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Introduction of an Innovation process within a medium sized company. The development of innovative products and services in the bearing industry.

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
Dr. Ing. Tom Duda

Dipl. Wirt. Ing. (FH) Michael Rößl

11805656

Vienna, 16.04.2023

Affidavit

I, **DIPL. WIRT. ING. (FH) MICHAEL RÖSSL**, hereby declare

1. that I am the sole author of the present Master's Thesis, "INTRODUCTION OF AN INNOVATION PROCESS WITHIN A MEDIUM SIZED COMPANY. THE DEVELOPMENT OF INNOVATIVE PRODUCTS AND SERVICES IN THE BEARING INDUSTRY.", 74 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

The constant development of new bearing solutions is driven by the never-ending effort to improve the performance of applications. Bearings should be able to work at very high speeds but maintaining low operating temperatures. Further those machine components have to produce less friction and show high wear resistance. The above mentioned and further demanding requirements build the challenges of today's bearing industry. In a competitive business climate, an organization's capacity for innovation is a crucial factor in ensuring its long-term success. Hence, it is mandatory to introduce the correct products to the market at the right moment with innovative, relevant benefits for customers.

The thesis focuses on the current market situation and future possible challenges within railway and wind bearing segment. Among others it analyses the strengths, weaknesses, opportunities and threats of a medium sized bearing manufacturer, by means of a SWOT analysis. Further, the thesis analysis the company's overall business strategy, taking into account the customer's needs of the wind and railway market and considers innovative approaches and product solutions.

The master thesis analyses state of the art innovation management tools, such as Stage Gate Model Process and sets the framework for a suitable innovation process and strategy, which can be applied for the development of innovative products at a mid-sized bearing manufacturer. Finally, this adjusted innovative process is applied in a case study which accompanies the development of a product solution for railway traction motors. This paper gives a comprehensive overview about the different development steps, which are supported by common Engineering methods, such as a thorough Design Failure Mode and Effective Analysis (DFMEA).

Furthermore, different service innovations are discussed, such as augmented reality tools and innovative service apps.

Keywords: Innovation, Innovation Management, Innovation Processes, Business Strategy, Railway Bearing Solutions, Wind Bearing Solutions.

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1 Introduction

In the last couple of years the bearing industry is continuously changing. It is noticeable that more and more bearing manufactures do not offer the bearing itself anymore as a commodity product. It is much more important to offer innovative bearing solutions, services and implement processes, where a significant customer value is added.

Furthermore, it is noticeable that innovative bearing solutions for emerginging industries, such as wind energy, hydrogen processing and green transportation are more and more requested by customers. Manufactures are continuously working to enhance performance, energy efficiency and reliability of bearing solutions. Engineers are focusing on to modify the design of all components used within a bearing, such as rings, rollers and cages. Moreover, technological advances in seals, lubrication, materials, etc. are creating tremendous opportunities for manufactures to optimize products. There is also a clear trend to integrate sensors within bearings or next to bearings in order to monitor operating conditions, such as speed, temperature and vibrations. The data is gathered and analysed in order to predict the bearing lifetime under the actual operating conditions and detect potential bearing failures in a very early stage to decrease downtime of the applications. A few manufacturers have started providing those kind of smart bearing already but still it is in a very early stage.

To sum up, in order to stay competitive it is crucial to be able to develop those new products and related services, faster, more easily and at lower costs. But it is important to point out that the above mentioned bearing industry trends are continuously developing and by far not complete, which requires to be very agile and search for new innovative ideas.

1.1 Challenges and Objectives of the Master Thesis

The overall current bearing market situation can be considered as challenging, especially due to the recent lack of availability of raw materials because of the global health crises COVID19 impacts. Bearing manufactures are fighting for customers and focus on the development of innovative bearing solutions, in order to differentiate from each other.

Nevertheless the bearing market is huge and expected to grow in the next years. According to the Grand View Research institute, the global bearing market size was valued at 111.59 billion USD in 2022. Further it is expected to have an annual growth rate of 10.6% from 2023 to 2030.[1]

In order to be competitive as a mid-sized company it is important to focus specifically on a few things and be aware about its value proposition at the market. That is why, recently NKE decided to focus on the Rail and Wind segment and build its value proposition in those segments. However, the analysed company still suffers of the lack of generic strategy guidelines for those segments. Currently NKE Austria has no common guideline which support the development of innovative products, which should be driven by the customer's needs. The Master thesis analysis the company's overall business strategy, taking into account the customer's needs of the wind and railway market and discusses innovative approaches, product solutions and services.

FERSA Group applies an internal, global research and development (R&D) process, which is adapted to the automotive industry's needs and its product portfolio. One of the main objectives of this research is to identify and analyses frameworks of existing

[1] (Grand Review Research Institute, 2023)

innovation processes and finally implement adjusted innovation processes for NKE, which are suitable for the industrial bearing industry business. In any case, there is still the possibility to share synergies of innovation processes between the different companies of the FERSA Group, although the other companies in the Group are focusing on automotive bearing solutions.

In the last couple of years, at NKE nearly no research and development was carried out in a structured way, therefore the current product portfolio shows some competitive disadvantages. Furthermore, at the time being, there are some internal barriers in terms of lack of communication between the different departments involved during current innovation projects. It is important that all departments involved, such as i.e. purchasing, quality, sales and engineering, are informed about the activities within a project. Consequently, new processes have to ensure that the new to be implemented structure fosters cross functional communication and exchange.

Moreover, the new innovation process is applied in a case study, which is about the development of an innovative traction motor bearing solution. Also innovative services for the wind turbine bearing industry are discussed.

The overall aim is to offer a general generic guideline which allows NKE to develop premium bearing solutions and services, which meet the respective customer expectations, in order to stay ahead of competitors.

1.2 Research Questions

Based on the actual competitive disadvantages of the product portfolio and services, in a very challenging dynamic market as well as the above listed objectives of the Master Thesis at hand the paper is built on two main research questions:

- What are the current bearing solution trends in the Rail and Wind segment and how do those match with the available product portfolio and the company's strategy? How has the company to be organized in order to be able to domain those two markets?
- Which tailored innovation process guideline is suitable for NKE and provides sufficient guidelines through the new product development process? The new guideline have to be proofed by a case study.

The following keywords can be associated with the above research questions: Innovation, Innovation Management, Innovation Processes, Business Strategy, Railway Bearing Solutions, Wind Bearing Solutions.

In order to answer above mentioned research questions and develop a suitable customized innovation process qualitative research methods are applied. However, the research methodology is thoroughly described in the following chapter two.

1.3 Limitation of the Master Thesis

The assessment of information and innovation processes presented in this study is restricted to the NKE Austria's Engineering Department and its associated activities. It is therefore worth mentioning that the findings and recommendations presented may not be applicable to other departments and subsidies of the FERSA Group or any other company.

The primary focus on the research is the evaluation and implementation of an innovation process and best practices to support the development of new products.

1.4 Structure of the Master Thesis

This thesis is composed of three main sections. The first pillar, which is covered by chapter three “Theoretical Framework”, builds the basics for strategic innovation management. It consists of a literature review, where some of the most relevant scholarly literature on innovation processes are examined. There are many studies and the available information is vast, however, the presented literature provides the fundamental background about innovation management and gathers some insights on common approaches, including market analysis and business strategy etc. In this chapter different innovation process models are presented and analysed. This theoretical part builds the important basics for the empirical part of the thesis.

The second part of the thesis represents the empirical part of the paper, which is covered in chapter four “Implementation of an Innovation Management Process at NKE”. In this practical part of the paper, qualitative research approaches are combined with the theoretical framework of chapter three, in order to develop and implement a suitable innovation process at NKE Austria. Although the innovation process steps are explained in a general approach, the overall process is additionally represented by a current innovation project. More precisely, the new implemented innovation process is explained by the product development of traction motor cylindrical hybrid bearings.

Further different ongoing service innovations in the wind bearing segment are discussed in chapter 5.

It has to be mentioned, that that some of the parts can provide only a very general overview of the results and ongoing activities at the company NKE, due to active non-disclosure agreements.

Finally, a conclusion of the main findings and an outlook is given.

2 Methodology and methods

This chapter describes the selected research approach in terms of used methods to obtain relevant data to answer the formulated research questions in the previous chapter. The systematically way to solve research problems is called research methodology. Research methods lay down the foundation of the research. There are two different common research methods used: quantitative and qualitative research methods.[2] In order to ensure thorough assessment of the business strategy, the innovation processes and to obtain different viewpoints on current issues, the research process involved a variety of methods, including self-study, active participation, meeting with colleagues and engagement with the different project stakeholders, including the external ones, as customers and suppliers. Further common business and engineering methods are explained and applied in the empirical part of the thesis, like Boston Consultant Group Matrix (BCG Matrix), Design and Process Failure Mode and Effective Analysis (DFMEA, PFMEA), Strength-Weaknesses-Opportunities-Threats Analysis (SWOT), PORTER's five forces business model or common processes like Design Validation Plan and Report (DVP&R) Processes.

2.1 Research strategy

Based on the raised research questions the research strategy illustrated in the below figure was created for the Master Thesis. This flow chart should provide a simplified guideline through the research approach of this thesis.

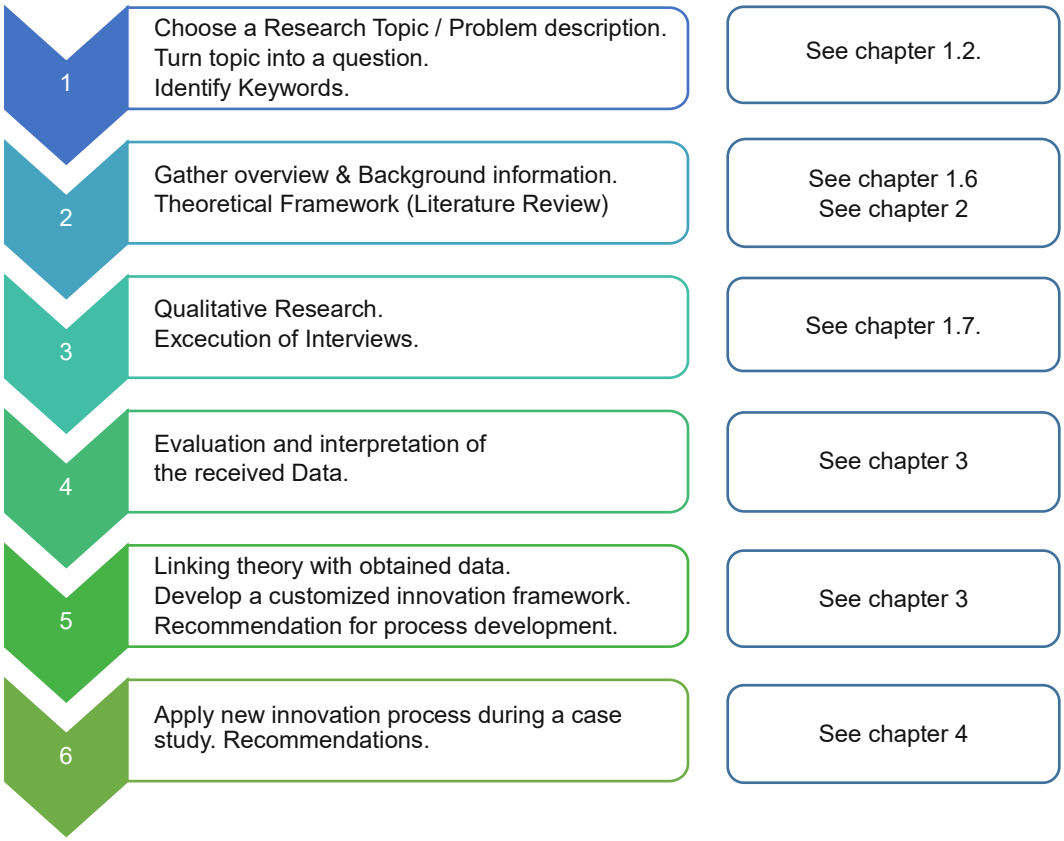


Figure 1: Research strategy (own illustration)

[2] (Biggam, 2008)

The research question and problem of the Master Thesis as well as the limitation of the paper and keywords are defined in chapter one.

Next to gain a basic theoretical overview and to be able to provide a theoretical framework in the relevant disciplines, the research strategy proceeds with a literature review. Building this theoretical framework is crucial to provide a state of the art understanding in theory of innovation management and highlight the different innovation process models.

In order to be able to get direct insights from the industry, interviews with important stakeholders were conducted. This means the thesis is focusing on a qualitative research approach. In contrast to the quantitative approach, which seeks to count things in order to explain what is observed, the qualitative research framework seeks to create a thorough and detailed description of observations as a researcher. Of course, this research strategy is subjective and requires a smaller sample size of carefully selected responders.[3] Consequently, the interview partners have been selected carefully in order to be able to get a broad and reasonable insight of current issues and approaches in the industry.

Based on the information gathered from the literature review and the information gained of the interviews, the author of this paper develops the relevant framework to implement an effective and efficient strategic innovation management process at the mid-sized bearing manufacturer NKE Austria GmbH.

Finally, recommendations are given and this adjusted innovative process is applied in a case study which accompanies the development of a product solution for railway traction motors.

2.2 Literature review

A literature review is an examination of scholarly sources (such as books, journal articles, and theses) on a particular topic or research question.[4] It was conducted in order to elaborate a theoretical framework for the specific topics related to the research questions.

The most significant information that is useful for the paper's empirical section is summarized and recapped in the literature review. Thereby the review is focusing on several specific areas, such as innovation, innovation strategy, innovation management and outlines different innovation process models. Apart from innovation topics also common business models and engineering tools are discussed.

The fundamental purpose of this review is to offer the reader of the thesis a thorough knowledge base in order to understand the threatened topic and to emphasize the importance of the research for the empirical part. Further, the literature review shows how this paper relates to existing research and what new insights it contributes.

All in all, the narrative based literature reviews provide the reader with a fundamental theoretical framework and knowledge base. On the basis of this framework, empirical data were analysed and the research questions are answered.

