fimecc

FIMECC SRA

Competitiveness through research

Strategic research agenda for Finnish metals and engineering competence cluster

22.1.2010

1. EXECUTIVE SUMMARY

Strategic basic research is something that companies can do together in order to increase the number of innovations. If the scientific discussion and communication is limited to technology platform areas instead of business details, companies can act open enough without endangering their information that is classified with non-disclosure label. Strategic basic research can be platform research carried out with competitors and other stakeholders in order to develop the understanding of business environment. Application development is the responsibility of each company separately and independently. The co-opetition strategy is based on two assumptions: Higher research volume, as such, produces typically more innovations than lower research investment, and more interfaces with different actors (competitors, research institutes, and other competencies) increase the probability of innovations to take place. The search for new innovations is researching together and competing on how to build applications on the joint platforms.

Strategic centres for science, technology, and innovations (in Finnish: SHOK) are directed to boost private sector initiated strategic research with public funding. In SHOK, the owners define both the focus areas of the SHOK research efforts and the select the resources to carry out this research. **SHOKs are important because they bring private industry and public research organizations closer to each other**. At the same time, industry can have stronger influence on the research themes and target setting. From research point of view, SHOK can provide researchers with funding instruments covering longer and wider research programs than the present project-based instruments. Furthermore, since SHOKs have many industrial owners, they work as platform developers be the means of strategic long-term research. Finally, industry can reach flexibility in the management and direction of research efforts.

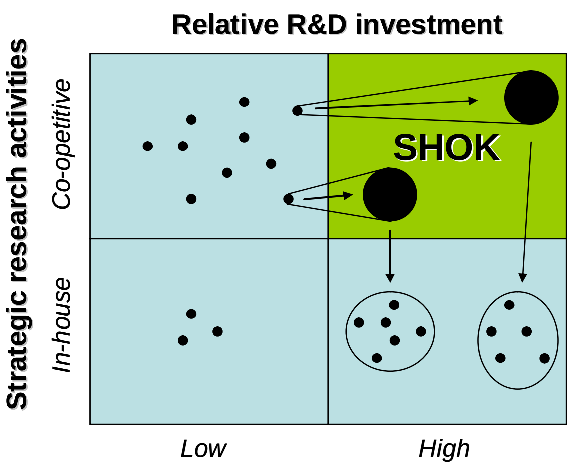
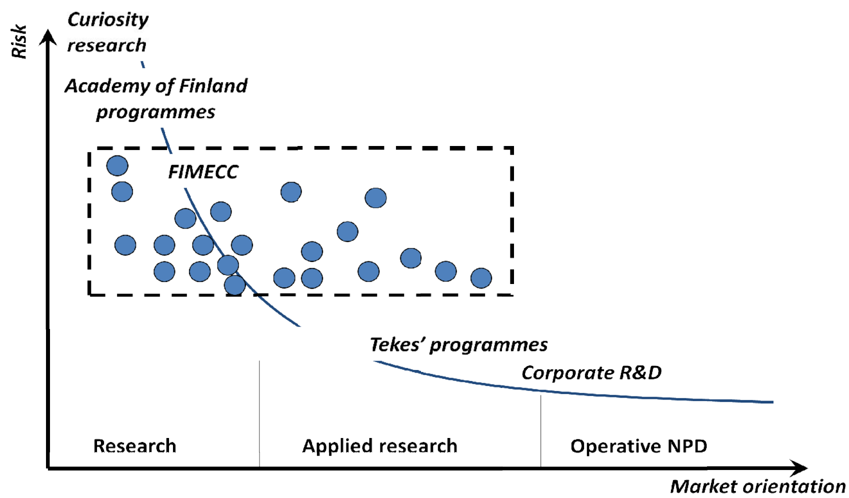


Figure on the left introduces the primary orientation and the role of SHOK in the R&D activity map. The most important required attitude from the members' side is co-opetition. Also significant (high) research volume is expected. Since SHOK is not responsible for all the research carried out in the area, many very early phase research efforts are funded outside the SHOK (left corners). These efforts must be academically freely selected and their research volume is typically not high. However, when companies are involved, and preferably co-opetitively, in certain point an activity may turn out to produce so promising results that SHOK participants are willing to define the research project or area as strategically important. In this phase, the research effort is moved into SHOK category and the investment is multiplied (from upper left to upper right corner). The SHOK research may produce technology platforms that in certain phase can be moved towards the application development and in-house activities (from upper right to lower right corner). In this phase, the volume of each single development effort is decreased but the number of efforts in certain technology area may be high.

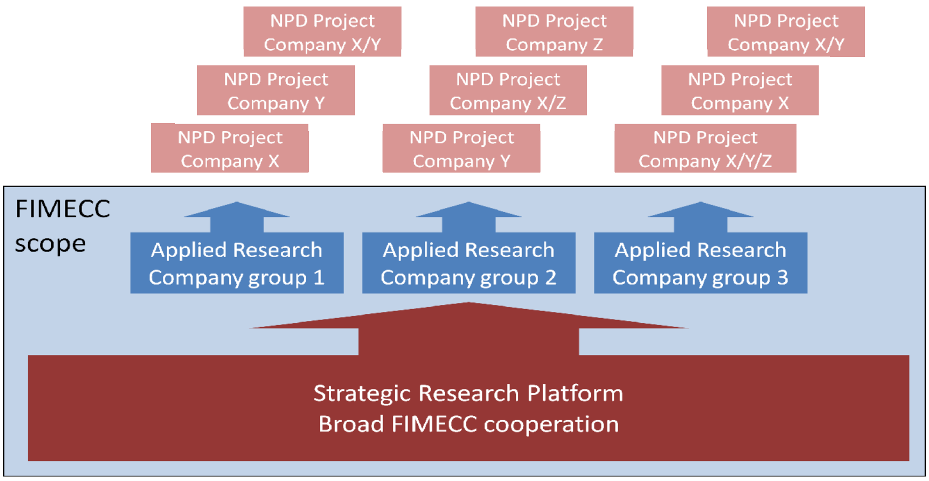
The difference of SHOK activities and later phase application development is that **SHOK activities are still in the high risk phase**. Companies can minimize the drawbacks caused by realized risks by carrying out this phase co-opetitively and in this way sharing the risks.

In metal product and mechanical engineering area, the SHOK is FIMECC Ltd. FIMECC activities can be positioned by utilizing the traditional Matthews' curve that describes the risk level and monetary funding. Traditionally, the



monetary funding increases while the market orientation increases. **FIMECC activities are positioned between pure academic research and new product development (NPD)** oriented applied research. The project portfolio of FIMECC consists of several projects, some of them being more application oriented than others. On average, the portfolio is Gaussian distributed so that strategic long-term research projects form the majority.

FIMECC is a way to carry out mid-term and especially long-term strategically focused pre-competitive research by setting goals and managing research actively. FIMECC is not an outsourced resource for companies' NPD projects. The most important FIMECC activities can be described as strategic platform research, in which the participants openly cooperate even though in the market they are competitors in the market. **The time frame for activities is 3-10 years before market launch.** From this set of platform research, applied research initiatives are evolutionary created. Here, some but not all the FIMECC participants form horizontal consortiums consisting of companies that jointly carry out pre-competitive applied research. In FIMECC, research activities can also be built around vertical supply chains, in which direct competition between companies does not exist. At certain point, market orientation becomes so evident that the activities must be funded by other means than FIMECC. After this point, many short-term oriented NPD projects are initiated by companies separately without cooperation.



The total turnover of metals and mechanical engineering industries in Finland was 38 B€ in 2006 representing 30% of the overall industrial output of the country. The value added in these industries was 10 B€ and the value of export was 23 B€. The export of these industries is one third of the total export of Finland. In 2006, the number of employees in these industries was 153 000 which represents one fourth of the total industrial employees in Finland. The industry's impact on Finnish national economy is significant. The R&D investment of the companies in the industry was 445 M€ representing 1.2% of the turnover. In addition to this, public R&D investment in universities and research institutes was 39 M€. **In 2006, the total investment in the research related to these industries in Finland was thus 484 M€ representing about four thousand employees' annual R&D input.** Due to the global recession after 2008, the figures of 2006 are more or less relevant in 2010.

The vision of FIMECC:

World Class Platform for Science-Based Competitiveness. FIMECC will create new international research networks, new top science, and new application-driven research contents. The competence and knowledge in selected focus areas will be raised to globally leading position. The research activities are based on ambitious target-orientation, openness, dynamics, and true internationality.

The primary targets of FIMECC:

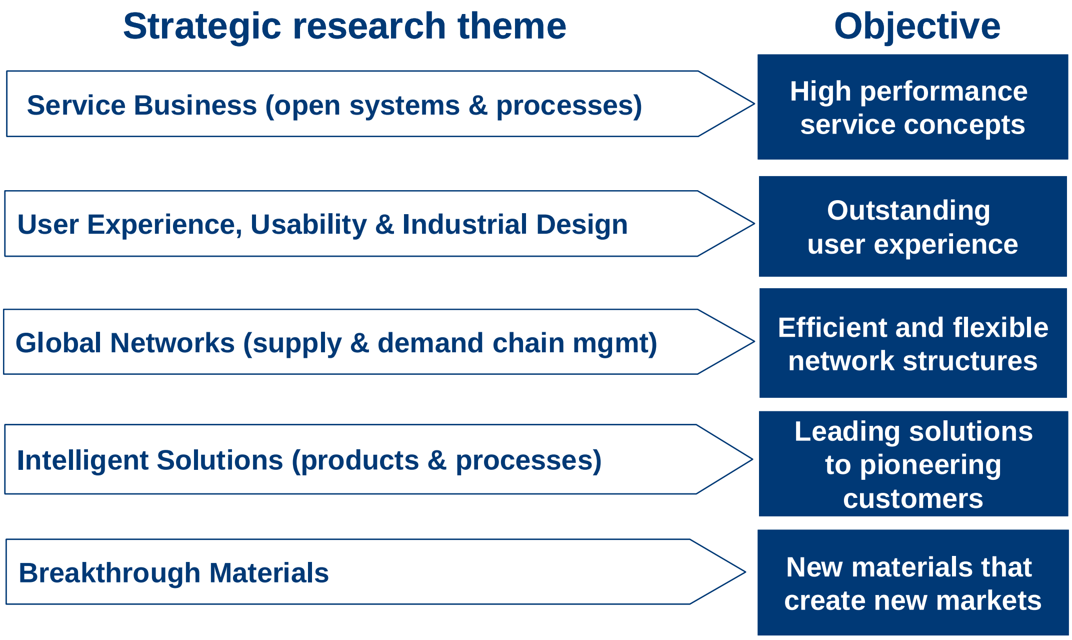
Revolutionary Engineering – Perceiving Customers' Needs First. Finland-based companies will make a difference in the global markets through utilizing new excellent knowledge of FIMECC especially in customer needs understanding, breakthrough market launching, and successful customer solution piloting and implementing.

The objective of FIMECC is to double the industry's R&D investment by the year 2015. This will be done step by step through implementation of SHOK activities in successful pilot programs after which more companies will be interested in participating into the activities. The increase of funding includes the objective of increasing also the absolute monetary R&D investments.

The estimated research volume of FIMECC as a percentage of the industry's total research volume is about 10 per cent in 2010. **The estimated monetary research volume of FIMECC in 2011 is ca 60M€, which means about 400-450 persons** working annually in the research programs of the FIMECC. This amount is invested on five research themes (on the right, a short summary of the research questions in each theme):

- **Service business** — How to build understanding on service business logics, customer demand forecasting, inter-organizational new service development, benefit sharing, and open service innovation systems?
- **User experience** — How to create established structures for understanding diversifying user profiles and design leadership platforms?
- **Global networks** — How to create and manage agile, flexible and resilient demand and supply networks in continuously changing business environment?
- **Intelligent solutions** — How to increase the value added of customer solutions by the means of product and process-integrated intelligence?
- **Breakthrough materials** — How to improve the performance of customer solutions by the means of new material development and use?

Each of these themes has a strategic research agenda that are introduced in this document. **The themes were selected by companies during the strategic research agenda preparation in 2007**. Most active companies in the first preparation phase between September-December 2007 were ABB, Cargotec, Kone, Konecranes, Metso, Nokia, Outokumpu, Outotec, Rautaruukki, STX, and Tieto. Two important features are that **all significant Finnish research units in the focus areas are incorporated** into FIMECC activities and all themes have, through leading Finnish researchers, **established connections to many internationally significant research institutes.**



2. TIIVISTELMÄ

Pääministerin asettama valtion tiede- ja teknologianeuvosto linjasi 2006, että Suomeen luodaan tieteen, teknologian ja innovaatioiden edistämiseksi strategisen huippuosaamisen keskittymiä (SHOK) tietyille teknologia-alueille, jotta Suomen nyt jo vahvat osaamisalat kehittyisivät globaalisti houkuttaviksi osaamiskeskittymiksi. Suomen on panostettava aineettomien menestystekijöiden kehittämiseen, jotta kilpailukykymme kohti tietopääomatyyppisten palveluiden myyntiä kehittyvässä maailmantaloudessa säilyy. Tutkimus on keino tuottaa aineetonta osaamista.

