Sammanfattning

Användandet av avancerade konstruktionskeramer förutspås öka kraftigt under de närmaste åren. De används nu i ett stort antal applikationer där framförallt slitage, vikt och värmebeständighet är viktiga faktorer. Då produktionsvolymerna ökar, processtekniken förbättras och användare blir mer medvetna om fördelarna, förväntas användandet accelerera än mer.

Vi har i denna rapport tittat på möjligheter för SKF att hitta affärsmöjligheter där produkten är tillverkad av avancerade keramiska material. SKF har inlett ett samarbete med en amerikansk tillverkare, Keramera[1], som redan idag förser en del av marknaden med keramiska produkter. Möjligheter att använda sig av Keramera som leverantör har beaktats i rapporten.

Meningen med detta arbete är att hitta lämpliga keramiska komponenter och applikationer för SKF att sälja och för arbetets överblick har förfarandet delats upp i tre delar. Den första delen är en kartläggning av ett stort antal komponenter som är utvärderade och rankade, där en databas innehållande cirka 140 stycken komponenter är skapad. Komponenterna är utvärderade och rankade för att möjliggöra en grov första sållning av komponenter som inte är intressanta att gå vidare med.

Det andra arbetssteget består av en analys och utvärdering av affärsmöjligheter för sex stycken utvalda komponenter och applikationer; kulventiler för oljepumpar, kamaxelrullar för dieselmotorer, mekaniska plantätningar för pumpar i livsmedels- och pappersindustrin, avvattningslister för papperstillverkningsmaskiner, bromsskivor för tågvagnar och bränsleinsprutningssystem baserat på piezo-teknik (PZT) för motorer.

Det sista steget slutligen, är en mer djupgående analys av en komponent – kulventiler för oljepumpar. Vi tror att detta är en möjlig väg för SKF att snabbt hitta en ny affär. Emellertid krävs mer kunskap om komponenten och dess marknad innan man ger sig in här på allvar. Detta ska anses som en sidoaffär och man bör även beakta hur väl i linje med sin kärnaffär man vill vara när man utvecklar affärsmöjligheter. I detta fall ligger både keramiska bromsskivor och mekaniska plantätningar väl i linje med SKF:s kärnprodukt och en mer djupgående utvärdering av dessa områden föreslås.

[1] Keramera är ett fingerat namn, vilket kommer att användas i rapporten av konfidentiella skäl.

Abstract

Engineering ceramics follow a persistent technical evolution with an increasing amount of applications within advanced industrial solutions. As it is a part of the technological progress, it is of importance that SKF maintain an understanding within the area and stay alert with changes in the environment.

There are three main deliveries generated from this report; a market scanning of the most interesting components within the field of advanced ceramics, a business evaluation for six products and an in-depth analysis of the best suited component for an immediate business opportunity. Special consideration when searching for the new business opportunities has been taken throughout the report to the collaboration with a manufacturer of advanced ceramics, Keramera. [2]

A market scanning has resulted in a database containing around 140 components with useful information for further research. The database can advantageously be used as a tool for market factors, producer information and customer problem/need. A business evaluation is created for the ceramic components: check valve balls for oil production, cam follower rollers for diesel engines, brake discs for train carriages, mechanical face seals used in pumps in the food and paper machine industries, slotted dewatering foils for paper machines and fuel injection for engines with possibilities for SKF to transfer this technology into automatic lubrication systems for bearings.

Finally, an in-depth analysis considers check valve balls for sucker rod pumps for oil extraction. We have found that there are good possibilities for SKF to explore this market at low cost and risk, but further knowledge about the market and the application need to be gained. The component is widely used and a ceramic solution is, technically, among the most suitable.

Furthermore, we believe that strategic decisions for business development need to be taken. To add more value to today's core proposition, bearings, both mechanical face seals and brake discs are well in line with SKF's core business. Further analyses on these applications are recommended.

[2] Keramera is a fabricated name, which will be used in the report due to confidential reasons.

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1 Introduction

Advanced engineering ceramics continuously find new application areas within a wide range of industry sectors. The ceramic solutions generally hold better material advantages such as hardness, wear, chemical resistance, resistance against electrical corrosion, weight reduction, better reliability as well as increased life length.

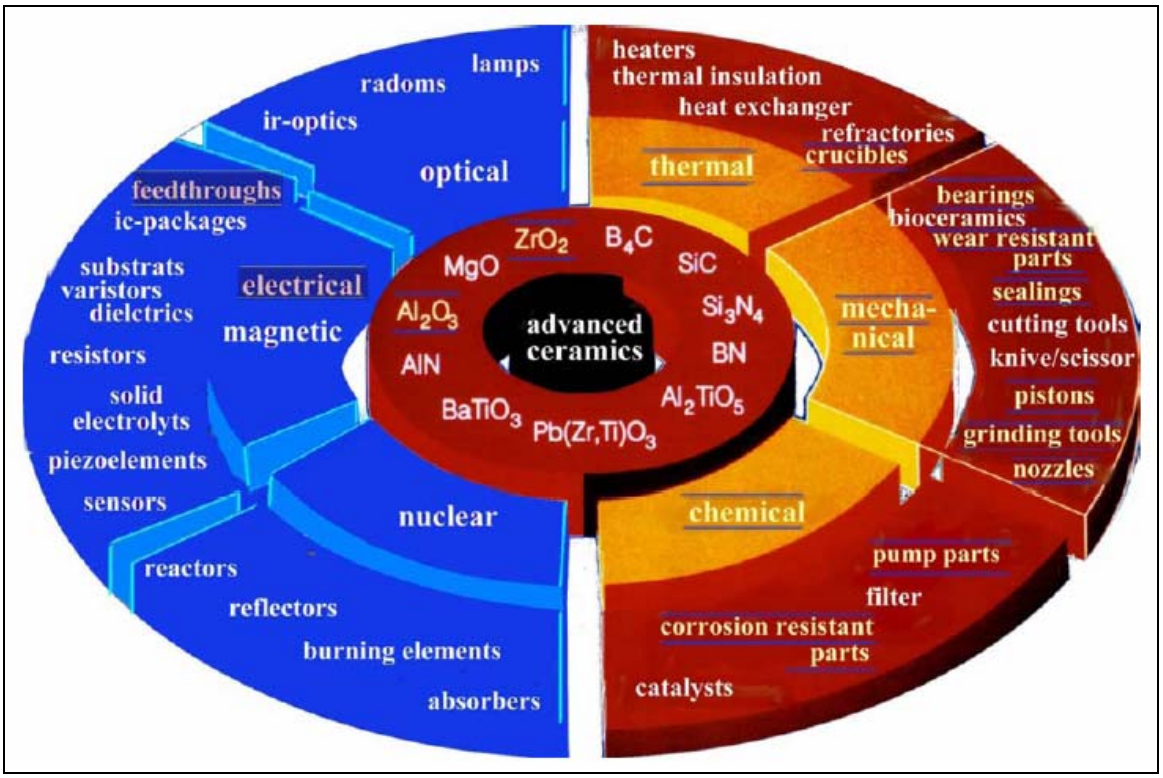


Figure 1. An overview of the different application areas is shown, where advanced ceramic solutions can be chosen. The parts of most interest for SKF are found in the mechanical group to the right in the figure. *(Source: Glynwed, Company Presentation).*

Today, there is a considerable amount of components and products that could be replaced by ceramics instead of the more conventional metal alloys and thermally coated solutions. Apart from existing products that could be improved, there are also possibilities to develop new products using ceramic materials within the collaboration frames. SKF, together with other bearing manufacturers have used ceramic balls in bearings for a number of years.

An American manufacturer of advanced engineering ceramics, Keramera provides SKF with ceramic rollers for hybrid bearings today. SKF and Keramera have recently initiated extended collaboration which enables SKF to look at additional customer solutions with ceramics.

With this background, SKF seeks to examine possibilities to broaden its business with additional components made of advanced engineering ceramics. The main materials of interest when discussing ceramics are silicon nitride, silicon carbide and aluminium oxide, to name a few.

Keramera is currently active in different markets with a range of products. For example, the ceramics are used for personnel armour within the defence industry, orthodontic brackets within orthodontics, as well as for components used in motors for heavy trucks.

Initiator of this project is SKF Austria with Rudolf Groiβmayr as principal originator. Most of the work is done in close understanding with Industrial Division Prominent Needs Development, SKF Gothenburg. Discussions regarding choosing the suitable track and important decisions concerning selection of components have been held throughout the process of the project in agreement with the "project team". The project team is primarily Rudolf Groiβmayr, Göran Lindsten and the authors: Johan Magne and Erik Kvarmo.

1.1 Purpose and Objectives

At present, SKF possesses knowledge and experience of hybrid bearings, together with a few other areas where ceramics are used.

There is a need for SKF to get more comprehension of the market for components with possible use of advanced engineering ceramics, and this project seeks to give a broad picture of the market as well as to identify and evaluate new business opportunities, primarily based on the collaboration between SKF and Keramera. The purpose for SKF is to broaden its business in markets with components made of advanced engineering ceramic material and to look for new business opportunities.

A key objective for SKF is to understand *which* products and components that have the most promising business opportunities, according to the use of advanced engineering ceramics.

1.2 Thesis Structure

The thesis is arranged by the following main sections: Introduction, Theoretical Framework, Methodology, Results and Analysis, In-depth Analysis of a Single Business Opportunity, Conclusions, Discussion, Recommendations and finally Appendix, which provides the reader with additional information.

The theoretical framework is a description of the theories and models utilized in order to support the processing of information and data. At that point, a three-stage model is described, which permeates the entire report. After each stage, there are queries we aim to elucidate, which are summarized and explained in the Problem Analysis section. Furthermore, in the Methodology section we discuss how the investigation is done and the aspects concerning reliability and validity. The Results and Analysis section is the main part of the first and second stages containing a database and analyses on the six selected components, and thus aspires to answer the queries asked. The third and last stage contains an In-depth Analysis for one selected component within a specific application. Finally, conclusions are drawn in the Conclusion chapter and the line of reasoning is treated in the Discussion chapter. Suggestions for further progression for SKF are proposed in the last section, Recommendations.

Throughout the report, numerous elements (components) are described, which are used in different applications and divided into segments. Not to confuse the reader and to clarify the terminology used, these elements are named as *components*. A component can be used in various different *applications*, and be divided into *segments*.

1.3 Delimitations

In the broad first selection of components to the database, we have not considered all components existing today. Instead, the selection descended mainly from discussions with experts in the ceramic field and material specialists together with prominent ceramic manufacturers' assortment and consideration of what is of interest for SKF. However, the selection does also show components that after further investigation have ended up being outside the frame of the interest for the project and SKF.

Six components are chosen from the database. There are more components than these six that are of interest, but due to limitations in time and/or suitability for SKF, only six are further investigated. Moreover, the last part, the in-depth analysis, treats one component and should be regarded as an *outline* of a business case, thus not an entire business plan, due to the same time restrictions. In order to use this analysis as a foundation for decision making, more investigation has to be done. We have not had the resources, time and high-quality contact channels to be able to monitor all the critical facts needed for an entire business plan.

Moreover, because of the somewhat two-dimensional focus with *both* a broad mapping of the ceramic possibilities on the one hand, *and* an in-depth analysis on one business opportunity on the other, adequate balance between the parts has been a requisite to obtain and to work after.

2 Theoretical Framework

In this chapter, models and theories used for data collection, results and analysis are described. The models are presented briefly to get enough understanding about why they are used and with what feature they can contribute in the support of logical steps in the phases of the analysis. As mentioned, the report is divided in three stages in order to obtain an easier overview and access to results as well as conclusions. All three stages are shown in the below figure.

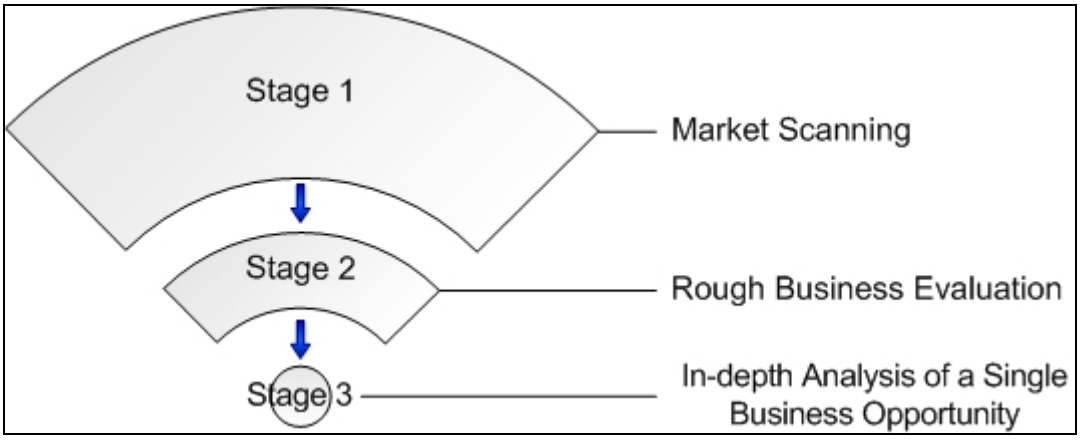


Figure 2. The figure displays the process of the project and how the focus of the objectives will gradually change as the working process carry on.

The first stage is called market scanning and it includes a collection of components gathered in a database. The components are all evaluated with estimations for a number of factors. They are also ranked according to an evaluation system, described in the sub-section called Evaluation Method for the Database. We have also grouped a number of selected components in the market scanning according to their position in the ranking list and other factors. The other factors are, for example, certain circumstances suggested from the project team. The second ranking consists of a few components only, where the components are grouped, processed and selected for the next and second stage, Business Evaluation. Both internal analyses and external analyses are made in this stage. For the internal analyses, resource mapping and gap analysis are used, and for the external analyses, the five forces model by Porter is utilized. Furthermore, to make the interconnection of the internal factors with the external possible, a SWOT analysis is the groundwork.

Factors as technology adoption life cycle and time perspective (time-to-market) are discussed in addition to the internal, external and SWOT analyses. The in-depth analysis finally, is *based* on business plan construction models.

2.1 The First Stage – Market Scanning

In the first stage, numerous ceramic components are gathered in a database, which includes, for SKF, relevant ceramic components. The components are ranked according to evaluation values. The values for each component are processed with an algorithm which led to an overall ranking, out of which a number of components were picked for further analysis. The components are subsequently grouped in order to enable the selection of one component form each group. The tool used for the grouping

and association is the Ansoff matrix, which supports how to do the selection when considering market and product strategies.

2.1.1 Evaluation Method for the Database

The database and description for it is found in the Results and Analysis section as it requires a more practical description before a theoretical. However, the ranking of its content is subject for a description in this section. An algorithm based on the values for each row of components is created, which supports a ranking used to find out *which* components to select for the further investigation.

The evaluation seeks to illustrate an overall rating and ranking of the various elements, and is performed in order to be able to get a rough guideline of which applications that are more important for this work than others. Furthermore, a weighting is done for the different factors, since there is an internal difference of importance of the factors. For example, a "2" in Ease of Entrance is worth more (of higher importance) than a "2" in for example Future Market Value. These values are formed through discussions with the team. A detailed explanation for how the evaluation is done is found in Appendix A – Spreadsheet on Engineering Ceramics, in the Evaluation section.

2.1.2 Ansoff's Matrix

In order to support the selection, and in addition to the ranking, a grouping of components is made by an Ansoff matrix[3] as it is a useful tool for indication of important strategy factors. The groups present different characteristics, and when having selected important parameters of strategic growth, six components are selected, to represent each group.

The Ansoff matrix portrays alternative corporate growth strategies with focus on the future and current products and customers, and offers strategic choices to achieve the objectives, considering ways to grow via existing products and new products, and in existing markets and new markets. These alternative directions, in which development can be made, are outlined in the following figure.

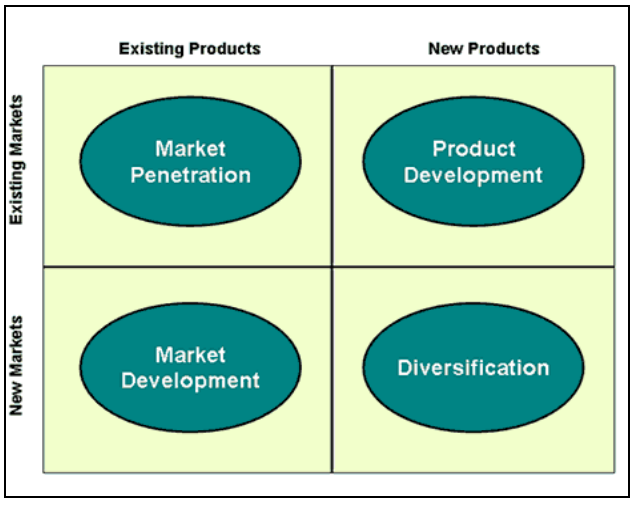


Figure 3. Ansoff's matrix focuses on the present and potential products and markets. Considering different ways to grow, there are four possible product-market possibilities. *(Source: Ansoff, 1957).*

[3] Ansoff (1957)

Existing Markets/Existing Products

Market penetration involves gaining market share as opposed to maintaining it (consolidation). When the overall market is growing, penetration may be relatively easy to achieve, because the absolute volume of sales of all firms in the market is growing and some firms may not be able to satisfy demand. In static or declining markets, a firm pursuing a market penetration strategy is likely to face intense competition.

The 'do nothing' strategy implies the continuation of an existing strategy. It may be appropriate in the short-term when the environment is static or when the firm is waiting to see how situations develop. However, in the long term, such tactics are unlikely to be realistic or beneficial. They may reflect a lack of strategic awareness on part of the management team.

Withdrawal may take place through the sale of business or through divestment, the sale of part or all of the business. Withdrawal may be an appropriate strategy if:

- There is an irreversible decline in demand.
- The firm is over extended.
- The firm is adversely affected by competitive pressure and environmental change.
- The opportunity cost is such that a better return can be earned if the resources used in the particular line of business are engaged elsewhere.

Large conglomerate groups sometimes find themselves too thinly spread and many choose to withdraw from selected markets. Consolidation takes place when a firm concentrates its activities on those areas where it has established a competitive advantage and focuses its attention on maintaining its market share. When this strategy has been prompted by falling profits, the situation is often referred to as retrenchment. Both cases may involve the firm in improvements to cost structure, increased emphasis on quality and increased marketing activity. In the case of retrenchment, the cost reductions may involve redundancies or the sale of assets.

New Markets/New Products

Diversification can be classified as:

1. Horizontal
2. Vertical
3. Conglomerate

1. Horizontal diversification refers to the development of activities which are complementary to or competitive with the organization's existing activities. It is often difficult to distinguish between horizontal diversification and market penetration because classification depends on how narrowly product boundaries are drawn.

2. Vertical integration refers to the development of activities which involve the preceding or succeeding stages in the organization's production process. Backward or upstream vertical integration takes place when the organization engages in an activity related to the proceeding stage in its production process. Forward or downstream vertical integration takes place when the organization engages in an activity related to a succeeding stage its production process.

Obvious examples of vertical diversification include the brewers' control of public houses and the oil industry's combination of exploration, refining and distribution.

3. Conglomerate diversification refers to the situation where at face value the new activity of the organization seems to bear little or no relation to its existing products or markets. The *advantages* of diversification include:

    - Cost savings due to the effects of *synergy* (where the combined effect exceeds the sum of the individual effects)
    - Spreading of risk
    - Control of supplies (mainly related to vertical integration)
    - Control of markets (mainly related to vertical integration)
    - Improved access to information
    - Escape from declining markets
    - Exploitation of under-utilized assets
    - Possible *disadvantages* of diversification include:
    - Inefficiency due to loss of synergy
    - Inefficiency due to loss of managerial control

Existing Markets/New Products

Product development involves the firm in substantial modifications, additions or changes to its present product range, but it operates from the security of its established customer base. In research and development-intensive industries, product development may be the main direction of strategy because product life cycles are short, and because new products may be a natural spin-off form the research and development process. New product development can be risky and expensive.

The product development strategy means increasing the revenue by, for example, promoting the product, repositioning the brand, and so on. However, the product is not altered. It has been SKF's desire for us to search for business opportunities within either this development strategy or the following, in new market/existing products (Market development strategy), since they allow growth at lower risk and cost.

New Markets/Existing Products

Market development can include entering new geographical areas, promoting new uses for an existing product and entering new market segments. It is an appropriate strategy to pursue when the organizations distinct competence rests with the product rather than the market.

The product and market development strategies, when either marketing an existing product to a new market, or promoting a new product to an existing market are, as said earlier, less risky projects than the diversification direction.

2.1.3 Technology Adoption Theory

The dynamics that subsist behind the reasons why a certain product gain success whereas others, not seldom with better technology and perhaps better financial capability, fail. In a high-tech market, by

observing the following bell curve, there is a crack between early adopters and early majority of a technological solution.[4] A lot of companies with excellent technological solutions disappear into the chasm and each company has to struggle in this early period of a product's life cycle. Difficulties in crossing the chasm will depend to a large extent on the mentality of the customer, and the willingness to adopt the technology.

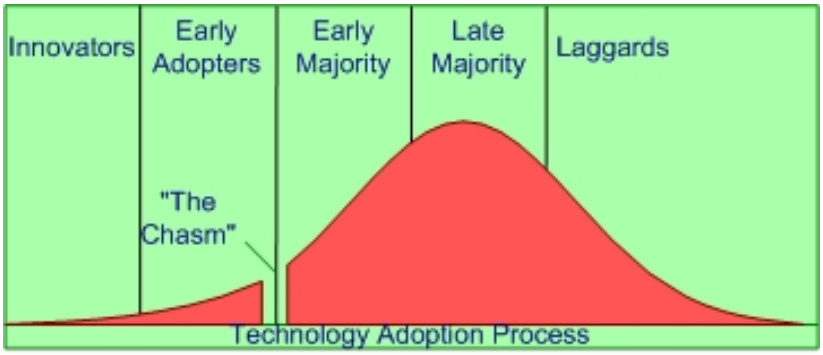


Figure 4. The revised technology adoption life cycle. The area below the Bell curve indicates the amount of adopters of the technology. *(Source: Moore, 1991).*

Firstly shown are *innovators* – which pursue new technology components aggressively, *early adopters* – like innovators, early in a product's life cycle, but more general, *early majority* – driven by technology process but also by a strong sense of practicality and wants to see well-established references before investing, *late majority* – awaiting an established standard and finally *laggards* – that do not want anything to do with new technology.