[3] (Biggam, 2008)
[4] (Biggam, 2008)

2.3 Interview, Expert Talks

One of the most important pillar of this Master Thesis is to investigate current practices of innovation management within different business areas, understand current challenges, identify trends in the industry and the needs of customers. The data was gathered mainly by interviews with employees in key position working in Research and Development, but also in Business Development, Sales and Procurement.

	Partner	Job Title / Group	Industry	Interview Type
Internal	A	General Manager	Bearing	Semi-structured
Internal	B	Sales Manager	Bearing	Semi-structured
Internal	C	Business Development Manager	Bearing	Semi-structured
Internal	D	Design Engineering Team	Bearing	Semi-structured (Workshop)
Internal	E	Application Engineering Team	Bearing	Semi-structured (Workshop)
External (Customer)	F	Railway OEM – Technical Director	Railway Drivetrains	unstructured
External (Customer)	G	Wind OEM – Technical Director	Wind Turbine Drivetrains	unstructured

Figure 2: Overview Interview Partners (own illustration)

It is important to note that interview partners have been strategically selected based on their experience, industry and responsibility. Interviews have been conducted internally within the FERSA Group but also two important customers have been involved.

Conducting interviews is one of the most common and often used method for gathering information unfiltered and directly. The interviews were executed face to face in person or via telecommunication.

During the thesis's qualitative research, two common interview types have been used:

- semi-structured and
- Unstructured interviews.[5]

The reason for that is that different target groups have been addressed. The respective type of the interview is given in the above table. It is obvious that the different interview formats and types gain different types of information.

The interview format that allows the most flexibility and spontaneity is an unstructured one. External partners such as key account customers of the railway and wind segment have been interviewed in an unstructured manner, as people tend to be much more relaxed and comfortable being honest during an unstructured interview. Moreover, the unstructured interview allows to lead the conversation and obtain additional insights through the option to ask additional questions.

In addition to that also two group interviews have been conducted. In here the questions were presented to specific target groups instead of to one individual. For this purpose a workshop have been organized.

[5] (Wilson, 2012)

As different target groups have been interviewed, also different questions have been asked. On the one hand, internal interview partners have been asked specifically about current challenges and problems which they encounter during innovative projects. Further, they have been asked to contribute in a SWOT analysis.

Internal Questionnaire:

a) How do you identify new potential innovation project? What do you associate with innovation and your professional experience? Is innovation happening at your company? Why is innovation important for the success of an organization?

b) How do you manage innovative projects? Do you have a standardized innovation process guideline? Which stakeholders are involved?

c) How do you decide to invest resources in new a technology and where do you obtain the basis for deciding to proceed with a particular technology?

d) How do you select promising ideas from the idea pool? Which decision methods do you use?

e) Does your company apply an innovative friendly culture? Does your organizational structure contribute to an innovative friendly culture? How do you have to change your organizational structure and culture to support Innovation?

f) Who is the driver of innovations? How do you create new ideas? What are the sources of the idea generation process?

g) In which areas of your company do innovation occur? Do you think that your organization is customer-centric?

h) What unique value do you bring to the market that no one else can offer? Can you address any unsatisfied needs expressed by your target customers? What are your primary points of differentiation? What distinguishes your product or service?

i) Why did previous customers leave? What drove them away?

j) With which engineering, strategic and business analysis tools, such as DFMEA, SWOT, BCG, etc. are you familiar? Which tools do you use in your current new product development process?

On the other hand, the questions provided to the external partners focused on the customer's needs, trends within their industry and pain points which are related to the current bearing supplier's services and product portfolio.

External Partners - Questionnaire

k) What are the current bearing solution trends in the Rail and Wind segment and how do those match with the available product portfolio of NKE and the offered services?

l) Where does NKE deliver below and above the expectations? Where do problems occur? Is there any pattern?

m) Which problems have you been able to solve by using our products or services? If you could modify our products and services, what would it be?

n) Which aspects and features of our service and products are the most valuable for your industry, today? What are your current and future pain points which a bearing supplier could tackle?

o) How do you manage innovative projects? Do you have a standardized innovation process guideline?

p) Would you recommend NKE to others? Why or why not?

All in all, the qualitative analysis process follows the following flow chart.

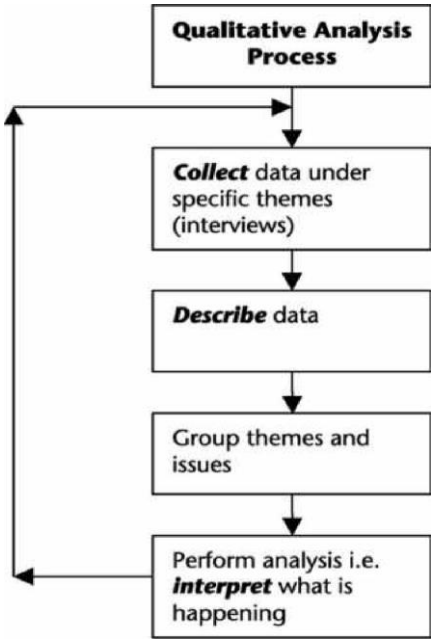


Figure 3: Qualitative analysis process (Biggam, 2008)

The collected qualitative data were recoded and transcript. The data have been analysed thoroughly in the empirical part. Hence, the available data was utilized for the study and then methodically reduced to its most valuable essence.

Next the data have been categorized in group themes and issues.

Finally, the qualitative categorized data is interpreted and the main findings are derived. The obtained information is used to adapt the business strategy of the company NKE and implement a customized innovation process guideline and give recommendations.

3 Theoretical Framework

This paper focuses on the development of a customized innovation management process and analysis in the empirical part the business strategy of a mid-sized premium bearing manufacturer. The following chapter provide the reader some fundamental knowledge to follow the argumentation within the empirical part of the master thesis. The theoretical framework focuses on the general field of innovation, innovation management and highlights different innovation process models. But only the most important topics are discussed, which are of relevance for the present research objective.

3.1 Innovation

Innovation has been conceived, defined, interpreted, and understood in various ways throughout history, but what is it?

"Making changes to something established by introducing something new."

"Creating something new that has never existed before."

(Oxford University, 1998)

There are numerous definitions of innovation used in various fields, including academia, industry, government, and service provision. The available academic literature relates to a broad range of disciplines and can cross disciplinary boundaries For this study, it is essential to have an innovation definition that is appropriate for the topic and research being conducted.

At the corporate level, it appears that management teams are aware that innovation may have an impact on costs, profits, and the overall long-term success of a company, such as organic growth.

While the word is derived from the Latin noun "innovates" and appears in print as early as the fifteenth century, the more modern interpretation and expounding of it go back to the famous economist Joseph Schumpeter and his writings in the 1930s. According to Joseph Schumpeter, widely regarded as the father of this field's research, innovation or development is defined as "new combinations" of new or existing knowledge, resources, equipment, and other factors in 1934. Among others innovation can occur to products, services and processes.[6] Schumpeter identified the five types of innovation. The description of this model is presented in the figure below.

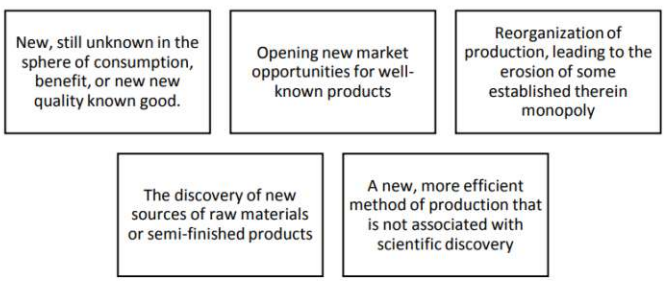


Figure 4: Schumpeter's five types of innovation (Timur & Antanas, 2017)

[6] (Timur & Antanas, 2017)

After Joseph Schumpeter, a number of studies were conducted on the topic of innovation, resulting in a large number of definitions. Another appropriate definition is given as *"Implementation of a new or significantly improved product (good/service) or process (method/practice/relationship)".*[7]

However, in general Innovation is essential because it leads to the formation of new businesses, which supports economic expansion. This is true whether these new businesses are new start-ups or new divisions within existing organizations.

According to Schumpeter's definition every new factor combination starts with a sound idea and it is common practice for a sound new idea to supplant an older, more well-established one. Putting this statement in the context with business, the overarching objective of every organization is the development of good ideas. Those good ideas are usually represented by innovative processes, products or services, and bring value to the customer or to the company. This increases the customer's satisfaction and contribute to the company's success.

Taking all these arguments into consideration one of the most meaningful practical definition is that, innovation is something new that is created by new ideas that differentiate processes, services or products from those that are already established, and add value for the customer and company. Often the terms "originality" and "novelty" are used in combination with innovation. However, those terms are highly subjective and cannot be described reasonably quantitative. However, it is important to point out, that for one organization a small change may be a big innovation for another.[8]

Today's challenging market situation and business environment requires that organizations continuously learn and adapt processes, products and services in order to stay competitive. For this purpose it is mandatory to understand customer's voice and fulfil their needs.

3.2 Categories of Innovation

Innovation is commonly associated with new product development. But innovation occurs, however, in processes that create products, services that deliver products, and services that provide intangible products. Many services even do not involve any sort of physical product. Each of the aforementioned innovations contributes value. Customers will return to purchase or use similar products or services in the future if they recognize this.

The following paragraphs discuss the characteristics of those three different innovation categories in more detail. To sum up, as already mentioned in the previous chapter it is important to highlight that innovation can occur to products, services and processes.

3.2.1 Product Innovation

Product Innovation entails making improvements to physical products. Synomnys and related terms which are often used are: product design, research and development (R&D) and new product development (NPD). The product innovation can be classified in the following different degrees of changes:

[7] (Skinner & Hanlon, 2015)
[8] (Timur & Antanas, 2017)

- Incremental improvements
- Additions to existing product families
- Next-generation product solutions
- New core products

Businesses have a portfolio of products that must be continuously enhanced or modified as problems in service or new requirements arise or requirements change. This means incremental improvements have to be implemented.

Further it is essential that organizations add products to their existing product families.

The work of the product design team on next-generation products or new product models is one of its primary activities.

An innovative design team is also able to design radical new products or is focusing on the design of new core products, which expand the existing portfolio significantly. Those new core products usually also requires new processes to create them. These new core products can provide the organization with the possibility to increase in revenue and growth. Additionally, there is the possibility that the organization will achieve a temporary monopoly in the market.[9]

3.2.2 Service Innovation

Service Innovation entails introducing advantageous modifications to the Services that customers employ. In general, Service innovation entails introducing modifications to intangible goods. i.e. education, technical service, banking, etc.

In the past decade, websites have offered a vast array of knowledge-based services. These services involve intangible goods, have a high level of customer interaction, and are typically activated by the customer on demand. It is obvious, that an important characteristic of a service is a high degree of interaction with the final consumer or customer.

Service innovation can be an effective strategy for a company to gain a long-term competitive advantage. Leading organizations in each area use service innovation to enhance customer value, promote brand preferences, and provide integrated solutions that increase cross-selling opportunities. This approach is often also called as “servitization”, which describes the organization’s ability to offer industry specific product services, based on the close relationship between manufacturer and the end-customer.[10] For example, the automotive manufacturer BMW has expanded its product offerings to provide leasing options, car-sharing/pooling, and vehicle renting.[11]

3.2.3 Process Innovation

Process Innovation involves making beneficial changes to the procedures used to produce products or services. The innovation of processes can result in key improvements, like in organizational improvements such as decreased inventory stock, fast and more flexible manufacturing processes and more efficient logistic.

[9] (Krithika, 2015)
[10] (Shelton, 2009)
[11] (Grenzlinger, Zejnilovic, & Bustinza, 2020)

The work of the operations and quality management movements over the past years has resulted in the emergence of a number of standardized methods for process innovation. Although those concepts may not be applicable for all businesses and industries, they can stimulate the innovation process. Common methodologies include:

- just-in-time management,
- total quality management,
- supply chain management,
- Enterprise resource planning and the application of lean manufacturing.[12]

3.2.4 Types of Innovation and the Product Lifecycle

According to the type of change innovations bring to the enterprise, innovations can be classed as incremental or radical.

Within the existing structure and strategy, incremental innovations improve the old product or process, while radical innovations create new business opportunities, strategies, and structures. It is important to note that a radical innovation is not always the product of a single "great jump" in an enterprise's development, but rather the outcome of many smaller changes that occur in tandem and collectively pull the organization into a radically different form. Finally, a radical breakthrough can be the outcome of several incremental innovations that reinforce each other in the same direction.

As an industry matures, the relative importance of the various types of innovations changes. This is illustrated by the well-known concept of the product life cycle.

A product life cycle begins with the introduction of a series of radical product innovations. In the market, various technological solutions to the same consumer problem compete until a dominant design is chosen. It establishes the parameters for the products continued evolution. In the subsequent stage of evolution, sales growth is pursued through significant process innovations that impact price quality and market segmentation.

Product innovations that are incremental augment and improve the original product. Because the product and its associated processes are so intertwined during the maturity phase, only incremental product and process innovations are possible.

Nevertheless, even minor modifications to a product or process can yield significant cost savings or quality improvements.

When the market reaches saturation, the maturity phase turns into decline. A market or technological shock can initiate a new wave of product innovations, and the phase of introducing the new substitute product can begin.