Metallituotteet ja koneenrakennus on Suomessa n. 38 miljardin euron laajuinen toimiala ja sen nykyinen kokonaistutkimusvolyymi on ollut n. 500 miljoonaa euroa. Tämä alue oli 2006 eräs perustettavaksi ehdotetuista SHOKeista. **FIMECCin eräs keskeisimmistä tarkoituksista on rakentaa aito rikastavan vuorovaikutuksen yhteisö metalli- ja koneenrakennusteollisuuden tutkimuskenttään.** Tämä edellyttää sekä yritysten ja tutkimuslaitosten nykyistä monipuolisempaa vuoropuhelua että keskenään kilpailevien yritysten avointa keskustelua perustutkimuksen ja esikilpailullisen soveltavan tutkimuksen alueella. FIMECC on suunniteltu rakenteeksi, joka mahdollistaa nämä molemmat toimintatavat. FIMECC sai Työ- ja elinkeinoministeriöltä SHOK-statuksen 23.1.2008.

Tässä tutkimusagendassa esitetään perustelut FIMECCin toiminnalle sekä esitetään, mille aihealueille strategisen esikilpailullisen tutkimuksen ohjelmia ja rahoitusta tulisi nykyistä voimakkaammin suunnata. Tutkimusagendan **osaamisalueet ovat toimialan suurimpien ja keskeisten yritysten ylimmän johdon esiin nostamia osaamisalueita**, jotka on koettu liiketoiminnan menestyksen ehdoksi. FIMECCin keskeisiä valmistelijoita yrityksinä ovat olleet ABB, Cargotec, Kone, Konecranes, Metso, Nokia, Outokumpu, Outotec, Rautaruukki, STX ja Tieto. **Osaamisalueiksi tunnistettiin palveluliiketoiminta, käyttäjäkokemus, globaalit verkostot, älykkäät ratkaisut ja läpimurtomateriaalit.** Kukin näistä on **yritysvetoisten asiantuntijaryhmien avulla jäsennetty osa-alueisiin ja haastaviin strategisesti tärkeisiin tutkimustavoitteisiin**. Tavoitteena on kullakin valitulla osaamisalueella luoda ja syventää maailmanluokan osaamista ja synnyttää kansainvälistä arvostusta nauttivia tutkimusryhmiä. Teemoittain on otettu kantaa myös siihen, miten tutkimusta teeman alueella olisi hyödyllisintä edistää.

FIMECCin **vuotuinen tutkimusvolyymi 2011 on arvioitu noin 60 miljoonan euron ja 400 - 450 henkilötyövuoden laajuiseksi.** FIMECC **on laajuudessaan ja vaikuttavuudessaan ulkomaisia asiantuntijoita houkutteleva työympäristö ja kykenee kansainväliseen yhteistyöhön maailman johtavien tutkimuskeskusten kanssa.** Strategisen tutkimusagendan lisäksi FIMECCin toimintaa ohjaavat osakassopimus, IPR-sopimus sekä osakkaiden keskenään sopimat hallintokäytännöt.

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4. FUTURE INDUSTRY MEGATRENDS

There are several megatrends in the global economy that change the business environment. These megatrends have an effect both on the way how customers make their choices and on the way how companies can operate. At least six megatrends are present in the future industry business environments (see e.g. Hernesniemi, 2007):

- Continuous globalization
- Industrialization of East and South, de-industrialization of West and North
- Acceleration of new technology adoption
- Rise of environmental consciousness
- Aging populations in highly developed countries
- Increased need for safety and security

The structure of metal product and engineering industries has fundamentally changed during last decades. Globalization has lead us to a situation in which the use of global resources is both possible and cost efficient. Global economy, as it is understood mostly free, covers now more geographical areas and countries than during the cold war. This means that new players have entered the global economic field. At the same time, cost efficient solutions in logistics and information sharing have made it possible to utilize all the resources so that they add value in metal product and engineering industries. The first two megatrends have a direct effect on the organization of supply chains and on the locations of primary markets. These mean that designing and managing global networks is essential.

The third megatrend, acceleration of new technology adoption, means that new generations are more eager to utilize technological innovations than previous ones. Those who wrap the new technology into best user experience will get not only the customers but will also control the communities utilizing these technologies. More and more, technologies are shared between social connections. The fourth megatrend, environmental consciousness, will lead to lower energy consumption and waste demands. This means especially better energy production and utilization technologies. In this direction, new materials (lighter, recyclability, etc.) have a key role. The more we increase productivity by adding intelligence to systems, the more this intelligence should repair the economic footprint of the users of these systems. The two last megatrends explain the need to utilize new technologies in business-to-customer service sector. While well-being, safety, and security services can benefit from existing technologies not applied yet, they also provide a basis for totally new service innovations. In business-to-business sector, the move towards services is driven by customers' need to concentrate on core business. For service providers this trend offers a great opportunity to grow through more stable business relationships.

The megatrends are important while directing a company's business models and R&D activities. The megatrends reflect the thinking of people in general and have serious effect on legislation and consumer demand. In the following chapter, the business environment change in Western industrialized countries is introduced.

5. THE RISE OF INTANGIBLES AND INTELLECTUAL CAPITAL

Exclusive resources at hand should be directed towards higher degree of immateriality and knowledge, because the customer value of these is higher than the producer's cost of using exclusive resources. In Finland, higher percentage of industrial resources than globally on average is exclusive which means that companies should direct activities located in Finland towards higher knowledge intensity. Strategic basic research creates both technological platforms to be reprocessed and upgraded towards applications and products, and critical mass competence basis to be utilized in any development direction needed in the business. In this chapter, the background for this statement is discussed.

The percentage of intangibles (intellectual capital (IC) or knowledge assets) in companies' sales figures and brand values has risen significantly in Western societies. The market-to-book value[1] of Standard and Poor's 500 companies was 1.1 in 1978 and 6.0 in 2001. Even if the historical costs that are presented in balance sheets were index fixed to today, the market-to-book value is about three times larger than 20 years ago (Lev, 2001). This increase is the case in Finland as well. The value of the IC (i.e. CIV[2]) of an average Finnish company during the period 2001–2003 was 3.6 M€. This was approximately half of the value of tangible assets of an average company (Kujansivu & Lönnqvist, 2007). Further details related to the different industries are presented in Table 1.

Table 1. Average values of IC and the relative value of IC in each industry. (Kujansivu & Lönnqvist, 2007)

	Number of companies	Average CIV (euros)	Average CIV / value of tangible assets
Food industry	331	5,590,490	0.43
Forest industry	344	13,955,580	0.22
Chemical industry	319	25,068,410	0.44
Metal refining	1,207	2,310,110	0.23
Electronics industry	184	51,121,530	1.28
Vehicle manufacturing	166	3,186,180	0.39
Construction industry	1,860	953,000	0.39
Business services	3,279	2,006,380	1.04
Electricity, gas and water supply	109	21,594,510	0.27
Wholesale and retail industry	5,308	1,770,050	0.44
Transportation, storage and telecommunications	2,145	3,614,720	0.39

The monetary value of IC differs in various industries. For example, the highest average value of IC (51 M€) can be found in the electronics industry. The relative values of IC also vary across industries. Clearly, the highest values are in the electronics industry (1.28) and business services (1.04). The average values in both industries are above one. Accordingly, the value of the IC of an average company in those industries is higher than the value of the company's tangible assets. The lowest relative values of IC appear in the electricity, gas and water supply (0.27), metal refining (0.23) and forest industry (0.22). These industries are perceived as "primary production"

[1] The ratio of the capital market value of companies to their net asset value as stated on their balance sheets.
[2] CIV is Calculative Intangible Value

industries, in which the value is largely based on tangible assets. Even though the relative IC value is rather low in some industries, the monetary value of IC may still be very significant. (Kujansivu & Lönnqvist, 2007)

The relative price for raw materials and physical routine activities has decreased because of the productivity development. The more actors in the field of competition, the more there are players that can perform routine tasks. This has led the early industrial players (countries and companies) to move towards embedding intellectual capital into products and services. Putting this development into the framework of value chain analysis (see Porter, 1985), many industrial companies have taken or/and are taking steps forward in value chains: They give up early production phases through outsourcing and increase the abstraction level through adding applications and services (Ylä-Anttila & Kulmala, 2007). This move in the value chain is universal across different industries. In Finnish metal product and mechanical engineering industries, many low value-added early value chain activities have been outsourced by the main contractors. The outsourcing has taken place both in Finland and through off-shoring (Ali-Yrkkö, 2007). The outcome is that most of the Finnish large companies are moving towards services, higher percentage of intangibles compared to all assets, and higher abstraction level.

The significance of strategic R&D activities in the evolution and development of business is related to two basic phenomena. Firstly, the more there are research activities the more there is competence in certain focus area. Competence is the primary driver for being able to make changes in the technology base of a company and in benefiting from new emerging technologies. After reaching so called critical mass, a multi-disciplinary competence centre attracts new competent people and the positive churn of innovation becomes reality (Himanen, 2007). Secondly, strategic R&D gives technology leadership compared to companies that do not invest in R&D. This means that R&D intensive companies launch new applications before the followers and can define the trends of an industry and utilize early adopter pricing. There is a significant positive rate of return to R&D investments at corporate sector and national levels, and intangible corporate returns may be twice the rate of return to tangible investment (Abernethy et al., 2003). The criticism against R&D investment comes from cost perspective: it has been mentioned that the followers do not have to pay for R&D but can still benefit from existing markets. This is true, but cumulative technology competencies developed through R&D can be utilized time after time while a copycat has to copy all the innovations each time separately. In the following chapter, different ways to approach research activities are introduced.

6. STRATEGIC RESEARCH – REORGANIZATION IN METAL PRODUCT AND MECHANICAL ENGINEERING INDUSTRIES

6.1. R&D strategy is a choice

There are two basic options to increase innovation: The first option is to increase the investment in research efforts and the second is to increase the probability of each single R&D effort in producing an innovation. There are, naturally, other possibilities as well, like buying innovations from market, but these are mostly variations of these two basic options. In the following, a framework for analyzing research strategies is introduced.

The first option is whether the percentage of revenues invested in R&D is high or low. High investment means that a company invests a significant percentage of revenues to research activities, follows selected scientific fields, and has an R&D strategy that supports the overall strategy. The implementation of R&D strategy is well-resourced. This selection defines the technological position of a company in the market among the competitors. Increasing R&D budget can be completed in many ways. A natural way is to manage an R&D portfolio, in which different projects are positioned to different investment categories. Very early phase curiosity research is not yet in the high-investment category, but some day after certain important results have been achieved, the project may be moved into this category.

The second option refers to acting alone or together. Multidisciplinary studies lead to new perspectives and increase the probability of getting innovations as the outcome of R&D efforts (see e.g. Himanen, 2007). In general, increasing interfaces and multidisciplinary confrontations and get-togethers make it more likely to create an innovation than a closed R&D project. Hence, the second option means increasing innovation probability of each individual R&D effort by carrying out R&D in a multidisciplinary and multi-interface environment. This is, in practice, open-source thinking, cooperation with competing companies (co-opetition), and close connections to research institutes. Because of the openness demanded in these activities, the activities are primarily directed towards technology platform R&D. In the phase where generic platform research seems to turn into applied research, application development or product development, a company can flexibly move towards in-house activities and avoid the problems of having competitors around the same research table.

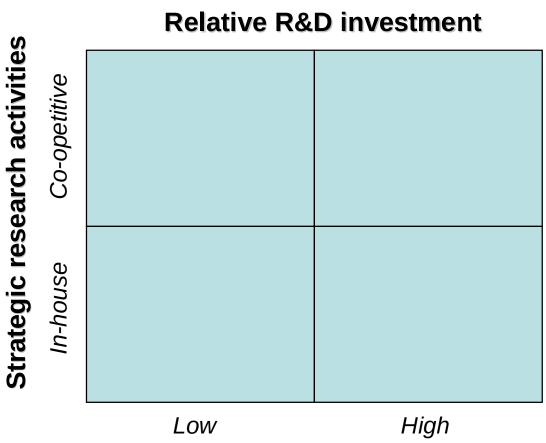

Figure 1. Classification of R&D activities

Figure 1 summarizes the classification of R&D activities according to the utilization of these two options. If none of the options is used (lower left corner), a company relies primarily on other competencies than technological leading. The business may be based on applying or even copying what others have developed earlier. If only the first option is utilized (lower right), a company either is afraid of competitors getting access into its knowledge or is sure about its technology leadership. Pure corporate R&D strategy calls for capabilities in managing both own and exclusively bought service research. If the second option is utilized alone (upper left), a company relies on interface strategy in which the investment effort is not too high but the effort is done with actors who increase the probability of innovation and especially R&D outcome applicability. Low investment into many scattered areas may end up with surprising innovations but lacks the determined goal-orientation. In this strategy, the key to success is to ensure the competencies and capacity to notice and further develop the winning technology platforms that happen to be at hand. If both options are utilized (upper right), a company may end up as a continuous innovator. With this strategy, a company can co-opetitively with competitors identify the primary sources of future competencies, carry out strategic R&D towards that, and move into in-house operations at the phase of too intimate business discussion at the joint table. Coordination and synchronization of co-opetitive and in-house R&D efforts is necessary in order to balance the independent work and the work that can be carried out jointly with others, not having to carry out same analyses twice.