There are gaps between all the different stages of the life cycle. In the figure is the most critical chasm displayed. A second crack, apart from the chasm displayed above, can be found, of approximately the same magnitude, which falls between the early majority and the late majority. The difference is that the market is well developed there and concerns the end user to be technologically competent and also the reluctance to invest before the references and standards have been well-established.

Different strategies are regarded depending on the nature of the product as well as location in the technology adoption life cycle. These aspects are important to consider when it comes to deciding on components to continue with.

2.1.4 Selection of Components

A selection of some components from the database is necessary in order to narrow down the task. Special consideration is taken to either the market development or product development sections in the Ansoff matrix. However, a selection of some components implies at the same time that others are deselected. The ranking of the components in the database can therefore also be seen as a tool to *filter out* components that are *not* selected. Nonetheless, there might be, far down in the list, components which are not selected, since the evaluation algorithm does not give an absolute and objective truth. From the upper part of the database ranking, 24 are handpicked in agreement with the project team. There is no specific reason why it is exactly 24 components, rather than when the components were grouped; it turned out to be a suitable amount to choose.

[4] Moore (1991)

As stated above, many of the selected components fit into groups according to similarities in which industry the application is utilized. Out of the first 24 selected components, six of them are selected for the evaluation of business opportunities. The selection is based on, among other factors, technology adoption theories, which relates, as described earlier to which factors that make a product moving from being a product purchased by the early adopters to be a volume product. The product is interesting if there is a clear potential to be a precursor for other, larger, markets.

The products located in the product development section together with the ones located in the market development section of the Ansoff matrix, are assenting from SKF's point of view regarding the technology adoption cycle, whereas especially the diversification is farther from the stated choice of growth strategy.

Summary of Stage 1

In the Market Scanning (stage 1), some questions are to be considered in order to keep on track. The overall question is: Which products are of most interest for SKF? The other questions are found in the following figure and they are reflected in the Results and Analysis section.

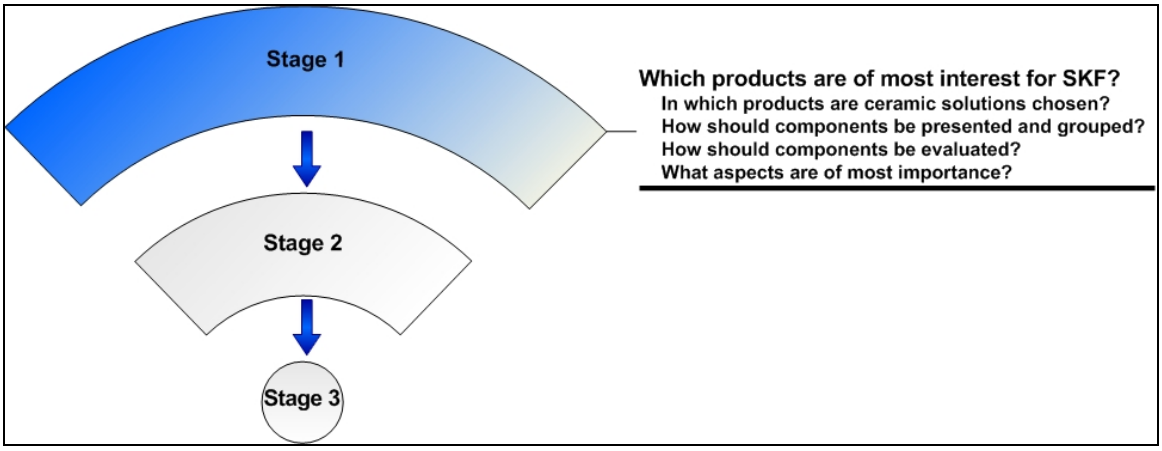


Figure 5. The questions asked in stage 1, of which the theory of this section aspires to reflect. These are considered in the results part.

2.2 The Second Stage – Business Evaluation

The first stage deals with the market scanning; a broad outlook, while in the second stage, the focus is narrowed down to deal with six components. These components are studied from different perspectives as shown in the figure below. For this second stage, additional data is collected.

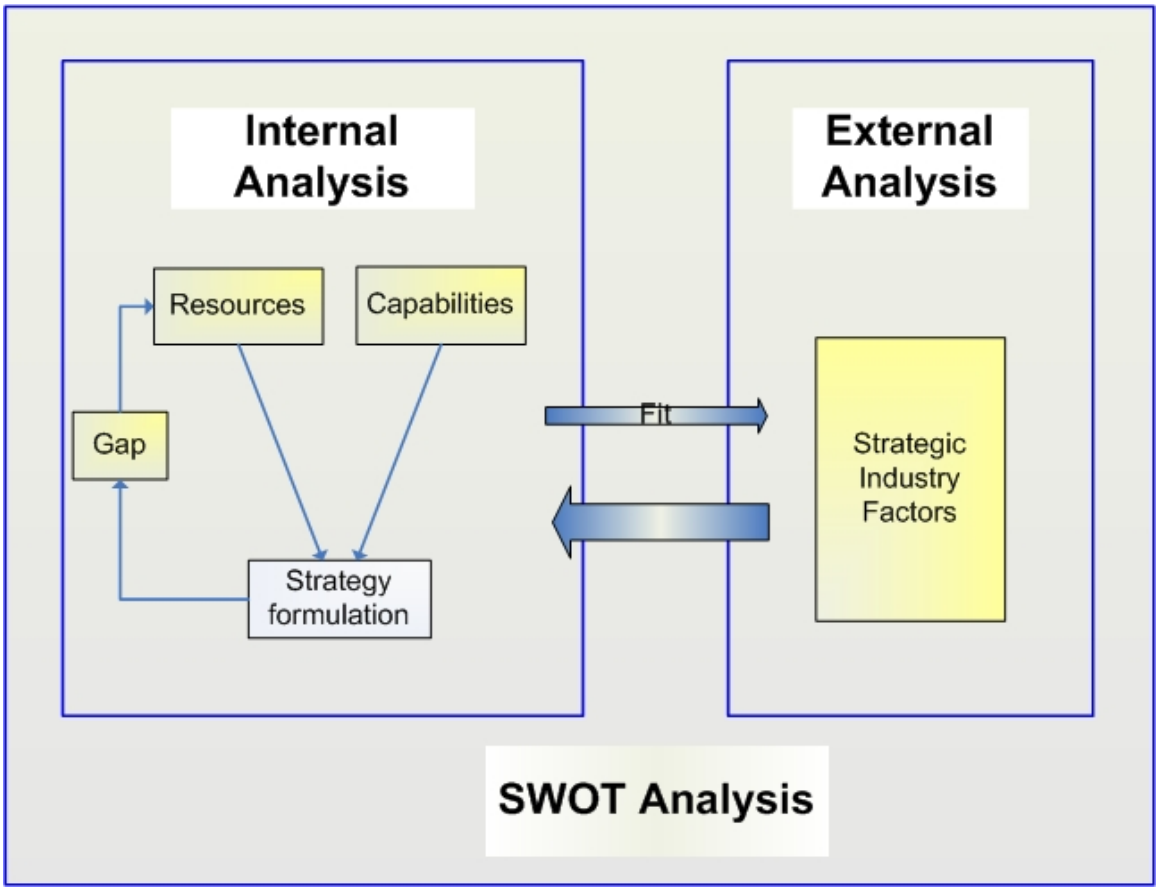


Figure 6. This figure shows the interaction of the internal analysis and the external. The internal analysis consists in mapping of SKF's internal resources, where the most important elements incorporated are resources, capabilities and gaps. The external analysis is supported by the industry competitiveness analysis. These two aspects are combined in a SWOT analysis that summarizes the study of the selected components.

The figure used is somewhat re-worked from its original structure in order to better fit our objectives. It is supported by the connections and relationships between determined strategic industry factors, and firm level resources, capabilities and strategic assets.[5] The left side of their model is modified from showing resources, capabilities and strategic assets to contain a strategy formulation model.[6] This procedure is used because the internal analysis in this report focus more explicitly on resources, capabilities and gaps than on strategic assets. Moreover, an internal analysis is performed where SKF's resources and capabilities are observed, and as they are influenced by external factors, the strategic industry factors are also examined. To manage the interaction of both

[5] Amit and Schoemaker (1994)
[6] Grant (1991)

sides of the theories, external and internal, a SWOT analysis is a useful tool in order to get a united and extensive view of the influencing factors.

2.2.1 Internal Analysis – Resource Mapping

The first and section of the analysis to be processed in the second stage is an examination of the resources *within* the organization. The figure above shows the overall correlations between internal and external analyses and this is consequently the left part of the figure. The aim will consequently be to map the company's internal capabilities. We also aim to identify factors that are needed but not present – gaps.

There are various articles and literature written on resource mapping, or resource-based theory, as it is formally called. Interest in the resource-based view of the firm continues to grow in the field of business policy and strategy[7] and most of this interest seems to have been focused on understanding the empirical implications of this theory, and especially on how a firm's resources and capabilities can affect its performance.[8] However, resource-based theory is not uncontested, but has caused a wild debate, or stimulating discussion, between three research perspectives: "First, the resource-based theory incorporates traditional strategy insights concerning a firm's distinctive competencies and heterogeneous capabilities. The resource-based approach also provides value-added theoretical propositions that are testable within the diversification strategy literature. Second, the resource-based view fits comfortably within the organizational economics paradigm. Third the resource-based view is complementary to industrial organization research. The resource-based view provides a framework for increasing dialogue between scholars from these important research areas within the conversation of strategic management. Resource-based studies that give simultaneous attention to each of these research programs are suggested."[9]

An additional dimension on these theories is the positioning of the resource-based view, which can be positioned relative to three theoretical traditions: SCP-based (structure-conduct-performance) theories of industry determinants of firm performance, neo-classical microeconomics, and evolutionary economics.[10] This dimension points out the relationship between different economical schools. Nonetheless, when utilizing resource mapping as a practical approach to chart a firm's resources, tools for the identification are sought after and methodological problems are pointed out. The internationalization studies reviewed, directly measure organizational learning as an intangible resource and links between the resource-based view and human resource management suffers from serious methodological shortcomings, producing illegitimate relationships or even reverse causation.[11] Furthermore, researchers have struggled to measure resources because many are intangible[12] and they should be diagnosed via qualitative methods.[13] Suggested are, for example, that because culture involves tacit knowledge, organizational members can not easily communicate culture's role in developing a sustainable competitive advantage (SCA).[14] Models for practical use of resource-based view are suggested, where the focus is, nonetheless, to compare resource-based view to an opportunism-based approach.[15] This point of view is a bit too far from our focus though, and the

[7] Barney et al (1994)
[8] Barney (1996)
[9] Mahoney et al (1992)
[10] Barney (2001)
[11] Peng (2001)
[12] Godfrey & Hill (1995)
[13] Rouse et al (1999)
[14] ibid
[15] Conner et al (1996)

line of reasoning develops as it is argued that analysing the resource side of the firm is more useful than exploring the product side.[16] However, we still need a better framework for the resource mapping and the models presented in the articles *The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation*[17] and *Strategic Assets and Organizational Rent*[18] are better suited to fit the purpose.

The suitability of the articles mainly has its origin in the fact that they aspire to identify resources and capabilities. On the other hand, the procedure used is the one illustrated below[19], which is not the aim with our resource mapping. It is merely used for first two steps; resources and capabilities, as well as the last step; resource gaps. With these restrictions, the model supports our internal analysis satisfactorily.

It is claimed that resource-based theory for strategic management in general is unclear for various reasons. [20] Contributions lack a single integrating framework as well as little effort has been made to develop the practical implications of the theory. Therefore, the aim will be to "make progress on both these fronts by proposing a framework for a resource-based approach to strategy formulation […]".[21] Nevertheless, we use this framework as it fits well despite some drawbacks.

Two main activities for mapping the resources are scheduled, leading to choice of strategy.[22] These steps seek to find relationships between *resources and capabilities*, as well as giving an understanding of the mechanisms through which competitive advantage can be sustained over time. Furthermore, a resource-based approach to strategy formulation will be made to be able to maximize rents over time. Moreover, the main target with the procedure is to formulate a strategy. In this part, however, we focus neither on strategy formulation, nor on identifying competitive advantages explicitly. Competitive advantage will indirectly be treated when investigating resources and capabilities. The resource mapping will finally lead us to detect resource gaps.

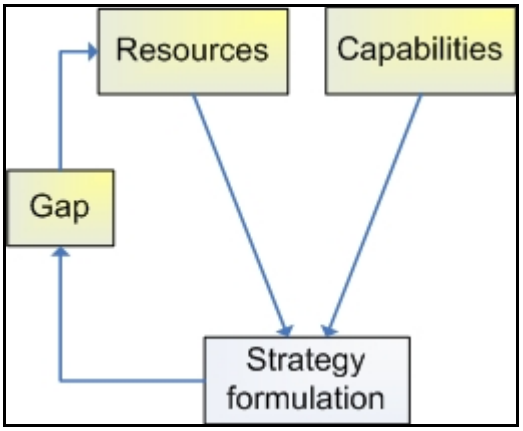


Figure 7. Modified figure of the stages in formulating a strategy, where the most important elements incorporated being Resources, Capabilities and Gaps. *(Source: Grant, 1991).*

[16] Wernerfelt (1984)
[17] Grant (1991)
[18] Amit et al (1994)
[19] Grant (1991)
[20] Grant (1991)
[21] ibid
[22] ibid

The framework presented is a four-stage procedure for strategy formulation. The figure illuminates the steps we focus on; mapping resources and capabilities, leading to resource gaps.

Resources and Capabilities

As a definition on a firm's resources, the following is stated:

> "*The firm's resources will be defined as stocks of available factors that are owned or controlled by the firm. Resources are converted into final products or services by using a wide range of other firm assets and bonding mechanisms such as technology, management information systems, trust between management and labour, and more. These resources consist of know-how that can be traded (e. g. Patents and licenses), financial or physical assets (e. g., property, plant and equipment), human capital, etc."*[23]

Although this definition gives a frame on what resources are, theoretically, a classification is needed to chart the resources. Another suggestion[24] is a organization in six major groups: financial resources, physical resources, human resources, technological resources, reputation and organizational resources. This classification is modified to better support this thesis. The main difference is that human resources and reputation are in the organizational resources only due to better correspondence with SKF's resources. The following groups are chosen: *technological, physical, organizational, market and financial resources.*

The technological column deals with intellectual property rights (IPR) and intangible assets whilst the physical concerns product and process technology. Organizational resources include customer channels and retaliatory capabilities. With customer channels, current customers are the most important factor. However, it is difficult to define customer channels because one can either mean customers that are likely to buy a new product, the product the investigation analyses or one can mean customer channels into a certain segment. An example for the latter case is that SKF currently sell bearings to automotive OEMs, and to sell another product apart from bearings does not necessarily mean the same company, even though customer relations exist closely related to the segment. In any case, it is obviously more beneficial to have customer channels related to the new specific customer than not to have it. Moreover, market resources embrace knowledge of the market. Because of the fact that most of the components we investigate are new fields for SKF, market knowledge is limited wherefore knowledge of the application also is considered. The last factor is financial resources at SKF. Under that segment, we deal with SKF's financial strengths and capabilities to take care of a business opportunity for the component discussed.

Additionally, this section, resource mapping, deals with six applications, and therefore, the focus changes depending on what factor that is described. For example, when talking about the financial situation, it does not make sense to describe it for each selected component individually, but for the entire company. On the contrary, when focusing on customer channels, and the remaining factors, each component possess individual circumstances.

Furthermore, a company's capabilities are the possibilities to utilize its resources and a definition for capabilities is as follows:

> "*Capabilities in contrast* [to resources], *refer to a firm's capacity to deploy resources, usually in combination, using organizational processes, to affect a desired end"*[25]

[23] Amit et al (1994)
[24] Hofer & Schendel (1978)
[25] Grant (1991)

This definition states that there is a connection between resources and capabilities. Because of the reciprocal interaction, it is suitable to discuss resources and capabilities jointly. Apparently, the resources a company possess are the base of its capabilities and when having identified these, a solid foundation is created in order to chart which desired resources that are lacking. This argumentation thus leads to the resource gaps.

The resources are graded in different matrices in the Result and Analysis section, with either "-" for negative impact for SKF "+" for positive impact.

Resource Gaps

It is of importance to find out a company's internal strengths and maybe of even more value to map weaknesses and resource disparities. Theoretically, resource gaps are said to include replacement investment to maintain the firm's stock of resources and to augment resources in order to support and extend positions of competitive advantage as well as broaden the firm's strategic opportunity set.[26] The resource mapping and gap analysis in this work mainly focus on identifying resource gaps, and not so much on approaches to changing the "firm's strategic opportunity set" because identifying gaps and list them in this report, will help the project team in their work of strategy formulation.

Finally, another aspect of resource-based theory is the importance of considering core competence versus core products. The tangible link between identified core competencies and end products is called core products – the physical embodiments of one or more core competencies.[27] Furthermore, it is stated that the company "Honda [unlike Chrysler] would never yield manufacturing responsibility for its engines – much less design of them of so critical a part of a car's function to an outside company – which is why Honda has made such an enormous commitment to Formula One auto racing. Honda has been able to pool its engine-related technologies; it has parlayed these into a corporate-wide competency from which it develops world-beating products, despite R&D budgets smaller than those of GM and Toyota."

What is the point with the above quotation? It is the further analysis of the case that makes it possible to connect Honda with SKF: "Of course, it is perfectly possible for a company to have a competitive product line-up but be a laggard in developing core competencies – at least for a while. If a company would like to enter the copier business today, it would find a dozen Japanese companies more than willing to supply copiers of the basis of an OEM private label. But when fundamental technologies changed or if its supplier decided to enter the market directly and become a competitor, that company's product line, along with all of its investments in marketing and distribution, could be vulnerable. Outsourcing can provide a shortcut to a more competitive product, but it typically contributes little to building the people-embodied skills that are needed to sustain product leadership."[28] Having defined this, we want to draw a parallel that it is of importance for SKF to consider its own resources even in the choice of product development and strategies for new business opportunities. When entering markets that are somewhat out of the core, it must at least be a very conscious move.

[26] Grant (1991)
[27] Hamel et al (1990)
[28] ibid

2.2.2 Industry Competitiveness – Five Forces Analysis

The most influential analytical model for assessing the nature of competition, and to understand the dynamics of the competitive structure, in an industry is the Five Forces Model.[29] Apart from understanding what resources that are required and more critical, and thus needed to be excelled in order for the company to operate successfully in a competitive industry environment, it is also important to understand the nature of the competition itself.

An industry is a group of firms that market products which are close substitutes for each other. The theory explains that there are five forces (with the interaction illustrated below) that determine industry attractiveness and long-run industry profitability. The analysis will conduct the external aspects (the section to the right side of the initial figure of this chapter), considering the strategic industry factors.

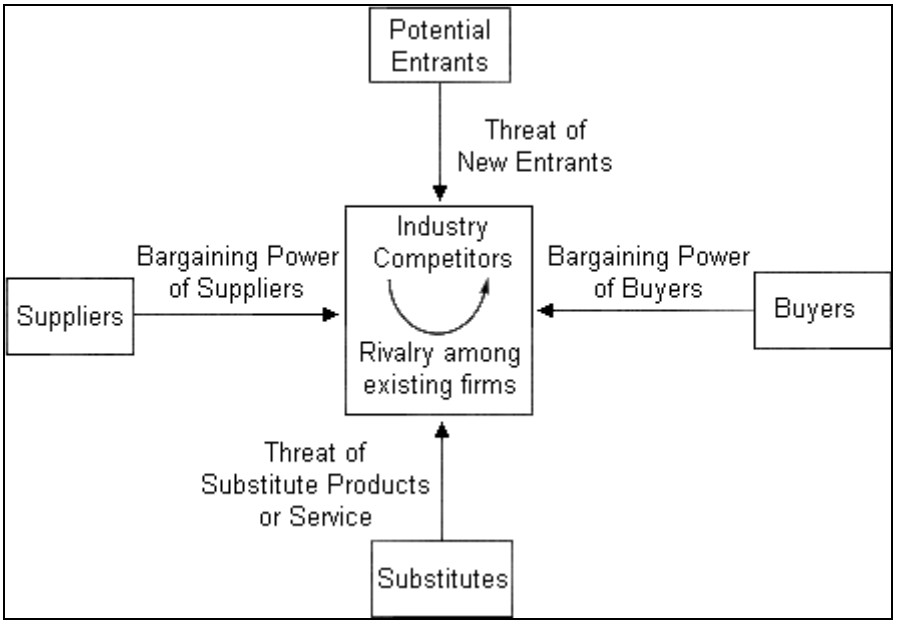


Figure 8. The Five Forces Analysis is a means of identifying the forces which affect the level of competition in an industry. The forces are: threat of entry of new competitors (new entrants), threat of substitutes, bargaining power of buyers and of suppliers and the degree of rivalry between existing competitors. *(Source: Porter, 1980).*

The investigation is embodied in assessing the industries of interest rather than on the level of the applications. We use the Five Forces analysis as an instrument to investigate the industries of our selected components in the business evaluation stage.

