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Working Paper

IST R&D and innovation in Estonia

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1. Introduction and basic RTD and economic indicators

1.1. Why research and technology development…?

The World has seen series of changes to the paradigm of the role of R&D in the society during the last 50 years. World War II positioned basic research and it's military applications for a decade prominenty into a number of national strategies. During the Cold War applied research was seen, as the instrument for strengthening "strategic industries".

Series of authors (Gurova et al 2002; Cleaver 2002) advocate for the emerging need for the Central and East European transition economies to switch from investment based economy to innovation based one (Porter 1998).

During the 1990s, focus on the R&D activities has shifted in the post-industrial countries once again. Research and development is nowadays largely seen, as the instrument for sustained economic growth and rising quality of life of the citizens (Lundvall 1999).

In December 2001, Estonian latest developments are very much in-line with this rationale. The Riigikogu (Estonian Parliament) approved national research and development strategy "Knowledge based Estonia" (2001).

Estonian research and development (R&D) strategy sees the future of Estonia, as knowledge based society, in which research, orientated towards new knowledge, application of skills and knowledge and development of human resources, all combined in balance, are source of economic and labour competitiveness and quality of life. In knowledge based society scientific research and development are acknowledged as being the prerequisite for functioning and development of the society as a whole (Lukas 2001).

In basically all countries in the World, there is the need to concentrate efforts in R&D and innovation into certain sectors, in order to reach critical mass and enhance competitiveness of the nation.

Estonian R&D strategy formulates three key areas for research and development:

- user-friendly information society technologies,
- biomedicine (including bio- and gene technologies),
- and materials technology.

Though, sustainable and regionally balanced development, Estonian language and culture are seen to be common priorities across all thematic research areas.

Recorded economic growth (in candidate countries) so far has come from new, small enterprises or those sectors where foreign enterprises were willing to act as restructuring agents. These sectors did not grow due to government industrial policy, but basically as a result of business opportunities exploited by foreign investors and domestic entrepreneurs. (Radoševic 1998)

Although FDI to Estonia have shown constant annual growth since 1992, funding allocated to research and development activities is still comparatively low. RTD investments comprised 0.7% of Estonian GDP in 1999 and 2000. European Union is lagging at the same time with its 1,86% average GERD behind Japan and the United States. Finland and Sweden are the forerunners among the OECD countries, investing more than 3% of their GDP into R&D (OECD 2001/2).

Similarly to the R&D intensity (GERD/GDP), the labour productivity in the candidate countries is only half of the EU average. Slovenia is close to 71%, the Czech Republic and Hungary are around 58% of the average level, while Estonia is slightly below candidate countries average, reaching only 37% of the of the EU member states level in 1998 (Eurostat 2001)

It’s therefore crucial for Estonia, as transition economy, to use the temporary financial surges from the privatisation and FDI to establish well functioning knowledge production and innovation system in the nation.

The figure 1 below represents the relationship between R&D intensity (R&D expenditure per GDP) and overall economic development level. It is obvious that countries with higher R&D intensity are also better performers in general economic terms. Obviously, one might want to present the relationship in reverse, as higher GDP per capita level ease sustaining higher R&D investments. However, as figure indicates the R&D intensity is not higher only in absolute terms in the case of increasing GDP per capita, but also in relative terms, it is common understanding that higher R&D investments have positive effect on country’s welfare level.

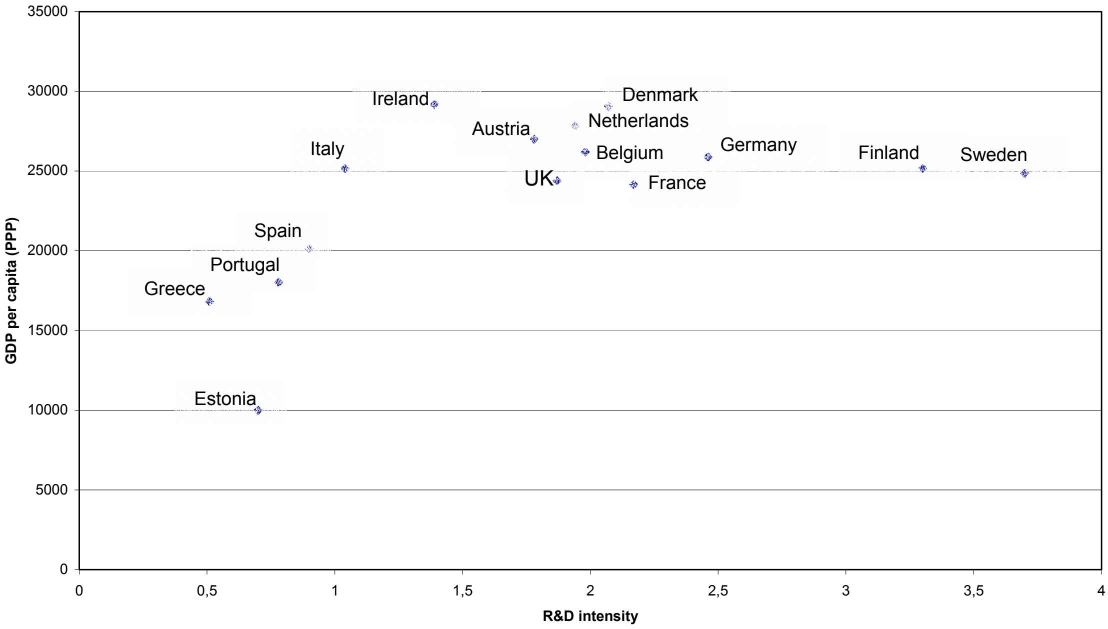

Figure 1. R&D intensity relative to GDP per capita (PPP), year 2000 (autor’s calculations based on OECD, Main Science and Technology Indicators, Volume 2001/2, 94 pp and National Accounts of OECD Countries, Volume 1, 2002).

Gross expenditure on research and development (GERD) and the number of researchers involved are both widely used, as indicators of RTD input, to measure the general build-up and “absorption capability” of the national innovation systems in the specific countries.

During the 1990s, Estonian R&D investments have comprised approximately 1/3 of the European average, increasing 13% annually in absolute terms, but staying around 0.6 .. 0.7% from the GDP. Continuation of this trend would mean, that Estonia would likely end up in European Union, but forced to compete using extensvely basic factor advantages (i.e. low wages, etc.), marginalised in terms of technology development and high value added production linkages, excessively dependant on budgetary transfers from EU (Radoševic 1998).

It is therefore important to create favourable environment for “in-depth” convergence with EU through the integration into R&D and product development networks, supported by the well established national R&D and innovation policies. It is essential that the mechanisms for co-ordination between the various national policies, affecting RTD and innovation, will be developed further, and the rise of the public expenditure planned in Estonia and several other Candidate Countries will be actually forthcoming for the support of the national RTD strategies (Stand-alone paper no 1, 2000).

The Parliament of Estonia foresees, with the recently adopted R&D strategy, the growth of GERD up to 1.5% of the GDP for 2006, while the latter is comparable to the current European

Union average. However, even this will not be enough for closing the gap. One has to keep in mind, that EU aims to rise R&D expenditure by 2010 up to 3% of GDP.

This kind of massive investment can't and shouldn't be made by the Government alone. Estonian future prosperity can be built up only with close involvement of private enterprise resources, rising at the same time also efficiency of the government research activities.

1.2. Basic IT R&D input-output indicators

Demolishment of the Soviet Union has affected RTD activities in Estonia, as many of the research institutions where closely tied into heavily centralised innovation system in the East. During the 10 years of independence, liberal open market environment and privatisation have contributed to restructuring Estonian economy. The Government intervention by the means of industrial non-existant and the role of science and technology policy has been also rather marginal in wider policy context. Accordingly industrial research has been left to suffer from the shock of a rapid transition to the private sector model.Research institutes have been let to struggle along with reduced public funding, embodied into universities, but no active support for reorientating R&D activities (Dyker and Radoševic, 1999).

R&D expenditure by the type of R&D activity, 1992–1999 (exluding private businesses)

Table 1

Year	Total expenditures, thousand kroons	of which basic research, thousand kroons	%	applied research, thousand kroons	%	Experimental development, thousand kroons	%
1992	100 122	79 508	79.4	18 796	18.8	1 818	1.8
1993	130 155	80 343	61.7	38 705	29.8	11 107	8.5
1994	216 460	121 281	56.0	78 917	36.5	16 262	7.5
1995	250 604	132 014	52.7	89 042	35.5	29 548	11.8
1996	299 656	168 553	56.3	90 556	30.2	40 547	13.5
1997	379 741	188 144	49.5	141 272	37.2	50 325	13.3
1998	375 734	180 398	48.0	147 463	39.2	47 873	12.8
1999	435 795	216 918	49.8	150 515	34.5	68 362	15.7

Source: Statistical Office of Estonia: Teadus, Science 1999

The distribution of RTD financing between basic and applied research and experimental development has undergone gradual changes by the type of R&D activity as compared to the beginning of the 1990ies. In 1992 approximately 80% of RTD funding was channelled to basic research, and the rest 20 was allocated to applied research. In 1999 the dominance of basic research has fallen to 50%, while the link between research labs and industry is still very weak.

It is imperative to ensure structural balance between different types of research to enable proper functioning of the National Innovation System (See Part I, 1.3). Basic research alone does not sustain economic as well as scientific competitiveness. Applied research and experimental development, which are comparatively more market tailored, should provide well functioning links between the science, economy and society, having also a distinct income generating function for the universities and public research entities. On the other hand basic research should not be undermined either, as it is a basis for quality higher education, applied research and experimental development.

Public sector RTD expenditure comprises in Estonia 79% of the Gross Expenditure on Research and Development (GERD), while in the OECD countries public funding comprises 39% and the rest derives from private sources. The advantage of engaging private sources into R&D is essentially related to public sector's ability to pursue more market tailored RTD activities, providing the rest of public co-funding with potentially higher returns. Breakdown of the RTD expenditures by the type of activity follows in the OECD countries frequently the rule of 1/3 to basic research and 2/3 for applied research and experimental development.

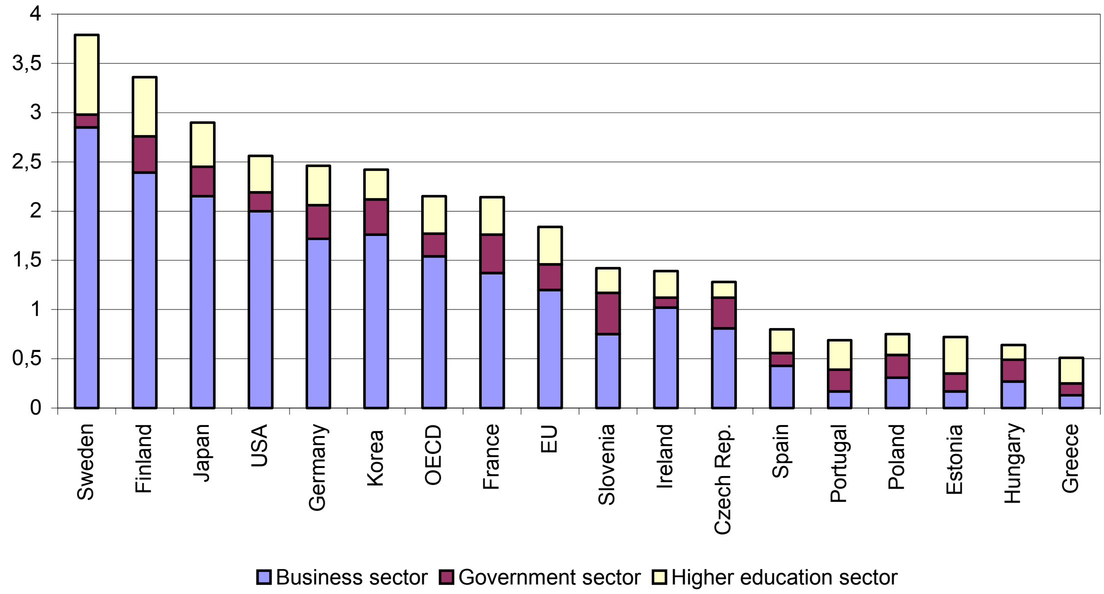

Figure 2. Participation in research and development activities in 1999 (% GDP)

Souce: Research and Development in Estonia 2000-2001

However, plain check of the absolute amounts or balancing of the R&D expenditure by the type of activity is cleary not enough. Having a single segment broken in the chain from the knowledge production to it's application for the benefit of the society makes the whole innovation system to suffer. Accordingly the public funding principles and general macroeconomic environment (taxation, etc) have to support proper functioning and continuous development of the national innovation system, formation of the public-private (university-enterprise) R&D partnerships. Only with the strong, well functioning and integral National Innovation System, mid-term gradual shift from the public RTD financing to private funding from well established industries could be expected.

