

# Competitive Reliability 1996–2000

Technology Programme Report 10/2001

Evaluation Report



**TEKES**

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Evaluation Report



National Technology Agency

**Technology Programme Report 10/2001**  
Helsinki 2001

## **Tekes – your contact for Finnish technology**

Tekes, the National Technology Agency of Finland, 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 aim to diversify production structures, increase productivity and exports, and create a foundation for employment and social well-being. Tekes supports applied and industrial R&D in Finland to the extent of some EUR 390 million, 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 for developing innovative products and processes 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. 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, a total of about 50 extensive national technology programmes are under way.

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# Foreword

The Competitive Reliability Technology Programme KÄKI was focused on increasing the international competitiveness of Finnish industry by developing techniques, methods and tools for better and more convincing control of product reliability and availability of production systems. KÄKI had an extensive interdisciplinary character combining expertise of hard engineering sciences (e.g. material research) and of soft human performance issues (like influence of the human in a socio-technical system).

The total value of KÄKI was about 12 million Euros and it was carried out during 1996-2000. KÄKI was targeted at three industries: energy production, process industry and metal industry. It included product and production development projects for companies and public research projects. KÄKI aimed at new business opportunities or cost savings as well as at the strengthening of the knowledge base. The evaluation of the programme had also two perspectives that were complementary to each other.

The Scientific and Technological Level of the programme was assessed by Professor Ward O. Winer, Georgia Institute of Technology. He has a remarkable career in tribology and diagnostics research and consulting. He has also been Principal Investigator on an U.S. research programme, which had the same goal as KÄKI.

The Cost/Benefit Analysis of the programme was carried out by Dr Mari Hjelt and Mr Mikko Syrjänen, Gaia Group. They have a good analytical background in utilizing decision-making methods in a variety of projects. While CBA is not widely used in ex-post analysis, this subproject also discussed the possibilities to use CBA method in future.

The evaluation was carried out during January - March 2001. The material consisted of publications, survey and interviews. Evaluators have had joint meetings, but they have prepared their report separately.

Tekes wishes to express its gratitude to the evaluators for their thorough and pioneering work. Tekes wishes to thank the participants of KÄKI Technology Programme for their contribution.

Helsinki, April 2001

Tekes, the National Technology Agency

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*Mari Hjelt, Mikko Syrjänen*

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# Cost-Benefit Evaluation

*Mari Hjelt, Mikko Syrjänen*

## Executive Summary

The competitive reliability technology programme was completed over a period of five years between 1996 and 2000. The objective of the programme was to increase the competitiveness of the Finnish industry by developing techniques, methods, and tools for better control over the product and production system reliability. The programme was targeted to three industrial sectors: energy production, process industry (particularly pulp and paper), and metal industry.

The programme consisted of two types of projects. Research institutes and universities started projects that were research oriented. These projects offered methodological support to product development projects that were mainly run by companies. In total the programme consisted of 31 projects of which 14 were methodological research projects.

The evaluation of the programme was done based on Cost-Benefit Analysis (CBA). CBA aims at measuring all the costs and benefits (both monetary and other types of costs and benefits) over the lifetime of the programme in monetary terms and at summarizing these in one indicator that describes whether the benefits outweigh the costs. In this evaluation, it was decided that the main stakeholders whose costs and benefits are assessed, are all the companies, research institutes, and universities that participated in any of the projects included in the programme. In total, 78 main beneficiaries were identified. Tekes is also a stakeholder in the sense that the funding provided by Tekes is included in the analysis. The analysis focused on direct economic costs and benefits and covered a time frame until year 2006.

With the used 5 % discounting rate, the direct economic costs related to the programme in the net present value were estimated to be 94 million FIM (the sum of cash flows over the years is 83 million FIM). The programme preparation costs and commercialization costs of the products are excluded. The present value of the total expected additional sales (both in research organizations and companies) is about 350 million FIM (the sum of cash flows over the years is 390 million FIM). Further, the present values of the total additional operating margins and the cost savings created by the projects sum up to 88 million FIM (the sum of cash flows over the years is 98 million FIM). From the companies' point of view, the public funding could be excluded from the analysis resulting overall in about 30% less costs. Thus, from the companies' point of view the programme is profitable. In addition to these costs and benefits, the programme resulted in a few new innovations that may lead to new spin-off companies.

The most important other than direct economic benefits resulting from the programme were assessed to be the increased awareness over the reliability in the participating companies and increased national knowledge. The participants did not consider environment, safety, and employment related impacts to be remarkable. The participants valued the role of the programme and generally felt that the projects were more beneficial and efficient when they were a part of a technology programme.

## 1 Introduction

### 1.1 Objectives of the Evaluation

This part of the report presents the results of evaluating the competitive reliability technology programme (KÄKI-programme). The evaluation in this part focuses on the economic costs and benefits resulting from the programme. The pro-

gramme is also evaluated with respect to its scientific and technical merits of which the main results are presented in Part 2 of this report.

The competitive reliability technology programme was completed over a period of five years between 1996 and 2000. The objective of the programme was to increase the international competitiveness of the Finnish industry by developing techniques, methods, and tools for a better control over the product and production system reliability. The programme was targeted to three industrial sectors: energy production, process industry (particularly pulp and paper), and metal industry.

The programme consisted of two types of projects. Research institutes and universities started projects that were oriented towards research. These projects offered methodological support to product development projects that were mainly run by companies. There were three separate streams of product development projects: 1) projects that were targeted to the energy production sector, 2) projects in process industry, and 3) projects in metal industry.

These separate streams of projects started over different phases so that between 3 and 9 projects were started each year. In total there were 31 projects of which 14 were methodological research projects. In addition to these projects, the coordination of the programme was organized as a separate project. The details of the coordination of the programme and each project are described in the final report of the programme that is published separately<sup>1</sup>.

The steering group of the KÄKI-programme and Tekes decided that the evaluation of the programme should be based on Cost-Benefit Analysis (CBA). CBA aims at measuring all the costs and benefits (both monetary and other types of costs and benefits) over the lifetime of the programme in monetary terms and summarizing these in one indicator that describes whether the benefits outweigh the costs. In designing the programme, it was felt that the issues related to reliability will be ever more important in improving the competitive position of the companies. In order to look

back at these assumptions at the end of the programme, it was felt that CBA is an appropriate approach to be used in the evaluation. CBA gives the participants an understanding over the scale of the benefits that can be expected from the type of R&D projects that are included in Tekes technology programmes. The information on the economic benefits related to the whole programme will thus be of particular interest to companies that participated in the programme.

Although the programme as a whole is evaluated in monetary terms, the objective of this evaluation is not to judge the projects individually, i.e., to make a judgement whether a right choice was made when each project was started. Even though the analysis is based on the costs and benefits of individual projects, information on individual projects is excluded.

Many of the previous programme evaluations commissioned by Tekes have given some estimates of the expected increase in the turnover resulting from the programme. Usually, the total costs of the programme have been included in the evaluations as well. However, in this evaluation, the objective was to study the economic information in more detail. One of the major objectives of the evaluation was also to evaluate the usefulness of CBA in the programme evaluation.

## 1.2 Implementation of the Evaluation

The evaluation was completed between January and March 2001 immediately after finishing the programme. Although the programme is officially finished, some of the projects will continue until mid 2001. These projects were included in the analysis as well.

CBA methodology and the assumptions used in this evaluation are described in detail in Chapter 2. Information collection for the analysis consisted of three parts:

1. *Literature review.* The programme material that was published during the programme and the project reports that were sent to the pro-

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1 Holmberg, K. (ed.) Competitive Reliability 1996–2000. Final Report, Technology Programme Report 5/2001, Tekes.

gramme coordinator were reviewed. However, the available material did not include confidential project proposals or the project reports that were directly sent to Tekes. The available material was mainly used in the beginning of the analysis to define the stakeholders who benefit from the programme and the scope of the costs and benefits to be included in the analysis.

2. *Mailed survey* (sent to most of the organizations that were potential beneficiaries). The main purpose of the survey was to inquire details over the economic benefits and future costs related to the projects and present questions related to the added value of the programme itself.
3. *Interviews with some members of the programme steering group*. These interviews were used to create an understanding of the programme as a whole, and of the role of reliability for the competitiveness of the companies in the participating business sectors.
4. *Interviews with the project leaders*. It was already clear when the survey was sent out that the responses will be limited and many of the questions will be left unanswered. Thus, a round of short interviews with project leaders was completed to cover the missing information.

This report is organized as follows: Chapter 2 presents the details of CBA methodology and how it is applied in this evaluation. Also, the limitations of the methodology are shortly discussed. Chapter 3 presents the results of the evaluation. Main conclusions are summarized in Chapter 4.

## 2 Cost-Benefit Analysis in Programme Evaluation

### 2.1 Description of Cost-Benefit Analysis

Cost-Benefit Analysis (CBA) seeks to quantify the costs and benefits of a project (or a programme) in a commensurate unit (usually in monetary terms). The costs and benefits should be understood broadly so that they can also include items, for which there are no satisfactory economic measures. In other words, also other than direct eco-

nomic benefits and costs, such as the prevention of the risks of environmental damage (benefit) or the increased risk for personal safety (cost), can be included in the analysis.

Traditionally, CBA is used to compare different alternatives before they are implemented (ex ante evaluation). A project (or a policy option) is selected if benefits outweigh costs (or the most cost-effective one is chosen). However, CBA can also be used in evaluating actions that already have taken place (ex post evaluation). In this case, parts of the costs and benefits already might have realized.

CBA generally consists of the following steps:

1. *Determine which stakeholders* will be included in the analysis. This is the most important question to be addressed, because both costs and benefits are relative; benefits of one stakeholder may be the costs of another. CBA should always clearly specify the boundaries of the analysis – whose costs and benefits and what costs and benefits are included.
2. Identify the *alternatives* that will be considered. Standard CBA is used to make a decision, whether a project or a policy option should be selected. In using CBA in the programme evaluation, there is only one option that already has been completed. In this case, the analysis could be extended to speculate how well the selected option did in comparison to other hypothetical alternatives.
3. *Identify the impacts (costs and benefits) to be included in the analysis* and select the appropriate *measurement indicators*. The selection of appropriate impacts is determined by the overall objective of the analysis. In the case of evaluating a large government programme, this is a very challenging task, because many of the benefits are indirect (e.g., the benefits resulting from the networking), difficult to measure in any quantifiable indicator, and may occur after a long time period. Already in the beginning, it should be discussed how different indicators will be translated into a single commensurate unit (i.e., whether money will be used as a common unit and how non-monetary impacts will be transformed into money).

4. *Select a time perspective and the discounting parameters.* Costs and benefits are spread over time. Particularly, in the case of a programme that has had a long duration and which will have impacts over a long time, one needs to clearly define the necessary time frame. The discounting of money over the time frame needs to be taken into account in the analysis, due to two reasons. First, the valuation of money is dependent on time. Generally, people prefer to make payments later and receive benefits sooner. This means, for example, that of two options where the costs and benefits are equal in absolute monetary units, the option where the costs occur later than the benefits is still preferred. Second, the value of the unit changes over time (inflation). For the fact that these two adjustments in principle are necessary, one needs to use discounting.
5. *Collect information on the impacts over the time frame (estimate future impacts or collect data on actual costs and benefits that have materialized).*
6. *Attach a monetary value to all of the impacts (if not already measured in money)*
7. *Find the net present value of the monetary amounts over time and add up the costs and benefits.*
8. *Perform a sensitivity analysis over the results.* CBA is based on a number of assumptions. The results should be examined by changing some of the key assumptions and with respect to the discounting parameters.
9. *Select the alternative with the largest net social benefits or the alternatives with positive net benefits (or in case of programme evaluation, state conclusions with respect to the results).*

## 2.2 Limitations of Cost-Benefit Analysis in Programme Evaluation

The strength of CBA is the simplicity of the final results. CBA aims at representing one figure as a final result: the net value of a project (or a programme). However, this is also the fallacy of the method as it gives a false feeling of accuracy and simplicity. The assumptions used in the analysis should be selected with care and they should be taken into account in interpreting the results.

Traditionally, CBA is used when one actor (a company) wants to make a decision. In a government programme, there are a number of actors involved and the benefits of one actor may be the costs of the other. For example, the creation of new employment opportunities in one company may result in a termination of work in a competitor's company. From a public point of view, these jobs should be summed up to create a view of the net benefits. There are also many indirect benefits that are very hard to estimate. The clear selection of the stakeholders and the definition of the impacts to be included in the analysis are both very crucial steps of the analysis.

The step to transform all the costs and benefits into monetary units is not easy and not even appropriate (e.g., estimating the monetary value of human life). Often, it might be more appropriate to use other commensurate indicators than money, or not to aggregate the costs and benefits (e.g., by using other multicriteria decision making tools).

The quantification of the costs and benefits associated with many uncertainties is always difficult. CBA does not offer any shortcuts. Particularly, in the case of the technology programme, the benefits materialize at a later date and will be measured through their expected values.