[29] Porter (1985)

Threat (Ease) of Entry

From SKF's point of view the threat of entry should be seen as an ease to enter the industry. In theory, any firm should be able to enter and exit a market, and if free entry and exit exists, then profits always should be nominal. In reality, however, industries possess characteristics, barriers of entry, which protect the high profit levels of firms in the market and inhibit additional rivals from entering the market. New entrants to an industry can raise the level of competition, thereby reducing its attractiveness. The ease of new entrants will largely depend on the barriers of entry.

Table 1. Ease of entry

Easy to enter if there is:
· Common technology
· Little brand franchise
· Access to distribution channels
· Low scale threshold
Difficult to enter if there is:
· Patented or proprietary know-how
· Difficulty in brand switching
· Restricted distribution channels
· High scale threshold

When industry profits increase, one can expect additional companies to enter and when profits decrease companies to exit. Moreover, companies are reluctant to enter uncertain markets. Nevertheless can companies, both individually and collective (an illegal action), keep prices artificially low in order to prevent potential entrants from entering the market.

Threat of (Ease to) Substitute

From SKF's point of view, the threat of substitute should be seen as an ease to substitute products. In Porter's model, substitute products refer to products in other industries. They have primarily their impact either through the demand of a certain product because of the impact of the price for a substitute product, or through the performance by the substitute application.

The presence of substitute products can lower industry attractiveness and profitability because they limit price levels.

Bargaining Power of Buyers and Suppliers

Table 2. Bargaining power of buyers.

Buyers are powerful if:
Buyers are concentrated – there are a few buyers with significant market share
Buyers purchase a significant proportion of output - distribution of purchases or if the product is standardized
Buyers possess a credible backward integration threat - can threaten to buy producing firm or rival
Buyers are weak if:
Producers threaten forward integration - producer can take over own distribution/retailing
Significant buyer switching costs - products not standardized and buyer cannot easily switch to another product
Buyers are fragmented (many, different) - no buyer has any particular influence on product or price
Producers supply critical portions of buyers' input - distribution of purchases

Table 3. Bargaining power of suppliers.

Suppliers are powerful if:
Credible forward integration threat by suppliers
Suppliers concentrated
Significant cost to switch suppliers
Customers Powerful
Suppliers are weak if:
Many competitive suppliers - product is standardized
Purchase commodity products
Credible backward integration threat by purchasers
Concentrated purchasers
Customers Weak

The buyers in the matrix are SKF's customers and the people / organizations, who create demand in the industry. If the power of the buyer is strong, then the industry comes close to a monopsony – many suppliers and one buyer, in which practically the buyer sets the price. The nature of a majority of the markets for ceramic components (depending on the level of differentiation of the component) will be a market that could almost be defined as a monopsony, or at least, some sort of asymmetry between the producing industries and the buyers.[30]

The cost of items bought from suppliers (e.g. raw materials, components) can have a significant impact on a company's profitability. Suppliers, if powerful, can exert an influence on the producing industry, such as selling raw materials at a high price to capture some of the industry's profits. If suppliers have high bargaining power over a company, then in theory the company's industry is less attractive.

Intensity of Rivalry

The most common indicator on rivalry is the concentration in the industry. A high rate of concentration indicates that a high concentration of market share is held by the largest firms, and with fewer firms holding large market shares, the competitive situation is less competitive (closer to monopoly). With lower concentration in the industry, many rivals exist, none of which have a significant market share, and the situation is very competitive.

2.2.3 SWOT Analysis

A SWOT analysis (Strengths Weaknesses Opportunities and Threats) summarizes the key issues from the analysis of the business environment and the strategic capabilities of the organization[31]. The aim is to identify the extent to which the current strategy of SKF's organization, and its more specific strengths and weaknesses, are relevant to, and capable of, the changes taking place in a business environment.

The analysis is founded on the resource analysis and the environmental analysis, where knowledge about the five forces generates threats and opportunities for SKF, and identifies the basic motives behind competitive ability. It should be seen as a useful way to summarize the relationship between the different analyses.

[30] Andersson, interview, 2004-01-28
[31] Johnson et al (1999)

The working method and how internal factors have an influence on key issues in the environment, is displayed in the figure below:

Table 4. Example of the overview of the SWOT analysis, using a fictions product, where the different factors are listed with decreasing impact.

Product "Adam"	
Main strengths	**Main weaknesses**
Process and prod. tech.(Keramera)	Lack of product experience
Brand name	Lack of tech. knowledge
Distribution channels	Small market share
Financial capability	Non-structured organization
Opportunities	**Threats**
Barriers of entry	Bargaining power of buyer
Technology development	Intensity of rivalry
Substitute products	
Technology trends	

Key environment issues are based on the critical external factors, where it is of importance that SKF excel to outperform its competition. The list should not exceed 7-8 key points[32], and as can be seen in the figure below, we have chosen a number of 5-6 external factors. Strengths and weaknesses are critical internal factors, based on the applications of competences and resources.

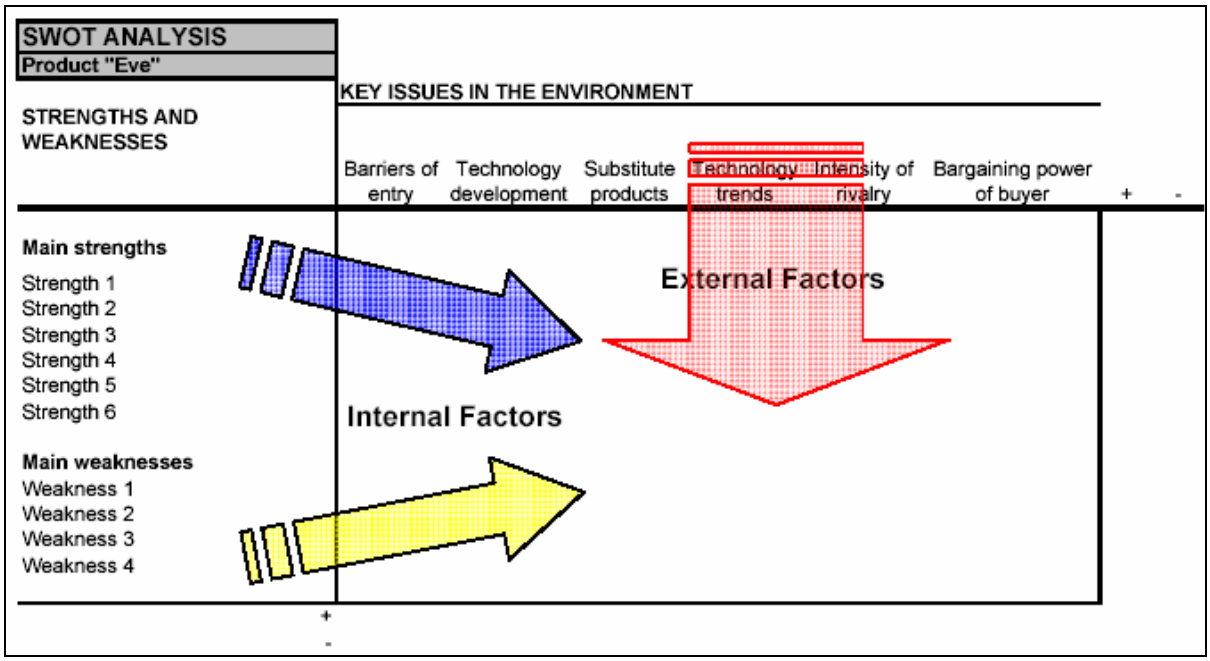


Figure 9. Example of SWOT analysis, using a fictitious product, where the interaction between external and internal factors of strengths and weaknesses is displayed.

Finally, the internal and external aspects are summarized in an overview where the main opportunities and threats, as well as strengths and weaknesses are presented.

[32] Johnson et al (1999)

Summary of Stage 2

In the second stage, the Rough Business Evaluation, some questions are to be considered in order to keep on track. The main question is what product that should be selected and further processed in the third and final step.

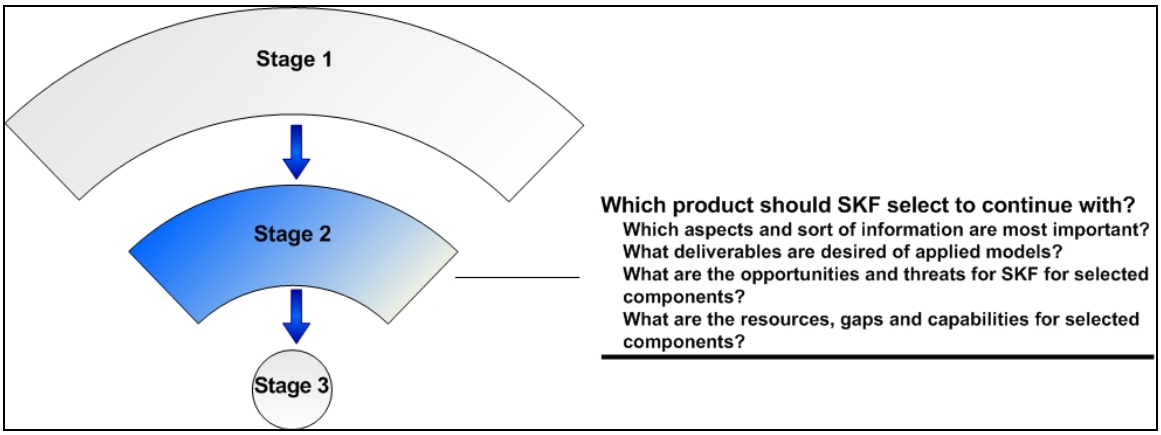


Figure 10. These questions are asked in stage 2, of which the theory of this section aspires to process, which will be further conducted in the results part.

2.3 The Third Stage – In-depth Analysis of a Single Business Opportunity

The second stage manages strategic instruments and leads us to one component that is the best suited to continue with into the third stage for business development, when having considered the specific objectives and strategic views.

Due to limitations mentioned earlier, in the Delimitations part, the in-depth analysis of a single business opportunity will not be a complete business plan; it should rather be seen as an analysis treating the business development of a selected component.

2.3.1 Building a Business

In order for a venture to be properly set off, an entrepreneur attitude in the start-up phases is valuable. However, as the business enterprise develops, not only the entrepreneurial capabilities, but also skilful business development abilities are of importance. Thus to be a good entrepreneur does not only stand for a talent to come up with proficient ideas. In order for the entrepreneurial team to build a durable business it has to be able to answer the following three questions:[33]

1. Are my goals well defined?

Before starting a business, an entrepreneur has to be sure of his/her "private" goals – Where do I want to go? The goals have to be explicit, for example: gaining independency by starting up an own project is not goal enough. It should answer questions such as detailed questions regarding the structure of the venture and what risks the entrepreneur is willing to take

[33] Bhidé (1999)

2. Do I have the right strategy?

A lot of entrepreneurs start up new ventures seizing the short-term opportunities without thinking about the long-term strategy.[34] A successful entrepreneur soon changes from a tactical to a strategic point of view, in order for crucial capabilities and resources to be created. The strategy needs to be well defined, meeting the goals regarding growth and profits as well as answering the question: How will I get there?

3. Can I execute the strategy?

Good ideas do not guarantee great performance; many entrepreneurs fail because of inability to execute the strategy.[35] The entrepreneur has to ask himself/herself if the adequate resources and relationship exist, if the organization is strong enough and if the entrepreneur can play his/her role well.

It is claimed that good ideas will not be enough for success and that one of the most critical factors to create a sustainable business plan that covers a broad spectrum of factors.[36] Among the most important factors are to sell the idea in order to tempt investors to offer venture capital, and it also shows that the main focus is to help entrepreneurs making their idea lift from being just an idea to be a long-lasting business. Therefore, the core predicament is how to sell the idea and get capital for a start-up. In this work, however, we do not face these issues to a significant extent even if they are important factors. SKF already have capital to invest in new business opportunities, but nonetheless, it is crucial at this point that the ideas generated in this thesis are "sold" to decision makers for their support in resources in form of capital and knowledge.

Additional important focus areas are market estimation, pricing strategies and mapping of competitors. As mentioned in the delimitations section, we do not focus exhaustively on these factors, as it will not be an entire business plan. Our outline follows the suggested[37], with some exceptions. We do not mention the aspects on choosing managerial body, specific product offer, profitability assessment and cash flow calculation. Our main focus is instead to gain deeper knowledge of one business opportunity and no single outline is appropriate for every new venture and business development situation. The following outline covers most of the important areas that are included:

- Background and purpose
- Customer need and problem
- Solution
- Market
- Competitive Situation
- Risks

The first three sections are informative and reveal information about the application, what the problem is and the ways to solve the problems. The market and competitive situation sections cover general market trends for the oil industry, and market estimation for the specific component as well as a concise summary of the competitors. Finally, the risks involved with this product development are included.

[34] Bhidé (1999)
[35] ibid
[36] McKinsey & Company (2001)
[37] McKinsey & Company (2001), Smith et al (2000)

The figure below contains a summary over queries that are regarded as means and instruments of how the objective is achieved. The main question is how, or perhaps what information is lacking in order to verbalize how, SKF should proceed with the selected component.

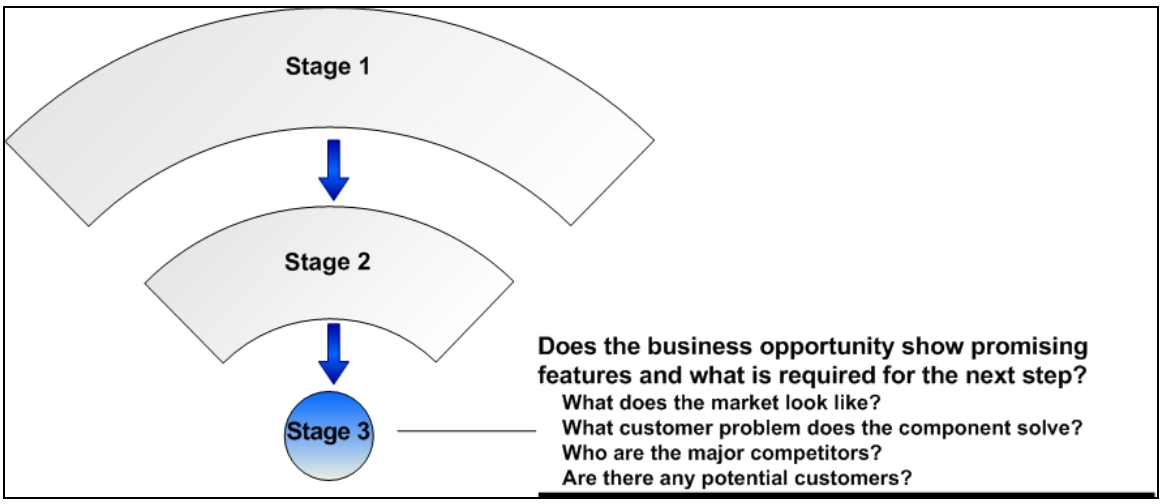


Figure 11. The figure shows the questions pointed out in the third stage.

2.4 Summary of the Theoretical Framework

In order to fulfil the purpose of the thesis, several problem areas must be analysed. In this section, we integrate the purpose, the theoretical framework and the analysis by constructing a practical framework, illustrated in the figure below.

As the disposition of the report consists of three stages, each stage has various sub-targets that need to be examined. Every step has a number of questions to be focused and answered, directly or indirectly. The figure shows the three steps and their core deliverables to the left, which have their origin in the questions to the right in the figure, and the deliverables can be regarded as *tools* to handle the questions.

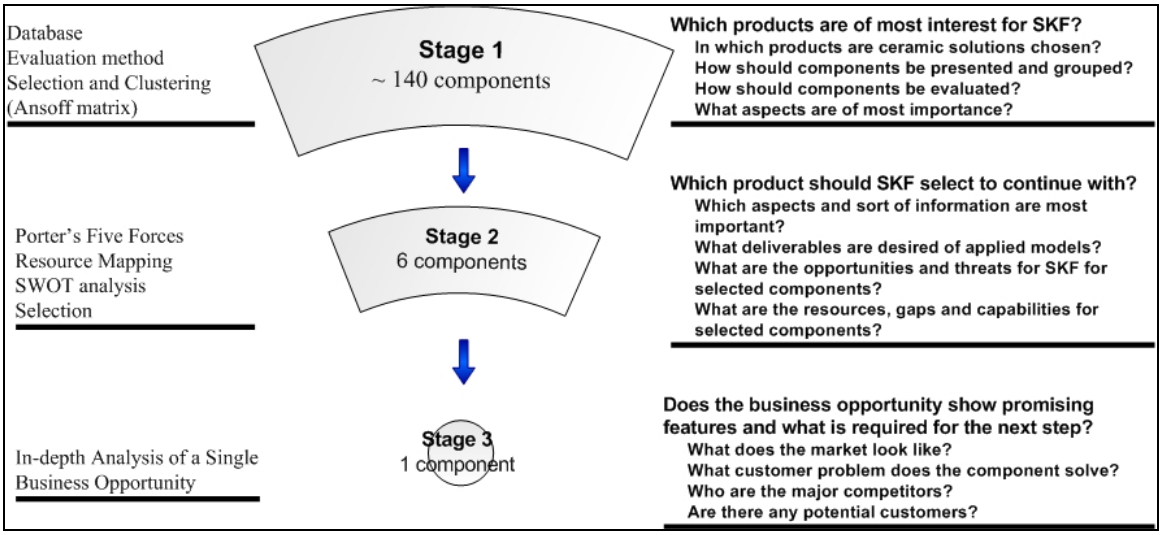


Figure 12. The figure shows the stages in the working process. The subject matters mentioned in the theoretical framework are listed to the right in the figure. To the left, from each stage respectively, the different deliveries in every stage of the working process are listed.

3 Methodology

This chapter describes the methods used throughout the work. It begins with a description of the procedure and the practical approach, and continues with the methods used while collecting information. Finally, an evaluation of the validity and reliability of the report is regarded.

3.1 Data Collection

Most of the data collection needed to perform the stages mentioned in the Theoretical Framework section, together with the processing of the data has been done through personal interviews and literature or electronic sources. Also of significance have been visits at fairs.[38]

The main idea and focus have been to cover sufficient components of the engineering ceramic market to be able to select interesting components without missing important parts of the market. Sources to the components are companies working with ceramic material in their products. This is obtained through a consistent and thorough working process during the data collection phase. To certify that the emphasis is set correctly, the method is built up continuously through verification of the data acquired.

In addition to this, knowledge is also gathered from business reports, market analyses and interviews with scientists and development departments at ceramic companies. A majority of the material upon which the in-depth analysis is generated springs out of interviews with existent customers and experts within the selected field.

An explanation of how the obtained data is presented follows in the next section, the Results and Analysis, and with a more extensive explanation of the database in Appendix A – Spreadsheet on Engineering Ceramics.

3.1.1 Interviews

The focus with the interviews has been to obtain a base of information, with both a varied and broad range of aspects and competences, why also different types of interviewing techniques have been used. Interviews have been used in order to acquire different types of information. First of all, the basic knowledge about ceramics and fundamental components and later more specified information regarding certain components. Depending on the motive for the interview, the structure[39] and realisation of the interview was decided.

Either the interview was open; an open formulation to which the interviewee could freely develop ideas and this could benefit the ability to assemble a picture of reality, since the interviewee can express its subject view. Another possibility is a more structured interview, where a relationship between predestined questions is sought. The more structured interviews were used in order to benefit the situation where a certain knowledge and question more strictly is wanted.

[38] Scanpack, fair, 2003-10-24 and Subcontractor, fair, 2003-11-11
[39] Lantz (1993)

Often were a mixture of the interviews mentioned above used, and to some extent directed concerning a, by the interviewer, specified area where a certain coherence between different subjects and related knowledge is required.

3.1.2 Validity and Reliability

A definition on validity is that validity is the measurement to which a question in reality reflects and evaluates the feature desired to investigate.[40] Either how the results can be used in other external assignments or to what extent the results correspond with the reality.

With reliability are the trustworthiness and the regularity considered during the process and can be seen as a measurement of how the used instruments and methods deliver the same result under different circumstances and moments in time.[41]

A limitation with the tools used is that an instrument of analysis can be very subjective – two people rarely come up with the same final version of SWOT for example. Therefore, it should be regarded as a guide and not a prescription, which have been taken into account while analyzing the results. The same amount of carefulness should be taken when using the Five Forces Analysis, Ansoff's Matrix as well as the Resource Mapping.

We have consistently made our analysis separately, in order to put together a combined result after discussions. In addition to this, we have on a regular basis gone through the results with tutors, from SKF as well as from the university, since a higher level of reliability is obtained if a large number of persons attain the results.

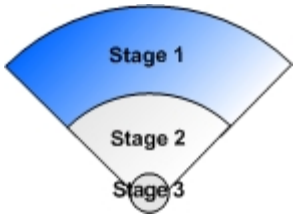
[40] Bell (1987)
[41] ibid

4 Results and Analysis

In this chapter, we present results and analyses from the data collected. Major part of the data is found in the database, as it is the base for information. Nonetheless, the database does not contain all information for the further investigation as a significant amount of components are handled. After the first stage's information collection for the database, additional interviews and research are done. This is also the case before arriving at the last stage, the In-depth Analysis of a Single Business Opportunity, where even more information is gathered. Moreover, the last stage is covered in a section *after* this chapter, and thus not in this chapter, the Results and Analysis.

For the first and second stages, market scanning and business evaluation, the major part of the data is derived from interviews with specialists within ceramics and their applications, apart from the above mentioned fairs, competing companies product catalogues etc. Moreover, interviews are also carried out with the following persons for the first and second stages: Kent Rundgren (Keramera Scandinavia and The Institute of Ceramics), Roger Karlsson (The Institute of Ceramics), Rolf Mendel & Björn Åhlander (Huhnseal), Claes Kuylenstierna (Volvo), Anders Hedlund (CeramTec) and Cornelia Barkebo (Glynwed). Apart from these, internal sources at SKF has been contacted, at a continuous basis or a one-time interview; Kjell-Arne Arvidsson (SKF Paper Machines), Ellinor Ehrnberg (SKF Business Development), Egon Ekdahl (SKF Railway), Håkan Zetterling (John Crane) and Lars Kahlman (Industrial Division Prominent Needs Development, SKF Gothenburg).