Developments in Estonia will follow similar patterns, provided a proper R&D and innovation policy is implemented, critical mass of intenationally well connected human capital is built up for the further development of the innovation system, and the activities supported from the public funds are to put into catalysing role, attracting growth of the private R&D investments and inflow of the related foreign investments.

Public sector funding, though by far the most dominating in RTD expenditures, has not been consistent enough to provide stability to research community. The figure below demonstrates real effective growth of public and higher education sectors' RTD expenditures through years 1996-2000, normalised against relevant GDP deflators. As we seen, real growth of expenditures has fluctuated, being in 2000 negative again.

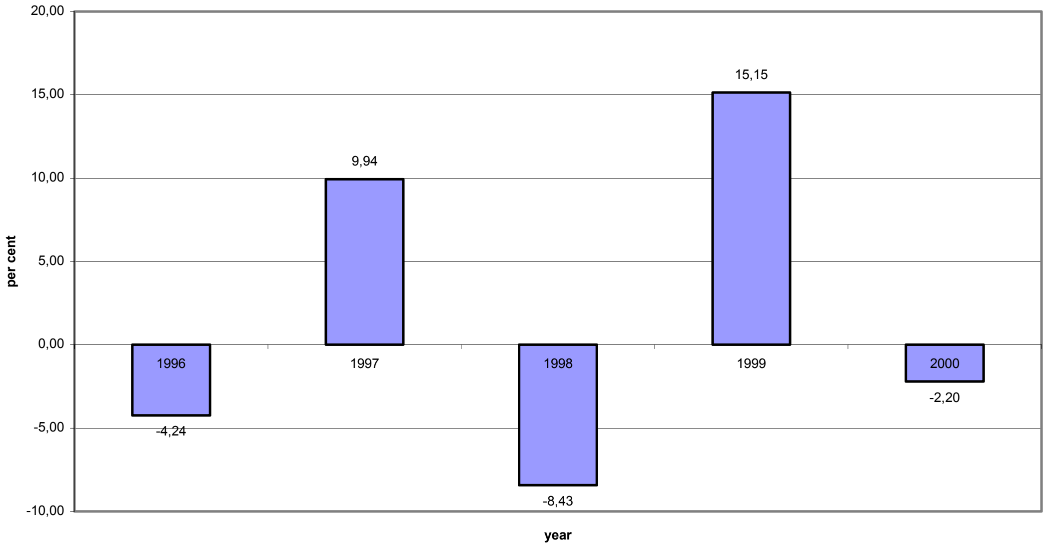

Figure 3. Real Growth of RTD Expenditures by Public and Higher Education sectors (*Source:* author's calculation based on Statistical Office of Estonia 2001, Estonian Bank 2002)

Today most substantial proportion of the Estonian public RTD funding goes to the natural sciences, which absorb 37% of all RTD resources. Technology and Engineering is second largest field for RTD investments, attracting 19% of the resources. Estonian Gross R&D expenditure has stayed proportionally quite stable during the last four years. However share of the investments into technology domain has fallen steadily within the last four years, while the role of agricultural sciences and humanities has risen.

Gross R&D expenditure by field of science, 1995–1999

T a b l e 2

	1996 thousand kroons	%	**1997** thousand kroons	%	**1998** thousand kroons	%	**1999** thousand kroons	%
Natural sciences	111 514	37	122 978	32	145 517	39	162 191	37
Engineering	76 617	26	93 536	25	76 969	20	84 899	19
Medical sciences	32 722	11	61 973	16	33 640	9	47 962	11
Agricultural sciences	24 591	8	35 768	9	49 982	13	53 435	12
Social sciences	26 013	9	32 669	9	33 736	9	39 839	9
Humanities	28 199	9	32 817	9	35 890	10	47 469	11
Total	**299 656**	**100**	**379 741**	**100**	**375 734**	**100**	**435 795**	**100**

Source: Statistical Office of Estonia: Teadus, Science 1999

Stagnate R&D appropriations from the State Budget, weak domestic industries, and very limited access to the international technology alliances have lead in many cases to the situation, where no significant new R&D directions were opened during the 1990s, and the system concentrates on saving existing R&D personnel and research directions.

In this situation grants from the Soros' International Science Foundation, HESP, Tempus, European Community 4th RTD Framework Programme, and other international sources have been of major help in retarding brain drain, retaining the existing research capacity in Estonia.

Integration to the European RTD networks, like 5th RTD Framework Programme, Cost and Eureka has openned new prospectives for research and technology development in Estonia. Full exploitation of these new opportunities is still dependant on specific instruments to be launched both for stengthening the existing centres of excellence and building capacity in the research directions needed for the future competitiveness of the society.

1.3. Public IST R&D expenditure

Information Society technologies (IST) are increasingly transforming our lives. Their social and economic impact is far reaching and represents key opportunities and challenges for individuals, industry and governments. Beyond new forms of doing business and accessing services, the expectations of citizens for a better quality of life are high as they start to appreciate the wider range of possibilities that IST applications and products can offer (IST Work Programme 2001).

IST vision targets development of an Information Society that is inclusive for all. Independent advisory group to the European Community IST Programme suggests in its report on *"Orientations for WP2000 and beyond"* (ISTAG 1999), the that IST R&D activities in Europe should further focus its activities on the realisation of a above vision that is user centred and aims at achieving an "ambient intelligence landscape".

Estonian R&D strategy sets information society technologies, as one of the key areas for research and development in Estonia. We believe therefore, that it is natural to base the national IST R&D strategy on the ISTAG vision, building on the Estonian demonstrated strengths in specific sectors, which are critical for realising the vision.

Keeping the above vision in mind, evaluation team has reviewed the list of R&D projects, supported from the Estonian public funds[1] in 2000-2001, identifying the projects (see Annex III), which contribute towards realising the IST vision.

Estonian public sector R&D investments comprise of the funding provided by the following sources:

- Grants from the Estonian Science Foundation;
- Targeted research funding from the Ministry of Education;
- Support to the national programmes, infrastructure and PhD studies;
- Grants and loans from the Estonian Technology Agency.

Estonian Science Foundation (ESF) supports basic and applied R&D with aims to develop novel research themes, support graduate studies, bring young researchers to the science, and develop international R&D co-operation (incl. through the programmes of the European Science Foundation). Approximately 71 million kroons have been allocated in 2000 and 2001 from the State Budget to fulfill these objectives.

Targeted funding is the main research policy instrument of the Ministry of Education. The obective of this instrument is to direct public research themes in Estonia by supporting specific (up to 5 year) research and development initiatives in the universities and R&D institutions. Total funding, distributed via this instrument in 2000, was 156 million kroons.

In addition to targeted funding, approximately 58 million kroons were spent in 2000 for the support to the research infrastructures. The remaing part of the Government R&D budget (42 million kroons) was invested into national programmes, participation in the 5th Framework Programme, and support to the PhD studies (Laasberg *et al.*, 2001)
Estonian Technology Agency (ESTAG) is the governmental financing body for applied and industrial R&D in Estonia. ESTAG supports technological development, promoting competitiveness of the Estonian enterprises and economy, as the whole.

[1] At this stage targeted funding from 2000, and the Estonian Science Foundation grants from 2000-2001, and ESTAG grants and loans from 2000-2001 were analysed.

Estonian public IT R&D funding, in thousand kroons

T a b l e 3

	1999	**2000**	**2001**
Estonian Science Foundation		2539	2219
Targeted funding	9492	8743	n/a
Estonian Technology Agency	n/a	n/a	n/a
Total		**11282**	

Sources: Estonian Science Foundation, Ministry of Education

In 2000, the above agencies have allocated around 11 million kroons for the IT R&D activities. Estonian Science Foundation has provided 47 grants of 54 thousand kroons per year on average, which comprises all together only 3.5% of the total R&D grant funding from ESF. The largest grants were up to 170 thousand kroons and the smallest being only 15 thousand kroons. All together 36 contracts of 62 thousand kroons on average have been granted by ESF in 2001.

14 IT R&D projects with the 8.7 million kroon total budget were supported from the targeted funding last year, i.e. approximately 5.6% of the targeted funding was allocated for IT R&D in 2000. Projects funded from this source are of much larger size than ESF grants – average funding from this source was 678 thousand kroons per year.

Estonian Technology Agency has had no significant influence to the IT R&D in Estonia, as only 4 IT product development grants and loans[2] are currently in force. The estimated 2 million kroon total amount of these loans is by far too small, to have any impact to the development of the IT enterprise sector.

As discribed above the weaknesses of the current R&D funding system are poorly defined objectives and substantial fragmentation of resources. However, as the in-depth evaluation of RTD funding system is outside the scope of the present paper, a separate independent international evaluation on the effectiveness of funding instruments applied presently should be organised.

Estonian Language Technology Programme is the only example of a specific well targeted national initiative for IT R&D so far. Funding of the program has been provided on the annual basis and outside regular public R&D funding schemes. However ending up with no funding at all in the 2001 State Budget and no clearly established funding frameworks proves that kind of system very unstable.

Therefore, establishment of multi-annual R&D funding instruments, which aim at solving specific problems in society, should be considered carefully. Also bureaucratic burdens should be reduced drastically, providing those more stability to the strategically important R&D efforts. Better focusing and concentration of the resources to the to-be established priority areas within the IST domain should be considered.

1.4. Innovation and enterprise IT R&D investments

Estonian IT enterprises are inclined to perform, according to the findings of the survey conducted, specific application development (eg. tailor-made software, information systems) rather than systematic R&D activity in more broader sense.. Application development activities are substantially less tied to R&D focusing on the development of new technology or upgrading the already existing one(s) instead.

To highlight this, 77% of all interviewed IT companies claimed to have introduced new product, new service or pursued product development during 1999-2000. The share is

[2] All the above contracts have been derived from the Estonian Innovation Foundation, predecessor of ESTAG.

relatively high indicating that companies work on finding new solutions in the competitive environment. New products and services are mostly developed by the companies themselves, only some 10-15%of the respondents admitted using collaborative measures with other companies or universities.

Introduction of new production processes is more rare, as due to type of economic activity and target markets only small part of the Estonian companies have solid production lines and processes in place, etc.

