Critical technologies for the North of Portugal in 2015: the case of ITCE sectors – information technologies, communication and electronics

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Abstract: *The Commission for Coordination and Regional Development of the North of Portugal (CCDR-N) promoted NORTINOV 2015, a project created to define a regional innovation strategy for the North of Portugal based on automotive clusters and Information Technology, Communication and Electronics (ITCE) clusters. Accordingly, it developed a technology forecast for the year 2015 in order to help the North of Portugal cope with the intensifying global competition and rapid technological changes.* This paper describes the methodology used to identify critical technologies for the regional economy of the North of Portugal under the project NORTINOV 2015. It involved three main steps: *technology identification and study*, in which a list of emerging technologies was implemented; *refinement of emerging technologies*, in which 90 technologies were identified and finally, *classification and hierarchisation of technologies*, in which 30 technologies were identified as critical for the crafting of regional innovation strategy. In this final step, a workshop involving major stakeholders of the three clusters under study played a major role.

Keywords: communication; electronics; information technologies; innovation systems; North of Portugal; technological prospective.

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1 Introduction

During the past two decades the following three events have been found to have a profound impact on the nature of economic activity in Portugal:

1 the liberalisation of internal and cross-border markets

2 the emergence of different growth rates among all Portuguese regions and

3 the increasing importance of the knowledge economy.

As Portugal has been a *less-favoured economy* in the European context, it has experienced a learning process dealing with intricacies of increasing competition. Nevertheless, some regions have managed to outperform the average national economic growth rates while in other regions there has been steady decline. The northern region, formerly dynamic and prosperous, has been losing power *vis-à-vis* other Portuguese regions over the past two decades. This region has relied heavily upon traditional industries such as footwear, textiles, cork and furniture even though significant economic activity can also be found in more technology–intensive clusters.

The *NORTINOV 2015* project was promoted in 2004 by the Coordination and Regional Development Commission of the North of Portugal (CCDR-N), with the main goal of defining a regional innovation strategy for the North of Portugal pertaining to automotive clusters and Information Technology, Communication and Electronics (ITCE) clusters for the year 2015. These clusters were chosen because they were

considered to be a driving force in the development of business in the region. The automotive cluster was selected as it is known to be an integrator of technologies and competencies. In contrast, the ITCE clusters were chosen since they were considered to be producers of technology that is applicable in different sectors.

The CCDR-N's decision was based on their choice of a new engine of innovation and underpinned it's decision on the cross-fertilisation effects of automotive (is known as an integrator of technologies and competencies) and ITCE (known for their pervasive effects in other business sectors) clusters in order to spark off a new model of development for Portugal's northern region.

This paper is the result of the authors' involvement in the *NORTINOV 2015* project, which included a foresight exercise involving ITCE clusters. The purpose of the paper is to present the main critical technologies of ITCE sectors in the North of Portugal for the year 2015, resulting from the above-mentioned project. Accordingly, it is a case study relevant to a number of smaller countries/regions with homogeneous characteristics (population, languages, economy, etc.) attempting to close their gaps relatively to technologically advanced countries/regions.

Based on the need to define a set of critical technologies for ITCE clusters in the northern region, it was then decided to use the innovation system approach that aggregates national and regional perspectives (taking into account both the network of agents and the territorial perspective that influence its socio-technical evolution) and technological approaches.

As expected in prospective studies, one of the most difficult issues was to define *what* and *how many* technologies. In order to make this study feasible, it was decided to define a methodology that supported the selection of relevant emerging technologies. Among them, those technologies that were considered critical to underpin the development of the regional innovation strategy were selected. As a consequence, the first target was to define a broad list of technologies and a methodological approach to identify the most important among them. From the 90 emerging technologies defined initially, several methodological steps were implemented to select the 30 most critical technologies for the development of ITCE clusters in the Northern region of Portugal. Clearly, the selection of technologies is not regarded as an end in itself; the technologies were subsequently proposed as input in the definition of the regional innovation strategy for the North of Portugal.

The paper has seven different sections. Section 1 presents an introduction. Sections 2 and 3 present the literature review: technology and innovation systems, respectively. Section 4 presents contextual data for the three clusters under analysis. Section 5 reports on the methodology followed in defining critical technologies for the year 2015. Section 6 presents the main results of the study and, finally, Section 7 provides the main conclusions of the paper.

2 Technology

The pressure of new technologies on firms and individuals is not a recent phenomenon. Since the first industrial revolution, technical advances have forced many firms to change.

Technology is a major input in economic development (Chesnais, 1986) and an essential element of economic progress (Dosi et al., 1988). Technology is present in each

activity throughout the value chain and it must be accounted for, given its capacity to alter the competitive advantage or the industry structure (Porter, 1985). It may also influence the firm's competitive strategy, which depends on its technological level and evolutionary technical capacity.

Technology has been defined in various ways. One of the broadest concepts is given by Nelson and Winter (1982) who consider technology as the specific knowledge used in the context on which it has been developed. For them, technology depends on the learning capacity of those who started its development. Steele (1990) very curiously says that technology is like beauty: "those who have it are obsessed with the idea of keeping it; those who do not are also obsessed with the idea of having it!"