4.1 The Database

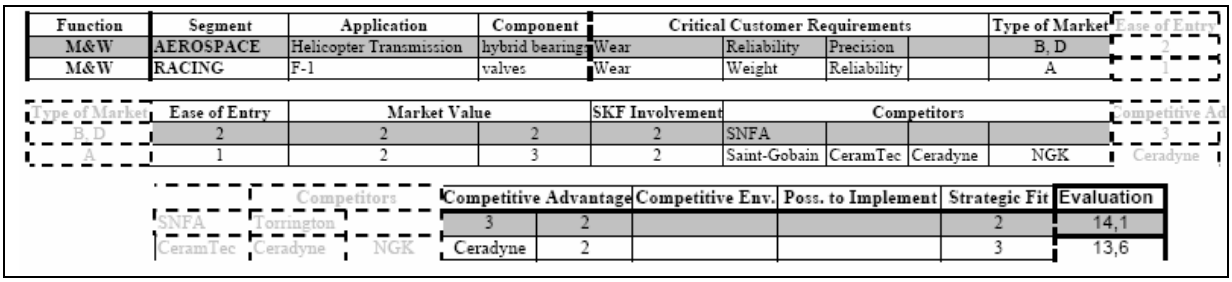


The idea with the database is to get an organized picture of which applications made of advanced engineering ceramics that are used today and the planned component usage for the near future - with interest for SKF. The database contains more than 140 lines with components. Every single line does not necessarily represent a unique component. In order to get an as complete picture as possible we are obligated to include for example hybrid bearings used in several applications. This means that such a component will be listed in more than one place with different application areas, which naturally is the case for a number of components and thus could the component name be not *one* specific component, but a *group* of components with similarities. There is a range of variants (sizes, materials, appearances etc.) of for example hybrid bearings[42], and they are grouped according to similarities in technology and application area.

The components found in the database are selected from various ceramic manufacturers' assortment; product catalogues, home pages and queries. Furthermore, interviews with experts of the engineering ceramic business are accomplished.

In order to do a selection, the components are ranked using assessed data; each *line* in the database has an estimate-number in the corresponding *columns*. This is schematically showed in the figure below.

[42] In the ranking of components, and the further work, hybrid bearings are not considered as a subject of interest in this thesis for the simple reason that SKF already possess knowledge in this area and it would require a considerable amount of investigation in order to surpass current understandings.



Function	Segment	Application	Component	Critical Customer Requirements				Type of Market	Ease of Entry
M&W	AEROSPACE	Helicopter Transmission	hybrid bearing	Wear	Reliability	Precision		B, D	2
M&W	RACING	F-1	valves	Wear	Weight	Reliability		A	1

Type of Market	Ease of Entry	Market Value		SKF Involvement	Competitors				Competitive Ad
B, D	2	2	2	2	SNFA				3
A	1	2	3	2	Saint-Gobain	CeramTec	Ceradyne	NGK	Ceradyne

Competitors			Competitive Advantage	Competitive Env.	Poss. to Implement	Strategic Fit	Evaluation
SNFA	Torrington		3	2		2	14,1
CeramTec	Ceradyne	NGK	Ceradyne	2		3	13,6

Figure 13. The figure displays an example of the function of the database divided into three parts because of the width of the spreadsheet. The elements are agreed upon different numbers in the different columns, where each figure is representing a certain estimated aspect.

The first columns are order under a generic term called "Market". This signifies the categorization of the component; in which segment it is classed, according to SKF internal classification system. One column also shows in which application the component is used. The columns following after "Market" are called "Data" and contain values for the evaluation. Included columns are: Critical Customer Requirement, Type of Market, Ease of entry, Market Value, SKF Involvement, Competitors, Competitive Advantage, Competitive Environment, Possibility of Implementation and Strategic Fit. The factors are chosen because of the need to indicate grade of attractiveness the component has for SKF to look for further business opportunities. Thus, "Attractiveness for SKF" is defined through collaboration with the project team. The main factors are:

- What type of market it is
- How intense competition it is, easiness of entering this market
- Potential value for SKF in this market
- How involved SKF is in this market today, either with customers or internal knowledge, or both
- Main competitors

An instructive description of the database is found in Appendix A – Spreadsheet on Engineering Ceramics, where detailed texts of what the different columns mean.

The main query for this section is which components that are of most interest for SKF, which is required to be shown in a logical way through grouping and presentation.

4.2 Processing and Evaluation of Components

The components in the database have an individual evaluation mark derived and they are sorted in a descending scale, according to the estimate of each component respectively. Naturally, other factors, such as possibilities for SKF to broaden the business within other markets for the same component are important aspects for the selection. Check valve balls, for example, can be used for oil production pumps, but also for pumps within the chemical industry. This idea with the different groups facilitate, as mentioned, the possibilities to exploit knowledge gained in one business area and then transfer these advantages into new sectors. This is the *cascading* factor.

Table 5. In the figure are the 30 highest ranked components listed from the data base. To the very right, the evaluation figure is found. Also displayed are the belonging applications as well as market segments and functions to each component. A star (*) to the right means that the component is selected for the further analysis.

#	Segment	Application	Component	Evaluation	
1	**MIN.&.CONSTR.**	Down Hole	Seals	15,9	*
2	**RAILWAY**	Carriage Wheels	break discs	14,6	*
3	**RACING**	F-1	brake discs	14,3	*
4	**RACING**	F-1	valves	13,6	*
5	**AEROSPACE**	Aircraft	aircraft engine seals	12,3	
6	**AEROSPACE**	Aircraft	struts and support rods	12,3	*
7	**FLUID-MACH.**	Hydraulic Systems	check valve balls	11,6	*
8	**FLUID-MACH.**	Oil Extraction	check valve balls	11,6	*
9	**MIN.&.CONSTR.**	Oil Extraction	measurement instruments	11,6	*
10	**PULP-AND-PAPER**	Paper Processing Machines	PZT, sensors	11,4	
11	**FLUID-MACH.**	Compressor	pump parts	11,3	*
12	**AUTOMOTIVE**	Engines	push rods	10,9	
13	**MAT.HANDLING**	Can Making	seaming roll hybrid bearings	10,8	
14	**POWER GEN.**	Nuclear Power	face seals	10,8	
15	**FLUID-MACH.**	Pumps	position components, PZT	10,8	
16	**RACING**	F-1	brake calliper	10,3	*
17	**PULP-AND-PAPER**	Paper Machine Foils	slotted dewater. centrifuges etc.	10,3	*
18	**AUTOMOTIVE**	Diesel Engines	turbo chargers	10,1	
19	**FLUID-MACH.**	Compressor	face seals	9,8	*
20	**FLUID-MACH.**	Injection Pumps	face seals	9,8	*
21	**AUTOMOTIVE**	Engines	rocker arm pads	9,4	
22	**FLUID-MACH.**	Pumps for Paper & Food Industry	face seals	9,3	*
23	**FLUID-MACH.**	Fluid System	valves	9,1	*
24	**FLUID-MACH.**	Diesel Engines	fuel injection, ceramic ball	8,8	*
25	**AUTOMOTIVE**	Diesel Engines	valves	8,8	*
26	**AUTOMOTIVE**	Engines	valve top	8,8	*
27	**FOOD & BEVERAGE**	Food Industry	spots, nozzles	8,8	
28	**POWER GEN.**	Fuel Cells	PZT	8,8	
29	**METALWORKING**	Metal Heating Ovens	masonry and fibre ovens	8,8	
30	**FLUID-MACH.**	Mixers, Stirrers	seal rings	8,8	*
41	**FLUID-MACH.**	Seawater Lift-Pumps	seals	8,3	*
48	**AUTOMOTIVE**	Diesel Engines	cam follower rollers	7,8	*
49	**FLUID-MACH.**	Diesel Engines	fuel injection needle seal	7,8	*
56	**AUTOMOTIVE**	Diesel Engines	exhaust gas control valve	7,3	*
66	**AUTOMOTIVE**	Engines	fuel injection, PZT	6,8	*

The list shows the 30 highest positioned components, and five additional components. These five are specially selected, originating from positions below the top-30. Out of all these, 24 components are selected after consideration of the most important aspects and fit for the organization, the

perspectives and expectations. The selection is based on ranking value, suggestions from the project team and cascading possibilities.

Furthermore, the groupings are based on the industrial segment in which they are used, but also its functionality. The Racing and Automotive Components groups are arranged according to the *industry* in where the applications exist. The Mechanical Face Seals and Check Valve Ball groups are ordered according to *functionality*. In the "Other" group, finally, are applications found that are not grouped because of dissimilarities in relation to the other ones.

Table 6. This table shows the selected components divided into groups. The total number being 24 components assembled in 5 groups. 19 of them are found among the top 30 on the database ranking list. The remaining 5 have been handpicked.

Group	Component	Application
Check Valves	check valve balls	Hydraulic Systems
	check valve balls	Oil Production
Mechanical Face Seals	Seals	Seawater Lift-Pumps
	Seals	Injection Pumps
	seals	Oil Industry Down Hole
	seal rings	Mixers, Stirrers
	face seals	Compressor
	face seals	Pumps for Paper & Food Industry
	fuel injection needle seal	Diesel Engines
Automotive Components	fuel injection, ceramic ball	Diesel Engines
	exhaust gas control valve	Diesel Engines
	valves	Diesel Engines
	valve top	Engines
	cam follower rollers	Diesel Engines
Racing	brake discs	F1
	valves	F1
	brake calliper	F1
Other	valves	Fluid System
	measurement instruments	Oil Extraction
	slotted dewatering foils/centrifuges and beds	Paper Machines
	pump parts	Compressor
	struts and support rods	Aircraft
	brake discs	Carriage Wheels
	PZT fuel injection	Engines

4.2.1 Ansoff Matrix

The 24 components are arranged in an Ansoff matrix in order to find which ones to continue with in the further analysis.

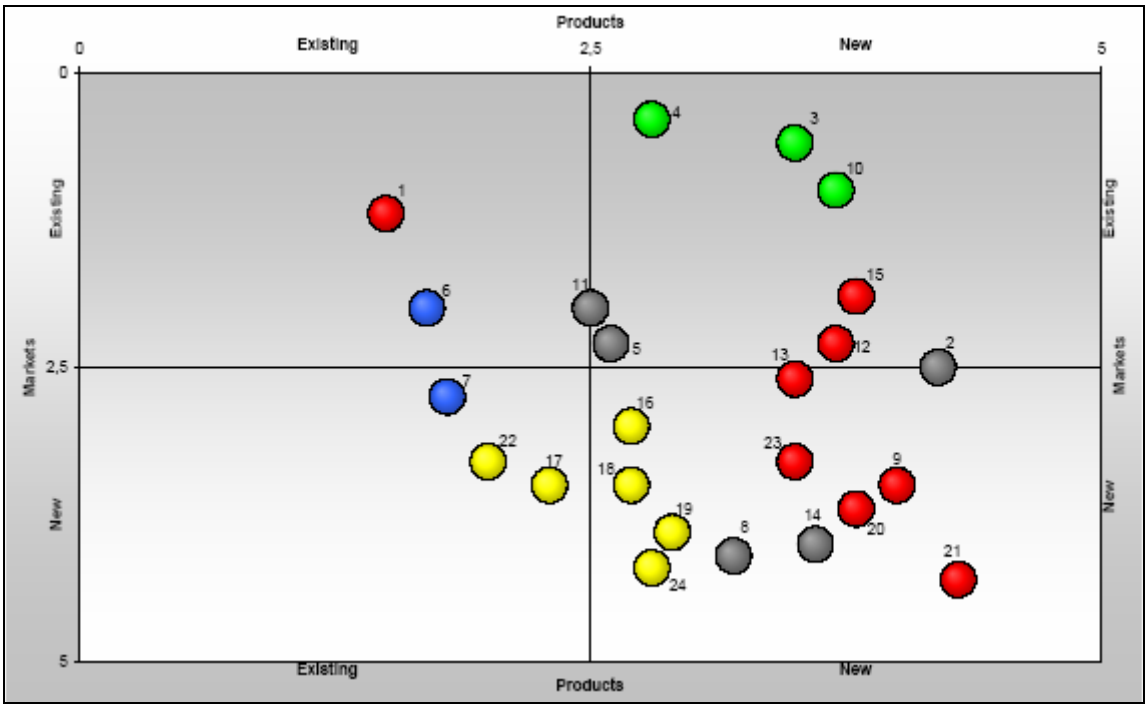


Figure 14. The figure shows the Ansoff Matrix of selected applications sorted in business areas – the colours Racing (green), Seals (red), Automotive Components (yellow), Check Valve Balls (blue) indicating each area. On top of that are a few applications that can not be sorted into the groups mentioned above (grey). The list with the components belonging to the numbers is as follows:

	Application	Component/Product		Application	Component/Product
1	Down Hole	seals	**13**	Injection Pumps	seals
2	Carriage Wheels	brake discs	**14**	Engines	PZT fuel injection
3	F-1	brake discs	**15**	Pumps for Paper & Food Industry	face seals
4	F-1	valves	**16**	Fluid System	valves
5	Aircrafts	struts and support rods	**17**	Diesel Engines	fuel injection, ceramic ball
6	Hydraulic Systems	check valve balls	**18**	Diesel Engines	valves
7	Oil Extraction	check valve balls	**19**	Engines	valve top
8	Oil Extraction	measurement instruments	**20**	Mixers, Stirrers	seal rings
9	Compressor	pump parts	**21**	Seawater Lift-Pumps	seals
10	F-1	brake caliper	**22**	Diesel Engines	cam follow. rollers
11	Paper Machine Foils	slotted dewater. Centrifuges, list and beds	**23**	Diesel Engines	fuel injection needle seal
12	Compressor	face seals	**24**	Diesel Engines	exhaust gas control valve

This matrix shows two dimensions; new/existing market and new/existing product. The components are thus placed where they fit the best and thereafter coloured according to similarities among them. The components' positions in the Ansoff matrix are based on SKF's view of the markets and products. "Existing product" means traditionally that the product is part of the current stock. With existing market it is meant that SKF sell products to customers which are likely to buy the

component, *or* if SKF in some way are involved in this market as such. This means, that in the upper left field of the Ansoff matrix, only a few components are found because we are looking into new products. Nonetheless, reasons why mechanical face seals are placed there, is that SKF today collaborate with Huhnseal for a certain mechanical face seal application. And the reason why a certain check valve ball application is placed in the same box is that SKF had sales to a customer with specific needs (mentioned further down in the resource mapping, market resources).

4.2.2 First Selection – Six Components

As declared in the theoretical framework, the components are under distinctive influence of the "Adoption life cycle-factor". They are ranked into three levels, *low, intermediate and high,* where low signifies a low liability of entering the chasm and consequently a low interference with SKF's choice of strategy in regards of location in the technology adoption life cycle:

Low:	Check valve balls
Intermediate:	Dewatering foils Face seals
High:	Cam follower rollers Brake discs Fuel injection

We have selected the applications where we see the best possibilities, and a good representation for the group and its development. Also we have sought a mixture of time perspective and scale as well as value. The initiative is that the selected component should function as a launched initiation, and that similar elements with other application areas in the future could follow. Further factors that have been considered for the specific selection from the groups are mainly margins of value, development position and competitive advantage. The selected components show more favourable features regarding these factors and represent the group.

Selected components (from groups):

- *Face seals for pumps in paper and food & beverage industry*. Chosen from the seals group; SKF has a positive position considering markets and products, and also considering the size and structure of the market.
- *Check valve balls for oil extraction.* Chosen from the check valve ball group; this has a good margin and better investigational and development possibilities and is also currently being manufactured by Keramera.
- *Cam follower rollers for diesel engines*. This application holds great possibilities in the future and is an interesting application as well as a good representative for the group and possesses more positive market factors (competition, current position etc). The component is currently manufactured by Keramera.

Selected applications (not belonging to groups):

- *PZT, fuel injection*. The technique employed in the PZT fuel injection appliance is very interesting and hold interesting characteristics for the bearing industry. On the other hand,

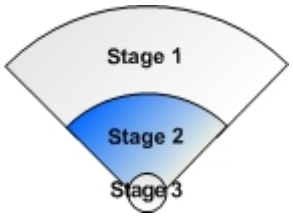
the application may not be the best suited application simply considering the yield of a short-time and decent return. It is currently being developed by giants such as Siemens and Bosch, with far-reaching developing programs, why it is of less interest for SKF for automotive applications, but in a longer perspective for utilizing the technology for automatic lubrication of bearings.

- *Slotted dewatering foils, centrifuges lists and beds, for paper machines.* These dewatering foils are very interesting. Mainly because of existing customers and the strategic fit of SKF, but also because its product that Keramera manufactures.
- *Brake discs for carriage wheels in the railway industry.* The application is interesting and customer channels and opportunities do exist, in various ways.

Some of these will show less optimistic characteristics, and others will stand stronger. The outcome is one component, which is given additional analysis. A further and deeper description of these components can be found in Appendix C – Summation of the Six Components.

4.3 Internal Analysis – Resource Mapping

The five forces analysis considers the external industry factors and the resource mapping charts internal factors at the company. The mapping is divided into two parts; the first section covers resources and capabilities while the second one treats disparities between requirements and resources, the resource gaps.



4.3.1 Resources and Capabilities

Firstly, resources and capabilities for all components, jointly, are described. This is done because equalities among the components are found.

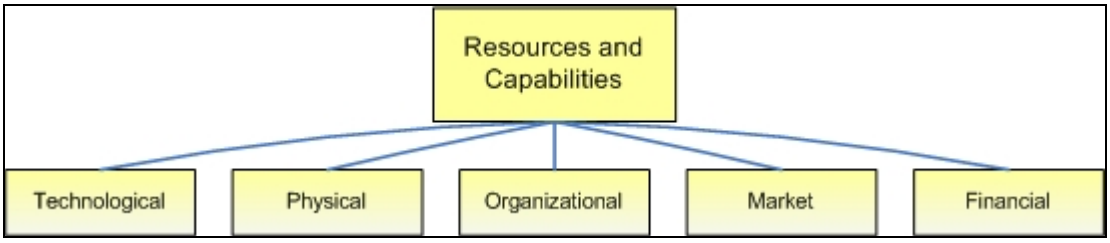


Figure 15. Resources and capabilities divided into subgroups. This classification is partly derived from the theory described in the Internal Analysis – Resource Mapping. *(Source: Derived from Grant ,1991).*

With the figure illustrating connections between res*ources, capabilities, competitive advantage, strategy* and *gaps* in mind, we have expanded the understanding of resources and capabilities with the figure above (from the Theoretical Framework section). It shows the resource areas we have considered; technological, physical, organizational, market and financial. The subgroups' contents are discussed in the theoretical framework.

Below follows results and analysis for each factor. The last part in this chapter is followed by a summary of all factors.

Technological Resources

This section briefly covers the intangible assets. Keramera has a patented process for manufacturing process for silicon nitride, which is the material used for a range of products. Of the six selected products, the check valve balls, cam follower rollers and dewatering foils are manufactured with this process. The patent makes it possible for exclusive right to the process generating competitive advantage for Keramera due to a more efficient process, the process hence allows for a beneficial price situation. When the process patent expires in a few years, a threat is of course that competitors copy the process. This risk, however, might not be very likely because of difficulties in copying an entire process. Even if employees with insight would move to another company, it is likely that it takes some years for it to become a real threat.

Table 7. This table shows technological resources as intellectual property rights (IPR) and intangible assets.

	Technological
	IPR, Intangible assets
Check Valve Balls	+
Cam Follower Rollers	+
Face Seals	-
Dewatering Foils	+
Brake Discs	-
Fuel Injection	- -
All 6 components	+

The remaining three components do not hold any advantage according to the patent situation. Mechanical face seals are a collection of different technologies where whole concepts/ solutions have patent protection. Brake discs are in a similar position as the face seals while fuel injection is a technology at the development stage making it hard to get a decent picture of the technology's intangible condition.

Physical Resources

Physical resources describe the aspects for how to physically manufacture the products. There are two columns on the chart; product and process resources. When discussing physical resources and capabilities it is done primarily considering Keramera. They are/will be the manufacturers of the ceramic components, which does not necessarily mean that components without technological connection to Keramera are out of the question. Supplying the components can be done from other manufacturers, but the main focus is nonetheless Keramera.

The component check valve balls are made of ceramics and currently used in various applications. The balls are manufactured by Keramera and the product technology rating is therefore high. Cam follower rollers are also currently manufactured by Keramera. Seals are currently not made by Keramera but SKF collaborates with the seal manufacturer Huhnseal. Dewatering foils are produced by Keramera, and materials used for the component are silicon nitride and silicon carbide.

Brake discs are not Keramera's business and will probably not become so either, since the most common material used is carbon fibre reinforced silicon carbide (C/SiC). SKF is in cooperation with the Italian brake disc manufacturer Brembo. However, other producers seem to be the leaders in this specific sector. SGL Carbon AG (Wiesbaden) is one of the major ceramic brake disc manufacturers for the automotive industry (mainly Porsche), whereas ceramic brake discs for train carriages are mainly manufactured by SAB Wabco.

Fuel injection with PZT is another technology compared to the other components. It is not produced by Keramera but the technology is interesting for SKF with possibilities in a range of applications, considering that one application is to utilize the technology for controlled lubricant injection in bearings.[43]

Process technology is a competitive factor for the components currently manufactured by Keramera; check valve balls, cam follower rollers and dewatering foils. The other ones have fundamentally dissimilar characteristics. However, face seals may be closest in technology of the three outsiders.