45% of the companies followed process innovation during the period of 1999-2000. Likewise in the case of product innovation, 77% of the enterprises admitted in-house elaboration. Thus, main source for both process as well as product innovation is derived inside companies.

The official statistics reports remarkable changes in the structure of the enterprise R&D activities in 1998-1999. It is very likely, that there is a strong occasional element in these data, would it be caused by a small number of enterprises active in R&D or random errors in the data collection. Therefore, one has to be careful in interpreting these figures as final truth.

Intramural (enterprise) research and development expenditures by type and economic activity, percentages

Table 4

Year	*Economic activity*	*Basic research*	*Applied research*	*Experimental development*		
				product, material, service	techno-logical process or system	other
1998	Manufacture of electrical and optical instruments	-	3	57	32	8
	Transport, storage, communication	2	-	89	9	-
	Computer services	-	40	2	58	-
1999	Manufacture of electrical and optical instruments	-	1	83	7	9
	Transport, storage and communication	-	3	55	42	-
	Computer services	-	30	10	60	-

Source: Statistical yearbook of Estonia 2000

Micro level approach to R&D issues in enterprises, according to the eVikings survey reveals one of the possible reasons for errors in official statistics – a number of IT companies claim unconsciousnessly their routine product development activities being R&D, despite it’s not actually the case by the following definition:

Research and experimental development (R&D) comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications. […] For a software development project to be classified as R&D, its completion must be dependant on the development of a scientific and/or technological advance, and the aim of the project must be resolution of a scientific and/or technological uncertainty on a systematic basis (Frascati Manual 1993).

It is very likely, that the statistical data on business enterprise R&D we have so far, is inconsistent. Therefore only awareness and training actions together with systematic collection of the profiles of the R&D projects, on-going with the build-up of the Estonian Research and Development Information System (www.esis.ee) would provide us with better basis for further analysis of the situation.

2. Human resources

2.1. R&D personnel and the performance of higher education system

Existence of the qualified human resources is clearly the most important input to any kind of R&D activity. According to Statistical Office of Estonia there were altogether about 4000 people involved in R&D in Estonia in 2000 (excluding those acting in enterprises), which makes 0.29% of total population. In Finland the relevant figure is somewhere around 0,6% and Sweden 0,7% (UNESCO Statistical Yearbook 1999). Thus, in relative scales the number of R&D personnel in Estonia is approximately 2-2,5 times lower than in neighbouring advanced economies.

Personnel engaged in research and development by field of science[3]

T a b l e 5

Field of science	*Scientists and engineers in 2000 (FTE)*	*Scientists and engineers in 2000*	*Scientists and engineers in 1999*	*Funding per personnel in 1999 (thousand kroons)*
Natural sciences		1 207	1222	134
Engineering		707	697	120
Medical sciences		443	433	108
Agricultural sciences		275	282	194
Social sciences		695	598	57
Humanities		736	680	64
TOTAL		**4 063**	**3912**	**109**

Sources: Statistical Office of Estonia 1999-2000, independent calculations

The table above indicates the total number of R&D personnel in Estonia, outlining also distribution of the personnel by field of science. As seen from the figure, the number of engineering and technology related R&D personnel has second position next to natural sciences.

Personnel engaged in R&D in business enterprise sector, 1998-1999

T a b l e 6

	Economic activity	**Scientists and engineers**	**Technicians**
1998	Manufacture of electrical and optical instruments	15	4
	Transport, storage, communication	95	49
	Computer services	43	27
	Total R&D personnel in enterprises	**468**	**173**
1999	Manufacture of electrical and optical instruments	32	n/a
	Transport, storage and communication	59	55
	Computer services	67	35
	Total R&D personnel in enterprises	**651**	**235**

Source: Statistical yearbook of Estonia, 2000

[3] Not including business sector R&D personnel.

Only data on the business enterprise R&D personnel could be found from the Statistical Office.The number of IT R&D personnel is not directly available in the official statistics. From the level of the public funding R&D staff of some 50..60 people could be estimated[4].

The official statistics reports once again, as seen above with the enterprise R&D expenditures, heavy changes in the personnel numbers in 1998-1999.

There are major differences reported between the public funding per R&D personnel and the rates of the IT experts in private sector, whereas the latter receive at least 4 times higher salaries. It is reasonable to believe, that the rise of the public R&D expenditure with no clear shifts in funding rules, will lead towards higher salaries in the public sector, but would not contribute much to the performance of the whole innovation system. (Romer 2000)

In order to reach the knowledge production (R&D) level and competitiveness of the western economies, consistent growth of number of R&D and product development personnel in enterprise sector is required (Eksportööride Uuring 2001).

The table below highlights the number of master and doctoral students enrolled and admitted as for 1999/2000. Enrolment and admittance is different in the case of master and doctoral studies – when master studies are most popular for commercial and business administration, medicine and public health perform a major role in doctoral studies.

Number of students at master and doctor courses by field of study *(enrolment and admittance — 1999/2000, graduates — 1998/99)*

Table 6

	Master courses			Doctor courses		
	Enrolment	Admittance	Graduates	Enrolment	Admittance	Graduates
TOTAL	**3 447**	**1 462**	**672**	**1251**	**386**	**135**
Teacher training	377	191	70	23	9	-
Fine and applied arts	179	49	17	8	1	-
Humanities	322	99	46	121	35	5
Religion and theology	37	17	15	13	3	-
Social and behavioural sciences	390	198	39	75	21	3
Commercial and business administration	928	338	153	56	30	2
Law and jurisprudence	81	50	7	15	4	-
Natural sciences	224	83	39	221	51	24
Mathematics and computer science	**115**	**57**	**14**	**47**	**14**	**6**
Medicine and public health	136	112	164	457	149	78
Engineering	346	155	63	135	41	9
Architecture and town-planning	19	3	2			
Agriculture, forestry and fishery	147	53	19	52	22	7
Domestic science	2	1	1			
Mass communication and documentation	47	10	9	11	1	1

Source: Statistical Office of Estonia: Teadus, Science 1999

[4] More information to become available with the IT R&D project profiles collected for the Estonian R&D information system.

Just for comparison purposes, when in Estonia approximately 3,3 per cent of Master students and 3,7 per cent of Doctoral Students are enrolled into Mathematics and Computer Science, then in 1999 in Finland the relevant numbers were around 20 per cent for Masters and 16 for Doctoral Students (Ministry of Education, Finland).

Places allocated to the mathematics and computer science degree studies are relatively modest, most of other sciences outperform the latter one. Admittance to IT bachelor and master studies in the Universities has risen significantly during the the second part of 1990s. Therefore significant growth of the number of graduates could be expected in the years to come.

Higher education in mathematics and computer science

Table 7

		1994	1995	1996	1997	1998	1999	2000
Diploma studies	Admittance				75	54	188	335
	Students				75	126	314	576
	Graduates							3
Bachelor studies	Admittance	88	90	91	159	179	214	309
	Students	423	370	361	551	671	775	1 044
	Graduates	33	64	54	35	36	56	76
Master studies	Admittance	22	16	26	39	28	57	73
	Students	49	49	58	79	80	115	150
	Graduates	15	15	10	11	14	14	20
Doctor studies	Admittance	7	7	10	12	13	14	11
	Students	10	16	23	31	43	47	49
	Graduates						6	4

Source: Statistical yearbook of Estonia, 2000.

As a worrying tendency roughly half of the students are leaving universities before graduation, which happens typically after 2-3 years of studies. Unfortunatelly no specific studies on the performance of the Estonian IT higher education system, and the students' feedback, have been conducted. We can therefore only suspect, that the lack of IT specialists in the market and higher education system weak response to the rapidly changing needs of the society have been causing that kind of negative developments[5].

It is of primer interest in the context of human resources what are the real needs for qualified IT specialists as seen from the prospective of IT industry and science on the whole. According to IDC, jobs in the ICT industry and in the industries that use ICT comprise some 8.3% of the total employment in the Western Europe, and will account for a share of 13.4% in 2003 (EITO 2001).

In Estonia, there is a study on the need for IT specialists currently prepared by the Ministry of Education. While awaiting results of this study only estimations can be used. Jaan Oruaas from the Estonian Information Technology Society suggests (Oruaas), that there will be a shortage of about 6000 IT specialists in 2002 in Estonia following the present trend and considering present enrolment. If the number of highly literate (bachelor level) computer specialists entering the job market is held at a level of 2500 each year, the potential need for such staff will fully be reached only by 2020, meaning a lag of at least 10 years behind market demand. Oruaas suggests to increase the number of highly literate computer graduates to 2000 by 2002 and by 2005 there have to be 4000 computer literate persons. He argues, that otherwise general slowdown in the growth of Estonian IT sector can be expected, and shortfall of the qualified personnel will turn into main impediment in the development process.

[5] From Higher education accreditation reports for University of Tartu and Tallinn Technical University, 1999.

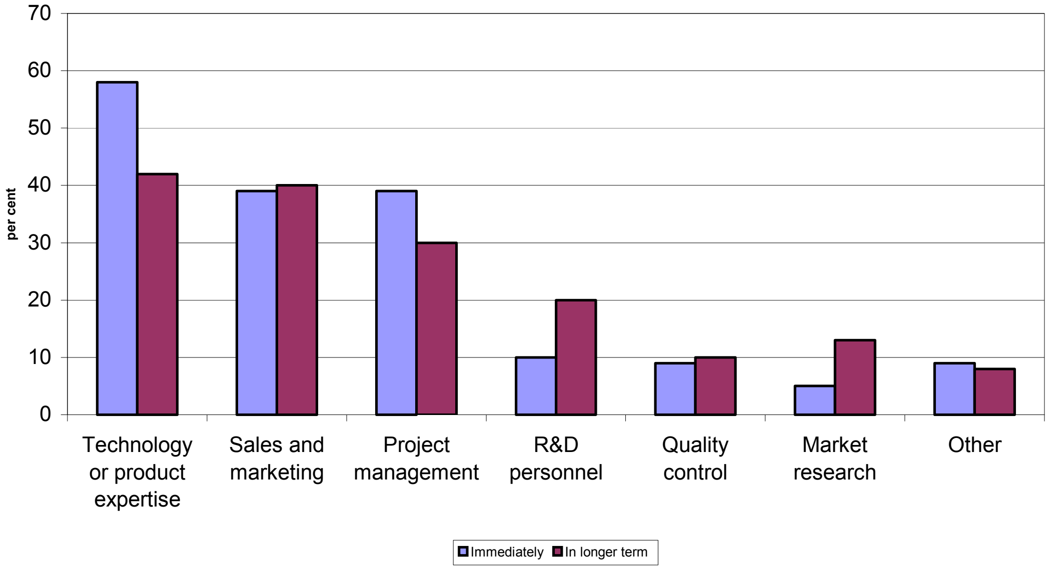

Figure 4. IT enterprise need for additional personnel

To overcome the gap between higher education outlet and market needs, 86% of the sample enterprises claimed to invest into personnel training and weighted average investment into training comprises appoximately 3% of the turnover of the companies.

As for 2001, 56% of the companies were in immediate need for specialists on specific products or technologies, 39% sought for project managers and sales staff. Only 10% experinece currently the lack of research and development personnel and 20% expect need for the additional R&D staff in longer term.

2.2. Management and strategic planning

It is important to point out from the management prospective, that approximately 8% of the IT companies try to foresee market developments for up to 6 month in advance, 71% for 1-2 years in advance, and rest of 21% up to 5 years in advance. Two third of the companies have their strategies formulated in written.