Technologies do have a competitive impact on products because they not only affect their costs and performance but also influence the way firms compete in the industry and the positioning of their products in the marketplace. An interesting classification of technologies has been put forward by Little (1981) who classifies technologies into three groups: emerging, key and base technologies. *Emerging technologies* are those in an embryonic stage, which do not yet have many applications. Their contribution to a given business area is still marginal and their potential development is very important for the firm's future impact. *Key technologies* are those that underpin the firm's competitive position. They are indispensable if a firm is to succeed in a given industry. Formerly, they were emerging technologies that were efficiently utilised which enabled a competitive advantage in comparison with other firms. They constitute the highest competitive asset of firms and in the future they will probably mature into base technologies. *Base technologies* are those that are standard in the industry and are highly used in a given business area. They were probably key technologies in the past, but they no longer provide a competitive advantage to firms because they are readily available and the majority of competitors possess them. Mastering base technologies is, however, necessary for a firm to remain in the industry.

As Dussauge, Hart and Ramanatsoa (1992) state, "it is not the characteristic of the technology that is important *per se*, but the competitive role it plays within a business". Consequently, a technology can be a base technology in one business, a key technology in another business and an emerging technology in a third business. To exemplify, they gave the example of CAD and its impact on aerospace, automobile and textile industries.

However, as the concept of critical technologies defended in different prospective studies is very broad, the present study has followed a concept of critical technology that takes into account how critical the technology is for the output of the system dependent on that technology and its influence in the development of the system (Popper, Wagner and Larson, 1998).

Besides its definition, the fact that technology represents a specific sum of knowledge in a particular activity is equally important. As such, given the focus on emerging and critical technologies, this paper will follow an evolutionary approach that:

1 incorporates activities which are undetermined, contingent and irreversible in nature

2 involves tacit forms of knowledge embedded in individuals and organisations and

3 generates technological competencies in performing agents (Nelson and Winter, 1982; Cimoli and Dosi, 1995).

In this perspective, it is shaped by the notions of technological trajectory and technological paradigms (Dosi, 1982).

Bearing in mind that a technological trajectory represents a set of activities that initiates a technological paradigm, it is important to highlight three features that have influenced the emergence of new technologies (Dosi et al., 1988):

1 *the knowledge of a technology*, which shapes and constrains the evolution and subsequent rates of technological change, regardless of the market

2 the stabilisation of *the pattern of technical change* until radical changes occur in knowledge bases and

3 the *technical change* that is partially influenced by technological changes created within that change which creates an imbalance for new technological changes.

3 Innovation systems

The term *National Innovation System* (NIS) was first presented by Freeman (1987) in reference to the complexity and dynamics of the innovation process. Freeman (1987) defines NIS as a set of public and private institutions whose activities and interactions generate, import, change and diffuse new technologies.

The European Commission, the Organisation for Economic Co-operation and Development (OECD) and the United Nations Conference on Trade and Development (UNCTAD) have used the NIS concept as an analytical tool, which has led several researchers to apply it on regions and sectors. As a result of the growing number of articles, Edquist (1997) has put forward the concept of *innovation systems* based on the following features:

- The innovation, intrinsically connected to learning, is at the centre of the analysis.
- The innovation follows a holistic and interdisciplinary perspective, given that it comprises innovation determinants and institutional, organisational, social and political factors.
- The innovation system follows a historical perspective because it is path-dependent.
- The lack of an optimal system.
- The emphasis given to the interdependence and non-linearity of the innovation process.
- The main role given to institutions.

Edquist (1997) defends the relevance given to NIS based on the fact that it captures important aspects of the policy of the innovation process. Thus, an NIS addresses governmental policies of science, technology and innovation, R&D competencies of both public and private systems, educational systems and financial institutions.

Although the initial analysis of innovation systems has been applied to a national reality, the same analysis has been made on a regional basis, which gives rise to *regional innovation systems* (Cooke, Gómez Uranga and Etxebarria, 1997). As stated by Cooke and Morgan (1998), NISs have been influenced by two different tendencies: globalisation and regionalisation. Therefore and taking into account that some regions have managed to prosper more than others, those thriving regions can become important development

centres given that the regional networks in which they perform are privileged factors for the establishment of trust relationships essential for the learning and innovation process.

A taxonomy proposed by Pavitt, based on the analysis of the sectoral innovation patterns, had a vast exposure to the neo-Schumpeterian literature. Considering the various patterns of industrial sectors in relation to external sources of knowledge, scientific and technological activities of institutions, the industrial structure and generation of competencies, Pavitt (1984) classified industries into five big conceptual groups: *supplier-dominated sectors*, *specialised suppliers*, *science-based sectors*, *large-scale sectors* and *information-intensive sectors*.

Although innovation plays a different role in each sector (for example, while in *supplier-dominated sectors* most innovations are embodied in capital equipment and intermediate input, in *information-intensive sectors* the innovation is generally generated outside the company that uses it), the global economic perspective is that all of them are intertwined in the underpinning of the generation of complex integrated innovation systems.