The interpretation of the results is not self-evident when CBA is used in the programme evaluation. If the benefits are higher than the costs, the programme can be said to be successful. However, even in this case the analysis does not highlight why this had happened or if some other option would have been more beneficial. Particularly when costs outweigh benefits, CBA does not offer clear answers to why this had happened and what should be done in a different manner in the future. CBA offers an ex-post opportunity to compare a set of actions. In the case of a Tekes technology programme, there is rarely any base for comparison (i.e., whether some other way of using the money would have yielded a better cost-benefit ratio).

The costs of a programme are relatively easy to assess, but the benefits related to *the programme* are less obvious. The main reasons to organize a group of projects into a programme are the benefits re-

lated to the synergy among similar projects, networking effects, and the opportunity to create a critical mass of knowledge. However, all these benefits are very difficult or almost impossible to measure in monetary units. When the analysis is done at project level, i.e., the costs and the benefits are assessed separately for each project, the added value of the programme itself is easily left out from the analysis.

In the case of the KÄKI programme, assumed benefits are related to the improved competitive position of the companies in the market. The analysis of the benefits would require a detailed market analysis for each participating company. However, within the scope of this evaluation, such analysis is not feasible.

There are long time delays between investing in R&D and receiving the benefits. Particularly, Tekes technology programmes are targeted to early phases of product development and to research projects. The economic benefits are dependent on many other factors as well, thus at later, it is difficult to make a separation on what benefits are purely due to the R&D project and what other factors affect as well.

## 2.3 Scope of Cost-Benefit Analysis in Evaluating Competitive Reliability Technology Programme

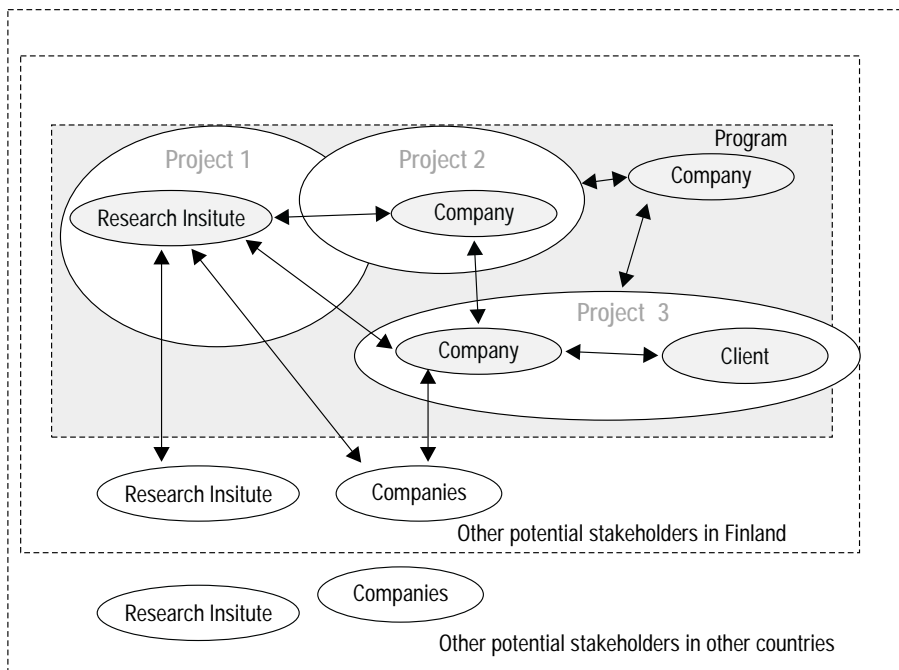
### 2.3.1 Identification of the Stakeholders

Tekes has an overall objective to increase the well being of the Finnish society. Thus, in principle, all the direct and indirect benefits to all possible stakeholders should be incorporated in the programme evaluation. Many of the projects in the programme were research-oriented and the research results most likely will benefit many companies in the future both in Finland and abroad. Also, the clients, sub-contractors, and other partners of the companies that participated in the programme may get some of the benefits. To restrict the scope of the evaluation so that it was feasible to complete with the given resources, the following rules were used to identify the relevant stakeholders:

- *Tekes is a stakeholder* in the sense that the funding provided by Tekes is included in the analysis. However, the costs related to the preparation of the programme before it was started and the costs for Tekes that are not directly targeted to the programme were excluded from the analysis.
- *All the companies, research institutes, and universities that participated in any of the projects included in the programme are the main stakeholders*, whose costs and benefits will be assessed.
- The clients of the participating companies, the users of the research results, and others who did not participate in any of the projects and get only indirect costs or benefits are excluded from the analysis.

Figure 2.1 illustrates the selection of the stakeholders. The definition for a stakeholder to be “somebody who participates in the programme” is clear in principle. However, in practice this distinction is not clear-cut. The ambiguity related to the participation in a project is due to that there is a variety of different structures for the projects where the participants have different roles. For example, the participants provide background information, do actual development work, participate in the piloting, and provide funding. In all of these cases there are no clear economic benefits. The main reason to exclude some of the participants that were initially named was that many companies only followed the progress of the work without any active involvement. They have followed the project only occasionally or have dropped out when they have felt that the project does not respond to their needs. Sub-contractors (buying programming services or equipment) formed another category of project participants. This category of stakeholders was left out from the CBA if the sub-contractor was not clearly benefiting from the content of the programme.

In total, there were 31 projects, which were lead by around 20 separate companies. One should note that most of the participating companies were large and separate units within a company or separate research groups were treated as separate participants. In total, we were able to identify 78 main beneficiaries (participants in the projects who can



**Figure 2.1.** The selection of stakeholders.

be thought of getting some concrete benefits from the programme and who had had some costs) based on the examination of each project and discussions with the project leaders. Of those, 36 were covered by the survey or interviews (see Table 2.1)<sup>2</sup>. It is important to note that although only half of the

beneficiaries were covered, these covered almost all the projects and together clearly cover all the main beneficiaries. Thus, our judgment is that the analysis covers most of the benefits and in conclusions the benefits of these stakeholders is compared against the costs of the entire programme.

**Table 2.1.** Numbers of the beneficiaries in the programme and the number of responses used in the analysis (note: those beneficiaries that were included cover all the main stakeholders and almost all the pro-

	Number of stakeholders identified as potential beneficiaries	Number of potential beneficiaries that were covered in the analysis (covered by the survey or an interview or both)
Research Organizations (or independent research groups)	24	13
Companies (or separate independent units within large companies)	46	23
<b>Total</b>	<b>78</b>	<b>36</b>

<sup>2</sup> One should note that all the respondents did not answer all the questions and so the total number of responses varies in presenting the results.

Although the aim was to estimate the costs and benefits of the entire programme, the main unit for analysis was a single project. This selection of the scope neglects some of the programme benefits and makes it more difficult to estimate the benefits related to the synergy between separate projects. For example, as illustrated in Figure 2.1, a company may participate in the programme but only monitor the work done in separate projects. However, the decision to focus on each project separately was necessary because it is difficult to specify any benefits without discussing it at a project level.

### 2.3.2 Selection of Types of Costs and Benefits

Based on the first review of the projects in the programme, it was decided that the analysis mainly focuses on the direct *economic costs and benefits* that are direct consequences from the project, i.e., the monetary costs and benefits that the project participants can name to be relevant for them.

The costs include 1) the project costs and 2) the near future development costs outside the programme. All costs related to the preparation of the projects and the programme were excluded as well as the general operational costs of the participating companies. Figure 2.2 illustrates the selection of the costs that are included in the CBA.

One major cost category is occurring in cases when the product development is likely to result in new spin-off companies. The commercialization of a new product will result in huge costs compared to the first R&D costs. However, also the resulting benefits may be very large. The costs and benefits related to the new businesses were not automatically included in the CBA, but are discussed in connection with the results.

An earlier survey was used to identify the potential benefits for companies<sup>3</sup>. In that survey, the participants were asked what concrete improvements are likely to result from the project. Table 2.2 classifies all the potential direct benefits based on these answers. Overall, the direct economic benefits of the companies who participated in the programme can be divided into three categories:

- A. Increased sales/revenue resulting from a new product that can be 1) a completely new product, 2) new features in existing product, or 3) a better sales method or argument (competitiveness of products).
- B. Increased competitiveness of the production processes or company operations that can be related to 1) decreased costs or 2) decreased uncertainties (competitiveness of production).
- C. Increased knowledge base that refers to increased skills, which can lead to benefits in the longer run, but at present, it is impossible to identify these benefits clearly.

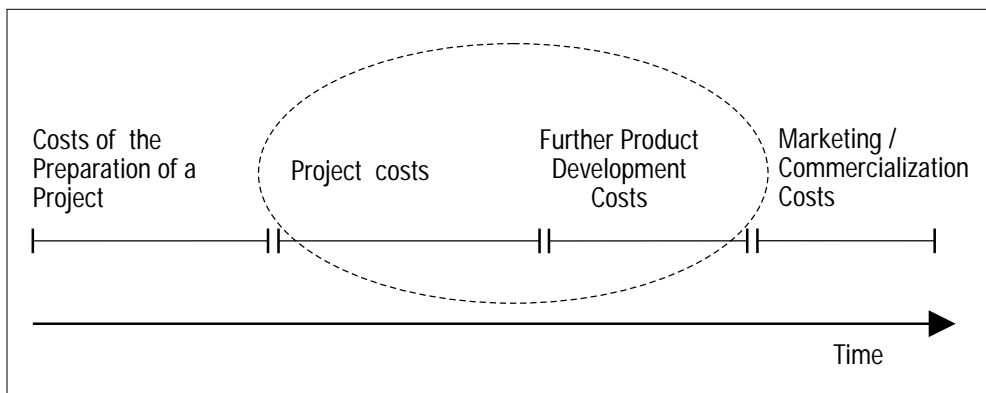


Figure 2.2. The costs related to a project.

<sup>3</sup> The survey was completed as a part of the program coordination activities.

It was decided that the research institutes and universities will be treated in the same way as companies so that the benefits are defined to be mainly economic benefits resulting from the selling of research services and from possible spin-off companies. It was decided that the CBA does not aim at measuring research achievements in monetary terms. The scientific and technical merits of the programme are evaluated in a separate evaluation. The following types of economic benefits were identified to be relevant for the research institutes:

- Research services that can be sold based on separate contracts (including different testing equipment and services related to the use of them)
- Software products
- New technical products

It was decided that the benefits resulting from the sales of products are measured by net profit. From the point of view of Tekes, the increased turnover is often used as a measure for the benefits resulting from the Tekes supported activities. However, increased turnover alone is not commensurable with project costs or lowering operating cost. Thus, the participants were asked to specify the approximate operating margin and that was used to calculate the net profit. In this way, the costs and the economic benefits can be compared with each other (i.e., the economic benefits can be thought of as a future profit that is used to cover the costs of the project). However, also the estimates of the increased turnover are reported.

**Table 2.2.** The categories of different economic benefits that the participating companies may get from the program.

<b>A. The competitiveness of products (increased sales/turnover )</b>	
Completely new product	A completely new technical product or innovation
	A completely new software product
	A completely new service product (e.g., consulting or maintenance services)
Value added to an existing product	The improvement of an existing technical product/replacement (with a more/or as reliable one, yet cheaper)
	The improvement of an existing software product (e.g., creating an additional feature)
	The improvement of a service product (e.g., better planning of a maintenance system)
	A service, guarantee or a warranty additionally sold with an existing product
	An added feature (e.g., data collection) to an existing product
	A new consulting product/research service combined with the product
Improved sales	A new argument for sales, e.g., better knowledge on the product's reliability
	Tools for sales, marketing etc.
	Enhanced image and customer satisfaction

Table 2.2. continues

<b>B. The competitiveness of production or operations (cost savings/improved margin)</b>	
The lowering of costs/expenses	Decrease in maintenance and repair costs in own production (primary expenses)
	The increase of operational reliability of own production (generally expenses decrease due to, e.g., fewer stoppages )
	The improved locating of faultiness or the improved targeting of maintenance (e.g., the costs of the sold maintenance service decrease)
	A saving in the storage costs of maintenance
	A tool or a technique for product development (an improved efficiency in planning e.g. the product launched faster into the marketplace)
	Instructions or processes applied to ones operations have improved
	A cost cutting tool for sales, marketing etc.
The reduction of uncertainty	A more precise budgeting
	Monitoring operational reliability (a more precise knowledge of it)
<b>C. The increase in intellectual capital (the actual gains will materialize at a later date and only through further measures)</b>	
Increased knowledge	Data collection software or equipment
	Information for product planning
	The requirements in operational reliability regarding purchases
	A more precise calculation of profitability in investments (the expenses over the whole life-span)
	Knowledge to create concrete further development plans
	The increase of the organization's general know-how.

One should note that all the benefits in the future include a lot of uncertainty. In principle, one should assess the probabilities related to the benefits. Some of the uncertainties were asked from the beneficiaries and will be reported, but mainly the given future economic benefits were treated as the expected monetary amounts (i.e., the average expectations).