Table 8. The table shows gradation on the components from a technological point of view. The two columns, product and process, divide up the physical view of the resource mapping.

	Physical	
	Product	Process
Check Valve Balls	++	++
Cam Follower Rollers	++	++
Face Seals	+	-
Dewatering Foils	++	++
Brake Discs	-	-
Fuel Injection	- -	- -
All 6 components		

Organizational Resources

In organizational resources we comprise customer channels and retaliatory capability. With customer channels we mean to what extent there exist sales from SKF to contemplated customers in the respective areas.

One of the most important resources is SKF's extensive customer network and sales organization. Check valve balls in this regard means the mining and construction segment in which SKF has numerous customers. Even though they might not be in a high number, the sales value is substantial.[44] Cam follower rollers are in the automotive segment, where SKF holds a large amount of customers.

Mechanical face seals hold different opportunities. One attention is to integrate bearings with mechanical face seals. If that would be the case, current customers do exist. But considering mechanical face seals as a stand-alone product, the customer base is different and SKF then has without doubt a lower involvement. However, mechanical face seals are nearby components to bearings, making this application the closest, among the other five, to customers existing today.

Dewatering foils are manufactured by Keramera today, making SKF competitive in technology. SKF has also many customers in the pulp and paper segment, as well an important segment. A majority of the sales being bearings, naturally.

[43] Lars Kahlman, interviews continuously
[44] Customers and sales, SKF internal document

A possibility for SKF is to develop a joint system with the brake disc system integrated with bearings. This hub unit should widen the solution provided for the customer. Because customers already exist for wheel bearings, it would be a small step, thinking on customer channels and retaliatory capabilities, to make the component around the bearing.

The initiative with Keramera partnership is that SKF has the customers and Keramera supplies SKF with ceramic material. There are some features making this partnership competitive. The strongest factors are price, quality and a closed contract. The price advantage is due to Keramera's unique process technology allowing them to manufacture at a very competitive price. However, this process did not gain sufficient quality as other, more expensive processes, did. Today, on the other hand, it is claimed that Keramera process technology meets the requirements very well. The third advantage is that Keramera and SKF has a contract that restrains Keramera from supplying to competitors to SKF. If this partnership is well utilized, it will be a considerable competitive factor.

Table 9. Showing organizational resources, divided into customer channels and retaliatory capabilities. From a resource point of view, check valve balls, cam follower rollers and face seals are the most promising applications.

	Organizational	
	Customer Channels	Retaliatory Capability
Check Valve Balls	+	++
Cam Follower Rollers	+	++
Face Seals	++	++
Dewatering Foils	+	+
Brake Discs	+	- -
Fuel Injection	- -	- -
All 6 components		

Market Resources

Market resources considers to what extent knowledge for the components exists within SKF. One may think that market knowledge is closely related to customer channels. This is, however, not always the case. SKF might have sales to a customer which gives a plus in the "customer channels" column. But sales to a current customer do not necessarily mean that the market is the same for another product even if it might be the same customer.

There are persons at SKF who have some technological knowledge of check valve balls. Applications are also known, but market knowledge is small. One customer has actually bought check valve balls from SKF - Siemens Building Technologies uses balls in security valves in buildings[45], as a side business.

Knowledge for cam follower rollers is possessed by SKF Austria making the mark positive. Check valve balls and cam follower rollers are quite similar in the resource mapping except from here, the market knowledge. Mechanical face seals, on the other hand, are components grouped with high

Table 10. This table shows the market knowledge factor. Application knowledge is also discussed.

	Market
	Knowledge
Check Valve Balls	-
Cam Follower Rollers	+
Face Seals	+
Dewatering Foils	-
Brake Discs	+
Fuel Injection	-
All 6 components	

[45] Göran Lindsten and www.se.sibt.com

involvement today. SKF has a considerable interest in face seals according to features such as good strategic fit and closeness to bearings. Mechanical face seals seem to be a step further from just a bearing solution. SKF collaborates today with the seal manufacturer Huhnseal for demanding off-shore applications.

The market resources for dewatering foils are not developed even though the customer base is substantial. The brake disks market, on the other hand, is to some extent penetrated, mainly through the partnership between SKF and the Italian brake disc manufacturer Brembo; development of electro-mechanical actuators for use in braking systems. Finally, the fuel injection components are known at a technology basis but because the product is quite newly developed, the market is not yet experienced.

Financial Resources

Currently, the financial situation is very good and SKF is willing to grow quickly and widely. This is to be done in various ways, mainly by widening of current businesses but also through acquisitions.[46] Additionally, the size (employees) and turnover of an organization has impact on its success in new markets. However, this is a somewhat difficult concept when applying it on our selected ceramic components, since it is not always clear who the exact competitor is. Without digging too deep into these concepts, it is a fact that SKF is competing with very strong competitive firms, such as Saint-Gobain (check valve balls), Siemens (fuel injection) and SAB Wabco (brake discs). Nevertheless, it is difficult to measure if Siemens as a gigantic company group is a relevant comparison when their main business is not in ceramic products, but a little part of it. We confine ourselves to state that SKF currently has a good financial position and is willing to spend money on new business areas.

Table 11. This Table shows financial resources as an overall rating for the six components.

	Financial
Check Valve Balls	
Cam Follower Rollers	
Face Seals	
Dewatering Foils	
Brake Discs	
Fuel Injection	
All 6 components	+ +

[46] Ehrnberg, interview, 2003-12-15

Table 12. This table shows a summary of the ratings for the components. The five main factors are discussed in each of the passages below. Individual ratings are done for all components except for financial resources, because an overall rating for all 6 components better shows the comprehensive view (also is a grey area found in the cell "All 6 components" where it is not possible to conclude an overall rating of the feature).

	Resources and Capabilities						
	Techno-logical	Physical		Organizational		Market	Financial
	IPR, Intangible assets	Product	Process	Customer Channels	Retaliatory Capability	Knowledge	
Check Valve Balls	+	++	++	+	++	-	
Cam Follower Rollers	+	++	++	+	++	+	
Face Seals	-	+	-	++	++	+	
Dewatering Foils	+	++	++	+	+	-	
Brake Discs	- -	-	-	+	-	+	
Fuel Injection	- -	- -	- -	- -	- -	-	
All 6 components	+						++

4.3.2 Resource Gaps

After having highlighted the resources, the next step is to identify missing the assets for SKF, the gaps, which are identified and extracted with the resource and capabilities mapping as foundation. The components are discussed briefly one by one, and at the end of the chapter, a table illustrates a summary of the gaps, and their main resources (qualitatively).

Check Valve Balls

Check valve balls are manufactured by Keramera and SKF have customers within the oil segment. These criteria make the gap concentrated to finding customer matching, which will be dealt with in the third stage, in-depth analysis. However, current customers are mainly concentrated in oil drilling, while sucker rod pumps with the check valve ball components are mainly used for oil production.

Cam Follower Rollers

Cam followers are also manufactured by Keramera. However, cam follower rollers do not necessarily have the same customer channels as other automotive components. One should keep in mind that SKF's main products are bearings, and sales to the automotive sector are primarily wheel and transmission applications. The significant question mark for cam follower rollers is whether the market is willing to pay the extra price for this solution. There is undoubtedly a vast interest from truck manufacturers but as the automotive industry is very price sensitive, volume sales will not come up before the cost/price balanced is achieved.

Mechanical Face Seals

Mechanical face seals seem to be very much in line with SKF's aims to broaden the offer within and around bearing businesses. Therefore mechanical face seals might be the forthcoming most important business to focus on. However, the main ceramic material used for face seals is silicon carbide which is not the major strength for Keramera.

For SKF to broaden its offer to mechanical face seals as a concept, products need to be developed. This increases the aspect time to market, which is explicitly stated as a major factor.

Dewatering Foils

Dewatering foils for paper machines are manufactured and sold by Keramera. SKF has gained knowledge within this segment according to substantial relationships with paper machine customers. On the other hand, these relationships are mainly based on sales of bearing, as the knowledge of dewatering foils is scarce.

Brake Discs

Ceramic brake discs have numerous possible applications as shown in the Appendix C – Summation of the Six Components. Both railway carriages and the automotive industry can benefit of the advantages of using a lighter and more reliable material. However, Keramera is currently not involved in this kind of ceramic components, which differ from their current assortment of components.

Fuel Injection

Fuel injection applications based on the special physical characteristics that piezo ceramics possess, are today still at a development stage. They are mainly being developed for fuel injection for combustion motors which may not be an application of interest for SKF. However, great possibilities exist in own adaptations and development out of this technology in use for automatic lubrication systems for bearings. It is not a field where Keramera possess knowledge today.

Summary of gaps and resources and capabilities

Below follows a table that shows a summary of the main gaps and resources and capabilities.

Table 13. The table shows the most important factors regarding resource match and gaps. Many of the components have customers as a gap despite good values in the previous table. The understanding behind this is that there are customers related to the component, as shown in the previous table, but they may not be the ones that potentially buy this component, even though they are in the same customer segment.

	Gap			Resources and Capabilities	
Check Valve Balls	Customers	Market knowledge	Application knowledge	Keramera manufacturing	Retaliatory capability
Cam Follower Rollers	Customers			Keramera manufacturing	Knowledge
Mechanical Face Seals	Fully developed products	Knowledge	Material	Customers	Collaboration
Dewatering Foils	Application knowledge	Customers		Keramera	
Brake Discs	Technology	Material	Fully developed products	Customers	Collaboration
Fuel Injection	Developed technology	Customers	Fully developed products	Knowledge	Apply techno-logy in bearings

4.4 Industry Competitiveness – Five Forces Analysis

With the internal strategic factors explained in the previous section, the five forces analysis is carried out at this juncture in order to handle the external strategic factors. Throughout the analysis, the basis and viewpoint is regarded as from SKF's point of view – supposedly a positive figure in the illustration signifies a positive factor and a negative figure a negative factor for SKF. It is considered which aspects and sort of information that is most important.

In one matrix for the respective industry, the characteristics are described and estimated as in the resource mapping, with either "-" for negative factors or as "+", if positive, with a variation of influence and intensity with the amount of signs respectively.

Ease of Entry

For SKF's concern, it is of highest interest whether it is easy for the company to enter the industry and also the easiness for the competitive companies to enter, i.e. if the ease of entry is high or low, which is displayed below.

Table 14. Ease of entry in each industry respectively. New entrants to an industry can raise the level of competition, thus reducing its attractiveness.

Ease of entry						
Application	**Aspect of external influence**					
	Economies of scale	Capital / Investment requirements	Customer switching cost	Access to industry distribution channels	Likelihood of retaliation from existing buyers	Σ
Check Valve Balls	+ +	+ +	+ +	-	+	5
Cam Follower Rollers	+	+	-	-	- -	-2
Face Seals	+	+	+	-	-	2
Dewatering Foils	+	+	- -	- -	+	-2
Brake Discs	-	-	+	-	+	-2
Fuel Injection	- -	- - -	- -	- -	- -	-8

The ease of entry is considerably less positive for the fuel injection, mainly because of the research involved in the development process, and because of the strong characteristics in the distribution channels of the automotive industry. The check valve balls, together with the face seals, have a lower development estimate why the easiness increases. Furthermore, the customer switching cost is low for the check valve balls and for the face seals, while it is higher for the cam follower rollers and the fuel injection. Fuel injection is a rigid market with mean competitors.

It should also be mentioned that SKF possesses a strong and well-known brand identity of quality that can be of importance, especially in the automotive industry and regarding check valve balls.

Ease to substitute

In the model used, substitute products refer to products in other industries. They have primarily their impact either through the demand of a certain product because of the impact of the price for a substitute product, or through the performance by the substitute application.

Table 15. Ease to substitute. Substitutes being products in other industries.

Ease to substitute				
Application	**Aspect of external influence**			
	Buyers willingness to substitute	The relative price and performance of substitutes	The cost of switching to substitutes	∑
Check Valve Balls	+ +	+	+	4
Cam Follower Rollers	-	+	-	-1
Face Seals	+	+ +	+	4
Dewatering Foils	- -	-	- -	-5
Brake Discs	+	+ + +	-	3
Fuel Injection	+	+	- - -	-1

Buyers are generally willing to substitute if the price and performance is satisfactory, especially considering valve balls and face seals as well as the brake discs (while not considering the cost of switching to substitutes).

However, the situation is slightly different regarding the cam follower rollers and especially the dewatering foils considering the nature of the products and the distribution channels. The pulp and paper industry and the automotive industry consider mainly features such as implementation problems and the costs connected with a switch to a substitute.

The automotive industry usually, opposes themselves to changes and their willingness to substitute is low. The case is somewhat different regarding the buyers willingness to substitute for the fuel injection, even if it is still fairly restrained. The latter displays a negative picture though, when considering the cost of switching to substitutes.

Bargaining Power of Buyers and Suppliers

SKF is regarded as the producing firm in this situation. The buyers in the matrix are SKF's customers and the people/organizations, which create demand in the industry.

Table 16. Bargaining Power of buyers in selected industries. Buyers are SKF's customers and the people/organizations, which create demand in the industry.

Bargaining power of buyers					
Application	**Aspect of external influence**				
	Number of dominant buyers and number of sellers.	Standardization of products.	Suppliers integrating forward.	Buyers integrating backwards.	∑
Check Valve Balls	- - -	- - -	+	+ +	-2
Cam Follower Rollers	- -	-	+	+	-1
Face Seals	- - -	+	-	-	-4
Dewatering Foils	- -	-	-	-	-5
Brake Discs	- - -	+	+	+	0
Fuel Injection	- -	+ +	- -	+	-1

The suppliers in the matrix below are the businesses that supply materials & other products (e.g. raw materials, components) into the industry.

The bargaining power of the buyer in the selected industries respectively is high, mainly because of the nature of the product supplied by the manufacturers. The overall bargaining power of the supplier is low; the products supplied are usually standardized and non-differentiated which is one of the reasons why it is mostly produced in low cost countries in Southeast Asia. The value and the bargaining power of the supplier is somewhat higher for the check valve balls, where the material is more sophisticated and is produced by only a few main actors.

Because of the nature of the products, the risk of buyers integrating backward in the supplying matrix is relatively low, generating plus signs in the column. On the other hand this possibility does exist in the buyers' matrix where the risk of a buyer integrating backward is higher. The bargaining power of the buyers is remarkable when evaluating the column of suppliers integrating forward.

Suppliers to the face seals and check valve balls industries have a lower risk of buyers integrating backward, mainly because of small possibilities in value creation for the buyer in doing so.

Table 17. Bargaining Power of suppliers in selected industries. The suppliers in the matrix are the businesses that supply materials & other products into the industry.

Bargaining power of suppliers					
Application	**Aspect of external influence**				
	Number of buyers and domination of suppliers	Undifferentiated, highly valued products.	Suppliers integrating forward.	Buyers integrating backwards.	Σ
Check Valve Balls	+	+	-	+ +	3
Cam Follower Rollers	- -	-	+	+	-1
Face Seals	+	+	-	+ +	3
Dewatering Foils	+	+	-	+	2
Brake Discs	+	+	-	+	2
Fuel Injection	- -	-	- -	+	-4

Intensity of Rivalry

The most common indicator on rivalry is the concentration in the industry. With lower concentration in the industry, many rivals exist, none of which have a significant market share, and the situation is very competitive.

Table 18. The intensity of rivalry in selected industries.

Intensity of rivalry					
Application	**Aspect of external influence**				
	The structure of competition	Degree of differentiation	Switching cost	Strategy objectives	Σ
Check Valve Balls	- -	- -	+	- -	-5
Cam Follower Rollers	- -	+	+	- -	-2
Face Seals	+ +	+	-	- -	0
Dewatering Foils	-	+	+ +	-	1
Brake Discs	-	+	+	- -	-1
Fuel Injection	+	+	+ +	- - -	1

Given that the involved companies are pursuing aggressive growth strategies, rivalry is more intense in the column of strategy objectives. The switching costs found in the matrix of threats of substitutes are connected with the switching cost found in this matrix, why it generates similar results.

The structure of competition generates a less intense rivalry situation regarding the face seals and the fuel injection since the industries have clearer market leaders, while the others have many small or equally sized competitors. In the column of the degree of differentiation the rivalry is generally lower because of the higher degree of differentiation regarding the cam follower rollers and the fuel injection.

Summation of Five Forces Analysis

All five forces discussed in the sections above, are summarized in the table illustrated below.

Table 19. The table shows an overview of the five forces analysis. Each external influence should be regarded in combination of other aspects; however this overview illustrates each component and the summation made for each force.

Overview of the five forces analysis					
Application	**External influence**				
	Ease of entry	Ease to substitute	Barg. Power of buyers	Barg. power of suppliers	Intensity of rivalry
Check Valve Balls	**5**	**4**	**-2**	**3**	**-5**
Cam Follower Rollers	**-2**	**-1**	**-1**	**-1**	**-2**
Face Seals	**2**	**4**	**-4**	**3**	**0**
Dewatering Foils	**-2**	**-5**	**-5**	**2**	**1**
Brake Discs	**-2**	**3**	**0**	**2**	**-1**
Fuel Injection	**-8**	**-1**	**-1**	**-4**	**1**

4.5 SWOT analysis

The different internal factors have unique and particular impacts on each and every one of the environmental issues. Resources and capabilities structure the internal key factors and the external factors take form out of the environmental issues. One should consider the strengths and weaknesses thoroughly when forming a strategy not to disturb the balance between them – strength could easily transform into a weakness if not exercised and without the proper management.

Important questions one should ask are if the organization possesses sufficient resources and competences needed to meet expectations, and also considering the fact that some issues could be either opportunities or threats, depending on the extent to which the organization can capitalize its strengths while coping with the weaknesses.

Since the report is carried out from SKF's point of view, the SWOT analysis, consequently, is performed from SKF's point of view and thus is not including Keramera specifically. However, as the supplier *is* involved it is clearly indicated, at each position in the table respectively, where the collaboration has a noteworthy impact.

Check valve balls

The process and product technology should be regarded as the main strength for the check valve ball application. Also listed among the strengths are primarily the brand name and distribution capabilities. The product is produced for the moment by Keramera and could be implemented reasonably easy to existing markets.

Table 20. SWOT analysis of check valve balls.

Check valve balls	
Main strengths	**Main weaknesses**
Process and prod. tech.(Keramera)	Lack of product experience
Brand name	Lack of tech. knowledge
Distribution channels	Small market share
Financial capability	Non-structured organization
Opportunities	**Threats**
Barriers of entry	Bargaining power of buyer
Technology development	Intensity of rivalry
Substitute products	
Technology trends	

Lack of experience with the exact product, together with the lack of technological experience within SKF, can be found among the weaknesses.

The main opportunities are the technology development that springs out of the cooperation with Keramera, together with the fairly low entry barriers for the product. Also to substitute the product should be seen as an opportunity. This kind of customers, within the oil industry, focuses mainly on the performance of the product, rather than the price – if down-time costs do not exceed costs for exchange of components.

The barrier of entry is rather low; however the bargaining power of the buyer is rather high and therefore does the buyer posses control of the pricing. The case is somewhat different the more specialized the product is, why the focus should be positioned on applications with greater margins. This aspect was considered when selecting a representation of each group.

Cam follower rollers

The product is manufactured at the moment by Keramera, and this reason together with SKF's brand name and its capacity for innovation should be regarded as main strengths. Among the weaknesses must be mentioned the lack of product experience for SKF as well as the lack of technology knowledge.

Surrounding and environmental aspects will present opportunities such as politics and new legislation. They speak in favour of a change in technology trends. Especially, and primarily, this will affect the industry producing heavy trucks.

Table 21. SWOT analysis of the cam follower rollers.

Cam follower rollers	
Main strengths	**Main weaknesses**
Process and prod. tech.(Keramera)	Lack of product experience
Brand name	Lack of exact customers
Capacity for innovation	Lack of tech. knowledge
Financial capability	Non-structured organization
Opportunities	**Threats**
Politics/Legislation	Competitive market
Bargaining power of buyer	Barriers of entry
Technology trends	Substitute products
	Technology trends

The automotive industry however is by tradition a very competitive one, which leads to high barriers of entry as well as difficulties to substitute products. Paradoxically the technology trend could also be seen as a threat, because of the lack of technology knowledge and product experience, why it could be difficult to follow the trend. It is important that SKF manages to mobilize its resources and competences in order to shape the macro features into opportunities.

Face seals

Table 22. SWOT analysis of the face seals.

Face seals	
Main strengths	**Main weaknesses**
Distribution channels	Lack of tech. knowledge
Capacity for innovation	Lack of product experience
Sales organization	Non-structured organization
Process tech.(Keramera)	
Opportunities	**Threats**
Market size	Competitive market
Substitute products	Bargaining power of buyer
Barriers of entry	Technology development

The strategic fit of the face seals even with the SKF's strategy with overall solutions to customer needs and the market is vast and probably reachable. SKF possesses of a sales organization with the necessary distribution channels and special market expertise.

One has to overcome the weaknesses, especially the lack of exact product experience and the exact technology knowledge, but if this is accomplished, there exists a fairly closely associated market. The customers are not far away from the existing ones in the bearing industry. This is one of the reasons why it should not be too difficult to substitute the product.

The first obstacle to overcome is basically the technology development in order to be able to offer an attractive solution to the customer. Besides this, the buyer possesses of a secure bargaining position, and the market is already a competitive one.

Dewatering foils

Table 23. SWOT analysis of dewatering foils.

Dewatering foils	
Main strengths	**Main weaknesses**
Committed employees	Lack of knowledge
Brand name	Lack of exact customer
Process & prod. tech.(Keramera)	Lack of experience
Distribution channels	Lack of exact product
Opportunities	**Threats**
Technology development	Bargaining power of buyer
Market competition	Barriers of entry
	Substitute products

The product is manufactured at the moment by Keramera; more exactly they produce dewatering foils for the paper making process industry. The process and product technology possessed by Keramera in combination with the sales organization form a range of strengths for SKF. Committed employees, the very essence of the sales organization, and the force that drives the progression forward using existing distribution channels, should be regarded as the main strength.

