Towards a competitive cluster

An evaluation of real estate and construction technology programmes

Petri Uusikylä, Ville Valovirta, Risto Karinen, Enno Abel, Thomas Froese

Technology Programme Report 6/2003 | Evaluation Report

TEKES

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TEKES

National Technology Agency

Technology Programme Report 6/2003
Helsinki 2003

Tekes – your contact for Finnish technology

Tekes, the National Technology Agency, is the main financing organisation for applied and industrial R&D in Finland. Funding is granted from the state budget.

Tekes' primary objective is to promote the competitiveness of Finnish industry and the service sector by technological means. Activities are aimed at diversifying production structures, increasing productivity and exports and creating a foundation for employment and social well-being. Tekes finances applied and industrial R&D in Finland to the extent of nearly 400 million euros annually. The Tekes network in Finland and overseas offers excellent channels for cooperation with Finnish companies, universities and research institutes.

Technology programmes – part of the innovation chain

The technology programmes are an essential part of the Finnish innovation system. These programmes have proved to be an effective form of cooperation and networking for companies and the research sector for developing innovative products and processes. Technology programmes promote development in specific sectors of technology or industry, and the results of the research work are passed on to business systematically. The programmes also serve as excellent frameworks for international R&D cooperation. Currently, 35 extensive technology programmes are under way.

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Foreword

The Finnish real estate and construction cluster accounts for some 70% of national wealth and it employs about half a million people. The status of the cluster contributes strongly to the infrastructure and the well-being of society. The cluster has seen several major changes within the last decade. These changes demand innovative solutions in order to improve the functionality and productivity of the cluster. Originally, the R&D input of the cluster was rather modest. In this cluster, Tekes has perhaps had a more central role in funding the projects and spurring the interaction than in other clusters.

The evaluation project consisted of three separate parts. The strategic evaluation of altogether 13 technology programmes was carried out by Net Effect Oy. The aim was to review all the real estate and construction technology programmes that Tekes has started and funded from 1992 to 2002. Two of these programmes ended in 2002. They were evaluated by two prominent experts in parallel with the strategic evaluation. Professor Enno Abel evaluated the Healthy Building Programme and Professor Thomas Froese the Vera Programme (Information Networking in the Construction Process). The steering group of the evaluation project consisted of the Tekes evaluation group (Pekka Pesonen, Robin Gustafsson and Eija Ahola) and representatives of the Tekes construction unit (Olli-Pekka Nordlund, Reijo Kangas, Jarmo J Heinonen and Ilmari Absetz) as well as Healthy Building Programme Manager Markku Rantama and Vera Programme Manager Arto Kiviniemi.

The evaluation report shows the evolution of the technology programme scheme. The earlier programmes were quite small and rather fragmented. Their focus was on the specific fields of technology and industries. The later programmes have a more coordinated and cluster-oriented approach. The results show that the chosen path has been appropriate; for example, the interaction between different actors has increased. One manifestation of this is the cluster's joint Vision 2010. However, there is still work to be done, especially in the international context. The report gives views on the next generation of technology programmes.

Tekes wishes to express its deepest gratitude to the evaluators for their profound and solid work. Their contribution has generated valuable results and conclusions that help to pave the way towards a competitive real estate and construction cluster. Special thanks are extended to all parties involved in the evaluation process, be they panellists, interviewees or respondents to the survey.

January 2003

Tekes

Contents

1 Introduction

The real estate and construction cluster has a pivotal role in creating wealth and well-being in Finland. It covers some 70 per cent of the entire national assets of the country and the total production volume of the real estate and construction cluster in 2000 was 40,000 million euros, of which international operations amounted to 8,000 million euros. The cluster also employs 500,000 people in Finland.

Given the importance of the cluster in macro-economic terms, it is very encouraging to note that major positive changes within the cluster have taken place during 1990s:

- The quality and results of business-driven R&D have improved and research and development investments have consequently doubled
- The formerly competing and dispersed group of actors (enterprises, public agencies and associations) have managed to form a dense, common goal-sharing inter-organisational network
- There are promising practices in the field of internationalisation and
- The focus has shifted from the building process to cover the whole life cycle.

The role of Tekes has been important in developing the strategic competence of the real estate and construction cluster as a whole. Thirteen technology programmes have covered a wide range of activities from building materials (wood, concrete steel) to building techniques and processes as well as thematic fields (environment, health aspects, ICT integration etc.).

This evaluation aims at assessing what the role of the technology programmes introduced by Tekes in this field of development has been; what has been the rationale of the programmes; how the implementation has succeeded; what impacts the programmes have had on the cluster as a whole; and finally what has been the real added value of the programme activities.

All these are important questions today, when the cluster has reached a more mature stage of development and Tekes needs to redefine its intervention strategy in the cluster. Should it still be active at all? Should it continue with similar types of programmes? And, if not, what would be a more suitable approach?

Evaluation criteria

When evaluating technology programmes in the field of the real estate and construction cluster, we first need to set out the criteria of our assessment. Determining the success of technology programmes involves making value judgements, which requires a careful definition of the relevant criteria. Our evaluation framework is presented in the figure 1.

The first point of departure is the general context of technology policy and the overall objectives set for technology programmes. This theme will be discussed briefly below in this chapter. The second issue concerns the characteristics of the real estate and construction cluster for technology research and development. One of the particular features here is the demand for R&D support from the actors in the cluster. We will look into these questions in the chapter 3.

The third set of issues is related to the 13 technology programmes in focus; the particular objectives, activities carried out and programme outputs and impacts. Each of the programmes will be studied in the chapter 4 in terms of these criteria. This will allow us to assess the overall effectiveness of the programmes by reflecting on the roles of technology programmes in terms of the expectations and objectives set for them. However, very definitive answers are not to be expected on this issue, since the focus is more on the general strategic questions concerning the relevance of the programming approach.

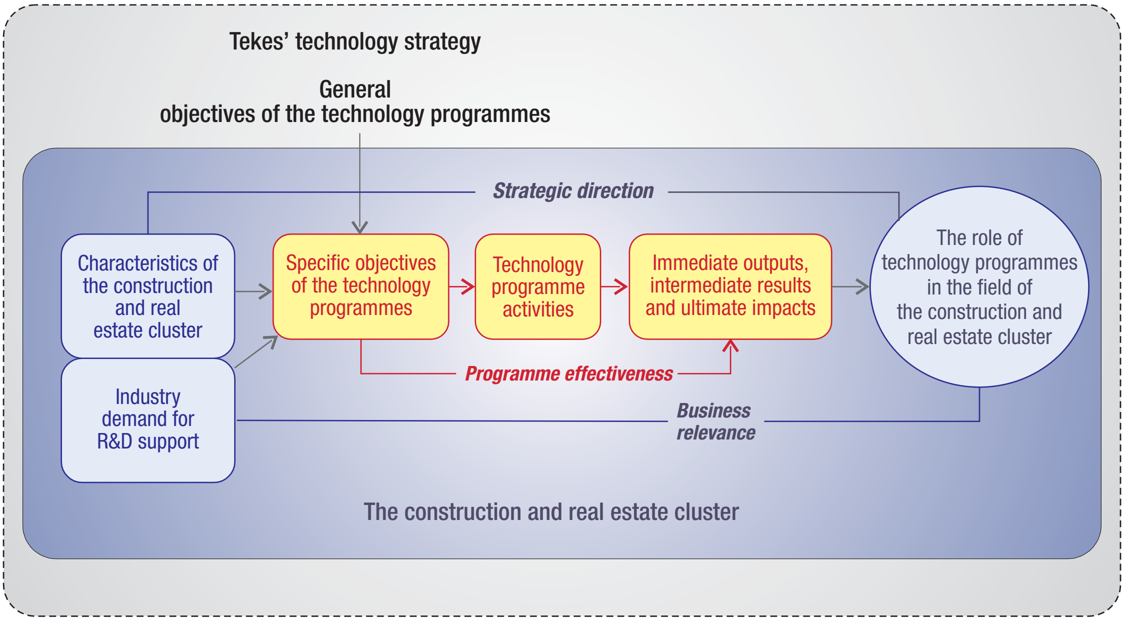

Figure 1. The framework for the evaluation.

The fourth, and the most important of the questions addressed here, is the role which the technology programmes have been playing in the cluster's development. Empirical material, collected by interviews and a stakeholder survey, will be presented in order to get a rich picture of the views different actors hold on this question. This will allow us to assess the programmes' significance in terms of the strategic direction of the cluster's development and the satisfaction of business needs.

Table 1 summarises the key evaluation questions and sources of data applied[1].

In designing the evaluation, after consultations with the commissioners, we have tried to build an evaluation approach that meets the quality criteria of triangulation. This means that various sources of information has been applied and findings and interpretations have been critically tested with alternative sources of data.

This report is divided into six parts. Chapter 2 discusses the technology programme concept in the Finnish innovation policy context. Chapter 3 introduces the characteristics and the main development aspects of the construction and real estate cluster. In chapter 4, the results of 11 out of 13 technology programmes (all except Vera and Healthy Building) have been presented. Chapter 5 summarises the main findings of the international evaluation of Vera and Healthy Building and compares some of the main findings with the data used by the Net Effect evaluation team. The complete expert evaluations can be found in the appendix. Chapter 6 assesses the impacts of technology programmes on the cluster's development. This assessment in mainly based on the results of an electronic survey. Finally, chapter 7 presents the conclusions and guidelines for the future.

1 *** = Main data source; ** = Secondary data source; * = Gives only partial information

Table 1. Evaluation questions and sources of data.

Evaluation question	**Documentary analysis** (incl. previous evaluations)	**Expert interviews** (see list in appendix)	**Expert-panels**	**Survey**	**Crest analysis**
Has the scope and rationale of the programmes been correct?	*	**	***	**	***
What has been the major contribution (outcomes) of the 13 programmes assessed?	***	**	**	**	**
What has been the impact of technology programmes for the cluster development?	*	***	**	*	
What has been the added value of the programme concept in this cluster?	*	***	**	**	
What could be the future logic of intervention by Tekes?		***	***		

2 Technology programmes in the Finnish innovation policy context

Technology programmes are broad constellations of development projects focusing on a particular field of technology. Certain areas of technology become selected through strategic scanning between Tekes, industry and other stakeholders, where changes in the business environment, needs for research and development support in industry and new ideas are balanced. The basic idea of the programming approach is to channel technology development efforts into large entities tailored for a particular field of technology, theme or a cluster-specific issue. Synergies are expected to emerge from the concentration of resources, cooperation between partners and international networking.

When assessing the effectiveness of technology programmes during a time span of ten years, we should not only look at the expectations in contemporary thinking, but also examine objectives set for technology programmes at the beginning of 1990s. The directions for technology programmes were outlined by a national committee in 1990. It proposed a distinction between three kinds of technology programmes. First, there should be *national programmes* concentrating on developing basic knowledge. Here, the proportion of public funding is high, as is the number of participating organisations, including both enterprises and research units. Second, there are *industry specific programmes*, which are tailored to meet the needs of particular industries. Where in the national programmes the results should become public knowledge, in industry-specific programmes the publicising of the results is more limited. Third, there are *programmes for a single enterprise or a group of enterprises*. This distinction also served as a basis for the early technology programmes in the construction industry.

The advantages of a programming approach lay in the coordination of common projects in areas were the resources of single actors would not be sufficient. Some general goals for technology programmes were set by the committee. These include promoting industries' capacity for technological renewal, creation of new knowledge, skills and technologies, strengthening dissemination and utilisation of research results, and enhancement of R&D cooperation both nationally and internationally. What is noteworthy here is the input-oriented view of public technology funding. Cooperation and networking aspects were not very strongly emphasised.

In the mid-1990s, the cluster thinking was forcefully introduced in the Finnish economy. The core idea of the cluster approach was the recognition of great positive externalities originating from the exchange of information and goods between enterprises. Technology programmes became instruments in promoting the cluster formation. By creating links between previously unconnected industries and sub-fields, the technology programmes could create an innovative environment for the business community. In the late 1990s, the national programmes (the first type above) were transferred to programmes defined on a cluster basis.

At present, a set of core goals for technology programmes can be identified. They are to a great extent derivable from contemporary thinking on the need for technology policy and, consequently, the rationale for public intervention in this field. The central issue is the enhancing of the national system of innovation and the field-specific innovation environments for technology development, transfer and implementation. The general goal for public technology then becomes the strengthening of networks, enhancing cooperation between actors, and connecting the Finnish context with international trends and developments.

These goals are related to more general rationales for public technology funding. Traditionally, technology policy has been pursued because of the perceived market failure of companies to invest sufficiently in long-range and risk-laden research and development. Due to this failure, support for basic technological research and additional R&D support for enterprises is required. Another implication is that the research and development infrastructure needs reinforcement in universities and research institutes. This has been noted in the recent technology strategies of Tekes by stating that without public inputs the companies' R&D inputs stay on a lower level than is necessary for keeping up with international competition[2].

More recently, a number of systemic shortcomings have been identified, which call not only for public investments in technology research and development, but also for collaborative activities. These failures are related to the systemic features of the innovation environment. First, technological change may be too slow and paradigm shifts may occur at too slow a pace. This change process needs to be accelerated. Second, diffusion of technologies and knowledge may be inadequate, which requires activation of networks and partnerships.[3]

The characteristics of Tekes' technology programmes have evolved over time. In terms of the time span of this study, we may state that the technology programmes have moved from a specific focus towards more generic approaches. At the beginning of the 90s, programmes were more directed at specific fields of technology and industries. In the middle of the 90s, more thematic approaches were introduced. The most typical of these thematic approaches is the pursuit of the environmental perspective. The latest change is related to the restructuring of the Finnish innovation system into a number of clusters, which has highlighted a need for broad cluster-specific programmes, where added value is sought across industries.

The technology programmes in the cluster have varied significantly in volume, as presented in the figure 2. The biggest programmes so far have been Vera, Environmental Technology in Construction, Healthy Building and Wood in Construction. Many of the programmes completed during the 90s were among the smallest ones, amounting to less than 5 million euros.

In addition to great differences in volume, the programme profiles also differ in terms of participating parties and the volume of Tekes funding. The clearest research institution profile is present in Healthy Building, where over one third of the funding has been directed at universities and research institutions. In Vera, on the other hand, the majority of funding has been allocated to SMEs. The relatively strongest presence of big companies was in Industrial On-The-Spot Building Programme, which was largely industry-driven by the nature of the topic. Tekes funding for individual technology programmes is shown in figure 3.

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2 Teknologia ja tulevaisuus. Tekes, 1998.

3 Lemola, Tarmo: Tiedettä, teknologiaa ja innovaatioita kansakunnan parhaaksi. Katsaus Suomen teknologiapolitiikan lähihistoriaan. (Science, technology and innovations for the good of the nation. A review of the recent history of Finnish technology policy.) Technical Research Centre of Finland, 2001; Lundvall, Bengt-Åke: Innovation Policy and Learning Economy, in Gerd Schienstock & Osmo Kuusi (eds.): Transformation Towards a Learning Economy. Sitra, 1999.

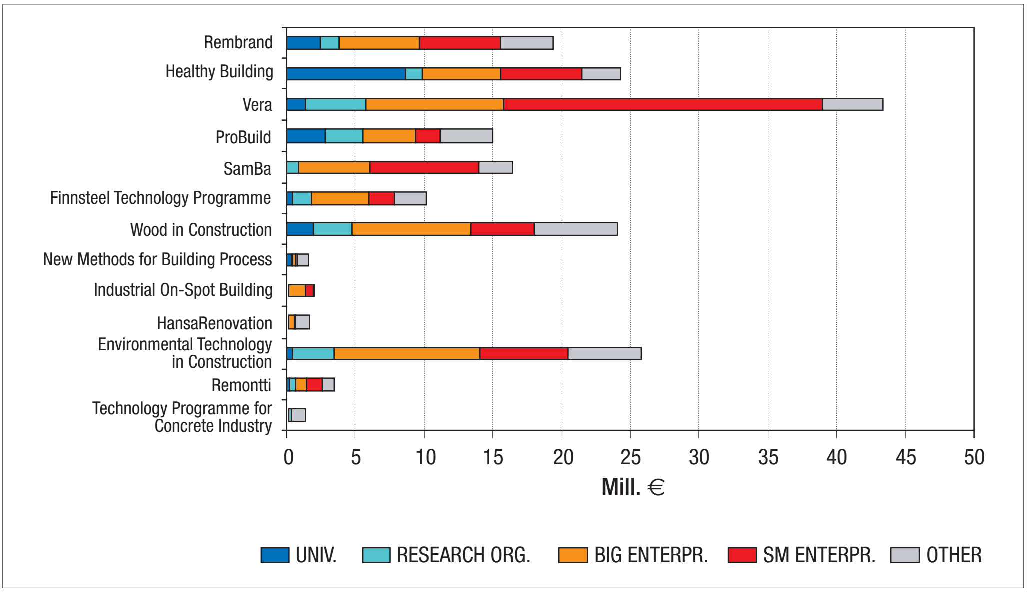

Figure 2. The total volume of construction and real estate technology programmes.

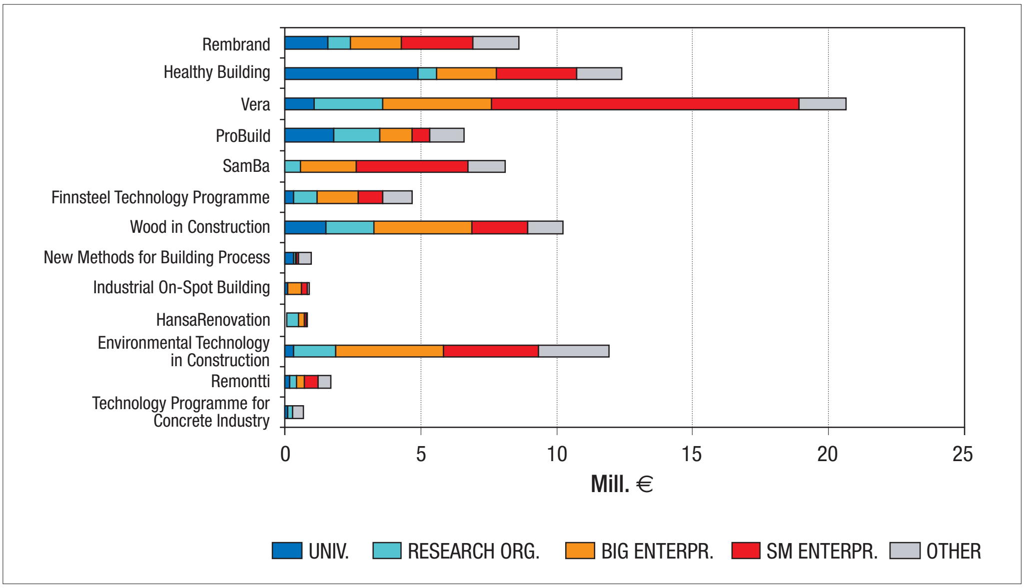

Figure 3. Tekes funding for construction and real estate technology programmes.

3 Characteristics of the real estate and construction cluster

Overall development of the cluster[4]

The overall development of Finnish industry policies in the 1990s has strongly emphasised the role of innovation within clusters composed of companies, universities, research centres and relevant public sector actors, i.e. the basic elements of renewed private–public partnership. Definition of the content of cluster is a crucial and on-going process affecting the identity of all actors comprising the cluster. In Finland it has , for a few years now, become common to define the real estate and construction cluster as comprising of five sub-fields. The *real estate industry* is responsible for the spaces required by various sectors of society. The *infracluster,* i.e. civil engineering, is responsible for transportation links and networks. The *building industry* builds spaces and networks. The *building products industry* and *the building services industry* supply products and services for construction. While keeping in mind this wide definition of the cluster, it has been calculated that, altogether, approximately half a million people worked in these sub-fields in 2000.

Approximately seventy per cent of national wealth is tied up with the real estate and construction cluster. Thus the cluster, as the biggest cluster of all, lies at the core of economic welfare and societal well-being. The cluster can, with good reason, be defined as the enabling cluster in the society, the one that forms the basis and platform for all other activities. As the needs of society and the economy change, so do the quantitative and qualitative requirements within the cluster. Partly due to the special characteristics of the industry, i.e. its enabling horizontal role and largely domestic nature, it has traditionally been influenced by strong regulation.

The development of the real estate and construction cluster is closely linked to macro-economic development and to social and demographic changes in Finland. Like the Finnish economy and society overall, the cluster and its sub-fields also went through severe structural changes in the 1990s. During the recession the low point in real estate and construction was reached just before mid-1990s. In addition to the harsh economic recession in the early 90s, membership of the European Union in 1995 changed the business environment by opening the traditionally closed domestic market. Moreover, decisions on interest rates are now done in the European Central Bank. The cluster has had to adapt to the changing macro-level landscape.

It could be argued that, in a way, these macro-level structural changes along with changes in the micro-level, especially in customer needs, have led to a conceptualising of the cluster in its present form, linking construction with real estate. The increasing requirements set, on the one hand, by customers and, on the other hand, by investors and new competitors, have demanded innovative ways to develop the functionality and productivity of the cluster. Traditionally there has been an absence of links between various actors in the cluster. The cluster has been characterised by fragmentation and partial optimisation.

The Real estate industry went through significant changes in the 1990s. Nowadays, real estate companies compete for investors' interest on the stock exchanges with other industries. Property management has been diverted from the core businesses of various companies into an industry of its own. The three main sub-fields of the real estate industry are ownership of facilities, use of facilities and production of facility-related services.

4 The chapter relies heavily on "Well-being through construction in Finland 2000", VTT Building Technology, 2000, http://www.vtt.fi/rte/dms/pdf/wellb2000.pdf.

The economic boom in late 1990s led to increasing activity in both non-residential sales and home sales, especially in the growing regional centres. Consequently, new service concepts have been invented to accommodate demands in the real estate industry. New innovations and brands have also been established. Non-residential building construction has been on the increase due to the general growth in the economy. The growth of regional centres has been strong, especially due to the needs of high-tech companies. However, the new housing industry has been the engine of growth to a great extent. Still, the total number of one-family homes in relation to the population is below average compared with many European countries. Nonetheless, strong migration between municipalities and especially to Helsinki and the regional centres of Oulu, Tampere and Jyväskylä, a general increase in the prices of old buildings, relatively low interest rates and a low debt-income ratio have increased the attraction of new one-family homes. It is noteworthy that regional differences in this respect are growing in Finland.

Although renovation and modernisation of buildings is the most stable sector in the construction market, the general economic development naturally affects the annual volumes. Overall, this sector has been on the increase due to the need to renew ageing dwellings and also due to the increasing quality demands of customers and inhabitants.

The *infracluster, i.e. civil engineering,* involves, generally speaking, the building and upkeep of a competitive environment for living, leisure and business. Most of the activities in the infracluster have traditionally been financed by the public sector. The infracluster consists of roads, streets, railroads, waterborne networks, energy supply networks, airports, water supply networks and other constructions. The special characteristics of the Finnish infracluster are naturally linked to geography, climate and the location of the population.

The building industry involves the construction sector companies that implement construction projects. Increasingly the companies have become more specialised. Lately, new kinds of service concepts have been established and bigger companies especially have taken into their business portfolios new tasks that were previously the responsibility of the owner. As sub-contracting has become more common, new quality tools and systems have been introduced to ensure the quality of the end product. The constant challenge is to define and accommodate the various customer and end-user needs. In the construction industry and in the building materials and products industry it is believed that international consolidation will continue.[5] Reorganisation is taking place on the European and also on the global level. However, while competition is becoming more global, the markets are still characterised by locally distinctive features.

The building products industry develops and produces products for clients and end-users. Technological innovations with modular products and production techniques, and various efforts at improving the ability to accommodate customer needs, have characterised recent developments in the industry. From a Finnish point of view, one of the most significant changes during the past few years has been the divestment of certain parts of the industry, especially mineral products, through Nordic reorganisations. It is also noteworthy that exports in the building materials and products industry have grown and become less linked with construction project exports.

The building services industry is a relatively young industry. In Finland it dates back to the mid-1990s. The field is lucrative due to a high degree of added value. Building services' share of total construction and management costs is on the increase. Consequently, competition is tight across national borders. An increasing share of the added value is generated in industry and offices.