Still, 50% of the sample IT companies reported, their “strategic” business plans being for up to one year or there is no plan at all. 24% answered, that they review and update their strategic plans on the annual basis, while 70% showed 3-6 month strategic plan update cycles. The latter cannot be really considered as serious strategies, but should be rather treated as tactical decisions or operational management.

One should normally presume at least 2..3-year planning and implementation periods for competitive research and development activities, after what the process of delivering the products to market will be pursued. It is therefore implicitly seen that max. 20% companies questionned could be possibly able of conducting any R&D activities under the current practice for strategic planning.

Substantial lack of the qualified personnel (seen above) leads very directly to retarding innovative development activities, as existing key specialists are tailored to the management of operative business processes. Therefore less time can be dedicated for research and development activities. A resilient solution to the lack of qualified specialists are active personnel training programs undertaken within a company, creating a cadre of skilled and necessity driven human capital.

The recent innovation policy study for European Commission DG Enterprise (Stand-alone paper no 2, 2001) concludes that, although the candidate countries' governments have retained relatively high levels of expenditure on education and the population generally possess a high level of education, the available data and analysis point to a mismatch between the skills developed and the needs of industry and commerce.

The above study also emphasises, that there are substantial deficiencies at the level of managerial and skilled employment i.e. the types of jobs occupied by university graduates. As this is the category of persons, normally responsible for managing innovation projects, there are important implications to future innovation policy. Need for the development of human resources for innovation has begun to be recognised as a policy issue in the candidate countries only during the last couple of years. Higher education and industry have started to develop courses together on the technical and organisational aspects of engineering, but the availability of qualified lecturers is a problem that is yet to be solved.

Joint efforts of the Estonian ICT enterprises and the Government for launching IT College in 2000 have been a good start in overcoming the depicted problems. The initiation of that kind of joint efforts for upgrading qualification of the IT enterprise personnel, is as almost perfect textbook example of the initiation of cluster development from the Porter's cluster theory (Porter 1998).

However, in short term scale most of the Estonian IT companies will remain busy in solving their immediate needs for additional technology experts, management and sales personnel. Nevertheless relevant efforts have been made recently by the Government. Similar efforts should be repeated in the graduate education to support capacity building and initiate further shifts towards rising industrial IT R&D activity in Estonia. eLearning could be seen, as an important instrument, enabling use of the best experts internationally, and also providing opportunities for continued life-long learning to the practitioners in the enterprises.

3. Key institutions, research competence areas

3.1. Public good research

The landscape of R&D activity in IT is relatively constrained for the number of qualified participants. Value added R&D activity is only a domain of few institutional players, while majority of R&D results deriving from universities and RTD labs are mostly basic research oriented without significant market relevance. Upon the mapping of such R&D structures in Estonia one could observe Tartu University and Tallinn Technical University as representatives of higher education system and research, and few private research based enterprises, as the key market players. The former ones are focused to a large extent on basic research with less substantial dedication also onto applied research, the latter ones specialise for the natural reasons on the market tailored solutions, mainly pusuing experimental development activities.

The following summaries about the organisation and the research conducted in the University of Tartu and in the Tallinn Technical University are mostly based on the Research Evaluation in the year 2000 (Arzen *et al.* 2000, Thoma *et al.* 2000), and the higher education accreditation reports from 1999 (Impagliazzo *et al.* 1999). Abbreviation of each unit name is given in brackets alongside with the evaluation result.

Tallinn Technical University (www.ttu.ee) is the second largest university in Estonia, providing an interdisciplinary higher education and research.

Faculty of Information Technology incorporates 5 departments:
- Computer Science
- Computer Engineering
- Informatics
- Radio and Communication Engineering
- Rehabilitation Technology Centre

Department of Computer Engineering (DCE, 5) was established in 1967 and it has three chairs: Computer Engineering and Diagnostics, Digital Systems Design, Systems Programming.

Basic research areas of DCE are design and diagnostics of digital systems. The following main research fields can be identified: decision diagrams, test pattern generation, simulation of circuits and systems, and design error diagnosis. The research activities of the department have a rather long history going back to 1970.

The group of scientists of DCE has developed a novel diagnostic model for digital systems based on decision diagrams, a new hierarchical approach to test generation, methods and a set of tools for test generation and fault simulation, new analysis and partitioning methods for hardware/software co-design used in designing of cryptographic processor.
The group has applicable outputs and, as a consequence, good perspectives to implement the obtained results. Unfortunately, at this moment there are not any industrial and marketing activities. International co-operation with the relevant industries should be seeked.

Department of Informatics (DOI, 4-) operates since September 1992 and the instruction and research at the department are organised through the four chairs: Foundations of Informatics, Software Engineering, Information Systems, and Knowledge-Based Systems.

Main research activities performed under the Institute of Informatics concern new testing and auditing methods for distributed uncertain knowledge based systems, a novel approach to knowledge based software testing, a new agent-oriented methodology for modelling, design and business information systems, and a electronic commerce methodology have been developed. The department is active in establishing contacts with industry and carries out several very application oriented research projects.

Department of Radio and Communication Engineering (DRCE, 3+) was founded in 1965. There are 5 chairs: Radio Engineering, Telecommunications, Microwave Engineering, Signal Processing, and Communication Equipment.

The activities of the department are focused on measurement systems in radio engineering, applications of digital spectral analysis of multi-channel signals, and applications in communication and biomedical engineering; new methods and technologies in telecommunication with focus on multimedia transmission over the GPRS network[6]; design of microwave equipment design[7]; research in new complex sonar signals and the development of precision sonars for sea ground mapping using digital signal processing. Finally research is conducted to support the standardisation and testing of the telecommunication equipment being imported to Estonia or designed and produced locally.

The department has novel results from research and development, but they are mostly application driven. The department has not been successful in applying for funds and grants, and has a rather high average age of the research staff. However, on the other side strong contacts with industry and good innovative experience have vigorously supported the development of the department. Yet, there is no international co-operation in basic research.

The Faculty of Systems Engineering consists of three departments:

- Computer Control
- Electronics
- Biomedical Engineering Centre

The aim of the faculty is to perform research in IT as used and required for design and implementation of embedded computer applications. The major research areas are theoretical and practical aspects of systems modelling, design and software development, methods and tools for electronic design and system development, and modelling, monitoring, and control of natural and artificial phenomena and processes.

Department of Computer Control formally consists of five chairs: real-time systems, automatic control and systems analysis, circuit theory and design, automation and process control, and theoretical informatics. The core research of the department has its origins in automatic control and automation, with the exception of the chair in circuit theory and design that has stronger connections to general electrical engineering.

The major problem for the department is the lack of students and small amount of generated theses. The groups are also critically small, making it difficult to bring in large contracts. The group has also suffered excessive brain drain to industry. The international contact network and publications vary a lot between the different groups from quite good to unacceptable. The internal structure of the department is not consistent; especially it is the case for the chair on circuit theory and design.

Department of Electronics consists of three chairs: applied electronics, electronics design, and electronic measurements. The research areas are the following:

- Theoretical and experimental study of new semi-conductor materials;
- Application of the new materials for development of electronic components;
- Development of measurement instruments and systems based on synchronous signal processing;
- Applications of measurement technology in technical test and diagnostics and in medical diagnosis.

In their vision for the future the aim is to additionally also work on electronic realisation of large-scale information systems, e.g., radar systems, navigation systems, and traffic monitoring systems, and to develop methods for design of diagnostic systems in medical applications.

[6] WAY application development and testing centre in collaboration with Ericsson.
[7] Long time experience in military atmospheric optical communication link design

In order for the department to succeed with its ambition to move towards large-scale information systems it is crucial that the connections to software research groups are tightened. The same holds also for small embedded mobile systems where hardware and software co-design is becoming an increasingly important technology.

Biomedical Engineering Centre (BEC, 4+) consists of two chairs: radio physics and biomedical engineering. The speciality of the centre is bio-electromagnetic systems, in particular interpretation of bioelectrical signals (EEG, ECG, EMG, etc), electromagnetic field interaction with biological systems (e.g., mobile phone effects), and applications of electromagnetic radiation for information gathering about physiological processes and systems.

The following are the main research activities and results. Work on microwave radiometry for cancer detection has been going in 1994-1998. An operational system has been developed that has been used at clinical experiments at a Tallinn hospital. Sensitivity of biological systems towards low-intensive electromagnetic radiation is another current area of the centre. Interesting results have been obtained concerning mobile phone effects. Other areas are coherent laser-based photo-detection for biomedical measurements, non-linear filtering of physiological signals, and evaluation of the quality of different heart rate adaptation algorithms for rate adaptive pace makers. The centre has lots of research contacts, mainly in biomedicine, and contacts with hospitals. The amount of industrial contacts is, however, small.

Institute of Cybernetics (IOC, 4-) was founded in 1960 as an institute of Estonian Academy of Sciences, associated with Tallinn Technical University in 1997.
IOC research themes in computer science include mathematical logic, automated program synthesis, knowledge-based software engineering, and software systems; and speech technology, conceptual analysis, control systems theory.

The leading researchers are working only part-time at IOC, and full-time mainly at the Tallinn Technical University (Thoma *et al.* 2000). Therefore, research evaluation strongly suggested the leading researchers to reconsider the division of work between the university and IOC. Evaluators also recommended that the research groups should put more effort to the development of their skills for coping with practical problems which would lead to a more active co-operation with the industry.

University of Tartu (www.ut.ee) is the oldest higher education establishment in Estonia, following the structure of classical *universitas*.

Department of Mathematics and Informatics of University of Tartu consists of 4 separate institutes:

- Institute of Computer Science
- Institute of Mathematical Statistics
- Institute of Pure Mathematics
- Institute of Applied Mathematics

Institute of Computer Science (ICS, 3+) was formed in 1993 on the basis of the Department of Programming established already in 1979. The Institute hosts two chairs: Theoretical Computer Science and the Software Systems. ICS has long traditions in computer science, especially in theoretical computer science and programming environments. More recent research areas include data security; computer based teaching and learning, natural language processing and programming environments.

Centre of Strategic Competence (CSC, 3) was founded in 1997 – the initiative was reinforced by the urgent necessity for conducting research activities in key technological areas. The Department of Information Technology (DIT) is a unit under CSC, responsible for the IT R&D activities. Accordingly, DIT has collected researchers from rather diverse areas, like public administration, distributed systems, psychology and computer science. The aim has been to promote interdisciplinary research, a key vision being coined as "information ecologies". Individual research topics include multi-agent systems, computer-assisted learning, distributed computing, economics and ethics of information ecologies, and models of representation of knowledge.

Partly because of very limited resources for the research activities, and partly because of the great number of diverse research directions carried out by the very small staff, none of the current IT R&D themes in Tartu has been able to become a significant group internationally, in spite of the competence of the research staff.

Contacts to the industry should be strengthened significantly. In particular, the institute should look for research topics that are relevant for Estonian software industry, and that can be partially funded by the industry. There should be special efforts for more systematic PhD guidance and training.

3.2. Key players in private sector IT R&D

Most of the private sector IT enterprises are undercapitalised comparied to their western counterparts both in terms of human capital and finances, to conduct any serious research and development work. (Porter *et al.* 2002) Although only 10% of the Estonian IT enterprises are interested in foreign investment into their company.

Own development work is the main source for upgrading the products or processes for almost 70% of the enterprises covered by the study. In 1999-2000, half of the enterprises have upgraded their production processes, 17% rely mostly on inward technology transfer and 12% consider upgrading their products not important.