Although the analysis focused on the economic benefits, two other types of benefits were covered qualitatively. First, the beneficiaries were offered a chance to indicate some non-monetary benefits in the survey that they felt to be important. These benefits included items related to, e.g., employment, environment, and awareness rising. Second, the added value of the programme was assessed separately.

### 2.3.3 Time Frame and Discounting Parameters

The KÄKI programme started in 1996 and the preparation work had started around 1995. The project costs started to run from the year 1996, and thus the analysis looks back for five years. It was decided that the analysis would look ahead until the year 2006. Some of the benefits certainly materialize also later, but for a longer time period there is likely to be other factors besides the work done in this programme that affect the benefits. Because of discounting, the value of the later benefits is also less significant.

The base case analysis used 5% discounting rate. However, the sensitivity of the results with respect to the discounting rate was studied as well. The unit of money is the FIM of the year 2001. Although the final results are presented with the present value, the yearly totals will be listed as well.

### 2.3.4 Information Collection

Information on the programme costs was received directly from Tekes (total costs of the programme for each year). Possible costs that may occur in the future as a direct follow-up of the project were asked in the survey.

Two separate surveys were designed, one for research institutes and universities and one for companies. The surveys covered all issues that were needed to assess the costs and benefits as described in the section 2.3.2. The questions that were included in the survey that was sent to the companies are presented in Annex A (In Finnish).

The surveys were sent to 69 project participants<sup>4</sup>. Some of them replied that the survey was not relevant to them or they returned only partially filled surveys. A set of interviews was done with the project leaders to cover all the missing information that was not covered in the survey and also to provide the project leaders an opportunity to give feedback on issues that were not asked in the survey. These interviews were also used to identify the total number of beneficiaries to be 78.

## 3 Evaluation Results

### 3.1 Costs of the Programme

As described in Chapter 2, the direct project and programme costs as well as the immediate project costs following the project are included in the cost estimation. The project cost information per year was received directly from Tekes and is presented in Table 3.1. The presented costs are based on the funding decisions made by Tekes and thus appear earlier than the costs actually realized. This also explains some of the year to year fluctuations. One should also note that one research institute which is operating as a company is classified as a company in Tekes's book keeping but treated otherwise as a research organization in the analysis.

The funding sources can be divided into two classes. First is the funding from Tekes that can be given either as a grant or a loan. Tekes funding covers 47 % of the total costs (based on the costs reported to Tekes). The participating companies and research organizations have funded the remaining 53 % of the total costs of the projects. The total costs of the individual projects vary significantly. Based on the information reported by the companies themselves, the biggest project accounted for 6,92 million FIM and the smallest for 190 000 FIM. On average, the costs of one project (31 all together) were 1,97 million FIM. Also the part of the costs covered by public funding varies and is between 25% and 95 % in the methodology projects and between 0 and 50 % in the product development projects.

One should note that the total costs of the programme differ from those reported in the programme final report (total expenditure 71,8 million FIM in the final report compared to 60,94 million FIM reported in Table 3.1). There is one project that was funded 100% by a company and thus it is not included in the numbers reported by Tekes<sup>5</sup>. However, this covers only a minor part of the difference between these figures (only 300 000 FIM). The estimate of the total costs in the final report is based on the costs that the companies re-

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<sup>4</sup> Tekes organized the collection of the contact information and mailed the survey.

**Table 3.1.** The costs of the programme (the project costs, million FIM).

	1995	1996	1997	1998	1999	2000	Total
Research organizations	2.30	2.42	0.00	7.91	4.65	3.53	20.81
Companies	7.76	2.46	17.97	4.20	6.25	1.49	40.13
Total	10.06	4.88	17.97	12.11	10.91	5.01	60.94

**Table 3.2.** Immediate future costs related to the projects (in 1000 FIM).

Further costs related to the projects	1996	1997	1998	1999	2000	2001	2002	2003–2006 (average per year)
in research organizations	0	0	0	240	2235	2206	1050	100
in companies	0	0	500	600	1340	3502	2832	1675
Total	0	0	500	840	3575	5708	3882	1775

ported directly to the programme coordinator, while the figures provided by Tekes are based on the real funding decisions. Based on the interviews, it seems that the companies and research organizations included in their estimates also additional costs that were not strictly project costs and were not related to funding by Tekes. In this evaluation, it was not possible to make a detailed analysis of the nature of the project costs included in the estimates given by the companies. Thus, the costs as they were reported to Tekes were used as a basis for the analysis because their distribution over time was known. However, one should keep in mind that the costs of the programme might be underestimated.

Many of the projects had direct follow-ups and further investments are needed before the benefits materialize. Thus, information about the near future costs was collected in the survey and in the interviews with the project leaders. These immediate follow-up costs are presented in Table 3.2. Over the used time period, the sum of cash flows of immediate follow-up development costs is 21,6 million FIM. One should note that these costs reported

by the companies may include some of the costs that the companies reported to the programme coordinator as project costs, which would explain the difference in total programme costs.

One should note that the follow-up costs reported for the future are estimates and include uncertainty. The uncertainties related to these costs are not studied in this project. It should be noted that the estimated costs include only direct follow-up work and exclude, e.g., commercialization costs. The costs related to a new spin-off company were excluded from the above table. The analysis to cover those costs would require a more detailed analysis for each case.

### 3.2 Economic Benefits Resulting from the Programme

The economic benefits were analyzed based on the survey and the interviews. The benefits that are difficult to evaluate in economic terms are analyzed separately in Chapter 3.4. This section firstly presents an overview of the benefits for research orga-

5 This project was also excluded from the detailed benefit analysis because it appeared to be almost impossible to find out which part of the company activities can be attributed to the KÄKI programme activities.

nizations (section 3.2.1) and secondly the benefits for companies (section 3.2.2).

### 3.2.1 Economic Benefits for Research Organizations

Economic benefits for the research organizations consist of new knowledge that can be sold as a research service, and different kinds of software and technical products. The numbers of different kinds of products developed in the research institutes are presented in Table 3.3. Majority of the new products reported in the research institutes consists of new research capabilities.

All the new research services are already in the market (from year 2000). However, most of the software and technical products need further development and it takes some time before they are in the market. An estimate for the additional sales generated by these services and products, and the corresponding operating margins are presented in Table 3.4. In total over the years, the cash flow of additional estimated operating margin is 11,6 million FIM.

One problem in estimating these figures is that it is difficult to separate the effect of an individual project from numerous projects over the same re-

**Table 3.3.** Types of products developed in the research organizations.

Type of product	Number of responses
Research service	8
Software	4
Technical equipment	2

**Table 3.4.** Additional sales and operating margins for research organizations resulting from the projects.

	1996	1997	1998	1999	2000	2001	2002	2003–6
Additional sales x 1000 FIM	0	0	0	700	1820	2395	14625	14450
Operational margin x 1000 FIM	0	0	0	90	313	421	2188	2170
Number of responses				5	7	8	10	10

search area. Also, a lot of same people have participated in different projects within the KÄKI programme. In discussions with the project leaders, it was checked that the increased capabilities to sell research services are not double counted when the analysis is done for each project.

In a few cases, a research project has resulted in a significant new innovation which will be further developed into a commercial product (in a new spin off company). In one case, the development work is far enough so that some estimates of both costs and benefits were given (this explains the sharp increase in sales after year 2002 in Table 3.4). However, the success of a start-up company is very uncertain. In most cases, potential economic benefits can be large as well as the costs of establishing a new company. The result that new potential innovations have emerged from the programme is a benefit as such, but in this evaluation they are not estimated in detail. A more detailed study of each of the cases should be carried out in order to estimate the risks and potential benefits.

### 3.2.2 Economic Benefits for Companies

The company representatives were first asked to name the types of benefits resulting from the project based on the list of benefits in Table 2.2. The numbers of different types of benefits that were selected are presented in Table 3.5. The resulting benefits cover all the three categories (A, B, and C). Each category was further surveyed separately. The economic benefits related to new and improved products (category A) and to improvements in production (category B) are analyzed in this section. The benefits related to intellectual capital (category C) are analyzed in Section 3.4.

**Table 3.5.** Number of respondents that selected each type of benefits for companies (note: each respondent was able to select more than one benefit).

<b>A. The competitiveness of a product (increased sales/turnover )</b>		
<b>Completely new product</b>		
	A completely new technical product or innovation	0
	A completely new software product	1
	A completely new service product (e.g., consulting or maintenance services)	3
<b>Value added to the existing product</b>		
	The improvement of an existing technical product/replacement (with a more/or as reliable one, yet cheaper)	7
	The improvement of an existing software product (e.g., creating an additional feature)	2
	The improvement of a service product (e.g., better planning of a maintenance system)	4
	A service, guarantee or a warranty additionally sold with an existing product	6
	An added feature (e.g., data collection) to an existing product	6
	A new consulting product/research service combined with the product	4
<b>Improved sales</b>		
	A new argument for sales, e.g., better knowledge on the product's reliability	7
	Tools for sales, marketing etc.	5
	Enhanced image and customer satisfaction	10
<b>B. The competitiveness of ones production or operation (cost savings/improved margin)</b>		
<b>The lowering of costs/expenses</b>		
	Decrease in maintenance and repair costs in own production (primary expenses)	6
	The increase of operational reliability of own production (generally expenses decrease due to. e.g., fewer stoppages)	6
	The improved locating of faultiness or the improved targeting of maintenance (e.g., the costs of the sold maintenance service decrease)	5
	A saving in the stocktaking of maintenance	0
	A tool or a technique for product development (an improved efficiency in planning e.g. the product launched faster into the marketplace)	5
	Instructions or processes applied to ones operations have improved	6
	A cost cutting tool for sales, marketing etc.	0

Table 3.5. continues

<b>The reduction of uncertainty</b>		
	A more precise budgeting	1
	Monitoring operational reliability (a more precise knowledge of it)	12
<b>C. The increase in intellectual capital (the actual gains will materialize at a later date and only through further measures)</b>		
Increased know-how/knowledge		
	Data collection software or equipment	9
	Information for product planning	11
	The requirements in operational reliability regarding purchases	7
	A more precise calculation of profitability in investments (the expenses over the whole life-span)	7
	Knowledge to create concrete further development plans	10
	The increase of the organization's general know-how.	13

Table 3.6 presents the expected additional sales generated by the products developed in the projects, category A, and the respective additional operating margins. Over the years 2000–2002 the expected increase in sales is about 30 million FIM per year. The figures indicate that the expected additional sales will be higher in the coming years. Between the years 2003 and 2006 the expected increase in sales is 50 million FIM per year.

It is important to note that a few products cover most of the expected sales. Only in 6 out of the 13 cases where these kinds of benefits were reported, an estimate for the additional sales was given. The number of answers and discussions during the interviews clearly indicated that it is difficult to estimate the additional sales generated by this type of new products, new features or new sales arguments. The main problem is that many of the projects contributed to additional new features that make an existing product more competitive. Also, it is very difficult to estimate the effect that the specific project or even better reliability in general has on the sales of a complex product like, for example, a paper machine. One project in electronics in-

dustry was excluded from the CBA because of this. Even small improvements in the reliability of a mass product (or in the production of mass products) may have huge benefits, but in this case it was impossible to specify within the scope of this evaluation which of the future benefits are due to the KÄKI project.

Most of those who were able to estimate the additional sales, already had their product in the market. For 5 out of the 12 respondents, the product or an improvement is not yet in the market. The estimated time required for the further development ranges from 0,5 to 1 years (only three responses). The product development also includes uncertainties, but the probability of success (achieving the benefits) is 80% or higher in all of the 6 cases where this was stated. It seems that the products and product improvements are tied to the existing technology and the product development projects do not include very high risk. The costs of further developing the products are reported in section 3.1. These costs include only the costs that are directly connected to the product, e.g., the marketing costs are excluded.

**Table 3.6.** Additional sales and operating margins for the companies.

	1996	1997	1998	1999	2000	2001	2002	2003-6
Additional sales x 1000 FIM	0	0	0	15000	30020	31600	33600	50700
Operational margin x 1000 FIM	0	0	0	3000	6002	6270	6620	8820
Number of responses				2	3	5	5	5

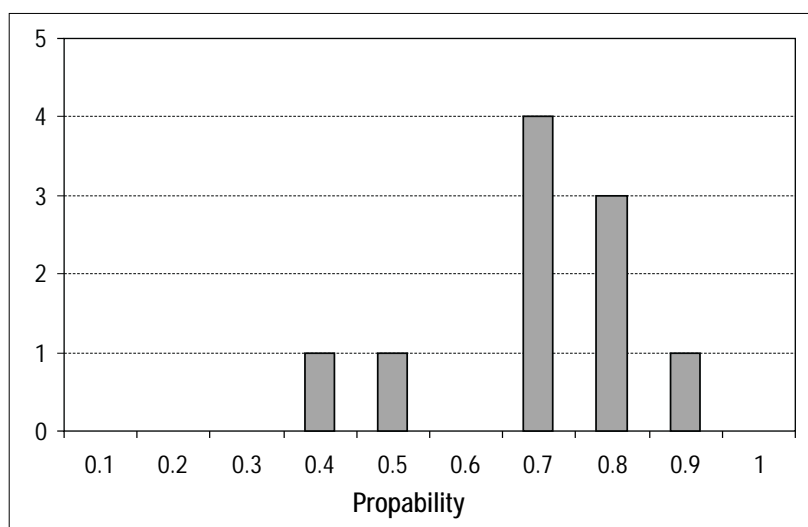
**Table 3.7.** Cost savings for the companies resulting from the projects.