Malerba (2000) defends a sectoral approach – *Sectoral Innovation Systems* (SISs) – arguing that families, regimes and technological trajectories are important contributors due to two main reasons:

1 They are the centres of all business activities.

2 Firms are active elements in the development and manufacturing of products and in the creation and use of technologies.

A SIS is clearly more specific than a NIS or a RIS. It focuses on the understanding of the sources and patterns of an industry's technological progress. Thus, its attention falls on the offer of an industry's new scientific and technological knowledge, leaving aside any concern for inter-industrial interactions.

Carlsson (1994) has followed a parallel approach, proposing the concept of *Technological Systems* (TS), which have been defined as networks of agents that interact in a specific technological area, under the influence of a particular institutional infra-structure, aiming to create, diffuse and use a technology.

Carlsson's approach (1994), though relatively similar to that of SIS's, gives more emphasis to specific technologies and hence, it has the disadvantage of requiring that the innovation and technology policy should address the specific problems of each technological area rather than of industrial sectors. Additionally, this approach is also not oriented towards the resolution of problems concerning the offer and creation of new technologies.

4 Context: regional and global framework

4.1 Global context

The main key figures of the global market of the ITCE clusters in the year 2002 are presented in Table 1. While the USA leads in the IT market, Europe leads in communication and electronics.

Table 1 Main global market figures of the ITCE clusters

	Market (Billion €)	*Market share (%)*			
		USA	*Europe*	*Japan*	*Rest of the World*
IT	933	42	31	12	15
Communications	1165	25	28	13	34
Electronics	1192	29	36	12	23

The growth rates of ITCE clusters are shown in Table 2. The annual growth rates are moderate for both communication and IT markets. As the growth rate of the electronics market has been poor, China is expected to exceed Europe's production volume in 2007 although not exceeding the USA (EITO, 2004).

Table 2 Growth rates (%) of European ITCE clusters

	1998/2000	*2001*	*2002*	*2003*	*2007*
IT	11	2	–	–	4
Communications	13	4	–	–	4
Electronics	–	–	–13	–2	0

The difference in *per capita* consumption of IT markets is broad: while it exceeds €1500 in the USA and €920 in Japan, it does not reach €250 in Portugal (EITO, 2004).

With the globalisation and concentration process of ITCE sectors, there is a growing tendency for the centre of gravity of business to shift to Asia due to the growing importance of local markets and production activities in the Far East (CCDRN, 2004a).

Among the main driving forces of the ITCE clusters, the following are very important:

- the growing importance of *e-business*, *m-business*, third-generation mobile networks and broadband for the e-economy
- the importance of *software*, *wireless* and mobility
- the emergence and subsequent strong growth of the multimedia market
- the investment in human resources and knowledge, which is essential for future growth
- the e-commerce and adoption of web technologies by enterprise applications.

4.2 Regional context

Portugal is a small country with a population of ten million inhabitants and a per capita Gross Domestic Product (GDP) of €12600. Although a member of the EU, Portugal is considered to be a *less-favoured country*. Its industrial structure has a long manufacturing tradition although largely specialised in traditional low-technology industries. Structurally, the Portuguese industry is described as:

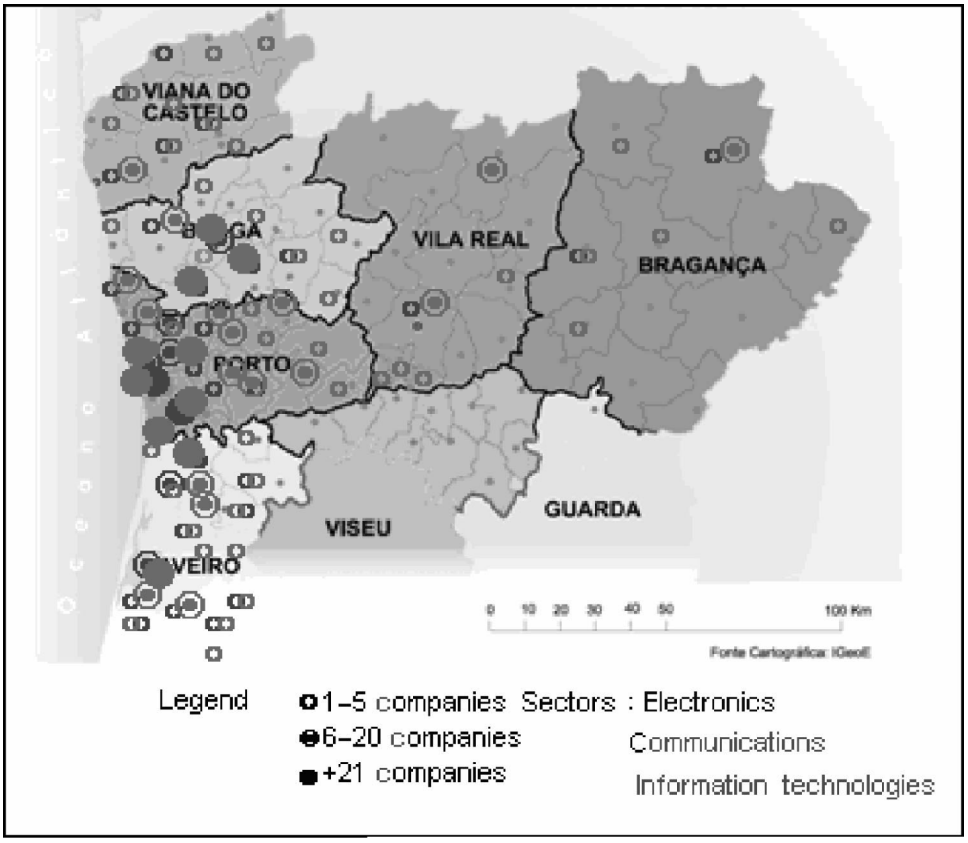
- a myriad of Small- and Medium-Sized Enterprises (SMEs) concentrated along the West coast characterised by limited technological competencies
- a limited number of large companies
- a small market for technology-based products.

