertheless, it is worth noting that there was a general lack of knowledge about RNSs, their implementation and how they can be of benefit to research institutions such as INEC TEC. For this reason therefore, this dissertation contributes immensely in creating awareness about RNSs and how specification of institutional requirements plays a key role in the selection process.

The second phase of the study was conducted within the context of CESE – one of the research centers of INESC TEC. In this phase, the role of a prototype – VIVO in serving the institutional requirements earlier specified was demonstrated. In addition to literature on VIVO, its key functional features were demonstrated through its platform. Scenarios corresponding to the requirements of CESE were explored and represented, indicating the fit between this RNS to CESE's needs. It was clear in this phase that the key functional requirements of VIVO included; a system that is simple and fast to use, a system that enables them to clearly and accurately represent their data, and one that is capable of automated data entry as opposed to manual – some of VIVO's key features. We are therefore, convinced that this dissertation contribute significantly to the body of knowledge on RNSs implementation. This knowledge will empower not only CESE but INESC TEC and research institutions in general about the role that VIVO plays in meeting institutional requirements. Meanwhile, to further inform the implementation process of VIVO, key elements of recommendations related to institutional data/ information

and organizational commitments were explained. This demonstrates the contribution of this dissertation to the envisioned implementation of VIVO in CESE and ultimately at INESC TEC.

Schleyer, T. et al. (2012) asserts that RNSs are *"systems which support individual researchers' efforts to form and maintain optimal collaborative relationships for conducting productive research within a specific context."* It is clear from this definition that RNSs are a bridge or gateway for researchers to work together within a given context in order to be more productive. From this we conceive that, if researchers are going to work together, they need to know each other based on their capabilities, of course. This is where RNSs like VIVO come in – to enable the integration and representation of a researcher's capabilities in a way that effectively conveys their competencies within a context such as CESE and across borders. Most important is ensuring that the gap between the requirements of the contextual institution and the RNS itself is closed. An institution must understand how it will benefit from implementing an RNS, only then will it know which system to select. Additionally, the functionalities of the RNS should provide the right capabilities to ensure ease of use and demonstrate its usefulness to the context. In our study, we determined this by relying on a theoretical framework that guided a previous study on enhancing RNSs for finding collaborators conducted by Bhavnani, Suresh K, et al., (2012). This is the theoretical framework of Technology Acceptance Models (TAMs) which suggests that users are inclined to accept a technology if they understand its perceived usefulness and ease of use (Bhavnani, Suresh K, et al., 2012).

It is important to mention that the methods employed to conduct the study for this dissertation were extremely useful, suitable and provided the data that was needed to achieve the research goals and answer the research question. The use of exploratory interviews in the first phase and a focus group in the second phase did not only give the researcher a deeper understanding of the phenomenon that was being studied but also allowed the researcher to see things from the point of view of the case study. The sample population consisting of key person (both in the first and second phases) were best placed to understand and provide concrete input for the study.

At this point, it is important to say that, this study was limited by a number of factors - one of them being time. Time was a major constraint on both the part of the researcher as well as that of the participants. INESC TEC is characterized by an extremely busy work environment where people hardly have time to spare without longer notice. The persons that fit into the sample type (senior researchers and managers) for the study are very busy due to the nature of their activities that are characterized by meetings and travels or other pressing commitments. There were also some technical difficulties related to the installation and configuration of the VIVO platform that took some time to be resolved. These factors put together constrained the pre-defined schedule of activities and unfortunately led to delay and a considerable amount of pressure towards the end of the duration for accomplishing this dissertation.

That being said, this dissertation provides a couple of opportunities for future work especially towards the implementation of VIVO in the context of CESE. It is our hope that, the results and recommendations of this dissertation will be explored and put to use not only in CESE, but in INESC TEC as a whole. Automated data ingest and maintenance is a key component of the VIVO implementation process and hopefully CESE can conduct this in the near future to test VIVO. It would therefore, be important to specify and implement ontologies for INESC TEC, based on reusing the general ontologies already present in VIVO; to define detailed procedures for automated data ingestion from the relevant data sources in the Portuguese science and technology system and to expose INESC TEC VIVO information as linked open data to be used for other applications both internally and externally.

Another interesting suggestion for further work would be exploring the feasibility of implementing VIVO to facilitate discovery of researchers and research across institutions – INESC TEC and its associate or partner institutions. Last but not least, depending on the success of the multi-institutional effort, an effort towards national VIVO to facilitate networking of researchers across Portugal could produce some interesting outcomes.

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APPENDICES

APPENDIX 1 – INITIAL COMMUNICATION

Subject	**Exploratory interview on Research Networking Systems**
From	António Lucas Soares
Cc	Sharon Okori
Date	20.01.2015 13:30

Dear colleague,

My master student Sharon Okori (Master in Information Science) is writing a dissertation about Research Networking Systems having INESC TEC as a case study. In a first phase of her study she needs to collect the opinion of key research leaders in INESC TEC. Hence, I am asking you if you could spend 30 min in an exploratory interview regarding this subject. If you agree, just reply all to this message and Sharon will contact you soon to schedule the interview. I am sure that this subject is very relevant for the management of competencies and scientific collaboration at INESC TEC. A short explanation of RNS follows.

Thank you for your attention,
als

RESEARCH NETWORKING SYSTEMS

What are Research Networking Systems?

Research Networking (RN) is about using web-based tools to discover and use research and scholarly information about people and resources. Research Networking Systems RNSs serve as knowledge/competency management systems for research institutions. RNSs connect institution-level/enterprise systems, national research networks, publicly available research data (e.g., grants and publications), and restricted/proprietary data by harvesting information from disparate sources into compiled institution profiles for faculty, investigators, scholars, clinicians, community partners, and facilities.