	1996	1997	1998	1999	2000	2001	2002	2003-6
Cost savings x 1000 FIM	0	0	0	200	1410	1770	3420	5700
Number of responses				4	8	8	8	8

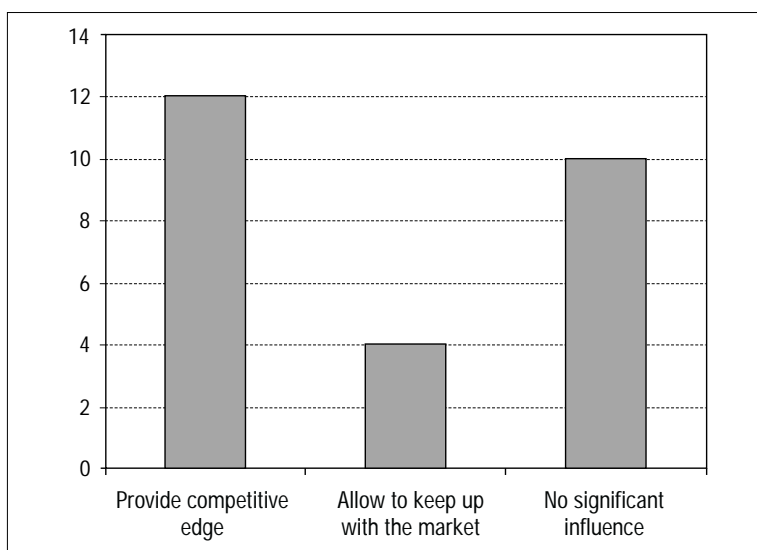
To further analyze the benefits reported in part B of Table 3.5, questions about the cost savings generated by the projects were stated. Table 3.7 presents the expected cost savings generated by the projects. Total cash flows over the years are 29,6 million FIM. Some of the interviewees highlighted that in a very tight competitive situation, the savings in production costs are very quickly absorbed into lower prices and in that way a net saving is very quickly eaten out. In the case of developing

new products, new market share may be gained and this has a more durable impact.

With the expected savings, 10 out of the 12 responses highlighted that further development is required and this work includes significant uncertainty. On average, the estimated time required for the further development is 1,7 years. The estimated probabilities for the success of the development work are shown in Figure 3.1.



**Figure 3.1.** The number of different estimated probabilities of success and further continuation of gained development from the companies' point of view (cost savings on the production etc.) (Total number of responses is 10).



**Figure 3.2.** The number of different effects of the projects on the competitiveness of the companies (Total number of responses is 26).

The respondents were also asked to judge how the benefits from the projects, i.e., product improvements and the cost savings, affect the competitiveness of the company or of the products. They were offered three choices: 1) the project clearly affected the competitiveness and helped to gain new market share, 2) the project helped to keep up with the competitors, and 3) the project did not have any effect on the competitiveness of the company. Figure 3.2 shows that in almost half of the answers, the effect of the new products and cost savings is estimated to give a competitive edge and provide a potential to increase the market share. However, almost equally many evaluated that the effects are insignificant.

### 3.3 Summary of Economic Costs and Benefits

This section summarizes the results concerning costs and economic benefits, thus presents the main results of the CBA. To be able to compare costs and benefits the time value of money has to be accounted. For this purpose present (2001) values of each of the reported or estimated cash flows were calculated by using a 5% interest rate.

First, the net present value of the total yearly cash flows of costs as they were reported to Tekes is *72,9 million FIM*. The net present value of the reported follow-up costs of further developing the results of the projects is *20,6 million FIM* correspondingly. The total costs of the programme and the further product development (either already realized or expected to be realized in the near future) in the net present value are thus in *total 93,5 million FIM*. The programme preparation costs and commercialization costs of the products are excluded.

Second, the present value of the total expected additional sales (both research organizations and companies) is about 350 million FIM and the present value of total additional operating margin is *62 million FIM*. Correspondingly, the cash flows of the reported cost savings create a present value of *26 million FIM*. This is comparable to the operational margin before depreciation so that the figures can be summed up to *88 million FIM*.

To analyze the sensitivity of the results with respect to the changes in the discounting rate, the rate varied between 3% and 9%. The present values of the costs and benefits using different interest rates are presented in Table 3.8. One can speculate

**Table 3.8.** Present values (2001) of costs, sales, and operating margin and cost savings using different interest rates (million FIM).

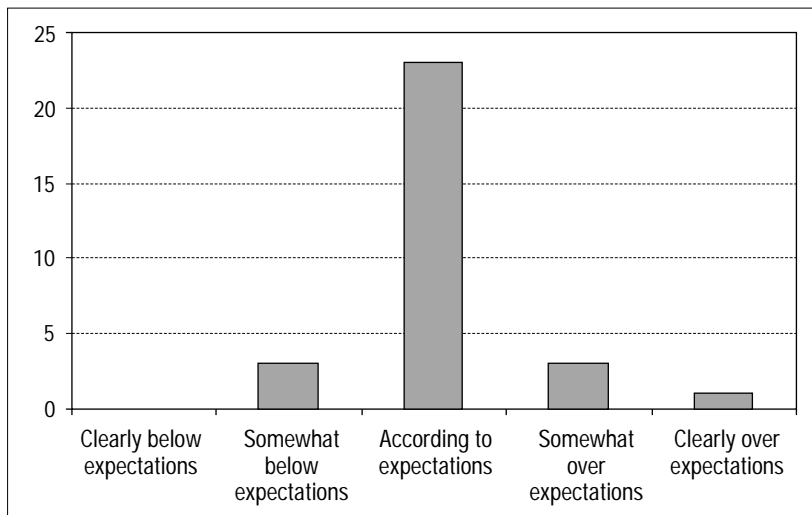
	9%	7%	5%	3%
Costs	104	99	94	89
Additional sales	325	337	351	365
Additional operating margins and cost savings together	82	85	88	92

which is the right level of discounting in these kinds of projects. The lower the discounting rate, the more value is given to benefits in the future. In principle the projects are applied science or risky R&D projects, so the discounting rate should be relatively high from a company’s point of view. However, in principle the partly public funded projects should bear more risk, thus a lower discounting rate is justified. With the base case of 5%, the economic benefits from the programme are still less than the programme costs. One should remember that from a company’s point of view, grants from Tekes could be excluded from this analysis and in that case one could result in higher benefits than costs.

The way in which the time is treated in the analysis is essential. In the above, the past costs are treated as they would occur now (past costs are higher in

the present value). However, one can as well discount the cash flows so that the time when the programme was started is used as a present time. This will change the actual numbers and the net value of the costs of the programme between the time period 1995–2006 are 70 million FIM in the year 1995 value and the benefits are 66 million FIM (with the 5% discounting rate). Though, the ratio of benefits and costs remains unchanged.

To compare the results with the expectations of the participants, it was also asked whether the additional sales or the resulting savings corresponded with the expectations. Most of the respondents both in research organizations and companies indicated that the results were according to their expectations (see Figure 3.3). Only in a few cases the additional sales exceeded or were below the expected.



**Figure 3.3.** Number of different opinions on how the benefits from the project reflected the expectations (Total number of responses 30).

### 3.4 Non-monetary Benefits Resulting from the Programme

In the survey, the respondents were also asked about the benefits that are difficult to assess in monetary terms. First, the benefits related to the increased intellectual capital are covered. The respondents were asked some details of what type of increased knowledge base primarily resulted from the projects and what might be the resulting benefits in the future (i.e., the benefits that cannot be measured in monetary terms now but perhaps in the future).

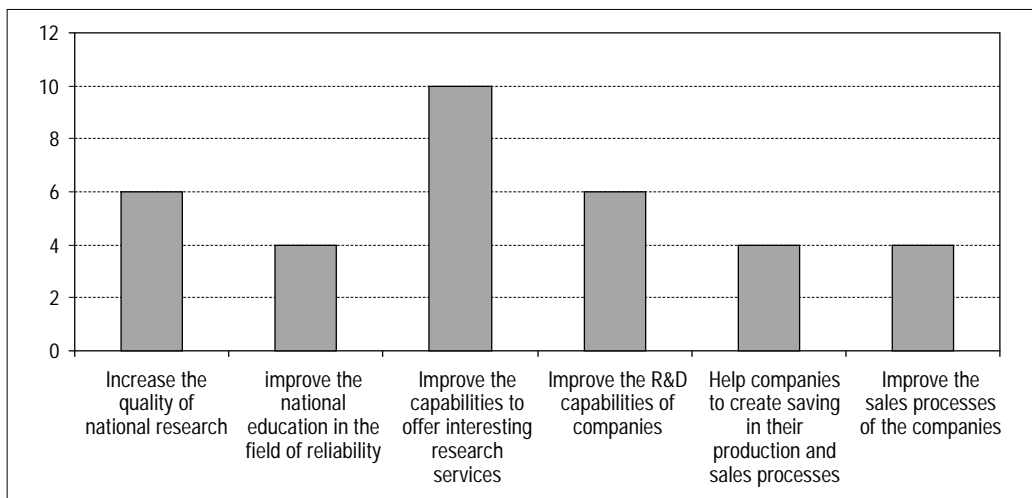
The research organizations were offered a multiple choice to indicate what they saw as the main role of the new knowledge generated in the programme. Figure 3.4 presents the responses. The organizations clearly see the better capability to serve the customers as the most important future benefit resulting from the increased knowledge. The other possible responses gathered a relatively even number of responses.

The company representatives were asked along three categories about the role of the increased knowledge. The categories were 1) to improve products and R&D processes, 2) to gain cost savings, and 3) to help in sales and marketing. All the

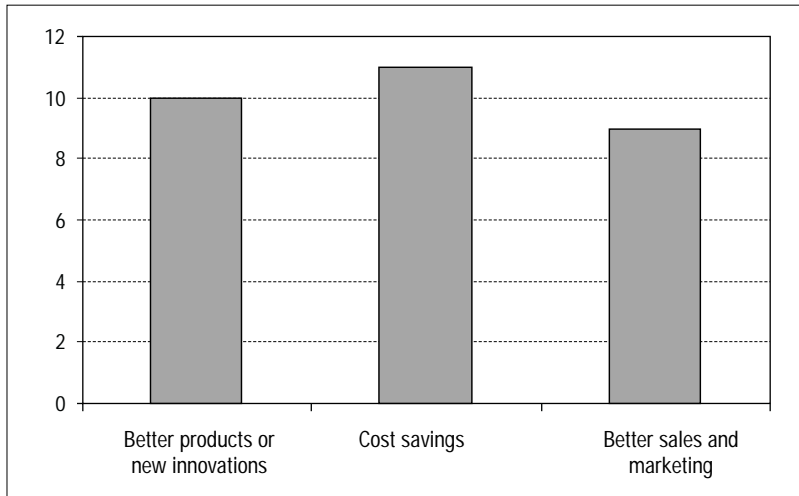
categories gathered a relatively even number of responses and the answers are in line with the benefits that were reported in part C of Table 3.5, but they materialize over a longer term.

To map the amount of intellectual capital, also questions concerning the number of people trained and involved in the projects were asked. It was estimated that altogether 220 persons in companies and research institutes have acquired new skills or knowledge that can be used for further development of the ideas needed to realize the benefits in the future. The research institutes instructed 130 persons outside their own organization about the knowledge developed in the project. Also, a question related to employment was asked. The companies and research institutes reported 14,5 new permanent positions. However, one should look at this number with caution. This was a question where most of the interviewees argued that mostly the types of improvements that the projects dealt with are more likely decreasing the employment in the participating companies. The indirect effects to other stakeholders most likely also result in a decrease in work opportunities.

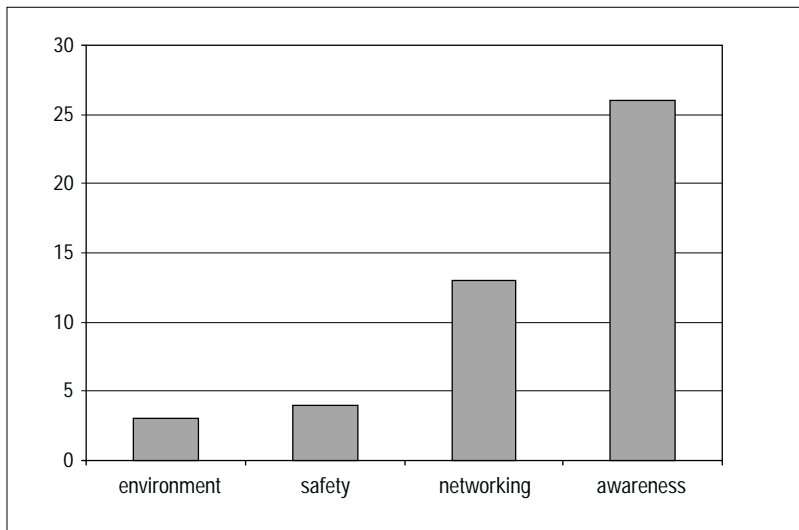
The respondents were also asked about other types of benefits than ones related to economic or intellectual capital. In most of the cases (in 25 out of 31



**Figure 3.4.** Number of different future benefits from the increased knowledge (opinions of research organizations) (Total number of responses is 34, it was possible to name several benefits).