The key figures of the northern region ITCE clusters are shown in Table 3. Although the electronics cluster has a high share due to the presence of some multinational companies in the region, the northern communications cluster owes its low share to the location of the main telecommunications operators in Lisbon (CCDRN, 2004a). There is a high geographical concentration in the districts of Porto (59%), Aveiro (17%) and Braga (17%), as shown in Figure 1.

Table 3 Key figures of ITCE clusters of the northern region

		Turnover		*Employment*	
Cluster	*Number of firms*	*National total (Million €)*	*Share (%) of national cluster*	*Number of employees*	*Share (%) of national cluster*
IT	996	175	16	3807	20
Electronics	156	1892	42	8589	20
Communications	4	42	20	177	0.9
Σ	1156	2110	–	12573	–

Figure 1 Territorial distribution of ITCE clusters of the northern region (CCDRN, 2004)



In order to characterise the regional context, it was decided that, apart from bibliographical research, work visits would be made with specialists of each industry. The objective was to conduct a survey relating to disperse information about different clusters, on one hand and to gain a real notion of field conditions, on the other hand. Equally, in order to complement this information, technological audits were conducted in 11 key companies and in ten R&D institutions in the region. These audits, which followed a qualitative approach, helped to monitor how leading entities of the northern region were performing, what technologies they were using, what competencies they had and lacked, what types of R&D projects they were involved in and what the future perspectives looked like.

The majority of Portuguese companies that develop software products are located in the northern region, which is a strong regional asset (CCDRN, 2004b). Most ITCE companies of the northern region, with the exception of foreign multinationals of the electronics cluster, do not develop clear internationalisation strategies. The IT cluster companies recognise internationalisation as an indispensable condition for their survival in the market.

The main motivating reasons given by companies for internationalisation were the small dimension of the national market and the saturation of some segments of the Portuguese market. The main obstacles to internationalisation elucidated were: the poor high-tech image of Portugal abroad, the small size of national companies relative to their main competitors, the need for high levels of investment and the lack of governmental support.

Generally, although most foreign multinational companies do not hold product development activities, most of the remaining companies do. The major barriers to innovation are related to the small market size, the amount of investments (for SMEs) and the lack of innovation culture.

In most multinational companies, strategy is focused on optimisation of processes and costs. In national companies, the strategic positioning is based on three main strands: the conquering of new markets, the nurturing of international ventures and the focus on market niches.

Generally, companies consider that their human resources are rather competent. Despite new graduates' excellent background, they still lack innovation and enterprising spirit. Most of the gaps found in education are related to the shortage of a skilled workforce and to the low level of mobility of the region's human resources. Generally speaking, business firms believe that universities in the region assure an up-to-date background knowledge; however, they feel those same universities do not fulfil their needs when it comes to specific and specialised training.

There are 28 R&D institutions in the northern region with competencies in ITCE sectors. Among them, 23 are R&D entities affiliated to universities, with five of them holding competencies in the areas of Electronics, five of them in the area of IT and electronics, three in the areas of ITCE, one in electronics and telecommunications, two in the Information Technology (IT) and Communication, six in IT and only one in the telecommunications area (CCDRN, 2004a).

A total of 479 PhD researchers were identified in the region, 399 of them being in R&D higher education institutions in ITCE-related clusters, four in interface institutions and 76 in FCT's associated laboratories.

There are 16 higher education institutions awarding degrees (Baccalaureates, Master's and PhDs) in ITCE clusters. Four of them are public institutions, four are

private and eight of them are polytechnic institutes (CCDRN, 2004a). In all higher education institutions, 123 degrees related to ITCE clusters were detected, 60 of them undergraduate degrees, 46 at the level of post-graduate and master's degrees and 17 PhDs. In 2002–2003, the total output rose to 1,017 undergraduates and 44 at the level of post-graduate or master's degree.

There are several European and national initiatives surrounding the *information society* concept that, directly or indirectly, benefit the ITCE mega-cluster. Nevertheless, although there are several technological and industrial policy instruments that players of ITCE clusters can make use of, there are no specific sectoral policies oriented towards this mega-cluster.

Some programmes and structuring projects have been created to strengthen the development of the ITCE clusters in Portugal articulating public policy, sectoral associations and business firms' interests. Projects of particular note are the *Digital SME* initiative, the *Digital Cities and Regions* and the *National Programme of Electronic Purchasing*.