Most of the (product) development orientated companies are however in the middle of the learning curve:
- imitating major development trends towards information society and selling their eBusiness, eGovernment, etc related production predominantly domestically;
- or sub-contracting their resources to the foreign clients, while relaying on the relatively lower cost base in Estonia.

65% of the IT enterprises have contacted foreign enterprises with proposals for concrete co-operation agreements, and 34% have participated to the foreign public tenders. Only 9% are actually co-operating to the domestic universities. Basically no co-operation with foreign universities or research institutes has been reported.

All together up to five companies with a few thousand employees can be identified, which could be able of subcontracting IT R&D work. In addition to that another half a dozen IT R&D intensive start-ups could be listed.

Web sites of respective enterprises and other public documents have been used in compiling the following review.

Cybernetica Ltd. (www.cyber.ee) was founded on May 8, 1997, when the Institute of Cybernetics of the Estonian Academy of Sciences was reorganised. The company is registered in the Ministry of Education as Estonia's first private research and development institution.

Cybernetica offers a wide selection of information security products and services, ranging from training and consultation to different "cutting edge" security systems. The latest projects of Cybernetica Ltd. have covered scattered control and operation systems in lighthouses and other navigation control systems (former Ekta Development Centre).

Cybernetica Ltd. is involved in several research projects, which include among the others:

- Timestamping and electronic document (E-Doc)

The Estonian government is going to implement legislative framework for giving legal power to electronic documents. So that E-Doc can be legally accepted as evidence, it must be possible to answer the question "To what, when and by who was the signature given?".

- Estonian ID card project ID.EE

The purpose of the project is to formulate the possibilities of implementing a new type of identification document (ID card) in Estonia. The card must be hard to duplicate and it must contain both visual and machine-readable information. The card can also be used for safely storing the official certificate used for signing E-Docs mentioned above[8].

Docobo Ltd. (www.docobo.com) is the RTD based start-up focusing in telemedicine area. The company has been successful in applying for funding from the EC Information Society Technologies programme and develops patient home care and monitoring systems.

Artec Design Group Ltd. (www.artecdesign.com) is a privately held professional engineering services and research company established in 1998. They provide procurement services for prototypes and full productions. Artec's VLSI Research and Engineering Division was introduced in the beginning of 1999 to address the increasing demand for integrated circuit design. It offers system-on-a-chip designs targeting ASIC and FPGA technologies.

JOT Estonia Ltd. has been operating in Tallinn since 1991, and is the winner of the annual technology development award 2000, recently granted by Enterprise Estonia.
JOT Automation combines robots and manufacturing machinery into automated workstations, combining then these automation cells into automated lines. JOT's clients are the world leaders in the telecommunications and electronics industries. That is why JOT has built up a global manufacturing and support network close by our customers' production facilities.

JOT Estonian unit has special expertise in the development and manufacturing of robotic applications for electronics industry and in testing automation. According to Estonian Investment Agency JOT Estonia has remarkable investments into research and development, approximately 15% of their turnover, which accounted for 87 million EEK in 2000. The company claims to have about 40% of it's staff related to R&D.

Regio Ltd. (www.regio.ee) was founded in December 1990. In the early years Regio's main business activity was map publishing. Today Regio Ltd. distinguishes three different principal fields of activity: cartography, production of spatial data, and geographical information systems. In conjunction with the adoption of digital technology Regio also began selling GIS software and solutions. Today Regio focuses on Location Based Services market and a number of steps for exploiting these new technological possibilities have been made by the joint efforts with Ericsson and EMT.

Estonian Telecom and especially it's mobile telephone communications subsidiary EMT (www.emt.ee) have recognised the convergence processes and changes very likely to influence the telecom markets worldwide in the next few years to come. EMT has become recently rather active in developing mobile applications, based on the existing GSM network. EMT has already made series of steps to be well prepared for the changes of the paradigms and restructuring the revenue streams towards applications widely foreseen with the forthcoming 3rd generation UMTS mobile telephone networks. Launch of the GPRS applications development and testing centre at Tallinn Technical University in 2000 and recent commercial launch of the nationwide GPRS network serve both the above purpose.

Radiolinja has responded to value added services development in EMT with it's own product development strategies. In co-operation with Nokia mCatch system has been developed and introduced in Estonia for the first time in the world. mCatch enables location based services

[8] Electronic ID card has been one of the most prominent projects for Cybernetica during last few years, as the idea has been taken up widely by the Government and large infrastructure companies (telecom, banks), how have been able to set for full-scale launch of Estonian electronic identity card system since January 2002.

to be introduced into mobile Internet networks. With new Location Based Services, mobile subscribers can access a range of new, exciting services, relevant to their location, such as tourist information, weather and traffic reports, tracking, restaurant and theatre ticket bookings.

Hansabank (www.hansa.ee) and **Estonian Union Bank** (www.eyp.ee), which are the two largest banks in Estonia controlling together approximately 90% of the financial services market. They are also two of the largest "software companies" in Estonia. The banks are first of all active in developing their internal systems, but also some RTD subcontracting and product development activities of possibly wider significance could be observed in the areas of data communications security, electronic commerce and language technologies. IT solutions in the sector are however covered by the law with bank secret, which makes wider exploitation of the results of in-house development work almost impossible.

Number of IT Personnel in Estonian Commercial Banks

T a b l e 8

	Hansabank	*Union Bank*	*Sampo*
IT Personnel	*450*	*130*	*30*
incl. development	*190 (40-45%)**	*45 (ca 33%)*	*10 (ca 33%)*

Source: personal interview (expert opinion)

In conclusion there are a number of promising developments in the private sector to make use of the market windows offered by the upcoming new technological solutions. At the same time lack of flexibility to adjust the RTD efforts and higher education system is seen from the universities side.

4. Reseach and technology development output indicators

4.1. Publications

Number of articles published in recognised international magasines is a one of the common indicators for assessing strength of the research group or the state of the art of the R&D activities in specific research direction or country.

Estonian authors have published 351 engineering, computing and technology related articles in the period of 1996-2000. The articles published belong predominantly to the physics, chemistry, material and environmental technologies.

Number of published international articles, 1996-2000

T a b l e 9

Category	*1996*	*1997*	*1998*	*1999*	*2000*
Engineering, Computing and Technology	76	69	75	57	74
IST domain	2	2	4	2	4
% of IST domain	2,6	2,9	5,3	3,5	5,4

Source: Current Content database 1996-2000

14 of the above articles (see Annex II) belong to information technology communications systems, computer science engineering, computer engineering technology applications or electrical and electronics engineering. Futher to that roughly half of the articles belong more specificially to the domain of electronics design, whereas Prof. R. Ubar together with his colleagues has published six articles of the above (Source: Current Contents database).

Several IT research labs have been regretably publishing predominantly in local or regional journals during the last few years (Arzen *et al.* 2000, Thoma *et al.* 2000, 2000).

4.2. Patenting activities

A patent is a formal document recognising the novelty of an idea, and provides official protection for unauthorised use of a certain technological solution. Therefore, higher number of registered patents refers to more intensive innovation activity alongside with market relevance of these new ideas.

Estonian inventors are relatively reluctant in applying for patents, as the specific means for the protection of intellectual property rights. The table below indicates that the total number of patents applied in Estonia during 1992-1999 is 2234, yet domestic patent applications comprise only 4% of these. Non-residents register rest of patents in order to protect their intellectual property on the territory of Estonia.

In terms of utility models Estonian applicants are a way more active. Total number of utility model applications for the period of 1992-1999 was 238, 89% of those applied by Estonian residents. Utility model is typically less sophisticated and procedure for granting utility model certificate considerably less reglemented. However, the protection scope of utility model is legally more narrow than that of patent’s.

Legal protection of industrial property, 1994–1999

T a b l e 10

	1994	1995	1996	1997	1998	1999
Filed applications						
Patents	482	82	213	375	463	619
utility models	32	52	31	45	47	31
of which Estonian applications						
patents	16	16	12	15	20	13
utility models	27	50	30	42	38	25
Registered						
Patents	-	-	22	108	82	103
utility models	15	55	28	36	51	32

Source: Statistical Office of Estonia: Teadus, Science 1999

According to the figure below, EU Member States are the most active partake of the patenting activity in Estonia, as they represent noteworthy 60% of the total patents granted. As the single country of origin, United States perform a substantial role, accounting for 27% of the patents granted. Swedish inventors follow closely with 26%, while Finland's share is only modest 5% in the number of issued patents.

It is interesting to notice that the correlation between patent holder country of origin and the typical Estonian trade partners is not very straightforward. Estonian main trade partners are Finland (27,5% of total imports), Sweden (9,8%), Germany (9,5%) and Russia (8,5%) (Statistical Office of Estonia, 2000). Relationship is more evident for FDI inflows and patent grantee's country of origin as highest FDIs are made by Sweden (37,6%), followed by Finland (28,7%), Netherlands (5,4%) and the USA (4,5%) (Bank of Estonia).

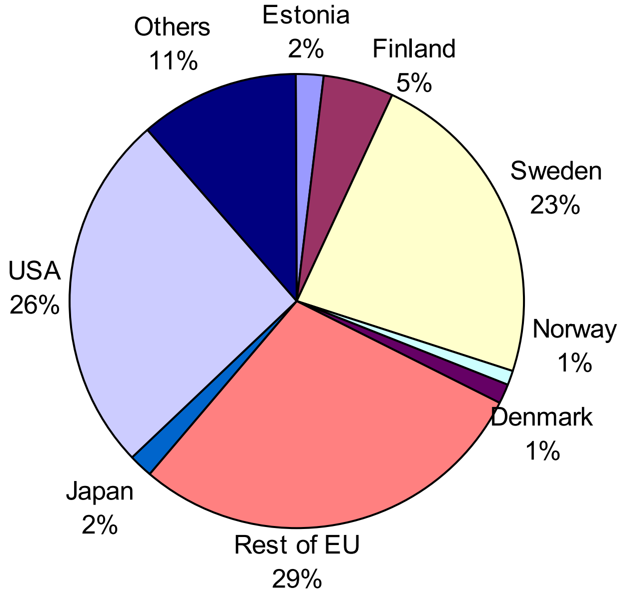

Figure 5. Patent gratees: breakdown by the country of origin (source: Statistical Office of Estonia: Teadus, Science 1999)

The statistics of patents from the United States, one of the largest homogenous and at the same time very dynamic markets in the world, is used frequently to give an idea of the role of the technologies developed in specific countries at the world market.

The following statistics should be taken with specific reservations nevertheless. Not every invention will be automatically protected by the means of patenting and it should be therefore considered, just as one a specific instrument of the marketing strategy.

Still, based on the series of interviews conducted amongst leading Estonian IT companies 7% of these claimed to possess patents. Patent applications are submitted predominantly to the Estonian Patent Office, though two patent applications have been filed also in the United States and one in Finland.