The below graph depicts the categories of innovations during the product life cycle.[13]

[12] (Krithika, 2015)
[13] (Riitta, 1994)

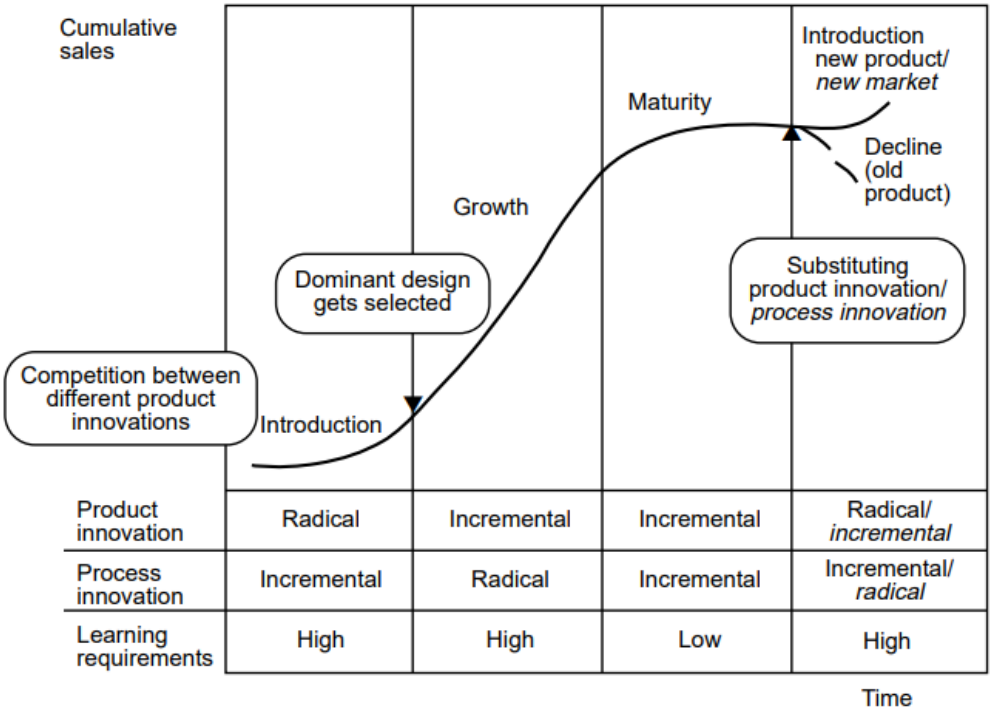


Figure 5: Types of innovation and product lifecycle (Riitta, 1994)

3.3 An Innovation Management Framework

Increasing numbers of new products and services are introduced today. In order to increase the effectiveness and efficiency of new product development, innovation management has grown in importance. It is key to point out that innovation is necessary for a sustainable long term success and innovation is about making changes.

The following picture represents the A.T. Kearney's House of Innovation model, which provides a four dimensions framework of innovation management. The four dimensions are: Enabling factors, Innovation Lifecycle Management, Innovation Organization and Culture and Innovation Strategy.

Figure 6: A.T. Kearney's House of Innovation (Messnarz, Pries-Heje, & O'Connor, 2011)

- The Innovation Strategy examines the most promising areas in which the firm may achieve better profit growth rates via new products/services, current products/services in new markets, new or enhanced processes or business models.
- This Innovation strategy must be supported by the company's Organization and Culture in order to achieve the profit growth objectives. Companies must build up a strong partner network, for instance, to incorporate external partners in order to be able to develop new innovative services, products or processes.
- Further, there are many enabling factors such as Knowledge Management, Project Management etc. which support a successful innovation management.

3.4 The different innovation process approaches

In both study and practice, process models are an essential part of innovation management. Numerous process models are presented in the literature and are difficult to overlook. Several process models in the literature describe how businesses develop or should develop new products or services. In order to streamline their innovation efforts, businesses create models of their process.[14] Those models serve distinct functions. In practice, process models are utilized as a management instrument to standardize development processes. Researcher attempt to identify activities present in each product development procedure. The structure of the various process models is diverse as their applications. It depends much on the practitioner's or scholar's goal. To sum up, there is no common best innovation management process method.

There is a vast amount of published information on the processes of innovation, but the thesis choose to focus on popular process models that obviously have had an impact on research or that are utilized by businesses. This collection does not make any claims to being comprehensive. However, the following chapters discuss commonly used different innovation process which are used for new product developments and should answer which kind of innovation process model is suitable for NKE Austria. The following process models have been considered:

- First generation innovation processes: Phase review process (Technology Push Model)
- Second generation innovation processes: second generation stage-gate process model (Market Pull Model)
- Third-generation innovation processes: third generation stage-gate model (more flexible stage gate model)

3.4.1 First-generation innovation process– Technology Push

The first generation innovation process or also called as “technology push” model and “phase review process”, were developed by NASA in the 1960s.

The development procedure was broken into separate stages to systematize and manage work with the different stakeholders. The inputs and outputs of each phase are outlined and a management review is carried out at the end of every individual phase to decide whether or not proceed with project. Basically, this means that the phase review processes require that each phase will be monitored consistently. The process can be described as linear sequential process, which does not allow any flexibility.[15]

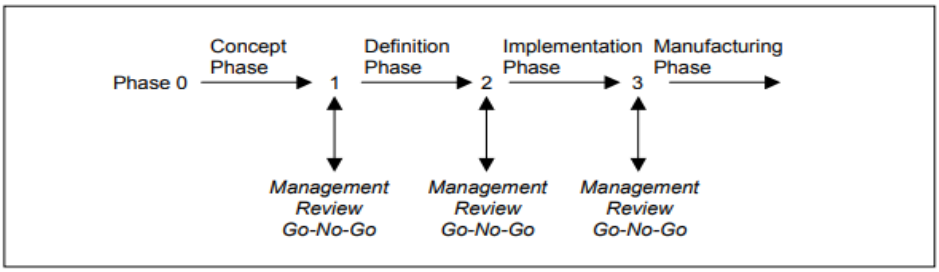


Figure 7: Phase review process (Hughes & Chafin, 1996)

[14] (Cooper R. G., 2011)
[15] (Herstatt & Verworn, 2002)

This could result in delays, since activities were put on hold until every activity associated with the next management review was finished. Moreover, this model deals only with the development phase and does not take into account the entire innovation process activities from idea generation to final launch. Also any kind of marketing activities are neglected.

However, a positive argument is that as phase-review processes are technology driven, one of their main advantage is the reduction of technical uncertainty.

It can be summarized that its primary goal is to drive technical innovation through significant research and development. But as the entire focus is on the creation of ideas, the marketing phase is neglected. The entire focus on research and development had the downside of ignoring client input and expectations. Therefore, the market frequently ignores innovations.

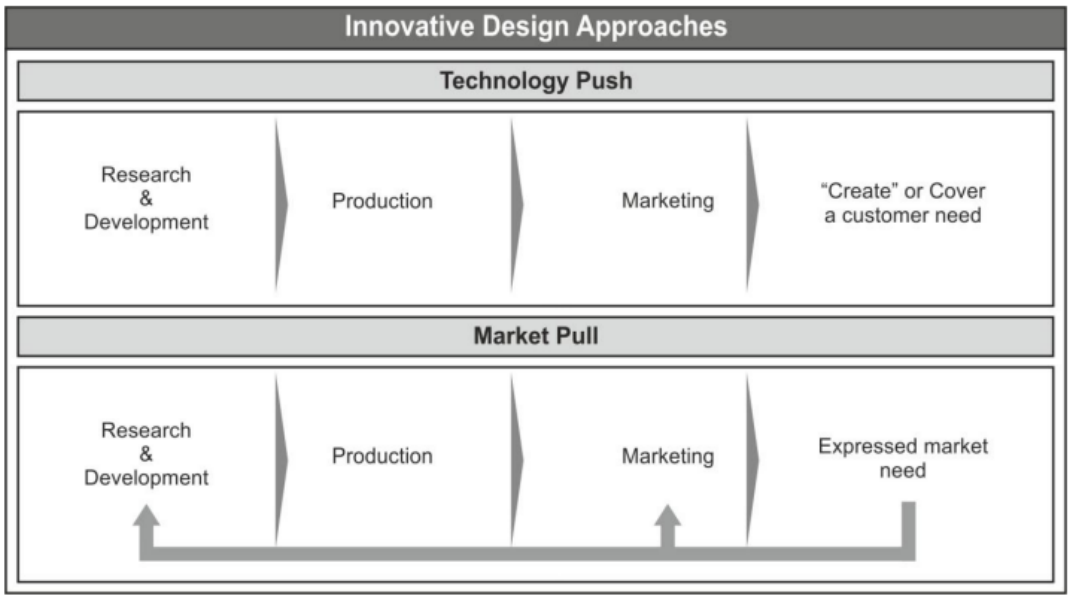


Figure 8: Technology Push Model versus Market Pull Model (Efkolidis, 2012)

3.4.2 Second generation innovation processes

Later technical push strategies were replaced more and more by the so called “market pull” strategy. Once more, the innovation procedure is separated into multiple phases. But issues that have been not considered in the first generation model are now being considered in the second. It covers each project’s cost-benefit analysis and a systematic resource allocation

The below figure shows a typical second-generation stage gate process according to Cooper. It is also called “game plan”. Cooper gives concrete recommendations and a guideline to enhance the success of a business.

The product development process starts with an idea originating from basic research, seed or unfounded projects, customer-based techniques, and creativity techniques. The following paragraphs discuss the individual stages of the stage gate model. At gates, multifunctional teams make decisions based on well-defined go/kill criteria.

At gate 1, the concept is reviewed based on must meet and should meet criteria, such as strategic business alignment, viability, and company policy compatibility. The first phase of a project is a fast, inexpensive evaluation of the market, technology, and

resources. Following passing a second gate, step 2 consists of in-depth investigations. The output of this gate is a business plan, which serves as the basis for the decision at the gate 3. The actual creation of the product and a marketing strategy comprise Stage 3. The deliverable for this phase is a product prototype. Gate 4 verifies that the generated product conforms to the specification given at Gate 3. Typical validation stage 4 activities include in-house product testing, field trials with customers, test markets, and pre-serial productions. At stage 5, Gate 5 determines production start-up and market introduction.

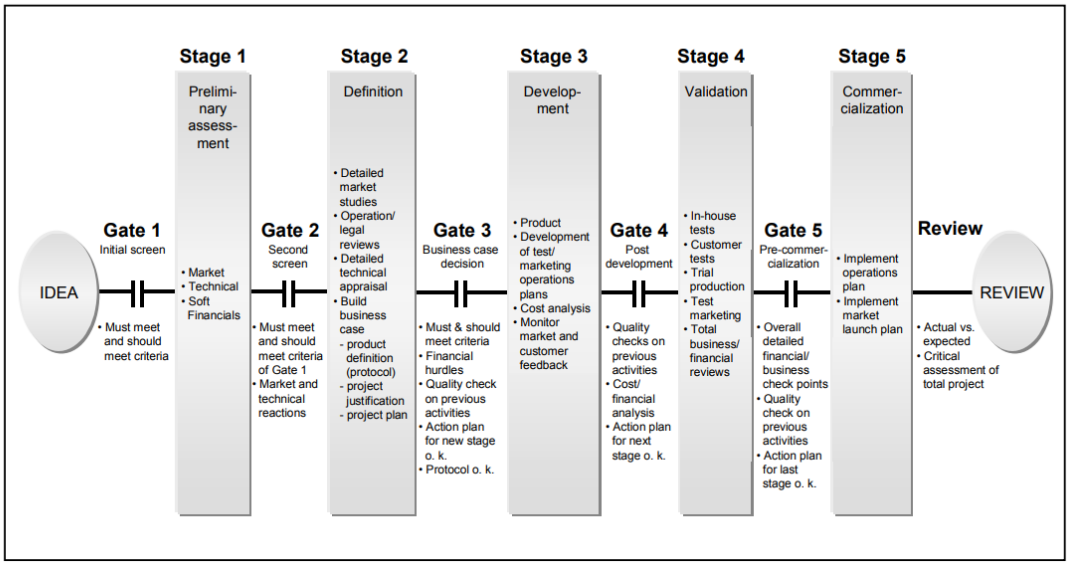


Figure 9: Typical second generation stage gate process (Cooper R. , 1990)

Finally, a review is carried out which compares the actual with the expected results and assess the overall project.

As already aforementioned, unlike the phase-review procedure, the stage-gate approach merges the engineering and marketing perspectives. In addition, the stage-gate process includes the full innovation process, beginning with the conception of an idea and ending with its implementation.

Activities can even be carried out in parallel if necessary in order to speed up the process. The procedure is not strictly sequential.[16]

3.4.3 Third-generation innovation processes and beyond

Coopers normative third-generation stage-gate-models strive for more flexible processes.[17]

Third-generation stages and gates are less stringent and less strictly sequential than second-generation stages and gates. There are more guidelines than strict rules and are adapted to the level of inherent risk in a project. Transitions between stages are smooth, and an increasing amount of work is carried out in parallel so that the product development process can be completed more quickly.

[16] (Cooper R. , 1994)
[17] (Cooper, 1996)

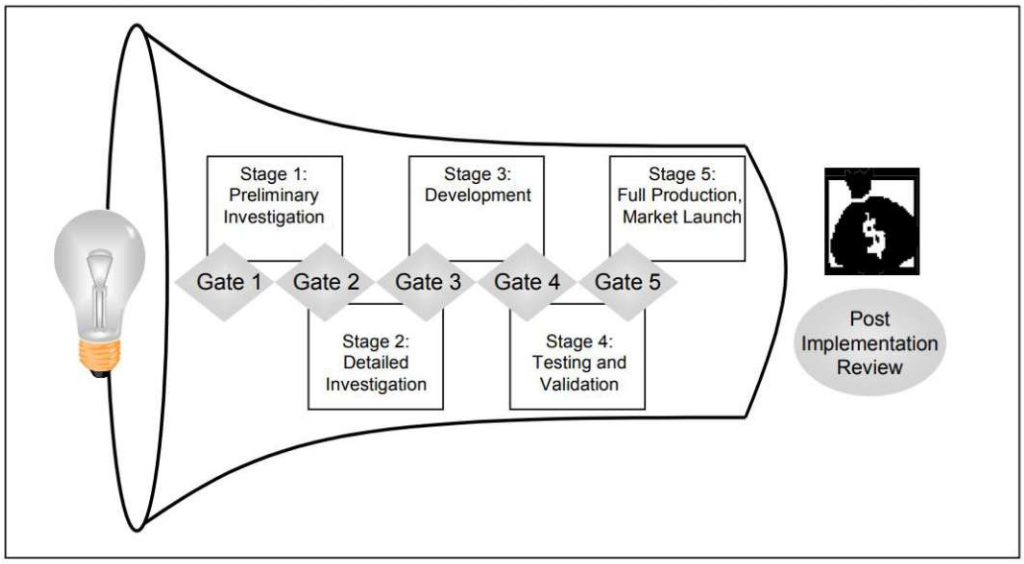


Figure 10: Third generation process model, more flexible (Cooper, 1996)

The third-generation stage-gate process is more realistic and therefore requires less effort to implement in a business. In the meantime, several other management tools and normative process models were developed, which overcome delays due to a strict sequential approach. Parallel activities were regarded as an effective method for reducing the duration of the overall development process.