5 "The future is in knowledge and competence; Technology strategy – a review of choices." Tekes, 2002, pp. 26-27.

Overall development of the business logics

Over the decades productivity in the cluster in Finland, as elsewhere, has been poor in comparison with other industries. It has been argued that the main factors affecting the low productivity of the cluster in Finland are the generally modest input into R&D, the old-fashioned tender processes concentrating on acquisition prices, the inflexible inward-looking industry structures and only partially optimised processes. The real estate and construction cluster has not constituted a real functional entity. Actors have been stuck with old modes of action while, at the same time, the demands have increased technically, ecologically and economically during recent years. Moreover, the evolving role of customers and their quality requirements emphasises the production of services instead of mere production of products. The ageing of the population and the changing values and demands of end-users have a significant impact on the general development of the cluster. New service models are emerging and, for example, transforming construction companies into service and construction companies.

For many actors in the field, real estate and construction has primarily been about domestic markets. Thus lots of the investments in the field have aimed at increasing volumes and improving quality especially in the domestic market. However, the present development is inspired by changing customer needs and technological development and, as a consequence, business customers are increasingly becoming more global and focusing into their core businesses leading to outsourcing that opens new opportunities for companies in the real estate and construction cluster. Consequently, real estate and construction is becoming an international business. Consolidation has taken place and is expected to continue.

As in other industries, the contemporary business management trend highlights the change from a traditional value chain to a comprehensive value net. The cluster, as defined here, has not generally been considered by the actors themselves to be a business ecosystem where cooperation contributes to increasing benefits for all parties. More commonly, the various actors have been playing a zero sum game and maximised their individual shares. Crucially, the actors have not been aware of the business logics that the other parties operate with. It remains to be seen how well real partnerships in the cluster evolve as the understanding of other parties' businesses increases. The changes needed require a new kind of transparency from all parties.

In many ways ICT not only serves as a tool for more efficiency, but also enables or enforces significant changes in the business logics within the cluster. With efficient use of ICT, the building process is seen to evolve towards project-specific knowledge management that links various actors more than before. Moreover, knowledge management in the field is moving towards utilising the information gathered throughout the whole life cycle of dwellings and constructions. In addition, the growing significance of the concept of life cycle contributing to sustainable development has led to new considerations on whole life-cycle cost, feedback systems from maintenance, environmentally responsible construction and utilisation of automation and information technology. The recent thinking on life cycle is giving rise to new kinds of services and products.

However, maybe one of the most lucrative prospects highlighted by the development of ICT is found in increased abilities to define customer needs, to customise solutions through the building process, and thus in the end to meet customer needs more efficiently. Consequently, improved customer-decision support aided by ICT, a product model based design and implementation process, management of product information and on-site information technology will all contribute to increasing data traffic within networks.

Use of ICT product models at various stages of the building process provides new possibilities to improve both efficiency and quality. The Finnish cluster is in many ways at the global edge in this development. The increasing use of ICT has also made possible the efforts for international standards in collecting and describing the information needed in various stages of the construction process. It remains to be seen how the quest for open global standards proceeds.

In summary, big expectations are being placed on the renewal of the cluster with the help of data and communications technology and the services based on them. Moreover, the more ICT is used, the more ICT is shifting to the core of the whole development of the cluster. It should be noted that as the increasing use of ICT changes business logics in the cluster, it will not in all cases be compatible with all traditional earning models and the logics of various parties.

Technology development in the cluster

Technology is the most important source of growth and productivity. The R&D investments on average in the cluster have throughout the 1990s been small in relation to turnover in comparison with other industries. However, it must be noted that variations in the intensity of R&D between the sub-fields of the cluster and between different companies are big, for example R&D investments in the building materials and products industry have traditionally been relatively large. The total annual R&D investment in the cluster was in 2000 approximately 250 million euros which amounts to 0.8% of the total turnover.[6]

Traditionally, the fragmented industry structures and the partial optimisation of the construction process have also provided the framework for the carrying of R&D activities. This has led to the fact that the R&D activities of companies have been directed at technologies and processes in narrowly specified fields or sectors. Thus the fragmentation of industry has spilled down to R&D activities.

Universities and specialised research centres are most commonly the driving force behind innovation in the cluster. According to some interviewees, the relatively low level of R&D in the cluster is also reflected in the quality and quantity of education available in Finland. Despite some world-class research, the total scientific basis is considered to be too narrow. The old-fashioned attitudes are reflected in cooperation between universities and companies. Prejudices exist on both sides. In order to bridge the gap, Tekes continuously emphasises that cooperation between universities and companies has to grow and improve. It is suggested that the industry increase financing of research in universities and research centres. Furthermore, Tekes is emphasising the need for international R&D projects resulting in increased skills, knowledge and innovations that have international or global significance.

The role of Tekes in the cluster has been somewhat stronger than in other industries. According to several interviewees, this is due to the special characteristics, especially the fragmentation, of the cluster. The role Tekes has taken was in several interviews described as “a necessity”. Overall, Tekes has had a central role in initialising and mobilising R&D activities in the cluster in the 1990s. This role was highlighted especially during the recession in the early and mid-90s, as the cluster suffered severe difficulties. Moreover, Tekes has been the central motive force in shaping and conceptualising the content of the cluster.

Recently, Tekes has focused on clarifying its programme portfolio in order to target its investments. It is stated in the cluster’s “Vision 2010”[7] that the main responsibility for the development in the field will shift to pioneering companies. The “Vision 2010” process, backed by Tekes, brought agents together from both public and private sectors to discuss and to outline the strategic goals and priorities for the coming years. The process has generally been seen as an important and necessary step in shaping the strategic intent within the cluster. It remains to be seen how much strategic guidance the vision will provide to the still fragmented cluster. The “Vision 2010” process, like the recent technology programmes, aims among other things to integrate the cluster by establishing stronger links between the actors.

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6 “The future is in knowledge and competence; Technology strategy – a review of choices.” Tekes, 2002, pp. 26.

7 “The Finnish Real Estate and Construction Cluster´s Vision 2010”, Foundations for a good life. 2002, p. 37.

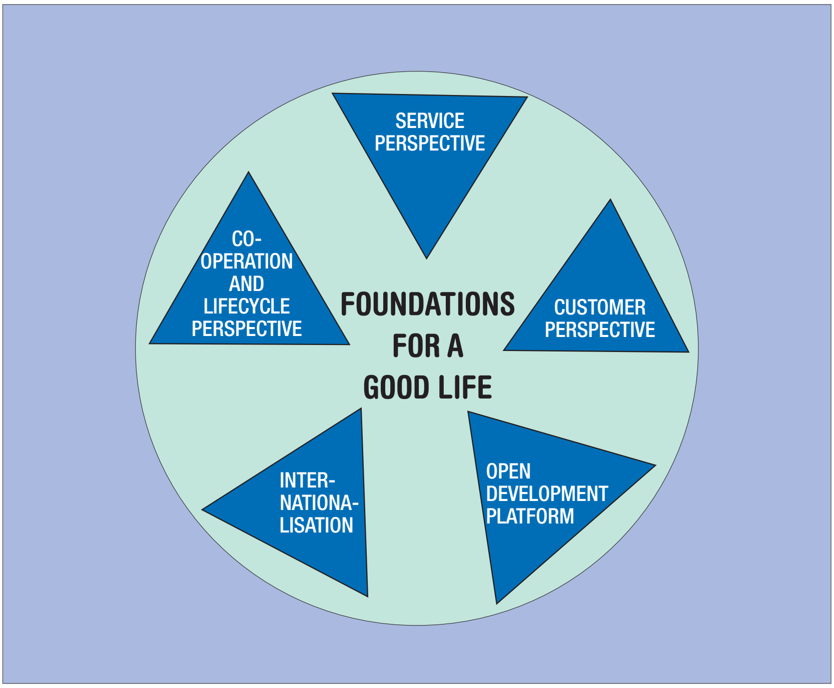


Figure 4. The main components of Vision 2010.

4 An assessment of 11 technology programmes

This chapter will briefly introduce the 11 technology programmes (excl. Vera and the Healthy Building) from a non-technical perspective. Also some overall assessment will be presented in relation to these programmes. The assessment is based mainly on three data sources: 1) documentation and previous evaluations of programmes, 2) expert interviews and 3) the opinions of expert panels.

All these programmes vary not only according to substance but also by the nature of the programmes they represent. There are three families of programmes: 1) Material or technology-based programmes (e.g. the Concrete programme, Finnsteel, Wood in Construction), 2) thematic programmes (e.g. Building automation or the Healthy Building) and 3) cluster-oriented programmes (e.g. ProBuild, Vera, Rembrand). All the programmes are listed in table 2.

Table 2. Description of the programmes assessed.

Programme	Time span	Finance	Main Stakeholders
Technology Programme for the Concrete Industry	1992–1995	8.1 million (FIM) – Tekes 50%	SBK; Building and Building Material Industry VTT; Tampere Technical University
Renovation	1992–1996	25 million (FIM)	Ministry of the Environment ; Ministry of Trade and Industry; Tekes; Construction industry; Kiinteistöliitto
Environmental Technology in Construction	1994–1999	135 million (FIM) – Tekes < 50%	VTT; Ministry of the Environment; Industry; TKK (Helsinki University of Technology); SAFA
HansaRenovation	1994–1996	7 million (FIM)	Ministry of the Environment; Ministry of Trade and Industry; Construction industry; associations
Industrial on-the-spot building	1995–1998	12 million (FIM) – Tekes 5.7 million	Firms: Lohja; Rudus; Polarkudos; Finnsementti; Optirock; Fundia betoniteräkset; Palmberg; Puolimatka; A-Rakennusmies Oy
New methods for the building process	1995–1998	10 million (FIM)	Finnish Association of Building Owners and Construction Clients (RAKLI)
Wood in Construction	1995–1998	125 million FIM (includes EU-funds)	The Forest Industry; The Wood Industry
Finnsteel Technology Programme	1995–2000	60 million FIM – Tekes 27 million	Firms: Rautaruukki; Kvaerner Pulping Oy; Teräsrakenneyhdistys;
Building Automation – Samba	1995–1999	100 million FIM	Finnish Association of Building Owners and Construction Clients (RAKLI); Sähköurakoitsijaliitto; Tampere Polytechnics, 140 firms

Table 2. continues...

Programme	Time span	Finance	Main Stakeholders
ProBuild – Progressing Building Process	1997–2001	50 million FIM – Tekes 28 million	Broad participation of the cluster: Firms; Associations
Vera – Information Networking in the Construction Process	1997–2002	44 million – Tekes 20 million	Construction Firms; architects; IT firms
Healthy Building – Construction Technology, Indoor Climate and Quality	1998– 2002	25 million / year – Tekes 50%	Ministry of Environment; Research Institutions; Universities, Construction industry
Rembrand – Real Estate Management and Services	1999–2003	125 million – Tekes 50%	Finnish Association of Building Owners and Construction Clients (RAKLI); Research Institutions; Universities; industry

4.1 Technology Programme for the Concrete Industry, 1992–95

During 1980s, the productivity rate of the building industry in Finland was below the overall industry's average. The reasons for this were limited resources for development work, the small and dispersed structure of the industry, and the low level of subcontracted tasks. To improve the situation, the Finnish Central Union for the Concrete Industry (SBK) set out an initiative to establish a technology programme for the concrete industry. There were several projects (i.e. RATAS and BEC) carried out during 1980s that laid good groundwork for the TPCI. These projects were aimed at optimising the logistic chains of the planning and building process and at developing open information systems to share the information during various stages of the building process.

Objectives

- To guarantee the national competitiveness and leading role for the Finnish Concrete Industry.
- To enable skeletons of buildings to be installed on-site at a competitive price compared to component technology.
- To develop CAD-based planning and building systems in order to make the building process more cost-efficient.

Key results

- The basic goals were achieved. However, the implementation of the results was rather modest, mainly due to a deep economic recession in Finland and problems in the Russian market.
- Poor success, even though the minimum results were achieved in a technical sense. Applications were not ready after the programme and industry was not keen on financing new technology. There were no new patent applications on the course of the process.

Overall assessment

The programme was one of the first technology programmes within the cluster in the early 1990s and the results remained rather modest. There were several reasons for this: firstly, the scope of the programme was too narrow given the needs of the real estate and construction cluster as a whole. It was mainly the concrete industry (namely SBK) that initiated the programme. Secondly, and strongly related to the first argument, additional R&D investments from the industry's side remained rather modest. This meant that there was relatively few commercial applications created on the basis of the programme. Thirdly, the economic recession hampered most of the potential that the *programme* had. And finally, Tekes had no clear strategy with respect to steering the implementation of the programme. All these factors together explain most of the failures during the course of implementation of the programme.

A positive factor was that the Technology Programme for the Concrete Industry laid the groundwork for further innovations (especially in the field of the automation of the construction process) that were created in the forthcoming technology programmes such as Samba and Vera later on in the decade.

4.2 Renovation Programme, 1992–1996

There were 1,550 million cubic metres of built environment in Finland in 1990. Of this amount more than half was built during last 20 years and almost 80% during the last 45 years. The value of annual renovations in 1990 was FIM 21 billion. There were (and still are) severe problems in the quality of construction in Finland due to a too marked emphasis on costs and schedules of construction. The Korvo-90 project stated that renovation building in Finland was (in early 1990s) still in its early stages. There was a strong vision in the early 1990s that renovation building should get much more attention. It was also evident that this area needed much more research and development.

Objectives

The main objective was to improve the knowledge, technology and the financial as well as administrative chances of overhauling and renovating buildings better. This required a strong emphasis on research and development activities. The expected result of the Renovation Programme was to invent new renovation technology and to give renovation companies new material, financial and technical tools to create new innovative service products.

Key results

The results of the Renovation Programme have been collected into a manual with six toolboxes: The planning, the implementation and the contracting of the renovation project. This serves as a handbook for renovation. Beyond that, the programme has collected dispersed research and other knowledge and created new demand for the renovation.

Overall assessment

The Renovation Programme was the first technology programme that shifted the focus from the construction process to the care-taking of real estate properties. It also introduced the new cluster-based approach to the technology programme in this field. The Renovation Book (Huoltokirja) is a good example of a product resulting from the programme that is still in use. Most of the interviewees conceded that there was a clear need for the programme in the first place. As a pioneer programme, Renovation perhaps lacked the ambition in its scope and innovation. It was a neatly planned and implemented small programme that laid the groundwork for the new cluster-based approach.

4.3 Environmental Technology in Construction (RYM), 1994–99

The building industry had set sustainable development as one of the key priorities in its strategy. Beside the overall importance, environment friendly construction materials were considered to have huge commercial potential that also had great image value. There was a clear lack of suitable technology in this area and therefore Tekes (together with the Ministry of Environment) saw this as a suitable area for a new technology programme. The potential import of wood materials alone into the construction process was considered to have a value of over FIM 20 billion in 1994.

Objectives

The overall objective of the programme was to develop internationally competitive products and methods to adjust the construction process to the principles of sustainable development. The programme had five specific areas:

- Life-cycle assessment – To develop a comprehensive framework for the assessment of the environmental impacts of the construction process.

- Planning methods – To develop guidelines and methods for a sustainable and environment friendly construction process (including the databases needed for this).
- Environment Geo-technology – To establish a new industry that would improve the condition of environment and use of recycled construction materials.
- Products and production methods – To create new sustainable construction products (ecosystems, solar panel technology, recycled materials etc.) and methods (energy saving processes, construction-site improvements), which would improve the competitiveness of the Finnish construction industry.
- Pilot construction – To launch new pilot projects (such as the Viikki eco-community project by the Ministry of Environment and SAFA).

Key results

The main result of the programme was to bring environmental thinking to the construction industry. Besides that, there were several concrete results, of which the following can be considered as the most important:

- Environmental facts for the construction products
- Guidelines and methods for sustainable construction planning
- Ecological construction methods
- Experience from the pilot projects
- Commercial ecological products, methods and services.

Overall assessment

The impacts of the RYM programme were very positive. It established a new culture of sustainable development in the Finnish construction industry. The industry realised that environmental aspects can also be turned into commercial products that increase the competitiveness of the Finnish construction industry. Beyond this, many new products were also launched. Some critics say that the results could have been even better if the programme had continued a bit longer. The start of the programme was slow, mainly due to a lack of interest by the industry. It was also observed that the programme took place too early – even today there are no reliable indicators for environmental impacts.

4.4 HansaRenovation, 1994–1996

After the collapse of the Soviet Union and the recovery of the former socialist countries in Central and Eastern Europe, a vast market and new business opportunities opened up for the Finnish construction industry. This potential was seen especially in the field of exporting Finnish renovation know-how. Approximately 40% of the houses in Central and Eastern Europe were (and partly still are) constructed out of element materials. Finnish expertise was considered to be suitable for massive renovation projects in those countries.

Objectives

The overall objective was make a market and environment analysis of particular countries (Germany, Poland, the Baltic States), with the aim of exporting Finnish knowledge and know-how to those countries. In order to do this there was also a need to create new renovation methods to meet the particular needs of the markets in those countries.

Key results

Despite the potential, the results of the programme were rather modest. A big effort was made to analyse the technical construction standards, legislation, environmental regulation, procurement norms etc. in those market areas. This, in principle, was important ground work should the Finnish companies have really managed to get into the Central and Eastern European renovation markets. There were some promising projects in Germany and Estonia, where new renovation methods were also tested, but in all the business opportunity was never really utilised.

Overall assessment

Although the results from the programme itself remained modest, some new networks and joint venture opportunities were created – especially in Germany. This may have a positive impact on the Finnish real estate and construction cluster in the long run. The biggest problem with the programme was that it was too much supply driven – it lacked real market demand and private business interests.

4.5 Industrial on-the-spot building, 1995–1998

On-the-spot building technology had been a neglected area. The concrete industry wanted to place a special emphasis on developing this technology. There was also a widely shared concern about the problems in the quality of concrete building. This new technology was seen as a potential means of improving the quality of building. Industry saw new business opportunities in terms of increasing the demand for concrete.

Objectives

The main objectives of the programme were to develop new technologies for the on-the-spot building process and to systematise the building process. These improvements were expected to improve the quality of the building process and to reduce overall costs. One of the objectives was also to improve the Finnish building industry's export activities and competitiveness in this field.

Key results

According to the 1999 survey the programme results were widely known among the planning professionals and building industry. The results of the programme remained rather modest, however. Only minor technical improvements were made, especially in areas of insulation and damp-proofing. The Kivitalo (Stone Building) book summarises very comprehensively the main results of the programme.

Overall assessment

This programme had too narrow a focus in the first place. The only actor that had a true interest for the programme was the concrete and construction industry – and only few enterprises within it. Therefore the dissemination of the results and new technical innovations remained rather modest. However, the work initiated in this programme continued later in the ProBuild programme, so that there was a clear continuation of these two programmes.

4.6 New methods for the building process, 1995–1998

The building process can be implemented in many different ways. The number of traditional piecework contracts had declined during the 1990s and had been replaced by split contracts, project management contracts and other planning and implementation models. Tekes also wanted to launch a research-oriented programme to study and develop new building process methods.

Objectives

The research and development was targeted on three areas: 1) the selection of the building process, 2) the integration of planning and construction, and 3) developed procurement and subcontracting arrangements.

Key results

There were altogether 13 research and development projects implemented under the programme. All these reports were published in the RKT series.

Overall assessment

The New Methods for the Building Process Programme was in fact the pilot-programme for the ProBuild programme and thus the results of this programme can only be evaluated as part of the ProBuild evaluation. As an independent programme, New Methods for the Building Process was too narrow in its focus and could perhaps have been a subprogram under ProBuild in the first place. It was unfortunate that economic recession and financial crises of many of the construction companies (especially the smaller ones) hampered the success of the New Methods programme.

4.7 Wood in Construction, 1995–1998

Wood construction was much hyped in Finland in the mid-1990s. The government had launched its Puun Aika (Age of Wood) programme and there was continuous foreign interest towards Finnish wood construction know-how. Wood construction naturally has a long tradition in Finland, but wood in construction had never broken through into mass-scale building processes.

Objectives

The main objectives of the programme were: 1) to create internationally competitive basic production in wood construction, and 2) to improve the manufacturing process to make production more efficient, environment friendly, and to enable high-quality wood construction in Finland and exports to other countries. The programme steering group defined more precise quantitative performance targets and indicators for the programme.

Key results

It is very difficult to assess the real impacts of the programme; the programme documents indicate that the programme has achieved very positive results. They indicate that during its implementation, the use of sawn timber in building increased 35% and that exports of manufactured wood products increased 15%. Wood also increased its market-share in facades of the houses etc. There is, however, relatively little evidence that even part of this was due to the programme.

Overall assessment

Wood in construction was one of the last material-based technology programmes that Tekes financed. There was great interest in the field of wood construction, but the results of the programme were relatively poor. There was no overall strategic focus for the programme and served more the narrow interests of the wood construction business and other organisatio-political aspects than the cluster as a whole.

4.8 Finnsteel Technology Programme, 1995–2000

Dramatic changes had taken place in the markets: globalisation, more intense competition, new building standards and new, alternative building materials and techniques had endangered the future of steel construction. Therefore, three Finnish steel construction companies (Rautaruukki, Rauma Offshore and Tampella Power) decided to start joint efforts to enhance their R&D activities.

Objectives

The main objectives of the programme were: 1) to develop construction systems and products related to these, 2) to shorten the building time and reduce costs compared to traditional on-the-spot building, and 3) to develop new systems and products for export markets.

Key results

The programme delivered 168 reports, publications and articles. It also enhanced collaboration between the firms and R&D institutions. New partnership networks were also created (especially the SteelBase and JOINT projects). There has also been a positive spillover of the results into SMEs in the same field.

Overall assessment

Despite positive results in the field of partnership networks, the overall results of the Finnsteel programme remained more modest than expected. The reasons for this were a lack of synergy between the main stakeholders of the firms. Also the focus of the programme was too narrow.

4.9 Building Automation – Samba, 1995–1999

Objectives

Samba (*Smart and Modular Building Automation*) is aimed at bringing together the building services industry, building owners and end-users to develop new intelligent and interoperable field devices as well as the necessary new services for their utilisation. The field devices are the basic modules of open building automation systems. Interoperability is based on LonWorks, the open protocol called LonTalk and the LonMark interoperability guidelines. Smart and modular building automation systems facilitate the creation of buildings and rooms that better serve their users.

Key results

According to a survey (among 300 experts in the field) carried out in 2000, more 90% of the experts agreed that the Samba technology programme had created a technological breakthrough in the building process, while 70% claimed that programme had created a major market shift. It had also made a major impact on changing the attitudes of various actors in the field.

The products and applications created in the Samba programme are still widely used in Finland. New export projects have also started. Developed technology has been exported to the Baltic states, China, Sweden, Germany and many other countries.

Overall assessment

It is a widely accepted view within the real estate and building cluster that the Samba programme has provided a major technological breakthrough in the industry. Open systems provide access to various actors related to the building process and thus the new innovative approach manages to cover the whole value chain of a building process. This has also enhanced collaboration and networking within the cluster.

4.10 ProBuild – Progressing Building Process, 1997–2001

The ProBuild programme was created to widen the scope of the New Methods for the Building Process -programme. A new need was emerging to map the building process as a whole – also including better recognition of the end-users' opinions instead of only focusing on product and production processes. This could only be done by linking together all the actors in the value-chain.

Objectives

The ProBuild programme aimed at: 1) changing the building culture by introducing new partnership models, 2) widening the scope of quality from narrow technical standards and product orientation towards end-user approach, 3) to improve the quality, productivity and innovation of the building process and, through this, to offer better products and services to end-users and new business opportunities to the Finnish building industry.

Key results

According to the LTT's evaluation, the programme has achieved its overall goals. The programme has had a positive impact on bringing together various actors in the field. The positive results have provided a positive cultural change. Also the programme concept has been seen to be a functional one.

Overall assessment

Although many experts were not too satisfied with the individual projects implemented under ProBuild, the programme as a whole managed to provide a new working culture in the real estate and building cluster. It has broadened the scope of building from narrow building orientation towards a whole-value network. This is an important shift when creating new innovative products and services to end-users throughout the life cycle of a building. The programme has also provided major support in creating a Vision 2010 for the whole cluster.