The strong concentration of software firms and universities in the region was identified as one of the main enablers allowing the creation of a software development regional cluster. The main restrictions were associated with the absence of a culture of innovation and enterprise and to the lack of *business angels* and venture capital specifically focused on the sector.

5 Methodology

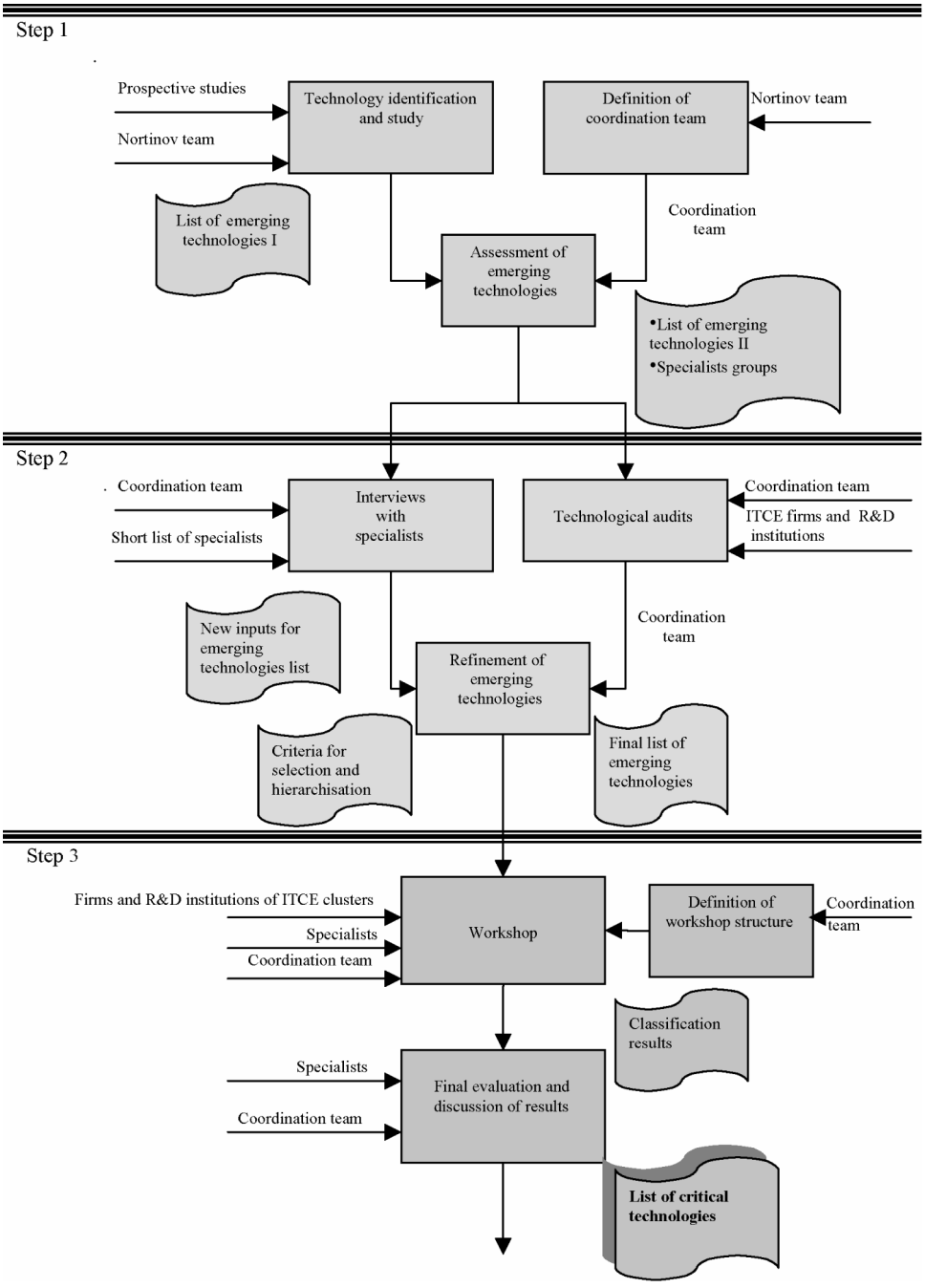
Although there is substantial research coming form other countries, the lack of previous research in similar environments suggested the adoption of an exploratory approach, which was divided in three steps, as shown in Figure 2.

The first step – *technology identification and study* – consisted of a national and international bibliographical review of prospective studies involving ITCE clusters (Ministère de l'Industrie, 1996; Walker et al., 1998; European Commission, 2001; Morato, Escobar and Mañá, 2003; Bullock and Cliff, 2004). The purpose of this step was the creation of a list of emerging technologies that underpinned the subsequent study.

The second step involved the following two main parallel tasks: the improvement of the lists of emerging technologies through interviews with specialists and the exploration of regional competencies through the realisation of technological audits. During the *interviews with specialists* several meetings were held with a short list of selected specialists and experts in the field. The purpose of this consultation was to gather their opinion concerning this preliminary (and not exhaustive) list of emerging technologies in order to improve and refine it. In this context, technology was approached in broad terms.