The following diagram gives an idea of parallel process steps instead of sequential phases in new product development processes.

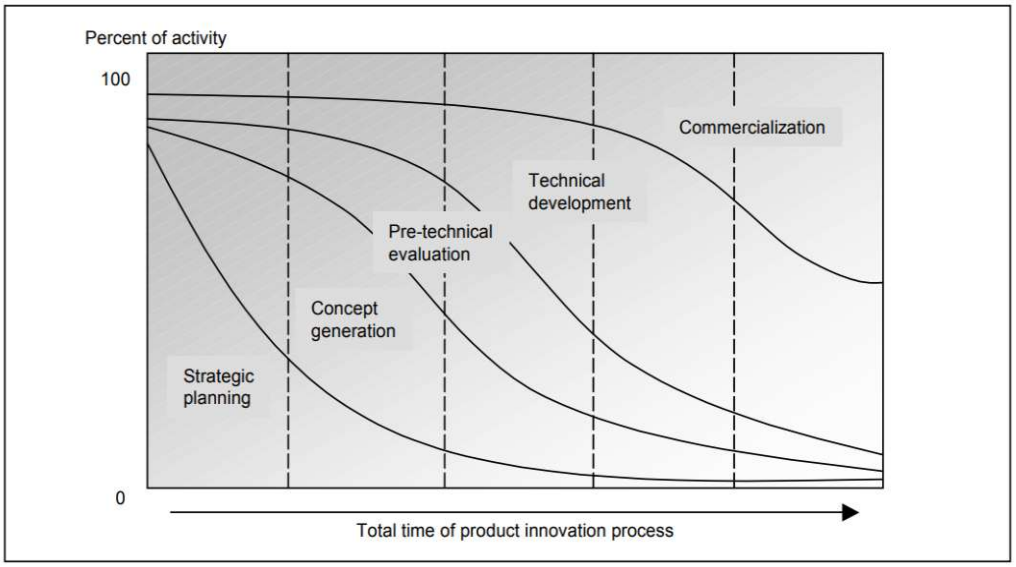


Figure 11: Simultaneous development phases (Crawford, 1994)

Many well-known companies, such as General Motors, Chrysler, Ford, Motorola, Hewlett-Packard, and Intel, employ a technique known as concurrent engineering or integrated product development. Concurrent engineering is the concurrent design and development of all processes and data required for new product development.

Focus is placed on enhancing product manufacturability and quality while reducing development cycle time and cost by resolving product, process, and organizational

issues at earlier stages For instance, manufacturing process designers begin developing tooling and manufacturing processes before product designers have finalized the product's specifications. Thus, phases of a project overlap. To maximize concurrent engineering's effectiveness, it must be tailored to each organization. It must be determined which tasks should be performed simultaneously.[18]

[18] (Herstatt & Verworn, 2002)

4 The Innovation Management Process and Strategy at NKE

This section of the master thesis is dedicated to a very important topic, which is the development and implementation of an innovation management process at NKE. In several previous chapters, the importance of a proper innovation management process have been explained. Further this chapter analysis the innovation strategy at NKE and highlights a potential innovative product development which is described in chapter 4.

4.1 NKE Austria and the Railway and Wind Bearing Segment

The Austrian Bearing manufacturer NKE Austria GmbH was founded in 1996 by two senior employs, of the former. Steyr Wälzlager. Nowadays, Steyr Wälzlager is known as SKF, which is currently considered to be one of the world's biggest bearing manufacturer. Since 2016, NKE belongs to the FERSA Group, which is a cooperate group and includes five different brands: DELUX Bearings, FERSA Bearings, PFI Bearings, A&S Automotive Solutions and NKE Bearings.

Fersa Bearings	NKE BEARINGS	A&S Automotive Solutions	PFI Bearings	DELUX BEARINGS
Automotive Industry OEM	**General industry**	**Automotive solutions for light vehicles**	**Automotive Aftermarket**	**Automotive Clutch Bearings**

Figure 12: FERSA GROUP Brands (own illustration)

The Austrian rolling bearing manufacturer NKE Austria is purely focusing on industrial bearing solutions, while the others have strong stragic focus on the automotive sector.

The Groups revenue is about 168.1 Mio. EUR per year and this yearly turnover comes from 52% OEM customers and 48% Aftermarket. The group have been grown organically as well as an-organically in the last years. The FERSA Group invests about 4.5 % of its annual overall sales in research and development projects.[19]

NKE is expert in bearing solutions for mechanical drivetrain and electrical drivetrain technologies, such as for Wind and Railway Applications. NKE is working on a one-stop shop solution for those application fields. This includes an extensive engineering service based on 20 years of industry experience by NKE's application engineering team, own flexible manufacturing capabilities and logistics.

The overall bearing market is huge. SKF[20], JTEK Koyo[21], NTN[22], NSK[23], TIMKEN[24], and Schaeffler[25] are the key market participants. According to 2016 data, SKF had a

[19] (NKE Austria, 2023)
[20] www.skf.com/en
[21] www.koyo.jtekt.co.jp/en/
[22] www.ntn-snr.com/en
[23] www.nsk.com/en
[24] www.timken.com/en
[25] www.schaeffler.com/en

total market share of around 11.4 percent, followed by the German joint stock company Schaeffler with 9.6 percent in 2016.[26] Efforts have been undertaken to determine more particular market share values, but no detailed and trustworthy information regarding individual market shares has been provided. However, it is anticipated that the Fersa Group's market share is merely a minor portion of the overall market share, most likely less than one percent. However, NKE is on the best way to domain some specific wind turbine markets and gradually get established as premium bearing brand in the railway industry segment. NKE's global footprint will support the strategies of the different market needs.

NKE supplies bearing solutions for Traction Drivetrains of Railway Applications to renowned OEMs worldwide. This includes bearings for the traction motor, which are typically special insulated bearings in order to protect them from potential harmful stray currents. Further, NKE manufactures Traction Gearbox Bearings for all positions within the transmission. Especially the bearings mounted on the output-shaft can be exposed to huge shock loads. Those bearings have to make out of special high quality material combined with superior heat treatment processes.

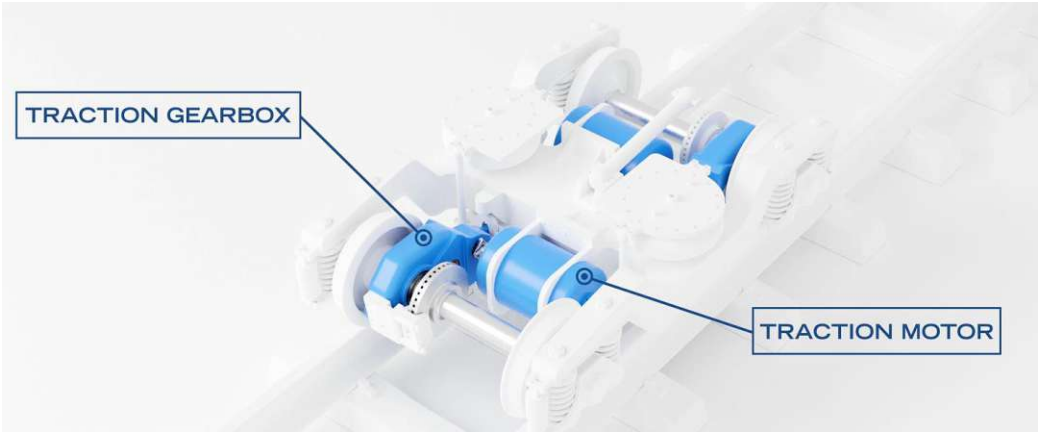


Figure 13: NKE Railway Bearing Solutions (NKE Austria, 2023)

NKE manufactures bearings for the entire mechanical power-drivetrain of wind turbine applications: Main shaft Bearings, Gearbox Bearing Solutions as well as Generator Bearing Solutions.

The bearing loads and rotating speeds vary considerably due to constantly changing winds. This means the features of wind turbine bearings is that they have to operate in a wide range of loads from light to heavy loads. The force that the main shaft bearing carries mainly includes the weight of the rotor and the hub, and the force of the wind acting on the main shaft through the wind rotor.
For example, a 2 MW class turbine is featured with 40 meters blades and a rotor hub of about 80 meters, with a total weight of about 200 tons. The principal role performed by the Main shaft bearing is that of supporting the rotor, while reacting non-torque loads. The power of wind turbines are increasing, which means that the loads that have to be transmitted by the gearbox and its bearings are increasing too. There are multiple different bearings used in a wind turbine gearbox. Bearings in the gearboxes have to cope with loads, stresses, vibrations and temperatures which are constantly changing.

[26] (Grand Review Research Institute, 2023)

The individual loads and requirements vary from bearing position to bearing position. i.e. Planet carrier bearing's speed is very less compared to High Speed Shaft Bearing Speeds
The loads within a Wind Generator are typically not a problem. But one of the main threats to bearings in variable-speed wind turbine generators is stray currents. If current is routed through the bearing, it can cause micro-pitting and other types of surface damage. Eventually, the bearing can fail – potentially leading to a catastrophic failure of the generator. In order to avoid this passing of the current, NKE developed the SQ77 Bearing portfolio, which are bearings featured with a ceramic layer on the inner or outer ring. This insulation layer does not conduct electricity and can resist a potential damage. Further the trend is to use NKE Hybrid Bearings which are featured by ceramic balls instead of common steel balls. The ceramic balls provide best insulation characteristic, but also offers a lot of other advantages, such as high speed suitability and best dynamical behaviour due to less weight, less friction, best running noise characteristic and also and extended service lifetime under severe lubrication conditions.

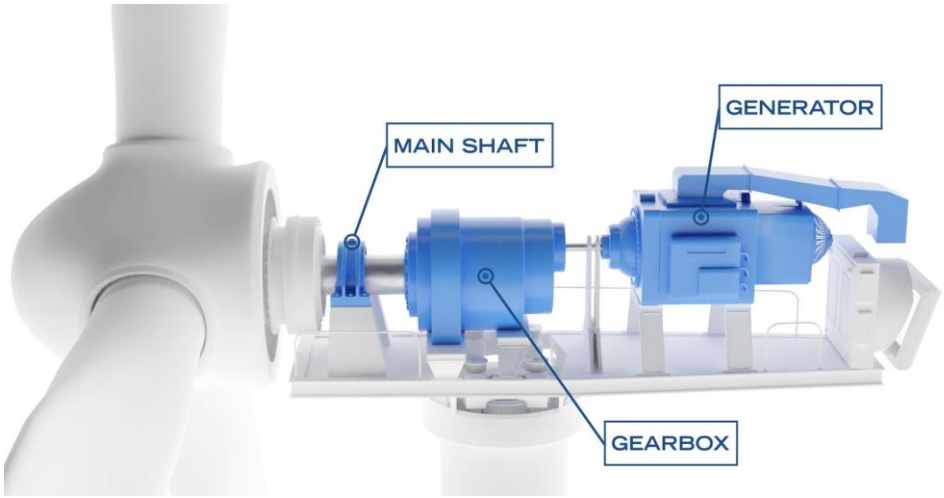


Figure 14: NKE Wind Bearing Solutions (NKE Austria, 2023)

4.2 Qualitative Research

The following chapter of the paper summarizes the collected information from the qualitative research process. In total seven interviews have been carried out and the feedback has been manually documented. The questions, interview type and interview partners have been carefully selected. All the input have been thoroughly analysed and processed according to the qualitative approach mentioned in chapter 1.7.

The results of the interview can be categorized in the following fields of interests:

- State of the art and challenges
- Perception of innovation at NKE Austria GmbH
- General Business Strategy
- Organization and Structure
- Process for new product development (NPD)
- R&D Roadmaps

It must be pointed out that the following paragraphs represents only a very general summary of the overall information obtained. The paper is focusing on the most relevant areas and some of the information is not shared because of a non-disclosure agreement.

4.3 State of the art and challenges

In order to visualize the main insights gathered during the interview a SWOT analysis is carried out. As the SWOT analysis offers the possibility to present internal as well as external factors, it is an appropriate format to show the main findings of the internal as well as the ones from the external (customers) interview partners in one diagram.

INTERNAL	**STRENGTHS**	**WEAKNESSES**
	• Direct Technical support • Flexibility • FERSA Group Capabilities (Investments) • Global footprint • Historic “Steyr” Brand • Fast response time • Special focus on customized solutions (niche) • Creative Problem solving • Good technical and application knowledge	• No dedicated R&D • Small market presence • Dependency on suppliers • No engineering partner network for NKE purposes • No innovation process, strategy. No NPD process. • Missing R&D Roadmap • Reserved thinking about innovation projects.
EXTERNAL	**OPPORTUNITES**	**THREATS**
	• Fast go to market strategy • New product developments • Companies look for cost savings. But still high quality bearings. • Automatization/Digitalization: get rid of non-value added work. • Homologation processes at OEMs	• Asian low price players increase quality. • Bearing failures and quality claims. (risk for human being, life etc.) • High cost pressure.

Figure 15: SWOT Analysis (own illustration)

First of all, the feedback of the interview partners have been analysed and the strengths are discussed.

Both, the internal interview partners as well as the customers are of the opinion that one of the major strengths of NKE is the fast and very competent technical support.

Especially the response time to technical inquiries, which is usually less than 24 hours for OEM customers, is highly appreciated by the customers. Further, it is highly appreciated that internal as well as external partner do have access to a direct contact at NKE Engineering. Other big manufactures offer only kind of common engineering ticket, where requests are managed by a ticket system.