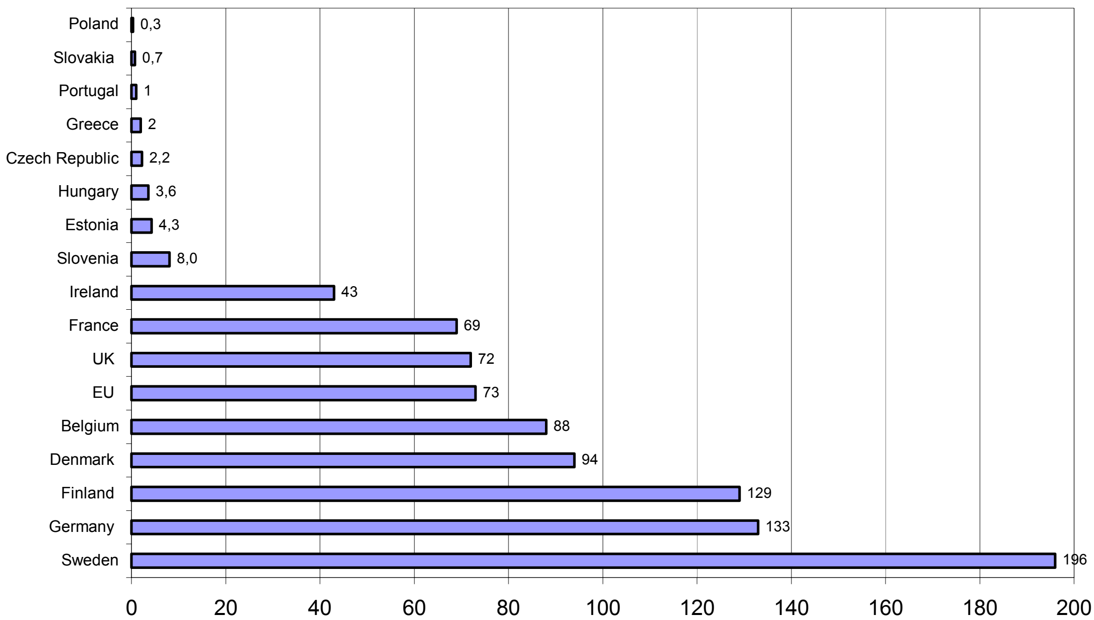

Figure 6. Number of patents per million inhabitants (source: Progress Report on Benchmarking of National Research Policies, Commission Staff Working Paper 2000 and independent calculations)

According to the statistics from US Patent Office there are altogather 6 patents registered on the name of Estonian residents, 2 out of these belong plausibly to ICT domain. This makes only 4.3 patents per million inhabitants, whereas an average number of U.S. patents granted to the EU Member States is somewhere around 70 per million inhabitants.

5. Estonian participation to the European R&D programmes

5.1. Motivation to participate in strategic alliances and international R&D

Estonia alone is unable to gain critical mass needed to access international markets, support techology standardisation activities or attract world-wide best people with specific knowledge needed. International research and technology development co-operation is therefore essential in gaining experience and skills, in adopting innovative solutions to the market needs. There is a large risk associated with any R&D activity leading to the launch of novel product. It is therefore necessary to pursue an adequate approach to share the risks at the international level and ensure best possible performance of such a product.

Relying on the responses from IT companies one can observe the fact that approximately one third of the enterprises have actually adopted active promotion strategy in introducing themselves to foreign investors. The number of enterprises having participated in competitive bids for subcontracting work is about the same. Those on positive side, Estonian IT companies have been rather active in contacting foreign companies with an aim to establish mutual business co-operation relationships.

About half of the companies are willing to pursue internationally software oriented business transactions, and 20% hardware oriented. Hardware is dominating on demand side: 40% of interviewed entities were interested in co-operation in the line of hardware use. Demand for software is also substantial, about one third of the enterprises revealed their interest in this domain. Though, pure business relations are not always the most effective source for knowledge spillover, and accession to the strategic alliances, aiming at the strengthening of product development activities, should be finally targeted.

Further observations refer to the fact that 30% of the enterprises expressed during the study their interest in international co-operation in the field of R&D and product development. This corresponds as well to the number of enterprises, which have actively promoted themselves to the foreign organisations. Interest of the ICT companies for foreign investments is still rather low, just 6% of respondents were searching for investments or were in favour of forming joint company. Willingness to invest into foreign enterprises was twice as high, in about 13% of cases.

5.2. Estonian participation to the IST programme

There have been 5 calls for proposals issued under the IST programme from the launch of the programme in 1999 till June 2001. These have resulted in a total of 6124 proposals being received and evaluated.

Estonian organisations have participated in 75 cases in these 5 calls for proposals and 75% of these have failed in one of evaluation criteria[9] – most notably due to low scientific and technological quality, low innovation and weak exploitation plans. Only 17% of the participations have been retained for contract negotiations, while the programme average is around 25%.

[9] Altogether five evaluation criteria are set in the evaluation manual and independent experts evaluate proposals in each of these. Failing in one of these makes the proposal automatically failed. See details in the Evaluation Manual at http://www.cordis.lu/ist/

Candidate countries participation in IST after 5 calls for proposals

T a b l e 11

	BG	*CY*	*CZ*	*EE*	*HU*	*LT*	*LV*	*PL*	*RO*	*SI*	*SK*
Ineligible	9	4	43	2	12	4	8	30	12	6	16
Not evaluated yet	1		1		3	1	1	9	1	2	
Failed on threshold	168	144	344	56	270	33	54	350	123	114	115
Ranked to low	40	33	35	4	43	7	3	56	35	25	12
Retained for negotiation	41	30	83	13	62	15	19	87	38	46	20
Total	259	211	506	75	390	60	85	532	209	193	163
Success rate	16%	14%	16%	17%	16%	25%	22%	16%	18%	24%	12%

Source: IST programme, June 2001

IST programme has received 3 proposals with Estonian co-ordinator during the 5 calls for proposals. Two of these, have been successful:

- doc@HOME project (www.docobo.com) is developing a novel telemedicine system for improved patent health monitoring and home care;
- Estonian eVikings (www.esis.ee/eVikings) project is aiming at improving competitiveness and helping at the establishment of the mid-to-long term development visions for the Estoian ICT cluster.

Average EC contribution to the RTD projects in IST programme is currently somewhere around 1.5 and 2 million euros. With the launch of the next European Community RTD Framework Programme, new instruments are launched:

- Networks of Excellence, as the joint research initiatives, aim at creating new knowledge;
- Integrated Projects seek at establishing technology development initiatives, would have a significant impact at the international markets;
- co-ordination of the national programmes under article 169 refers to the fact, that only 5% of the RTD funding in Europe is handled through the Framework Programme – co-ordinating national initaitives could have a significant effect therefore.

Independent IST Advisory Group (ISTAG WG7, 2001) has advised the European Commission to launch IPs, as the large-scale initiatives with the 50..250 million euro budget each. However, more specific discussions on the use of IPs are still on-going.

Relatively larger size of the projects and longer time to market criterias will dampen Estonian possibilities to receive public funding from FP6 unless enterprises learn to follow visionary application methods and pursue tighter co-operation with universities and research labs. Otherwise the competition with western enterprises will not give any chance to survive in higher value added market segments.

5.3. Estonian participation to Eureka and Cost

Industrial R&D in information and communication technologies holds a prominent position in Eureka is held by, as 37% of the project participations fall in this domain. The Candidate Countries are very active in this programme as quite substantial portion, approximately 12% of all project participations in on-going projects, comes from these countries. Most of the Candidate Country activity in Eureka is targeted at the environment, new materials, medical and biotechnology. Candidate Countries form only 2% of the total participation to the on-going ICT projects. This is very small by any measure.

Candidate Country participation to the on-going COST actions and Eureka projects

T a b l e 12

	Eureka		*COST*	
	ICT	*All domains*	*ICT*	*All domains*
Bulgaria	0	**1**	5	24
Cyprus	-	**-**	5	37
Czech Republic	3	**73**	7	82
Estonia	0	**0**	0	3
Hungary	1	**18**	14	119
Latvia	0	**3**	2	28
Lithuania	1	**13**	1	24
Poland	2	**34**	8	72
Romania	1	**16**	4	59
Slovakia	0	**6**	4	32
Slovenia	3	**21**	12	85
All projects	**125**	**615**	**25**	**≈200**

Source: COST secretariat, EUREKA secretariat, June 2001

The different nature of the COST programme should be taken into account when comparing the above statistics. It seems however, that the Candidate Country researchers are quite active in COST, and modest participation in the industrially oriented competitive RTD programmes in Europe, is rooted at the weak ICT enterprise sector in these countries.

5.4. Main factors hindering internationally competitive RTD activities

The level of domestic market competition and comprehensiveness of business strategies does not assume yet introduction of R&D-intensive products and sevices.

- many potential participants in NAS have **major difficulties with understanding basic logic and modalities** of the competitive RTD programme. Potential newcomer participants find the IST Work Programme and the Guide to Proposers unclear and too extensive. Accordingly they also don’t understand the reasoning behind the system and consider the proposal submission procedures too complex;
- another of major problem, indicated by potential participants from NAS, is the difficulty of making **contact with strong partners** (eg experienced co-ordinators);
- the formulation of sound **exploitation plans** is consequently also difficult;
- the **cost of the preparation of a proposal**, in particular of finding partners and preparing project plans, seems to be an important obstacle for many of the potential SME participants.

6. Co-operation between research institutions, industry and support structures

Due to compartmentalisation of research landscape, primarily niche products are developed, with relatively insubstantial market power and very specific field of exploitation.

Different levels of compensation in industry and research segment facilitate institute staff to leave their places and search for more lucrative options in private sphere. It is a distinct problem at the level of master and doctoral students, especially in light of scarce number of skilled specialists. But it is also the factor bewaring institutes to collaborate too tightly with enterprises, as the necessity to maintain their staff is prevailing the need for market tailored research.

Despite of on-going integration between industry and research, awareness about research institutes and their activity is very low amongst private enterprises. Only scarce 35% of those interviewed admitted they have some knowledge about existing research institutes. The number of companies who have used professional help of such institutes is significantly lower, just 7%. More than half of the respondents referred to excessive academic orientation of universities and R&D institutes, which may also be the reason for modest cooperation.

Most of the enterprises considered, disappointingly enough, such co-operation unnecessary, as domestic market competition does not assume yet strong enterprise R&D activities. One may observe as well the tendency of companies to collaborate more willingly between themselves than with universities and research institutes. About half of respondents referred to incomplete information about such co-operation possibilities.

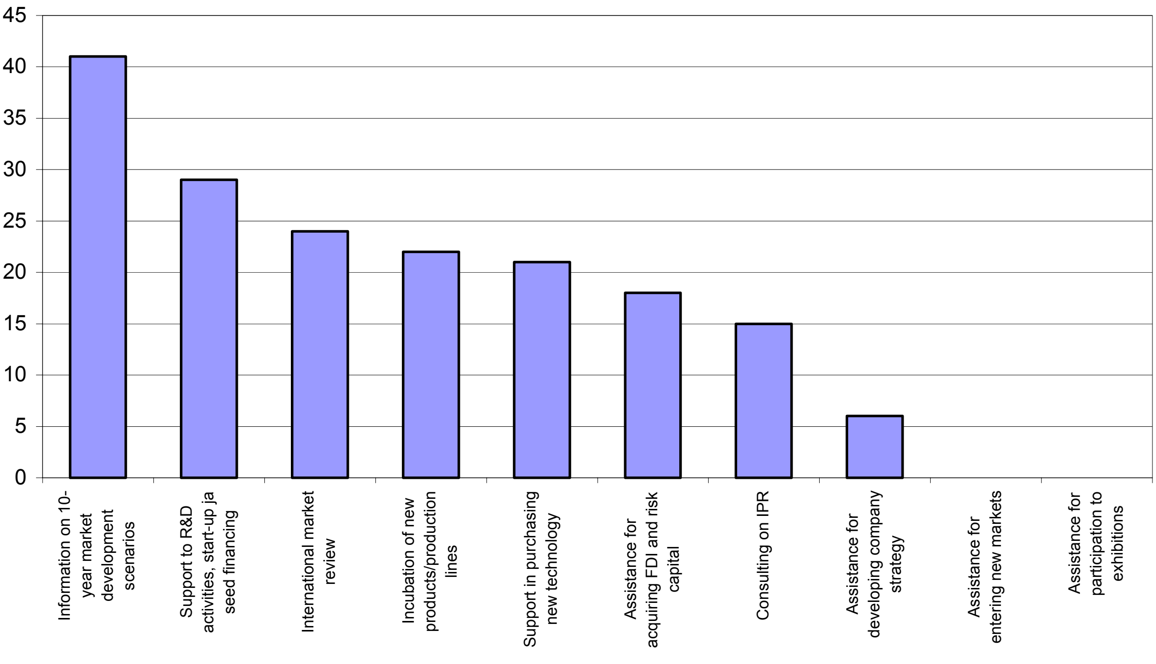

Figure 7. Most needed support measures by enterprises

Though research institutes perform an indispensable role in generating new knowledge and innovative technological solutions, they constitute only a part of the whole innovation system. Support structures like Technology Parks, Innovation Centres, Technology Agency etc have a catalysing role in channelling generated ideas into marketable product. Thus, the extent of cooperation between private enterprises and these support structures indicates the intensiveness of innovation activity. Support structures are generally better known than specific research institutes – Technology Agency has been most successful in disseminating information about its profile. Around two third of private companies have knowledge about

Technology Agency, though the rate of the companies who have actually used the services of the Agency is limited to 12% only.