4.11 Rembrand – Real Estate Management and Services, 1999–2003

Rembrand (Real Estate Management and Services) is a new type of technology programme that aims at directing development effort into creating a service-oriented real estate cluster by generating new ideas and processes and modes of operation. The programme seeks to promote and encourage the creation of new customer service products and concepts of space, and to enhance the functionality of the existing building stock and the efficiency of information transfer.

Objectives

The key objectives of the programme are as follows: 1) to provide globally competitive serve concepts that rely on partnerships and networks, 2) to create transparent markets and transparent organisational cultures in real estate functions, 3) to enhance the efficient use of capital and knowledge to support the core businesses of the customer, 4) create life-cycle collaboration concepts agreements that functionally integrate the sectors into the service-oriented real estate cluster, 5) to produce and maintain environments that support the core functions and enhance the well-being of end-users and 6) to provide integrated education and R&D to enhance the speed of technology transfer.

Key results

The programme is still ongoing – therefore it is to early to assess its results.

Overall assessment

Even if it is too early to say anything about the results of the programme, the concept itself is a new and interesting one. It shifts the emphasis not only from the building process to the maintenance of buildings but also from product orientation to service orientation. First-hand experiences (based on interviews) have been rather positive. The final implementation of the programme will show what the real added value is and will open a discussion as whether this is a type of activity (service development) in which Tekes should be active at all.

5 A review on the Vera and Healthy Building programme evaluations

In terms of the two technology programmes that are to be completed at the end of 2002, a more thorough summary will be made below. We will review expert evaluations of these programmes by Dr. Thomas Froese and Professor Enno Abel. Their conclusions will be reflected in our findings so as to bring about an interplay between these three pieces of evaluation study. The complete expert evaluations by Froese and Abel are appended to this report.

5.1 Vera – Information Networking in the Construction Process

The Vera technology programme runs from 1997 to 2002. The themes of the programme are information management and integration. The target is to promote the implementation and use of information technology and networks and to make it possible to manage the information flows during the entire life cycle of a building. The programme is aimed at developing both construction processes and information systems simultaneously.

The programme will last until the end of 2002. When the programme started in 1997 the planned total volume was expected to be 28 million euro, of which 12 million euro would be funded by Tekes and the rest by the industry. However, the industry's interest in R&D projects in this area has been so strong that the total budget will be 43 million euro, of which 20 million euro is coming from Tekes. About 20% of the funding is for applied technical research (public projects) and 80% is for industrial R&D projects.

Objectives

The goals of the programme are presented below. Through these goals, the programme is expected to achieve an improvement in the return on investments, improved quality and overall profitability of construction, and increased construction exports.

The first goal is the management of the information flow during the entire life cycle of the building: information should be part of the product, and the as-built information should be handed over at the end of the construction project to form the basis for the use and maintenance of the building. The second goal is the improvement of information management among the project parties: to manage the information flow and to be able to develop integrated information systems, it is necessary to agree on the content, structure, format and presentation of the data. The third goal is utilisation of information technology and information networks in the whole construction process: the various parties in the industry have applied and developed information technology focusing only on their own needs. Internal systems are therefore for the most part in place, but information sharing between the parties and joint utilisation of this information is a bottleneck. Networking is contingent upon broad utilisation of information technology in the whole value chain. The fourth goal is process development: information technology must be used as an enabling technology to re-engineer the design, construction and facility management processes.

Key results and overall assessment

An evaluation of the programme has been carried out by Dr. Thomas Froese. According to Froese, the major strengths of the programme were the clarity of the technological vision, the very broad coverage of the various segments of the industry and the technology, the ability to foster and support a large amount of technology development, the strong international focus and the achieved clear advances to the knowledge base. According to

Froese, the main area for improvement is the ability to capture and transfer the collective body of knowledge. Additionally, Froese identifies minor weaknesses, for example lack of quantitative data to support the basic value proposition of the Vera vision, low involvement by small architect companies and certain engineering disciplines, and little collaboration between projects.

According to Froese, "the overall conclusions regarding the Vera programme are that it began with a very well developed and appropriate work plan, that it carried out the plan very effectively, that the vision and priorities held up well over the life of the programme in spite of rapidly changing technology, and that the results of the programme were in line with the highest of expectations. The programme set out to do no less than cause a major technological and procedural shift in one of the nation's largest industries. This is a vast and exceedingly difficult undertaking. The shift has not yet taken place, but the momentum has definitely been created and there is a strong feeling that the critical mass has been reached to make this shift inevitable. In all respects, Vera has been a very successful programme."

Froese's main recommendation in the short term is that any efforts that can be taken to capture, formalise, and disseminate the body of knowledge generated by the Vera programme should be pursued. Froese notes that the amount of technological and procedural advancement required is still very large and, over the longer term, "if unaided, the path will be long and difficult". His final recommendation is that "there is every reason to believe that the successful results of the Vera programme could be repeated if a future programme of a similar nature were initiated".

In the larger evaluation framework of this study, Froese's main findings concerning the Vera technology programme are supported by data derived from the questionnaires regarding the thirteen technology programmes in the field of real estate and construction. Almost without exception, Vera was considered to be among the most successful technology programmes carried out in the cluster.

As stated above, Froese notes that the largest weakness was that there was no effective means of capturing the large, cumulative body of knowledge generated through all of the projects, and of transferring this knowledge throughout the industry through detailed documentation, in depth training, etc. He estimates that "this appears to be a weakness of the Tekes technology programmes in general, rather than of Vera in particular, since the mechanism of company-initiated, commercial R&D creates no incentive for this type of knowledge capture and, in fact, intellectual property and confidentiality issues can provide a strong barrier to knowledge transfer." This claim that the problem of effective knowledge gathering and dissemination is more connected to the overall logic of technology programmes in general than the Vera technology programme in particular is also supported by the data received from questionnaires and views expressed in several interviews with the experts in the field while looking at the thirteen technology programmes.

However, according to the interviews carried out in the context of this study, more emphasis should be put on the concern that as the internationally pioneering work undertaken in the Vera technology programme has already opened, and will continue to open, several global opportunities and new strategic directions in the further development within the cluster, the present ability and mental readiness to utilise the tools developed is limited, taking into consideration the fragmented nature of the Finnish cluster overall. Moreover, the edge now achieved in R&D is hard to maintain in the increasingly competitive global market. Thus, the requirements for efficient commercialisation and international marketing are tough. Moreover, the promising views are not fully concretised in the form of increased exports and productivity. This point reflects the larger concern regarding the Finnish innovation environment, namely that the ratio of public inputs into R&D and into commercialisation and marketing is not optimal.

5.2 Healthy Building – Construction Technology, Indoor Climate and Quality

The Finnish Healthy Building technology programme represents a substantial effort to improve the knowledge and develop technical solutions for improved indoor climate in new buildings and in existing buildings with indoor climate-related problems. The programme was initiated in 1998 and it will be completed during 2002. The total extent of the programme has been about 23 million euros of which 12.3 million euros have been contributed by Tekes. About a third of the funding has been assigned to university departments, while the rest has gone to projects carried out by companies.

Objectives

The programme has focused on four key areas, namely services and business concepts, ventilation and building services, moisture and emissions. The basic idea has been that the objectives are to be attained through active cooperation between the research sector, the public health sector, the real estate sector, the construction business and the manufacturing industry. The goals of the programme in shortened form are as follows:

The first goal is enhancing knowledge about the relationship between physical effects and indoor air, and the development of building construction methods to raise indoor air quality to the high level of international excellence. The second goal is the development and implementation of indoor air and health criteria and support for the quality classification of buildings and of products and services in buildings. The third goal is the development of key spearhead products and processes that are competitive and exportable. The fourth goal is the development of processes for diagnosing and rectifying the indoor air and health properties of buildings.

Key results and overall assessment

The programme evaluation was carried out by Professor Enno Abel. According to Abel, the major strengths of the programme have been the following: Firstly, a number of functioning constellations between university departments and between university researchers and research groups outside universities have been brought about. Secondly, constructive cooperation between research groups, manufacturers and contractors, aiming at methods and components for application in practice, has been established and has been very fruitful, especially in the moisture problem area. Thirdly, the positive involvement of real estate companies has contributed to the relevance and has, above all, facilitated fast implementation, primarily in the moisture problem area. Finally, the concentrated effort supported by substantial funding, combined with the cooperation mentioned above and a rather tough time schedule has surely contributed to the good generation of applicable results. Of the individual goal areas mentioned above, Abel notes that the work done on moisture has been in a way more concrete than the work in other key areas.

Abel notes some areas for improvement. He emphasises the need for more extensive international publication and especially peer review publication of results from the research projects, "because such publication involves international quality control that is beneficial on the long run". He also notes the possibility of generating quite a few more Ph.D. theses than has been the case in the programme.

According to the data gathered through questionnaire and interviews regarding the thirteen technology programmes in the focus of this study, it is estimated that "Healthy Building" is among the most successful. In this wider context some additional aspects should be emphasised. The fact that "Healthy Building" has had a quite straightforward problem-solving approach has been appreciated by enterprises despite the early problems in getting the enterprises involved. The increasing quality awareness has also been considered to be an important advancement for the whole cluster. The research undertaken has been of very high standard. However, it was pointed out by several interviewees that the real challenge of "Healthy Building" is the question of extent to which the research and development done is translated into practice. This is directly linked to the fact that it is questionable whether the whole cluster has been committed to the goals set for the programme.

6 Impacts of technology programmes on the cluster's development

A central question in this evaluation concerns the forms of the Tekes-funded technology programmes and the extent to how they have affected development of the real estate and construction cluster. On this question, the evaluation relies on three empirical data sources. First, the evaluation team interviewed a number of programme managers and implementers as well as key stakeholders in the cluster. Second, a survey targeted at a larger group of stakeholders was conducted. Third, linked to the survey, a Crest analysis was carried out.

In the following, we will report the main results of the survey. The questionnaire was sent to people representing companies and research organisations who had applied for technology development funding during the last four years. A total number of 155 people answered the survey questionnaire. Slightly over half of them had worked in a company project and 40% had worked in a research project (see figure 5).

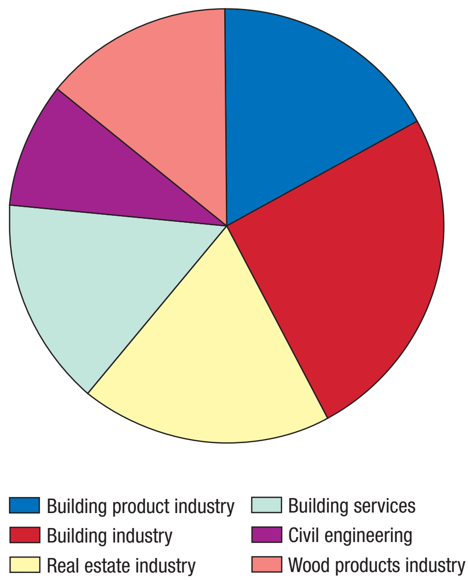


Figure 6. Respondents by industry (primary industry affiliation).

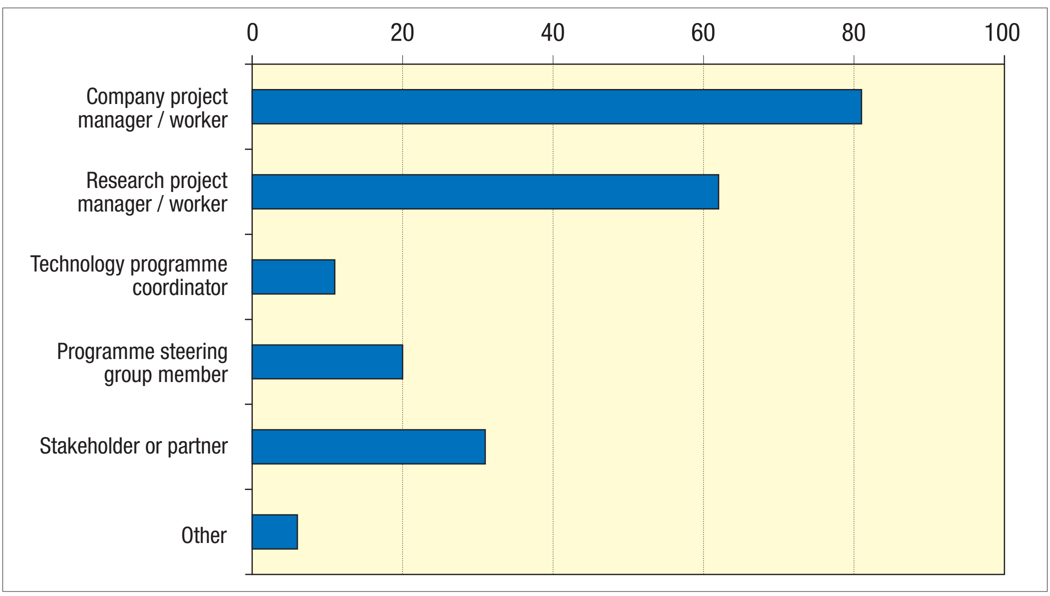


Figure 5. Respondents by their role in the programmes.

Included were also technology programme coordinators, steering group members and stakeholders. (Note that single respondents may have acted in multiple roles in technology programmes.)

Six industries were represented in the target group as shown in figure 6, the building industry being the most strongly represented.

6.1 The significance of technology programmes

In the survey, the respondents were asked to render their judgement on the perceived impacts of technology programmes on various issues. As shown in the figure 7, the most visible impacts were found on the quality of R&D activities, the level of knowledge and know-how produced, as well as national networking and cooperation. Also new products, processes and services were ranked relatively high on the five-point scale.

A much more modest, even negative average assessment was given to technology programmes' impacts on international networking and cooperation. Especially critical were the representatives of company projects as well as stakeholders. The ultimate impacts on society were considered a bit more positive, the average being 3.5 on the scale from 1 to 5.

The results relating to technology programme impacts were confirmed by open questions, in which respondents were asked to describe the significance of the programmes. In general terms, a high number of respondents pointed to the significant role that the technology programmes have had in the cluster's development. More specifically, the programmes were seen as having different roles in the various phases of technology development. In the figure 8, the respondent answers have been reconstructed into a cause-and-effect presentation about the significance of technology programmes at various stages.

First, many remarks were made on the particular features of the real estate and construction industry. The conservatism towards R&D and fragmented and inflexible business structures have serious implications leading to a low level and a weak tradition of R&D in the cluster. Short-sightedness and partial profit maximisation combined with resistance to change and intra-cluster barriers do not provide the business with optimal conditions for technology development.

Consequently, Tekes and its technology programmes have gained a pivotal and strategically significant role in the cluster. Programme funding and activities have had major roles in motivating actors to engage in technology development. Without public support many projects would not have been launched in this cluster.

Remarks were also made on the critical mass required for technology funding. For the industry, the programmes enable contributions to product development projects. For the research institutions, the programmes maintain their research capacity. Within the real estate and construction cluster, Tekes is regarded as the only funding institution for technology R&D projects, which is a very different context compared to e.g. the medical industry, where a multitude of private and semi-public foundations finance research projects. Tekes programmes enable more in-depth research and development efforts.

As regards the strategic role Tekes has had, many respondents stated that Tekes programmes have functioned as "an engine" or "a motor" for the cluster's development as a whole. Tekes as a public actor has "forced" the industry to renew by keeping R&D issues on the agenda. The programmes are credited for bringing impulses, inspiration and activation into the business. One further feature of the programmes is that they provide a strategic framework for networking actors and projects.

When asked about the significance of the technology programmes, many remarks were presented about their impacts on the cluster. These include

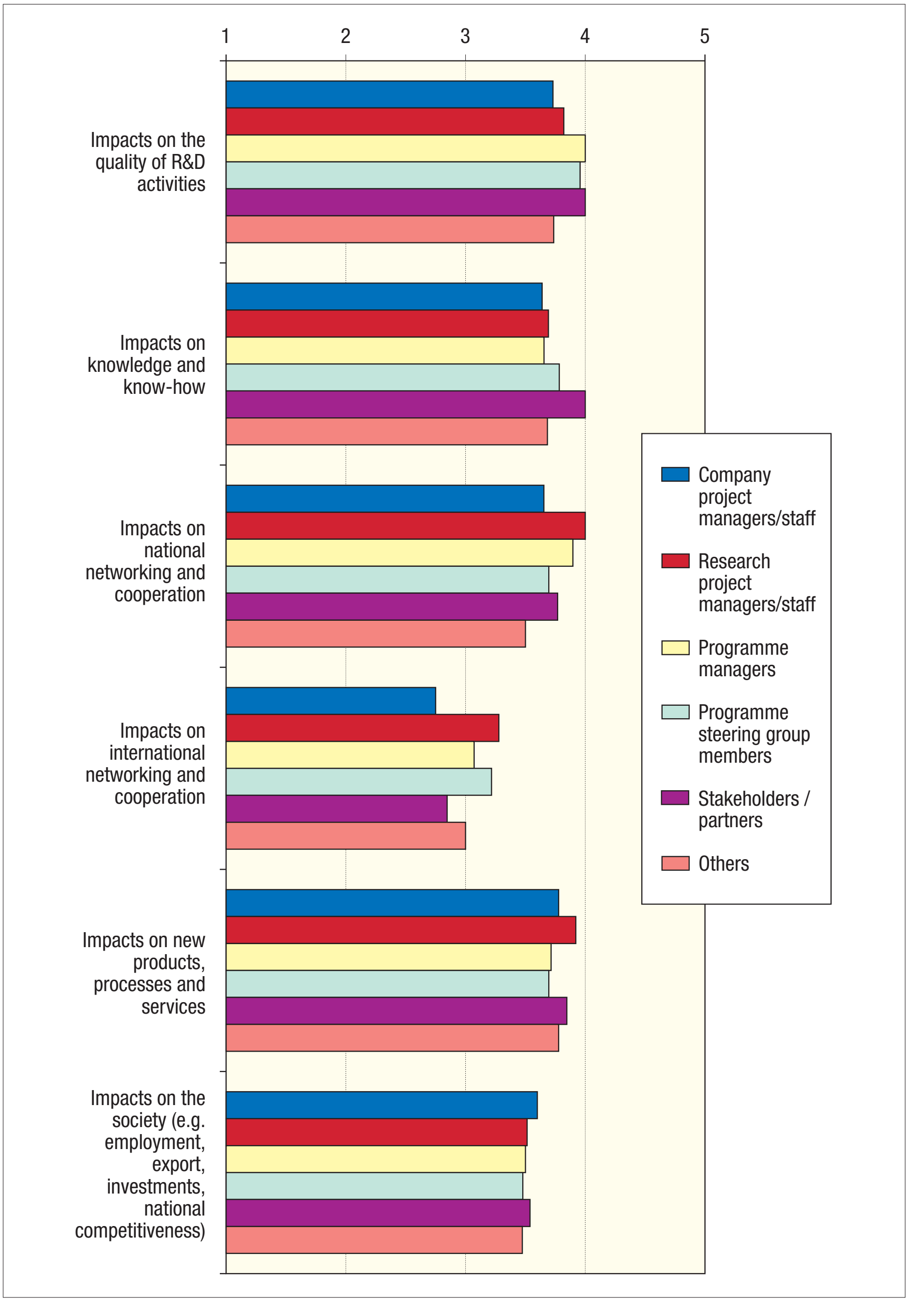


Figure 7. Respondents' assessment of the impacts of technology programmes.

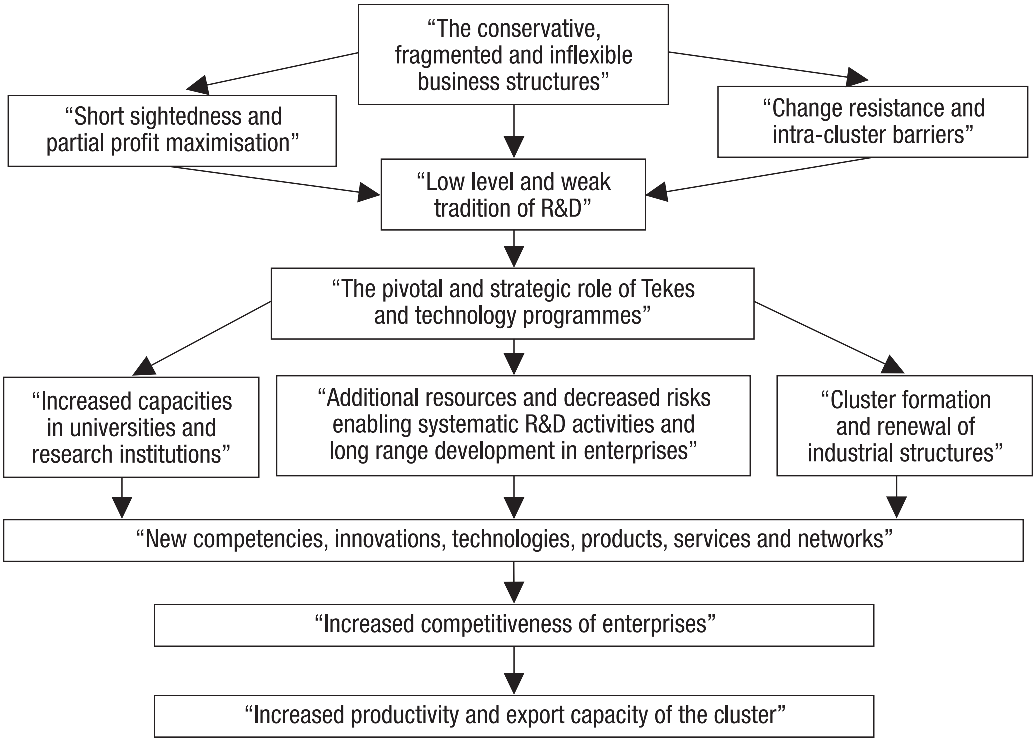


Figure 8. A reconstruction on the significance of the technology programmes according to the respondents.

business-enabling issues, such as networking and the creation and dissemination of knowledge. Business impacts in the form of new product ideas, techniques, products, services and processes were also referred to in many sub-industries.

As regards the impacts on the development of the cluster as a whole, few issues came up in the survey responses. The consolidation of common practices for the cluster is regarded as significant for results emanating from the technology programmes. This has implications for the renewal of the entire industry. As even wider-ranging implications, some respondents were able to identify some economic effects emerging from technology programmes. The competitiveness of the industry is expected to have increased due to Tekes' efforts within the cluster.

An aspect that received surprisingly scant attention in the remarks was the international aspect of the programmes. Only a few respondents referred to the role of the programmes as enhancers of the internationalisation of the cluster. According to the survey results, there are certain differences between the industries, as presented in figure 9.

The perceived impacts of technology programmes on international networking and cooperation were considered strongest in the building industry and building services. The least influence was seen in the business fields of civil engineering (infra) and the building product industry. However, the many aspects of international networking should be noted here. First, it means importing knowledge into Finland from abroad through expert invitations and research commissions. This was mentioned as a positive impulse from the technology programmes in the interviews. Second, there are expectations that, through the networks that are being built up by technology programme activities,

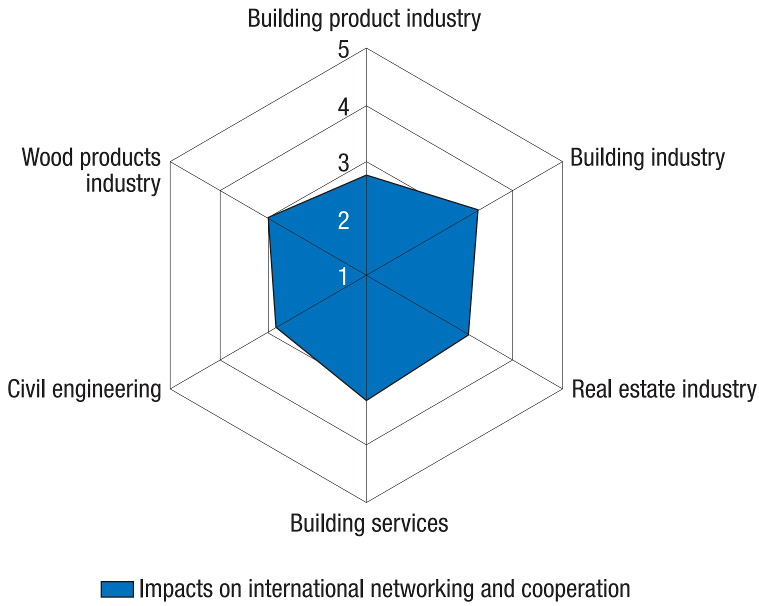


Figure 9. Impacts on international networking and cooperation by industry.