The company is also offering highest flexibility, which in general helps to respond to market changes effectively and quickly. However, the interview partners point out that NKE's flexibility relates more to the operational daily business and not the long-term strategic business. For example, NKE is able to shorten the lead time of the raw-material and adjust production plans to a minimum if necessary. In contrast to large bearing manufacturers such as SKF, NKE also handles requests from smaller customers, which are typically ignored by the big companies. Also NKE has a flat hierarchy with fast decision making channels, which guarantees a high flexibility level for internal decision making processes in project but also is reflected to the customer.

One of the key strengths is, that NKE is part of the global cooperate group FERSA GROUP. The combined bearing industry experience is about 50 years. Since 2016 NKE benefits from a global footprint. The Group is present on all continents and has four R&D centres, six production facilities, four quality centres and about 19 distribution partners.

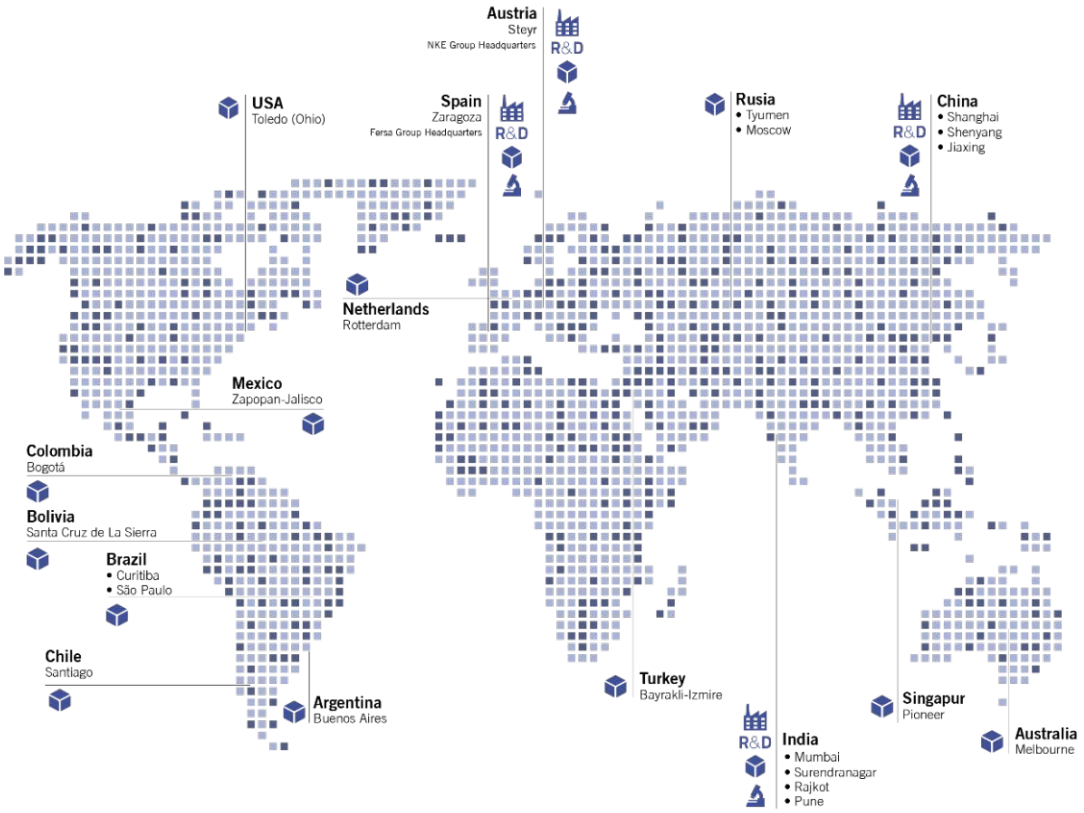


Figure 16: Global Footprint FERSA GROUP (NKE Austria, 2023)

For global active customers in the railway and wind segment this is very important, as their strategy is usually to source components whenever possible locally, with a more efficient supply chain. This is often even a requirement by the end customer or national law. For example in order to be considered in an Indian Railway Project, usually the bearing manufacturer have to have a local supply chain based in India. Of

course this supply chain will also be audited. But the overall specifications, requirements, process plans etc. have to be managed by the Headquarter of the Bearing Manufacturer, like NKE Austria in Steyr. In contrast to the Railway industry, it seems that the wind industry customers usually requires even a direct Engineering support in their countries.

In the last couple of years NKE is focusing more on specific industries. NKE's deep knowledge in the wind industry, railway industry and agricultural industry is very important and can be considered as an important game changer. Even though their much less Engineers working for NKE than for the big manufacturers, the company has already a very good reputation in those fields.

One of the main weaknesses which is very clear for the internal interview partners, is that NKE does not have dedicated teams nor a dedicated Research and Development team which is actively driving innovations. Nowadays, innovations are not actively pushed in the organization. Somehow the application engineering team of NKE is working on operational daily business but also tries to focus of the implementation and integration of new innovative products, services and process. But still an organizational innovation strategy and structure is missing. Also there is no proper new product development process defined. Both, the external as well as the internal partners share the feeling that NKE just follows the trend of the big bearing manufacturers. Right now, apparently there is no product or service for which NKE is popular for or dominates the market in a specific area. This is also linked to another weakness, which is to the lack of a R&D Roadmap. So far NKE does not follow a specific R&D Strategy. But it this is mandatory to maintain success short term, midterm and long-term. All in all, this means that resources for further innovation development activities are limited.

Currently, NKE does not have a well-established industry partner network. It is a fact that a medium sized company is not able to provide information and deep knowledge in all specific areas, such as simulation technology, lubrications and sealing. But it is important that the customers consider NKE as one stop shop solution. For example, OEM customers in the wind and railway segment require detailed information about the lubrication lifetime and settings etc., which NKE bearing should be able to offer. However, NKE is not a dedicated lubrication supplier nor a lubrication manufacturer, which makes it necessary to build up strong partner who cooperate with the company together in these topics.

It is important to note that some of the internal interview partners associate innovative solutions and its development within the bearing industry with huge amount of finical investments. They feel concerned about whether it even could be profitable for a small to medium sized company to focus on innovative solutions in such a highly competitive market, like the bearing market.

The results of the interviews can also be categorized in opportunities for the company. It is commonly understood that in order to grow, businesses must adapt fast to changing markets. NKE Austria offers a relatively flat hierarchy structure which could provide quick responses to the market needs. In general, a fast go-to-market strategy can help NKE to be a pioneer in specific areas.

The interviewed customers pointed out that one the one hand, nowadays companies look for cost savings more than ever before. On the other hand the quality levels of the components have to still be high. This could be a chance for NKE to grow on market share, as NKE offers an attractive combination of reasonable pricing and high quality.

Moreover there is a big room for improvement in terms of digitalization and automatization. Customers claim that there is no online NKE bearing technical database nor database for common calculation tools or CAD software offered, yet. It is also important to get rid of non-value added tasks. For example generic drawings could be generated by means of a parametric system, instead of doing it manually. The internal interview partners are convinced that there are many opportunities which can be optimized and automatized.

In order to secure a sustainable growth, it is important to be homologated by the biggest, most powerful target customers. At the time being, NKE is already in the process of some of those homologation processes but still a common strategy is missing. However, both internal and external interview partners expect a significant grow in trust once the company is approved by key customers. It is expected that the efforts put into the homologation process pay off in the OEM segment but also in the Aftermarket business. The wind and railway market is very conservative and usually only bearings, which have been used in the OEM application can be used for services and repair jobs.

Undoubtedly, quality claims as well as any kind of premature bearing failures, are classified as threat by the customers and the company. A premature bearing failure even can endanger life or health or have a big finical impact. For instance, an axle box bearings assembled in railway vehicles are safety relevant components. A sudden premature bearing failure could lead in the worst case to the derail of the train.

According to the Indian Institute of Technology, most of the accidents in the railways are due to wheel and bearing failures.

Failure type	Failure frequency
Axle Bearing	40.70 %
Wheels	19.56 %
Tyre Corrosion	16.08 %
Bogie Suspension and Structure	9.15 %
Others and Unknown	14.51 %

Figure 17: Rolling stock related accidents in Iran from 2001 – 2004 (Kundu, 2018)

In order to underpin this threat a short research about the financial impact of unplanned downtimes of wind-turbines is given in the next paragraphs:

- A customer of NKE assembled 3000 Mainshaft Bearings (Multibrand Spherical Roller Bearings) in 2022. Out of 3000 the customer had 16 mainshaft bearing failures so far. The failure mode for these bearings have been spalling, which is a common fatigue failure. However, a material analysis have shown that the heat treatment process of the rings was not properly done.

  The costs for the unplanned replacement of one bearing have been reported as the following:

  - Onshore Application: 1.500.000 RMB = 198.500 EUR
  - Offshore Application: 6.000.000 RMB = 794.000 EUR

  The cost of one individual bearing is 20.000 EUR.[27]

[27] (NKE Austria, 2023)

- *"The National Renewable Energy Laboratory's (NREL) Gearbox Reliability Database (GRD) shows that 76 percent of wind-turbine gearboxes failed due to bearings, while 17 percent of failures were caused by gears."*

(Aikin, 2020)

- *"Recently reported figures show that main-bearing (MB) failure rates (over a 20 year lifetime) can be as high as 30%"*

(Hart, Turnbull, Feuchtwang, & McMillan, 2019)

Another threat identified is that low cost competitor bearing manufacturers, mainly located in Asia, could be able to increase the quality of their products. This could increase the already existing cost pressure significantly.

To sum up, this SWOT analysis just represents the main findings and gives a rough overview of the information received during the interviews and provides a status quo analysis of the current business and innovation strategy. Also in the following chapters the insights of the interview partners will be considered and analysed carefully.

4.4 Perception of Innovation within NKE AUSTRIA

During the interviews, very soon it got obvious that there is no clear innovation strategy nor innovation process or R&D roadmap at NKE in place. But during the interview it has been found out that at least the FERSA Group invested a lot in innovation management and build up a specific innovation process and strategic partner network. However, this process and network is very specific and tailored to the needs of the automotive industry and considered as not appropriate for the industrial segment.

It is notable that innovation still occurs at NKE. In the last couple of years NKE focused on the development of special Hybrid Bearings for Wind Generator Applications, which are already available on the market. Moreover, a smart bearing solution, called MoSS – Modular Sensor Bearing has been developed, but so far only prototypes are available. Obviously, innovation has not the relevance as it should have.

For example, the two above mentioned projects have been driven besides the daily operational business by the Application Engineering Team. In the last years many resources have been spent to properly integrate within the FERSA Group and also maintain and develop existing business relationships. There was no clear focus on innovation. In general, the company is more focusing on incremental innovations, like cost optimization and small product and service improvements. In order to stay competitive also resources in terms of time, money and people have to be invested which have to focus more on potential radical innovations.

The overall impression of employees at NKE is that the most talented people are fully occupied with daily operational activities and do not have any time to work on new creative innovative solutions. Further, the interviewed people stress the point that it is mandatory that cross functional teams work on those projects. At the time being there is a lack of information between the different areas in the company.

4.5 General Business Strategy Guideline

The creation of a structured and efficient innovation system requires also input from the organization's overall strategy. The following chapter analysis the strategy of NKE today and gives recommendations.

The company has defined the following vision and mission:

> *Vision: "We put the world in motion through innovative, tailor-made and high-quality bearing solutions at attractive prices."*
>
> *Mission: "We are the most flexible and best alternative in the premium class of the bearing market"*
>
> (NKE Austria, 2023)

One of the companies key goals it also to develop towards an innovative company focusing on sustainable solutions.

In order to analyse and to determine the corporate strategy, the industry's structure is identified by means of the Five Forces Model of Porter. The qualitative input of the interviews as well as internal knowhow within NKE is applied. It is necessary to understand the level of competition within a specific industry and enhance company's long term success. The following figure represents the five forces model.

Figure 18: Porter's Five Forces Model (Bruin, 2016)

The industrial sector is big, applications of bearing solutions and thus competitors and products are different. It would not be reasonable to carry out a Porter analysis for the entire industrial sector. Even though it is not mentioned within the Vision and Mission Statement of the company, NKE wants to focus more specifically on the rail and wind bearing segment.

The first of the Five Forces: Rivalry among existing competitors, refers to the quantity of competitors and their capacity to undercut a company. The more competitors, as well as the quantity of comparable products and services they provide, the less powerful a corporation. In general, the main competitor within the railway and wind

market are known by NKE. The main competitors within the railway segment are Schaeffler FAG, SKF and TIMKEN. In the wind sector the main competitors for NKE are Schaeffler FAG, SKF, NTN, NSK and TIMKEN. This information is based on the internal knowledge of NKE, which have been gained during several projects.

However, this list of competitors is also confirmed in the Global Wind Turbine Bearings Market Forecast 2028, issued by the institution Global Market Estimates.

> *"The global wind turbine bearings market is expected to grow from USD 6.2 Billion in 2023 to USD 11.5 Billion by 2028 and is projected to grow at a CAGR of 13.15% from 2023 to 2028. The paramount competitors covered in the global wind turbine bearings market report include Dalian Metallurgical Bearing Group Co. Ltd., IMO Antriebseinheit GmbH & Co. KG, Liebherr-International AG, NSK Ltd., NTN Bearing Corp., Rollix Defontaine S.A, Rothe Erde India, Schaeffler AG, SKF Group, and Timken Company among others."*
>
> (Global Market Estimates, 2023)

The second force of the model is represented by the "Threat of new entrances". Existing businesses operating in an industry that has high entry barriers have an advantage over new businesses seeking to enter the market because they are in a position to charge higher prices and negotiate more favourable terms. Both industries, such as Wind and Rail have very high entry barriers. The homologation processes are very demanding, expensive and long. There is almost no possibility to speed um approval processes, as customers usually require to proof long term experience in the field. A common homologation process in the wind segment last at least about three years.