The profile of Tartu Science Park and TTU Innovation Centre is familiar to 56% of respondents, though only 8% have pursued cooperation with these support structures. Archimedes Foundation, the National Contant Point Organisation for EC 5th RTD Framework Programme, is used even slightly less. Only 6% of the observed enterprises have approached Archimedes Foundation for assitance in participation to EU R&D activities.

The figures above indicate that cooperation between companies and support structures remains relatively inefficient. A number of enterprises actually do not know about the possibilities, the rest are mostly sceptical about the help or non-eligible for their ideas and approaches.

Lack of collaboration between ICT companies, research institutes and support structures is especially concerning in light of the fact that two third of enterprises confessed shortage of skilled labour, and one fifth lack of experience and knowledge. About 30% of observed IT companies stressed the need for additional R&D investments, about the same number were interested in incubating their novel products. However, most of the highlighted problems can be minimised with the help of wider collaborative incentives, as it is possible to delegate some of the assignments to specialised institutions such as R&D institutes. Also, problems deriving from insufficient R&D financing can be overcome by tighter cooperation between the universities and industry.

Thus, one can conclude that up to one fourth of the IT enterprises, who actually need the support from specialised institutions are active enough in searching further contacts. The rest of the enterprises prefer to operate by themselves either due to the lack of initiative or poor awareness.

7. Analysis of the public sector IT R&D project portfolio

Following the methodology set by the Integrated Project Portfolio Analysis (IPPA) of the European Community IST programme, the risks related to market dynamics were analysed also in the context of the national R&D efforts in Estonia. In the course of the analysis market opportunity windows (time windows within which the relevant markets present opportunities) were identified. Then these opportunities were compared with the estimated time it will take for the R&D projects to deliver marketable products.

The rationale of the Estonian public sector portfolio analysis is the same as for the above European Community IST R&D:

- Projects that fall within the market opportunity window have relatively low market risk (i.e. project results are delivered at a point when markets are ready to absorb them).
- Projects that have time to market outside the market opportunity window normally aim at the next generation of products and services. The degree of innovation is critical to the success of these projects. Simple incremental developments in technologies or applications are generally not enough. If innovative enough, such projects could be highly rewarding (high risk/high return) in terms of new high-value products and services.

As the result of matching the Estonian public sector funded IT R&D projects against certain market segments, relatively weak response to the emerging information society related markets has been identifed.

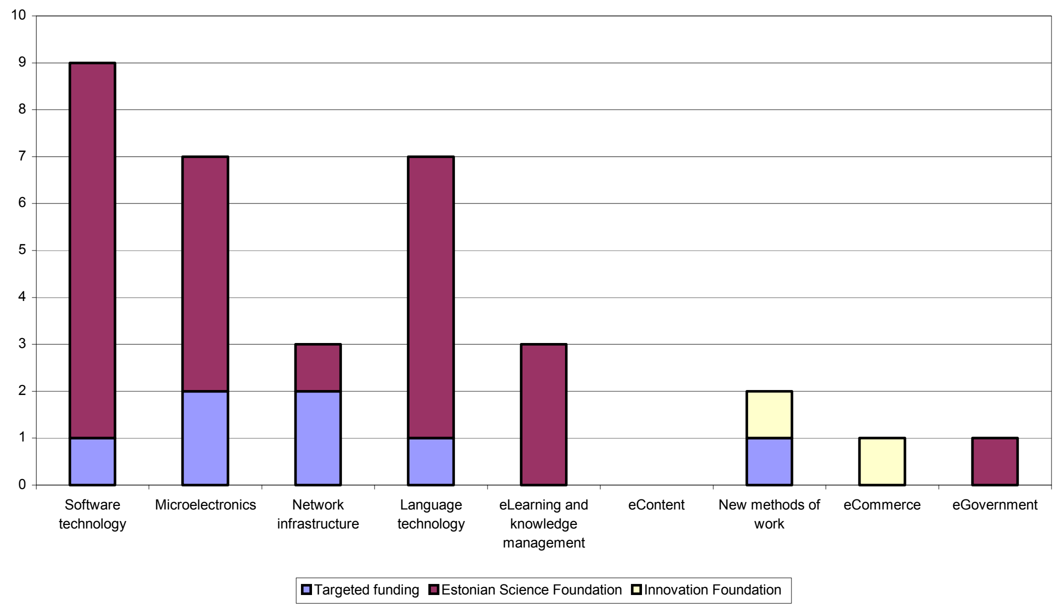

Figure 8. Public sector R&D portfolio by source of funding

An independent IST Advisory Group (ISTAG) has been set up to assist the European Commission with recommendations on the content and direction of the programme. Further to the ISTAG vision – to start developing an environment where a citizen's everyday surroundings become interface to information society resources (ISTAG 1999), ten Key Emerging Technologies (KET) have been identified, which are needed to make the vision a reality.

The IPPA team with European Commission has accordingly examined, after 3 calls for proposals (IPPA 2001), how the projects in IST portfolio contribute to the development of KET. All together 70% of the projects matched one of the KET-s[10].

Similar matching has been done with based on the existing information on the public sector sponsored IT RTD projects in Estonia. Thorough review of these preliminary conclusions would be needed, as soon additional information will become available. The preliminary findings show nevertheless, that only up to one third of the projects contribute to one of the KET, while the rest tend to be very theoretical with no clear market prospective foreseen.

None of the 4 product development projects supported by the ESTAG makes any contribution to the KET.

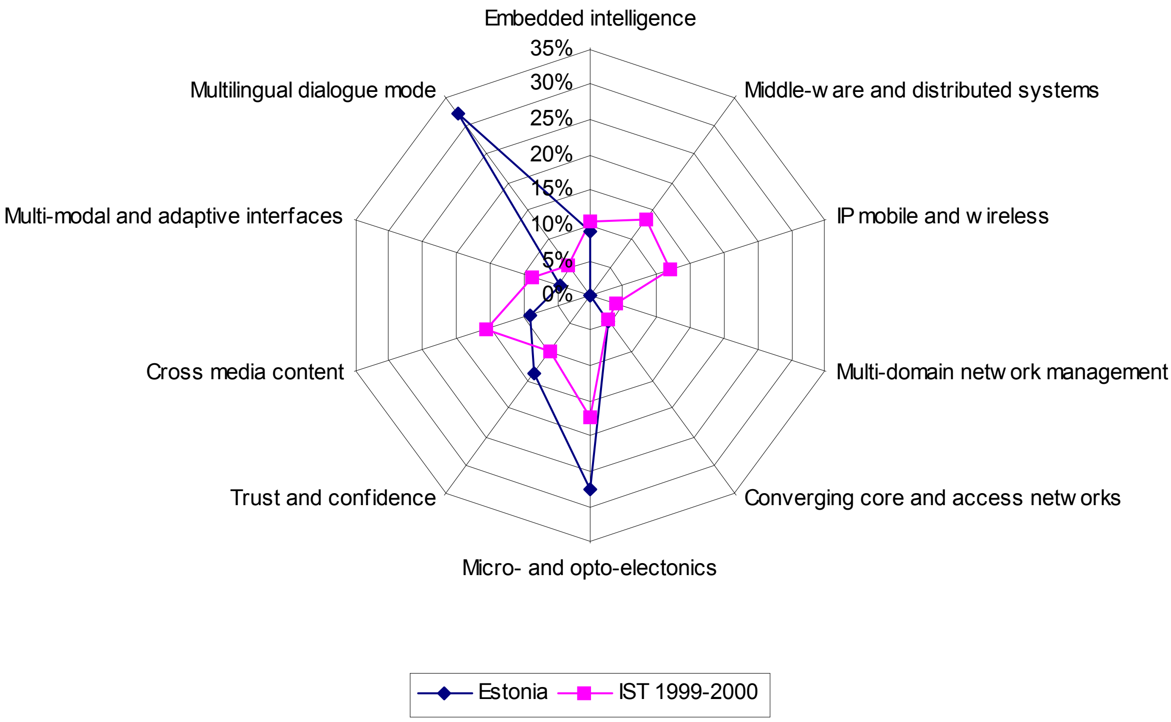

Figure 9. Estonian public IT R&D projects by Key Emerging Technologies

[10] Repetition of the exercise and review of these preliminary findings is needed for two reasons – clear visions on the directions for IT R&D should be agreed nationally, adjusting funding mechanisms accordingly; systematic collection of the information on the content and objectives of the IT R&D projects should be established, to make the portfolio analysis results more exact.

8. Conclusions

There are very limited national R&D resources are invested first of all onto strenthening higher education system and building critial mass in the specific IT areas of strategic importance for Estonia. There are substantial deficiencies at the level of managerial and skilled employment i.e. the types of jobs occupied by university graduates. The review of curriculum should be pursued and adapted to long-term socio-economic needs (foresight activity results possibly).

Despite of the fact that public sector RTD expenditure comprises in Estonia as much as 79% of the Gross Expenditure on Research and Development (GERD), while in the OECD countries public funding comprises 39%, the overall picture is not satisfactory, as businesses are reluctant to go along. The advantage of engaging private sources into R&D is essentially related to public sector's ability to pursue more market tailored RTD activities, providing the rest of public co-funding with potentially higher returns. Public sector funding, though by far the most dominating in RTD expenditures, has not been consistent enough to provide stability to research community. In 2000 the real growth of RTD expenditures declined by 2,2%.

Also, funding agencies do not anticipate prospective development scenarios and the system in place doesn't support launch of the new high-risk and possibly high-return R&D themes. Estonian Technology Agency has had no significant influence to the IT R&D in Estonia up to the present moment. Public IT R&D funding does not favour university-enterprise partnerships for applied R&D, whereas in the western economies, integrated R&D and product development cycle is the common practice for elaboration of new technological solutions. The authors of the paper suggest conducting additional independent research on the effectiveness of funding instruments and restructuring these more in line with universtity-enterprises partnership.