Finnish companies are capable of exporting products, services and knowledge abroad. These expectations only rarely seem to be met. Few success stories within the whole cluster came up in the evaluation. It was suggested that if some great internationalisation processes of the cluster take place, it will emerge from the Finnish companies being merged with European or global corporations. This will open the door to transferring innovations globally on a novel manner.

While taking a closer look at the answers given by the respondents from each sub-industry, some further observations can be pointed out. In the *building product industry*, the significance of the technology programmes is seen to derive especially from improved quality of product development and products. Moreover, respondents relate the effect of technology programmes to the increased emphasis on quality in the whole industry. The impact on improved exportability is also mentioned.

In the *building industry*, the answers place much more emphasis on the positive effect of the technology programmes for networking and increased cooperation within the whole cluster. The importance of internationalisation as a means of acquiring knowledge from abroad with the help of the technology programmes is also noted. Especially the improved quality of the building process is seen as an achievement where the technology programmes have had a crucial role.

In the *real estate industry*, increased networking and cooperation as a consequence of the technology programmes is also noted. In addition, the increased importance of customer perspective and general service-based thinking are mentioned as important achievements where the technology programmes have had an important role to play.

In the *building services industry*, basically all the above-mentioned effects of the technology programmes are mentioned. Moreover, the financing aspect of technology programmes is also considered to be important. According to respondents, the technology programmes have generally improved the use of information technology and the information flows within the cluster.

In the *infracluster*, i.e. civil engineering, the importance of increased networking is mentioned often. New technical skills and technological innovations due to the technology programmes are also noted.

Moreover, the opportunities offered to SMEs within the programmes are seen as important factors in the overall development of the sub-industry.

In the *wood products industry*, increased networking has been achieved with the help of the programmes, according to respondents. New product innovations, processes and products have been developed, affecting the overall usability of wood in construction. In addition, improved export capabilities are also seen to have developed as a consequence.

The results presented above are all perceptions of positive implications of Tekes for the real estate and construction cluster. Generally speaking, the majority of the survey respondents hold rather positive views on the technology programmes' role for the cluster. As a conclusion, the actors' perceptions about the significance of Tekes' programmes largely correspond to the expectations set for them by Tekes itself.

6.2 Problems and risks

In the previous section, the positive aspects of the technology programmes were presented. However, some doubts and critical remarks were also presented, which do not outnumber the positive aspects, but which should be presented here. In figure 10, a tentative picture of the problems and risks related to the technology programmes are presented. The different conditions and problem descriptions are linked. These remarks also emanate from the open answers in the survey, with the connecting interpretations made by the evaluators.

Due to the characteristics of the cluster as well as Tekes' technology strategy and programme approach, some problems and risks can be identified. These are confined inside the oval in the figure. First, because of simple expectations for subvention for R&D projects, enterprises may not become truly engaged in the networking. Second, due to a move towards broad cluster programmes, the pro-

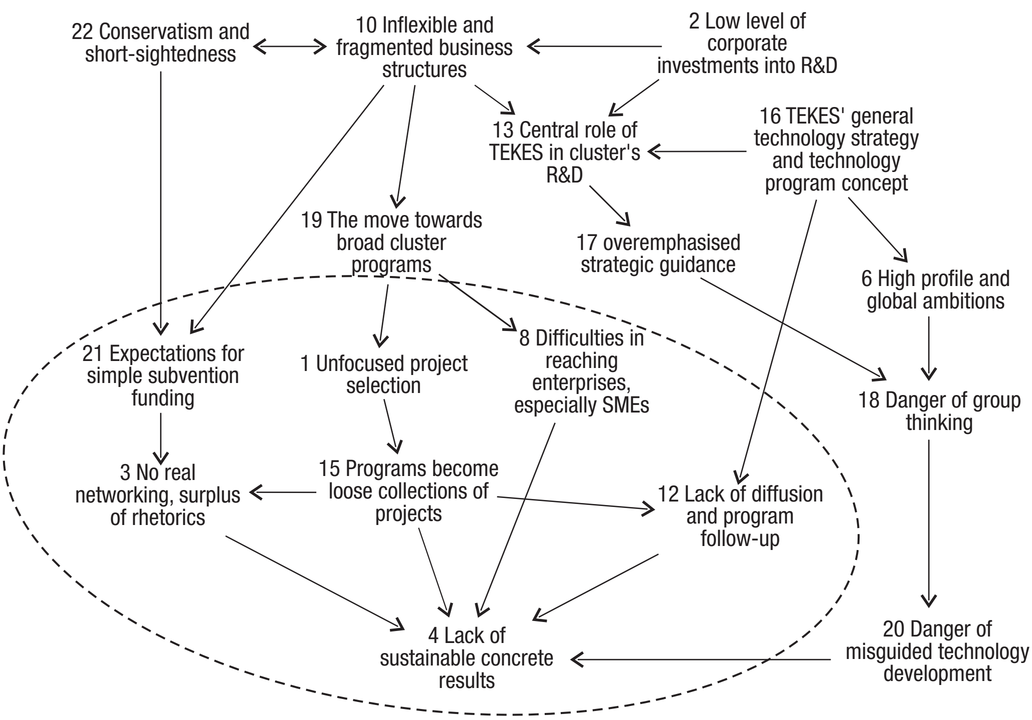


Figure 10. Problems and risks in the present programming approach.

ject selection may become unfocused, leading to only loosely connected collections of projects without a common goal. Third, programmes may not be able to reach enterprises – and especially SMEs – sufficiently. The fourth identified factor leading to a lack of sustainable concrete results is the inadequate diffusion of results and programme follow-up. The results are not utilised to the extent where the full benefits of knowledge sharing would be reaped.

6.3 Expectations for future technology programmes

Hopes and expectations for what kind of technology programmes there should be in the future were asked in interviews and in the survey. The most important question is whether the move towards wider programmes should be continued or not. In figure 11 support for four types of programmes are presented.

The average support is stronger for broader programmes linking together industries and clusters with common themes than for narrow, technology-based programmes. When asked about the directions for the future programmes, a great number of respondents presented a hope for inter-cluster programmes and interdisciplinary approaches.

The desirability of the different types of technology programmes varies between the sub-industries as presented in the figure 12.

However, many of the people interviewed pointed out the need for different kinds of programmes existing in parallel. It was also pointed out that there should be different kinds of objectives and expectations for different kinds of programmes. For technology-focused programmes, the goals would be more directed at product development, whereas in cluster programmes, the development of common practices and changes in thinking are more important.

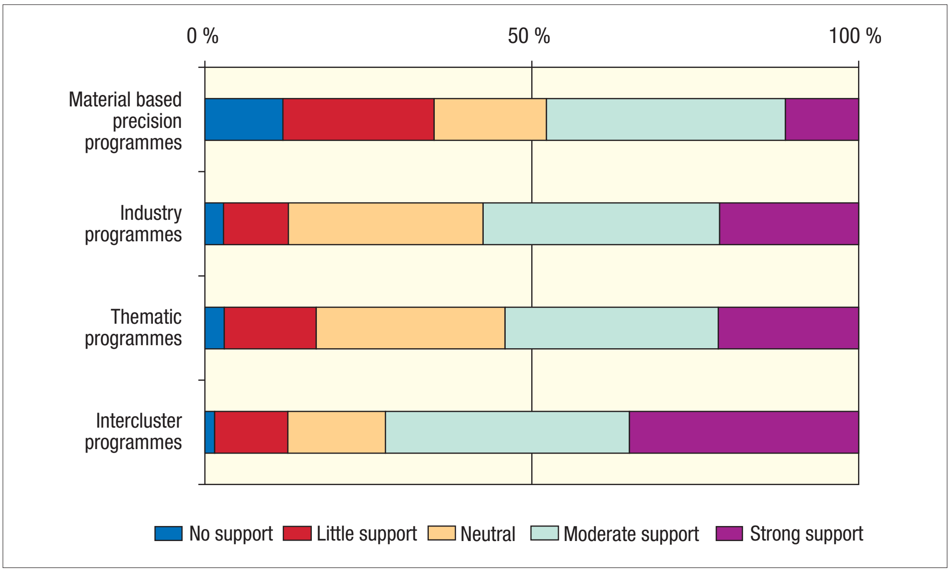


Figure 11. Support for different types of technology programmes.

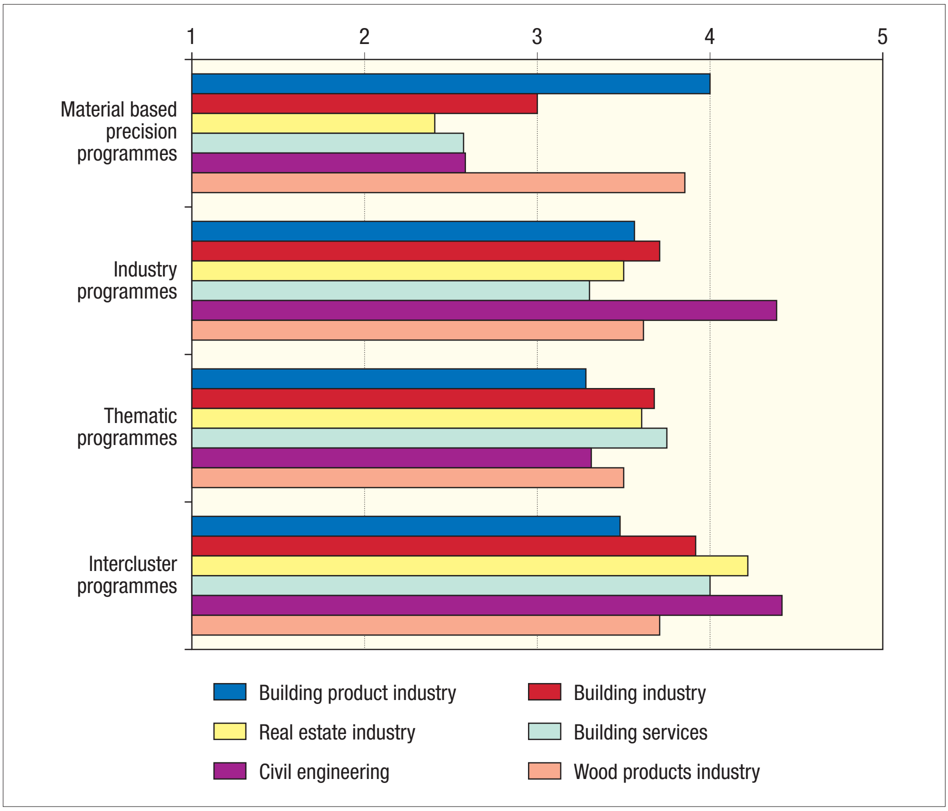


Figure 12. The desirability of technology programme types by industry.

6.4 Expert panel results

The programmes' impacts and added value were also tested by applying new survey technology, labelled here as Crest analysis. Crest analysis[8] is an Internet-based strategy tool that resembles other panel techniques such as the delfoi technique. Experts were given three two-dimensional space charts and their task was to plot the 13 real estate and construction technology programmes on the charts based on their opinion of programmes. Experts were also given a chance not to plot particular programmes should they not have sufficient knowledge of the programmes.

Invitations to the Crest panel were sent to a total of 960 experts between 30 September and 9 October, 2002. The invitation list was prepared by the evaluators and representatives of Tekes and consisted of the same people as in the survey. During this period, 141 experts joined the panel and shared their expert opinions on the programmes.

In the first assessment, matrix experts were asked to judge the programmes according to their importance to the field and to the success of the programme. Figure 13 represents the results of this analysis.

Figure 13 shows that there seems to be a strong positive correlation between the importance of a programme and its success. Four programmes can be spotted in the upper-right corner (high importance – high success). These are spear-head pro-

8 Crest analysis was developed by Prof. Esko Ala-Saarela of the University of Oulu.

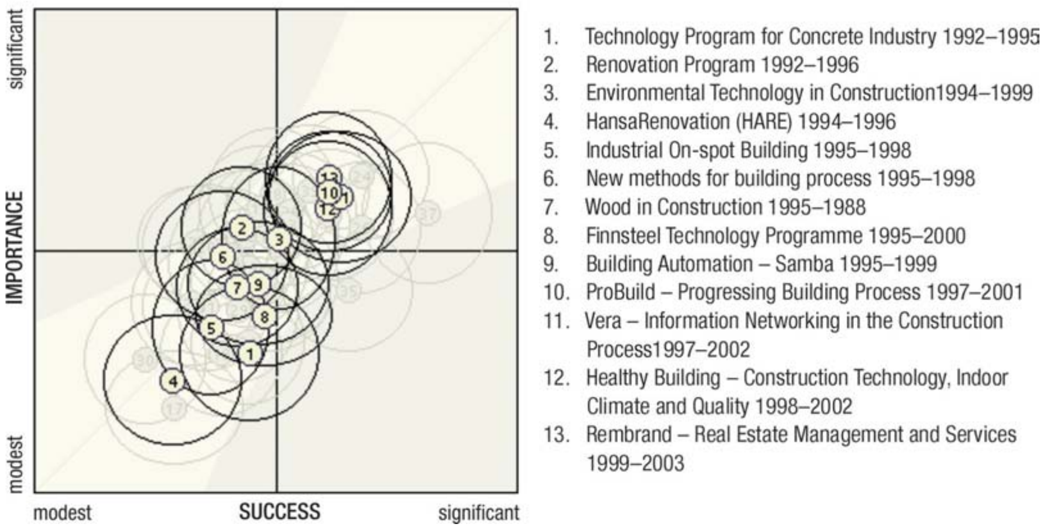
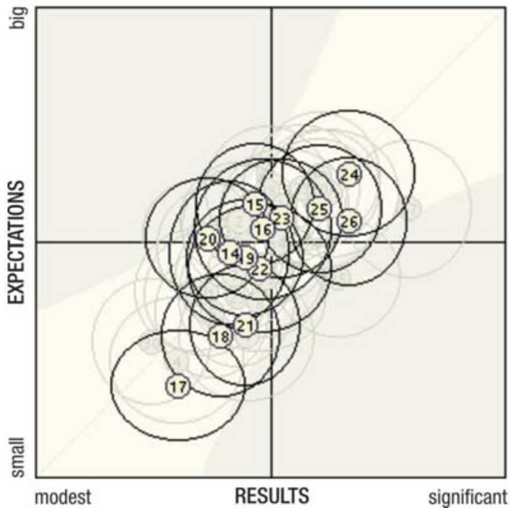


Figure 13. Programmes according to their importance and success.

grammes that meet the criteria of high importance and high success, namely Probuild, Vera, Healthy Building and Rembrand. All these programmes are recently implemented technology programmes in this field. They all can be labelled as comprehensive, cluster-based programmes that have a strong emphasis on networking and partnership. They also aim to cover the whole life cycle of the building process and value-chain of this process. The programmes that receive the most critical judgement are Hansa Renovation, the Technology Programme for the Concrete Industry, Industrial on-the-spot building and Wood in Construction. All these are not only early programmes (implemented in early or mid-1990s) but they also have a narrow, material specific focus. It is understandable that their importance cannot be that high – given their narrow scope – but it is somewhat surprising that the success of implementation is judged to be so poor.

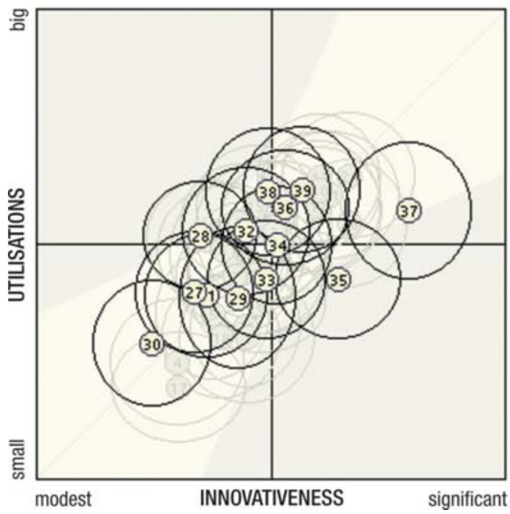
In figure 14, experts have plotted the programmes according to the expectations they had of programmes before implementation and the results achieved during the implementation. According to these criteria the Vera programme seems to be the most successful. It had high expectations and it also managed to produce very good results. The same observation also arose during various expert interviews. The active role of programme manager Mr. Kiviniemi in international contexts was mentioned as one of the key factors in this. Other successful programmes seem to be the Rembrand programme and Healthy Building. In these two cases expectations were not that high at the beginning, but the good results have surprised the field. On the bottom-left corner there are programmes such as HansaRenovation, Industrial on-the-spot building and Finnsteel, which represent the cases where expectations were rather low and where also the results achieved remained modest. The strategic retrospective judgement is that these are the programmes that should not have been initiated in the first place. These latter cases are all rather narrow programmes supported by only a few advocates in the field. One of the biggest disappointments seems to be the Wood in Construction programme, where expectations were much higher than with the three low-low -programmes but the results were nearly non-existent.

The results presented in figure 15 have been assessed as a programme with extremely high innovativeness and a positive amount of commercial utilisation. Building Automation – Samba seems to provide many new technological innovations that are still lacking commercial applications at present. Rembrand and Healthy Building are



14. Technology Program for Concrete Industry 1992–1995
15. Renovation Program 1992–1996
16. Environmental Technology in Construction1994–1999
17. HansaRenovation (HARE) 1994–1996
18. Industrial On-spot Building 1995–1998
19. New methods for building process 1995–1998
20. Wood in Construction 1995–1988
21. Finnsteel Technology Programme 1995–2000
22. Building Automation – Samba 1995–1999
23. ProBuild – Progressing Building Process 1997–2001
24. Vera – Information Networking in the Construction Process1997–2002
25. Healthy Building – Construction Technology, Indoor Climate and Quality 1998–2002
26. Rembrand – Real Estate Management and Services 1999–2003

Figure 14. Programmes according to expectations and results.



27. Technology Program for Concrete Industry 1992–1995
28. Renovation Program 1992–1996
29. Environmental Technology in Construction1994–1999
30. HansaRenovation (HARE) 1994–1996
31. Industrial On-spot Building 1995–1998
32. New methods for building process 1995–1998
33. Wood in Construction 1995–1988
34. Finnsteel Technology Programme 1995–2000
35. Building Automation – Samba 1995–1999
36. ProBuild – Progressing Building Process 1997–2001
37. Vera – Information Networking in the Construction Process1997–2002
38. Healthy Building – Construction Technology, Indoor Climate and Quality 1998–2002
39. Rembrand – Real Estate Management and Services 1999–2003

Figure 15. Programmes according to their innovativeness and commercial utilisation.

perhaps not as innovative but nevertheless provide a great variety of commercial applications. Hansa-Renovation – once more – is considered to be the programme that lacks both of these qualities.

These findings are in line with the expert opinions surveyed in several interviews and expert panels. During a Board of Excellence[9] meeting on 27 May, 2002 chairpersons of various real estate and con-

9 Represented in the Board of Excellence are chairpersons of real estate and construction technology programmes. This group meets on a regular basis to discuss strategic issues related to the development of the cluster.

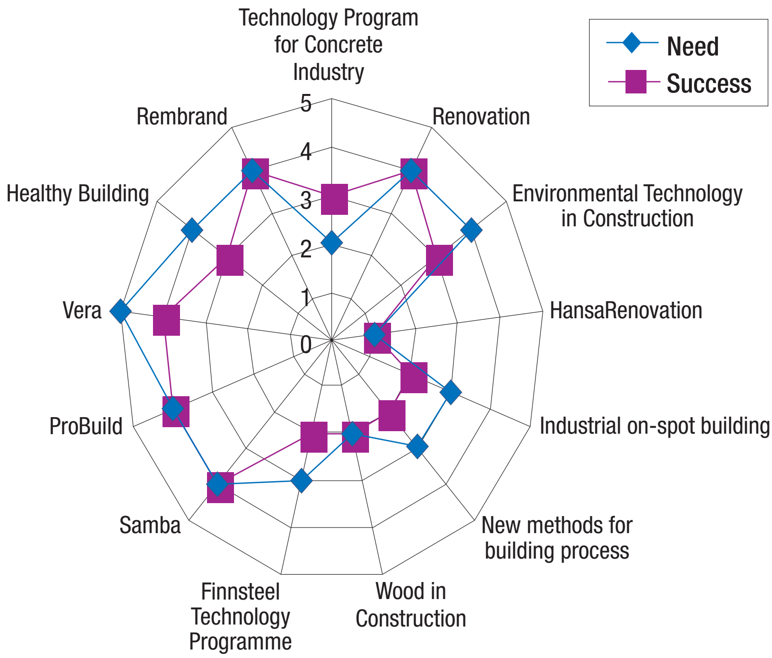


Figure 16. Results of Board of Excellence voting.

struction technology programmes assessed all 13 programme according to their needs and success. Assessment was made by consensus voting (each programme was discussed so long that there was a consensus on the voting scores). Figure 16 presents the results of the consensus panel.

Figure 16 shows that the same programmes that were considered to be the most successful ones (namely Vera, Healthy Building, Rembrand) in the Crest analysis are also considered to be best practice examples by the members of the Board of Excellence. The most critical judgement is given to Hansa Renovation and Wood in Construction. According to the Board of Excellence members, Hansa Renovation should not have been established in the first place. There was not enough market information and knowledge behind the decision to carry out renovation-related export activities in Russia, the Baltics and Poland. In respect of Wood in Construction; it was considered to be an example of an unrealistic supply-driven programme. It was the wood industry that initiated the programme and there was only a vague expectation that the building industry would take an interest in the programme. This appeared not to be the case.

7 Conclusions and guidelines for the future

The definition of the cluster in its present form links real estate business with construction business. Tekes has had a pivotal role in redefining the cluster, and the technology programmes have been major instruments in establishing broadly defined cluster thinking. The evolving definition of the cluster has already had and will continue to have profound implications for the whole business in the future. First, technology policy formation, strategic intentions and business needs are defined on a new basis. Second, the more holistic cluster approach has brought about a new understanding of the business logic, which entails a shift from value-chain thinking into a value-net perspective. Third, establishing new partnerships and interactions have become the central focus in the business, where technology programmes have been assigned a large significance. Fourth, along with this change, a new vocabulary with novel concepts has emerged. Fifth, more comprehensive and integrated cluster thinking has generated prospects for new products and services, where the potential from bringing together the whole cluster has been realised. However, these changes are still, to a great extent, at the level of new comprehensions, not yet fully realised in increased productivity and competitiveness.