The third aspect taken into consideration by the Porter model is the degree to which suppliers are able to readily drive up the cost of inputs. It is impacted by the number of suppliers of essential inputs of a good or service, the degree to which these inputs are distinctive, and the amount of money it would cost a business to move to another provider. There is a direct correlation between the number of suppliers in an industry and the degree to which a company is dependent on those suppliers. NKE is highly depended on suppliers for the raw material but also for finished goods, like cages and rolling elements. As the audit of sub-suppliers is part of the overall homologation process of the end-customer, it is not possible to change the supply chain very easily. This means even though there are many capable raw material suppliers available, the supply chain must be constant and therefore the supply has significant critical power. Due to the demanding homologation processes, usually even a single source strategy is applied.

One of the Five Forces is the ability of customers to push down prices, which may also be understood as their amount of power. It is impacted by the number customers an organization now has, the significance of each client, and the amount of money it would take for an organization to find new customers and explore new markets. The power of customers in the rail- and wind segment is huge. However, NKE follows a competitive pricing strategy and undercuts competitor's prices slightly. It encourages customers to try their products and helps the company to grow in the industry.

The fifth and final element of the Five Forces model is known as threat of substitute products. A competitor's products or services that offers a suitable alternative that can replace the existing ones pose a danger to the organization. In the Rail and Wind Bearing industry, there are multiple research projects ongoing. Recent development such as Hybrid Bearings for Wind Generators, Journal Bearings for Wind industry gearboxes or split spherical roller main shaft bearings have shown that developments

can still occur on the product level and bearings should not be considered only as commodity.

Both Porter's Five Forces analysis and SWOT (strengths, weaknesses, opportunities, and threats) analysis are examples of useful tools for conducting research and make decisions on a strategic level. However, the insights gathered in the SWOT analysis and the Porter's Five Forces model can be combined reasonably and match each other.

Moreover the so called Porter's Generic Strategy Model offers a great starting point for choosing the right strategy. There are three fundamental strategic choices that businesses can make in order to acquire a competitive advantage, in accordance with the model of Generic Strategies developed by Michael E. Porter. The first is "Cost Leadership," followed by "Differentiation," and then "Focus."

The qualitative research via interviews has shown that in the past the company did not apply a common strategy. NKE focused and is still focusing on too much industries. Within NKE there are different customer group segments, such as distribution, Aftermarket, all OEMs and OEMs in Wind and Railway segment. In order to adress those different customer target groups different appropiate strategies and processes are fundamental. Instead of following a clear strategy NKE is used to try to apply a mixture of all kind of strategies. This is the best example of failing to choose between one of the available strategies. Porter describes it as "being stuck in middle", which means that the company even does not have any competitive advandtage.

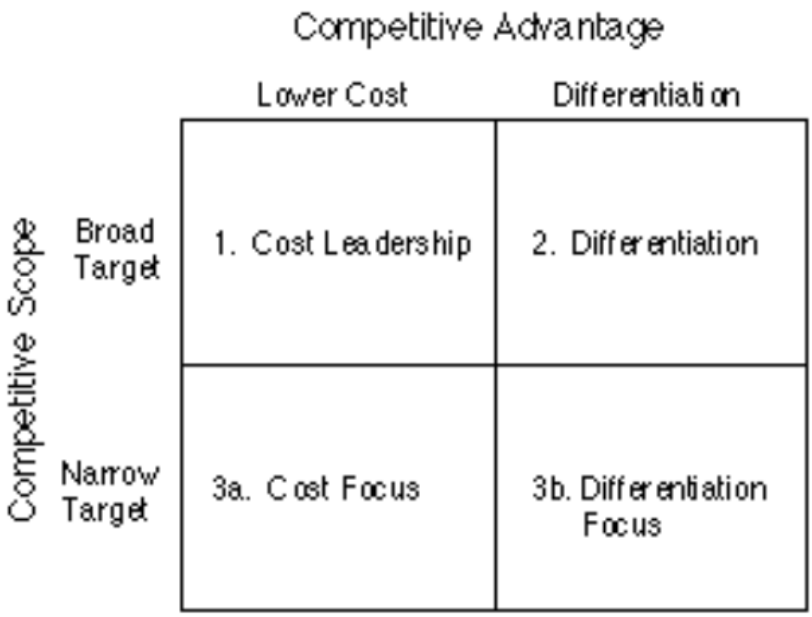


Figure 19: Porter's Generic Strategic Model (Porter, 1985)

Cost leadership means to be the most competitive company in cost in the entire market. Differentiation strategy means to be a distinctive organization known for its uniqueness, quality or personality. The Focus strategy can be classified into two parts: "Differention Focus" and "Cost Focus". The phrases "Cost Focus" and "Differentiation Focus" are rather ambiguous because they could be understood to indicate either "a focus on cost" or "a focus on differentiation," respectively. Keep in mind that "Cost Focus" refers to the practice of placing an emphasis on "cost-minimization" within the

context of a targeted market, while "Differentiation Focus" refers to the pursuit of "strategic differentiation" within a focused marked.

After looking on the different models, it is highly recommended that NKE should follow a focus strategy. Companies employing Focus strategies concentrate on certain niche markets and, by comprehending the market's dynamics and the specific needs of its clients, design low-cost or well-defined products for that market. Those two markets would be the rail and wind bearing market.

Once you have decided that a Focus strategy will be your primary approach, it is still vital to make a decision on whether or not you will seek Cost Leadership or Differentiation. But focus on its own is typically not sufficient to achieve success in the market. However, whether you utilize Cost Focus or Differentiation Focus, the key to making a generic Focus approach successful is to guarantee that you are adding some extra service or extra to your product, additionally. Just serving the niche market is typically not enough. For example this “something extra” can help to reduce costs or increase differentiation through additional service, like onsite technical service etc.

It is highly recommended that NKE follows a focus strategy and focuses on the two niche markets: railway and wind. Primarily a cost focus strategy is important to enter the market. Once the brand NKE is well established in those two segments, it is key to apply a kind of different ion focus strategy. In order to differentiate from the available competitors NKE needs to focus on innovative services, processes or products.

4.6 Organization and Structure

During the interview it has been specifically asked how the current organization and organizational culture supports innovation. Further it has been asked if there are any barriers for innovation. The main problem identified is that there are no dedicated innovation related resources. Almost all internal experts complain that there is no time to work on innovations, as resources are spent mainly for day-to-day business, such as customer projects. An innovation-friendly environment requires the establishment of a nearly stress-free and creative atmosphere devoid of strict deadline constraints. All people interviewed are of the opinion that innovation project should be leaded by an engineering related area, but at the same time it is important that the project team itself is very cross functional. In order to dedicate more time and more importance to innovation, it is highly recommended to implement two project platforms.

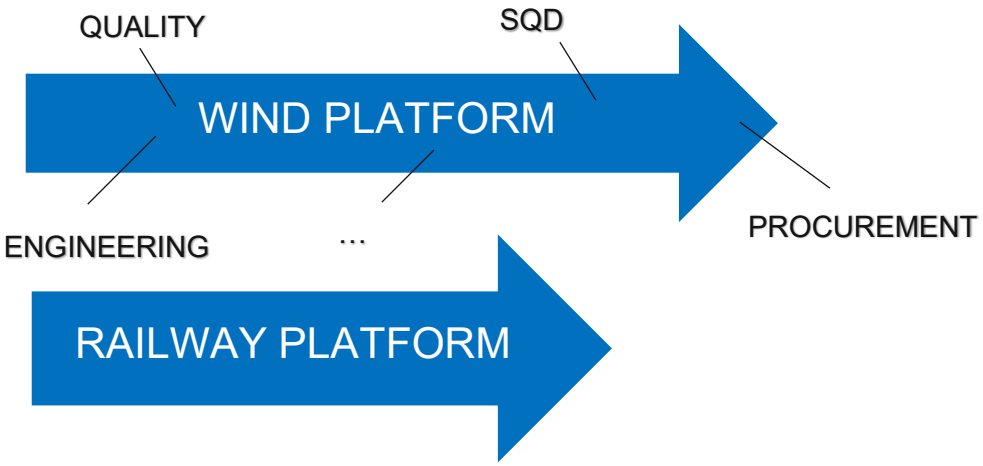


Figure 20: NKE Railway and Wind Platform (own

The idea of the two project platform is that the individual status of the ongoing projects and future projects will be shared. Two project teams (Railway, Wind) are defined to work on the projects cross-functional. Also two war rooms for those two strategic platforms should be implemented in order to underpin the importance of this new structure and create a space for creativity and innovation. A war room should support the idea generation and is a place to brainstorm new ideas. However, it is important to have a full global structure for the NKE Railway and Wind Segment. The following illustration has been created by the author to propose a potential working structure:

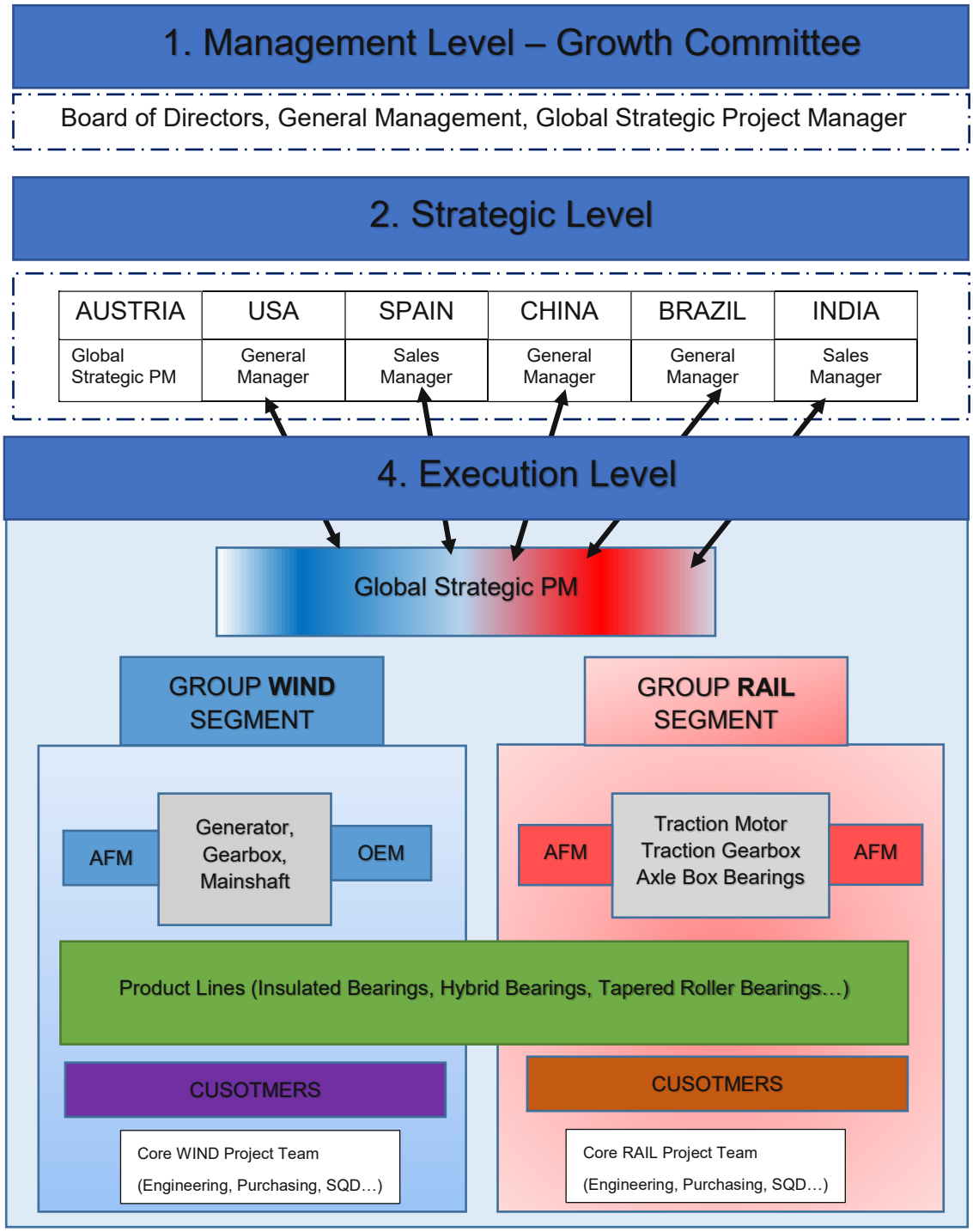


Figure 21: NKE Focus Projects Wind and Railway (own illustration)

The two project platforms at the execution level have to be supported by a strong engineering department. At the time being the Engineering Department consists of a Design and Application Engineering Team. However, an Advanced Engineering Department should be implemented, which should be the leader of innovative solutions throughout the overall organization.

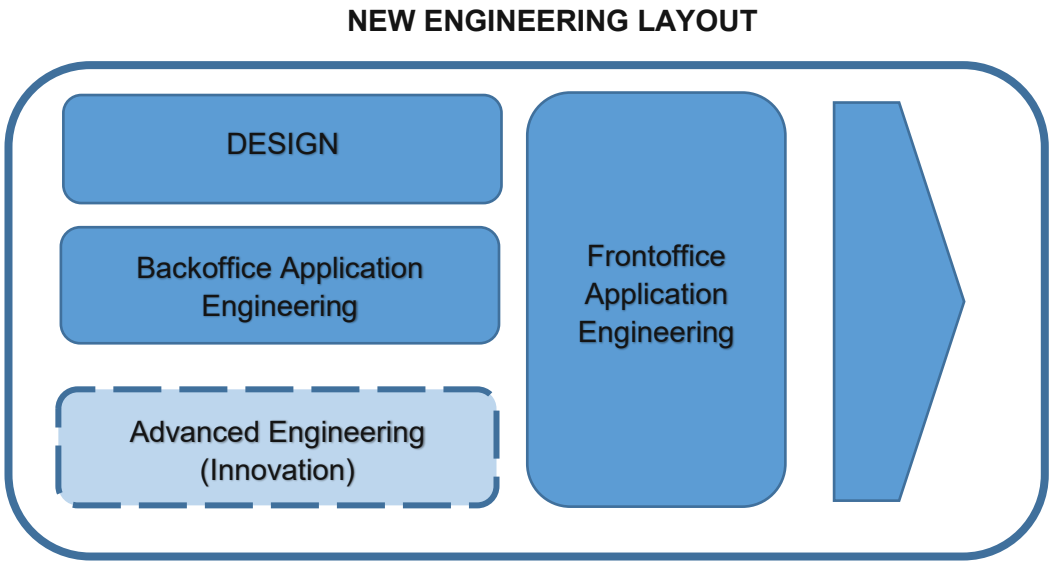


Figure 22: NKE Engineering Layout (own illustration)

The Advanced Engineering department should be mainly released from the day-to-day business. In any case the advance engineering department should not carrying out basic research. The research have to be practical oriented with a strong focus to solve customer's problems.