Distribution channels do exist, but maybe not the direct customer for this specific product, although closely related. This aspect together with the lack of knowledge and experience for SKF regarding the product should be seen as weaknesses.

Opportunities that can be located are related to the technology development and the potential retrieved from the Keramera cooperation. The market competition is low, and this mainly has its origin in the fact that the willingness to substitute products by the buyer is low. The impact of price and performance is not crucial and they worry more about the switching costs and the uneasiness and difficulties with a switch of product, even if the substitute is showing more promising results.

Brake discs

The retaliatory abilities should be seen as the main strength. The brand name expresses a certain indication of security and reliability. Together with the financial capabilities of the company and the capacity for innovation, SKF holds a significant assembly of strengths. Furthermore, the Brembo-SKF cooperation is of advantage.

The lack of knowledge of the product should be seen as a considerable weakness. The company has not been involved in the development process of the product and consequently does not hold the exact product experience.

Table 24. SWOT analysis of brake discs.

Brake Discs	
Main strengths	**Main weaknesses**
Retaliatory capability	Lack of knowledge
Brand name	Lack of product experience
Financial capability	Lack of exact customer
Capacity for innovation	Non-structured organization
Opportunities	**Threats**
Substitute products	Competitive market
Technology trends	Barriers of entry
	Technology development
	Politics/Legislation

Provided that the product proves itself to be more reliable and less expensive than conventional products, it should be interesting of a substitution point of view. The technology trend also speaks in favour of the component. One has to be even more careful though with drawn conclusions and with the progress considering the safety aspect of such security products. Nevertheless, it should not be ignored that sizeable advantages can be gained in changing to a ceramic solution; A part from the significant weight difference, also the advantages in performance and maintenance.

The competition will increase though and the barriers of entry are considerable, especially because of the development process associated with the component.

Fuel injection

Table 25. SWOT analysis of fuel injection.

Fuel injection	
Main strengths	**Main weaknesses**
Committed employees	Lack of knowledge
Brand name	Lack of product experience
Retaliatory capability	Capacity for innovation
	Non-structured organization
Opportunities	**Threats**
Politics/ Legislation	Competitive market
Substitute products	Barriers of entry
	Technology development

SKF possesses to some extent retaliatory capabilities, but more importantly does the company consist of committed employees and has a strong brand name in the industry. These aspects make small difference however, considering the significant shortness regarding knowledge, experience and development for this specific product. Better structured and mobilized companies such as Siemens and Bosch have far-reaching development projects and are unlikely to be threatened.

The probability for this product to carry on developing is most probable, especially considering the environmental aspects and thus politics and legislation. Once better performance is obtained a changeover to this component should be most likely to take place in the automotive industry.

The threat is mainly the extremely competitive market for this specific component and the very high barriers of entry. The type of industry is an economy of scale with high capital requirements.

4.6 Second Selection – One component

There are several aspects that need to be taken into consideration in order to perform the second selection of one component. The time perspective is a factor of importance, and what in fact is meant by time perspective is principally time to market; the relative time for SKF to have a completely developed product on the market. It is especially important in this project since a main focus has been to find new businesses with relatively short development time.

As seen in the below figure, fuel injection has a longer time perspective, whereas the check valve balls, together with the dewatering foils and the cam follower rollers, quicker could develop into business opportunities (mainly because that they are products currently manufactured by Keramera).

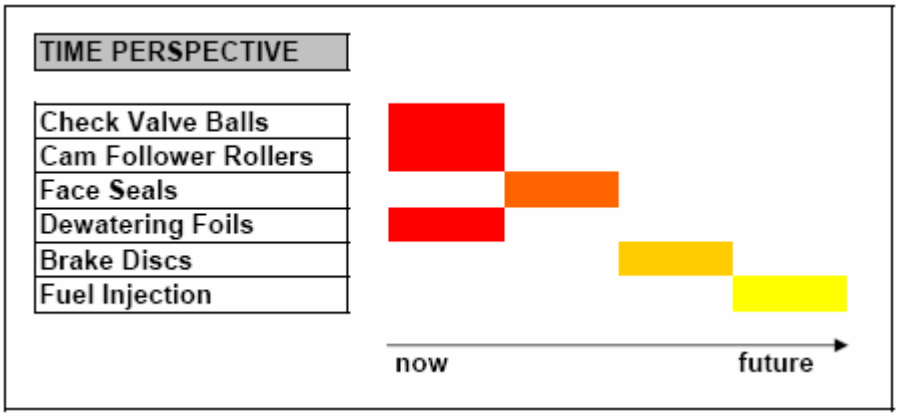


Figure 16. The table shows time-to-market relatively for the components. Check valve balls, cam follower rollers and dewatering foils are ready products from Keramera today. This aspect gives them short time-to-market. Fuel injection on the other hand, is neither manufactured by Keramera nor is it a fully developed product for SKF yet.

Another aspect is the position in the technology adoption life cycle and SKF's desire not to be situated too early in the life cycle, but rather to choose elements that have passed this stage. The fuel injections together with the brake discs are located in an early stage. Therefore, should it be concluded that it is not for SKF to get involved with the fuel injection component – at least not under current circumstances and perspectives. The position of the dewatering foils and face seals are more difficult to define, whereas the check valve ball has a more favourable position in the adoption life cycle. In the table that follows, the previous treated "adoption life cycle-factor" is shown.

A summary of the six components, based on all analyses from the section, is as follows:

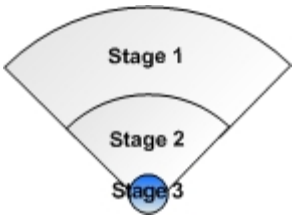
Table 26. The table shows a summary based primarily on the SWOT analysis, which itself is an overall study of internal and external factors. Check valve balls is the highest ranked component, and is chosen for further exploration in the last stage, the In-depth Analysis of a Single Business Opportunity.

Ranking of selected components SWOT and "adoption life cycle-factor" considered							
		Overall advantage			**Overall disadvantage**		**Adoption life cycle-factor**
1	**Check valve balls**	Process technology	Barriers of entry				low
2	**Face seals**	Distribution channels	Capacity for innovation	Substitute products	Technology development		intermediate
3	**Cam follower rollers**	Process technology	Bargaining power of buyer		Substitute products		high
4	**Dewatering foils**	Distribution channels	Process technology	Substitute products	Lack of exact customers		intermediate
5	**Brake Discs**	Technology trends	Substitute products		Lack of product experience		high
6	**Fuel injection**	Committed employees	Substitute products		Lack of product experience		high

The component check valve balls for oil extraction is highest ranked. According to that and careful consideration with the project members, this component is chosen for further investigation in the third stage.

5 In-depth Analysis of a Single Business Opportunity

This section aspires to reflect if the business opportunity chosen, check valve balls for oil extraction pumps, show promising features and to chart what is required for further decisions.



For this chapter, the major part of the data is derived from interviews with specialists within ceramics and their applications. The following persons have been interviewed: Stephan Andersson (Keranova), Patricia Kraabacher (Thompson Pump Company), John Mangels (Keramera), Augusto Podio (The University of Texas at Austin, Petroleum and Geosystems Engineering Department), John Porea (SKF USA), Reg Prostebby (Quinn Pumps), Daniel Renteria (Weatherford) and Tony Tagliavore (Saint-Gobain Advanced Ceramics). Further information about the interviewees is found in the reference list.

5.1 Background and Purpose

The function of this in-depth analysis of the check valve balls, with its different relations between the elements, is displayed on the next page. The purpose is to create, through usage of the interface shown, an *outline* of a business plan including its most important components. It is based on models described in the Theoretical Framework section. The lower section of the figure, the possibilities, is treated in the Recommendations chapter.

Figure 17. The figure shows field operation a sucker rod pump.

Check valve balls within the oil industry are mainly used as a component in *sucker rod pumps*. The check valves are used when oil is pumped from a down-hole in *artificial lift systems*. In cases where the pressure is high enough for the oil to be self-extracting, no pump is needed.

The artificial lift system is used because of long history, reliability and ability to reuse components in different well applications. Advantages are high system efficiency, upgraded materials that reduce corrosion, repairs that can be conducted while the well is in service and a high salvage value for surface and down-hole equipment. A primary limitation with the system is depth due to rod capability.

This kind of *reciprocating* rod lifting system is most effective in low-to-medium volume applications, lifting light or heavy oil. Typical range is between 20 and 1000 barrels per day (b/d), and with certain conditions up to 3500 b/d. Normal operating depth range is between 600 and 3700 m, with exceptional cases down to 5300 m.

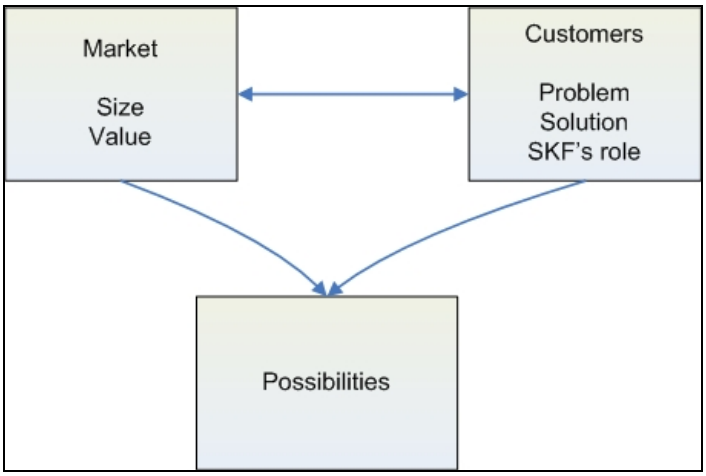


Figure 18. Displayed in the figure is the working process for this in-depth analysis and the interaction between its different components.

5.2 Customer Problem

When oil is pumped, valves are needed to prevent back flow down to the source again. Different materials are used for check valve balls in the pump and a part of these are ceramic balls. The oil producer needs the pump system to be reliable and show high efficiency in order to avoid production stop. A main objective is to increase returns through decreased down-time.

Reciprocating rod lift systems are powered by either gas or electricity and are flexible considering that production can be controlled by adjusting the stroke length and/or pump size and speed.

Pump Problems

The sucker rod pump has to be productive for as long time as possible with few interruptions. It is operating in a harsh environment with wear problems due to turbulence as a main factor to failure, or at least decreased efficiency.

The following quotation states that the valves are very critical components in the pump and that silicone nitride balls are one style of ball that is used very successfully in severe abrasive environments: "The check valve balls you refer to are the standing and travelling valves on a bottom-hole sucker rod pump. These valves are two of the most critical components of a pump. The ball is very light in weight, will not corrode, and handles abrasives. It is one of the premium balls that can be used. In some areas, these are used 100% of the time. They also command the highest price. If a ball wears out or chips, or has washing/erosion, the seal between the ball and seat is compromised, and the valve leaks. As the leak increases, pump efficiency decreases until it is un-economical to produce the well in this condition, and the pump is pulled to replace the worn valves." [47]

[47] Prostebby, interviews continuously

In addition, a troubleshooting guide[48] gives examples on what the problems that can be expected when utilizing the sucker rod pump, and in many cases the valves are mentioned:

- Flush fluid or hot oil with clean fluid to circulate any debris off the valves in the pump.
- If the wing valve on surface is closed and the pump pressures up on the upstroke, but loses the pressure on the down stroke, it is possible that the standing valve is damaged (washed, plugged, worn, etc.).
- Ensure that the check valve is in place and not leaking, as this would cause the fluid to circulate up the tubing and back down the casing.
- If the casing is full of fluid, but the pump can not pressure up, it may be an indication that the strainer nipple or standing valve is plugged/scaled off and no fluid is entering into the barrel (starved pump).
- If the pump pressures up very slowly may be an indication of a worn travelling valve and/or plunger, or no fluid in the well, or the fluid is very gassy and it takes a long time to compress this mixture.
- If the pump pressures up and then loses pressure at or near the end of the upstroke, check what jewellery is in the pump. It could be that a Side-Kicker was installed in the pump and the action of the mandrel pushing the travelling valve off the seat will cause the pressure loss at the end of the upstroke.

Moreover, the Petroleum and Geosystems Engineering department at The University of Texas in Austin is running a research project currently investigating which the major problems are for this application. Their problem statement is as follows: "Although sucker rod pumps are installed in nearly 90% of all oil wells in the United States and have been widely used for decades, there are many issues regarding their performance that are not well understood. This is due to the difficulty of simulating well bore conditions in the laboratory and of obtaining data on pump performance down hole. Many persistent problems in sucker rod pumping, including partial pump fillage, gas interference, gas locking, fluid pound, sticking valves, rod compressional loading, equipment failure, and reduced production, are difficult to diagnose from the surface."[49]

5.3 Solution

Balls and seats *are* critical components that work under high pressures due to the depths involved in the oil production. Only a precise design and a correct selection of material can guarantee a long lasting service life. Within the wide range of possible materials are the following used in larger extensions: stainless steel (440SS), cobalt alloy, tungsten carbide, titanium carbide, nickel carbide and silicon nitride[50]. Silicon nitride is used for the more harmful environments, mainly when the oil is very dirty and/or sandy.

[48] http://www.quinnpumps.com/troubleshooting.htm
[49] http://www.pe.utexas.edu/2phaseweb/sucker-rod/pump.html
[50] http://www.worldoil.com/WO_CC/bolland/bolland.pdf

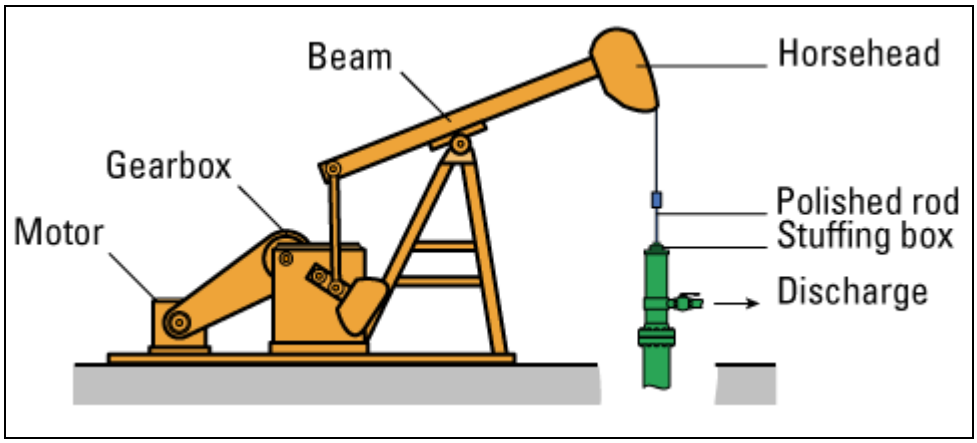


Figure 19. The figure shows the main details of a sucker rod pump. The check valves are not present in this drawing because they are operating under the ground, down in the oil well itself.

The picture above shows the main details of a sucker rod pump whereas the below schematic drawing shows the check valve balls' function. The standing and travelling valves are the components discussed.

The average service life for a sucker rod pump is about six months[51] and it can be up to two years,[52] though, in wells with good conditions and high-quality technical solution usage, but also as low as one month in very rough conditions and not using the highest-quality pump systems.

According to Morgan Matroc Ltd, the balls are available in a variety of materials to a basic core design which can be produced singly or in large batch sizes, with bore sizes in the range 12-150 mm with either through or blind actuator slots.[53] Keramera manufactures these balls and they are produced to grade 25V from Ceralloy® 147-31N silicon nitride[54] and are widely used throughout the Permian Basin and other regions[55].

[51] Kraabacher, interview, 2004-02-15
[52] Renteria, interview, 2004-02-17
[53] http://www.highbeam.com/library/doc0.asp?DOCID=1G1:43744365&refid=ency%5Fbotnm
[54] http://www.Keramera.com/Materials/SiliconNitride.asp
[55] http://www.Keramera.com/products/ic_oilfield.asp

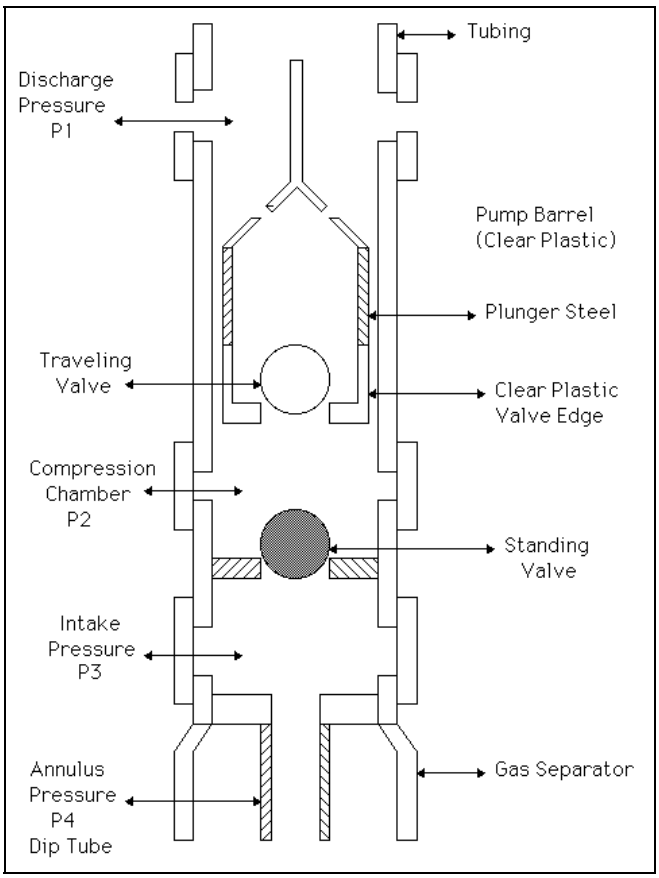


Figure 20. The figure shows a schematic picture of the functions of the valves. Note that this is a laboratory drawing, thus containing components as "Clear Plastic Valve Edge". However, it shows the valves used in a sucker rod pump, called standing valve and travelling valve. Each pump utilizes between two and four balls and each ball also requires a ball seat. *(Source: http://socony.pe.utexas.edu/2phaseweb/sucker-rod/system.html).*

5.4 Market

There are two different types of markets for check valve balls, one being the market of new sucker rod pumps. The other market type is the after sales service market for worn-out pumps. The first type is primarily dominated by large world wide actors while the after sales market is much more fragmented.

5.4.1 The Oil Industry

The oil industry is highly dependent on oil prices and thus does the price set the cycles for the industry. However, many factors impact the oil prices that are extraneous to the economic basics of supply and demand. These external factors include agreements between the OPEC countries on oil production, weather, governmental regulations, world economies, and other economic forces. In some ways, the oil industry is a very mature industry with little growth and stable technology. The number of components sold can be seen as a direct consequence of trend of the oil production industry.

A significant amount of innovations are to come within the industry leading to greater productivity, reliability, safety and efficiency, showing the way for high performance solutions. Furthermore, the most interesting market is considered to be the market of repairs and service.

5.4.2 Potential

The main manufacturers of sucker rod pumps are located in the USA. Among them, Weatherford holds about 30 % of the total market of sucker rod pumps.[56] The largest accounts in the oilfield OEM segment for SKF are listed below:

Table 27. SKF Industrial division direct sales to Oilfield OEM Segment. The company holds a couple of large accounts and a handful smaller.

	2001	2002
	Sales (SEK)	Sales (SEK)
BAKER HUGHES	18,669,786	13,009,361
NATIONAL OILWELL	14,362,709	11,265,797
WIRTH MASCHINEN	12,888,852	3,320,915
AMCLYDE	2,929,096	5,687,827
WESTERN RUBBER	2,313,740	4,075,541
VARCO DRILLING SYSTEM	1,838,779	999,987
BRANDT	1,517,804	2,031,102
LUFKIN INDUSTRIES INC	1,026,257	831,163
SPM FLOW CONTROL INC	888,623	362,680
GEFCO	875,417	1,608,260
CANRIG DRILLING TECHNOLOGY	853,153	560,166
INGERSROLL RAND CO	845,369	951,651
HUTCHINSON-HAYES SEPARATORS INC	683,860	560,052
TURBOSCOPE DREXEL	623,363	591,559

5.4.3 Market Size and Value

Of all oil wells around the world, more than 70 % are located on land and between 80 to 90 percent of these accounts for some form of artificial lift systems.[57,58] Artificial lift systems include rod lift, progressing cavity pumping, gas lift, hydraulic lift and electric submersible pumping.[59] Another 80 percent of all artificial lift systems in use worldwide are reciprocating rod lift pumping systems. This means that between 60 and 70 percent of all land based oil rigs use some type of rod lift pumping system. The most common of is the traditional beam pump system. The system includes a beam-pumping unit and a sucker rod, attached to a down-hole pump. Each pump utilizes between two and four check valve balls.[60]

[56] Renteria, interview, 2004-02-17
[57] ibid
[58] Prostebby, interviews continuously
[59] Weatherford Artificial Lift (Weatherford brochure)
[60] Renteria, interview, 2004-02-17

The two tables (below) show the total number of oil rigs in use around the world. Unfortunately, North America is not included although the USA is the second largest country (after former USSR) for oil production, 16 percent share of the world production. The rig count is an indicator of how busy the industry is, and oil companies keep track of how many drilling rigs are working domestically and internationally for a fixed time period. Industry then looks at this and determines rig utilization rates, etc. This means that the numbers in the tables are momentaneous measures for each month (seen as year in the tables). However, the numbers are not the important part in these diagrams, but to show the division of rigs between land and offshore, as well as among the parts of the world.

