Final Programme Evaluation Report

Vera –

Information Networking in the Construction Process

A TEKES Technology Programme

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Table of Contents

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 Finish 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 3.1 captures the essence of the Vera vision.

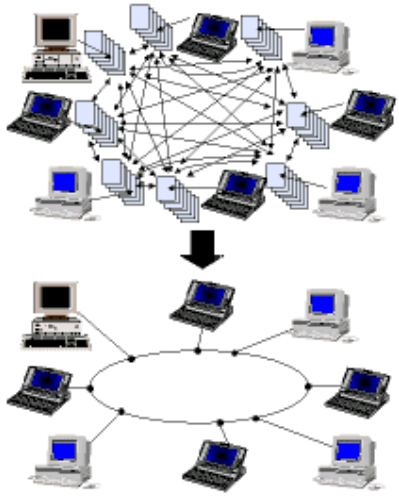

Figure 3.1: The target of the Vera Technology Programme is to help the parties in a construction project to form networks and share project data instead of paper documents.

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 **(∆).** In both cases, issues seen to be particularly important are indicated as **(+!)** or **(∆!).**

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 5.1). 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.

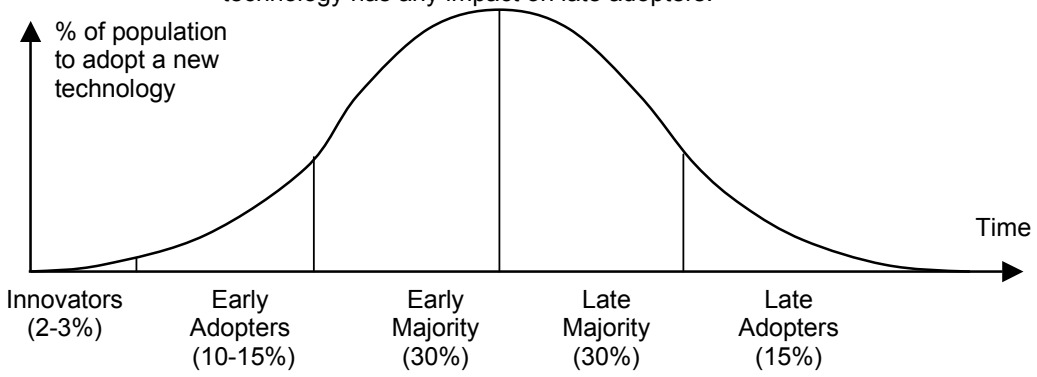

Figure 5.1: A general model of technology adoption rate over time

Furthermore, the degree of technology adoption may be compared to the lifecycle stage of the technology research and development. Figure 5.2 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.

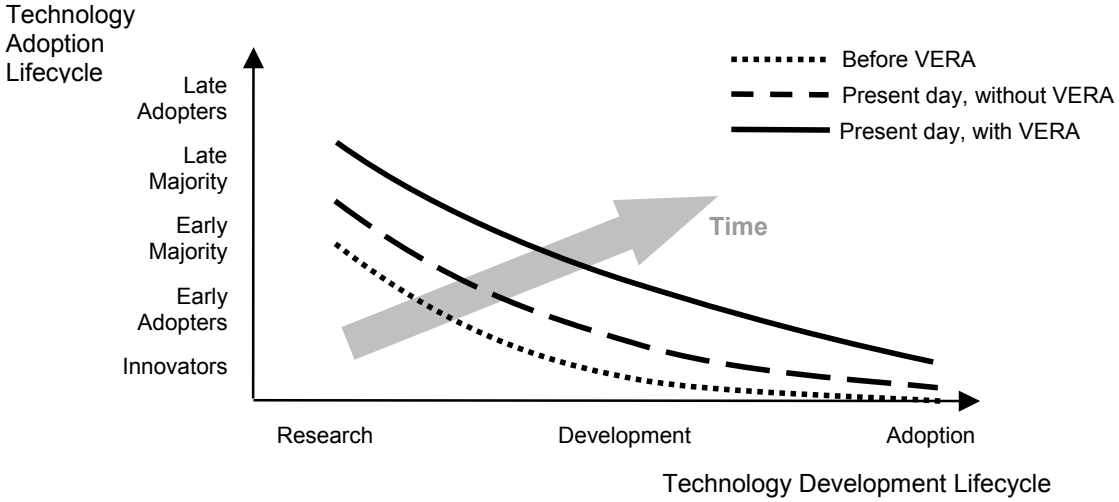

Figure 5.2: Technology adoption vs technology development.

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. **(∆)** 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. **(∆!)** 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. **(∆!)** However, there has been almost no efforts to capture, structure, and formalize to overall knowledge base resulting from the sum of the individual projects. **(∆!)** 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. **(∆)** 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 Were 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 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 I: 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*	R

Software and Multimedia Laboratory	
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	R

Engineering and FM - *VTT*

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 II: "Mind Map" of Vera Analysis