A set of *technological audits* was carried out in 11 business firms and in ten R&D institutions of ITCE clusters of the northern region. These audits had two clear objectives: to assess the technologies in which local business firms had competencies to compete with, on one side and to identify which emerging technologies were already being used in ITCE sectors, on the other side. In this way, the list was improved taking both the supply and the demand side into account.

Figure 2 Methodological steps for the generation of critical technologies



Detailed questionnaires were developed to conduct these technological audits in companies and R&D organisations. The questionnaire used in the technological audits to business firms included the following main themes: general company characterisation, products and markets, main competitors and partners, internationalisation strategy, human resources competencies, innovation activities, R&D projects, distinct competencies, present key technologies, future trends, emerging technologies, company future strategy and regional environment (clusters, R&D centres, barriers, incentives and policies).

The questionnaire used in R&D organisations included the following main themes: general organisation characterisation, competencies, research priorities and results, human resources, main R&D projects, policy of valorisation of project results, cooperation dynamics (partners, leader companies, R&D organisations, etc.), future trends, development potential, relevant emerging technologies, development potential and regional environment (clusters, R&D centres, barriers, incentives and policies).

The result of this step was the *refinement of emerging technologies* list, since the original one was enriched with several changes: new inputs were identified and added; some technologies eliminated and several inputs corrected according to the information gathered throughout this step.

After gathering all the information, the final list of emerging technologies was obtained. From the 90 emerging technologies identified, 35 were from the IT cluster, 36 from the communication and 19 from the electronics clusters.

In the third phase, *classification and hierarchisation of technologies*, the main players of the ITCE clusters were invited to attend a workshop in which the main purpose was to discuss all emerging technologies and to assess the technological capabilities at regional level in order to identify the critical technologies for the strategic development of the sectors in the region. The following criteria were used in the classification of each emerging technology identified in the previous steps:

1 Generic aspects

- technology development potential
- importance of the technology to the market
- potential competitive advantage generated by the technology.

2 Regional aspects

- technology added value to the region
- relevance for the regional innovation strategy
- technology mastery in the science and technology system
- competencies of the business sector
- training and education available.

A large list of specialists was invited to attend the workshop. The list included the leaders of key business firms and R&D institutions of ITCE clusters. A total of 38 representatives attended the workshop, 26% from the business sector, 21% from universities and 53% from R&D institutions.

The methodological approach to the workshop was as follows. The first session joined all participants and the project team presented the objectives of the workshop and the first draft of the regional innovation strategy. The main objectives were the definition of the critical technologies that should be included in the regional innovation strategy of the ITCE clusters for the North of Portugal, according to the general and regional criteria defined earlier and the validation of the first draft of the RIS. The presentation of the strategy helped to define what technologies could optimise the contribution to the formulated RIS of the northern region. The session ended with a period of discussion.

The second session of the workshop was organised in three parallel panels: one for each cluster under study (IT, electronics and communication). Each panel was led by a specialist in the field invited for that purpose. The list of relevant emerging technologies of each panel was presented and organised in groups. Each group of technologies was presented by the invited specialists and discussed among the participants. In each panel, the main conclusions were agreed on. In the end of the session, the participants filled out a questionnaire where they classified emerging technologies according to the criteria defined earlier.

The conclusions of the parallel sessions were put forward during a final plenary session that took place after the parallel panels. The result of the classification of the list of emerging technologies with the above-mentioned criteria was considered as the *list of critical technologies* for the ITCE clusters in the North of Portugal.

The workshop involved two types of studies: a quantitative and a qualitative analysis. Firstly, the quantitative study enabled the hierarchisation of the technologies under study, according to the generic and regional aspects referred in the previous section. Secondly and perhaps more importantly, the qualitative study was performed based on the debate of various technologies, their application, their differentiation, their degree of innovation, their added value and their sectoral interaction.

During the workshop some of the major problems of each regional cluster were put forward and debated. As most of these problems hinder the creation of added-value technologies, it was decided to present them during the plenary session in order to have a clearer idea of each of the technologies assessed and a picture of real competencies of each cluster.

6 Results

The regional innovation strategy defined a vision for the automotive and ITCE clusters of the northern region of Portugal for the year 2015 that was expressed in the following way (CCDRN, 2004c): “The North of Portugal as a region of added value through the creation and production of knowledge-intensive, global and innovative products”. In this context, the following strategic goals were defined in order to achieve the development of the ITCE clusters:

- the development of a software cluster underpinned in the conception and the development of global software products in areas like mobile services and applications, ambient intelligence, e-business and e-government, GIS
- the development of a cluster of solutions for communications in several critical areas, like communications equipment for market niches, appliances, network management applications, location and mobility applications and GIS

- the exploration of opportunities in specific market niches in the electronics industry
- the development of cultural, entertainment and education applications and
- the promotion of the supply of shared services such as IT and communications data centres, software development, technical support services, training, design and engineering services and call centres.