The role of Tekes has been more integrative in this cluster than in other industries, which is due to the special characteristics of the cluster. Overall, research and development efforts have moved from a fragmented state to a Tekes-driven state. At the present, we are on the move towards a more organic co-evolution and interplay between enterprise needs and Tekes' strategic guidance. As is visible in work within the Vision 2010 process,

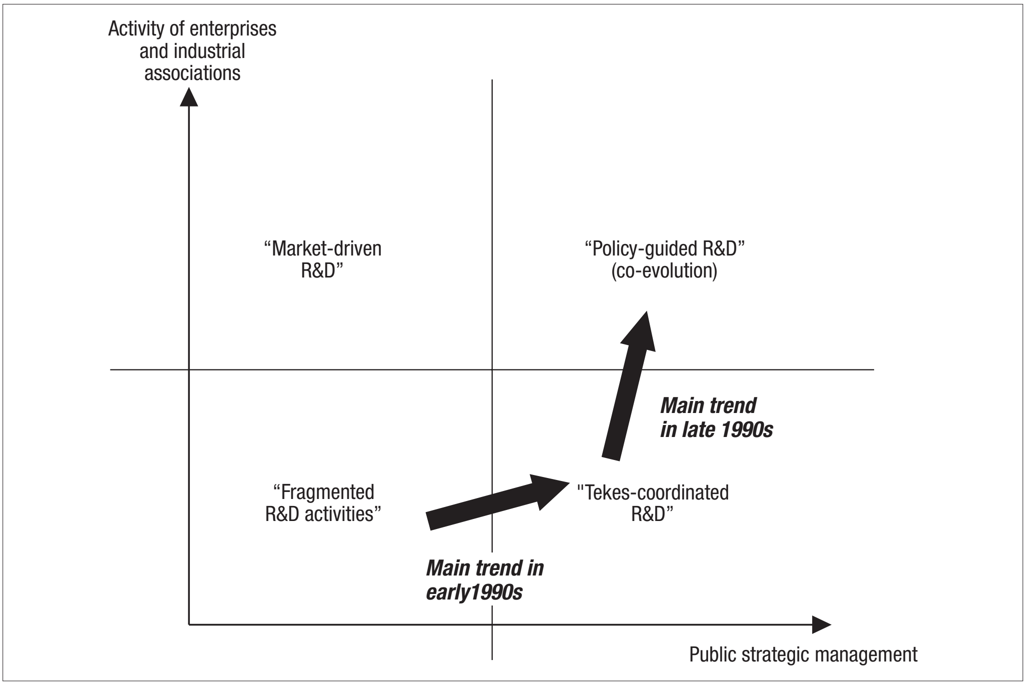


Figure 17. Interpretation of the development of strategic decision-making within the cluster.

the industry associations, research organisations and other stakeholders are increasingly taking part in the formulation of strategic directions.

Recommendation. Tekes should continue to encourage enterprises and industry associations to take a more active and independent role in strategic formulation and R&D priority setting within the whole cluster. This requires a cluster and actors strong enough to take the leading role.

- There are clear indications within Tekes that it should give the business community a stronger role in defining the strategic directions. This trend is illustrated in figure 18 as a move towards a more market-driven R&D culture in the cluster (the arrow pointing to the left). An alternate direction would be to strengthen the co-evolutionary character of the cluster, with Tekes continuing to have a significant role in strategy formulation, but strengthening the links with other public and semi-public actors in the innovation environment (the arrow pointing to the right). However, it is necessary to note that the various possibilities as regards the formation of strategic directions are not necessarily linked to the level of public technology funding allocated to the real estate and construction cluster. The level of technology funding is primarily agreed on the national political level when allocating public resources for different policy sectors.

Recommendation. If the industry were to take a more active and directive role in priority setting, the role of Tekes would become – in addition to the basic financing function – more of a balancing actor, facilitator and collaborator. In practice, this means that it would be the responsibility of the cluster to set up and articulate R&D needs. The role of Tekes would be to facilitate and support the identification of the needs and tailor technology programmes to meet the needs. As part of an evolving role, Tekes should develop multiple foresight capabilities, i.e. taking into consideration the combination of technological, political, social, economic and ecological change prospects and factors.

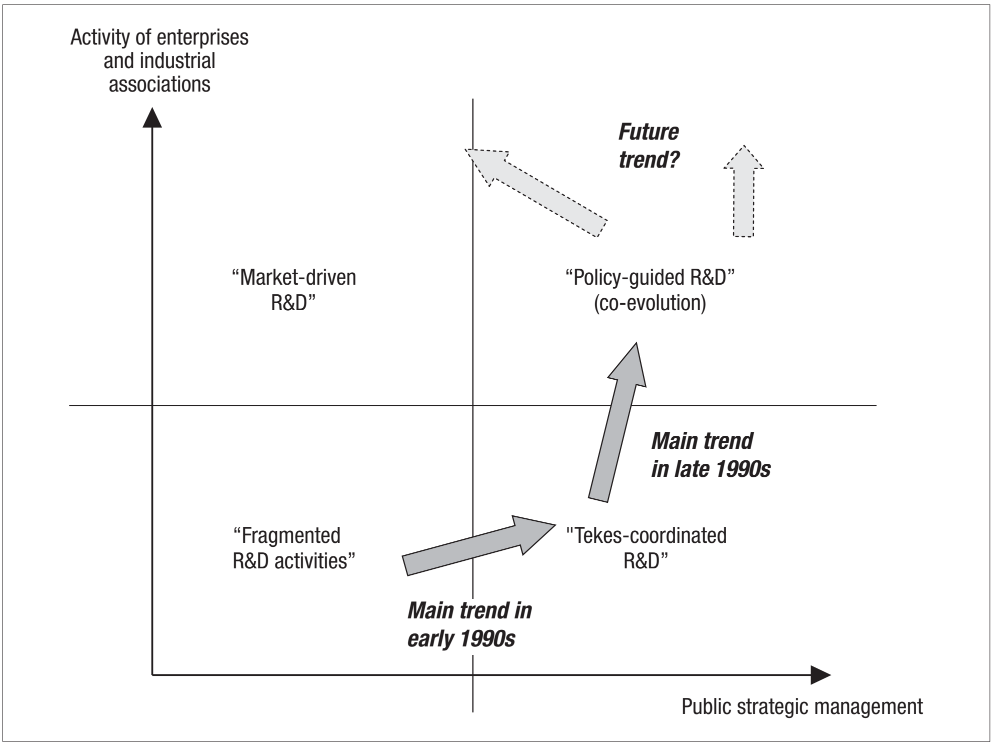


Figure 18. Future trends for the role of Tekes.

- There has been a shift from specific material or technology-focused programmes towards more comprehensive programmes on the level of the cluster. This is consistent with the cluster-based thinking in the Finnish innovation system. In our understanding, this also increases cooperation and interaction between various actors. However, a certain challenge concerns the definition of programme objectives when moving onto a more comprehensive level. The programmes may become loose collections of development projects without a clear understanding of how the programme-level objectives are to be achieved. Consequently, in practical terms, individual organisations have troubles in linking their development needs into these general formulations. There appears to a risk that project selection becomes unfocused.

Recommendation. In programme design, a more articulated understanding of how project activities are linked to expected programme outcomes should be elaborated. The strategic road map, along with particular chains of activities and their expected effects, should be made explicit.

- The level of R&D activities in the cluster has traditionally been on a lower level than in other industries. Despite recent progress, including some world-class research results, the academic tradition at large is rather thin in the cluster. The integration of research organisations into the programmes has been strongly emphasised by Tekes. However, there has been and still remains a certain reticence towards academic research within the industry. The research input and the involvement of universities and research institutions has not met all expectations. Combined with the thin research basis, this partly explains the lack of collaboration between enterprises and research institutions in the real estate and construction technology programmes.

Recommendation. Tekes should continue and enhance its motivation of all parties' involvement in linking basic research, product development and commercialisation.

In addition, closer collaboration between Tekes and other R&D funding institutions – e.g. the European Union, the Academy of Finland – should be aspired to. There should be more cross-institutional connections and a more horizontal approach in the selection of projects.

- Tekes places a strong priority on increasing international connections through technology programmes. However, the connections have been unilateral in many cases, importing expertise into Finland. Only in the latest programmes (especially Vera) has the direction become truly bi-directional. The strong domestic character of the construction and real estate industries has not opened up many quick and easy avenues for wide internationalisation as yet. On the other hand, international connections have remained strongly on the programme level, in the form of seminars and other general activities. Concrete support in creating international connections are needed at the project level.

Recommendation. International cooperation should also be taken to the project level.

- Tekes emphasises that the actors within the cluster should themselves take an active responsibility in implementing the results. However, there is an explicit wish among actors to continue Tekes' support more strongly in the product development phase. The public support ceases at the end of the programme, and many actors feel that the job is left unfinished. This seems to be a problem that especially touches the small and medium-sized enterprises, whose R&D resources and product development competencies are limited.

Recommendation. Cooperation between public actors relating to technology and economic policy should be further strengthened (i.e. Finnvera, Finnpro, Employment and Economic Development Centres, etc.). The innovation process should be constructed more holistically, whereby the interconnections between various public actors would be streamlined into a seamless R&D support process.

Recommendation. Systematic follow-up procedures should be strengthened. These would include reviewing the projects after their completion, combined with some supportive and consultative measures, like communication.

- A related question concerns the utilisation and dissemination of research results. One of the problems concerns the diverging time span between research projects and technology programmes. The results of the research projects are often completed only some time after the programme has been finished. There does not exist proper mechanisms that would ensure the transfer and use of the knowledge for the whole cluster, even though in recent programmes there exist some good examples.

Recommendation. The communication function should become an essential element in every technology programme. Intermediating organisations – both public and semi-public bodies and associations – should be activated to take responsibility in this matter. In areas where existing intermediaries cannot be identified, initiatives to establish such institutions should be encouraged.

List of people interviewed

Mr Ari Ahonen	Director	Tekes National Technology Agency
Mr Juha Hetemäki	Managing Director	Skanska Etelä-Suomi Oy
Mr Jyrki Jalli	Managing Director	Insinööritoimisto Mikko Vahanen Oy
Mr Petri Janhunen	Managing Director	Addtek Research and Development
Mr Jouko Kankainen	Professor	Helsinki University of Technology
Mr Arto Kiviniemi	Chief Research Scientist	VTT Technical Research Centre of Finland
Mr Erkki Leppävuori	Director General	VTT Technical Research Centre of Finland
Mr Ralf Lindberg	Professor	Tampere University of Technology
Mr Kauko Linna	Director of Development	Lohja Rudus Ltd.
Mr Aarni Metsä	Director	Wood Focus Ltd.
Mr Markku Rantama	Programme Manager	The Finnish Real Estate Federation (Suomen Kiinteistöliitto ry.)
Mr Pekka Peura	Research Manager	UPM-Kymmene Wood Products
Mr Lauri Ratia	Managing Director	Lohja Rudus Ltd.
Mr Juhani Reen	Managing Director	The Finnish Association of Building Owners and Construction (Rakli)
Mr Veli-Pekka Saarnivaara	Director General	Tekes National Technology Agency
Mr Pertti Sandberg	Director	Rautaruukki Group
Mr Raimo Taivalkoski	Managing Director	Rakennustuoteteollisuus RTT ry
Mr Pertti Vanhanen	Managing Director	Antilooppi Oy
Mr Markku Vesa	Consultant	Eurodevo Oy

Vera – Information Networking in the Construction Process

Tekes Technology Programme

Evaluation Report

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September 21, 2002

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Appendices

1 Introduction

This report presents of the findings of an evaluation of Vera, a Technology Programme of Tekes, the National Technology Agency of Finland. The Vera programme addresses information technologies (IT) for the architecture, engineering, construction and facilities management (AEC/FM) industries. The programme ran from 1997 to 2002, and the evaluation was carried out in June 2002.

This report begins with a summary of the overall findings. Next, the report provides an overview of the Vera programme and the evaluation procedures. The report then provides a detailed analysis of the overall findings regarding the Vera programme as a whole, with an emphasis on its efforts to foster industry-wide technological and process innovation. This is followed by brief evaluations of project-level and international issues.

2 Summary of Overall Findings

The evaluation identified many very positive aspects of the Vera programme. This section lists the most significant strengths, the areas where the greatest changes are warranted, and the overall outcome of the programme.

2.1 Major Strengths of the Programme

2.1.1 Vision

The vision underlying the Vera programme was founded on a broadly based understanding of the AEC/FM industry and a comprehensive goal of improving work practices. Yet the solution envisioned for achieving this broad goal involved a fairly specific area of technological and process innovation.

This technological vision was centered on the integration of all AEC/FM information throughout the lifecycle of projects using information modeling standards—specifically the Industry Foundation Classes (IFCs). The work carried out within the Vera programme spanned a wider range of technologies and processes than just the IFCs, but the specificity and clarity of the core vision provided the central thread throughout all of the projects, keeping them headed in a common direction and offering the potential to tie all of the results together over the long term.

Furthermore, the focus of the overall vision was not at the level of individual companies, but rather on the integration of companies spanning the lifecycle of projects and throughout the industry as a whole—at the level of networks of companies. Achieving such systemic technological innovation is a very great challenge, but the potential benefits of the target technologies can only be realized if they attain such widespread use.

This vision was well understood by all of the leading figures within the Vera programme and by many of the participants of the individual Vera projects. Furthermore, the degree of acceptance of this vision as the necessary and desirable way forward for the industry appeared to be almost universal.

The clarity of the technological vision, the specific technologies targeted, the industry-wide focus, and the degree of support for the vision were all excellent and had a major positive influence on the programme.

2.1.2 Coverage

The Vera programme benefited from a very broad coverage of the various segments of the industry and the technology. A high percentage of the many types of organizations involved in AEC/FM projects were represented. The programme also had good coverage of the many layers of technology and work processes involved in the overall vision.

2.1.3 Development Support

One of the strong features of the Vera programme was that it was able to foster and support a large amount of technology development: the middle phase of the research, development, and adoption lifecycle. In the field of IT, development is much more resource intensive than research, and the AEC/FM industry has traditionally had very limited capacity to carry out development. Innovation is hindered because the risk for software vendors to develop new research areas are very high without established market demand, yet the industry is unable to move towards new technologies until mature software tools have been fully developed. Through the Vera programme, many IT development projects have been able to break out of this "chicken and egg" cycle, and a critical mass of interoperable tools has begun to emerge.

2.1.4 International Focus

The Vera programme placed a high emphasis on an international focus. There are several aspects to this: the programme established Finland's reputation as a world leader in this area of technology and helped to create international business opportunities for Finnish technology companies. Perhaps the most important international aspect is that the technological vision is based on the creation of standards for exchanging project information, and this is necessarily an international task. Support and input from the Vera programme had a significant positive impact on the progress of the International Alliance for Interoperability's IFCs.

2.1.5 Advances to the Knowledge Base

Another very positive outcome of the Vera programme is that it contributed significantly to the overall base of knowledge and expertise in this area of technology in Finland. This was achieved primarily through the Vera seminars and other presentations by Vera participants, and by the involvement of large numbers of people in the numerous Vera projects.

2.2 Areas for Improvement

2.2.1 Capturing and Transferring the Collective Body of Knowledge

Although it was a strength of the Vera programme that it was able to advance and disseminate a knowledge base in the target technology areas, at the same time, it is perhaps one of the largest weakness that there was no effective means of capturing the large, cumulative body of knowledge generated through all of the projects, and transferring this knowledge throughout the industry through detailed documentation, in depth training, etc. This appears to be a weakness of the Tekes technology programmes in general, rather than of Vera in particular, since the mechanism of company initiated, commercial R&D creates no incentive for this type of knowledge capture and, in fact, intellectual property and confidentiality issues can provide a strong barrier to knowledge transfer. Still, a vast amount of knowledge developed through Vera will be "lost" because of this weakness.

One specific mechanism that could have helped to address this issue would be stronger ties with University researchers and with University and Industry-based training programmes. There appears to have been little of this within the Vera programme, partly because this is not the mandate of the Tekes programmes and possibly because there may not be appropriate faculty within Finnish Universities for this topic area.

2.2.2 Minor Weakness

There were no other areas that were found to be major weakness of the Vera programme. The following areas were identified as weaknesses but are unlikely to have had a major negative impact on the programme:

- There was a sharp lack of quantitative data to support the basic value proposition of the Vera vision.
- In spite of broad coverage of the industry segments, there are some important holes, such as weak involvement by small architects or by certain engineering disciplines.
- Many of the individual projects members had very little recognition of their role relative to the overall programme, and collaboration between projects, although very effective when it did occur, was probably less than it could have been.
- The project objectives aimed at changing industry processes and introducing business re-engineering practices seem to have been less effective than those relating to specific information technologies.
- Although there was a good deal of satisfaction with the tool set that is now available, it is still far from providing broad coverage of all the necessary disciplines and work processes. A great deal of ongoing software development is still required.

2.3 Overall Results

The overall conclusions regarding the Vera programme are that it began with a very well developed and appropriate work plan, that it carried out the plan very effectively, that the vision and priorities held up well over the life of the programme in spite of rapidly changing technology, and that the results of the programme were in line with the highest of expectations.

The programme set out to do no less than cause a major technological and procedural shift in one of the nation's largest industries. This is a vast and exceedingly difficult undertaking. The shift has not yet taken place, but the momentum has definitely been created and there is a strong feeling that the critical mass has been reached to make this shift inevitable. In all respects, Vera has been a very successful programme.

2.4 Recommendations

In the short term, the primary recommendation is that any efforts that can be taken to capture, formalize, and disseminate the body of knowledge generated by the Vera programme should be pursued.

Over the longer term, it will be some time before the technological change envisioned by the Vera programme takes place. This is as expected; the original Vera planning anticipated that the impact would be 5 to 10 years after Vera. For the present, Vera appears to have successfully seeded the industry with the critical technologies, awareness, and expertise needed for this future change to come about. It seems (though it can only be a matter of speculation) that as long as the technology does possess the expected advantages, that the eventual adoption by the AEC/FM industry is inevitable. In that sense, the Vera work may be considered to be completed. However, the amount of technological and procedural advancement required is still very large and, if unaided, the path will be long and difficult. A final recommendation is that there is every reason to believe that the successful results of the Vera programme could be repeated if a future programme of a similar nature were initiated, and the AEC/FM industry and society at large would surely benefit from it.

3 Vera Programme

The following description of the Vera programme comes, in part, from the Vera web site at http://akseli.tekes.fi/Resource.phx/rapu/vera/en/description.htx and from the programme brochure located at the same address.

3.1 Goals and Objectives

The themes of the Vera programme are information management and integration (networking). The target is to promote the implementation and use of information technology and networks and to make it possible to manage the information flows during the entire lifecycle of the building. The programme is aimed at developing both construction processes and information systems simultaneously. Figure 1 captures the essence of the Vera vision.

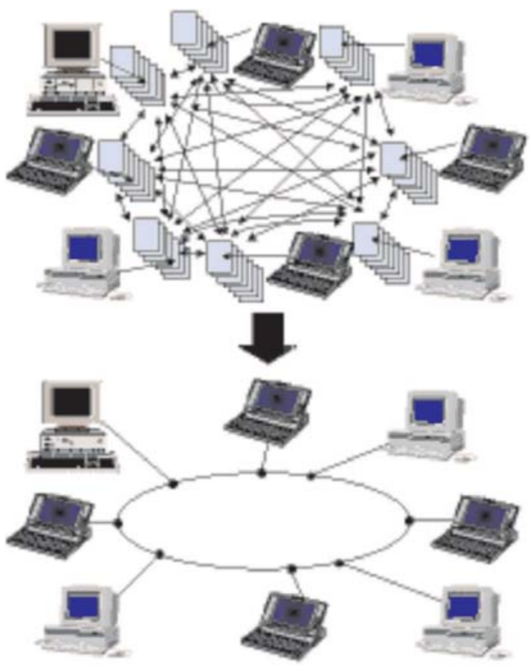


Figure 1. The target of the Vera Technology Programme is to help the parties in a construction project to form networks and share project data instead of paper documents.

The goals of the programme are as follows:

- *Management of the information flow during the entire lifecycle of the building.* Information should be part of the product, and the as-built information should be handed over at the end of the construction project to form the basis for the use and maintenance of the building.
- *Improvement of the information management among the project parties:* To manage the information flow and to be able to develop integrated information systems, it is necessary to agree on the content, structure, format and presentation of the data.
- *Utilization of information technology and information networks in the whole construction process:* The various parties in the AEC/FM industry have applied and developed information technology focusing only on their own needs. Internal systems are therefore for the most part in place, but information sharing between the parties and joint utilization of this information are a bottleneck. Networking is contingent upon broad utilization of information technology in the whole value chain.
- *Process development.* Information technology must be used as an enabling technology to re-engineer the design, construction and facility management processes.

Through these goals, the programme is expected to achieve:

- improvement in return on investments
- improving quality and overall profitability of construction
- increasing construction exports.

The programme also creates new businesses for the AEC/FM industry. These include services primarily in information technology.

3.2 Schedule and Budget

The programme will last until the end of 2002. When the programme started in 1997 the planned total volume was expected to be 28 M euro, of which 12 M euro would be funded by Tekes and the rest by the industry. However, the industry interest on the R&D projects on this area has been so strong that the total budget will be 43 M euro, of which 20 M euro is coming from Tekes.

About 20% of funding is for applied technical research (public projects) and 80% is for industrial R&D projects.

3.3 Operations of the Programme

The latest information on the Programme and its projects is available from the Internet:

- http://www.tekes.fi/english/programmem/vera/
- http://cic.vtt.fi/vera/english.htm

3.3.1 Projects

The main activity carried out by the Vera programme was the funding of projects submitted by private companies. The Vera programme did not initiate many projects itself, but its members were active in selling the main ideas and themes to companies to encourage them to get involved from their own point of view. Well over 100 individual projects were funded, organized into the following categories:

- Software Products
- Service Products
- Process Development
- Basic Technologies and Know-how
- Surveys and Reports

A list of all Vera projects is provided in Appendix I.

3.3.2 Seminars and Web Site

One of the main mechanisms that the Vera programme employed to communicate with the AEC/FM community was through regular seminars. An average of 150–200 people attended the seminars given 5 or 6 times a year. In addition to the seminars, a large number of presentations were given by the Vera Programme Manager and other representatives of the programme. Material from the seminars and other programme and project information was also maintained on the Vera web site.

3.3.3 International Participation

The Vera programme placed a high priority on international participation. This was particularly true with respect to the support given to the development of the Industry Foundation Classes data standards by the International Alliance for Interoperability, where Vera was one of the largest supporters and participants. Vera was also well represented in other international forums such as conferences.

4 Evaluation Process

4.1 Evaluation Overview

The evaluation was carried out by Dr. Thomas Froese, PhD, PEng., Associate Professor in the Department of Civil Engineering at the University of British Columbia. Dr. Froese specializes in information technology for the construction industry, particularly IFC and model-based data exchange standards for project management. He has been involved in research and development of computer tools for construction since 1986, has authored over 110 papers and reports, and supervised 16 graduate students working on the subject. He has founded two companies, consulted on several Canadian and International projects involving IT for the construction industry, and has participated in the development of the data standards efforts such as the IAI IFCs and aecXML standards. This background was found to be in very close alignment with the technological focus of the Vera programme.

This evaluation makes up a component of a broader evaluation of Vera and other Tekes technology programmes being carried out by Net Effect Oy. The methodology for the evaluation consisted of interviews with a representative set of Vera projects. No quantitative evaluation was conducted, although an industry survey will be included as part of Net Effect's evaluation process. The objectives of the interviews were to obtain a clear understanding of each project and the organizational context in which the project was being carried out, and to determine the project participants' views on aspects of the Vera programme. Twelve projects were interviewed in Helsinki from June 17 to June 20, 2002, and two additional projects were interviewed in Palo Alto, California on June 28. Each interviews lasted approximately two hours, included Dr. Froese, Arto Kiviniemi, and one or two representatives of the project. The general outline of topics covered in the interviews is as follows:

- *Individuals:* introduction to the person or people representing the project at the interview, their background and their role with respect to the company or organization and the project.
- *Company:* general introduction to the company or organization conducting the project. Size, major products, services, and markets of the company.
- *Project:*
  - *Overview:* the "basic idea" for the project. The timeline (starting and end dates) for the project.
  - *Goals and objectives:* the overall goals and objectives for the project. The relationship between the project and corporate/organizational goals and objectives.
  - *Activities:* a description of the tasks carried out for the project.
  - *Participants and resources:* the participants involved in carrying out the project.
  - *Technology:* a detailed description of the technology involved in the project.
  - *Results:* results achieved from project.
- *Vera project issues:* topics relating to interactions between Vera and the project.
  - *Role of Vera funding:* the significance of Vera funding in carrying out the project.
  - *Involvement of Vera:* the degree and nature of involvement of the Vera programme in setting up and carrying out the project.
  - *Role of project with respect to the overall Vera programme:* ways in which the project was seen as being a component of the overall Vera programme, contributions of the project to the programme.
- *Vera programme issues:* topics relating to the overall Vera programme, beyond considerations of the specific project.
  - *Awareness of programme level issues:* level of awareness of the overall Vera programme, its objects, other projects, etc.