Even though it is nearly impossible to get a correct picture of the total number of check valve balls used for this application world wide, an estimate could be made. Augusto Podio[61] says the number of sucker rod pumps annually sold in Texas is around 150 000 and around half a million worldwide. On the other hand, Daniel Renteria at Weatherford pumps says that the total number of sold sucker rod pumps could be millions every year. These figures present an estimate and it could be assumed that the number of check valve balls sold every year is at least one million. Even if these numbers are very approximate, there is a huge after sales market.

There are a few major manufacturers supplying sucker rod pumps to a considerable share of the world market and the most important ones are primarily:

- Weatherford (www.weatherford.com)
- Harbison-Fischer (www.hfpumps.com)
- Quinn Pumps (www.quinnpumps.com)

The following medium sized manufacturers are also of importance:

- National Oilwell (www.nationaloilwell.com)
- Thompson Pump Company (http://thompsonoilpump.com)
- CE Franklin (www.cefranklin.com/index4.html)
- Boland Industries (Argentinean pump manufacturer, (www.bolland.com.ar)
- Wilson

All of these companies that are mentioned are also the major service and maintenance businesses. They are based in the USA and Canada, except from Boland Industries which is from Argentina. They all supply on a world wide basis although there are some smaller local players as well. On many locations, though, the local components are insufficient in quality, but the very small production businesses can not afford expensive imported products.[62]

Each sucker rod pump needs, as declared, 2 to 4 sets of valves and one set means one ball *and* one seat. The sets are made of various materials and differ a lot in price. It is not preferable to have a ball and a seat of the same material and the cheapest solutions are steel balls and seats. The retail price for such a set is from about US$ 170. The most expensive solution is silicon nitride, which could range up to US$ 1300, or more than 7 times the price for the cheapest solution. The as well common solution, tungsten carbide, can be found somewhere in the middle of steel and silicon nitride regarding pricing as well as quality.

Moreover, National Oilwell is listed above among the manufacturing companies and is one of SKF's customers. However, according to John Porea's contact at National Oilwell, it has shown that they do not have a current need of ceramic check valve balls.[63]

[61] Podio interview, 2004-02-24
[62] Prostebby, interviews continuously
[63] Prostebby, interviews continuously

It is possible to make brief market estimation if we do some assumptions and consider what we know of the Keramera/Weatherford business. The following assumptions need to be drawn; Weatherford hold a 20 % market share, they buy 1500 check valve balls at a price of US$1300. This makes this order worth US$1 950 000. So, a market share for SKF should also be worth this and the entire market almost US$ 10 Millions. The usage of check valve balls is only around some percent, so if it would be increased according to new market channels, the total market value would be very significant. Moreover, it is also possible to estimate how many sucker rod pumps that are sold, or repaired every year. It seems to be 187 500, not at all as much as we have information on; Thompson Pump Company and Quinn claimed the entire market to be between half a million to more than a million. Anyway, the total market for check valve balls is worth *at least* US$ 10 Million, but very likely much more.

5.5 Competitive Situation

We will limit our research in describing the main competitors and not deepen the investigation neither in factors such as strength-weaknesses, the price situation nor differentiation. These factors have been considered but due to time limitations and difficulties in retrieving the information, why only a short description of the competitive situation follows.

The check valve ball market can be seen as divided between players only supplying ceramic balls and those companies using various materials. Main competitors for ceramic balls *only* are a part from Keramera, Saint-Gobain and A1 Carbide. Saint-Gobain has a long and profound knowledge within the ceramic area, even though their area of expertise is slightly larger ceramic balls. The CERBEC division of the Saint-Gobain advanced ceramic division supplies check balls into the oil industry, but they see it as a smaller niche market[64].

Among the companies supplying balls made from other materials than ceramics are Deloro Stellite and KennaMetal and Coles Carbide.

Summary of the main suppliers of check valve balls apart from Keramera, which all supply on a world wide basis:

- Saint-Gobain
- Deloro Stellite
- KennaMetal (www.kennametal.com)
- A1 Carbide
- Coles Carbide

Furthermore, Weatherford buy check valve balls from Keramera and the annual sales to Weatherford are approximately 1000-1500 balls.[65] Quinn Pumps buys their balls from KennaMetal and A1 Carbide (at least).

SKF's value proposition for this business consists primarily of *material knowledge, quality reputation, customer channels, sales & retail organization* and possibly *price advantage* in accordance with the process provided by Keramera.

[64] Taglialavore, interview, 2004-02-25
[65] Porea, interviews continuously

5.6 Risks

Before entering the market, there are certain possible risks that have to be appraised. We have identified the following:

- Substitute solutions. The common choice of material is steel based alloys and carbide steel solutions. Titanium carbide and tungsten carbide are also used frequently. These are cheaper and traditionally used; special alloys can as well be used under normal circumstances bringing down the costs.
- Better solution by competitors. Price and performance by competitor. Depends also on the solution provided by competitor.
- Unwillingness from customers to substitute to SKF as supplier. Depending on relation, price and performance of substitute product.
- Customer already buys its products from Keramera. In that case the customer is unavailable and little opportunity exists, unless the companies could benefit from a unified venture.

The Ansoff matrix from the Result and Analysis chapter shows two aspects on product launching; new/existing market and new/existing product. We can adjust those factors and claim that the ideal situation in this situation is if one has current sales to a customer that is a potential buyer of this additional product, and that this product is an existing one for the sales company. For SKF, the product is new, but Keramera has gained experience from it.

SKF have a long history of sales to many customers within the oil industry. However, these customers are mainly at the *down-hole* (off-shore) side of the oil market. Check valve balls for sucker rod pumps are needed at the *production* side. Anyway, at least two current customers exist at SKF that actually manufacture sucker rod pumps; Weatherford and National Oilwell. Unfortunately, Keramera already sell to Weatherford, and for National Oilwell it is unclear whether or not they have a demand for this component.

6 Conclusions

This part of the report gathers conclusions from the entire project. It is divided into two parts; the first treats conclusions drawn regarding the business development for check valve balls, and the second part treats the six selected components for the Business Evaluation part in general. The conclusions are presented relatively brief in order to get a better overview of the major arguments. For a more extensive reflection, we either refer to the main thesis or to the upcoming Discussion section.

In-depth Analysis of a Single Business Opportunity – Check Valve Balls

- Customers do experience problems with current check valves and if ceramic balls have the right price, the interest is high because the valves are critical for the production. The silicon nitride check valve ball holds superior characteristics and SKF could contribute with tribological knowledge. Sales and distribution channels already exist to some extent, which can be utilized.

- The price is very important aspect when it comes to the buyer to purchase the check valve balls. Thus it is not only the price and performance that is of importance, where there is little doubt in the superiority of the silicon nitride solution.

- Sucker rod pumps are used in the major part of oil production. There is a market for the check valve balls, even though it might not be huge for ceramic components alone.

- There are certain risks such as substitute or better solutions, unwillingness to buy from SKF or that Keramera already supplies the attended customer. SKF lacks exact customers for the application, but there is still a good way in to the industry through current and closely related customer channels.

- Most of the sucker rod pump manufacturers are American, but not necessarily the users. Great potential in the rest of the world such as Russia, Asia etc, even though more differentiated and unmapped.

- Consider this as an immediate side business with low risk. Exploration of this market does not need to cost much; no product development costs and low costs for deeper market investigation. However, before really entering this market, more information is to be gained. Certainly is an investigation of what the potential customers are willing to pay for a ceramic solution required.

Overall

- The ceramic market is substantial and will certainly grow as prices decreases according to higher volumes and realization that highest grade ceramics are not needed for applications with lower requirements.

- The database is a useful tool in the search for information on ceramic components. Search is possible for many parameters; customer need/problem, producers/competitors, market aspects etc.

- SKF should reflect on broadened solutions from current core knowledge as the main objective. Considering the bearing business; **break discs, PZT** (technology for controlled lubricant injection) and **mechanical face seals** are the closest products that will widen the offer for SKF in a strategic way with ceramics. However, there are businesses that can be seen as side branches, as for example check valve balls, which will lead to sales and profit. How far from the core business SKF will go is an issue that has to be discussed.

- Keramera collaboration has potential. Start investigation on their current products, but also consider possibilities for them to manufacture components SKF demands. They are willing to take up face seal manufacturing according to Eddie Belfield, if there is a demand.

Possibilities and Potential of Realization

There are various indications on the six selected components, which are all more or less interesting but from different perspectives. We have gathered some of these in the figure below, where four factors for the six components are illustrated. The x-axis shows the time perspective of realization. The y-axis shows the strategic fit for SKF. Ring size is a relative estimation of the market value. Colours signify cost of realization. Green means low cost, blue intermediate and red high.

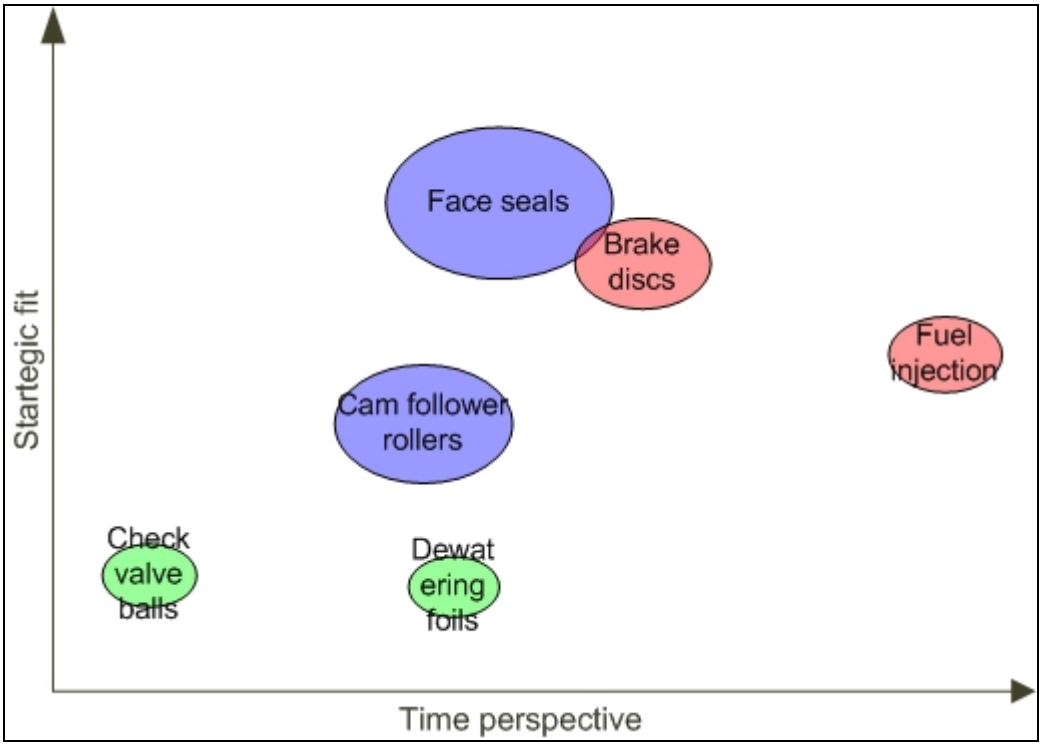


Figure 21. The figure shows four perspectives on possibilities and potential of realization for the six components, namely strategic fit, time perspective, estimated market value and cost to complete an offer.

The figure shows quite clearly some of the important factors for realization and possibilities for the six components. Check valve balls, dewatering foils and cam follower rollers do not correspond to the strategic fit. On the other hand, time perspective for realization is promising as well as cost for product development and market penetration. Mechanical face seals on the other hand, are well in

line with strategic fit and have high estimated market value. Cost of realization is not as low as for check valve balls and dewatering foils due to a need of product development for mechanical face seals, but not unreasonably high, whereas the break discs are in somewhat the same situation as mechanical face seal considering the time and strategy factors. Even though, they need time, effort and expenses for developing a product, maybe through collaboration with a break disc manufacturer. Fuel injection, finally, is believed to hold optimistic market outlooks and is even more in line with SKF's core interest, but it is not a fully developed product yet. However, it is important to emphasize that the application intended is not the fuel injection for engines, but the controlled lubricant injection in bearings.

Furthermore, the check valve ball component can be cascaded, as mentioned. Therefore, the sucker rod pump application can particularly be seen as a way in to a market with vast potential, after having gained appropriate knowledge and experience.

7 Discussion

Firstly, ideas from the analyses are discussed, whereas the latter part of this discussion section concerns appreciations that have developed during the project.

The industry attractiveness and long-run industry profitability is described with the five forces, evaluating the external industry factors. The ease of entry is fairly positive for the check valve balls and the face seals, whereas it is considerable more negative for the fuel injection and the cam follower rollers. It is also low for brake discs and dewatering foils. The reason for this is mainly because of the extent of the development and the economical and technological constraints connected with the process. An involvement in the competition of the fuel injection is not of interest for SKF, but a later cooperation and exchange of know-how is of great concern, because of the range of possibilities for bearings linked with the piezo technology for the fuel injection application.

The ease to substitute in comparatively positive industries of check valve balls as well as for the face seals and the brake discs, while it is lower for the cam follower rollers and the fuel injection and especially for the dewatering foils, mainly because of the impact of existing customer channels. Different relations and priorities lead to different assessments in the bargaining power of buyers' and suppliers' matrices. This trend is most evident when considering the industries, especially the automotive industry (and in particular the established cam follower rollers) and the dewatering foils, whose precedence usually is the customer-buyer relationship. The overall bargaining power of the buyer is high while it for the supplier is low; the products supplied are usually standardized and non-differentiated.

The higher number of and the more equally sized competitors, the higher degree of rivalry is obtained in an industry. Of course is the contrary also valid, shown clearly for the fuel injection and the dewatering foils. The check valve ball industry together with the cam follower rollers and the brake discs show negative figures. The strength balance for the forces in an industry can be affected by the strategic measures. Changes can also be estimated and evaluated in order to increase the competitive strength of a company and improve the ability to react and interact. The forces should be thoroughly analysed and kept well-known to facilitate the process of protection and the aptitude of revolving the forces into SKF's own capabilities.

Considerations of the internal and external analysis in the report should be prepared. SKF must excel in the performance of the internal factors, the resources and capabilities and consider the gaps, in order to protect from the external factors, the strategic industry factors, in order to turn them into opportunities. Our section of strategic analysis should be a helpful instrument in this process.

We chose to investigate the check valve balls in the in-depth analysis of a single business opportunity. The main reason for this was its high ranking credits, but perhaps even more the explicit wills from SKF's side to consider short time-to-market in order to reach the sales targets.

The in-depth analysis shows that the main customer problem that the silicon nitride solution can solve is the wear issue, given that the sucker rod pumps are operating in a harsh and abrasive environment which leads to decreased efficiency. A silicon nitride solution can, for a reasonable price, prolong the life length of the sucker rod pump with less maintenance and a higher production as a natural effect. It seems that the silicon nitride solution certainly is a better solution, so if SKF can meet the market with a product with the right price we can not see why this should not be a successful business.

However, is this choice a strategically good business development? Is it with this kind of possibilities or should they develop components starting from the core business, bearings? We believe that it might be a good notion to find out where SKF can grow in the long-run, and that brake discs and mechanical face seals are more in line with the current strategy, even if the applications require more time and money for product development and market knowledge. However, check valve balls could be a good start for exploring a new type of product. There is a huge potential in cascading this application to other ones, for example the chemical industry. Nevertheless, the business plan is a bridge between strategy and implementation, why management should be well settled on a strategy before preparing the concluding business plan.

The brake discs should be regarded as a potential business opportunity. It is probably not for SKF to start off advancements on its own, but a joint-venture with a manufacturer of brake discs could very well generate in valuable yields.

What are the possibilities with Keramera cooperation? We believe that it has to be thought through what kind of relationship that is desired. If SKF decides to go for products that Keramera provides, there is a great potential in achieving business.

8 Recommendations

Firstly, ideas for recommendations regarding the in-depth analysis are discussed, whereas the latter part of this recommendations section concerns suggestions that have risen throughout the project.

In-depth Analysis of a Single Business Opportunity – Check Valve Balls

The suggestion regarding only the in-depth analysis are listed below:

- Find out who all the exact customers to Keramera are, apart from Weatherford. As Keramera is the provider of the component it would not be beneficial to pursue the same customers.
- Find out exactly what the customer are willing to pay for the component – How much the advantage is worth of not having to replace the check valves in the sucker rod pump.
- Investigate the interesting OEM actors' attitude to the silicon nitride solution – and if there is a twofold aspect of it when considering that the major sucker rod manufacturers also hold a substantial share of the aftermarket in service and repairs.
- Make a detailed action plan for next steps in entering the market and contact sales staff.
- Create a profitability calculation – Perform a detailed and specific overview of the financial status of the venture and the cost/benefit situation.
- Set out funding requirements with a time perspective. Decide on how to react at different financial scenarios and with what the company is willing to back up the venture.
- When positioned, examine the possibility to use this component in other applications. As mentioned at the selection of this component, special consideration was taken to possibilities to exploit ceramic check valve balls for pumps in general. Keramera currently supplies to the sucker rod pump application used in oil production only.

Overall

The overall suggestions are listed below:

- Use the main database as a tool when searching for information on ceramic components, both regarding the problem approach and method as well as the information currently presented.
- Use the theoretical framework to manage other applications, and for further investigation of the, in this work, treated components.
- Contact the food and beverage segments regarding the face seals component as well as the automotive and railway segments for cam follower rollers and brake disc components. We see possibilities in the long run with these components, and we strongly recommend SKF to do further research in the area.

- Once the PZT technology has been fully developed for the fuel injection application, we recommend that the advantages with using the technology in self lubrication of bearings should be investigated.
- Consider thoroughly the strategic approach for the future – what kind of growth strategy the company wants to adopt and which solutions the company would like to provide.

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Appendix

A. The Spreadsheet on Engineering Ceramics

Market

The most precise level of the database is the component level. In this case, a component is the ceramic part used in a product, or the product itself, if the entire product is ceramic. These components are further placed in application of use. The component and its application are then classed into a business segment. This segment is not a global classification system, but how SKF would divide these products. The most left classification is done due to function and explained later. Consider for example hybrid bearings in machine tool spindles. This view is as below.

	Market		
Function	**Segment**	**Application**	**Component**
M&W	**MACH.TOOLS**	Machine Tool Spindles	hybrid bearings

This excerpt should be regarded as follows: The component hybrid bearing is used in the application machine tool spindles, in this case. Hybrid bearings are used elsewhere as well, but have then other applications and therefore an own line. It could also be the other way around as explained in the following example. The application mining and construction machines in the segment mining and construction have two types of components (figure below).

	Market		
Function	**Segment**	**Application**	**Component**
M&W	**MIN.&.CONSTR.**	Min. and Constr. Machines	hybrid bearings
M&W	**MIN.&.CONSTR.**	Min. and Constr. Machines	liners for min. industry

A third possibility is when two or more of the same components are used in the same application but classed in different segments (below).

	Market		
Function	**Segment**	**Application**	**Component**
M&W	**FLUID-MACH.**	High Speed Generators	hybrid bearings
M&W	**AUTOMOTIVE**	High Speed Generators	hybrid bearings

This procedure is to cover many different situations when mapping ceramic applications. At last in the classification is the market outlook headline. This is a functional classification with broad product sectors, namely Mechanical and Wear Parts (M&W), High Temperature Process Parts (HT) and Catalyst Support and Membranes (CS&M). The main area for SKF, and where the majority of the applications can be found, is in the first (M&W) including bearings, pump seals, wear parts etc.

		Market		
	Market Outlook	Segment	Application	Component/Product

Data

The next step in the database is named Data. Each application has allotted features with different significance and function. These seek to assist the user in evaluating the situation considering a range of aspects. The features are from left to right: critical customer requirements, type of market, ease of entry, market value, SKF involvement and competitors.

Critical Customer Requirements

The first column, critical customer requirements i.e. the customer needs or problems associated with the product are listed with increasing importance to the left.

	Data	
Critical Customer Requirements	Type of Market	Ease of Entry

A number of requirements serve as instruments for this description:

Table 28. Critical Customer Requirements.

1) Wear		11) Environment
2) High temperature		12) Reliability
3) Friction		13) Special Physical Needs
4) Service Life		14) Thermal Conductivity
5) Weight		15) Precision
6) Electric Erosion		16) Sanitation
7) Stiffness		17) Chemically Inert
8) Corrosion		18) Aesthetic
9) Non-Magnetic		19) Radar Transparency
10) Insulation		20) Pressure

Type of Market

	Data	
Critical Customer Requirements	Type of Market	Ease of Entry

Each market is evaluated and presented by the following list:

Table 29. Types of Markets.

A) Converting – A market where great domination by ceramic products are expected. B) Duplicating – A market where different solutions are expected, i.e. not only ceramic solutions.
C) New Market – New solutions and applications, with less defined and developed markets. D) Developing Market – Markets where continued development and change is expected. E) Mature – A market where products and markets are well-defined.

Normally a market can either be converting or duplicating as well as one of the three alternatives for the market and its level of development; new, developed or mature. The arrangement of alternatives reveals the best suited combination for respective market.

Ease of entry

	Data	
Critical Customer Requirements	**Type of Market**	**Ease of Entry**

This column is considering whether or not it is hard to enter the specific market. This is based on competitor strength, nature of market and products as well as level of technology difficulties. The grades are "1", "2" or "3". "1" means that it is a high barrier to enter this market, "2" intermediate and "3" relatively easy. The ease of entry gradation considers technology level as well as how level of market competition this specific component has. This is to be seen at a general level, not with SKF in mind. Rather, how easy it is for a company, as a new player, to penetrate the market.