**Figure 3.5.** Number of different future benefits resulting from the increased knowledge (opinions of companies) (Total number of responses is 30, it was possible to name several benefits).



**Figure 3.6.** Number of different other benefits indicated to result from the projects (Total number of responses is 46, it was possible to name several benefits).

answers), the answers show that also these benefits are estimated to be significant. Most important other benefits consequently are networking and the increased awareness of future questions related to the reliability (see Figure 3.6). It is likely that this awareness would have also been acquired without the programme, but the programme as a whole gave an important impulse for many companies to think

reliability issues. Safety and the reduction of environmental risks are estimated to be relevant potential benefits only in a few cases. However, many of the interviewees noted that these types of benefits may be relevant indirectly to other parties like the customers of those who participated in the programme.

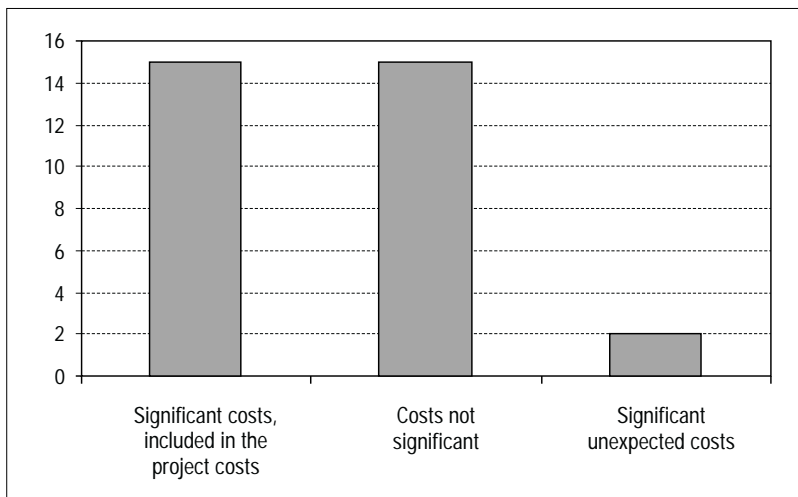
### 3.5 Added Value of the Programme

The costs and benefits were assessed separately for each project. However, a part of the survey focused on the added value of the programme itself. The main question was that what is the advantage of organizing a set of projects as a programme instead of having them separately.

In this programme, the companies also paid a part of the programme coordination costs. The additional costs of organizing the projects as a programme (costs of the co-ordination project M0) were 3 million FIM (already included in the costs presented in Table 3.1) of which the participating companies and research institutes themselves paid 51%. In addition to that, one should note that participation in the programme is not free. Communication that is organized as a part of the programme and the reporting required by the programme may be extensive (including the activities related to the evaluation process.) In the survey, the respondents were asked for their opinion on the costs caused by the programme activities – whether they were significant and whether they should be separately included in the CBA. The costs caused for the partic-

ipants by the programme activities (seminars, steering committees etc.) were evaluated in 30 out of the 32 responses either to be insignificant or that the costs were already included in the project budget (see Figure 3.7). In two cases where the costs were estimated to be significant, they were minor in any case compared to overall costs and were left out from the analysis<sup>6</sup>. There is no difference in opinions between research organizations and companies.

In order to evaluate the role of the programme, the beneficiaries were first asked which factors have been important for the completion of a project. The respondents used a scale where “insignificant” on the one end meant that the same results in the same time would have been achieved even without the factor. “Very significant” indicated that without the factor in question the project would not have been completed. Figure 3.8 presents the responses to these questions. The most relevant factors have been the funding from Tekes and the co-operation between companies and research institutions. These are the factors that were most often essential for the completion of the work (“very significant”). Neither of these factors is directly related to



**Figure 3.7.** The opinion of the respondents about the significance of the costs related to the participation in the program (seminars, reporting etc.) (Total number of responses is 32).

<sup>6</sup> One respondent complained that the participation in the overall coordination costs came as a surprise to the company.

the programme activities. However, also the networking and communication organized in the KÄKI programme and company-with-company and research institute-with-research institute co-operation were considered significant. There are only a few responses where these factors had been very significant in a way that without them the project could not have been completed. One should note that very few named any of these factors completely insignificant in order to complete the project.

After this question, the respondents were asked details of whether a project would have ended with the same results without the programme (assuming same funding, objectives and participants, but no programme activities). 27 out from 33 respondents felt that the project was more successful because it was organized as a part of the programme compared to a situation where it would have been an independent Tekes project. The remaining 6 responses indicated cases where the respondents felt that the project would have essentially been the same also without the programme.

Those who felt that the programme had an added value, also indicated the main benefits that were due to the programme (see Table 3.9). The main

contribution of the programme was the information dissemination that helped to increase the knowledge in the organization. The same type of added value is also the participation of research institutes that brought in new knowledge. These results are in line with the analysis of the non-monetary benefits where the role of the projects in increasing the awareness over the reliability was considered to be the most important non-monetary benefit.

In addition to these factors that were included in the survey, some additional issues came up during the interviews indicating the added value of the programme.

- The programme creates a better commitment towards completing the project. First, the companies can benchmark their progress against the other projects in the programme and, second, the programme coordination activities provide support and monitor the progress of the projects during the programme.
- Within a programme, bigger research projects can be initiated (or more of the same type of smaller research projects that have synergy with each other). One interviewee noted that the researchers have more ambition and seriousness

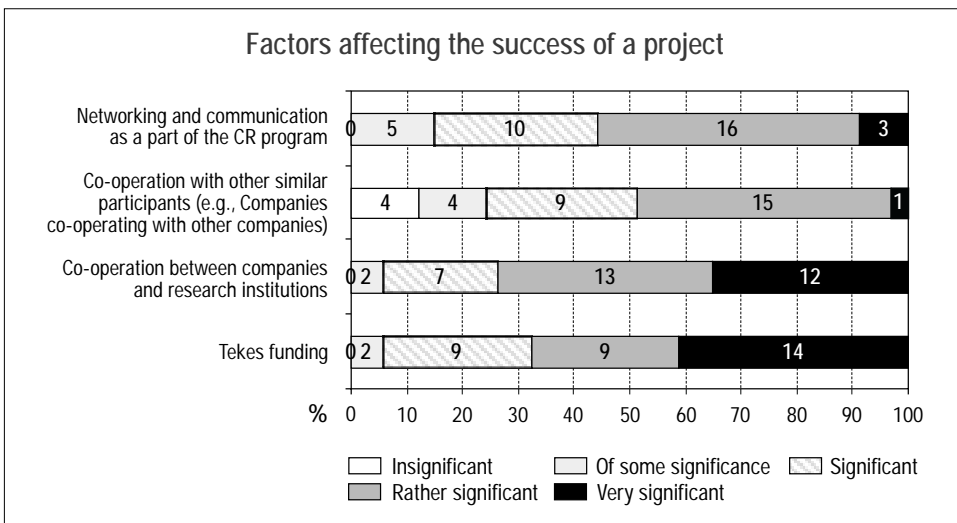


Figure 3.8. The importance of some of the factors affecting the success of the project.

**Table 3.9.** The number of respondents who selected different factors indicating the added value of the programme (each respondent was able to select more than one factor).

Dissemination of information as a part of the programme essentially increased the knowledge in the organization.	19
Participating research institutes brought in new knowledge	17
New co-operation partners were found due to the programme activities (beyond the project and the program activities)	13
The programme helped to plan the follow-up activities.	13
The programme helped to find new development ideas outside the project that will lead to further development projects.	13
As a part of the programme, new solutions were found beyond the project work.	10
The programme helped to get in contact with the co-operation partners that were not known when the project was designed.	9

towards the projects that are a part of a larger programme.

- Within companies, it is easier to get acceptance for a Tekes project that is a part of a technology programme.
- The participation in a technology programme is good for the image of the company, the publicity value of the programme is good.
- The programme created an opportunity to compare experiences and problems related to reliability over different industrial sectors.

Although it was asked, the interviews and surveys did not reveal any information on that the programme would have done any harm (i.e., reduced the benefits). As described earlier, the costs of the programme were not considered to be overwhelming for companies although most often the participant recognized these extra costs. The used governance model where the programme coordination costs were partly paid by the companies was considered to be good (those companies that closely participated in the steering group work of the programme paid together 51% of the coordination costs, together about 1,5 million FIM). At least for that amount, the companies had a feeling that they had received value for money and better access to all the information that flows within the programme. In light of these results, one could argue

that the program coordination costs could even be completely paid by the companies. However, this question was not further analyzed in a way that the participants would have been asked how much they are willing to pay of the programme coordination costs.

### 3.6 The Experiences of Using CBA in Programme Evaluation

Overall CBA worked reasonably well for evaluating the direct economic costs and benefits resulting from the programme. The main bottleneck is in collecting the necessary quantitative information for the analysis. Some respondents did not answer the questions concerning the future costs, sales, and cost savings. Some of them felt that the information is too confidential, but most of them were able to provide some estimates during the interviews after discussing the details. With respect to the information collection, it was necessary to do both the survey and as many interviews as possible. This makes the evaluation itself heavy and expensive. Most of the necessary information could have been collected as a part of the reporting related to the programme coordination, but this would have required a decision in the beginning of

the programme that the evaluation will be done by using a method such as CBA.

It was also surprisingly difficult to identify the participants of the projects and the potential beneficiaries. Projects are organized in many complex ways and in the future a deeper look should be taken at the dynamics within a project and the interactions among different stakeholders in a programme. During an earlier phase of the programme, the project leaders were asked to list all the participants in each project. Based on that listing, the programme seemed to have 110 different participating organizations (some of them in a same company or a research institute, but a different unit). However, when the concrete contact information was sought for, the project leaders were able to define about 60 relevant participating units (the survey was sent to them). After detailed discussions during the interviews, 78 participants were identified to satisfy the definitions of a beneficiary.

After reviewing the programme activities, it was decided that this evaluation should focus on direct economic costs and benefits. The added value of the programme itself and the increased knowledge were evaluated only qualitatively. This evaluation did not take the challenging step towards trying to find a common unit to also incorporate these benefits in a quantitative analysis (e.g., by using multi-criteria decision making methods). Although it was appropriate to focus on economic costs and benefits with this programme, it should be noted that some other technology programmes would require a more throughout treatment of other impacts, such as societal and environmental consequences. In these cases, CBA may not be the best approach.

The CBA of the KÄKI programme revealed that the economic costs slightly overweigh the benefits. The question remains how this piece of information is used. The information produced by the CBA may be the most useful for companies who are used to think in terms of CBA in evaluating their choices. This was also an issue that the steering group members highlighted when they were asked about their expectations with respect to the evaluation. Today it is ever more important to justify the potential benefits of early phase R&D pro-

jects. A positive result where the direct benefits from the Tekes projects overweigh the costs may help a company to initiate next time a similar project. However, the interpretation of the results from the point of view of Tekes needs some further thinking. The main bottleneck is that appropriate reference points that would reveal interesting information are missing. Would there have been more benefits if the Tekes funding had been used in some other way? What would have been the benefits of these projects if they had not been organized as a programme? Were the benefits and costs resulting from this programme smaller or larger than benefits and costs typically resulting from Tekes technology programmes?

## 4 Conclusions

With the used 5 % discounting rate, the direct economic costs related to the programme in the net present value were estimated to be 94 million FIM (the sum of cash flows over the years is 83 million FIM). The programme preparation costs and commercialization costs of the products are excluded. The present value of the total expected additional sales (both in research organizations and companies) is about 350 million FIM (the sum of cash flows over the years is 390 million FIM). Further, the present values of the total additional operating margins and the cost savings created by the projects sum up to 88 million FIM (the sum of cash flows of the operating margins and cost savings over the years is 98 million FIM). In addition to these costs and benefits, the programme resulted in a few new innovations that may lead to new spin-off companies.

The role of the long duration of the programme needs to be taken into account in the analysis and affects the results. The above results show that without discounting the cash flows of benefits overweigh the costs. Though, when the time value of money is taken into consideration, the future benefits are treated as less valuable and the past costs as more expensive. This means that the programme costs overweigh the benefits when the discount rate is increased.

One interesting way to analyze the information is to calculate the net values, as it would be a moment to think whether the programme should be started. Although this does not change the ratio of costs and benefits, the actual numbers change. The costs of the programme between the time period 1995–2006 are 70 million FIM in the year 1995 value and the benefits are 66 million FIM (with the 5% discounting rate).