6.2. SHOK – reorganized strategic research

Strategic basic research is something that companies can do together in order to increase the number of innovations. If the scientific discussion and communication is limited to technology platform areas instead of business details, companies can act open enough without endangering their information that is classified with non-disclosure label. Strategic basic research can be platform like research carried out with competitors and other stakeholders in order to develop the understanding of business environment. Application development is the responsibility of each company separately and independently. For example, German auto industry and mobile communication companies have long traditions of integrating competing companies into same technology projects. The co-opetition strategy is based on two assumptions: Higher research volume, as such, produces typically more innovations than lower research investment, and more interfaces with different actors (competitors, research institutes, and other competencies) increase the probability of innovations to take place. The search for new innovations is not only researching and producing alone something, but researching together and competing on how to build applications on the joint platforms.

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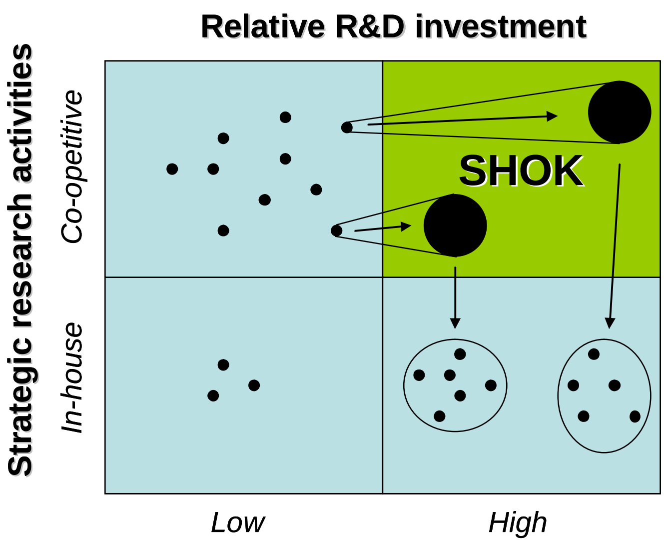

Figure 2. The position of SHOK in the generic classification of R&D activities.

Figure 2 introduces the primary orientation and the role of SHOK in the R&D activity map. The most important required attitude from the members' side is co-opetition. Also significant (high) research volume is expected. Since SHOK is not responsible for all the research carried out in the area, many very early phase research efforts are funded outside the SHOK (left corners). These efforts must be academically freely selected and their research volume is typically not high. However, when companies are involved, and preferably co-opetitively, at a certain point an activity may turn out to produce so promising results that SHOK participants are willing to define the research project or area as strategically important. In this phase, the research effort is moved into SHOK category and the investment is multiplied (from upper left to upper right corner). The SHOK research may produce technology platforms that in certain phase can be moved towards the application development and in-house activities (from upper right to lower right corner). In this phase, the volume of each single development effort is decreased but the number of efforts in certain technology area may be high.

The difference of SHOK activities and later phase application development is that SHOK activities are still in the high risk phase. Companies can minimize the drawbacks caused by realized risks by carrying out this phase co-operatively and in this way sharing the risks.

6.3. History of FIMECC SRA

In metal product and mechanical engineering area, the SHOK is FIMECC Ltd (Finnish Metals and Engineering Competence Cluster). FIMECC was established in April 2008 after one year of preparations. The preparation had two phases: Initial research theme selection in spring 2007 carried out by consultants through interviewing the most important decision makers in industry and research institutes. In fall 2007, organizations interested in being shareholders were organized into five theme groups and these groups were responsible for the first SRA writing.

The Federation of Finnish Technology Industries was the process owner and companies took responsibility of the chairmanship of the five selected themes. In The Federation of Finnish Technology Industries, the process was led by Juha Ylä-Jääski with Ilkka Niemelä and Harri Kulmala as the operational task force. The five chairmen in themes were Nelli Paasikivi (Konecranes Oyj), Anne Stenros (KONE Oyj), Fredrik Nordström (ABB Oy), Jukka Ylijoki (Metso Automation), and Arto Ranta-Eskola (Rautaruukki Oyj). The first SRA was written in short time period September-December 2007, and the Finnish Ministry of Labour and Economy promoted FIMECC with SHOK status in January 2008.

The company was established and operation details are available in the annual reports. The board of directors decided to update SRA in 2009 and this version is the one and only FIMECC SRA steering the company's activities.

6.4. Positioning of FIMECC research activities

FIMECC activities can be positioned into the field of all research by utilizing the traditional Matthews' curve that describes the risk level and monetary funding. Traditionally, the monetary funding increases while the market orientation increases. In Figure 3, FIMECC activities are positioned between pure academic research and new product development (NPD) oriented applied research. The figure is a simplification, the complexity of issues and circumstances related should be remembered. The project portfolio of FIMECC consists of several projects (see circles in Figure 3), some of them being more application oriented than others. On average, the portfolio is Gaussian distributed so that strategic long-term research projects form the majority.

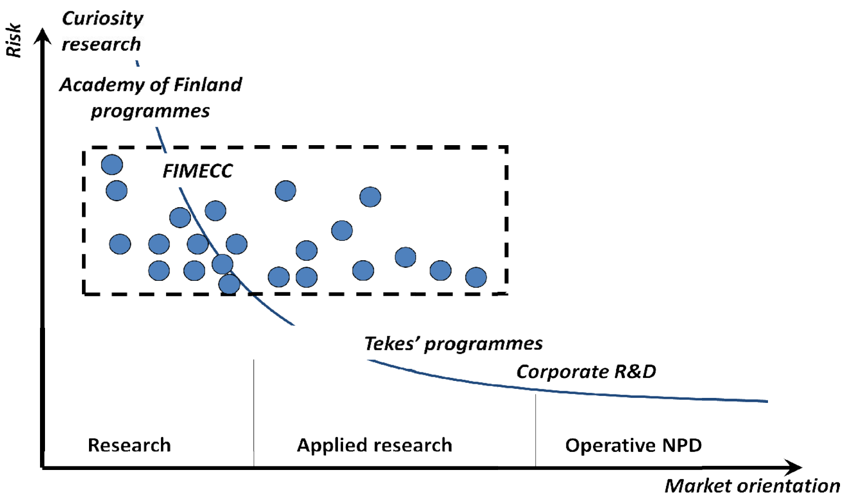

Figure 3. Position of FIMECC research activities in the Matthews' curve.

The role of FIMECC activities in the overall industry research and innovation system is introduced in Figure 4. Here we see FIMECC as a way to carry out mid-term and especially long-term strategically focused pre-competitive research by setting goals and managing research actively. FIMECC is not an outsourced resource for companies' NPD projects. The most important FIMECC activities can be described as strategic platform research, in which the participants openly cooperate even though in the market they are competitors in the market. The time frame for activities is 3-10 years before market launch. From this set of platform research, applied research initiatives are evolutionary created. Here, some but not all the FIMECC participants form horizontal consortiums consisting of companies that jointly carry out pre-competitive applied research. In FIMECC, research activities can also be built around vertical supply chains, in which direct competition between companies does not exist. At certain point, market orientation becomes so evident that the activities must be funded by other means than FIMECC. After this point, many short-term oriented NPD projects are initiated by companies separately without cooperation.

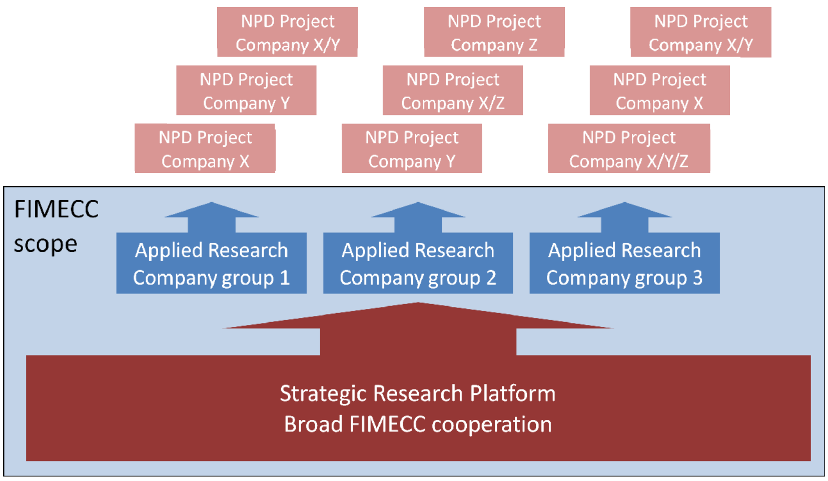

Figure 4. The role of FIMECC research activities in innovation system.

The creation of this kind of innovation system into the industry is not possible without companies' commitment to the model. The most significant education & scholarship centres in the world have proven through 5000 years of history that the model of co-opetition creates enriching communication leading to more innovations than without communication (Himanen, 2007). Being part of this kind of enriching communities makes it more likely for companies to success than being out. However, the system is not an automated innovation generator. The companies that do not invest also into their own final NPD cannot fully benefit from continuously developing technology platforms.

7. OBJECTIVES

7.1. Research investment in practice

The total turnover of metals and mechanical engineering industries in Finland was 38 B€ in 2006 representing 30% of the overall industrial output of the country. The value added in these industries was 10 B€ and the value of export was 23 B€. The export of these industries is one third of the total export of Finland. In 2006, the number of employees in these industries was 153 000 which represents one fourth of the total industrial employees in Finland. The industry's impact on Finnish national economy is significant. The R&D investment of the companies in the industry was 445 M€ representing 1.2% of the turnover. In addition to this, public R&D investment in universities and research institutes was 39 M€. In 2006, the total investment in the research related to these industries in Finland was thus 484 M€ representing about four thousand employees' annual R&D input. Due to the global recession after 2008, the figures of 2006 are more or less relevant again in 2010.

The vision of FIMECC:

World Class Platform for Science-Based Competitiveness. FIMECC will create new international research networks, new top science, and new application-driven research contents. The competence and knowledge in selected focus areas will be raised to globally leading position. The research activities are based on ambitious target-orientation, openness, dynamics, and true internationality.

The primary targets of FIMECC:

Revolutionary Engineering – Perceiving Customers' Needs First. Finland-based companies will make a difference in the global markets through utilizing new excellent knowledge of FIMECC especially in customer needs understanding, breakthrough market launching, and successful customer solution piloting and implementing.

The objective of FIMECC is to double the industry's R&D investment by the year 2015. This will be done step by step through implementation of SHOK activities in successful pilot programs after which more companies will be interested in participating into the activities. The increase of funding includes the objective of increasing also the absolute monetary R&D investments.

The estimated research volume of FIMECC as a percentage of the industry sector's total research volume is about 10 per cent in 2010. The estimated monetary research volume of FIMECC in 2011 is ca 60M€, which means about 400-450 persons working annually in the research programs of the FIMECC. This amount is invested on five research themes (below, a short summary of the research questions in each theme):

- **Service business** — How to build understanding on service business logics, customer demand forecasting, inter-organizational new service development, benefit sharing, and open service innovation systems?

- **User experience** — How to create established structures for understanding diversifying user profiles and design leadership platforms?
- **Global networks** — How to create and manage agile, flexible and resilient demand and supply networks in continuously changing business environment?
- **Intelligent solutions** — How to increase the value added of customer solutions by the means of product and process-integrated intelligence?
- **Breakthrough materials** — How to improve the performance of customer solutions by the means of new material development and use?

The primary objectives of the themes are expressed in Figure 5. Each of these themes has a strategic research agenda that are introduced in Chapters 6-10. The themes were selected by companies during the strategic research agenda preparation. The national and international cooperation of companies and research institutes / universities is introduced in each theme. Two important features are that all significant Finnish research units in the focus areas are incorporated into FIMECC activities and all themes have, through leading Finnish researchers, established connections to many internationally significant research institutes.

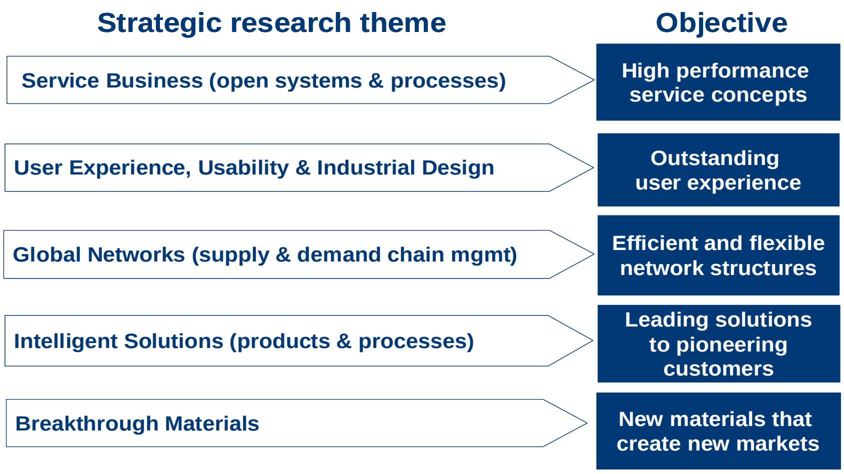

Figure 5. FIMECC research themes and objectives.

7.2. Cooperation

During the research agenda preparation, FIMECC themes have been cross-checked with three other SHOKs. In addition, the operational principles and contract documents of FIMECC do not significantly differ from those in TIVIT Ltd. The connections between FIMECC and other SHOKs key responsible persons have been established.