What are the benefits of RNS?

RNSs facilitate the development of new collaborations and team science to address new or existing research challenges through the rapid discovery and recommendation of researchers, expertise, and resources. RNSs differ from search engines such as Google in that they access information in databases and other data not limited to web pages. They also differ from social networking systems such as LinkedIn or Facebook in that they represent a collection of data ingested from authoritative and verifiable sources like PubMed, MEDLINE e.t.c. rather than predominantly individually asserted information, making RNSs more reliable (Wikipedia).

The information that is obtained from these systems is required for a variety of reasons. Strategically, it informs an institution of its performance and competitiveness and allows it to take decisions based on that information. Operationally, RNSs are required to support day-to-day administration of research and fulfil the needs of external stakeholders. These can help focus institutional strategies on research quality, raise the profile of an institution's research nationally and internationally, manage talent, and build a high-quality research environment.

How can RN be implemented in a research institution?

A variety of both commercial and open source RNSs are available on the market, among which are; Profiles RNSs which has been implemented at Harvard University and others, Digital Vita at the Health Sciences Centre of the University of Pittsburg, VIVO which is a massive RNS adopted by numerous academic, research institutions, agencies and companies in more than 30 countries all over the world. Nevertheless, implementation of RNSs by institutions is generally influenced by the factors in play at a particular institution. These factors include; user requirements, institutional culture, financial and administrative factors, policy issues to mention but a few.

What is this study about?

This study seeks to understand and specify the requirements of INESC TEC for implementing a Research Networking System. If they be found useful, the results of this study may inform the eventual implementation of an RNS at the Institute.

APPENDIX 2 - EXPLORATORY INTERVIEW GUIDE

Ethical Consideration:

First, I would like to thank you for making time to participate in this interview. I would like to request for your permission to audio record this interview to enable me capture the entire interview. It would be impossible for me to capture everything by writing it down. I assure you that the information from this interview will be entirely for the purpose of realizing my dissertation and nothing else. Additionally, your privacy and anonymity is guaranteed.

Title of this study:

Implementation of a Research Networking System in the Institute of Systems and Computer Engineering, Porto (INESC TEC): An Exploratory Study to specify institutional requirements.

Main aim of study:

With reference to the background information sent in the initial communication, the main aim of this study is to specify the requirements of INESC TEC to implement a Research Networking System

Purpose of this interview:

This interview intends to gather insight from key persons in INESC TEC such as yourself, concerning the subject of the study. The interview is officially scheduled to last 30 minutes. You are encouraged to speak freely during when answering a question.

Main Topics to be covered during the interview include:

1. The State of Research Networking (RN) in INESC TEC;
2. Management of research information and competencies in INESC TEC;
3. Current trends in Research and Development;
4. Expected benefits of implementing an RNS in INESC TEC.

APPENDIX 3 - LIST OF COMPETENCIES IN INESEC TEC BY CENTER

S/N	RESEARCH GROUP/ CENTRE	COMPETENCES
01	Centre for Robotics and Intelligent Systems (CROB	• Land, maritime and aerial robots; • Industrial and indoor robotics; • Intelligent sensors and perception systems,
02	Centre for Enterprise Systems Engineering (CESE)	• Collaborative Network Management; • Information and Knowledge Management In Collaborative Networks; • Operations Management and production planning; • Cutting and packaging problems
03	Centre for Biomedical Engineering	• Bio Instrumentation; • Biomedical Imaging; • Neuro Engineering
04	Centre for Innovation, Technology and Entrepreneurship (CITE)	• Technology Entrepreneurship; • Innovation Management; • Innovation Networks; • Technology Strategy; • Engineering Systems Design; • Technology Policy
05	Centre for Industrial Engineering and Management	• Service Design and Engineering; • Decision Design and Intelligent Systems; • Performance Management and Business Intelligence;
06	Centre for Applied Photonics (CAP)	• Optical Fibre Sensors; • Micro Fabrication; • Optical Fibre Sources; • Electronic and Optoelectronic Systems Integration;
07	Centre for Research in Advanced Computing Systems (CRACS)	• Computational Models and Languages for Scalable Computing;

		• **Information Mining and Web-based Systems**
08	Centre for Power and Energy Systems (CPES)	• Decision Making, Optimisation and Computational Intelligence; • Forecasting; • Static and Dynamic Analysis of Energy Grids; • Reliability Analysis
09	High Assurance Software Laboratory (HASLAB)	• Software Engineering; • Distributed Systems; • Cryptography and Information Security
10	Centre for Telecom and Multimedia	• Information Processing and Pattern Recognition; • Multimedia Communication Technologies; • Communication Networks; • Optical Technologies and Electronics
11	Laboratory of Artificial Intelligence and Decision Support (LIAAD)	• Data Mining; • Data Analysis and Statistical Methods; • Modelling and Optimization
12	Centre for Information Systems and Computer Graphics (CSIG)	• Computer Graphics and Virtual Environments; • Software Engineering; • Information Management and Systems
13	Research Centre in Real-Time and Embedded Computing Systems (CISTER) [Associate R&D Unit]	Focuses on real-time communication networks and protocols, wireless sensor networks, real-time operating systems and programming paradigms, distributed and embedded real-time computer systems, cooperative computing and applications QoS-aware (Quality of Service), programming and planning analysis (including multiprocessor systems), and cyber-physical systems.