One important aspect is that from a company point of view, the public funding could be excluded from the analysis resulting overall about 30% less costs. Thus, from the companies' point of view the programme is clearly profitable.

The interpretation of these results is challenging. The main objective set for the programme in the beginning was that it should enhance the competitiveness of Finnish industry by means of developing techniques, methods, and tools for a better control over the product and production system reliability. The direct economic costs and benefits that were used here to measure the success of the programme show that clear competitive edge in economic terms is not yet achieved. However, one important aspect is that in the case of R&D focused projects, the benefits materialize over a longer time perspective and it might be of interest to repeat the analysis after some time. The problem here is however to separate the benefits resulting from the programme from the benefits caused by other activities.

Despite of the decision to use CBA in the evaluation, it did not attempt to transform all the benefits into monetary terms. It was felt to be still more appropriate to cover some of the aspect qualitatively. The most important other benefits resulting from the programme were assessed to be the increased awareness over the reliability in the participating companies and increased national knowledge. The

participants did not consider environment, safety, and employment related impacts to be remarkable.

CBA does not directly offer good tools for analyzing the added value of the programme itself. Based on a separate analysis, the added value of the programme was considered to be significant in a way that most of the projects would not have been equally successful without the programme. There was satisfaction with the quality of the extensive research done within the project and the governance model used in the programme. The project coordination was organized as a separate project of which the participants paid part of the costs. The participants felt that this was a good model and at least in this programme, they might have been willing together to cover all the coordination costs.

CBA was quite suitable method for collecting information related to the KÄKI programme. The main bottleneck in taking the analysis further is that there was no material for any comparison with other Tekes activities. It is not known whether this programme exceeded the benefits that typically result from Tekes technology programmes. To think about the use of CBA further, more analysis should be made by looking at different types of programmes and sets of different projects. Also, the analysis could be repeated over different times in the programme life cycle, i.e., before the programme is started, immediately after finishing it, and after some time.

However, the CBA did not help to address all the necessary questions in the programme evaluation. Technology programmes have very complex impacts and all of them should not be aggregated nor can be reliably quantitatively assessed. In the light of this evaluation, the CBA covers one dimension of the evaluation and works well when it is combined with other approaches.

# Scientific Evaluation

*Ward O. Winer*

## 1 Introduction

This evaluation report is to assess the scientific merits of the competitive reliability technology programme financed by the National Technology Agency of Finland (Tekes) and organized by the Technical Research Center of Finland (VTT) during the period 1996–2000. The programme was carried out by the Technical Research Center of Finland (VTT), Helsinki University of Technology, the Institute of Occupational Health, the Finnish Pulp and Paper Research Institute, and twenty-five companies from related industries. The evaluation is based on the review of two drafts of the final report, several English language publications (including student theses, annual symposia, reports of the programme, and open literature publications) and two days of interviews (March 12–13, 2001) with the principal investigators of the projects in the programme. The objective of the programme was to enhance the competitiveness of Finnish industry through improved reliability and availability of their products.

The organizational structure of the programme was well suited to achieve the programme goals. A central core of engineering science and human factors was provided by projects at VTT, Helsinki University of Technology (HUT), and the Institute for Occupational Health. This central core collaborated with four industry-based sets of projects, which insured relevance to engineering systems and products as well as insuring technology transfer between research organizations and industry. In addition, the industry programmes were financed by cost sharing between the industrial firms and Tekes. This organizational and financial structure helped insure relevance and applicability of the research conducted as well as advancement of the overall goal of improving competitiveness

of Finnish industry in the international marketplace.

Because of the makeup of the programme and the broad common goal of competitive reliability, the probability of the engineering science developed in the programme having a positive impact on Finnish industry competitiveness is good. In general, the quality of the science and technology developed in this programme was good. It would be well accepted in the international science and engineering community. In fact, many of the programme results have been accepted in peer reviewed archival journals and presented at meetings, which are well-recognized venues in the international science and engineering communities. This acceptance indicates the good quality of the research conducted in the programme.

Reliability of engineering systems is not a new concern. Historically it has been a concern of engineering product development. Historically, reliability has been more of a qualitative issue than a quantitative issue. This programme recognized the need to quantify system reliability and that defensible quantification of reliability will provide a competitive edge to the producer who can deliver it with confidence in the global marketplace. The benefit of this programme goal is that, if met, it will contribute to Finnish industry competitiveness – the underlying justification for the government support of the programme. The programme results are a positive contribution towards meeting the programme goals.

## 2 Comments on the Programme Outcomes

The programme outcomes take many forms. Comments here are based on those results written in English (programme final report drafts, some student theses, open archival literature and confer-

ence proceedings). It is recognized that there are numerous other beneficial products from the program including a number of Finnish language publications and documents and, probably the most important of all, internalized knowledge in the workforce. Additional benefits are organizational changes in companies and educational institutions that will increase the focus on engineering equipment reliability.

## 2.1 Overall Comments on Project Results

The investigators have a good understanding of the need for reliability and how to obtain effective reliability in the engineering systems for which they are responsible. The investigators generally recognized that an effective reliability (dependability) programme uses a combination of engineering, financial, management, and other practices to fully understand what the implementation cost will be and how it will impact company profits. Investigators also generally recognize the consequences of a machine failure on profitability of the company using the machines as well as that of the machine producer. They cite that profits can be influenced by:

- improved efficiency and extended operating life
- reduced repair time and cost
- detection of machine deterioration in advance of failure
- maintenance of process output until machine repair is conducted at scheduled off-peak times
- understanding the impact of design changes and tolerance requirements
- employee involvement in the improvement process through surveys and educational programmes.

However, investigators tend to overlook the fact that profits are also influenced by improving safety to enhance the credibility of the machine environment (which results in lower insurance premiums and decreased litigation and medical costs). They also seem to overlook the many benefits associated with minimizing the waste of unwarranted maintenance. By eliminating unwarranted or unnecessary maintenance through improved reliability, society benefits in that the needs of the present are met

without compromising the ability of future generations to address their needs.

Investigators recognized the need to avoid the stigma of a false alarm report or missing an indicator that could avoid a failure. But they did not appear to recognize that once alarm levels are set, a review process is needed to allow for adjustments due to operating experience on the machinery. Investigators tend to focus on failure tree analysis (FTA) and failure mode effects analysis (FMEA) rather than looking to technology for assistance through techniques such as condition monitoring techniques, better data transmission capabilities, and improved understanding of system deterioration processes. They also seem to underestimate the impact that root cause analysis (that is learning from history) can have on reliability programmes of specific machinery.

Finally, given the impact that probability and statistics have on reliability analyses, it is surprising that none of the projects appeared to focus on the development of mathematical tools to assess the integrity of information that is collected and conclusions that are obtained.

The programme consists of an impressive collection of different disciplines and industries focusing on the same important issue of competitive reliability. Not only were there several industries and companies within those industries involved in the project, but from the basic engineering science perspective the programme was also an unusually broad collection of interests including basic mechanics, electronics, tribology, corrosion chemistry, and human factors. It is to the credit of the organizers of this programme to have brought such a collection of researchers together to work on a common goal that is important to all of the different industries represented.

## 2.2 Energy Production Projects

The projects in this section included studies of components of energy production facilities as well as overall power plant quality and reliability studies.

The steam boiler fluidized bed circulation project focused on collecting both historical and current data on performance behavior of fluidized bed steam boiler systems. Data collection consisted of on-line real time data recording as well as the use of a graphical user interface on the worldwide web to transmit the information to central locations. The data collected was more characteristic of a generic system, however, and appeared to lack specifics that could help make improvements tailored to component needs. The project would benefit from considering the use of telemetry to transmit data to a central location. It would also benefit from the use of wearable computer technology onsite to access equipment manuals.

The gas turbine project used reliability centered maintenance procedures to gather data on performance, which in turn was used to optimize standard maintenance models for the system. This permitted better preventive maintenance programmes to be developed to enhance the availability of the machinery by the user. Although some of the information was proprietary and not available, the programme appears to be a good approach to improving reliability.

The project concerning valvewear and leakage prediction focused on an energy production system component that is used in numerous locations in energy production. Valve reliability is crucial to the overall reliability of energy production systems. The reliability of these components is connected to the wear of the sealing surface elements in the valve. Therefore tribology is the applicable discipline. Tribology is a notoriously difficult discipline in which to unambiguously relate laboratory tests to performance of the engineering component. The project appears to have developed a methodology to predict valve wear that can be used in the design and manufacture of valves with improved reliability. The reliability of the valves will in turn enhance and improve the reliability of energy production systems.

The project concerning overall powerplant quality, reliability and availability involved gathering information from customer experience with plants. This information was used to develop methodology to improve the maintenance process and in-

crease time intervals between maintenance activities, thus increasing both the reliability and the availability of the machinery.

## 2.3 Process Industry Projects

These projects covered a wide variety of activities within the pulp and paper industry. They included broad analyses of the steps in the process including the analysis of a logic tree based on engineering judgment and plant records. They also used models to identify system bottlenecks. There appeared to be little use of root cause analysis to develop an understanding of the cause of component failures.

In one of the projects on automated condition monitoring in the field, the Internet was used to transmit the data to a central location. They also used a host driven diagnostic system to interrogate the operating system for performance but the system appeared to lack any methodology to identify falsely reported faults in the system. One of the other projects in this set studied the corrosion behavior of materials in a pulp washer system. The methodology appeared to be scientifically sound. The results were used for material selection as well as recommended changes in the composition of the washing solutions.

Finally, a project concerned with life cycle cost and profit analysis related to the installation of lubrication and sealing systems in the pulp industry was included. The presence of this economic analysis pointed out the lack of an economic analysis in many of the other programmes. Economic analysis needs to be part of a reliability and availability programme.

## 2.4 Metal Industry Projects

This group of projects consisted of five well defined and thorough projects. One project concerning paper machine take-up reels was notable for determining which component was the major cause of downtime in their paper machines. When a root cause analysis was done to review the problems causing the component failure and solutions were generated to improve the reliability of this

component, the solutions included automation upgrades, improved design development, and employee education to improve employee attitude toward the handling of the equipment. Through the use of failure tree analysis (FTA), failure mode and effects analysis (FMEA), and human error analysis (HEA), this project indicates it achieved an availability of the take-up reel to be in the neighborhood of 99.8 to 99.9%. However, the criteria for this determination were not presented.

The sheet metal machine reliability project was interesting in that it had developed automatic data transfer technology via the Internet. The data was sent to a maintainer of the machine for recording a log of information on failure type and description. Such a system should enhance the ability of the manufacturer to improve the reliability of the machines as well as improve the capability of maintaining machines in the field, hence improving the reliability and availability of products already sold. The project report lacks specifics concerning some of the data collection methods, as well as the sensor technology and sensitivity used in finding the faults. The authors state "It will be several years before ... conclusions can be made" as a result of this study. This appeared to be inconsistent with the urgency of the overall programme to improve reliability and competitiveness.

The project concerned with fault tree analysis undertaken by Nokia Corporation was one of the more interesting and wide ranging projects. The programme was started at the beginning of a new product cycle and focused on early stage mobile phone design for reliability. They recognized that focusing on the entire product was too complicated so they narrowed the activities to focus on a few items within the product. They also mention that reliability was just one of many targets that they had to deal with. Others included costs, features, legal and environmental issues. They learned that by putting more funding into the early stages of the design cycle focused on reliability they could get a bigger payback. In fact, initial estimates of payback are anywhere from 20 to 60 times the initial investment. It was pointed out that the design for reliability programme was complementary to the six-sigma programme initiated in the electronic packaging industry several years ago to reduce

manufacturing defects. It was particularly interesting to learn that the reliability and availability focus has resulted in Nokia now having 40 people concentrating on this area in their product design. This programme clearly has had a strong impact on this manufacturer.

The programme concerned with the diagnostics of steel rolling mills also appeared to be a very strong and effective programme. They presented an excellent summary of the methodology needed to develop an expert diagnostics system from sensor measurements to signal analysis to data integration. The results presented lacked specifics concerning particular rolling mill applications. It was uncertain as to the strategy to be used to determine optimum sensor number and optimum sensor location in the programme. They may benefit from considering parallel fault detection paths to check for false alarms and to consider the possibility of using a neural network approach to educate the system as data is updated.

The final project in this group was concerned with mobile work machines for processing forest products in the field. A positive aspect of this study was the use of failure analysis, customer supplied data and warranty reports to identify root causes of failures in the systems. The data was collected and taken back to the designer or manufacturer to be incorporated in future products and for remedial action to retrofit of systems currently in the field. The project did not discuss the relative merits of the condition monitoring technologies used to assess power transmission systems; such as vibration, wear particle counting, thermography, and infrared imaging. The project also lacked a cost benefit analysis of the efforts proposed and used. The project might also benefit from the use in the field of digital images of failed components to obtain expert evaluation from engineers at the manufacturing site without shipping components back from the field to the factory.