Despite of on-going integration between industry and research, awareness about research institutes and their activity is very low amongst private enterprises. Most of the enterprises considered, disappointingly enough, co-operation with universities unnecessary, as domestic market competition does not assume yet strong enterprise R&D activities. One may observe as well the tendency of companies to collaborate more willingly between themselves than with universities and research institutes.

IT enterprise product development is orientated mostly to the domestic market (as approximately 2/3 of IT enterprises see domestic firms as their direct competitors), which does not exactly require for the world class leading solutions. Most of the R&D and development efforts in the enterprises comprise therefore of a strong learning component, but frequently still tend to copy the work have been done already elsewhere in the world. Estonian IT enterprises are inclined to perform specific application development (eg. tailor-made software, information systems) rather than systematic R&D activity in more broader sense. Application development activities are substantially less tied to R&D focusing on the development of new technology or upgrading the already existing one(s) instead.

Upcoming Estonian technology foresight initiative has the objective to partly resolve aforementioned problems, by initiating public discussion groups and uniting stakeholders into vision-creating process.

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Annex I: Key Enabling Technologies[11]

KET 1: Embedded intelligence: Development and deployment of networked embedded systems (and software) in common-place appliances (fixed and mobile) to improve comfort, safety, and functionality of applications at home, at work, on the move, in leisure etc.

KET 2: Middle-ware and distributed systems: Multi-layered architectures to enable interoperability, inter-working, openness and integration of applications and services across platforms. This includes Java and Corba like architectures and component based software development. Are also included the technologies and methodologies that enable businesses to deploy agile and integrated processes that cut across companies and organisations in support of the development of new value chains.

KET 3: IP mobile and wireless: IP technologies that underpin the development of the ambient intelligence landscape including mobile and wireless internet technologies, the evolution of IPv6 and future generation of nomadic IP solutions in areas such as mobile e-commerce, e-work etc.

KET 4: Multi-domain network management: Dynamic optimisation of network resources and network integration to assure service transparency and quality of service in a multi-domain context. This includes as well active networks management and self-reconfiguring networks and distributed network management approaches in the context of increasing numbers of interconnected appliances that are wireless, fixed or mobile.

KET 5: Converging core and access networks: Integration, inter-working and interoperability of networking infrastructure including both access and core networks (fixed, mobile and wireless) as well as technologies for integrated broadband networks.

KET 6: Micro- and opto-electonics: Microelectronics and opto-electronics for high speed communications and for better connectivity and mobility including Chipless/fabless Intellectual Property based developments and the development of Systems-on-a-chip (SOC) for information and communication terminals, and communication systems and networks.

KET 7: Trust and confidence: Technologies and applications to support privacy, security, and users and suppliers rights, as well as tools and methodologies to improve technology and infrastructure dependability, adaptability and survivability.

KET 8: Cross media content: Production and delivery including the integration of online and broadcasting services and technologies as well integrated authoring tools and applications in areas such as entertainment, advertising, publishing and education and training. “Context” based retrieval of, and access to content is a key feature of the ambient intelligence landscape.

KET 9: Multi-modal and adaptive interfaces: Technologies to improve the interaction between people, information appliances and information services through the integration and use of multiple modalities, including language, gestures, haptic contacts, emotions, augmented, synthetic and virtual reality. Personalisation and intuitiveness of interfaces and their application in challenging areas are included.

KET 10: Multilingual dialogue mode: Includes speech and language technologies to enable natural interaction with IST applications and services. Cross-lingual information retrieval and categorisation is included as well as contextual and deep semantic information analysis.

[11] Excerpt from the IST Programme Integrated Project Portfolio Analysis, February 2001

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11. Annex III: Public sector funded IT R&D projects

Researcher	*Project name*	*KET*	*Duration*	
	Estonian Science Foundation 2000-2001			
Haav, H.-M.	Mõisteline lähenemisviis arvutivõrkudega ühendatud infoallikate kirjeldamiseks ja organiseerimiseks		1997	2000
Rang, T.	Laia keelutsooniga materjalidest pooljuhtstruktuuride kontaktide valmistamistehnoloogiate uurimine ja kontaktalade füüsikalis-matemaatiline modelleerimine		1997	2000
Männama, V.	MCCC sünergia: Mõõtmise, arvutamise, side ja juhtimise integreerimine informaatiliselt ja elektriliselt ühilduvates süsteemides		1997	2000
Mõtus, L.	Teadmustehnika meetodite rakendamine reaalajasüsteemide projekteerimisel	1	1997	2000
Tombak, M.	Teoreetilisi ja konstruktiivseid uurimusi keerukusteooriast		1997	2000
Roosmaa, T.	Eesti keele formaalse grammatika väljatöötamine	10	1998	2000
Keevallik, A.	Digitaalsüsteemide dekompositsiooniline süntees entroopsete keerukushinnangute alusel		1998	2000
Rüstern, E.	Dünaamiliste süsteemide juhtimise ja modelleerimise meetodid		1998	2001
Kukk, V.	Segamoodiliste IC-de ning nende disainivahendite arendamine	6	1998	2000
Meister, A.	Spektraalanalüüs ja klassifitseerimisalgoritmid rakendustega keerulistele signaalidele		1999	2001
Ubar, R.	Digitaalelektroonika disaini ja testi virtuaallaboratoorium	6	1999	2002
Randvee, I.	Otsustussüsteemide optimaalse struktureerimise meetodid informaatikas ja juhtimises		1999	2001
Kotta, Ü.	Rekursiivsed juhtimissüsteemid		1999	2002
Oit, M.	Digitaalsed ajatemplid	7	1999	2000
Tamre, M.	Puusaliigeste rehabilitatsiooni ja proteesimise simulatsioonimetoodika		1999	2001
Elmik, L.	Meetodiarendus: Infosüsteemide subjektikeskse arendamise metodoloogia		1999	2001
Lippmaa, E.	Tuumaspin-magnetresonantsil baseeruvate kvantarvutustehnika loogikalülituste ja loogikamassiivide realiseerimine termilisele ansamblile vastava tihedusmaatriksi unitaarteisenduste kaudu		1999	2001
Kalja, A.	Raalprojekteerimise ja modelleerimisülesannete lahendamine tehisintellekti süsteemide abil		2000	2003
Buldas, A.	Digitaalsignatuuride notariseerimine	7	2000	2001
Kalda, J.	Mastaabi-invariantsus ja juhumuutlikkus südamerütmi variaabelsuse juures		2000	2002
Meister, E.	Kõneleja-spetsiifilised tunnused kõnesignaalis	10	2000	2003
Uustalu, T.	Intermediaar- ja modaalloogikad programmikeelte teooria ja formaalmeetodites		2000	2002
Vain, J.	Formaalsed meetodid hübriidsete dünaamiliste süsteemide verifitseerimiseks		2000	2003

Mihkla, M.	Kõnesünteesi kvaliteedi hindamine ja kasutajaliidesed eestikeelsele tekst-kõne süsteemile	10	2000	2001
Grossschmidt, G.	Interaktiivne programmipakett Eestis projekteeritavate hüdroajamite simuleerimiseks objekt-orienteeritud programmeerimissüsteemi NUT vahenditega		2000	2001
Näks, T.	Tarkvaratehnika tööriistad reaalajasüsteemide projekteerimiseks ja verifitseerimiseks	1	2000	2002
Ellervee, P.	Multiparadigmaline ühekiibi digitaalsüsteemide projekteerimise keskkond	6	2000	2001
Tepandi, J.	Tarkvaraagentide rakenduste töökindlus ja ohutus		2000	2002
Ubar, R.	Disainivigade diagnostika digitaalskeemides ja -süsteemides	6	2000	2003
Velmre, E.	Üleminek ränilt ränikarbiidile pooljuhtseadistes: mudelite väljatöötlus, testimine ja struktuuride mõõtmised	6	2000	2001
Vainikko, E.	Kasutajakeskne hajuskeskkonna mudel ATM baasil suurte rakendusülesannete lahendamiseks	5	2000	2001
Sarapuu, T.	õpiotstarbeliste veebilehekülgede kasutamise efektiivsus õpilaste keskkonnahariduslike normatiivsete kompetentsuste kujundamisel		2000	2003
Koit, M.	Eestikeelse dialoogi modelleerimine arvutil	10	2001	2003
Roosmaa, T.	Eesti keele kahetasemelise morfoloogia väljatöötamine ja keele automaattöötluseks vajalike arvutisõnastike koostamine	10	2001	2003
Haav, H.-M.	Ontoloogiate disaini ja ontoloogiapõhise otsingu meetodid	8	2001	2002
Kotta, Ü.	Algebralised meetodid mittelineaarsetes juhtimissüsteemides		2001	2004
Penjam, J.	Eesti arvutiteaduse talvekool 2001		2001	2001
Tamm, B.	Agent-orienteeritud programmeerimine keeruliste inimene-masin süsteemide modelleerimiseks ja rakendamiseks	9	2001	2003
Oit, M.	Andmebaaside ja registrite päringuvastuste autentsuse pikaajalisuse tagamine	7	2001	2002
Kikkas, K.	Eestikeelse kõne-tekst tuvastussüsteemi loomine puuetega inimestele	10	2001	2003
Kukk, V.	Analoogsidude analüüsi automatiseerimine		2001	2002
Mõtus, L.	Agendid ja nende käitumine reaalses maailmas		2001	2004
Männama, V.	Meetodid ja vahendid sonsorsignaalide töötlemiseks: analüüs, rakendus ja integratsioon kõrg-tehnoloogilises keskkonnas		2001	2003
Sudnitsõn, A.	Lõplike automaatide dekompositsiooniliste sünteesimeetodite arendamine ja vastavate WWW-põhiste disainivahendite loomine		2001	2002
Vene, V.	Programmide matemaatiline konstrueerimine II		2001	2003

	Targeted Funding (sihtfinantseerimine) - 2000			
Tombak, M.	Arvutiteaduse mudelid ja meetodid infotehnoloogias		1998	2002
Tepandi, J.	Meetodid ja tehnoloogiad hajus- ja teadmussüsteemide uurimiseks ja arendamiseks		1997	2000
Kotta, Ü.	Lähendusmeetodid mittelineaarsetes matemaatilistes mudelites ja juhtimissüsteemides		1998	2002
Penjam, J.	Teadmuspõhiste juhtimis- ja infosüsteemide arenduskeskkonnad kõrgjõudlusega arvutivõrkudel	8	1997	2000
Vain, J.	Juhtimis- ja tarkvarasüsteemide projekteerimise meetodid ja vahendid raalintegreeritud süsteemides		1998	2002
Õim, H.	Arvutuslingvistiliste vahendite väljatöötamine ja rakendamine eesti keele arvutiressursside loomiseks	10	1998	2002
Meriste, M.	Organisatsiooni infokeskkond		1998	2002
Min, M.	Mikrotehnoloogial põhinevad elektroonikakomponendid ja -süsteemid ning intelligentsed mõõtevahendid		1996	2000
Mõtus, L.	Süsteemide analüüs, modelleerimine ja juhtimine		1998	2002
Ubar, R.	Digitaalsüsteemide projekteerimise ja diagnostika alased uuringud, väljatöötlused ja rakendused	6	1998	2002
Meister, A.	Telekommunikatsioonitehnika alased uuringud		1998	2002
Tammet, T.	Automaatse teoreemitõestamise meetodid formaalsete spetsifikatsioonide verfitseerimiseks		1999	2002
Kalja, A.	Lairibavõrkude tehnoloogiad ja rakendused		1998	2001
Hindrikus, H.	Bioelektromagnetiliste signaalide interpreteerimine		1998	2001