Forest Cluster Ltd. (SHOK for forest and paper industry) is in continuous discussion with FIMECC because of two reasons. Firstly, the paper machine and forest sector equipment companies are primarily operating in mechanical engineering industry. This means that they are interested in both SHOKs. Secondly, some of the FIMECC research themes are non-industry specific, which means that also Forest Cluster Ltd. shareholders are interested in participating into FIMECC research activities.

TIVIT Ltd. (SHOK for information and communication technologies) is mainly built around four technology-oriented research themes and services. Their participants have been active especially in the preparations of generic business-oriented research themes in FIMECC. CLEEN Ltd. (SHOK for energy and environment issues) is in the phase of research theme preparation and many FIMECC shareholders and program participants seem to be active also in CLEEN. This is mainly caused by a large proportion of mechanical engineering companies' activities in building energy production and energy saving equipment.

RYM Ltd (SHOK for built environment) and SalWe Ltd. (SHOK for health and well-being) start programs and activities in 2010 and will be in close link with FIMECC.

FIMECC builds joint research initiatives and programs with other SHOKs during 2010-2012. SHOKs foster cross-industry innovation by bringing together researchers and practitioners from different industries and SHOKs avoid double work by cross-checking program contents.

Year 2010 will be the start of wider and deeper international cooperation in FIMECC activities. Normal and traditionally good international cooperation of the actors in our programs will be supported by FIMECC-level international activities and partnerships.

8. SERVICE BUSINESS

8.1. Background and motivation

Service business has grown in importance in all industries. For an increasing number of companies service business is becoming critical in order to achieve a sustainable competitive advantage. When the possibility to make technological breakthrough innovations decreases, **new sources for competitive advantage have to be found.** There are two basic options:

- Competing with price and
- Offering customer-based innovative services.

Price competition tends to be difficult unless a sustainable cost advantage can be maintained. For many companies it is instead the second option, offering customer-based innovative services, that offers a real basis for a sustainable competitive advantage.

8.2. Vision, mission, and synergies

8.2.1. Vision

In 2015, Finland is the leading country in service business leadership and management which leads to success for the Finnish industry as well as their customers.

8.2.2. Mission

FIMECC service business research supports Finnish companies' ability to successfully develop, design and implement customer-centric service and thereby manage business relationships with customers on a global level. The research also raises the level of competence, skills and cooperation of Finnish service research to a higher level.

Service business research

- generates new understanding for the participants of how an internationally sustainable competitive advantage can be developed through the adoption of customer-centric services for industrial companies,
- generates new innovative business models, and
- creates new understanding regarding operative service processes and the management of these.

The service research aims to serve participant companies and their management by developing their business models, processes and solutions so that they better can support their customers' business and value creation. Furthermore, the research aims to serve the customers so that they are able to develop their own business and operations and fully benefit from the services. Thereby the customers will gain competitive advantage while the service providers will find innovative new paths towards a growing internationally sustainable, service-oriented business.

8.2.3. Synergies with FIMECC's other research areas

There are significant synergies with other focus areas such as Intelligent solutions, Global networks, and User experience. The life-cycle approach of equipment and systems, especially the data and knowledge gathering processes, is important link to service business. The gathered information is an essential part of how value is delivered to the customer and how to better serve the customers' value creation process. Also in the theme of

Global networks there are synergies in service production process since most service are designed, developed and managed together with others in a network of interlinked companies. User experience as a theme is close to Service business since they both focus on the customer; how the customer uses and values the product oftentimes in terms of processes thus services.

8.3. Focus areas and research objectives

Five focus areas for the research have been identified:

- Service business and earnings logic in industrial companies
- Service design, productization, product management and development process
- Service production and operative management in local and global scales
- Profitability and productivity in service organizations
- Conceptualizing and categorizing service business

Service business logic means that customer-centric services can be offered to customers as standalone activities (e.g. a repair activity, spare part, consultation service) or as an integrated part of an offering to customer in a life-cycle relationship (e.g. integrated support to the customer's business including products and service activity components). When the business is based on the logic that the provider aims to understand and improve the customer's business then we talk about service as business logic.

8.3.1. Service business and earnings logic in industrial companies

Description of research focus:
Today, companies manage and organize their service activities according to certain business logic. Some firms' focus is to develop new service activities, but in most cases the management challenge is to reorganize the product and service components into integrated offerings or to reorganize the service activities into a business managed by a service-based logic. The idea of service logic in management is to integrate products and service activities into an integrated customer relationship based service business.

Ultimately, the management challenge is to reorganize the entire business according to service logic, in order to secure a sustainable competitive advantage. Another challenge for many firms is to understand how service activities can be used to gain a share of a customer's total need for services and products.

To have service as business logic means to renew and redefine value creation for the customer, value capture for the provider, benefit sharing, earnings logics and pricing models, and measurement instruments and metrics. All this needs to be done in order to understand the managerial implications of these viewpoints when a company is operating according to service logic or moving towards the service logic.

Why:
The outcomes of service business logic help companies to develop innovative service offerings or integrated offerings including products and service components in a customer-centric way. Furthermore, the focus area aims on assisting management of such offerings, and respectively the customer relationship, successfully. It should also help companies move towards adopting service-based logic not only for a separate service business but also for the entire business. This is considered as an opportunity for sustainable competitive advantage.

8.3.2. Service design, productization, product management and development process

Description of research focus:
Service design, productization and service product management have proven to be challenging. For physical products it is easier to define physical measures and references to the products. For services, the level of abstraction is higher, and this means that it is not clear that the customer understands what the value or content of a service is. In some cases it seems that it is not so clear for the service provider either.

The design or productization of services is not a synonym for standardization. The aim in productizing services should be to maintain the flexibility and adaptability to customer needs and requirements while still achieving efficiency of operations through systemizing them.

Why:
When a service is productized, it enables a customer to understand the content and, hence, the value of the service in more detail. From a service provider viewpoint the productization increases understanding of the content and it systemizes the way in which a service is delivered, which in turn makes the delivery of the service more efficient.

All these increase the mutual satisfaction in service business: the services are understood in a similar manner by different interest groups and service delivery is taken care of in a professional manner, thus achieving the expected efficiency and quality. This focus area helps companies to productize offerings in ways that are geared towards inherent sources of competitive advantage in services.

8.3.3. Service production and operative management on local and global scales

Description of research focus:
Service processes are open systems, i.e. systemic in a company network. A systemic process requires collaboration of two or more entities that are separate but interdependent.

These processes, their management and related information and knowledge management differ from the closed processes within an organization. The dispersed service processes should be considered over the different levels of organizations. Firms also face challenges to design global service offerings, production and management, that can be adapted to local conditions. Operating in a network setting is often an integral part of international business and this poses many challenges for the industrial companies offering services.

Why:
Value is created in these systemic processes. On the other hand, so are the costs. Understanding the systemic service processes and the factors that influence them enables good management models, practices and processes. Good management of service and service delivery processes enhances service quality and efficiency.

8.3.4. Profitability and productivity in service organizations

Description of research focus:
The productivity models and metrics that are used in manufacturing are based on a *closed system* situation, where:

- The production process (resources used, flow, timing) does not have an impact on the customer's processes and business,
- The customer is not involved in the production process and is not influenced by the process (by resources used, the flow of the process, and the time schedules),

- Regardless of changes made in the input into the production process (resources used, flow, timing), the quality of the output, i.e., product quality, can be maintained by quality control processes, and hence
- Changes in the cost do not have an effect on revenues, but instead a more or less direct positive effect on profitability.

In service none of these closed system characteristics are true.

Service processes are *open systems* where production and usage, and thereby also service provider and customer, interact to a considerable degree. Changes in the service production process (resources used, flow, timing) have an immediate impact on the customer's perception of the quality of the service. The revenue-generating capacity of the service provider is affected.

As a consequence, when traditional manufacturing models and metrics are used in service processes, the outcome is often unwanted. Lower costs ("improved productivity" in a manufacturing sense) do not result in improved profits. Instead it may create customer stress, unsatisfied customers and lost business.

Why:
In services, productivity is more a *business process-level issue* than a cost consideration only. Hence, the development of service based productivity model that takes into the consideration the open system nature, and related metrics, is critical to a successful service business. Solving this issue would enable companies to more accurately manage profitability in service businesses, and create e.g. valid reward systems.

8.3.5. Conceptualizing and categorizing service business

Description of research focus:
There is a large variety of different services, ranging from spare part services and maintenance to operating a customer's plant. Clearly, it is important to study what is included in the field of services and to develop a categorization of services.

Why:
Service business is unclearly defined and there is a variety of different services and service terms. Thus, misinterpretations and –understandings take place and there are difficulties in communication.

This focus area helps in understanding the current state of service business and it creates a solid understanding of different approaches to services and service business. It also helps us to understand if we have reached our goals in 2015.

8.4. Industrial and research partners

The estimated annual research volume of service business theme is about 5 M€ consisting of 40-50 researchers. Five of them are new recruited senior post doc researchers and five new recruited graduate students. This means significant new research investment in the strategic research of service theme. International researcher mobility will be utilized, and companies will participate in service business research community enlargement by providing scientific challenges and facilities for researchers.

In the following list, the national research institutes - universities and research centers - that have been funded from the Tekes Serve technology programme are identified:

- Aalto University, Helsinki School of Economics – HSE
- Aalto University ,Helsinki University of Technology – TKK

- Lappeenranta University of Technology – LUT
- Hanken School of Economics– Hanken, CERS
- Tampere University of Technology – TTY
- Technical Research Centre of Finland – VTT
- Turku School of Economics – TSE
- Aalto University , University of Art and Design Helsinki – TaiK
- University of Helsinki – HY
- University of Jyväskylä – JY
- University of Oulu – OY
- University of Tampere – TaY
- University of Turku – TY
- University of Vaasa - VY

8.5. International research institutions and cooperation

During the research in FIMECC service business theme the aim is to increase and expand international research collaboration. Current international cooperation is built around three efforts:

- Industrial service business development forum's (BestServ Forum) EU-funded joint research program (InCoCo), which is coordinated by Forschungsinstitut für Rationalisierung (FIR an der RWTH Aachen, Germany)
- Cooperation with U.S. universities (Berkeley and Stanford) originating from IBM's Service Science, Management, and Engineering initiative and Tekes
- Preparation of joint research program with Cranfield and Berkeley Universities.

Other important international research institutions in the area of service business in industry include e.g.:

- Centre for Service Leadership, Arizona State University, USA
- Fraunhofer Institut, Germany
- Fudan University in Shanghai, China
- Indian Institute of Management Bangalore, China
- Service Research Centre, Karlstad University, Sweden
- Université de Bretagne Occidentale in Brest, France
- University of Lille, France

The focus in the future is especially in identifying the research institutions in the growing service economies - mainly in Far East, e.g. India, China, Korea.

9. USER EXPERIENCE

9.1. Background

9.1.1. User experience, usability and customer satisfaction

User Experience (UX) means users' perception of a device, product, service or system during its whole life cycle in a given context. *Usability* is a key factor in user experience referring to the quality of use of a system including its efficiency, effectiveness and users' satisfaction. In addition to usability, a range of personal, technical, social, business and cultural factors influence on UX.

Because metals and engineering industry typically operates on business-to-business markets good user experience is not enough, if it does not lead to *customer satisfaction*. Customer refers to the organizations applying metal and engineering products and services for running and developing their businesses. Users refer to persons interacting with the products including, e.g., installation, operation and maintenance. Users are often but not exclusively employed by the customer organizations.

9.1.2. Design for user experience

Design for user experience (DUX) refers to an approach where user experience and customer satisfaction are guiding the design through ideating, creation, planning, prototyping, production and use of products and services. Design for user experience is a cross-disciplinary integrated design approach, which includes, e.g., design research, industrial design, interaction design, communication design, service design, participatory design, work and organizational research, engineering design and business planning activities in a strategically orchestrated manner. In addition to the technical level also individual, societal, business and cultural levels need to be considered in DUX. Even if the impact of user experience on customer satisfaction in metals and engineering industry is recognized, companies presently lack means to study user experience, to design good user experience and to set measurable targets for user experience.

9.1.3. Changes in design environment

Innovation environment is changing because of increasing globalization, democratization of innovation, environmental concerns and technical development.

Customers of metals and engineering industry are increasingly expecting to get comprehensive service solutions that enable them to focus on their own businesses. These need to be usable, even though the underlying technical solutions are getting increasingly complex. When targeting good user experience, complexities need to be managed ensuring that users understand the systems and have easy ways to control them.

In the future, innovation competence is based on the access to knowledge networks rather than the ownership of knowledge. Professional boundaries are blurring with multi-professionalism and interdisciplinary design approaches. Technologies, products and services are seen as enablers and platforms for co-operation, communication and competence creation. User role is also changing; user can be a content creator and increasingly also a co-designer. Open innovation calls for new kinds of collaboration models between different types of organizations.

Requirements for sustainability set additional demands to the design of full life-cycle solutions. Global markets and distribution of manufacturing and design over several geographic areas and cultural environments increase the challenges in design collaboration.