During the plenary session of the workshop several problems/opportunities were presented. The following were considered as the most important for the definition of critical technologies:

- Technologies *per se* are not important: the interaction of the technologies with both their application and between clusters must be taken into account.
- As firms' competitiveness depends on market performance, regional innovation strategy must address not only firms' technological capabilities but also organisational, marketing and project management competencies.
- There are vacant market niches in communications equipment where it is possible to develop a differentiated product supply.
- There is a huge potential in the high-end mobile market, which should be seen from the application point of view (i.e. departing from the application it is easier to define the set of incorporating technologies).
- Energy consumption should be a transversal concern for all ITCE clusters.
- Professional and domestic low-energy consumption systems and local/mobile energy generation systems are expected to have a key impact on all ITCE clusters.

Tables 4–6 show the set of critical technologies and regional competencies identified as a result of the application of the methodology and criteria used during the workshop.

One of the main conclusions is that, from a list of 90 emerging technologies, it was possible to define the 30 most critical ones for the development of the ITCE clusters of the northern region.

In relative terms, the IT cluster is strongly represented with 50% of the critical technologies. The communication and the electronics industries are almost equally represented with seven and eight critical technologies, respectively. From Table 7 it is possible to conclude that the North of Portugal has strong R&D competencies in only seven of the 30 critical technologies, being the IT sector the one with the strongest R&D competencies.

The business sector of the region has strong competencies in only two of the 30 critical technologies found and has weak competencies in eight of them. Again, the communications sector is in relative disadvantage when compared with the other two clusters.

This discrepancy between intersectoral competencies is mainly explained by the difference in dimension between sectors. Despite their relative positions, all the above-mentioned critical technologies still have a strong contribution for the northern region. The R&D institutions and the firms' competencies should be taken into account in the definition of the regional innovation system in order to define how they can contribute to the competitive advantage of the North of Portugal in 2015.

Table 4 R&D vs. business regional competencies in the IT sector

	R&D	*Firms*
Cyber trust and crime prevention	◐	◐
Web technologies	●	●
Ontological development	◐	○
Software agents/multi-agents systems	●	○
Software quality assurance	●	◐
Ambient intelligence	◐	◐
Support collaboration systems	●	◐
e-government/e-democracy	◐	◐
Business intelligence/ data mining	◐	◐
Applications based on GIS	◐	◐
Information systems for environment	○	◐
Applications for special needed people	◐	◐
Business process modelling	●	◐
Contents development	◐	◐
Telemedicine	◐	◐

High: ●; medium: ◐; low: ○

Table 5 R&D vs. business regional competencies in the communications sector

	R&D	*Firms*
Wireless broadband Networks	◐	○
Metropolitan networks based on 802.11	◐	○
Wireless internet	◐	◐
IP based broadcast networks	◐	○
Networking/QOS	●	◐
Mobile services	◐	◐
Universal multimedia access	◐	◐

High: ●; medium: ◐; low: ○

Table 6 R&D vs. business regional competencies in the electronics sector

	R&D	*Firms*
Low energy consumption systems	◐	◐
Local power generation	◐	○
Wireless sensor networks	◐	◐
Optic fibre sensors	●	●
Artificial vision	◐	◐
RFID	◐	◐
EPC – electronic product code	◐	◐
'Drive by wire'	◐	◐

High: ●; medium: ◐; low: ○

Table 7 Report on the technologies and regional competencies of the ITCE clusters

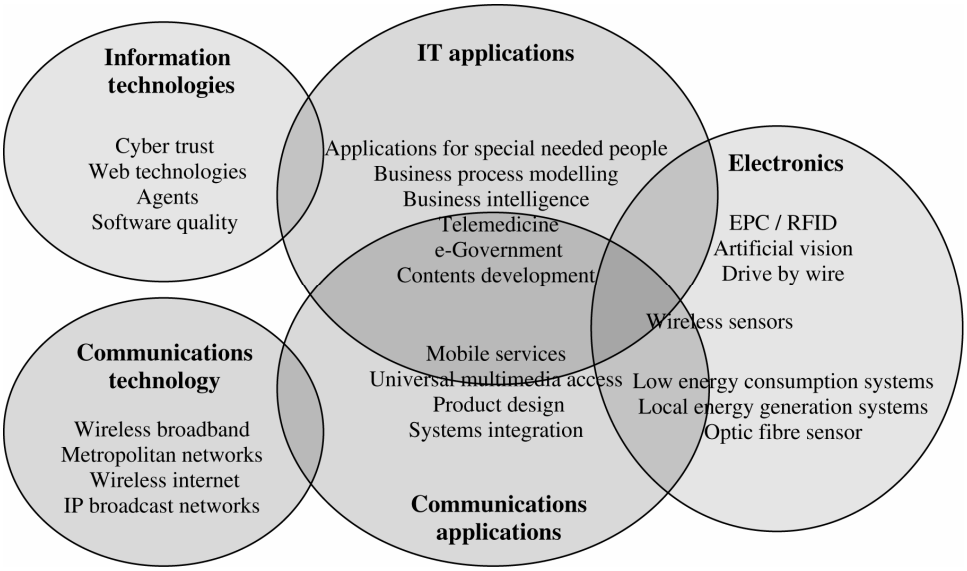
	IT	*Communications*	*Electronics*
Emerging technologies	35	36	19
Critical technologies	15	7	8
Strong regional competencies in R&D	5	1	1
Average regional competencies in R&D	10	7	6
Strong regional competencies of the business sector	1	–	1
Average regional competencies of the business sector	11	3	7

Another important aspect considered during the definition of the critical technologies was their transversal influence in the different clusters analysed. It is possible to argue that a great deal of companies of the IT cluster could be considered as specialised suppliers. On the other hand, the applications generated by this cluster have important effects in information-intensive sectors.