However, still resources within NKE are limited and especially radical innovations and its innovation disciplines may require capabilities which are beyond the internal capabilities of the FERSA Group. Consequently, it is also important to build up in parallel an innovative ecosystem of industrial partners, universities and research institutes. Those partners have to match with the requirements and disciplines of NKE's innovative project areas and the R&D roadmap. A proposal for an innovative ecosystem is given in the following chapter 3.8.

4.7 Generic Innovation Funnel at NKE

Any innovation must evolve through a number of steps before it is economically viable. This is true, irrespective of the sort of innovation—whether it is a new product or a new service.

This chapter is about the implementation of the so called “Innovation Funnel” at NKE. It is a technique used by organizations to systematically process the feasibility of creative ideas. Thanks to this process it is easier to separate winning concepts from hose that are not worth to follow. It combines lean thinking and the stage gate model approach, which are described in the theoretical framework of this thesis.

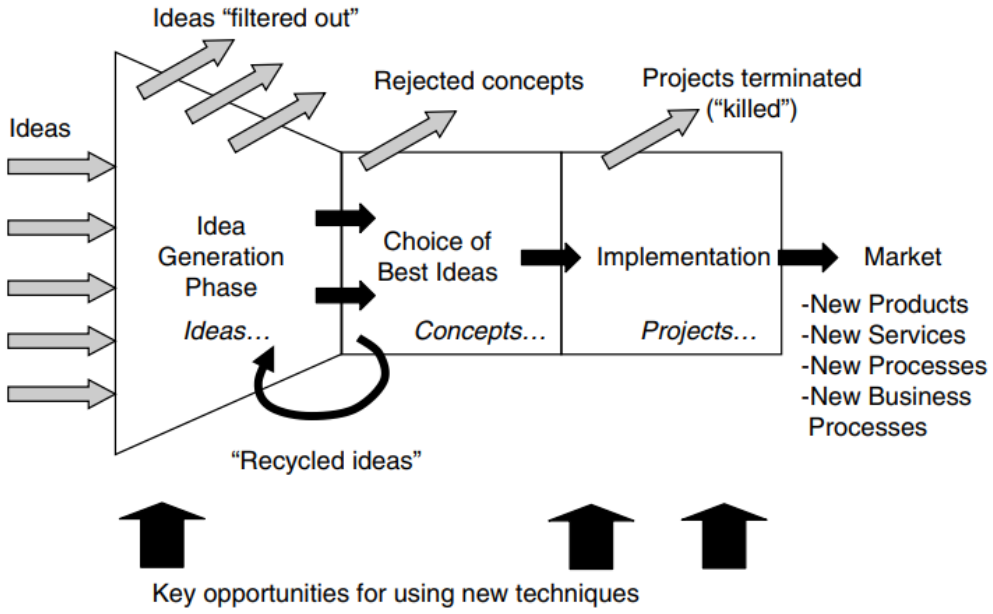


Figure 23: Innovation Funnel Concept (Keith, 2010)

The innovation funnel to be implemented at NKE has four phases:

(1) Analysis: In order to create concrete goals and analyse actual opportunities, customer needs are examined, market trends are examined, and in-depth competition benchmarking is performed.

(2) Idea Generation

(3) Screening: Choice of best ideas

(4) Conceptual elaboration

(5) NPD – New Product Development Process NKE

(6) Launch of the project

4.7.1 Idea Generation Phase

All innovations begin with the generation idea generation. There are numerous idea generation techniques that can be used to generate new ideas. For example: Brainstorming, Creative Thinking and Design Thinking. The generation process itself is backed by input from the customer point of view, market insights as well as the input of all employees.

The qualitative research has pointed out that employees at NKE request to have a common way to submit unconventionally potential new ideas. To support this innovation at NKE a creative idea platform is recommended. These kind of platforms can be realized very easily via the existing ERP System and provide a common place to submit ideas every time. Furthermore the submitted ideas can be monitored and specific KPIs (Key Performance Indicators) can be derived. i.e. Ideas submitted, Ideas implemented.

Moreover, it is highly recommended that innovation workshops are organized, in which specific questions and ideas can be raised and discussed. The participant should be from different departments and knowledge areas.

4.7.2 Screening and conceptional elaboration

Next the ideas have to be screened, which is the process of evaluating ideas. There is no clear process recommend to implement, but the following criteria should be evaluated carefully:

- Relevance: Does the idea meet your objectives? Does the idea match your strategy?
- Assumptions: Is the idea based on reasonable assumptions?
- Constraints: Is the proposal consistent with your restrictions such as Budget, resources, Dates?
- Valuable/Risk: How valuable is the idea? What are the main risks?

In order to answer the above questions, it is mandatory to build already a rough concept of the idea.

The screening of ideas is often done by only qualitative methods. However a quantitative approach can help to gain an objective overview of your ideas. In order to quantify the quality of ideas at NKE, the following matrix has been created.

RATING				
Rate	1	3	6	9
Risk Level Assessment	High Risk	Moderate risk	Low risk	No risk
Innovation strategy fit	Minimal fit	Modest fit	Good fit	Strong fit
Impact if killed	…	….	…	…
Project Complexity, Feasiblity	Difficult to define, many unknown factors	Can be defined but many hurdles	A challenge but achievable	Complexity low
Planned Investments	500 kEUR	250 kEUR	100k EUR	20k EUR
Planned Resource in h	1000	750	500	250

Figure 24: Idea screening evaluation matrix (own illustration)

By means of this matrix the potential ideas are rated in terms of economic aspects, risks and the strategic match. In total six aspects are rated.

Furthermore it is highly recommended to apply portfolio analysis to visualize the screening process. The below diagram represents a bubble diagram of NPD projects. The size of each bubble indicates the annual resources spent on each company division and the shading is the product line.

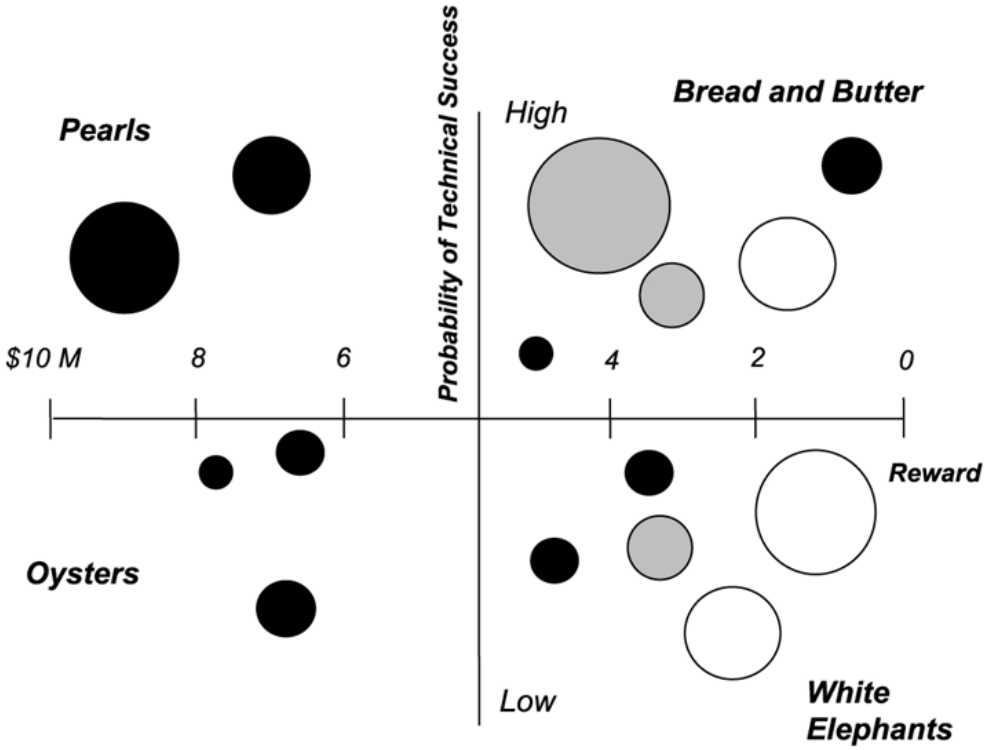


Figure 25: Bubble diagram of a portfolio of new product projects (Cooper E. K., 2012)

But the screening of ideas can be very different and individual. In the chapter 4 a qualitative screening combined with a strategic market analysis by means of the Boston Consultant Group Matrix (BCG) has been applied.

4.8 New Product Development Process at NKE

The new product development process at NKE should be based on a stage gate process model. The below presented flowchart represents a stage gate process, which is tailored to the needs of NKE and is proposed by the author.

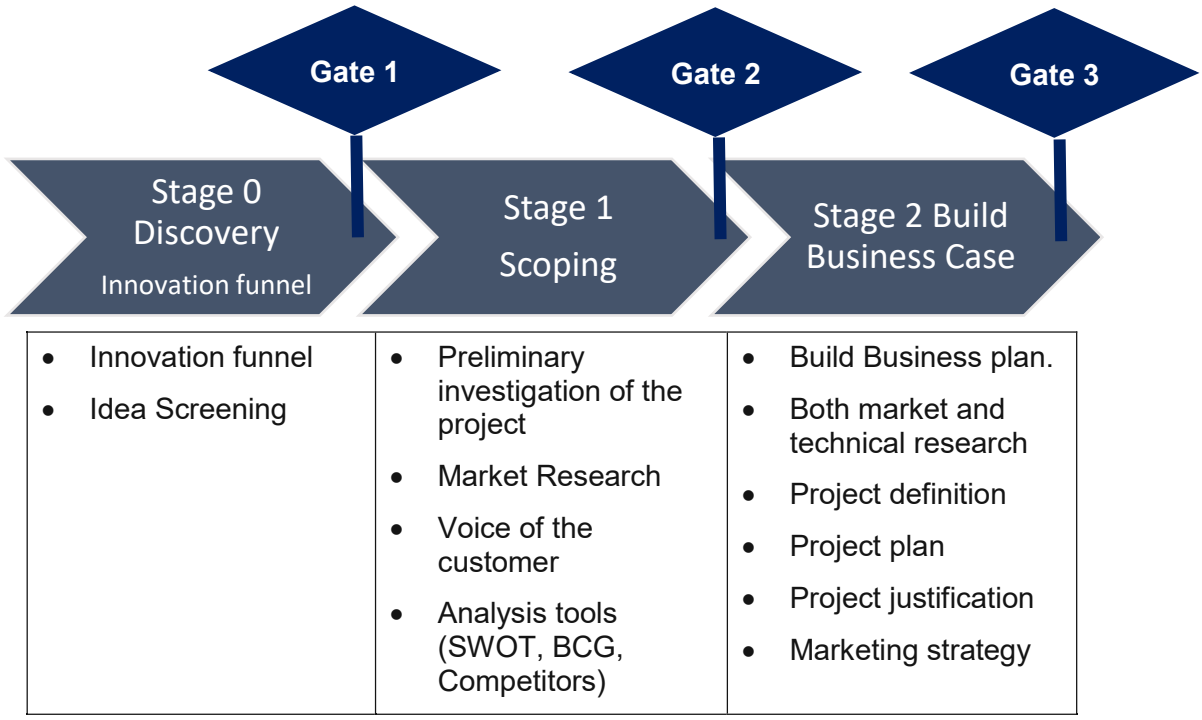


Figure 26: NPD Process at NKE (own illustration)

The new product development is divided into several phases. The important milestones are represented by gates. At those gates, gatekeepers which are defined for each project individually conduct a gate review. The gatekeeper can 1.) Approve a project to proceed into the next phase –"Go", 2) kill the project, 3) hold the project, 4.) Recycle the project or 5) conditionally proceed a project (conditional go).

The discovery phase is already represented by the Innovation funnel, which involves idea screening in the previous chapter. The most promising ideas enter the stage gate process.

Next the dedicated project team scope the potential project and define the product definition. A preliminary investigation of the overall project, market researches, analysis of the customer's needs and tools like SWOT are carried out, in order to remove risk from the project and to get an overall overview.

After defining the project's scope, the team develops a comprehensive business case. Typically, this involves a comprehensive product description, a market strategy, a project plan, and a technical feasibility evaluation, with deliverables connected with each of these activities. This is a project planning and definition exercise.

The stage 3 represents the core engineering phase of the overall stage gate process. The overall detailed design specification is defined, the design is reviewed by a DFMEA and the quality requirements are defined. Further the manufacturing process is build and reviewed by a PFMEA. Finally a prototype is manufactured.

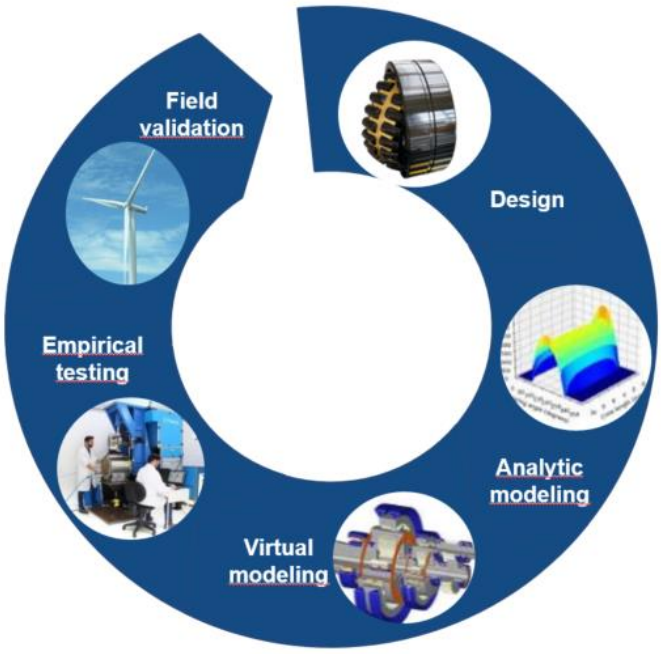


Figure 27: Complete Engineering Loop (own illustration)

One of the key phases before launching a product at the market is testing and validation. Usually the testing is done in-house, at external testing centres or together with the customer in the field. Often times testing is also a part of the homologation process at the customer. Moreover, benchmarks to competitor products or the existing product portfolio are carried out. Testing removes the remaining risk from the project significantly.