9.1.4. Development perspectives

Turning the present change factors into innovation assets requires deep understanding of user experience and customer satisfaction. New competences in DUX are needed including new design methods, models and tools to facilitate user and customer driven design approaches. The metal and engineering industry needs design strategies to develop its competence and innovation capability in the area of user experience. To conclude, Design for user experience and usability theme has recognized four development perspectives:

- *Strong UX knowledge base*: industry-wide understanding of the impacts of usability and user experience on customer satisfaction and business profitability
- *Cutting edge UX design practice*: developing and adopting customer and user driven open innovation methods and practices
- *Leadership in UX solutions*: Improving user experience and usability by developing and adopting advanced user interaction tools, environments and solutions
- *Commitment to design strategy*: Developing strategies for continuous improvement of Design for user experience capabilities

9.2. Vision 2015

In the year 2015 the market success and competitiveness of metals and engineering companies are strongly related to how well the companies understand their users and customers. User experience and customer satisfaction are central business factors that are continuously monitored and that guide daily operations and future plans. Complex systems show to their users as simple personalized services. Design includes increasingly collaboration in open innovation networks with customers, users, other companies and the academy. Knowledge transformation between research and practice, academy and business is essential for ideating and innovation processing. Regardless of their scale and scope – global, international, or SME level – the Finnish industries are well known for their wide and proactive approach in design. Companies utilize virtual and augmented reality solutions as well as multimodal user interaction tools to provide good user experience in interaction tasks and to improve usability and productivity.

In short, year 2015 there are several companies in Finland with ownership in design strategy, and cross-disciplinary design processes as well as user and customer driven innovations. Finnish companies are well known for their ability to manage and integrate design, technology and business.

9.3. Focus areas

The theme Design for User Experience and Usability drives knowledge creation and new practices in developing user and customer experience excellence. It increases the capability and competitiveness of Finnish metals and engineering industry by developing and implementing new design and collaboration methods that produce excellent user experiences leading to strong customer satisfaction. The theme offers an opportunity to learn about the latest knowledge of user experience in the context of open innovation and complex systems together with different parties: companies, universities, research centers and end-users.
Several actions are planned to enhance the cooperation and both efficiency and effectiveness of research:

- Regular theme workshops together with researchers and companies with carefully defined topics and invited key note facilitators
- Close co-operation with the FIMECC Intelligent solutions and Service and Global Networks themes and TIVIT
- Environments and facilities for co-creation and open innovation
- Planning and launching the close co-operation with the top international research partners at the area

- Launching an exchange and recruitment program together with companies and research institutes to provide the necessary research force for the needs of the theme on both academic and business sides

The results will be realized in companies both in short and long term. The theme enhances development on five levels:

1) User experience as a business factor
2) Open innovation practices
3) Design of complex systems
4) Interaction tools and
5) Strategic foresight and decision-making.

The first results will be available already during the first two years. Better product and service platforms help companies to benefit from industrial design in much wider scale than ever before. Understanding how design can be used in reducing complexity, manufacturing and assembly costs and other life cycle costs will help companies to launch more competitive products and services that are not easy to copy.

The focus areas of the theme are described in more details below:

9.3.1. User experience as a business factor

This focus area aims to recognize the factors that good user experience and customer satisfaction consists of. The relationships and differences between user experience, customer satisfaction, usability and business performance need to be analyzed and communicated broadly with metals and engineering industry. The impact of good usability and user experience as a business factor is indirect, vague and difficult to measure because of the multitude of situational, cultural, ideological, financial, functional, emotional, motivational etc. aspect. However, in order to achieve changes in present R&D practices the business value of UX should be demonstrated. Firm connections to business processes require setting concrete measureable goals for user and customer experience. This requires that UX could be successfully defined and implemented for different practical purposes. It is also important to understand the local in the context of global, i.e. cultural knowledge, trends and life style studies, user variations, social graphs, and social networks. 'User experience as a business factor' has a strong educational mission and is more conceptual and close to basic research than the rest of the focuses.

9.3.2. Customer and user driven open innovation practices

The customer and user oriented innovation can create growth and profit for companies through empowerment and engagement of users. The design of every machine, device, automation or service system should include users' perspective and explore and anticipate their experiences; recognize key user groups among different stakeholders and identify their motives and concerns. Customer and user driven design is an approach where customers and users inform and inspire the design teams but also act as co-designers contributing to the design with their professional knowledge and ideas. In addition, companies need to utilize also other actors' contribution. Open innovation means a paradigm shift from the innovation process to innovation networks where companies are actively using not only internal but also external partnerships for ideating and innovation processing. In this focus, globally best practices for customer and user driven innovation in complex systems will be identified; applied and further developed in case studies. The research will include international collaboration with world-class companies and research institutes.

9.3.3. Human-centered design of complex systems

Design for user experience is increasingly utilized to ensure usability, reliability and efficiency of highly-automated complex systems. By complex systems we mean the transformation from one-to-one user-product interaction to personalized systems of integrated technologies and services that may involve many users in different professional and consumer roles. It also emphasizes that products, services or systems are parts of larger systems and that is why design can seldom be carried out in isolation but the new system has to be smoothly integrated with existing systems to facilitate good user experience. New human-centered design approaches and methods are needed to understand and design the complex human actors-technologies-services entity as a functional unity.

9.3.4. New interaction solutions

Usability, user experience and work efficiency can be improved with new user interaction tools that create e.g. realistic feeling of (virtual) presence and versatile ways to control the system. Virtual and augmented reality as well as distributed and multimodal interaction tools facilitates new kinds of control rooms with feeling of presence, broad co-operation possibilities and realistic feeling of control. Interaction tools that allow users to customize their own environments and solutions for supporting learning are also needed. Remote operation is typical in future machines and this requires new interaction tools based on virtual and augmented reality and multimodal interaction tools. Virtual modeling can be utilized in the design and early user studies of complex systems. Important user experience factors include competence, feeling of presence, being in control and trust.

9.3.5. Design strategy development

The changes in innovation environment and especially in the role of design as a mediator between different stakeholders call for commitment on developing design capabilities. It is not enough that the focus is only on learning to apply new methods and techniques for more efficient design project completion, but the organizations need to acknowledge the potential of design as change agent. Metals and engineering companies need to ensure mutual exchange of knowledge between design and business development and create strategies for collaboration and competence development. Design strategy development is a focus that requires deep company research institution collaboration as it there is no universal correct design strategy applicable for different industries and companies.

9.4. Partners

9.4.1. Industry partners

The following industry parties have participated to the planning of research agenda, and indicated their willingness to join the research theme based on the following strategic reasons: KONE sees the urbanization both a challenge and an opportunity in the business. Understanding the changing needs in urban areas as well as the user's point of view is crucial for the future success. Differentiating through the human-centered innovation and design is one strategic objective in the global competition.

One of the core strategic elements of ABB is energy efficiency, both from the viewpoints of customers' business and the global environmental load. ABB is strongly a B-to-B oriented company. Therefore the research subjects related to usability, user experience and user interface are most interesting in strategic sense.

Nokia is one of the most advanced companies in applying industrial design in all operational levels. The above mentioned trends, designing of user experience, personalization, in use modularity, are among many others the issues that make the FIMECC research theme interesting and strategically important for the company.

Metso has developed its industrial design competence systematically for years. The company has launched an in-house design center that serves the business units. Industrial design is an essential and seamless part of product development and concurrent engineering projects. The strategic tasks of industrial design in Metso are: facilitation of concurrent development, spreading best practices, advancing cost effectiveness and awareness in product development, supporting technology leadership by differentiation and customer and user centric design. FIMECC research theme is in line with the future challenges of Metso Industrial Design and the whole company.

Other potential parties include at least Rautaruukki, Konecranes, Valtra, SRV, Sweco, Deltamarin, Elomatic, Ponsse, Cargotec, Amer. The estimated volume for user experience research theme in 2010 is 1,5 M€ employing approximately 10-25 researchers.

9.4.2. Research partners

Research parties pointed out by the industrial companies include:

- Aalto University (Industrial and Strategic Design, Medialab, Designium, Design Factory, IDBM Program, Organization and Management, Usability School, BIT research centre, Machine Design, Architecture)
- VTT, Technical Research Centre of Finland (Human Technology Interaction)
- University of Helsinki (Cognitive psychology)
- Jyväskylä University (Agora Center)
- University of Lapland (Industrial Design)
- Tampere University of Technology (IHTE)
- Lahti University of Applied Sciences, Institute of Design

9.4.3. International cooperation partners

The list of potential international research parties is based on the business and cultural interests of the industry. On the other hand, in order to avoid unfocused and numerous list of contacts, the highly ranked, well known, or especially interesting ones are favored. The list below includes only already established cooperation:

- Stanford University (Center for Innovation, d-School) has developed cooperation with Finnish universities and companies (e.g. Nokia) for years.
- Massachusetts Institute of Technology (MIT, several institutes e.g. Sloan School of Management) and Rhode Island School of Design (RISD) are continuously and successfully cooperating with Aalto University and Finnish companies. E.g. Nokia has a research unit situated at MIT campus.
- Illinois Institute of Technology (IIT): Institute of Design, and its Strategy Conference would be excellent partners for the program.
- University of Maryland: KONE has good relationships with the Center for Convergent Design.
- Design Management Institute (DMI): The leading forum for design management in the world, based in Boston, US, a good collaborator for the program.
- Indian Institute of Technology (ITT, in Mumbai and Kanpur) is a highly ranked Indian university. There is strong interest in cooperation.
- The Hong Kong Polytechnic: KONE has very good connections to one of the leading universities in Asia.
- The Royal College of Art, and University of Cambridge are established research parties with Nokia. Both are highly appreciated actors in design research and education.
- Philips Design: KONE has started collaboration with the design teams based in Eindhoven.
- ABB Global Labs. ABB is interested in connecting some their international research sites to the FIMECC activities

10. GLOBAL NETWORKS

10.1. Vision 2015 – Flexible, Innovative Networks

Emerging economies are driving the dynamics of global business. Companies of all sizes need to operate in new markets and utilize local resources, while maintaining global competitiveness in their chosen business areas.

In the year 2015, management of global networks is a capability that creates substantial value for Finland. The “Finnish way” to create and participate in networks is strong leadership through management practices and processes that are measurably efficient and effective in controlling flexible and innovative networks of collaborating firms. Customer focused operations are seamlessly integrated into leadership and mastering technology. The adoption of advances in technology and management research makes it possible for manufacturers to sell a product and thereto related services globally that is manufactured and delivered - with uniform quality and efficiency - in several interchangeable sites around the world. Planning and management makes efficient use of real-time visibility across customer channels, retailers, manufacturers, third-party service providers as well as suppliers.

The “Finnish way” is world-class in operating high-performance dispersed logistics for: (1) project business and engineering driven processes, and (2) cost efficient manufacturing of high product variety. The industry in 2015 has acquired the skills and know-how to develop and use technology and management research in a way that enables it to rapidly capture emerging markets, and opportunities in supply and logistics by developing, creating and re-structuring demand-supply networks. Product life-cycle management and product-service systems support these networks that are responsive, agile and resilient, or said in another way, self-adaptive and self-organizing. Central characteristics in these networks are concepts like modularization and high utilization of widely accepted standards enabling scale of economics.

Companies are skillfully benefiting from development in collaboration with users, customers, and suppliers. In 2015 enterprise tools are network centric and service based. The IT tools deployed incorporate the ‘self-organizing’ features of the best web applications and take the human perspective into account to enable breakthroughs in innovation, efficient marketing and network collaboration.

10.2. Long term objectives

FIMECC Global network (GN) is supporting Finnish companies with world-class experts, tools and management practice in global network design and management. The goal is to ensure the competitiveness and value creation capability of Finnish industry according to the vision above.

To fulfill its mission FIMECC must maintain a clear strategic understanding of what is required in order to recognize how global project business and logistics needs to be developed and how Finnish industry can best benefit from the development. Research on what type of operations and industrial structures can help Finland prosper, are key for strategic understanding. On a more tactical level, it is important to do research on how to manage reliable and swift transfers of operations, technology, inventory and information on a global scale. For the long term objectives the focus areas listed in the table below have been identified.