– *Plus/Delta:* opinions on things at which the Vera programme has been particularly successful (plusses), and things that might be changed in the future to make similar programmes more successful (deltas).

4.2 Projects Studied

The following projects were examined during this evaluation:

- INTPRO – New Generation Integrated Software Applications for Structural Design & INTCON –Intelligent software for detailing and fabrication of pre-cast concrete structures – Tekla Oy
- Product model based design-production-maintenance – Confederation of Finnish Construction Industries
- BS-PRO – Product Model Based Information Management of Building Services Implementation Process – Olof Granlund Oy
- Spadex – YIT Oy
- Service Life Planning from theory to practical processes – VTT Building and Transport
- BS-VE – 3D Visualization of Building Services in Virtual Environment – HUT, Telecommunications Software and Multimedia Laboratory
- Virtual Model for Construction – Skanska Oy
- IFC-Check, Analysis of IFC-based product model – implementation project – Solibri, Inc.
- IFC Model Server – VTT
- Computer-Integrated Project Management System in Construction – Rakennuttajatoimisto CMC Oy
- IFC Next Step – Eurostepsys Oy
- NetModeler – Enterprixe Software Ltd.
- Product Model 4D – Construction Pilot – Senate Properties
- Roadmap to Intelligent Product Model (IFC) – VTT

5 Detailed Analysis

The general approach adopted for this evaluation was to gather as much information as possible about the Vera programme, and to interpret this information to formulate an overall understanding of the industry and technology context, the operations, and the results of the Vera work. The amount of information gathered was vast and the scope of the interpretation was broad. To present the interpretation of the information gathered, this section breaks down the related issues along several dimensions, and highlights both the strengths and weaknesses of the Vera programme from a number of different perspectives. In this section, issues that are considered to be a particular strength of the Vera programme are indicated with a (+) and issues where changes are recommended are indicated with a (Δ). In both cases, issues seen to be particularly important are indicated as (+!) or (Δ!).

5.1 Assessment of Goals and Objectives

As discussed earlier, the goals and objectives of the Vera programme are strongly focussed on the integration of information throughout networks of companies collaborating on AEC/FM project using an underlying technology of IFC-based information exchange. In addition to the IFC-related technology itself, this focus includes any type of software tool capable of supporting AEC/FM work processes that can interact with IFC data, and many issues related to the work processes and services associated with the adoption of these technologies in practice.

Internationally, many practitioners in the AEC/FM industry are not familiar with these technologies, so there is not widespread support for these goals. Among those practitioners, researchers, and technology experts who are familiar with advanced IT in AEC/FM, however, this is a major area of interest and there is broad acknowledgement that this is generally the way of the future.

A necessary aspect of this technology is that the focus is at an industry-wide level, not at the level of individual firms: what use if interoperability if you don't have anyone to interoperate with? As such, the Vera programme took on a very challenging task of changing the technology and work processes of the entire AEC/FM industry. Much of the following sections focus on the resulting issue of how to induce significant technological innovation throughout an industry.

5.2 The Process of Technological Innovation

This section considers the Vera programme from the perspective of the process by which an industry undergoes technological innovation.

5.2.1 Technology Adoption Life cycle

General models of the adoption rate of new technologies over time show a normal curve with a small number of innovators adopting the technology first, followed by early adopters, then the majority, and finally late adopters (see Figure 2). Relative to this general model, the adoption of model-based interoperability technology within the AEC/FM industry in Finland appears to be in the early adopter phase. More specifically:

- *Innovators:* (+) the technology is well-known to, and adopted by, industry innovators.
- *Early adopters:* (+) there appears to be a significant number of organizations that are beginning to adopt the technology. Although the total number is still small, the examples that exist are providing real leadership within the industry, and a solid "beach head" for the technology appears to have been established.
- *Majority:* the technology is clearly not established within the majority or mainstream of Finnish AEC/FM industry (it is far from being common practice). Significantly, however, there appears to be good general awareness of the technology within the industry mainstream (although this observation is based on a small and non-representative sample).
- *Late adopters:* as to be expected, it will be quite some time before the technology has any impact on late adopters.

Furthermore, the degree of technology adoption may be compared to the lifecycle stage of the technology research and development. Figure 3 illustrates that prior to the Vera programme (1997), model-based interoperability technology was becoming well-established within the research community, a few innovators were beginning to develop tools based on the technology, and there was no adoption of the technology within the industry. Based on comparison with other countries, an estimate of the present-day situation *if the Vera programme had not taken place* shows that the technology would be more well-established within research, but would still be in the innovation stages for software development and adoption by industry. (+) Because of the Vera programme, however, the technology is very well-established within the Finnish research community, well-established in software development and in the early adoption phase of use by industry.

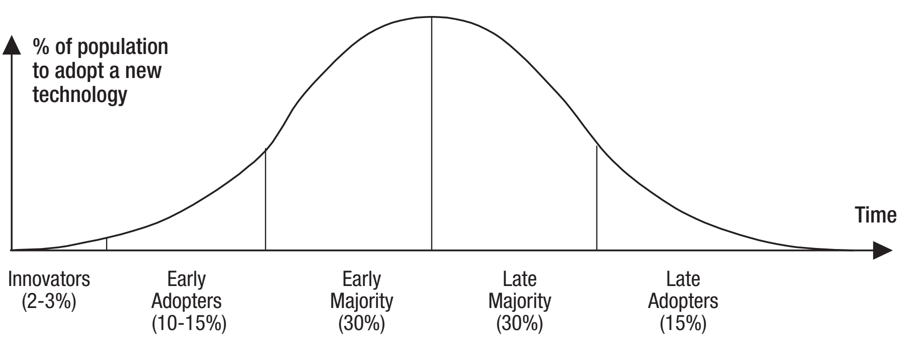


Figure 2. A general model of technology adoption rate over time.

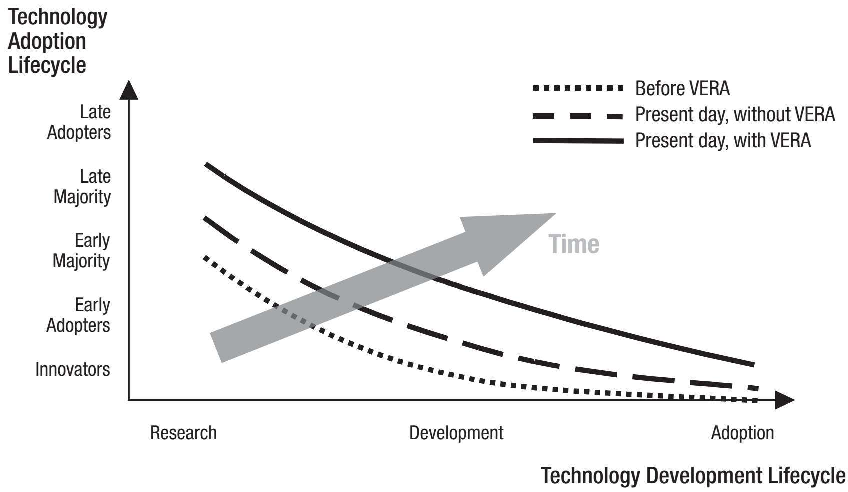


Figure 3. Technology adoption vs technology development.

5.2.2 Demand for Change

Technological change can be driven by a combination of a "pull" arising from the need to solve existing problems and a "push" from the opportunities presented by technological innovations. This section discusses the apparent demands for technological solutions that currently exist within the Finnish AEC/FM industries. Overall, there was little evidence of strong, wide-spread, underlying problem areas or a strong demand for technological change. Still, several people interviewed expressed the following needs for technological solutions:

- *Societal issues:*
  - *Challenge for competitiveness of small country:* as a relatively small country, there seemed to be a desire to find technological solutions that would provide a national competitive advantage to reduce foreign competition domestically and improve business opportunities internationally. (+) Through Vera, this demand is being met in terms of developing an international reputation as technological leaders in the field of IT for AEC/FM .
  - It is likely that there has been little actual impact to date on Finland's international competitiveness arising from the Vera work, since little of the technology has entered common practice. However, if Finland's technological leadership continues in this area as expected, the resulting competitive advantages may well be significant.
- *Industry issues:*
  - *Dissatisfaction with current practice:* there appears to be some sense that current practice is not what it should be, that too many mistakes are made. This appears to be particularly related to the high degree of fragmentation within project organizations and the pressures imposed by fast-tracking (overlapping the traditional design and construction phases).
- *Information management issues:*
  - *Dissatisfaction with current software tools:* there is a general perception that the industry is not being well-served by current generation software tools (the specific areas of weakness were not examined).
  - *Problems with information management:* similarly, there is a general dissatisfaction with the typical levels of information management, communications, and data sharing, etc.

5.2.3 Opportunity for Change – The Technology

This section discusses the opportunities for change created through the development of new information technologies.

Vision

The development of new technology is led by the vision that has been established for the development efforts. The stated goals and objectives for the Vera programme are expressed in fairly broad and general terms relative to the theme of information networking. (+!) Behind these general goals, however, the leadership of the Vera programme appear to have had a very clear and specific vision for the technology that could be advanced through the programme. This is the technology of model-based interoperability, specifically, the IFCs, and all of the issues related to their development, implementation, and application throughout the industry. The specificity of this vision may, to some extent, have deterred alternative technological solutions. However, the strong and specific technological vision has been extremely beneficial in focusing and directing the research and development efforts, and it is a very positive feature of the Vera programme.

Value Proposition

If the vision provides the direction for technology development, the value proposition, or perceived benefits of the new technology, provides the motivation. (+!) A very positive aspect of the Vera-related work is the very wide-spread support for the idea that model-based interoperability is the way forward for the AEC/FM industry in Finland. Support for this technology appeared to be essentially unanimous among all of those interviewed. Also significant is the fact that many key industry leaders are among the strongest and most active supporters for the technology. This degree of acceptance of the value proposition offered by the technology has been an important factor for success in the Vera programme.

However, the support for the value proposition is predominantly qualitative. (Δ) People believe that it is the right path to pursue, yet there is very limited "hard evidence" to support this belief. In only a few cases (e.g., in data collected by YIT) have there been any quantitative studies to prove the benefits of the model-based interoperability approach. This does not invalidate the belief in and support for the technology, but good quantitative data would go a long way towards justifying this belief and convincing the rest of the industry. A high priority should be placed on studies that provide qualitative evidence of the benefits of the technology.

Technology Creation

This section addresses the process of technological innovation as it relates to the development of the underlying technology itself.

- *Development of the core technologies:*
  - *Existing expertise:* (+) the development of the underlying model-based interoperability technology within the Vera programme was well-served by having an existing base of experts in this area stemming from the earlier RATAS programme. It is unclear how much effect RATAS had on industry practice, but in the sense of building up a base of technical expertise, RATAS was quite successful and many of the Vera projects built upon this expertise.
  - *Coverage of full scope of related technology:* the development of model-based interoperability, like other major technological advances, involves a number of basic technologies and components. All of these pieces must be in place before the overall approach becomes viable. (+!) A significant positive feature of the Vera programme is that it has supported a very comprehensive coverage of the full range of technologies related to the overall technological vision.
  - *Support for the development stage of technology:* the development of new technologies for the AEC/FM industry is often hampered by the lack of support for the "development" phase of the research, development, and application lifecycle. Research is often supported at universities and research organizations, but the results are not fully developed for industrial scale use. Industry is capable of adopting new technology once it is ready. However, the development phase, which brings new technology from research to full applications, is much more resource intensive and risky than research alone. The lack of support for development poses a real barrier to technological innovation in AEC/FM. (+!) Within the Vera programme, projects address all phases of the research and development lifecycle, with a number of significant projects addressing the development phase. This is the key contributor to the success of the programme.

- *Influence on international development*: (+) in addressing the development of the core technologies required to attain its vision, the Vera programme carried out several activities related to international development efforts. These include, for example, extensive participation in the International Alliance for Interoperability, research programmes such as the Center for Integrated Facilities Engineering at Stanford University, and relationships with foreign software developers such as Graphisoft and VISIO. This influence on international activities appears to have been productive, since Vera projects have been able to exploit these global resources more effectively than other groups.

- *Standards:* (+!) the Vera programme contributed significantly to the development of international standards relating to model-based interoperability, specifically the Industry Foundation Classes. These standards are critical to the success of the Vera programme's vision and the IAI was significantly strengthened through these contributions.
- *Software infrastructure and tools:* (+) several of the Vera software development projects were well served by a few projects that contributed to the "infrastructure" and tools that support software development specific to the target technologies, such as model-servers.
- *Applications:* a number of the Vera projects focused on developing the software applications that provide the tools that support the target AEC/FM users. From the end users perspective, these applications, and their ability to work with the shared project models, form the primary focus of the entire approach towards interoperability. These projects covered a range of areas of application, and were successful overall. (Δ) It may have been beneficial to place even more emphasis on fostering a greater number of application-related projects.
- *Adaptation of applications to industry processes:* some of the Vera projects focused on the adaptation of software to industry processes. However, this area was not as well developed as the technology development area.

Creating Services / Processes
In addition to creating the technology itself, there is a need to create services and work processes related to the new technology. The way that AEC/FM projects are managed may involve significant differences from current practices if integrated model-based approaches become wide spread, and various new information management services may be required. The Vera projects interviewed did not place much focus on these areas, but the need for work in this area will grow as the technology enters mainstream use.

New Industries Centered Around Technology
In addition to the goal of improving the target AEC/FM industry, the development of new technology can lead to new industries centered on the technology itself, such as software development and service industries. Nationally, the potential market for such services may be too small to be of much significance. However, there is a definite potential to develop an international market for such industries. (+!) Several Finnish companies associated with Vera projects are developing an international reputation for leading edge technology in this area.

5.2.4 Mechanisms for Change

Given a demand for technological innovation established by industry needs and an opportunity created by the development of new technology, there are various mechanisms that influence the process of technology adoption.

Champions
One of the most important mechanisms for technological change is strong champions—individuals that are committed to the change and that are in a position to influence their organizations. (+) Throughout the Vera projects studied, there were many examples of strong champions for the new technologies.

Awareness of the Technology
Widespread technological change requires a good level of awareness of the technology throughout the industry. (+) Within the Vera projects studied, there was good awareness of the technology among key industry leaders (key people within key organizations). (+) There also seemed to be a good

distribution of individuals that were aware of the technology through many organizations. (Δ) However, there was some indication that there is still little known of the technology throughout the industry mainstream.

Understanding of Technology

In addition to general awareness of the technology, there needs to be an understanding of the technology and how to work with it. (+!) Many of the people interviewed pointed to the Vera seminars as one of the most positive features of the programme. These seminars have had the effect of "seeding" the industry with a good base of people that have a basic understanding of the technology and the way that it works. (Δ!) On the other hand, the Vera programme was not able to implement any mechanism that introduced a systemic base of technologically knowledgeable people throughout the industry, or a widespread degree of training. It may be that this would be outside of the scope of a Tekes technology programme, but the rate of technology adoption is closely linked to the number of trained people within the industry, and any efforts that Vera or related programmes could do to increase training would directly affect the success of the programme.

Acceptance of Value Proposition

(+) As noted previously, in spite of the lack of quantitative evidence, there appeared to be almost universal acceptance of the value proposition offered by model-based interoperability technology.

Adoption of Tools

The most direct action associated with the adoption of the technology is the use of software tools that are capable of model-based interoperability. As discussed earlier, the evidence suggests that innovative and some early adopter companies are beginning to use these tools, but they have not yet entered mainstream use.

Adaptation of Work Processes

Some pilot projects are beginning to address the issue of adapting work processes to better fit the new technology, but there has been very little progress in this area to date.

Support for Small and Medium Sized Enterprises

At present, it is still much easier for large firms to be involved in the development and adoption of the emerging technology. There appears to be a particular problem with the lack of participation by small architecture firms. Nevertheless, appropriate tools are practical for small and medium-size businesses, and ongoing tool development and industry awareness should allow smaller firms to participate fully.

5.2.5 Barriers to Change

In spite of all demands, opportunities, and mechanisms for change, barriers remain. Within the scope of the Vera programme, there appeared to be few major barriers that are not being addressed.

Scepticism

During the interviews, there was surprisingly little evidence of scepticism among participants, or among the rest of the industry as reported by the programme participants. Although this was not a representative sample from the industry, it did seem to be less that might be expected in other countries. (+) Possibly, the Vera programme should take some of the credit for creating a very "positive" attitude towards the whole area.

"Chicken and Egg" Problems in Software Development

One of the biggest barriers to technological innovation is the lack of support for the development phase of the phase of the research, development, and application lifecycle (as discussed earlier). Industry users won't adopt the technology before a fully developed suite of high quality software applications are available, yet software developers won't invest the very large resources required to develop these tools until they have some confidence that the market wants the tools. This creates a "chicken and egg" problem that has stymied advancement in many countries. (+!) The Vera funding appears to have been significant in allowing many companies to break out of this cycle, and develop new technologies with manageable degrees of risk. Many companies stated that they would have carried out little, if any, of their development without the Vera funding. The provision of funding to allow companies to pursue development projects that they would not otherwise attempt is probably the biggest single benefit of the Vera programme.

5.3 Coverage of the Industry

5.3.1 Participants / Stakeholders

(+!) The Vera projects represented an extremely broad coverage of participant types throughout the AEC/FM industry. The following list provides a break down of key industry participants. The projects reviewed for this evaluation covered the majority of these participant types, and other Vera projects likely covered many of the remaining types of participants. No significant omissions were observed, with the possible exception that (Δ) linkages with Universities in both research and training appeared to be weak (it may be that there is little representation of the related topic areas within Finnish Universities).

Supply chain participants
- Users
- Owners
  - Public Owners
  - Private Owners
    "Professional" owners (e.g., large corporations)
    Small owners
- Facility managers
- Financiers
- Developers
- Designers
  - Architects
  - Engineers
- Constructors
  - General Contractors/CM
  - Specialty contractors
- Inspectors
- Suppliers
- Manufacturers

Supporting Participants
- Technology providers
  - Software providers
    Application providers
    Development components/tools
    Standards organizations
- Researchers
  - Industry-based researchers
  - Universities
  - Research organizations
  - Research funding organizations
- Training
  - Industry-based training
  - Universities
- Participant Associations
  - Builders associations
  - Professional associations
  - Trade associations / Unions
- Regulators
  - Building code producers
- Policy-makers
- Professional services
  - Legal
  - Accounting
- Information providers

5.3.2 Other Industry Dimensions

A breakdown by participant is just one of the ways that the AEC/FM industry can be categorized. Along other dimensions, the degree of industry coverage was not quite as high.

Project Lifecycle
The coverage of the various phases throughout the lifecycle of AEC/FM projects was quite good from detailed design through to construction and facilities management. One area that does not seem to be well supported currently is the beginning phase (project programming, conceptual design, etc.).

Disciplines
A number of the core design and construction disciplines were addressed within the scope of Vera projects: e.g., architecture, structural systems, mechanical systems. Many other disciplines, however, had little or no coverage (e.g., geotechnical and excavation, electrical, building envelope, landscaping, etc.).

Industry Segments
The Vera project focused on buildings and most types of buildings would fall within the scope of the Vera projects. Other types of structures within

the built environment were generally not included (e.g., roads, underground utilities, bridges, etc.).

5.4 Coverage of the Technology

The Vera programme appears to have placed a heavy emphasis on a somewhat narrow technological focus related to model-based computer tools and interoperability, though other technologies were certainly not precluded. There is some risk associated with this approach, since there is always a high degree of uncertainty associated with forecasting new technologies and this uncertainty can be countered, in part, through diversity in the technologies being developed. Nevertheless, there is a high degree of believe that the Vera programme is "on the right track" in its technological direction, and this technology has benefited greatly from the Vera focus.

Vera projects provided good coverage across several layers of technology. In particular, a strong focus was placed on the development of software tool/applications and on interoperability, as well as the application of software tools to industry processes.

An analysis of the specific areas of technology covered by the Vera programme is beyond the scope of this report.

5.5 The Technology Programme

This section addresses issues relating specifically to the administration of the Technology Programme.

5.5.1 Role of Programme Manager

(+!) By all accounts, the Programme Manager, Arto Kiviniemi, exerted a very strong and very positive influence over the Vera programme. He was an excellent champion, both nationally and internationally, actively promoting the programme with an infectious enthusiasm in 40 or 50 presentations per year. His administration of the programme appeared to be very good. Of particular note was his active participation in helping to establish many of the projects, and his leadership role within the International Alliance for Interoperability (which was particularly beneficial during a difficult time for the organization).

5.5.2 Identification of Project Topics

In identifying the individual projects to fund, there can be a trade off between the goals of individual projects and the goals of the overall programme. The project identification mechanism followed was that companies could submit proposals to the Vera programme for review and possible funding. (+) This provided a great deal of flexibility for companies to define projects to fit their own business needs and opportunities. (+) At the same time, there appeared to be effective "informal" mechanisms for helping to guide projects in ways that would help contribute toward the overall Vera goals and objects (e.g., through the direct involvement of the Programme Manager in helping to create project proposals).

(Δ) Nevertheless, the programme may have suffered because it did not have any mechanism for targeting specific work of high strategic importance. For example, some additional work on supporting software components (such as model servers), or work on capturing and recording the overall body of knowledge arising from the collection of projects may have improved certain programme outcomes significantly, even if they created no particular business opportunities for any one company. The Vera programme would have benefited from some mechanism of commissioning a small number of important strategic projects rather than responding only to projects submitted by others.

5.5.3 Dissemination of Information

Seminars
(+!) The Vera programme organized frequent industry seminars to disseminate information. An average or 150–200 people attended the seminars given 5 or 6 times a year. Presentations were given about Vera projects or other related topics. Most of the people interviewed mentioned these seminars as being highly beneficial as one of their primary sources of information about the related technologies.

Capturing the Resulting "Knowledge Base"

Ultimately, the largest benefit of a successful technology programme is the culmination of knowledge generated through the programme's activities. This knowledge base is only useful to the extent that it can be captured, maintained, and exploited. (+) The Vera programme has built up a very large and successful knowledge base in the sense that the knowledge about the related technologies is embodied in a large number of highly trained people dispersed throughout the industry. (Δ!) However, there has been almost no efforts to capture, structure, and formalize to overall knowledge base resulting from the sum of the individual projects. (Δ!) Furthermore, there is very little dissemination of the knowledge base other than the seminar series. These failings represent one of the largest shortcomings of the Vera programme.

5.5.4 Project Interaction

(+) There were many instances where there was good interaction between individual Vera projects, for example, between companies developing software tools and companies using the software to design and manage buildings. (Δ) On the other hand, many of the project participants did not have much of a sense about how their projects fit within the overall programme. Had they understood this better, they could have had a better focus on programme goals and could have created more opportunities for collaboration and leveraging results.

5.6 Specific Evaluation Questions

The requirements for this evaluation included some specific questions, which are addressed in this section:

5.6.1 Where the chosen strategy and goals for the programme the right ones?

The chosen goals and strategy were very good. The target industries are very important for the Finnish economy and society. The opportunities offered by new technologies and methodologies in information management are significant. Prior to Vera, the essential ingredients for the new technologies had emerged, but it was proving to be very difficult to build up the critical mass to develop these technologies and update industry processes (in Finland as well as in other countries). The end goal has not been reached yet, but the Vera programme has provided a very substantial boost in the right direction.

5.6.2 What is the quality of the programme in world terms?

As an overall technology programme focused on information technology in the AEC/FM industry, the Vera programme has been recognized around the world as a leading effort. It is likely to be the most well-funded such programme per capita, and the general impression internationally is that it is working in the right direction with good results. Many of the individual Vera projects are world-leading efforts in their areas.

5.6.3 Was there a correct mix of different kind of technologies, projects and participants?

As discussed above, the Vera programme managed to address a very broad spectrum of participants and segments throughout the AEC/FM industry—it was excellent in this regard. The programme placed a particular emphasis on a somewhat narrowly focused area of technology relating to model-based systems and interoperability, but this focus was justified and quite successful.

5.6.4 Was the programme managed effectively?

Both at the programme level and at the level of the individual projects considered, all activities appeared to be managed effectively and no significant problems were found (additional detail is addressed above).