## 2.5 Methodological Research Projects

There were several research projects conducted the Technical Research Centre of Finland, Helsinki University of Technology, the Finnish Pulp and

Paper Research Institute and the Finnish Institute of Occupational Health. This group consisted of a wide range of fundamental topics that were supportive to the field. They often provided results that were generic to several industries and not just the industries that participated in the overall program. The studies included data acquisition technology and analysis, lifetime prediction methodology, plant integrity, sensor development (MEMS devices), ultrasonic inspection technologies, data screening, and human factors. In general these research projects were thorough and of value, especially when coupled with the industrial/applied projects. They also increased the value of the industrial projects in the program. In addition, many of these research projects were of value beyond the this program. They were of value broadly to engineering systems.

The quality of these research projects on an international scale seems to be assured both by the impression of this reviewer, and, more importantly, by the fact that numerous publications and presentations have already been accepted and presented in a wide variety of international science and engineering venues. Forty-two of the fifty-four international publications or presentations from the total programme were from ten of the research-oriented projects. The research performed met international standards in the science and engineering community.

### **3 Interdisciplinary Aspects of the Competitive Reliability Technology Programme**

Engineering systems reliability requires interdisciplinary effort and attention. The programme organizers are to be complimented for focusing a wide range of disciplines on the programme goals. This collection of projects included both basic and applied research ranging from fundamental research, to applied research, to the design and operation of engineering systems. In the applied research arena, several industries with different aspects of each of the industries was involved. At first glance, it may seem that they have relatively little in common but the underlying concept for competitive reliability

was applicable across the range of industries represented. Several basic disciplines of engineering, and the “soft” sciences of human factors research were included in the programme. Human factors research is important to reliability of engineering systems but often overlooked and not included. Design engineers often forget that human beings will operate the system and will react in a variety of ways to the performance of that system. It is commendable that human factors specialists were included in this overall programme. Human factors are important when focusing on applied engineering issues such as engineering system reliability. This programme went a long way towards accomplishing this needed communication

In competitive reliability, the programme organization did an admirable job of including a wide range of disciplines and fostering interaction among them. If there was one area that the programme could possibly have benefited from that was not included, it is the area of probability and statistics. Virtually all issues associated with reliability and availability involve dealing with probability and statistics in predicting possible outcomes (prognostics). Prognostics apparently was not addressed in the current programmes, but would be a logical extension of this programme.

Given the programme goal of enhanced competitiveness for the Finnish industry, it is important that there are lasting benefits from the programme and that many issues associated with the programme continue to be pursued. Competitive advantage in industry is short-lived. Once competitors become aware of the advantage, and particularly in an area such as improved reliability of engineering machinery, they will quickly catch up and the competitive advantage will be narrowed or lost. Companies and research groups must continue to deal with the subject matter to maintain a competitive advantage. It is important that the companies continue their efforts focusing on reliability issues for their product, but more importantly the research community independent of companies must also be funded and continue their basic contributions toward to the general field of reliability.

In this regard, it is satisfying to see that the programme has already had an impact on engineering education. One indication is the amount of student thesis research activities directed toward reliability. Another indication is the initiation of a program at one university in Finland through the appointment of a professor that had been involved in this program. There also is the initiation of continuing education for professional engineers to advance their careers through short course studies in reliability. All of these activities, incorporation into undergraduate engineering education and the development of continuing education programs, will have a lasting contribution to the advancement of Finnish engineering industry reliability.

As already mentioned before, it is good to note that human factors researchers have been brought back into engineering development. Many years ago, there were closer connections between human factors researchers and the engineering community. However, with the development of more specialization in both the sociology community and in the engineering community, the two groups have drifted apart. This has been a loss to each. This programme, having brought them back together, may result in a longer lasting interaction between human factors researchers and engineers. Both of these groups can benefit from that interaction.

Finally, technology transfer has been enhanced by the organization of this project. The involvement of a number of people from the research side of the community and a number of people from the industrial sector of engineering enhanced the technology transfer in both directions. Technology transfer is also enhanced through the future graduation of students in engineering and through the lifelong learning opportunities of professional engineers through the continuing education efforts.

#### **4 Comparison of the Tekes Programme with the MURI Programme**

At nearly the same time the Tekes programme was in progress, a programme of similar size with similar objectives was underway in the United States

from 1995 through the end of 2000. A Multidisciplinary University Research Initiative (MURI) was underway at Georgia Institute of Technology at the Center for Integrated Diagnostics. It was funded by the U.S. Department of Defense at about \$10 million and involved twenty-one projects at three universities (Georgia Institute of Technology, University of Minnesota, and Northwestern University). The programme involved researchers from four engineering academic departments (Mechanical Engineering, Electrical Engineering, Materials Science & Engineering, and Civil Engineering). The reports, including the final report of the MURI Center for Integrated Diagnostics, can be found on a website ([www.me.gatech.edu/diagnostics](http://www.me.gatech.edu/diagnostics)).

The two programmes (Finnish Tekes Competitive Reliability Technology Programme and the U.S. MURI Center for Integrated Diagnostics) were similar in the sense that they had a common goal – the increase of the availability of engineering systems and a more reliable prediction of that availability. They were also similar in that they both involved students. The programmes differed in many ways of approaching this goal. For example, the Tekes programme heavily involved industry while the MURI had relatively less industrial participation. The Tekes programme focused on specific engineering systems associated with the industrial partners while the MURI focused on generic technology that would be widely applicable – although the primary motivation was application to military rotorcrafts and ships. Probably the most important difference was that the Tekes programme focused on system design changes to improve subsequent product reliability and availability while the MURI programme focused on diagnostics technology to be retrofitted to existing engineering systems to detect incipient failure. A goal of the MURI programme was to afford the user the opportunity to take corrective action without major loss of equipment assets. The reason for pointing out this comparison between the programmes is, that both approaches are necessary for an effective programme to enhance the reliability, performance and profitability of engineering systems. Attention must be directed to design and manufacturing to make the product more reliable. But even the best design and manufacturing will

not eliminate unforeseen failures in the field. There will always be a precursor to a system failure which if detected and acted upon can prevent a potentially damaging failure and all the concomitant losses associated with the downtime and loss of equipment assets. By the same token, only looking for incipient failures does not make sense when there is the opportunity to modify the design and manufacture of next generation systems. The Tekes and the MURI programmes, in retrospect, are very complementary efforts. Future efforts in reliability and availability of engineering systems should have a balanced focus on both aspects of the issue.

## 5 Summary

In summary, the general quality of the overall Tekes programme was good. The programme contributed to improved reliability and availability of Finnish engineered products. There were notable contributions from many of the individual projects within the programme. Of particular effectiveness in advancing the cause of reliability and availabil-

ity was the organizational structure of the programme. The involvement of both academic and industrial people on the one hand, and hard engineering sciences and soft human performance issues on the other, help advance the goals of the programme. From science and engineering points of view the programme also had impact on the broad issues of reliability and availability beyond that of the individual projects. The fact that an impact has been made on the engineering educational system of Finland, the focused efforts of companies on their products with the involvement of academic research, and the introduction of continuing education in the field should have a lasting impact on Finnish engineering industry that will provide more knowledgeable personnel within companies.

In answer to Tekes's question of whether the science and technology developed in the programme was competitive in an international forum, the answer obviously is yes. This is not only the opinion of this evaluator but is obviously demonstrated by the significant number of papers and presentations presented in international venues.

### The Survey Sent to Companies

#### 1. Yleiskuva ohjelman tuottamasta lisäarvosta

Arvioi seuraavien seikkojen merkitystä projektissa saavutettujen tulosten kannalta asteikolla 1–5 (1 = ilman tätäkin samat tulokset olisi saavutettu samassa ajassa, ..., 5 = ilman tätä ei olisi pystytty tuottamaan saavutettuja tuloksia)

	1	2	3	4	5
Tekesin taloudellinen tuki	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Yritysten ja tutkimuslaitosten välinen yhteistyö	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Yhteistyö muiden yritysten kanssa	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
KäKi-ohjelman tuottamat henkilökontaktit ja kommunikointi (seminaarit, kokoukset, julkaisut jne.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

##### 1.1 Olisiko sama projekti (samat Tekesin rahoitus, tekijät, budjetti ja tehtävät) ollut olennaisesti yhtä hyvä toteutuksen ja tulosten näkökulmasta, jos se olisi toteutettu yksittäisenä projektina sen sijaan, että se oli osa KäKi-tekniologiaohjelmaa?

- Kyllä, ohjelma ei tuottanut olennaista lisäarvoa tai siitä oli haittaa
  - Ei, mielestäni projekti osana ohjelmaa hyötyi siitä, että (voit rastittaa useampia):
    - Mukana olleet tutkimuslaitokset toivat mukaan olennaista tietotaitoa, jonka ei tiedetty olevan olemassa.
    - Ohjelman piiristä löytyivät olennaiset projektin yhteistyökumppanit, joita ei oltu tunnistettu projektia suunniteltaessa.
    - Ohjelman puitteissa järjestetty tiedonsiirto kasvatti olennaisesti osaamista yrityksessäni.
    - Ohjelman puitteissa löydettiin projektin ulkopuolelta ratkaisumalleja projektin käyttöön.
    - Ohjelman puitteissa löydettiin uusia yhteistyökumppaneita (yksittäisen projektin tai koko ohjelman ulkopuolella tapahtuvaan työhön).
    - Ohjelman puitteissa selkeni projektin jatkokehitys.
    - Ohjelman puitteissa saatiin projektin ulkopuolisia uusia ideoita, jotka johtivat tai johtavat jatkokehitys- tai tutkimushankkeisiin yrityksessäni.
    - Muu ohjelmasta aiheutunut hyöty. Mikä?
-

**1.3 Olivatko ohjelman aiheuttamat kustannukset** (seminaareihin osallistumiseen käytetty aika, tiedonvaihdon seuraaminen, ohjelmaan liittyvät kyselyt ja seuranta) **mielestäsi**

- Merkittäviä, mutta ne on jo sisällytetty projektin kustannuksiin
- Merkittäviä, ylimääräisiä, ennalta arvaamattomia kustannuksia aiheutui projektin osalta koko ohjelman ajalta \_\_\_\_\_ tuhatta markkaa.
- Merkityksettömiä

## 2. Projektin tuottama taloudellinen hyöty

Käki-ohjelman päällimmäinen tavoite on ollut osallistuvien yritysten kilpailukykyyn kasvattaminen käyttövarmuuteen liittyvien keinojen kautta. Olette jo aikaisemmin mahdollisesti vastannut ohjelman puitteissa tulosten hyödyntämistä koskevaan kyselyyn. Haluamme tällä kyselyllä kartoittaa hyötyjä tarkemmin ja kysyä arvioitanne hyödyistä markkamääräisinä ja hyötyihin liittyvistä epävarmuuksista.

**2.1 Alla olevassa taulukossa on listattu mahdollisia projektien tuottamia taloudellisia hyötyjä (jo toteutuneita tai tulevaisuudessa realisoituvia). Merkitse alla olevaan listaan ne projektin tuottamat hyödyt omassa yrityksessänne, jotka ovat kohtalaisen tai erittäin merkittäviä. Kysely lähetetään erikseen kaikille projektissa mukana olleille yrityksille.**

A. Oman tuotteen kilpailukyky (lisääntynyt myynti/ liikevaihto)		
Kokonaan uusi tuote	Kokonaan uusi tekninen tuote tai innovaatio	<input type="checkbox"/>
	Kokonaan uusi ohjelmistotuote	<input type="checkbox"/>
	Kokonaan uusi palvelutuote (esim. konsultointituote tai kunnossapitotoiminta)	<input type="checkbox"/>
Lisäarvo nykyiseen tuotteeseen	Olemassa olevan teknisen tuotteen parantaminen / korvaaminen (luotettavammalla tai yhtä luotettavalla mutta halvemmalla)	<input type="checkbox"/>
	Olemassa olevan ohjelmistotuotteen parantaminen tai sen lisäominaisuus	<input type="checkbox"/>
	Palvelutuotteen parantaminen (esim. kunnossapidon parempi suunnittelu)	<input type="checkbox"/>
	Olemassa olevan tuotteen lisänä myytävä huolto- tai käyttövarmuuspalvelu tai takuu	<input type="checkbox"/>
	Lisäominaisuus (esim. tiedonkeruu) olemassa olevaan tuotteeseen	<input type="checkbox"/>
	Uusi konsultointituote/tutkimuspalvelu liittyen tuotteeseen	<input type="checkbox"/>