10.2.1. Focus areas

Focus area	*Example of research questions in focus area*	*Type of research needed to answer research questions*
1. Strategy and global networks		
Global change and trends	*Change in project and engineering driven business: emerging trends in global value networks* What is changing the customer and supplier perspective? What are the changing forces? How are operational processes changing?	Foresight studies, economic research
Impact on Finnish industry	*The effect of outsourcing parts of value chains in Finnish project business* What type of operations can survive in Finland, which disappear, which move and where?	Value chain modeling, case study, survey research
Strategic response	*How can Finnish companies respond to global change*	Scenario workshops, roundtable
Strategic relationship analysis	Under which conditions are different kinds of relationships and control mechanisms at their best? *How does value creation emerge?*	Case study, statistical analysis
2. Value network design and management		
Dispersed dynamic enterprise network design	*Network re-configuration in project delivery* How to select logistics partners and information systems designs that can easily link and handle materials and information from different parties?	Best practice surveys, solution design cases, simulation modeling, economic value analysis, DSM mapping and analysis
Real time enterprise	*Service supply chain* How to apply installed base visibility for positioning spare parts and service personnel efficiently? *Rapid manufacturing* Role of rapid manufacturing and other digitally defined product and production technologies in global real-time manufacturing and service operations?	Technology analysis, business scenarios, simulation modeling, economic value analysis

Leadership	*Leading global networks* How does leadership affect network performance? What are the "Good network leadership practices"? What are the new priorities in management and project management? What competencies are needed to lead and manage in emerging global networks? What role does trust play in different network relationships? What are the mechanisms and concepts for creating trust within networks?	Best practice surveys, performance measurement, case studies and assessments
Demand and supply management	*Tactics for dealing with uncertainty in demand and supply* How to ensure agility, flexibility and responsiveness in changing network structures? How to use product/process structures as a basis for improving responsiveness and efficiency? How can risks be measured and managed in global networks? How can network performance benefit from creating unstable network structures? How are unstable structures managed?	Supply chain architectures, D/SC modeling, performance measurement, network collaboration rulebook
3. Product lifecycle management in dispersed global networks		
Dispersed R&D and manufacturing	*Product data management* How to ensure that the right product data and product data changes are used by all network members? How to deal with product responsibilities when the factories are not nearby? *Outsourcing R&D and manufacturing* How to measure and control network activities (joint development, sales, engineering, manufacturing, services production etc.)?	Information Management Aspects: business objects, schema design, master data and instances. Network rulebook: Ramp-up / Ramp-downs. Performance measurement and economic analysis
Innovation mechanisms	*Innovation in global networks* How is innovation lead in global networks? How should network structures be created to enable innovation rich constellations? Which characteristics enable and which disable	Business case analysis, performance analysis, Network rulebook: IPR-issues

	innovation in networks? How are immaterial rights handled in global networks? Innovation is becoming more democratized in many business segments. How to prepare business and innovation mechanisms for open source constellations?	
Real time communicative information systems	*Network centric and service based IT tools* What kinds of enterprise systems enable quick adaptability and take local user and cultural needs into account?	Best practice surveys, performance measurement, case studies and assessments
Design for Global Manufacturing	*Modularization of product and value network* How to use product/process structures as a basis for improving responsiveness and efficiency?	Product platform analysis, postponement modeling, differentiation analysis, DSM mapping and analysis
Environmental impact of global value networks	*Environmental impact of logistics solutions* What is the environmental impact of outsourcing to low cost countries?	Developing measures and tools for Eco-analysis

10.3. Short term tasks

The first step towards the vision and long term objectives is launching initiating projects. The project should be closely connected to the objectives and provide an interesting insight on high profile research that combines industry needs with current global network theme. In short term, the objectives are supported by two research programmes:

(1) **Innovation and Networks (I&N)** programme develops open innovation methods for netrworks in project business. The programme aims to increase innovation activity within business environment and develop methods for managing dispersed R&D. Novel manufacturing and assembly technologies are in special focus area. More than 15 companies, including STX, Rautaruukki, Cargotec and ABB, participate I&N programme.

(2) **GP4Variants -** Global processes for high variety programme research product life-cycle management in globally dispersed design and manufacturing environment and high-mix low-volume production. Special attention is paid to design methods and tools enabling service business creation and energy-efficient material flow. The programme involves several remarkable international companies such as Kone, Metso, Nokia, Wärtsilä with suppliers and close research participants.

These programmes consist of projects and work packages that are proposing new solutions on the following domains:

- **Best practices - Product data change management in dispersed networks**. This project includes collecting requirements of network-level product lifecycle management and developing new tools for successful information sharing in dispersed ramp-up and ramp-down situations.

- **Rulebook for network design and collaboration.** Fast configuration of supply networks requires understanding efficient network designs and a set of collaboration rules that are easy to define in supply contracts. This project aims at developing a method for measuring the fit between supply network design and business objectives, and creating contract templates for defining lead times, delivery terms, service levels and other relevant contract items.

- **Network innovation capability optimization and incentive systems.** Profiting from network innovation requires fair deals and systems that support knowledge creation.

- **Pre-requisites for information systems supporting global dynamic operations**. What is beyond ERP? This project tries to answer how global networks with new suppliers and multiple factories can be managed from information system point of view.

The inaugural projects would be followed by projects related, but not limited to following topics: managing global ETO (engineer-to-order) manufacturing, manufacturing mobility and technology transfer – best practices study, network operation efficiency measures and risk assessment, quantifying environmental impact of low cost country sourcing? - Sensitivity analysis, target costing and logistics network strategies.

10.4. Research and industry partners

The leading manufacturing companies in Finland are involved in manufacturing different types of products: machinery, telecommunication equipment, professional vehicles. Many of products are based on high-level engineering and applications of several fields. The key companies include ABB, Cargotec, Kone, Konecranes, Metso, Nokia, Outokumpu, Ponsse, Rautaruukki, Sandvik, STX Finland, and Wärtsilä. All companies have multiple global locations and can be categorized under industries in addition to metal and machine building. The companies' operations are supported by innovative component suppliers and IT system suppliers operations such as Tieto, Shippax and Variantum. When selecting theme topics, the companies preparing research agenda have used their corporate strategies as a basis:

ABB: Developing the global footprint means alignment of engineering, manufacturing and supply operations with dynamically changing market conditions. Proactively and continuously re-shaping our global footprint is an essential element in ABB's long term strategy as well as developing the existing network.

STX Finland: Maintaining and developing awareness and skills to adapt to changing global business environment and to benefit from new opportunities in shipbuilding business.

Metso: Serving customers globally with a competitive offering requires Metso to continuously explore new designs for agile integration of ideas, concepts, products, and services across value-creating networks.

The research community in Finland in this field is conducted mainly in technical universities and business schools within the area of industrial management and logistics, but increasingly also in faculties of information technology. The key players in Finland within the theme area include the following research units:

- Åbo Akademi University
- HANKEN
- Aalto University
- Lappeenranta University of Technology
- PBI -Research Institute
- Tampere University of Technology
- Turku School of Economics and Business Administration
- University of Jyväskylä
- University of Oulu
- University of Vaasa
- VTT

The total annual research volume of the units within the research theme area is approximately 7 MEUR employing 70 researchers and yielding an estimated 50 journal publications in 2008. FIMECC programme volume in these areas make close to 40 MEUR between 2008 and 2013 (I&N 15 MEUR, GP4Variants 25 MEUR).

10.5. National and international cooperation

Industry – university cooperation is a common way of organizing joint projects. Other national partners are VTT Technical Research Centre of Finland, RFID Lab and the National Logistics Competence Center in Vantaa. The FIMECC global networks theme is related to the Forest Cluster, and TiViT. The list below shows proposed intensive co-operation partners and other important partners, which have operational connections to Finnish industry and universities (track of joint projects and publications).

Inteded intensive co-operation partners	**On-going co-operation partners**
Strategy and global networks – University of Cambridge – ImF. **Value network design and management -** MIT Sloan School of Management. **Product life-cycle management –** Efficiency and Environment – Stanford University, University of Lausanne, University of Michigan.	o Imperial College o Stanford University o St. Petersburg State University, Graduate School of Management o Technical University of Berlin **Intended co-operation partners** o Aalborg University o Cardiff University o Chalmers University of Technology o Eindhoven University of Technology o Erasmus University, Rotterdam School of Management o Groningen University o Indian Institute of Technology o Linköping University o Lund University o Nanyang Technological University o Norwegian School of Management o Norwegian University of Science and Technology o Tongji University, Shanghai o Transport and Telecommunication Institute o University of Brighton o The Wharton School of the University of Pennsylvania

In addition to academic research institutions, specialist organizations such as Goldratt / TOC Society and CIM Data are potential collaboration partners.

The research results of global networks are published in several journals. A drastic increase in the number of published papers during the last decades has spawned new journals with an emphasis on scientific citation indices based rankings. The central publication outlets in the area include journals from logistics management, operations research, business management, information systems, and industrial engineering.

International cooperation between the FIMECC and selected world-class units should be based on joint projects and empower technology transfer. In addition to FIMECC funding the research part, joint activities can include participation in EU funded research projects within the area. Participation in international forums such as Council for Supply Chain Management Professionals (CSCMP), Smart Business Network, EU Manufuture meetings should make the FIMECC brand known among the research institutes.

11. INTELLIGENT SOLUTIONS

11.1. Background

The FIMECC industrial group consists of companies that manufacture metals, equipment, automation systems, machines and ships for customers in different industrial sectors. The products are often components or subsystems used to build up larger systems such as mining systems, mineral and metal processing systems, paper machines, and harbor terminals. The companies are both continuing to develop their strong products-oriented businesses and extending towards delivering systems and solutions and offering various support services during the life cycle of the systems.

Sustainability, safety, optimization of energy consumption, and minimized environmental footprint have climbed at the top of the requirements. The end users also require effective systems and processes that are characterized by high availability, stability, flexibility, and increased functionality with respect to changes in production plans and products. All these features should be offered in the market at an acceptable and competitive price and delivery time.

The products are continuously increasing in complexity with new demands related to environmentally healthy, safe and comfort solutions along the whole life-cycle of the products. Products often need to be operated in hazardous environments and arctic or other extreme conditions.

All current mechanical engineering products are increasingly multi-technology systems, i.e. they are combinations of mechanics, electronics, materials and software. To manage this complexity we need fast design, engineering and product development supported by e.g. simulation, knowledge management and other advanced engineering tools. The systems often need to be customized, and at the same time efficient to design, build and use, e.g., employing new forms of modularity. Furthermore, there is the need of advanced manufacturing systems and methods, such as micro manufacturing, additive manufacturing methods and laser processing, together with their respective advanced production and assembly control, and automation technologies.

The cost of computer technology and processing power is continuously decreasing, and this enables increasingly sophisticated embedded computing systems and solutions. The increasing digitalization of products and production systems means that the share of software and the cost of software engineering in the products and systems become more and more important or even dominant in the future.

Intelligent controls require accurate measurements and e.g. identification and localization information. Sensor technologies providing various types of new information are developing fast. The integration of information from different systems is also developing rapidly in terms of software interfaces, architectures and modeling of information. This enables the vertical integration of machine unit level embedded systems with the production level automation and information systems up to business level information systems. Internet and wireless technologies offer many possibilities to connect machines, their users and manufactures remotely and globally.

Amount of data is growing as the solutions become more intelligent. Data needs to be refined to meaningful information. This calls for sophisticated algorithms for e.g. environment perception, motion control, condition monitoring, fault diagnostics and localization etc.

Due to the fast development of information technology a growing need for standardization of solutions or interfaces to ensure systems integration and interoperability has emerged.

11.2. Vision and mission

11.2.1. Mission

FIMECC Intelligent Solutions theme produces new strategic knowledge for creating global competitiveness for the Finnish metal and machinery industry.

This knowledge is used in development of intelligent solutions that make the users' processes and operations sustainable and productive.

Sustainability and productivity are measured by:

- Energy efficiency, minimized environmental footprint, raw material efficiency
- Product and process availability, stability, flexibility and performance
- Safety
- Competitive life-cycle cost

FIMECC Intelligent Solutions works under this mission in close co-operation with other FIMECC themes, with other Finnish competence clusters and with leading international research partners.

11.2.2. Vision 2015

In 2015, Finland is the technology leader and globally admired brand for sustainable and effective intelligent solutions in metal, machinery, process equipment and ship building industries.

11.3. Focus areas

All different businesses using and developing intelligent solutions share the same three common partially overlapping focus areas: sustainability, productivity and competitive life-cycle. The more specific research objectives are grouped under these three common focus areas.

Focus areas	Key factors	Research objectives
Sustainability	energy efficiency, environment footprints, raw material efficiency	• New resource efficient metallurgical processes • New machine concepts • Zero emission machine, • Zero waste plant
Productivity	availability, reliability, stability, flexibility, ,key performance indicators (KPI), safety	• Automation and production management • Autonomous, semi-autonomous and remote-operated machines • Advanced manufacturing systems
Competitive life-cycle	multi-disciplinary, agility, extended product, service platform, product lifetime management	• Multi-technology engineering • Virtual engineering, modeling and simulation • Control architectures and platforms, sensors • Intelligent condition monitoring and maintenance

11.3.1. Sustainability

Environmental requirements are a megatrend that will without doubt affect also the business environment. The future regulations regarding environmental impact such as reduced CO2 emissions or need for better raw material efficiency– including lower energy consumption - are challenges to the metals and mechanical engineering industries. In this focus area the target is to turn these challenges into a competitive edge for Finnish industry with the help of science based innovative solutions. The key success factors are a better integration of technologies related to energy production and consumption together with deeper know-how in controlling the environmental impacts.

11.3.2. Productivity

In this focus area the research concentrates on development of the performance and capacity of end products, production and control processes. The know-how of the productivity on the system level and new efficient products and processes will be in the key role in the future competence of Finnish industry. This means needs to research and develop the process and production management systems as well as new ways to build and control processes which consist of autonomous and semi-autonomous machines or machine groups. Safety is considered as one important factor of total productivity.

11.3.3. Competitive life-cycle

In this context the competitive life-cycle means that costs are taken into account in all stages of a product or system during its lifetime: idea or concept stage, various design stages, implementation, manufacturing, assembly, testing, use and recycling. In addition to normal operative use, the delivered product or system often enters a condition monitoring and various kinds of maintenance programs. Many kinds of upgrades or modernizations are also commonplace along typical system or product life cycles. Ever more, these activities will be performed by integrators, vendors or third parties.