5.6.5 Are there potential commercial success stories, and what kind of impact will the results likely make?

The technology has not yet entered mainstream use. Yet in the few pilot projects and implementations by early adopters, significant benefits to the overall AEC/FM were found. It is reasonable to expect that as these technologies become more wide spread, there should be a significant productivity improvement throughout the range of AEC/FM activities.

There are a few commercial successes or potential successes relating to companies in new market areas relating to producing the technology itself (computer applications)

5.6.6 What could be the next steps in this technology area?

Through Vera, the technology area has received a substantial boost along the development lifecycle and a solid mass of awareness and knowledge has been established. However, the technology is not fully ready to support the industry and it has not yet reached mainstream use. Given the current state of development, it seems likely that if the technology does indeed offer the expected benefits, then its continued development and adoption are inevitable. Still, this development and adoption will be a long and difficult path if there is no ongoing support. To fully and rapidly capitalize on the progress made to date by the Vera programme, an ongoing programme to support the technology is required.

6 Project-Level Analysis

Each project was examined individually with respect to its goals and objectives, methodology, outcomes, etc. Overall, no major problem areas were identified. This section summaries issues relating to individual projects.

6.1 Appropriate Focus

Overall, the focus of the projects appeared to be appropriate. The projects all contributed well to the overall programme goals and objectives. Of note, this was found to be true even though several of the project teams reported that they did not have a good sense or understanding of the overall programme goals. A likely reason for this is that the Programme Manager was closely involved in the formulation of most of the projects; he had the opportunity and he took the initiative to ensure a good alignment of all project goals.

Furthermore, the magnitude of the scope (the amount of work attempted within each project) was appropriate.

6.2 Alignment with Core Business Activities

In all of the cases studied, the projects were well aligned and important to the company's core business activities.

6.3 Well Managed

The projects appeared to be well managed. The projects were, in general, being carried out on a level similar to other core business activities within the company. The projects appeared to have appropriate staffing and resources. There was no indication that the companies were using the programme funding for anything other than a serious pursuit of the proposed projects.

6.4 Informal oversight

The degree of project oversight carried out by the Vera programme was very minimal. If projects were not being well managed or adequately carried out, there did not appear to be a mechanism for the Vera programme to influence the project (except in cases of serious concerns). However, no evidence was found to indicate that this had been a problem on any of the projects studied.

7 International Issues

Several issues relating to an international perspective of the Vera work have been discussed previously, but these international issues can be summarized as follows:

- There is broad support for the vision adopted by the Vera programme from among international experts in IT for AEC/FM.
- The Vera programme has entrenched Finland's international reputation as a leader in the area of IT for AEC/FM.
- If the technologies and processes promoted by the Vera programme are adopted throughout the Finnish AEC/FM industry, it will significantly enhance the industry's international competitiveness.

- Vera-sponsored work is already beginning to create an industry for Finnish companies to offer IT tools and services to international markets.
- The Vera programme has made significant contributions to international standards and tools in this area of technology.

8 Conclusions

The overall findings and recommendations of this evaluation were presented in section 2. As a final conclusion, the author would like to offer his personal opinion that Vera was a unique and very encouraging programme, and the opportunity to evaluate it in detail was both interesting and rewarding. The contributions of everyone that participated in this evaluation are most gratefully acknowledged.

Appendix 1

List of All Vera Projects

The following is a listing of all Vera projects, as reported on the web site:
Http://akseli.tekes.fi/Resource.phx/rapu/vera/en/projects.htx,
updated by Arto Kiviniemi on 23.6.2002

The projects in Vera Technology Programme are categorised in the following groups:

- Software Products
- Service Products
- Process Development
- Basic Technologies and Know-how
- Surveys and Reports

Each project is also categorised as either of the following:

- R = research project
- E = enterprise project

Software Products	
Concept to define customer needs and support for decision making - *Visual computing Oy*	E
INTCON - Intelligent software for detailing and fabrication of pre-cast concrete structures - *Tekla Oyj*	E
Bild-IT - Integrated Software Design Tool for the HVAC Industry - *Olof Granlund Oy*	E
IFC Next Step - *Eurostepsys Oy*	E
IFC-Check, Analysis of IFC-based product model - implementation project - *Solibri, Inc.*	E
NetModeler - *Enterprixe Software Ltd.*	E
INTPRO - New Generation Integrated Software Applications for Structural Design - *Tekla Corporation*	E
IFC ToolboX -project - *Eurostepsys Oy*	E
KAIMA - Knowledge Acquisition for IFC-Product Model Analysis - *Solibri, Inc.*	E
BS-LCA - Product Model Based Management of Environmental Impacts In The Building Services Life-Cycle Process - *Olof Granlund Oy*	E
CAD Software Based on the IFC Standard - *Jidea Oy*	E
BS-PRO - Product Model Based Information Management of Building Services Implementation Process - *Olof Granlund Oy*	E
WWW FM Software - *Rapal Oy*	E
QNS - Quality Network on Site - *Jyväsdata Oy*	E
TIKLI - User Interface for Project Databank - *Granlund Kuopio Oy*	E
KIPI - Integrated Product Family - *Komartek Oy*	E
Scale-CAD - *Parma Betonila Oy*	E
FM Network - Lease Management - *Sky-Data Oy*	E
FM Network - Register for Real Estate - *Miragel Oy*	E

FM Network - Space Management - *Kupari Solutions Oy*	E
LINK - Integration of Design Tools for Electrical Engineering - *Olof Granlund Oy and AIO Group Oy*	E
Pipemodeler Software - *Cadex Software Oy Ltd*	E
Software Interfaces for Design, Construction, Marketing and Facility Management - *Jidea Oy*	E
Virtual Project 2000 Software Development: ELVIS 2000 HVAC Engineering - *Progman Oy*	E
Virtual Project 2000 Software Development: Architectural Design and Electrical Engineering - *AIO Group Oy*	E
Virtual Project 2000 Software Development: Facility and Property Management - *Viasys Oy*	E
Virtual Project 2000 Software Development: Contractors for Building Services - *Tietovalli Oy*	E
Virtual Project 2000 Software Development: Main Contractors - *ToCoMan Oy*	E

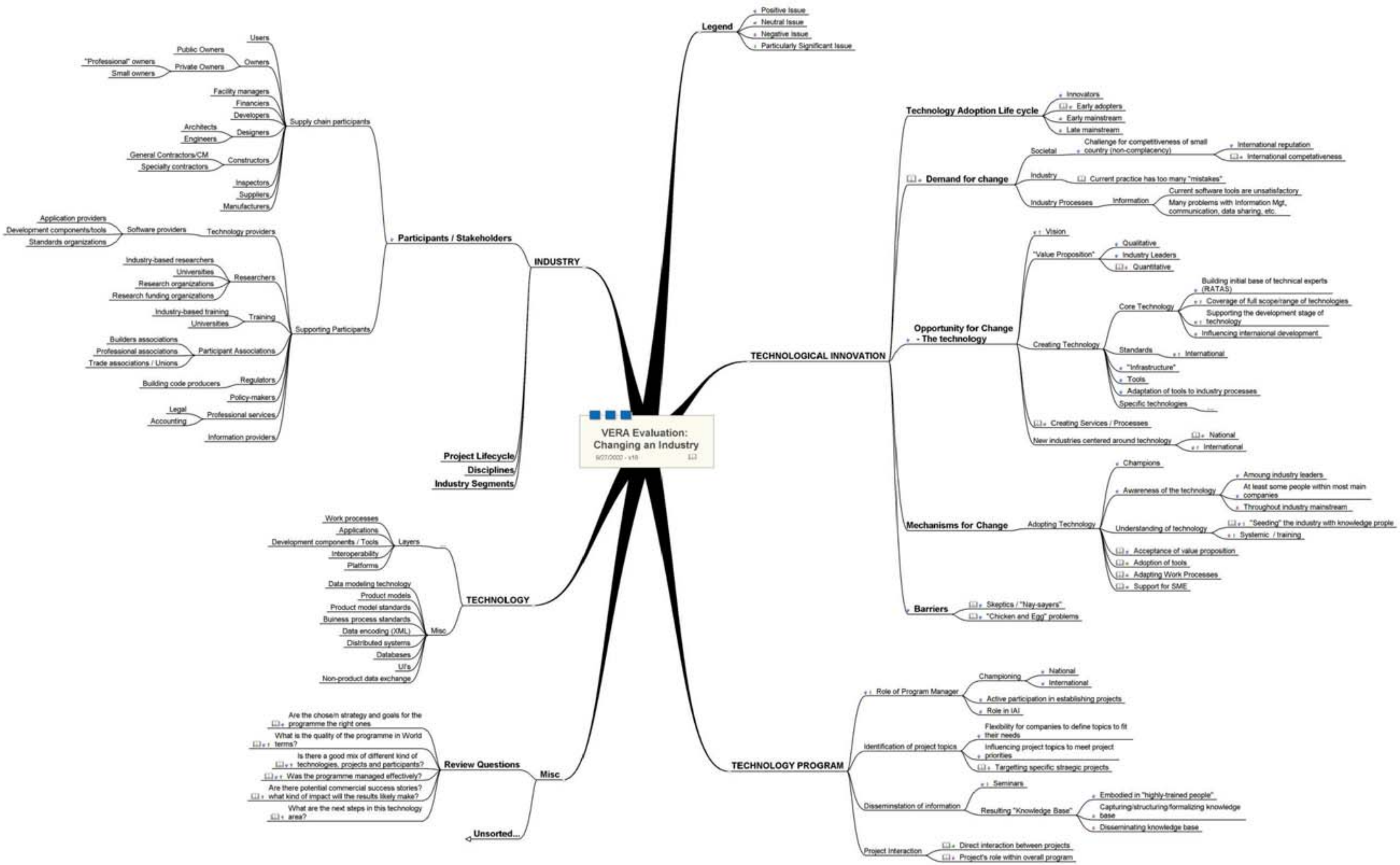
Service Products	
ILCon - Information Lifecycle in Construction Industry - *Buildercom Oy*	E
Construction Project Partner - *TektonSolutions Oy*	E
Potential of Information Transfer from AEC to FM - *VES Virtual Enterprise*	E
Product Code System for Building and Fitting Industries - *Rasi*	E
Next Generation GIS (Geographical Information System) - *Viasys Oy*	E
Computer-Integrated Project Management System in Construction - *Rakennuttajatoimisto CMC Oy*	E
Integrated Information Management System for CNC Production of Light-gauge Steel Sceleton - *Rosette Systems Oy*	E
Datasoft-DIME - Price Monitoring Service - *Komartek Oy*	E
Viraps 3b - Virtual Apartment Service Pilot Project - *Asuntosäätiö*	E
Product data management of ventilation components from manufacturer's point of view - *Halton Oy*	E
Digital Reporting in Collaborative Construction - *SRV Viitoset Oy*	E
Digital HVAC Product Information -*LVI-tietokeskus*	E
BQM - Building Quantity Management System - *ToCoMan Oy*	E
Management for Facility Life Cycle Costs -*JP-Talotekniikka Oy*	E
BASE-KuHa - Repair Management Software for FM - *Uudenmaan Valvontamestarit Oy*	E
R.E.I.N - Real Estate Information Network - *Kiinteistöalan tietopalvelut R.E.I Oy*	E
Interactive WWW Tools for Trafic Design - *Matrex Oy*	E
Project Server for SME's - *Suomen RaksaNet Oy*	E
Tecmi Software - *Siimisoft Oy*	E
Information Networking for Prefabricated Wooden Elements - *Iin Fasadi Oy*	E
3D Modelling of Existing Buildings - *Tilat Oy*	E
TOTU - Information as a Part of the Product - *Onninen Oy*	E
Integrated Tendering System for Timber Houses - *Niemenharjun Puujalostus Oy*	E
KURNET - Extranet Solutions for the Municipal Proprietor - *Jyväsdata Oy*	E
VIRAPS - Virtual apartments - *University of Art and Design Helsinki*	R
PESU - Renovation Planning Application - *Architect Office Jukka Tikkanen Oy*	E
FACI - Facility Management Integration - *Evata Finland Oy*	E
IMIT - Information Management in the ThermoNet Delivery Chain -*ABB Installaatiot Oy*	E

Process Development	
ePurchasing - using e-commerce as the part of the purchasing process of the building company - *Jydacom Oy*	E
Mass.A - MassCustomization in building industry - *University of Art and Design / Future Home Institute*	R
BS-Nordic - A Nordic Model for Development of Client Oriented Building Services Design Process, Data Management and Software Tools - *Olof Granlund Oy*	E
Service Life Planning from theory to practical processes - *VTT Building and Transport*	R
Circulation speed of the stock at building site - *Rakennusliike U. Lipsanen Oy*	E
eLEGAL - Specifying legal terms of contract in ICT environment - *VTT*	R
Product Model 4D - Construction Pilot - *Senate Properties*	E
Renoir - Life Cycle Asset Management Tool - *VTT*	R
Virtual Model for Construction - *Skanska Oy*	E
ETAP - Automation Project for Prefabricated Concrete Industry - *Euroquest Oy*	E
Lapland's Vera - *Rovaniemen teollisuuskylä Oy*	E
Quantity 2000 - Development of Quantity Survey - *NCC Finland Oy*	E
Spadex - *YIT Oyj*	E
Transfer Methods in the Networks for Trade Information in the Construction Industry - *CM-Systems Oy*	E
Change Management in the Construction Project - *Architect Office Riitta Korhonen Oy*	E
Deployment of IT on the Construction Site - *Rakennusliike U.Lipsanen Oy*	E
ELSEWISE - European Large Scale Engineering Wide Integration Support Effort - *VTT*	R
Development of the Data Management and Construction Process - *Skanska Oy*	E
ProPlan - Production Planning System - *YIT Oyj*	E
RECO - Reengineering of Construction - *YIT Oyj*	E
SUMA - Supply Management by Product Concept - *YIT Oyj*	E
FINNCORE - Construction Process Reengineering - *YIT Oyj*	E
Project Manual for Construction Clients - *The Finnish Association of Building Owners and Construction Clients (Rakli)*	E
Ratas Manual for Structural Engineering - *The Building Information Foundation RTS*	E

Basic Technologies and Know-how	
Development of IFC R3 HVAC domain models in BS-8 co-operation - *VTT Building and Transport*	R
PC-VR - PC technology based virtual reality - *VTT Building and Transport*	R
BS-VE - 3D Visualization of Building Services in Virtual Environment - *HUT, Telecommunications Software and Multimedia Laboratory*	R
IFC Model Server - *VTT*	R
PCC-IFC - Precast Concrete Construction IFC -project - *Finnish Association of Conctruction Product Industries (RTT)*	E
Matrix - *Viasys Oy*	E
3D Visualization of Building Services in Virtual Environment - *HUT, Telecommunications Software and Multimedia Laboratory*	R
BS2000 - Product Data for Building Services Software - *Satakunta Polytechnic: Development and Research Centre O'Sata*	R
Osmos - Open System for Inter-enterprise Information Management in Dynamic Virtual Environments - *VTT*	R

MoPo - Models for the Construction Process - *VTT*	R
IAI BS-7 - Building Performance Monitoring - *VTT*	R
FinnST-1 - Finnish participation in the IAI ST-1 Steel frame construction -project - *Finnish Constructional Steelwork Association (FCSA)*	R
RINET - Building Product Database - *VTT*	R
Information Networks in Facility Management - *Tampere University of Technology*	R
VIRIL - Applications of Virtual Reality Technology for Building Construction Delivery - *VTT*	R
Construction IT Thesis - *Tampere University of Technology*	R
IAI: Assistant for the International Technical Director - *ToCoMan Oy*	E
IAI Forum Finland - *VTT*	R
Surveys and Reports	
Construction Process Management Tool Development - feasibility study - *TektonSolutions Oy*	E
Advancing Electronic Activities in Selling Construction Products - *The Finnish Association of Construction Product Industries (RTT)*	E
Roadmap to Intelligent Product Model (IFC) -*VTT*	R
ProCE - Project Management and Organisation in the Concurrent Engineering Environment - *Suomen Raksanet Oy*	E
VALE - Value Extracted from Virtual Value Chain - *YIT Oyj*	E
NTBC - New Technologies in Building Cluster - *University of Art and Design Helsinki*	R
Transfer of Finnish Information Technology to Japanese and Chinese Construction Business Markets - pre-study - *VTT*	R
Product Code System for Building and Fitting Industries - feasibility study - *Rasi*	E
Business Possibilities in Collection and Utilisation of Facility Information - *Rapal Oy*	E
Strategic Development of Information Technolgy Systems for Real Estate Management - *Vaasa Institute of Technology*	R
Information Networks for Real Estate Management - pre-study - *Institute for Real Estate Economics*	R
Finnish Construct IT Center - feasibility study - *The Building Information Foundation RTS*	E
Finnish Strategy of the Product Modelling for the Building Service Domain - *Development Centre for Finnish Building Services Ltd*	E
TIMI - Benefits of IT in the Construction Industry - *ToCoMan*	R
SCENIC - Support Centres Network for IT in Construction -*VTT*	R
Alternative Methods for Product Modelling - *VTT*	R
HVAC Product Libraries in Networks - *Development Centre for Finnish Building Services Ltd*	E
Information Networking in the Construction Process - Survey: Building Material and Component Industry - *Eurostepsys Oy<*	R
Information Networking in the Construction Process - Survey: Design, Structural Engineering and FM - *VTT*	R
Information Networking in the Construction Process - Survey: Main Contractors - *NCC Finland Oy*	R
Information Networking in the Construction Process - Survey: Building Services - *Olof Granlund Oy*	R

Appendix 2 “Mind Map” of Vera Analysis



The Tekes Healthy Building Technology Programme

Evaluation Report

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Contents

1 Introduction

On request by Tekes, the National Technology Agency of Finland, the Tekes Healthy Building Technology Programme has been evaluated with focus on the technical relevance of the programme and the projects, the scientific quality of the projects and the realisation of the programme and the projects. The evaluation is one part of an overarching strategic evaluation of the Building and Construction Technology Programmes.

The following report begins with some brief information about the Tekes Healthy Building programme, the material and information that forms the basis of the evaluation and the principles of evaluation applied. (Paragraphs 1.1, 1.2 and 1.3).

Next is provided a summary of the evaluation with general conclusions and recommendations concerning the programme as a whole. (Paragraph 2).

Finally the realisation of and the results from the four key areas of the programme are discussed shortly. (Paragraph 3).

Interviews and internationally published papers are accounted for in the enclosures.

1.1 The Tekes Healthy Building technology programme

The Finnish Healthy Building technology programme represents a substantial effort to improve the knowledge and develop technical solutions for improved indoor climate in new buildings as well as in existing buildings with indoor climate related problems.

The programme has been carried out in co-operation between Tekes and real estate and construction companies. It was started 1998 and is to be finished during 2002. The total extent of the programme has been FIM 138 million, corresponding to about EUR 23 million. EUR 12,3 million has been contributed by Tekes.

The programme has been focused on four key areas, including in total 121 projects or project phases, which stretch from basic technical and behaviour research to products close to application.

Key areas
1. Services and business concepts
2. Ventilation and building services
3. Moisture
4. Emissions

A basic idea has been that the objectives are to be obtained through an active co-operation between the research sector, the public health sector, the real estate sector, the construction business and the manufacturing industry. This is reflected in the types of individual projects. About a third of the funding has been assigned to university departments, while the rest has gone to projects carried through by companies. Quite a few of the latter projects have a pronounced character of research.

1.2 The basis of the evaluation

The evaluation has been based on
- 76 project summaries
- Short summaries of projects in English on htpp://www.tekes.fi/english/programm/healthybuilding
- Interviews with project leaders and researchers (*Encl 1*)
- 47 internationally published scientific papers (*Encl 2*)
- A number of technical reports, technical leaflets, project compilations, etc.

1.3 The evaluation process

The evaluation has, as mentioned, been focused on technical relevance, scientific quality and realisation of the programme and the projects. It has also been considered that the Healthy Building Technology Programme has a strong focus on development of knowledge and technical solutions, which should lead to application in practice in a foreseeable future.

The effort has been to look at the programme as a whole, but the base has naturally been the individual projects or groups of projects carried through.

This is reflected by the brief discussion about key areas in Chapter 3.

Tekes has asked the different project leaders for short summaries of the individual projects, the results obtained, etc. Such summaries are provided for most of the projects. Many of the summaries, as most of the more detailed reports, are available in Finnish only, which has implied some problems for the evaluation. However, with additional information and explanations received at interviews, it has been possible to get a quite clear image of the projects as well as the programme.

There has been one week of interviews with project leaders and researchers from ten of the most extensive groups of projects, representing about 2/3 of the total funding. *(Encl 1)*. The interviews have provided valuable information about the thinking behind and in the projects. They have also accounted for how different issues have been approached and how the projects have been carried through. Also they have given a picture of the scientific level of the work in the different projects.

There are a great number of technical reports, policy documents, working plans etc in Finnish. Presentations from Tekes and the interviews have made it possible to get an overview of these as well.

Those of the projects in the Healthy Building Programme, which are or have been carried through at universities, are mainly in the field of technical science or in the field between science and application. This is also the case with quite a few projects carried through by individual companies. There are about 60 internationally published papers. In *Encl 2* are listed 47 internationally published papers originating from research projects in the Healthy Building Technology Programme. Four doctor theses have been finalised within the programme and some more are in different stages of completion.

The internationally published papers have been a main basis for the assessment of the scientific quality of the scientific projects.

There are also a number of projects focused on technical development, close to application. These projects are carried through within companies. Some of the projects are extensive. The international publishing is limited.

Scientific quality is a criterion on the reliability of the results obtained. The general goal of a scientific approach is to guarantee the reliability of conclusions and results. This means that it is important that there is a scientific approach even in projects focused on technical development and applications. Here the assessment of the scientific quality has been mainly based on information obtained at the interviews.

The projects are also weighed against the goals of the programme, their status in an international perspective and their commercial potential.

2 Summary of the evaluation

Below are compiled conclusions and recommendations with reference to the Healthy Building Programme as a whole, outgoing from the findings dealt with somewhat more in detail in paragraph 3.

2.1 General viewpoints

After going through the Healthy Building Technology Programme it seems obvious that the establishing of the extensive programme is a result of an awareness of that:

- there are increasing problems in Finland, as in Scandinavian countries in general, with moisture and emissions from the building structure and that it is necessary to remedy these problems in existing buildings and to prevent future such problems in new buildings
- the design, construction and maintenance of ventilation and air conditioning systems must be improved so that only positive contribution to the indoor climate is ensured and that better founded criteria must be established for these systems

- for a real step forward within the areas above it is necessary to make a substantial effort and to establish a targeted co-operation between resources both on the research level and in the field of building and building management.

This awareness has resulted in a substantial funding and a strongly targeted programme with projects, which in many cases are carried through in constellations efficiently working towards a common goal. In most cases the goals are tied to application in practice. A number of conglomerates have been established with different university research groups and companies, stretching from basic technology to real estate owners. In a number of cases a probably stable purposeful co-operation has been built up within these constellations.

With this as background the following major strengths of the programme should be brought forward:

- A number of functioning constellations between university departments as well as between university researchers and research groups outside universities have been brought about.
- A constructive co-operation between research groups, manufacturers and contractors, aiming at methods and components for application in practice, has been established and has been very fruitful, especially in the moisture problem area.
- A positive involvement of real estate companies has contributed to the relevance and has, above all, facilitated a fast implementation, primarily in the moisture problem area.
- The concentrated effort with a substantial funding combined with the co-operations mentioned and a quite tough time schedule has surely contributed to a good generation of applicable results.

This is in accordance with the strategy behind the programme.

It seems appropriate to point out explicitly that the programme and its realisation are from many aspects impressive.

2.2 The strategies and goals

The objectives of the programme[1] are in a somewhat shortened form:

- to enhance the knowledge about the relationship between physical effects and indoor air and to develop building construction methods for high indoor air quality, to a level of international excellence.
- to develop and implement
  - indoor air and health criteria
  - supporting quality classifications for buildings, products and services in buildings
- to develop key spearhead products and processes that are competitive and exportable
- to develop processes for diagnosing and rectifying the indoor air and health properties of buildings

These objectives comprise a group of problems, which have an impact on health and well being and also have economic consequences. They cover on the whole the core of what is needed to increase the certainty for an indoor climate well adapted to its purpose. Yet some general comments might be appropriate.