Parantunut myynti	Uusi myyntiargumentti, esim. parempaa tietoa tuotteen luotettavuudesta	<input type="checkbox"/>
	Työvälineet myyntiin, markkinointiin jne.	<input type="checkbox"/>
	Parantunut imago ja asiakastyytyväisyys	<input type="checkbox"/>
<b>B. Oman tuotannon tai toimintojen kilpailukyky (kustannussäästö/parantunut kate)</b>		
Kustannusten aleneminen	Oman tuotannon huolto- ja vikakustannusten aleneminen (primäärikulut)	<input type="checkbox"/>
	Oman tuotannon käyttövarmuuden lisääntyminen (laajasti ottaen kulut esim. seisokkien takia alentuneet)	<input type="checkbox"/>
	Vikojen paikantaminen tai huollon parempi kohdennus (esim. myytävän huoltopalvelun kustannukset alentuneet)	<input type="checkbox"/>
	Säästö huoltotoiminnan varastointikuluissa	<input type="checkbox"/>
	Työväline tai menetelmä tuotesuunnitteluun (parantunut suunnittelun tehokkuus esim. tuote nopeammin markkinoille)	<input type="checkbox"/>
	Omaan toimintaan liittyvät toimintaohjeet tai prosessit parantuneet	<input type="checkbox"/>
	Kustannuksia alentava työväline myyntiin, markkinointiin jne.	<input type="checkbox"/>
Epävarmuuden pieneneminen	Tarkempi toiminnan budjetointi	<input type="checkbox"/>
	Käyttövarmuuden seuranta (tarkempi tieto käyttövarmuudesta)	<input type="checkbox"/>
<b>C. Osaamispääoman kasvu (hyödyt materialisoituvaa möhemmin ja vasta jatkotoimenpiteiden kautta)</b>		
Lisääntynyt osaaminen/tieto	Tiedonkeruulaitteistot	<input type="checkbox"/>
	Tietoa tuotesuunnitteluun	<input type="checkbox"/>
	Ostoihin liittyvät käyttövarmuusvaatimukset	<input type="checkbox"/>
	Tarkempi investointien kannattavuuslaskenta (elinajan kustannus)	<input type="checkbox"/>
	Tietoa konkreettisen jatkokehityshankkeen pohjaksi	<input type="checkbox"/>
	Organisaation yleinen osaamisen lisääntyminen	<input type="checkbox"/>
D. Muu kilpailuetu tai kustannussäästö? Mikä?		<input type="checkbox"/>
_____		
_____		
_____		

## 2.2. Tuotteen kilpailukyky

(vastaa vain mikäli valitsit kysymyksessä 2.1 kohtaan A liittyviä hyötyjä, siirry muuten kohtaan 2.3.)

Mikäli projektissa on valmistunut tai valmistumassa useampia selkeästi erillisiä tuotteita, vastaa kysymyksiin 2.2.1 – 2.2.5 (kopioi tämä sivu) erikseen jokaiselle tuotteelle.

2.2.1 Kohdassa 2.1 A mainittujen uusien tuotteiden tai nykyisten tuotteiden lisäarvojen valmiusaste

valmis (kaikki tai osa tuotteista ollut myynnissä vuodesta \_\_\_\_\_ )

jatkokehitys ennen myynnin alkamista tulee viemään \_\_\_\_ vuotta

2.2.2 Todennäköisyys, että jatkokehitystä vaativan tuotteen jatkokehitystyö onnistuu ja hyödyt toteutuvat:

0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2.2.3 KäKi-projektissa kehitetyn tuotteen tai tuotteiden jatkokehitystyön kustannukset (vaaditut investoinnit) KäKi-projektin ulkopuolella (toteutuneet ja arvio tulevista) yhteensä (tuhatta markkaa/vuosi)

1996	1997	1998	1999	2000	2001	2002	2003–2006 keskimäärin:
_____	_____	_____	_____	_____	_____	_____	_____

2.2.4 Arvio KäKi-projektin ja (onnistuneen) jatkokehitystyön seurauksena syntyvästä liikevaihdon lisäyksestä (tuhatta markkaa/vuosi):

1996	1997	1998	1999	2000	2001	2002	2003–2006 keskimäärin:
_____	_____	_____	_____	_____	_____	_____	_____

2.2.5 Käyttökate keskimäärin yllä mainitun liikevaihdon osalta (liikevaihto vähennettynä muuttuvilla ja kiinteillä kustannuksilla suhteessa liikevaihtoon):

noin	5%	10%	15%	20%	25%	30% tai enemmän
	9	9	9	9	9	9

2.2.6 Vastasiko projektin seurauksena syntynyt liikevaihto tai arvio tulevasta liikevaihdosta projektille alussa asetettuja odotuksia?

- Odotettu ylittyi merkittävästi
- Odotettu ylittyi jonkin verran
- Vastasi odotuksia
- Odotettu alittui jonkin verran
- Odotettu alittui merkittävästi

2.2.7 Kuinka projektissa syntyneet tuotteet ovat yleisesti vaikuttaneet yrityksen kilpailukykyyn markkinoilla?

- Kehitetty uusia tuotteita ja/tai lisäarvoja, joita kilpailijoilla ei vielä ole myynnissä (potentiaali kasvattaa markkinaosuutta)
- Päästy samalle tasolle kilpailijoiden kanssa (estetty markkinaosuuksien pieneneminen)
- Projektilla ei nähdä olevan merkittäviä suoranaisia vaikutuksia markkinaosuuksiin

### 2.3 Tuotannon kilpailukyky – kustannussäästöt (vastaa vain mikäli valitsit kohtaan B liittyviä hyötyjä, siirry muuten kohtaan 2.4)

Mikäli projektissa on useampia selkeästi erillisiä kustannussäästöjä aiheuttavia tuloksia, vastaa kysymyksiin 2.3.1 – 2.3.5 (kopioi tämä sivu) erikseen jokaiselle tuotteelle.

2.3.1 Projektin liittyvien kustannussäästöihin tähtäävien toimenpiteiden valmiusaste:

- Hyödyt ovat realisoituneet jo vuodesta \_\_\_\_\_
- Jatkokehitys ennen hyötyjen realisoitumista vie \_\_\_\_\_ vuotta

2.3.2 Todennäköisyys, että jatkokehitystyö onnistuu ja hyödyt toteutuvat:

0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2.3.3 Jatkokehitystyöhön/valmiuksien ylläpitämiseen liittyvät kustannukset (vaaditut investoinnit) KäKi-projektin ulkopuolella (toteutuneet + arvio tulevasta) yhteensä (tuhatta markkaa/vuosi)

1996	1997	1998	1999	2000	2001	2002	2003–2006 keskimäärin:
_____	_____	_____	_____	_____	_____	_____	_____

2.3.4 Arvio yritykseeni kohdistuneista kustannussäästöistä  
(tuhatta markkaa/vuosi)

1996	1997	1998	1999	2000	2001	2002	2003–2006 keskimäärin:
_____	_____	_____	_____	_____	_____	_____	_____

2.3.5 Vastasiko projektin seurauksena syntynyt kustannussäästö tai arvio tulevista kustannussäästöistä projektille alussa asetettuja odotuksia?

- Odotettu ylittyi merkittävästi
- Odotettu ylittyi jonkin verran
- Vastasi odotuksia
- Odotettu alittui jonkin verran
- Odotettu alittui merkittävästi

2.3.6 Kuinka projektissa syntyneet kustannussäästöt ovat yleisesti vaikuttaneet yrityksen kilpailukykyyn markkinoilla?

- Saatu aikaiseksi merkittävä etulyöntiasema, joka olennaisesti parantaa kilpailukykyä (potentiaali kasvattaa markkinaosuutta)
- Päästy samalle tasolle kilpailijoiden kanssa (estetty markkinaosuuksien pieneneminen)
- Projektilla ei nähdä olevan merkittäviä suoranaisia vaikutuksia markkinaosuuksiin

## 2.4 Osaamispääoman kasvu

2.4.1 Projektin ansiosta kertyneen tiedon tai uuden osaamisen (esimerkiksi tietokannan kokoamisen tai koulutuksen kautta saadun tietotaidon) voidaan nähdä tulevaisuudessa ensisijaisesti

- parantavan yrityksen tuotteita tai tuotekehitystä (parempia tuotteita, uusia innovaatioita)
- säästävän yrityksen kustannuksissa (mukaan lukien suunnittelun kustannukset)
- parantavan yrityksen myyntiä ja markkinointia

2.4.2 Kuinka monta henkilöä organisaatiossanne on saanut uusia valmiuksia viedä projektin aihepiiriin liittyvää kehitystyötä eteenpäin, jotta hyödyt tulevaisuudessa konkretisoituvat?

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### 3 Projektin tuottamat muut hyödyt

3.1 Kuinka monta uutta pysyvää työpaikkaa organisaatioonne on syntynyt projektin seurauksena?

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3.2 Onko projekti tuottanut hyötyjä, jotka ovat hankalasti rahalla tai osaamispääoman kasvuna mitattavissa?

- Ei, projektin hyödyt ovat pääsääntöisesti rahallisia tai osaamisen kasvuun liittyviä.
- Kyllä (voit valita myös useampia):
  - ympäristöriskien pienentäminen (pienempi todennäköisyys ympäristövahingoille)
  - työturvallisuuden kasvattaminen (vähemmän loukkaantumisia)
  - yhteistyöverkoston luominen
  - tietoisuus käyttövarmuuteen liittyvistä tulevaisuuden kehitystarpeista
  - joku muu, mikä?

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## Annex B

### Resume

**Ward O. Winer** received a B.S.E., M.S.E. and Ph.D. from the University of Michigan (1958, 1959, 1962) and a Ph.D. in physics from Cambridge University, England (1964). He was on the Mechanical Engineering faculty at the University of Michigan (1963–1969) prior to joining Georgia Institute of Technology in 1969 where he is now the Eugene C. Gwaltney, Jr. School Chair of the George W. Woodruff School of Mechanical Engineering. Professor Winer has been consultant to numerous corporations and law firms. He has been principal investigator on projects sponsored by the National Aeronautics and Space Administration, the National Science Foundation, Department of Transportation, Department of Energy, and Defense Advanced Research Projects Agency, and many industrial firms. Since 1995, he has been principal investigator on a U.S. Department of Defense Multi-University Research Initiative focused on the integrated diagnostics of mechanical systems involving 21 Co-PI's in seven departments at three universities (Georgia Tech, Northwestern University, and the University of Minnesota).

Professor Winer received the 1998 University of Michigan Alumni Society Merit Award for the Department of Mechanical Engineering and Applied Mechanics, the Sigma Xi Monie A. Ferst Memorial Award for Sustained Research from the Georgia Tech Chapter of Sigma Xi (1975), ASME Melville Medal (1975), and the ASME Pi Tau Sigma Charles Russ Richards Award in 1988. In 1986 Professor Winer received the ASME Mayo D. Hersey Award. In addition, he received the Tribology Gold Medal from the British Tribology Trust of the Institution of Mechanical Engineers, Institution of Production Engineers, the Royal Aeronautical Society, and the Department of Industry and Trade, Great Britain. In 1983 he received the Jacob Wallenberg Foundation Grant from the Royal Swedish Academy of Engineering Sciences. He was named the 1986–87 Distinguished Professor at Georgia Institute of Technology. In 1995 and 1996 the American Society for Engineering Education honored Dr. Winer with the Benjamin Garver Lamme and Donald Marlowe Awards, respectively. He was elected to the National Academy of Engineering in 1988.

Professor Winer is author and co-author of more than 200 technical papers and reports, and editor with M.B. Peterson of the *ASME Wear Control Handbook* (1980). He has lectured widely in the United States, Europe, Japan, Taiwan, Korea, and the Soviet Union. He is a Fellow of the Society of Tribologists and Lubrication Engineers, the American Society of Mechanical Engineers, and the American Association for the Advancement of Science. He was Chair (1980) of the Gordon Research Conference on Friction, Lubrication and Wear; a member of the Board of Directors of the Society of Engineering Science, Inc. (1980-1984) and the Board of Directors of ASLE (1982–1986); Chair of the National Research Council Steering Committee on Recommendations for U.S. Army Basic Scientific Research (1984-1987); and a member of the Mechanics, Structures, and Materials Engineering Division Advisory Committee of the National Science Foundation (1984–1987). He was a member of the National Nuclear Accrediting Board (1994–1998). Professor Winer is a Professional Engineer registered in the State of Georgia.

**Dr. Mari Hjelt** has received her doctor of technology degree in Systems and Operations Research from the Helsinki University of Technology in 1998. Her background in operations research and control engineering has given her expertise in a wide range of mathematical tools – particularly in optimization, statistics, and simulation. In her research, she has focused on risk analysis and decision making methods. She has worked with complex policy projects in the areas of technology evaluation and foresight, environmental management, transport, and health care. Mari Hjelt joined Gaia Group Oy in 2000 and is one of the partners of the company. Prior to that she has worked with RAND Europe in the Netherlands as a senior policy analyst. She continues representing RAND Europe in Finland.

**Mikko Syrjänen** holds a M.Sc. (eng.) from the Helsinki University of Technology. Currently he is researcher and Ph.D. (Econ.) student at Quantitative Methods Unit at the Helsinki School of Economics and Business Administration. He is a member of the Graduate School in Systems Analysis, Decision Making and Risk Management. His areas of research are productivity and efficiency analysis, especially Data Envelopment Analysis (DEA), and resource allocation based on efficiency information.

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