The nature of competitive life-cycle research is cross-disciplinary. Energy-efficiency, durability, reliability, safety, maintainability, usability, engineering efficiency through life-cycle stages – all along with increased versatility, complexity, and combination features – all determines a competitive life-cycle. A recent concern is the environmental impacts – over all life-cycles – that must be taken into account.

11.4. Research objectives

FIMECC Intelligent Solutions calls for high quality research for the following research objectives. The research can take place in a program dedicated to a certain objective, or in programs that that combine efforts towards several of the key objectives.

High energy efficiency and low environmental impact are repeated leading principles inside most research objectives and programs. Close co-operation in planning and implementation with CLEEN (Cluster for Energy and Environment) and its programs is essential for successful research towards these targets.

11.4.1. New resource efficient metallurgy processes

New type of metallurgy processes with significantly improved resource efficiency – including energy efficiency - need to be created.

Topics for research:

- Simulation and modeling of the metal industry unit processes as well in hydrometallurgical processes as in high temperature processes, casting, hot rolling, annealing and cold rolling
- Simulation and modeling of metals industry customer processes like welding and forming, behavior of materials in new intelligent customer processes and products

11.4.2. New machine concepts

In order to achieve new breakthroughs in energy efficiency and emission level of machines the traditional ways and technologies to build machines and systems shall be questioned. New machine concepts utilize known technologies in new purposes and applications.

The research objective is to support development of new concepts such as:

- Hybrid drives in mobile machines
- Electric drives in new applications

11.4.3. Zero emission machine

A zero-emission machine is completely neutral with regard to nature and environment, during its entire life-cycle: its energy resources are sustainable and it does not produce any harmful emissions (regarding harmful substances, noise, danger, etc.) and its materials are entirely recyclable. The machine design is optimized to minimize material usage and reduce weight. Still, the machine needs to fit to its purpose in a competitive manner - without compromising performance and costs, user or public acceptance, versatility of features, etc.

Topics:

- low energy consumption
- minimized local emissions
- alternative fuels

11.4.4. Zero waste plant

Zero waste plant is a manufacturing or process industry unit that by utilizing leading edge intelligent solutions produces an extremely low amount of harmful emissions and waste – ultimate target always being zero emissions and waste.

11.4.5. Automation and production management

Communication and interface technologies throughout production chains and networks are still evolving fast, offering a challenging area for research and providing deep industrial interest. As a specific topic in this field, interaction and optimization between traditional production and office layers is increasing.

The research objective is to define intelligent generic automation/information system which supports the goal for high equipment availability over the product lifetime. Factors influencing availability probably change over the product lifetime, and these should be taken into account in the development. Open systems integration and collaboration based on new emerging software architectures and standards should be utilized as basis for the system solution.

Real-time machine or process control, on the one hand, and production management or supply-chain management, on the other hand, is traditionally considered distinct domains, with distinct systems, tools, and organizations. However, many companies are facing the needs to link these two layers, to be able to manage a broader operational state of plant or site (compared to that of basic control), to operate the modes of automation, manage forecasts of future conditions, relay economical impacts to control, etc.

11.4.6. Autonomous, semi-autonomous and remote-operated machines

Autonomous or semi-autonomous systems and remote operation are needed to improve productivity and safety level of machines. Progress in environment perception will enable applications with co-operating manually controlled and autonomous machines. Driver assistance automation supports the way towards fully autonomous machines.

The research objective is to support the technology base for autonomous or remotely operated machines and to create new or improved solutions for the following topics:

- Remote operations
- Obstacle recognition and avoidance
- Worksite management from ERP to production tasks
- Task description and subtask generation
- Software architectures for co-operating machines
- Design methodology for autonomous multi-machine systems and their management
- Work area mapping tools and standards
- New positioning solutions for factory and worksite environment
- Optimization to minimize operation cost

11.4.7. Advanced manufacturing

There is a need to develop new manufacturing technologies, together with respective production automation and assembly systems, user interfaces, etc. Disruptive manufacturing technologies, like micro manufacturing, additive manufacturing methods and laser processing, will change the way how, when and where products will be manufactured.

Topics:

- new manufacturing technologies
- new product concepts, possibly with new material technologies
- flexible production and manufacturing control / management
- seamless integration of product & production design and manufacturing
- novel distributed / networked design and manufacturing paradigms or business models

11.4.8. Multi-technology engineering

Devices, machines, systems and larger integrated products are increasingly multi-technology systems, i.e. combinations of mechanics, electronics, materials and software, setting major challenges to meet the requirements of faster product development, industry grade quality and unique features to differentiate in competition. The research focuses on development of design framework and tools that covers the multi-technology scope of future machine / device / system development and testing. Use of simulation tools, knowledge engineering, etc., in all phases of development and testing will be critical for maximal automation of the design tasks.

11.4.9. Virtual engineering, modeling and simulation

Modeling and simulation are deeply connected with several of the research objectives. Design, implementation and use of automation systems and networks would all benefit from easier-to-use and cost efficient modeling and simulation tools. One of the key challenges in this area is to enable easy and intuitive modeling, preferable as a side product of other manual work or as a fully automated feature. Another important issue is better integration of simulation tools and daily user tools as well as lowering skills required to perform simulations.

Extending the use of simulators to various directions brings the need of multi-technology simulation, multi-accuracy simulation or multi-purpose simulation which hasn’t become a practical reality so far. Automated testing trough simulation / emulation is also a growing demand in industry, because products become more and more complex.

11.4.10. Control architectures and platforms, sensors

The research objective is the definition of the future software architectures for intelligent devices, machines and process or manufacturing plants. The architecture should support the implementation phase, as well as, variations. Companies can gain significant advantage in cooperating to select and establish a smaller number of platform solutions to match different requirements within the companies and their products.

Modern sensors are considered as essential components of the system architecture.

Topics:

- New prototypes and concepts of control architectures
- Development of final software or hardware components where necessary
- Selection or development of the appropriate software engineering tools and methods for implementation of products compliant with the architecture
- The respective software life cycle management

11.4.11. Intelligent condition monitoring and maintenance

Condition monitoring, maintenance support services and asset management offer new business potential and require research and development effort.

Condition-based monitoring and maintenance consists of the following building blocks:
1) Capability to identify the intended or exceptional condition of target machine, system, component, etc.
2) Capability to infer or prognoses the impacts of indentified condition (e.g., to estimate the remaining durability - versus the intended or on-going mission)
3) Optimal (maintenance or ready-to-continue) decisions that are due to the previous

Intelligent condition monitoring means use of extensive use of measurements, advanced signal processing, accurate load or usage systems or components, in order to initiate accurate, cost-effective, etc., maintenance procedures. Current modern and especially future business concepts include distributed organizations with remote service centers, on-site central services, machine instrumentations, advanced logistics of spare-parts and maintenance personnel, etc.

The main research topics in this area are:
- Technologies: sensoring, signal processing (diagnosis & prognosis), wireless technologies, knowledge and expertise management, human-system interaction, asset management
- Service business models, valuation, service products, service offering (cf. Service Business)

11.5. International cooperation partners

Existing international research collaboration and networking are presented in the following table. The table is not fully comprehensive, but points out the most important partners.

Research partners and collaboration areas in the theme.

Partner / Activity	Common projects	Exchange of visitors and knowledge	Network cooperation
ACCM (Austrian Center of Competence in Mechatronics)	x		
AIST (National Institute of Advanced Industrial Science and Technology, Japan)		x	
AFCR (The Australian Centre for Field Robotics)		x	
CETIM (Centre Technique des Industries Mécaniques)			x
ESTEC (European Space Research and Technology Centre)	x	x	
EURON, European Robotic Network			x
FPCE, Fluid Power Centres in Europe			x
FPN, International Fluid Power Net			x
Fraunhofer IPA, IFF, IAO	x	x	x
FSR, International organization for Conference of Field and Service Robotics			x
IFAC, International Federation of Automatic Control			x
ITIM (Finnish-German Co-operative Graduate School Network)		x	
KTH	x	x	
MEFOS (Metallurgical Research Institute AB)	x		
RWTH Aachen University	x		
The Robotics Institute of CMU		x	
Technische Universität Dresden		x	
TNO	x	x	
University of Auckland		x	x
University of Cardiff	x		x
University of Newcastle	x		x
University of Patras	x	x	
University of Warwick	x		x
Utah State University	x	x	

International research collaboration will be carried out also in the 7th EU Research Framework Programme (FP7). Within the FP7 the Cooperation programme is the most important one regarding research collaboration in the form of projects. Important themes are Information & communication technologies (ICT) and Nanosciences, nanotechnologies, materials & new production technologies. However, also some other themes as e.g. Energy and Transport may offer suitable calls for intelligent solutions related research projects.

Interesting partners for future cooperation are e.g. the following universities: MIT (U.S.), Technische Universität München (Germany), and Tsinghua University (China)

12. BREAKTHROUGH MATERIALS

12.1. Background

Five focus areas were defined in the original Strategic Research Agenda for Breakthrough Materials. Two research programmes have been started and a third one is under preparation. Most of the research areas that were considered in the SRA were found to be relevant and are included in these programmes. However, division of the material production and product manufacturing technologies into separate focus areas was considered to be somewhat artificial they were removed from the agenda. Some of the planned research has been moved to the ELEMET research programme under the theme Intelligent Solutions. Most of the remaining activities have been merged into the other focus areas as part of the projects, which investigate solutions based on these materials and manufacturing technologies.

12.2. Vision for the Breakthrough Materials Theme 2015

For Finland to become the European leader in the research and development of:

- Breakthrough materials for sustainable life cycle performance
- Material solutions for competitive and difficult-to-copy product differentiation
- Material solutions for energy saving, safety and environmentally friendly applications

in the operational fields of companies participating in the theme.

The strategic goals in the breakthrough materials theme are:

- to secure a strong competence base supporting domestic material producers and users
- to enhance high level research to ensure expeditious application of new materials in Finnish engineering industry and
- to fill in missing links in the value chain via strong international networking.

12.3. Focus Areas

This research agenda has been revised in co-operation between the Finnish metal producers, engineering companies and their research partners in key Universities and VTT. The work has been mainly carried out by the companies and research partners participating in the programmes which are ongoing or under preparation.

For this research agenda the following definitions apply:
Breakthrough materials: new materials and material concepts, which allow differentiation in products via material or production technology and/or require or enable the redefinition of the business, service or product concepts.
Production technology: development of production technology for breakthrough materials.
Manufacturing technology: development of technologies for manufacturing components and structures out of breakthrough materials.
Material properties: properties in three categories, i.e., basic material properties, functional properties and properties related to production and manufacturing technologies.
Material usability: a concept, which ties together material properties and applications and includes material selection and suitability for different applications.

This research agenda focuses on new materials and material technologies for:
- **Light and efficient solutions** providing e.g. reduced operation and life cycle costs, improved safety, improved performance and decreased environmental impact.
- **Active and functional solutions** e.g., materials and material solutions for sound and vibration damping, embedded intelligence, multifunctional surfaces, light and solar energy production.

- **Demanding applications** involving e.g. wear, corrosion, fatigue, extreme service conditions, solutions for minimizing friction and energy consumption.

12.4. Research Objectives

Materials technology can influence several strategic themes. In the present context, those having the largest impact are related to **materials allowing improved structures and machinery** (e.g. increased performance, lighter weight, longer service time, reduced wear, vibration, noise levels, friction, etc), **the design and manufacturing of solutions based on these materials and research related to the performance of the materials in various applications and environments**. The new **solutions must be environmentally friendly and energy efficient**. In certain applications **superior after-market products** can be created allowing substantially improved performance and reduced life cycle costs.

12.4.1. Light and efficient solutions

Breakthrough light solutions for the metals and engineering industries require simultaneous developments in high-strength and low density materials, processing technologies, product design solutions and manufacturing technologies. The strategic vision of this theme is to gain a leading international position in the development of a future generation of advanced materials, structures and systems, with reduced weight, increased performance, improved energy efficiency and a reduced environmental footprint.

High-strength steels are increasingly used in lightweight applications. New innovations provide the potential for manufacturing steels with strengths up to 1500 MPa. Structural safety is a necessary pre-condition for the use of these materials. Safety is ensured via simultaneous high-strength, good weldability, excellent fatigue properties and good low temperature ductility. Understanding and controlling changes in the material properties at all stages of the fabrication process are essential. In some cases, alternative joining methods, post-weld treatment methods or new design alternatives need to be explored, developed and validated.

Developing a new generation of high-strength stainless steels is another strategic target. The exceptional combination of strength and ductility of metastable austenitic grades can be further improved by optimizing the chemical composition or by incorporating special heat treatments. Less expensive alloying elements are needed in order to maintain and improve price competitiveness. The influence of potential nickel-replacing alloying elements on the microstructure and properties of austenitic stainless steels needs to be explored.

Novel manufacturing technologies can be used to develop hybrid materials which provide significant assets by combining the inherent strengths of two materials. The development of new processing routes for hybrid composites is an important strategic objective. Low density materials like metal foams, metal honeycomb structures, metal-polymer hybrids and GRP-, CRP- or nano-composites are traditionally associated with the aircraft industry. One goal of the theme is to increase the use of these materials in a wider range of products and structures. Current challenges when using these materials include relatively high costs, processing and joining challenges, long term performance, in-service repair, recycling and other environmental issues.