It is praiseworthy that "building construction methods" are mentioned explicitly. The on site construction phase is a too common source of indoor climate problems, yet it is usually not focused in research programmes as clearly as here.

It adds to the value of objectives that there is an emphasis on development *and* implementation.

In some way development of competitive spearhead products is a normal part of the tasks of a manufacturing company. The meaning is presumably that development work of such kind is not included, which might have been mentioned more clearly.

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1 Healthy Building, Construction Technology, Indoor Climate and Quality. Tekes information in English

The strategy of the programme for a real step forward toward the objectives is

- an active co-operation between the research sector, the public health sector, the real estate sector, the construction business and the manufacturing industry.
- a substantial concentration of resources of high competence with defined time limits

The combination of objects and strategy described is definitely well suited for a substantial step forward on the way to ensure a prevailing really "optimum" indoor climate in new buildings and in rectified problem buildings, presupposed that there is a consciousness that substantial funds must be reserved. Obviously there has been a clear awareness of this, which makes the chosen combination of objectives and strategy to a very good base for the programme.

2.3 The quality of the programme in world terms

There are a number of research programmes, more or less comparable with the Tekes programme, going on internationally. The closest seem to be the International Centre for Indoor Environment and Energy ICIEE at the Technical University of Denmark and the Swedish Healthy Building Programme. A comparison between these two programmes and the Tekes Programme might be motivated.

The Danish research centre ICIEE is financed by the Danish Technical Research Council and Danish industry. It has the focus on indoor environment, its impact on human comfort and productivity and on factors influencing the indoor environment. The research is mainly of a basic scientific character and has a high international reputation.

The Tekes programme also includes some research about the impact of indoor environment on productivity, but it is a small part of the programme. This part is focused on the impact in normal working environment while the ICIEE research is mainly laboratory based. The approach in the Tekes programme is difficult but will surely complement, and to a certain amount balance, the results from the Danish Centre. It adds to the international value that the indoor climate – productivity research in the Tekes Programme is integrated in an overarching technical project "Productive office".

The Swedish Healthy Building Programme is closer to the Tekes programme, but has also a basically scientific aim and direction. The main task is to identify the causes of unsatisfactory indoor climate situations, point out risk factors and indicate appropriate measures, not to develop technical solutions and components. The field of research is somewhat wider and the funding smaller compared with the Tekes programme.

As to the rest it seems that international research programmes in this area are more focused on specific questions and less aimed at technical solutions than the Tekes programme is.

To sum up has the Tekes Programme its own goals and qualities and complements the international research and development going on in the area.

The Tekes Healthy Building Programme characteristics:

- obvious strive towards practical applications
- co-operation between university departments, companies and real estate owners
- a concentration of resources
- gives it a special international quality.

Some parts of the programme have got a good international response, but in general a somewhat stronger international impact might have been expected.

There has been an extensive presentation with 23 papers at the Indoor Air Conference, San Jose July 2002, but in total the international publication seems to be somewhat limited with regard to the magnitude of the programme, especially as far Peer Review papers are concerned. One reason might be the time factor, as the research programme has been running three years only and Peer Review publishing tends to take some time.

Anyhow a stronger focus on international publishing could be recommended.

2.4 The mix of projects and participants

In general the mix of projects and the combination of participants seems to be successful. A number of project combinations have already resulted in applications, which would hardly have become a reality without co-operation between researchers, manufacturers, constructing companies and builders. Some examples of this are the transducer system for moisture control, the moisture control routines introduced in the construction process and the clean ventilation system groups of projects. All these combine research, development and application ending up in valuable practical applications within the objectives of the programme.

Considering the large amount of projects and that much of the detailed information is available in Finnish only, the assessment has mainly been focused on the bigger projects and project combinations. As far as these are concerned it seems that approved competence and experience has in most cases been a decisive criterion when participants have been selected. This has of course contributed to the quality.

In general the mix of projects and participants seems in most cases successful.

2.5 The management of the programme

An important part of the management has obviously been to establish a well functioning and creative co-operation between different groups. This has certainly contributed to the level of the programme on the whole. It has most likely also resulted in lasting co-operations, which will be valuable in the future.

It seems also that the programme management has had a continuous and creative dialog with an insight in most of the projects, which according to my experience and opinion is very important and contributes to successful research and development.

The formal management, i.e., the orderliness of project information, etc, seems to be excellent as all formal information about projects, economy, etc, has been provided promptly and in a very comprehensible form.

Looking at the programme from a university point of view, it seems that there should be a real potential to doctor dissertations within the quite extensive research projects carried through by university departments. There are some on the way, but they seem to be somewhat few considering the extent of the funding of the projects The Tekes Healthy Building Technology Programme and similar programmes seem to have a considerable potential for doctor dissertations at the university departments involved. This is of course primarily a responsibility of the university departments involved, but there might be beneficial if Tekes and the management of the programme would stress that explicit in the future.

2.6 Potential commercial success stories

When a research and development programme as the Tekes Healthy Building is concerned, it seems relevant to look at commercial success from two aspects. One is the common one:

- products that have a market success and create a profit.

The other is a more indirect one, but nevertheless important from economic point of view:

- improved knowledge and new methods, which eliminate problems with accompanying costs and might in a longer perspective initiate new methods and products.

The latter ones might be transformed to a market success if applied as means for strengthening the competitiveness of a company.

Possible success stories of the first kind seem to be:
- the transducer system for moisture control
- the complete duct cleaning system.

The developed bathroom renovation systems might also involve a component of success.

Possible success stories of the other kind could be:
- the well based applicable results from the projects dealing with the distribution pattern and flow of moisture in ground and floor structures
- building foundation design for prevention of moisture problems
- application of moisture control in the construction process
- development of healthy building criteria
- the clean ventilation system and corresponding classification projects.

One project that includes moments that might lead to a future success is the "Productive office", HUT et al. There are however quite a few difficulties involved.

2.7 Possible impact of the results

The extensive and apparently essentially successful work in the moisture related projects will most likely improve the design and construction of moisture sensitive structural parts of buildings and therewith decrease future moisture problems. The implementation is strongly facilitated by the involvement in the program of construction companies and real estate owners.

By the projects carried through in the moisture area many future errors will probably be avoided.

The clean ventilation system concept with connected projects will influence the ventilation technology positively. Yet, a somewhat stronger engagement from the manufacturing industry would be beneficial.

The systematically built up healthy building criteria will certainly influence the technology for indoor climate positively.

Both the clean ventilation system concept and the work with the healthy building criteria has already have already gained international respect and are influencing at least the European codes and recommendations.

2.8 Some remarks

As has been emphasised already, the over whole impression of the programme is very positive. Yet some remarks might be of interest for future development of the programme.

There might be valuable to emphasise a more extensive international publication and specially Peer Review publication of results from the research projects. Besides the reputation effect such publication involves an international quality control that is beneficial on the long run.

Considering the extent of the research projects it seems to be possible to bring about quite a few more doctor exams than has been the case in the present programme. Many of the research projects include elements well suited as parts of doctor theses. It could be recommended that this is emphasised when funding research projects.

Co-operation and strive towards common goals characterises the programme. This gives it a special quality and contributes to the many successful results. When projects are prolonged or new projects are started, it might be beneficial to express this even more than has been already done by Tekes.

3 Project level analyses

The evaluation has included a quite thorough assessment of the different projects carried through or going on within the four key areas:
- Services and business concepts
- Ventilation and building services
- Moisture
- Emissions.

Below is discussed briefly the research and development carried through and going on in these key areas. The comments are based on analyses of the printed material obtained and on the interviews. The schedule of the interviews and the project leaders and researchers taking part are accounted for in *Encl 1*.

3.1 Service and business concepts

In this key area there are projects of a general character focused at methods and technical solutions towards healthy buildings.

One looking forward constellation of projects has the goal to develop an overarching general model for the choice of design criteria and design solutions for buildings and its HVAC systems. One part of this is to apply the mentioned studies of the relationship between indoor climate and productivity. The goal is a model that contributes to decisions about HVAC system and building characteristics, which are optimal from economic, reliability and personnel total performance point of view.

It is a question of a number of models, which should provide information as support for decisions in a number of steps. Even if the goal should not be reached in full a number of valuable design aids will be developed.

One essential part is the already mentioned effort to prove a quantitative relationship between indoor climate and productivity in normal working conditions. This is a more difficult task than laboratory tests, which dominate the research in this area, but whatever results are obtained, they will be most valuable and certainly noticed internationally. It would be most beneficial for the indoor climate technology and for the field of HVAC if it would be possible to prove real economic effects of special indoor climate qualities. In my opinion, based on the interviews and their first published paper, this group, if any, might achieve substantial results, but it will not be an easy task.

Another part is to draw up and implement criteria for healthy buildings, which has gained international response already.

The constellation of projects exemplifies a fruitful co-operation between different fields of technology and science, involving competence and experience from basic and applied technology, medicine and studies of human behaviour.

In general there seems to be an efficient and positive co-operation in the key area between the research groups and between the researchers and industry.

The projects in the key area seem through out to be within the scope of the Healthy Building Technology Programme. One PhD dissertation is in progress.

3.2 Ventilation and building services

In this key area there is a constellation of projects with the goal to produce criteria and methods, which ensure that ventilation systems provide hygiene, comfort and healthiness. The research and development work is almost finished and is under implementation.

The whole air supply process, air treatment, air cleaning and air distribution, is dealt with. Criteria for development of clean components, a method for labelling of clean components, guidelines for design of clean systems, guidelines for the construction phase and guidelines for operation and maintenance have been developed.

Also a complete system for cleaning of ducts has been developed by the companies involved.

There is a special quality in the fact that the constellation of projects covers the whole area from setting targets to control of cleanliness in plants in operation and cleaning of duct systems without polluting the premises.

There have been extensive information activities both in Finland and internationally. International guidelines under preparation are clearly influenced by the work carried through.

Here the Healthy Building programme, by establishing a targeted co-operation between research and development groups, has provided a complete system of methods and equipment that is already in commercial implementation.

The projects in the key area are mainly well within the scope of the program and most of them have a good scientific and technical quality. One PhD has graduated, partly based on research within the Healthy Building Technology Programme. Two more PhD dissertations are in process.

3.3 Moisture

The key area focused on moisture is in a way more concrete than the other key areas. It has been a question about a certainly complicated but clearly defined complex of problems. The key area is a substantial effort to solve by adequate measures problems that occur in many existing buildings and to prevent future problems by enhanced knowledge, improved design and improved construction processes. It is evident that it has been understood that improvement of both of the basic knowledge and of the processes applied during construction is needed.

There has been carried through and is going on a quite extensive research in this area, primarily in the Nordic countries. It is obvious that the research groups involved in this Healthy Building Technology key area have been very well aware of this and have focused their research towards topics which really need additional research and development. This appears clearly from the reports, which are provided with relevant and exhaustive lists of references and account for an obvious aspiration to focus on topics, which have not been sufficiently clarified earlier.

There seems to have been an excellent co-operation between researchers, construction companies and real estate owners. Very much due to that, a couple of project constellations have been very successful.

One of these is the development of a transducer based system for humidity monitoring in building structures.

The transducers include a humidity sensor and a transmitter and could also be provided with a memory. They are to be placed in from moisture point of view critical parts of the building structure, for future control of the moisture level inside the structure. The transmitter is activated and the humidity level read from outside, once a year or every second year. This will enable a continuing control of the moisture situation during the lifetime of the building. The first generation of the transducers is now implemented in a considerable number of new one family houses.

The project constellation combines basic theoretical work at an applied electronics university department, application in building technology by specialists in building physics and technical development of components and instruments with implementation by building companies. The work seems to have a fair chance to become a real success story.

Another constellation of projects has resulted in a methodology for control of the humidity in concrete floors after casting in order to ensure a correct humidity level before applying the flooring material.

By measuring the humidity of the concrete it can be made sure that the humidity is acceptably low before the surface is covered. This means that the risk of moisture problems is decreased and the construction time might be shortened. The methods are well tested in a large number of construction projects. The introduction of humidity measurements as a routine has been combined with a thorough work on the physical behaviour of different floor structures and extensive information activities.

Extensive research work has also been carried through about the mechanisms behind moisture risks in exterior wall structures and different floor structures. A large number of measurements of material properties as heat conductivity, vapour permeability, sorption characteristics and capillarity have been carried through and made available.

There is also a test program focused on different technical solutions combined with simulations of the behaviour of moisture in buildings in operation. One of the factors studied is the consequence of different material moisture levels on the future moisture situation in the structure. It has been shown that the existing codes about vapour resistance of wall structures ought to be strengthened.

A group of projects has been focused on moisture problems originating from the ground and on crawl spaces. It has been shown that existing codes concerning the fillings under foundations should be improved according to the results obtained.

The work concerned with moisture behaviour in building structures and construction routines for avoiding future moisture problems, is throughout of high quality and will certainly contribute to a decrease in future problems with moisture, presupposed the results are applied in practice.

Due to a positive co-operation with construction companies and real estate owners and efficient information efforts, the prerequisites for a broad application in practice seem to be very good.

Three PhDs have been graduated and two more are on the way.

3.4 Emissions

This is an area where quite a lot has been done during the last ten years and where there are quite few studies going on about material properties and also many research projects about material behaviour in progress internationally. The research in this key area of the Healthy Building Technology Programme seems to be focused on topics, which have not been made sufficiently clear earlier.

The behaviour of from emission point of view classified building materials has been studied in real buildings in operation. The studies have been focused on ammonia, formaldehyde and VOCs. A large number of FLEC measurements of concrete surfaces, with and without levelling agents have been carried through. Floors with parquet and with glued PVC have been studied. It has been shown that after some time there will be high ammonia concentrations under a glued PVC covering. However, as long as the covering is tight the emission into the room is marginal.

The works are of good scientific quality.

Enclosure 1

Interviews

Interviews were carried through August 5th –9th.
The interviews comprised both research projects and development projects.

Research projects		
Date	**Participants**	**Organisation**
Aug 5	Prof Raimo Sepponen	Applied Electronics Helsinki University of Technology, HUT
Aug 6	Prof Olli Seppänen Dr Jarek Kurnitski MSc Jorma Säteri	HVAC Technology Helsinki University of Technology, HUT
Aug 7	Prof Kari Reijula Prof Raimo Niemelä	Nyland Occupational Health Inst. UaTTL Finnish Institute of Occupational Health
Aug 8	Prof Ralf Lindberg Lic Juha Vinha	Structural Engineering Tampere University of Technology, TUT
Aug 9	MSc Kristina Saarela MSc Mikael Salonvaara	VTT Technical Research Centre of Finland
Development projects		
Date	**Participants**	**Organisation**
Aug 6	MSc Pentti Lumme MSc Tarja Merikallio MSc Ari-Veikko Kettunen	Lohja Rudus Oy Humittest Oy Humi-Consulting Oy
Aug 7	Lic Juha Salminen MSc Kari Kiviluoma	NCC Finland Oy
Aug 7	Dr Kim Hagström	Halton Solutions Oy
Aug 8	MArch Marja Kauttu	Finnish Real Estate Federation, Rakli
Aug 9	MSc Vesa Mäkipää MSc Timo Jalonen	LIFA AIR IAQ Oy

Enclosure 2

International publications

Below are listed the internationally published papers and the doctor exams in connection with the Tekes Healthy Building Technology Programme.

There are also internal reports, some printed books and 4 doctor theses. However, the list below includes only papers published in international periodicals.

	Author	Title	Publication
1.	Saarela, K. et al	Building related factors and inhabitant exposure to indoor air volatile organic compounds in the EXPOLIS Helsinki study 6pp	1
2.	Tuomainen, M. et al	TVOC, formaldehyde and ammonia levels in two new blocks of flats	1
3.	Asikainen, V. et al	Oil residues on HVAC components	1
4.	Hyttinen, M. et al	VOC emissions from dusty air filters	1
5.	Björkroth, M. et al	Measurement of sensory load from ventilation systems by trained and untrained panels 6 pp	1
6.	Asikainen, V. et al	Selection of lubricant for manufacture of HVAC components	1
7.	Björkroth, M. et al	Cleanliness criteria and test procedures for cleanliness labeling of HVAC components	1
8.	Björkroth, M. et al	Labeling system for clean ventilation components	1
9.	Holopainen, R. et al	A visual inspection method to evaluate cleanliness of newly installed air ducts	1
10.	Kolari, S.	The effect of duct cleaning on indoor air quality in office buildings	1
11.	Holopainen, R. et al	The amount of accumulated dust in ducts of new HVAC installations	1
12.	Luoma, M. et al	Development of a clean installation method for ventilation systems	1
13.	Tuomainen, M. et al	Modelling the cost effects of the indoor environment	1
14.	Järnström, H et al.	Indoor air quality and material emissions in new buildings	1
15.	Villberg, K. et al	Correlation between VOCs emitted from building materials and diagnosed building related symptoms	1
16.	Murtoniemi, T. et al	Effect of liner and core materials of plasterboard on microbial growth, spore induced cytotoxity and production of TNF in macrophages	1
17.	Saari, M. et al	Healthy sauna	1
18.	Matilainen, M. et al	Transport of fungal spores from crawl spaces to indoors	1

	Author	Title	Publication
19.	Kovanen, K. et al	Performance characteristics of soaked air filters	1
20.	Pesonen, E. et al.	The effects of cleaning on concentrations of surface dust and airborne particles	1
21.	Wirtanen, L. et al	The moisture content and emissions from floors subjected to a moisture load	1
22.	Järnström, H et al	The appointment of volatile organic compounds and the effect on remedial action at two indoor air problem sites	1
23.	Seppänen, O.	Ventilation, energy and indoor air quality	1
24.	Hagström, K. et al	Calculation of room velocity using kinetic energy balance 11pp	2 2000, V.106, Pt 2
25.	Kurnitski, J. et al	Crawl space air change, heat and moisture behaviour. 10pp	3 2000, 32, 1
26.	Kurnitski, J. et al	Moisture conditions of outdoor air ventilated crawl spaces in apartment buildings in a cold climate	3 2000, 33, 1
27.	Matilainen, M et al	Moisture conditions in highly insulated outdoor ventilated crawl spaces in cold climates	3 Submitted 2000
28.	Matilainen, M. et al	Moisture conditions and energy consumption in heated crawl spaces in cold climates	3 Submitted 2002
29.	Niemelä, R. et al	The effect of air temperature on labour productivity in call centres - a case study	4 2002, 34, 8
30.	Holopainen, R. et al	Modelling the cleaning performance of rotating brush in duct cleaning	4 2002, 34, 8
31.	Kurnitski, J. et al	Ground moisture evaporation in crawl spaces	5 2001, 36, 3
32.	Asikainen, V. et al	Assaying mineral oil residues on new HVAC components	5 1999
33.	Matilainen, M. et al	Crawl space moisture control by the ground cover´s moisture capacity, thermal insulation and ventilation	5 Submitted 2000
34.	Kurnitski, J. et al	Simultaneous calculation of heat, moisture and air transport in a modular simulation environment	6 2000, 6, 1
35.	Kurnitski, J. et al	Moisture convection around a crack by pressurization	6 2000, 6, 1
36.	Holopainen, R. et al	The effect of cleanliness control during installations work on the amount of accumulated dust in ducts of new HVAC installations	6 2002, 12
37.	Asikainen, V et al	Oil residues and dust on HVAC ducts	6 2001
38.	Holopainen, R. et al	The field comparison of three measuring Techniques for evaluation of the surface dust level in ventilation ducts	6 2002,12,
39.	Kurnitski, J. et al	Space moisture and microbes	7

	Author	Title	Publication
40.	Kurnitski, J. et al	Lightweight expanded clay aggregate ground cover moisture behaviour in crawl spaces.	7
41.	Matilainen, M. et al.	Crawl space moisture control by the ground cover moisture capacity in crawl spaces	7
42.	Matilainen, M. et al.	Crawl space moisture control by thermal capacity and insulation	7
43.	Niemelä, R. et al	Work environment effects on labour productivity. An intervention study in a storage building	8
44.	Lahtinen, M. et al	Psychological dimensions of solving indoor air problem	9
45.	Kurnitski, J. et al	Crawl space ground covers, air change and dehumidification to reduce humidity	10
46.	Kurnitski, J. et al	Crawl space moisture behaviour and air change.	11
47.	Kosonen, R. et al	Integration of heating mode into ventilated cooled beam 6pp	

1. Proceedings of Indoor Air, San Jose 2002, Volume I-V
   Conference paper with reviewed abstract
2. ASHRAE Transactions.
   Reviewed paper
3. Energy and Buildings
   Reviewed paper
4. Energy and Buildings – REHVA Scientific
   Reviewed paper
5. Building and environment
   Reviewed paper
6. Indoor air
   Reviewed paper
7. Engineering Proceedings, Estonian Academy of Science
   Reviewed paper
8. American Journal of Industrial Medicine
   Reviewed paper
9. Indoor Air
   Reviewed Paper
10. Proceedings of Healthy Buildings, Espoo 2000
    Conference paper with reviewed abstract
11. Proceedings Int.Building Physics Conference, Eindhoven, 2000
    Conference paper with reviewed abstract

Beyond the papers listed above, there are 13 conference papers, connected with the different projects dealing with clean ventilation systems and cleaning of duct systems.

Tekes' Technology Programme Reports

6/2003	Towards a competitive cluter – An evaluation real estate and construction technology programmes. Evaluation Report. 89 p. Petri Uusikylä, Ville Valovirta, Risto Karinen, Enno Abel and Thomas Froese
5/2003	Developing technology for large-scale production of forest chips. Wood Energy Technology Programme 1999–2003. Interim Report. 53 p.
4/2003	Code Technology Programme 1999–2002. Final Report.
3/2003	VÄRE – Värähtelyn ja äänen hallinta -teknologiaohjelma 1999–2002. Loppuraportti. 90 s.
2/2003	Kenno – Kevyet levyt -teknologiaohjelma 1998–2002. Loppuraportti.
1/2003	FFusion Technology Programme 1999–2002. Loppuraportti.
14/2002	Technology and Climate Change. CLIMTECH 1999–2002. 258 p. Sampo Soimakallio, Ilkka Savolainen (eds.)
13/2002	Avautuneet sähkömarkkinat ja jätteiden energiakäyttö – lainsäädännöllä synnytettyinä markkinoina. TESLA- ja Jätteiden energiakäyttö -teknologia-ohjelmien arviointiraportti. 62 s. Mervi Rajahonka, Lasse Kivikko, Mikko Valtakari, Matti Pulkkinen
12/2002	Information Technology and Electric Power Systems, TESLA Technology Programme 1998–2002. Final Report. 80 p.
11/2002	Informaatiotekniikka sähkönjakelussa, TESLA-teknologiaohjelma 1998–2002. Loppuraportti 102 s.
10/2002	Kilpailukykyä yritysten toimintatapoja kehittämällä – GPB-, ProBuild- ja Laatu-ohjelmien arviointi. Arviointiraportti 44 s. Mikko Valtakari ja Mervi Rajahonka
9/2002	Energiateknologiayritykset liiketoimintaympäristön murroksessa. Materiaalit energiatekniikan palveluksessa, KESTO-teknologiaohjelma 1997–2001. Arviointiraportti. 31 s. Lasse Kivikko
8/2002	Materials for Energy Technology, KESTO Technology Programme 1997–2001. Final Report. 128 p.
7/2002	Materiaalit energiatekniikan palveluksessa, KESTO-teknologiaohjelma 1997–2001. Loppuraportti. 128 s.
6/2002	Water Services 1997–2001. Evaluation and Final Report. 132 p.
5/2002	Pigmentit paperin raaka-aineena 1998–2001. Loppuraportti. 87 s.
4/2002	Global Project Business, Kansainvälinen liiketoiminta 1998–2001. Loppuraportti.
3/2002	ETX – Electronics for the Information Society 1997–2001. Final Report. 387 p.

Subscriptions: www.tekes.fi/english/publications