Although some critical technologies of the electronics cluster are associated to the science-based sector, they have pervasive applications on the IT and communications clusters, as is the case of the low energy consumption systems, local energy generation systems and Radio Frequency Identification (RFID).

Finally, the communications cluster has a set of critical technologies that are vital to the society, both in social and economic terms that should not be overlooked, as is the case of wireless broadband internet. Thus, the identified critical technologies and their interactions are shown in Figure 3.

Figure 3 Critical technologies in key-areas and their interactions



Although the interactions between the diverse groups of technologies are important, there are some interactions that should be regarded with care. As can be shown in Figure 3, communications applications and IT applications have strong interactions between each other. The critical technologies of the electronics cluster also have a strong impact on the group of IT and communications applications. As a consequence, public policy should address the set of critical technologies as an intertwined group of technologies and not as a group of 30 independent technologies.

7 Conclusion

The purpose of this article was to present the set of critical technologies for Portugal's northern region in order to implement the regional innovation strategy as presented by the *NORTINOV 2015* project, which was a foresight exercise based on the ITCE clusters for the year 2015. Clearly, instead of providing a detailed analysis to each one of the analysed technologies (which would question the project itself due to financial and time imperatives), this prospective activity aimed to identify the 'most promising movements' with potential effects for the region considering both science and technology system institutions and the business sector.

The notion of relevance in prospective studies is strongly connected to the specificity level with which technology, its components and its applications are analysed. Although the individual trajectories of the technologies and/or applications may not be significant *per se*, their collective contributions may have important consequences. Given that the starting point was that of the contribution to the RIS, we tried to keep the approaches of the technological path in consideration, bearing in mind that we were dealing with a SIS. Thus, it was intended to deal with the individual technological aspects following a

multidisciplinary approach congregating several technological disciplines in order to assess their collective contributions to the RIS.

The original objective set by the *NORTINOV 2015* project was achieved because it resulted in a clarifying perspective of the tendencies and future directions for the critical technologies in 2015. Nevertheless, as technologies are means to an end and as specific strategic actions are needed to achieve the vision proposed for the regional innovation strategy, the following main lines were proposed in order to complement the potentialities of the 30 critical technologies:

- a *strategic line*, in order to create conditions for the development of a ITCE innovative cluster
- a *sustainability line*, intended to deepen the cluster specialisation and to facilitate the interaction with other clusters and
- a *structural line*, in order to develop structural conditions and to position the North of Portugal as a world-class region.

The essential strategic lines are based on the strengthening/promotion of:

- a more dynamic software cluster underpinned in the development of international software products
- the communications cluster based on the development of solutions in critical areas
- the electronics industry in specific market niches generated by spillover effects from Foreign Direct Investment (FDI) in the region
- the development of cultural and educational content applications for both the internal and global market
- the supply of shared services as IT and communications data centres, software development, technical support services, training, design and engineering services.

This sustainability line involved the following priority actions:

- the interaction of ITCE clusters with other clusters in which the North of Portugal has strong capabilities
- the promotion of the capital equipment industry through the launch of a *Technological Upgrading Programme* involving ITCE technologies and the producers of capital equipment
- the launch of a regional *Mobility* project in order to promote the intersection between telematics and transportation clusters.

Finally, the following actions were recommended within the structural line:

- the encouragement of regional governance as well as a consistent territorial marketing in order to underpin international competitiveness of ITCE clusters, to attract structural foreign investment, to develop innovative solutions and to create a solid international image
- the promotion of solid intermediate qualification, which is one of the handicaps of the region

- the attraction of high-quality and technical employment
- the financing of results-oriented innovation
- the development of physical accessibilities and the digital economy
- the generation of regional strategic information in order to underpin both public policy decision-makers as well as business managers in key areas such as markets, technologies, products, firms, S&T institutions, international programmes, etc.
- the development of an entrepreneurial culture and an innovative environment.

The northern region of Portugal has very peculiar characteristics as a less-favoured region. It is clear that economical, historical, geographical and technological specificities will vary from country to country and from region to region. Nevertheless, this case study could be replicated in developed as well as in developing countries attempting to implement foresight studies. The methodology is also relevant not only to small regions in developed countries (e.g. Wales in the UK, Newfoundland in Canada, Slovenia, etc.) but also to smaller economies (Sri Lanka, Paraguay, Guatemala, etc.).

Regardless of the uncertainty of the future, potential paths depend on overcoming the barriers. So, it is obvious that the identification of critical technologies is an important step towards a future that will be better if innovation policies are properly underpinned on the right competencies.

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Notes

[1]Although I am now with the University of Aveiro, this work was done while I was a Senior Researcher at INESC-Porto.