Light and efficient solutions can be greatly enhanced by developing new structural concepts. In some demanding load-bearing applications, sandwich-type or other thin-walled structural alternatives can replace heavier sections. Strategic research topics include manufacturing technologies for sandwich and cell panels. Double-skin beams and columns which may have weight savings up to 50 % are of significant interest. Design guidelines and joining technologies for these new structural solutions are needed.

Awareness of the benefits of light and efficient solutions is increasing, as international discussion moves away from simple calculations of production costs to also encompass issues of energy consumption, carbon footprint, recyclability and raw material usage. It is strategic for Finnish industries and research institutes to be active in the development of these new metrics and to use them to identify new business opportunities for lightweight solutions.

12.4.2. Active and Functional Solutions

For sound and vibration damping new materials create opportunities for breakthrough structures and product differentiation. Visions of future materials solutions for e.g. vibration damping are hybrid materials such as polymer-metal hybrids or polymers with inorganic fillers, for example MSM-polymer composites for both passive and active applications. Another group of future materials for damping are hybrid metal honeycomb or foam based materials and viscoelastic materials with tailored damping properties. Sandwich structures or multilayer coatings are also possible key technologies for sound and vibration damping applications.

Self-monitoring materials and components that reveal the extent of eventual or unexpected changes in material or structure performance, such as fatigue and creep or corrosion damage or the aging of polymeric materials in early stage are also under consideration. Sensor materials are needed for detecting the eventual changes in operating environment, which may cause corrosion, aging or other damage to the structures. Key R&D areas are the development of functional materials for active or passive vibration damping of structures, multifunctional surfaces (e.g. for easy-to-clean, self-healing, anti-frosting, anti-bacterial, color producing, light emitting, solar energy), development of materials and components with embedded self-monitoring and remote-diagnostics systems as well as the development of design and manufacturing methods for structures made of functional materials.

12.4.3. Demanding Applications

Material solutions for demanding applications involving e.g. wear, friction, corrosion, fatigue, or high temperature are essential both for the Finnish material producers and engineering industry. As many equipment and machine manufacturers operate globally, intensive research is needed e.g. on wear, friction and corrosion under varying conditions.

In the case of *high-strength structural and abrasion resistant steels,* there is a need to improve the strength/hardness - toughness - ductility balance throughout the whole production chain. To achieve these goals, it is necessary to obtain fundamental understanding of the interactions between chemical composition, processing parameters, microstructure and material properties and usability and to discover processing routes to economically achieve optimized properties.

Stainless steels are used in conditions where exceptional corrosion and/or heat resistance is needed. Modified and completely new alloys with enhanced properties are needed, for instance, in sustainable energy production. A general trend in stainless steel market is the increasing share of new low-nickel and nickel-free stainless steels, e.g., novel ferritic and duplex steels. These new grades require different and more controlled production processes compared to conventional grades. Development of surface properties and new surface finishes is also an essential research area. The metallurgical knowledge base needs to be strengthened, for instance, to better understand various embrittlement phenomena of the steels. Extensive research is necessary to develop fabrication processes for the novel steels and to characterize their performance in demanding service conditions.

Multi-phase materials or otherwise functionally tailored materials such as for example metal-ceramic composites (designed for special applications) are needed for extremely good wear and thermal resistance, e.g., in tooling or other applications with high requirements against abrasive and erosive wear appearing in all main process industry applications, especially mining, chemical, energy, metallurgy and pulp and paper industries. The strategic research aims at understanding the role of matrix, reinforcement materials and their interfaces to enable the tailoring of metal matrix composites for wear and mechanically loaded structural components. Special research activity should be directed to the safe, efficient and economic recycling of composite materials.

Large energy losses are often due to friction and the development of new material solutions such as *new surface engineering methods* are beneficial. Such techniques are e.g. the chemical and physical vapour deposition techniques (CVD and PDV) that offer the possibility to deposit a thin, only a few micrometer thick, surface coating with very low friction and excellent wear resistance.

Research on *production technologies* provides tools for developing new materials or producing components for applications and needs of the other projects in the programme. The production methods to be applied include techniques basing on the melt processes as well as on the powder metallurgical route. These techniques allow fabricating the bulk products either with local modification (FGMs, hybrid materials) or making them totally of tailored new materials. Special melting techniques are applied, in general, for metals and alloys with especially high requirements for purity or cleanliness and structure homogeneity and soundness.

Key R&D areas are the development of improved understanding of wear mechanisms in applications for process and energy industry, development of materials for improved friction and wear, corrosion and high temperature performance. Material models are combined to lifetime estimation and performance evaluation. Integrated monitoring technology together with verified material models enables optimum performance, extended service life and failure detection in advance. Ultimate goal is care free, self-sensing/repairing structure or equipment.

12.4.4. Operation Model

Actions in the implementation phase of the programmes are:

1) Further development of knowledge clusters (excellence centres) for the focus areas consisting of a responsible research partner and a network of co-operating partners. The clusters network globally in critical areas of materials technology.
2) Planning for the national split of responsibilities and the development of research infrastructures. The number of the partners depends on the needs of the focus area.
3) Continuous programme and project renewal for the adoption of the Strategic Research Agenda by the participating companies and research partners in the focus areas.
4) Initiation of the development for the candidate and master programmes at the participating universities and integration of the existing researcher training programmes (graduate schools) with the theme.
5) Development of the international network of research providers and companies. Establishment of links to EU Platforms (especially European Steel Technology Platform and EU-MAT).
6) Plan for the participation in the EU 7th FWP calls.
7) Establishment of agreements for subcontracted work and joint research with external and/or international partners.

Co-ordination of each programme is managed by a key-professor. The network employs 10 - 20 researchers, of which at least half are senior researchers. Co-operation with e.g. Graduate Schools should increase the number of researchers by about 3-5 researchers per focus area. The annual volume of the research within the theme is approximately 10-15 M€.

12.5. Description of Industrial and Research Partners

12.5.1. Industrial Partners and Link to Key Company Strategies

Four companies participate in the LIGHT and nineteen companies in the DEMAPP research programme. Three additional companies are expected to join LIGHT in 2010. It is anticipated that two or three large companies and a multitude of smaller new technology companies participate in the Active and Functional Solutions programme. SHOK shareholder companies participating in the ongoing programmes and the link to the company key strategies:

Andritz Oy is a global market leader for *customized plant, systems and services for hydropower, the pulp and paper, steel and other specialized industries.*

Materials technology is a strategic technology for business lines of **Metso Corporation** due to its importance for *after sales products, new process and machine solutions*.

Outokumpu Oyj's R&D strategy focuses on the *new nickel-free and low nickel stainless steels*, which reduce dependence of steel price on the volatile nickel price. These new steels include ferritic, duplex and austenitic Cr-Mn-Ni grades.

Rautaruukki Oyj has a strong focus on solutions in the engineering and construction industries and thus, the R&D related to material technology has two focus areas: *ultra high strength steels*, especially hot rolled plate and strip products and *coated sheet steels*.

In **Outotec Oyj´s** offerings of process solutions, technologies and services principally for the mining and metals industries, materials are selected on the basis of *good performance, sustainability and optimal economical and technological solution*.

STX Finland Cruise Oy has built, or is building, 15 largest cruise ships in the world. Finland´s biggest export product to date *Freedom of the Seas* was delivered in April 2006. An even larger *Oasis of the Seas* will be delivered in 2009.

Other companies with a major participation in the two ongoing programmes are **Wärtsilä Oyj Abp, Teknikum Oy, OSTP Oy Ab, Femdata Oy, Ecocat Oy and TVO Oyj.**

12.5.2. Research Institutions and core competencies

The most important research performers within the defined technology focus areas are research groups at Aalto University (TKK), TUT, VTT, OU and LUT. The competence areas of the research performers are complementing each other allowing the formation of strong clusters. The performance record of the research partners is shown in the table at the following page. A number of external evaluations of the groups and units have been performed recently. These can be found at: http://www.aka.fi/fi/A/Suomen-Akatemia/Julkaisut_/Julkaisusarjan-julkaisut/ (5/08 Mechanical Engineering Research in Finland 2000-2007. Evaluation Report), http://www.aaltoyliopisto.info/aaltorae and http://ntsat.oulu.fi/rae2007/s/reports.html.

Partial performance record of the research partners within the theme, 2002-2007.

Research Partner	Human Resources 2007			Funding of Research Projects (2002-2007)				Publications (ISI Impact >1 and <1) Doctoral Theses and Patents 2002-2007			
	Professors	Doctors	Doctoral Students	SA (kEUR)	Tekes (kEUR)	EU (kEUR)	Others (kEUR)	ISI ≥ 1	ISI <1	Thesis	Patents
Aalto University (TKK)	8	22	50	1137	14379	3244	7362	106	108	21	10
Lappeenranta University of Technology (LUT)	4	5	23	330	3564	735	1673	46	90	9	1
Oulu University (OU)	7	8	20	1302	4002	1197	6707	16	54	9	2
Tampere University of Technology (TUT)	8	4	37	1112	9546	4800	1899	74	29	21	22
VTT Technical Research Centre of Finland (VTT)	5	15	-	320	16250	3750	2500	120	120	-	7
Total	32	54	130	4201	47741	13726	20141	362	401	60	42

12.5.3. Related On-Going Research, National Co-operation and Relation to Other SHOKs and OSKEs

Current concentrated long-term activities in the field of metal products and engineering industry are carried out in the context of the Tekes Research Programmes NewPro (2004-2009), Functional Materials (2007-2013) and FinNano (2005-2010). In the Finnish Academy programmes such as Sustainable production and products (2006-2010), and Nanoscience research programme FinNano (2006-2010) as well as on the Application of Information Technology in Mechanical, Civil and Automation Engineering, KITARA (2005-2009) bear relevance to the current topic.

There are a number of other activities in Finland, which are important for the current research theme. Links will be established especially with the Cluster for Energy and Environment (CLEEN Oy), and Cluster for Built Environment (RYM-SHOK Oy). A number of other knowledge clusters (KC/OSKE) under the umbrella of the knowledge centre programme of the Ministry of the Interior as well as Forum for Intelligent Machines ry (FIMA) have also relevance with the current theme. Exchange of information will be made in order to coordinate and transfer the results of the long-term research to the local national activities.

12.6. Development of International Co-operation and Networking

The members of the Association of Finnish Steel and Metal Producers and the participating universities have a long tradition of Nordic co-operation, during which long term projects have been carried out within Jernkontoret coordinated research programmes and more recently Research Fund for Coal and Steel (RFCS) funded projects.

Swedish research institutes and metal producers have regularly participated in these projects. Also European research institutes and cooperation bodies are important partners. Finnish steel producers have actively participated in the preparation of the European Steel Technology Platform for the long-term research agenda.

The engineering companies participating in the theme are global actors. As the operation environment of the equipment varies substantially and e.g. local sourcing may be required, co-operation with regional research institutes and universities is in many cases essential. This is often also a requirement of the customers as they cannot rely on efficient co-operation and direct assistance from a far away supplier. Therefore, research institutes in countries like China and Russia have recently become important especially for the pulp and paper and mining and metallurgical industry equipment suppliers. Some companies also have local manufacturing sites in these countries. This makes networking with local universities even more critical.

12.6.1. International Research Institutions

International research institutions that are important for networking and co-operation are e.g., **SE**: MEFOS, KIMAB, KTH, Lund University, **FR**: IRSID, **DE**: BFI, Max Planc Institute, Bremen University, Aachen University, **BE**: University of Ghent, OCAS, KU Leuven, **EE**: Tallinn Technical University, **US**: UCLA, Purdue University, **CA**: University of British Columbia, **CN**: South China University of Technology, Central China University, Beijing University of Technology, SINANO, **PL**: Wroclaw University of Technology, Kielce University of Technology and **RU**: St. Petersburg State Polytechnical University. The agreements with partners in each programme will be made during the implementation phase.

12.6.2. Integration of Companies Globally

Development organizations and companies identified for the existing international R&D co-operation are: Alfa-Laval, Sandvik, Andritz, Bosch, Butting, Euroinox, IISI, ISSF, Jernkontoret, Metco, SSAB, VDEh.

12.6.3. Linking to the International Research Programmes

The research agenda is linked to the following European technology platforms: European Steel Technology Platform, EU-MAT Platform. Mechanisms for the integration of FIMECC programmes with these will be reviewed during the implementation stage.

13. CONCLUSION

FIMECC is a strategic initiative to re-organize strategic private sector research around a platform of enriching communication. The R&D investment in FIMECC is significant both from monetary and resource point of views. By creating a co-opetitive actor into the Finnish research field, we can improve the possibilities of companies in steering strategic pre-competitive research and bring research institutes and companies closer to each other.

The research activities in FIMECC are organized into five themes: Service business, User experience, Global networks, Intelligent solutions, and Breakthrough materials. The research agendas of the themes, implemented through FIMECC research programs, bring us to new level of knowledge in these topics. They represent state-of-the-art point of departures and can create strategic centres of critical mass in intellectual capital. The overall estimated research volume of FIMECC is 60 M€ annually.

The commitment of companies, research institutes, and persons during the research agenda writing has been great. Since the Finnish innovation system needs restructuring and companies seem to be ready to take the next step in the move towards immateriality, the time is right for full speed in bringing the visions presented in this research agenda into practice.

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