Market value

	Data		
Ease of Entry	**Market Value**		**SKF Involvement**
	today	Forecast	today

The parameter is based on the value for the specific market compared to the whole value of ceramic applications. Grades are "1", "2" and "3". "1" means low market value, "2" stands for an intermediate value and "3" a high market value. The value of the market is estimated both today as well as for the future. The market value should be considered as how high the share is of the ceramic total market for the component. Once again, one should not consider this from an SKF view. For example, the Formula 1 industry is significantly important for SKF's ceramic business. But when regarding the total ceramic market, Formula 1 industry is not that important. This is however shown through the next step, SKF involvement.

SKF involvement

	Data		
Ease of Entry	**Market Value**		**SKF Involvement**
	today	Forecast	today

An illustration of how much SKF is involved in this market today. It is based on actual sales on the particular component. Grades are "1", "2" and "3". "1" means no involvement and "3" means a high rate of involvement. "2" means intermediate involvement.

Competitors

There are four columns under the headline named Competitors. These columns contain names on companies active in the specific application. These companies are put in order of importance in the specific application with increasing importance to the left. In many cases there are more than four competitors but in the database there are no more than four listed.

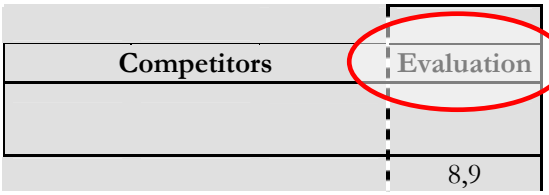
Competitive Advantage

The following two columns after Competitors are named Competitive Advantage. There are two types in this category; Technology Knowledge and Customers. Technology knowledge means that SKF in some way has knowledge about the application. It can for example be through internal research or involved colleagues. The other category, Customers, means that SKF has customers that today buy SKF products with relationship to the component in the database. Grades are "1", "2" and "3". "1" means no advantage and "3" means significant advantage. "2" means intermediate.

Strategic Fit

The last column contains figures on strategic fit. This seeks to display if the component is in line with SKF overall product strategy. Some applications have high values on all parameters but are not at all in line with SKF core business. This column sorts out these kinds of components in order not to get a mismatch. Grades are "1", "2" and "3". "1" means no strategic fit and "3" means well in line with SKF strategy. "2" means intermediate.

Evaluation



The evaluation seeks to illustrate an overall rating and ranking of the various elements. This is done to be able to get a rough guideline of which applications are more important for this thesis than other ones. Each application (row) has got a value in the evaluation column. In the spreadsheet ranking is done with the following algorithm:

$$\frac{15*\textit{Ease of Entry} + 5*\textit{Market Value Today} + 10*\textit{Future Market Value} + 8*\textit{SKF Involvement} + \textit{Type of Market (value depends on type)} + \textit{Competitive Advantage (value depends on type of comp. adv.)}}{10}$$

Formula 1. Evaluation algorithm for the database.

The values in each column (as specified above) are multiplied with the weighting number. Further, all column products are added to each other. The entire sum in the algorithm is finally divided by 10. This is an adjustment to not get too large numbers.

The weighting of the parameters is done because there is an internal difference of importance in the various parameters. For example, a "2" in Ease of Entrance is worth more (of higher importance) than a "2" in for example Future Market Value. These values are created through discussions with SKF on priorities when to select which components to go further along with.

Table 30. Values for the different features used for the evaluation process.

Ease of Entrance		
1	=	15
2	=	30
3	=	45
Future Market Value		
1	=	10
2	=	20
3	=	30

Competitive Advantage					
Tech. Know.				*Customer Relations*	
1	=	0	1	=	0
2	=	20	2	=	10
3	=	30	3	=	15

SKF Involvement		
1	=	8
2	=	16
3	=	24
Type of Market		
B, D	=	10
B,C	=	14
C	=	15
Current Market Value		
1	=	5
2	=	10
3	=	15

Maximum value for the evaluation possible to receive is 17,4 [(45+30+30+15+24+15+15)/10]. A high number indicates an area with an optimistic combination of parameters. The spreadsheet serves as an indicator and guidance for the further selection and analysis.

B. Market Outlook

As described by John Briggs in his report of engineering ceramics in Europe and the USA. In the report is discussed the evolution of materials and product forms, and highlighted new business opportunities.

Market Outlook Markets for engineering ceramics	**Market**			
	US		**Europe**	
	2002 ($ million)	AAGR to 2009 (%)	2002 (€ million)	AAGR to 2009 (%)
Mechanical and wear parts	**539**	**4,3**	**494**	**4,5**
Cutting tools	110	3	68	2,5
Pump seals	115	4	110	2,5
Bioceramics	7	4	53	5,5
Armour	45	5	13	3
Bearings	10	3	13	7,5
Other wear parts	252	5	237	5
High temperature process parts	**261,5**	**1,4**	**395**	**0**
Molten metal filters	55	3,5	50	2
Continous casting parts for steel	120	0	200	-2
Advanced kiln furniture	73	1,5	135	1,5
Hot gas filters	13,5	4	10	6
Catalyst supports and membranes	**547**	**2,3**	**386**	**7,7**
Automotive catalyst supports	360	3	320	2
Industrial catalyst support	175	0	35	5
Membranes	9	10	18	9
Diesel particulate traps	3	10	13	4,8
Total	**1347,5**	**2,9**	**1275**	**4,2**

C. Summation of the six components

Summary

This document should be regarded as a short summation of the functions of the chosen applications from the main spreadsheet. They are selected out of different criteria and represent the components best suited to continue with, out of our calculation. Factors that have been considered are mainly *margins of value, development position, competitive advantage, fit* and *adoption life cycle theories.*

We have selected the applications where we see the best possibilities, and a good representation for each cluster respectively and its development. Furthermore, we have sought a mixture of time perspective and scale as well as value, and a profound summation of the six selected components is as follows in the upcoming pages.

Check Valve Balls

Figure 22. Check valve balls manufactured by Keramera.

Keramera manufactures **balls for check valves** for the oilfield industry, and other applications. These balls are produced to Grade 25V from Ceralloy® 147-31N silicon nitride[66]. These components are used widely throughout the Permian Basin and other regions to extend the life of "sucker rod" pumps used in oil production. Silicon nitride is used because of its high strength, fracture toughness and wear / chemical erosion resistance. Silicon nitride balls are used in the most demanding of the oilfield applications[67].

Check Valve Operation[68]

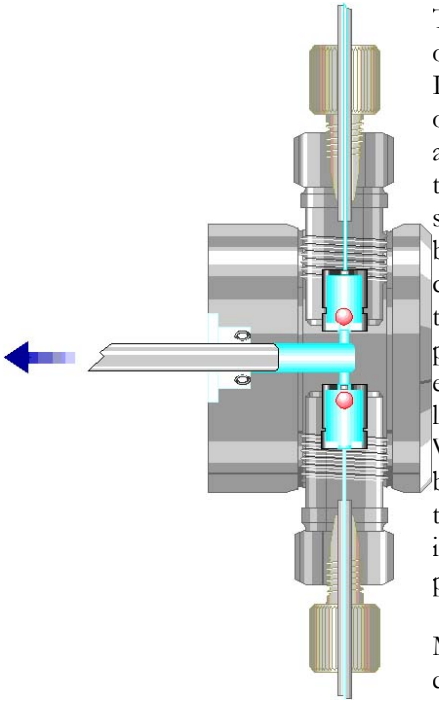


Figure 24. Check Valve operation 1

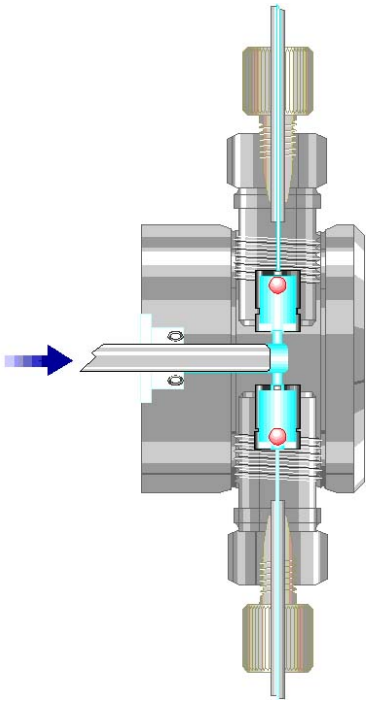


Figure 23. Check valve operation 2

The mechanics of check valve operation are not complicated. Inside most check valves, a ball of a certain diameter sits freely above a seat containing a single through-hole with a diameter slightly smaller than that of the ball. Liquid should not pass the check valve in any way but through the seat. When the pressure behind the seat exceeds that above the ball, liquid flows through the valve. When the pressure above the ball exceeds the pressure below the seat, the ball returns to rest in the seat, forming a seal and preventing solvent backflow.

Most modern HPLC pumps deliver solvent at high pressure using two reciprocating pistons in series or parallel. Check valves are located in series above and below the piston, restricting flow to a single direction, usually upward. As the piston completes a delivery stroke and begins the intake stroke, the pressure inside the pump head drops. High pressure above the outlet check valve causes it to seal, while the inlet check valve opens as solvent is drawn through it and into the pump head. When the piston switches direction for the compression stroke, the pressure inside the head increases, and

[66] http://www.Keramera.com/Materials/SiliconNitride.asp
[67] http://www.Keramera.com/products/ic_oilfield.asp
[68] http://www.westernanalytical.com/optimize/optimax.htm

soon exceeds the pressure below the inlet check valve. The inlet valve seals, then the outlet opens, and solvent flows up through the open valve.

Numerous factors determine how effectively and reliably a check valve will perform. First and foremost, it is the integrity of the seal made between ball and seat that defines a check valve's performance. Other factors such as the weight of the ball and the amount of travel it is allowed within the valve affect the response time of the valve. Check valves must seal rapidly in response to pressure changes if pump pulsation is to be minimized, but the amount of ball travel allowed must be sufficient to allow unrestricted solvent flow through the valve.

Cam follower rollers

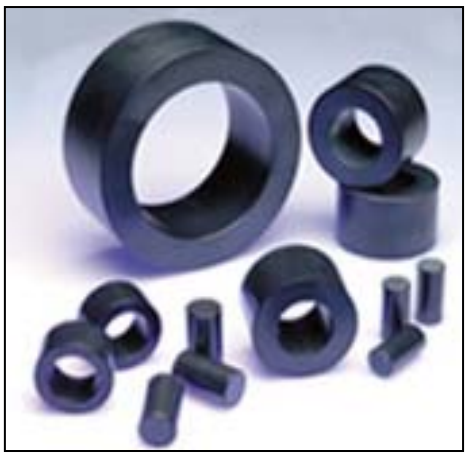


Figure 25. Cam follower rollers manufactured by Keramera.

Ceramic cam follower rollers are used in heavy diesel engines where wear is a problem. Silicon nitride is normally used for these components. According to Keramera there is an industry trend of increasing fuel injection pressure and cylinder operating pressures, and other component modifications designed to improve emissions and fuel economy that will only exacerbate warranty problems with metal components. Furthermore, engine manufacturers are increasing warranty coverage on engine components, making reliability of the engine components more important. Ceramic components show much better performance compared to traditional metal components.

Silicon nitride cam followers are also used in other large engines, for example electrical fuel pumps powered by diesel engines.

For example have the Series 50 and 60 Engines from Detroit Diesel ceramic cam follower gaining the benefits described, of less wear and higher injection pressure to meet stringent particulate and smoke emission standards without exhaust after treatments.

Face seals

Mechanical face seals are used in numerous different applications and industries.[69] Everywhere fluids are pumped, compressed or stirred the seals are needed. When using ceramic material in these components their functional reliability is exceptional. They have[70]:

- high wear resistance
- high corrosion resistance
- ability to withstand temperature and
- imperviousness to sudden fluctuations in temperature

Figure 26. Seal rings

Other advantages include lightness, stiffness, low centrifugal forces and good emergency and dry running properties.

Most common materials used are aluminium oxides and silicon carbides. Competing material to these are diamond coatings.[71]

Main industries for mechanical face seals are process industries where liquids and gases with wear, poisonousness and corrosion characteristics are found. Therefore, the process industry is one of the most important markets. This industry is also among the first one to use this kind of seals. The very first one, however, was the automotive industry using seals in cooling water pumps.

There is a trend that food and beverage and pulp and paper industries increase their use of ceramic mechanical face seals. It is also noticed that double seals are used more widely. This is basically just two individual mechanical face seals used together to improve performance.

There is a competing technology in magnetic couplings which is a solution without seals as showed on the image (right). These function as plain bearings with magnetic running. According to Zetterling, John Crane, silicon carbide is used in these products as well.

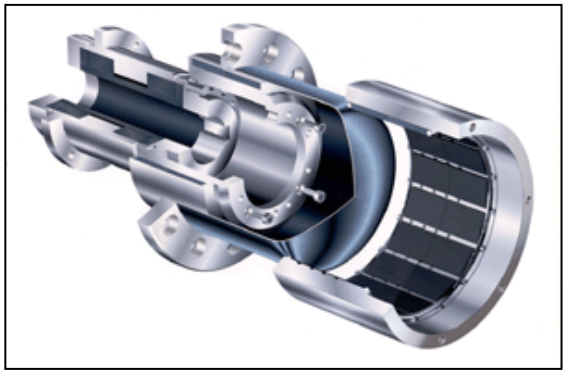


Figure 27. Magnetic Coupling

69 http://www.mcnallyinstitute.com/10-html/10-2.html
http://www.offshore-technology.com/contractors/bearings/huhnseal
70 www.ceramtec.de/intl/pgr/ta=pgr*370/la=en/le=0/
71 Zetterling, interview, 2004-01-26

Dewatering Foils

There are a number of opportunities for ceramics to be used to solve wear related problems during the paper making process. The most critical is in the "wet" end of the paper making process. Here the water is removed from the pulp slurry by moving over ceramic **dewatering foils**[72] at high rates of speed, often in excess of 100km/min. This represents a very demanding application since the paper pulp is very abrasive and the chemical environment of the pulp is severe.

Initially, aluminium oxide served this application. However, this market is being taken over by both silicon nitride and silicon carbide "black" non-oxide ceramics as the environments become more demanding. The high hardness, fracture toughness, wear resistance and thermal shock resistance of these materials are the key reasons for the switch to non-oxide ceramics.

Keramera is Tier 2 supplier of silicon nitride segments for use in paper processing.

Dewatering Foils Operation

Figure 28. Paper processing machines where Keramera's dewatering foils are being used.

Figure 29. Example of Perplas's Plus Dewatering Foil, (using EVO2 material, polyethylene). The picture shows the function of the component.

Ceramic lining are resistant to wear and chemical attack and they maintain the working surface flatness and constantly sharp edges for a long time. By fitting these uniform dewatering and paper sheet forming are achieved, return wash-out and longitudinal strips on the paper are avoided.

[72] http://www.Keramera.com/products/ic_paper.asp

Brake discs

Advantages with ceramic brake discs are mainly two: weight and heat resistance. There are figures indicating that these discs weigh some 50 % less than conventional discs. They are also extremely shock resistant making them ideal when brakes are used frequently. Applying ceramic discs on train carriages makes it also possible to exclude some of the surrounding brake housings and other components due to the use of fewer discs in total.

"Brembo and DaimlerChrysler Form Ceramic Brake Joint Venture
Brembo and DaimlerChrysler have signed a contract that will see them establish a joint venture for the manufacture of ceramic brake discs. Each company will hold a 50% stake in Brembo Ceramic Brake Systems SpA. Brembo Ceramic Brake Systems SpA will be located in the new Science and Technology Park 'Kilometro Rosso' in Stezzani, Italy, with the joint venture becoming effective on January 22, 2004. The two companies will contribute related expertise for the development and manufacture of ceramic brake discs."

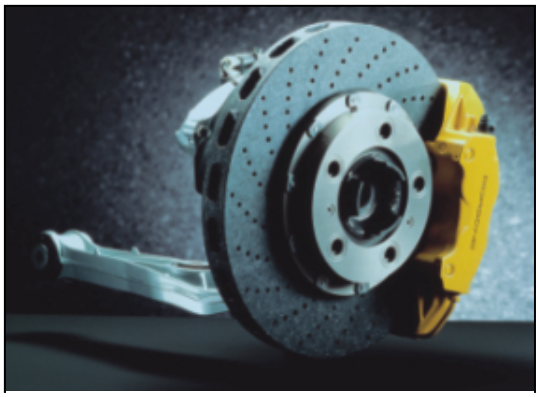


Figure 30. Example of Brembo brake disc.

Brembo and Ferrari has a collaboration stating there is a difference between traditional composite brake discs and ceramic composite material (CCM) brake discs.

Furthermore, SAB Wabco has is developing and testing ceramic brake discs for high speed train carriages and LRVs (light rail vehicle). There are many advantages with the usage of ceramic material in these applications. Firstly, weight can be reduced very much. Partly by less material weight but also by lesser number of brake housings needed according to reduced numbers of discs because the ceramic discs are more durable than conventional material used. Weight can be reduced by more than 5 tons per train, giving perspective on the potentials.[73]

According to a news article (Sept 2000) the car manufacturer Porsche has started series production of its so called Porsche Ceramic Composite Brake (PCCB) for Porsche 911 Turbo is made of carbon fibre reinforced silicon carbide (C/SiC). They are made from carbon fibre reinforced silicon carbide. This is made through co-operation with SGL Carbon AG (Wiesbaden).[74] Useful life is claimed to be 300 000 kilometres, or more.

[73] http://www.sglcarbon.com/sgl_t/brakedisc/index.html
[74] www.autointell.com/news-2000-2/September-05-00-p5.htm

Fuel Injection, PZT

Direct fuel injection using piezo injections which controls the fuel directly towards the glow plug in more exact dosing could save up to 20 percent of the fuel consumption in petrol combustion engines[75]. However the technique is not fully developed and does not exist in more than a handful of cars when writing this. The technique is planned to be fully developed within a few years, Siemens aim is 2006.

Fuel injection systems[76] are already highly advanced. The fact that another gigantic technological advance has become possible, making engines even cleaner and more economical, is because of the visionary ideas of Andreas Kappel. He has developed innovative piezo injectors for the piezo common rail injection system of Siemens VDO Automotive. This revolutionary technology was first introduced in standard diesel-powered passenger cars in 2000 and will be used also in gasoline engines in the near future.

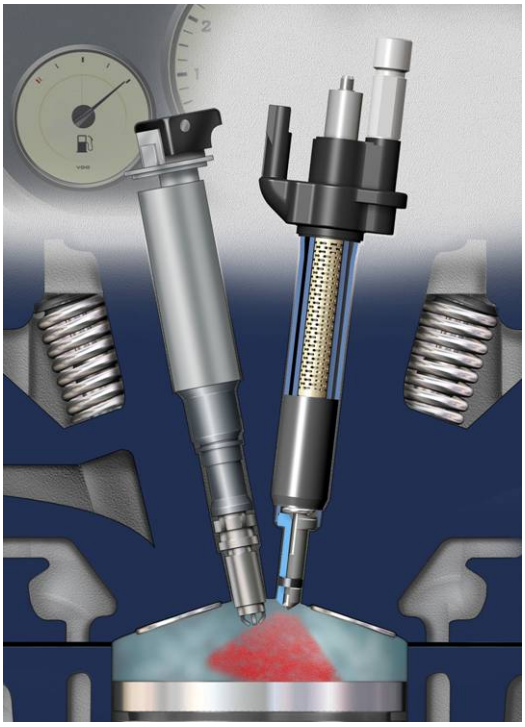


Figure 31. Example of Siemens's fuel injection system using the PZT technology.

The piezo injection system which will reduce fuel consumption in lean-burn gasoline engines to the level typical of diesel engines; they are also investigating possibilities increasing the performance of Formula-1 engines.

Fuel Injection Operation using PZT technology[77]

Engineers at supplier Siemens VDO are currently developing a new technology: An injection system for SI engines that is expected to offer up to 20 percent lower fuel consumption by comparison with a standard SI engine with intake manifold injection.

Until now, wall-directed or air-wall directed combustion processes have been used for gasoline direct injection engines. In these processes, the fuel is directed towards the spark plug via cylinder wall and piston base, rather like a billiard ball. The Piezo Direct Injection (PDI) process developed by Siemens VDO permits the use of a jet-directed combustion process, where the injection jet transports the fuel directly to the spark plug.

[75] http://www.nyteknik.se/pub/ipsart.asp?art_id=30505 (Ny Teknik October 2003)
[76] http://www.siemens.com/index.jsp?sdc_rh=null&sdc_flags=null&sdc_sectionid=0&sdc_secnavid=0&sdc_3dnvlstid=&sdc_countryid=0&sdc_mpid=0&sdc_unitid=999&sdc_conttype=2&sdc_contentid=1045767&sdc_langid=1& (Siemens 2002-12-17; Inventor's Award 2002: Dr. Andreas Kappel; Corporate Technology, Munich)
[77] http://www.siemens.com/index.jsp?sdc_p=t2csuo1094423pnflm&sdc_sid=2143193937&

The fuel is injected in the direct vicinity of the spark plug. The plug immediately creates an ignition spark that ignites the highly inflammable mixture. This process only functions if the amount of fuel and the injection timing are exactly matched. The piezo ceramic element switches four to six times faster than conventional solenoids; the fuel can be far more precisely metered even at very high pressures of up to 200 bars.

The piezo actuator is integrated into the injection valve and acts directly on the nozzle needle. As soon as the piezo element receives an electrical impulse, this needle opens the injection valve to the outside. The valve is completely open after just 0.0002 seconds and the fuel is injected in the shape of a cone. Because the valve opens to the outside, it is exceptionally well protected against coking, despite the proximity to the spark plug.

But the injector is only one component in the complete injection system. An important role is also played by the high-pressure pump that delivers the fuel into an intermediate storage. So that this process does not require an unnecessary amount of energy, Siemens VDO has equipped the pump with a flow control system. The high-pressure pump therefore always delivers just the amount of fuel required for the momentary engine output.