Finally, in the subsequent phase, the project will enter the launch phase. This phase may include a marketing and sales strategy, distribution strategies, manufacturing

plans, quality control plans, and other business activities designed to assure a successful launch.

It is very important that gate reviews are conducted based on objective criteria and metrics. A stage date process is evidence based. Furthermore, it is important that a cross functional project team is involved. It is important to define clear roles and responsibilities, to make sure that everybody know who is doing what at each phase.

Of course, there will be many sub-processes involved, but the here presented NPD process is the main one to follow. Moreover, it is important that the NPD can be considered as first guideline. For sure a more detailed process description, including input, output definition of processes.

4.9 R&D Disciplines, partner innovation ecosystem

In general, NKE's innovative development project should be triggered either by the customer's demand as he is facing a pain point or either focusing on one of the global megatrends. It is especially important to know how megatrends drive innovation. The following figure represent some of the most important global megatrends. The red-marked ones may influence the bearing industry more than the others.

Figure 28: Megatrends (Androsh & Redl, 2019)

During a workshop with the Engineering department at NKE Austria, engineering areas, disciplines and activities have been defined which are of high interest for NKE and future innovative projects. Also the customer's requirements have been taken into account. This is also the baseline for the engineering roadmaps and the innovation ecosystem.

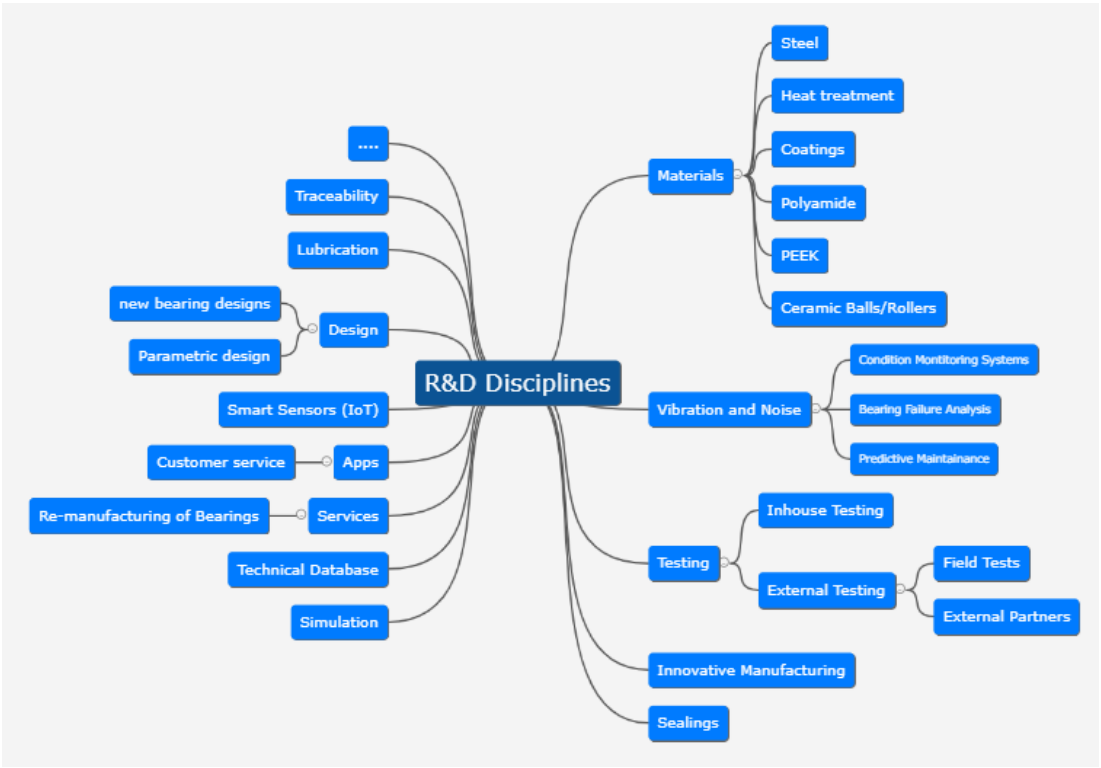


Figure 29: R&D Disciplines Overview (own illustration)

Based on the above defined focus disciplines, a proposal for a suitable innovation ecosystem have been established. In general, the proposed innovation partners can be categorized in:

- Colleges, Universities, Schools
- Research Centres
- Industry
- Network Associations
- Customers
- Government
- Consultants

Due to confidential reasons and know-how protection, not all the important innovation network partners can be shared. However, among others a cooperation with the University Leoben[28], the University RWTH Aachen[29] and the Technical Research Center LCM – Linz Center of Mechatronics[30] has been established.

[28] www.unileoben.ac.at
[29] www.rwth-aachen.de
[30] www.lcm.at

5 The development of a Traction Motor Hybrid Bearings

This chapter describes the most relevant issues of the new product development process of NKE Traction Motor Cylindrical Roller Hybrid Bearings. Due to confidential reasons only a rough overview is presented.

5.1 Traction Motor Bearing Solutions, Stage 0

This paragraph of the paper is dedicated to the analysis of NKE Austria's product portfolio in the railway segment. More precisely the focus is on traction motor bearing solutions. At the time being NKE mainly manufactures common standard Bearing types and insulated bearing types for the Railway traction motor bearing market. Recently, NKE developed large sized Hybrid Bearings, which are equipped with ceramic rolling elements, for Wind turbine Generators. So far only deep groove ball Hybrid bearings, with ceramic balls, are available. In the wind market there is no need to develop cylindrical roller hybrid bearings, as the generators are usually featured with two equivalent bearing positions on the rotor shaft. In wind generators mid to large sized bearings are used: inner diameter Ø150 mm – Ø175 mm.

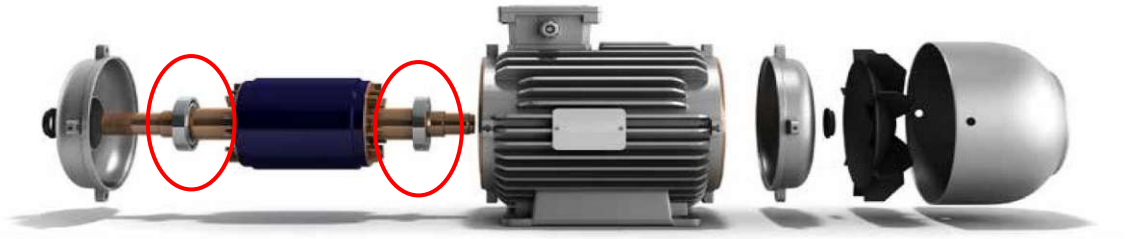


Figure 30: Exploded view of a common electric motor (NKE Austria, 2023)

In contrast, in railway traction motors usually one deep groove ball bearing and one cylindrical roller bearing is used. Also the bearings are significantly smaller (inner diameter: Ø35 mm – Ø100 mm.

<table>
<tr><th colspan="2">Hybrid Bearing (HYB)</th><th colspan="2">Insulated Bearing (SQ77)</th></tr>
<tr><td colspan="2"> 
</td><td colspan="2">  </td></tr>
<tr><td>Deep Groove Ball B.</td><td>Cylindrical Roller B.</td><td>Deep Groove Ball B.</td><td>Cylindrical Roller B.</td></tr>
<tr><td>Wind (ID: Ø150 – Ø175 mm)</td><td>Wind: N/A</td><td colspan="2">Wind (ID: Ø150 – Ø175 mm)</td></tr>
<tr><td colspan="2">Railway (ID: Ø35 – 100 mm)</td><td colspan="2">Railway (ID: Ø35 – 100 mm)</td></tr>
</table>

Figure 31: NKE Hybrid Bearings and Insulated Bearings (own illustration)

The deep groove ball bearing serves as locating bearing position. Such bearings are generally axially preloaded by a spring in order to achieve a very good low running noise characteristics. The cylindrical roller bearing as non-locating bearing.

On the one hand, conventional standard bearings are frequently sufficient to assure the appropriate operation of an electrical machine. But on the other hand, standard bearings are often also pushed to their limits. For example, standard bearings most likely face severe issues if the operation speed is very high or electric current passes through the bearing itself. Furthermore, challenging environmental conditions such as poor lubrication are very challenging for a standard steel bearing. Hybrid Bearings addresses all those challenges and offers a variety of advantages for different industries. Based on a competitor analysis, on customer's feedback and NKE's experience with Hybrid Bearings in the Wind industry the following key advantages in the different applications can be derived.

The following matrix matches those advantages with the respective industry applications.

	Electrical insulation	High speed suitability	Extended service life	High wear resistance	Low running noise behaviour	Insensitive to false brinelling	Low friction	High rigidity
Electrical Drives  - Electric motors - Generators	x	x	x	x	x	x	x	
Wind  - Wind Generators	x	x	x	x	x	x	x	
Mechanical Drives  - Gearboxes			x	x		x	x	x
Railway  - Traction Motors	x	x	x	x	x			
Pumps & Compressors		x	x			x	x	

Figure 32: Hybrid Bearings Advantages / Applications matrix (own illustration)

Even though Traction Motor Cylindrical Hybrid Bearings are already offered by some competitors, it has to be pointed out that for NKE it can be classified as incremental innovation project, as using ceramic rollers instead of rollers made out of bearing steel, is a fundamental different approach. This requires changes and implementation in the overall organization, such as technical specification, new supply chain and quality controls. It would also be foolish to say that experiences which have been gathered by the development of large sized Deep Groove Ball Hybrid bearings can be transferred instantly to Cylindrical Roller Bearings. To sum up, Cylindrical Roller Hybrid Bearings can be considered as new product type. This development project has entered the innovation funnel and is considered in the next different stages.

5.2 Scoping: A customer driven development project, Stage I

The overall goal of this section of the paper is to understand why Hybrid Bearings gain more and more importance within the Railway market and get familiar with the individual customer's needs. For this purpose two different customers of the railway market have been interviewed. The following paragraphs show the questions which have been asked during this qualitative research method. Due to conventional reasons answers are not represented in this paper. The questions can be classified in four different groups: (A) Current situation, (B) Motivators for Hybrids, (C) Homologation Process) and (D) Outlook: mid-term and future.

(A) Current Situation:

- Do you feature your drivetrain applications with Hybrid Bearings?
- Which kind of Hybrid Bearings do you use nowadays? (Bearing type, Clearance…) Which are the most common part numbers?
- Do you have already long-term experience? Are you using Hybrid Bearings in Prototypes or already in the serial production?
- Do you have any design preferences? i.e. cage material, heat treatment of rings etc.

(B) Motivators for Hybrid Bearings:

- Do you foster to use Hybrid Bearings in new drivetrain applications?
- Why do you Hybrid Bearings? Where do you see the big advantages?
- What are your major achievements with Hybrid Bearings?

(C) Homologation Process of Hybrid Bearings:

- Are there any additional tests or quality controls required from your end?
- Which kind of quality documentation must be delivered with the final product?
- Who are involved in the decision making process?

(D) Outlook: mid-term and future:

- Do you expect that Hybrid Bearing will replace the common insulated (SQ77) Bearing portfolio?
- Do you consider Hybrid Bearings always for new developments?
- Is there any potential retrofit for existing applications planned?
- Do you expect any fast mover hybrid bearing?

Generally speaking, the customer interview results show that Deep Groove Ball Hybrid Bearings are already well established within the railway-segment, while Cylindrical Roller Bearings are often too expensive. However, the overall expectations are to move to a complete Hybrid Bearing arrangement on one single shaft. At the time being, design setups are often contradictionary, as often on one side a Hybrid Bearing is mounted and on the other side a conventional insulated bearing due to cost saving measurements.

All in all, it can be summarized that spending resources in the development of Hybrid Bearing Cylindrical Roller Bearings can be considered as reasonable based on the customer's feedback. There is definitely a need of those products in the railway segment.

5.3 Scoping: A strategic driven development project, Stage I

In order to evaluate the project from strategic point of view, a SWOT analysis and Boston Consultant Group Matrix analysis is carried out.

The below matrix shows the main results of the SWOT analysis for the project at hand.

INTERNAL	**STRENGTHS**	**WEAKNESSES**
	• Strong Hybrid Deep Groove Ball Bearing product family • Strong application understanding, close to the customer. • Business cases are given by the customers.	• Ceramic roller suppliers are rare. • No in-house ceramic material production • Limited experience with ceramic material and the related areas, such as quality inspection.
EXTERNAL	**OPPORTUNITES**	**THREATS**
	• Market competition mainly only by two other bearing manufacturers – "Pioneer" • Grow market share significantly. • Extend Railway Product Portfolio	• Competitors are able to provide Hybrid Bearings at very competitive prices • In-house manufacturing of ceramic rolling elements by competitors.

Figure 33: SWOT Analysis Hybrid Cylindrical Roller Bearings (own illustration)

The Boston Consulting Group's product portfolio matrix (BCG matrix), also known as the "Growth/Share" Matrix, is specifically designed to support long-term strategic planning by analysing a business by reviewing the respective product portfolio, deciding where to invest resources and money, and discontinuing or developing new products. As a result, conducting a BCG analysis is highly recommended, particularly before commencing to produce new goods. Because it must be evaluated whether it is

reasonable to spend considerable resources to further development of a new product in the early stages of development.

The analysis is based on reasonable assumptions and actual sales data of NKE. As one can see the Hybrid bearings market growth rate is considered as high.

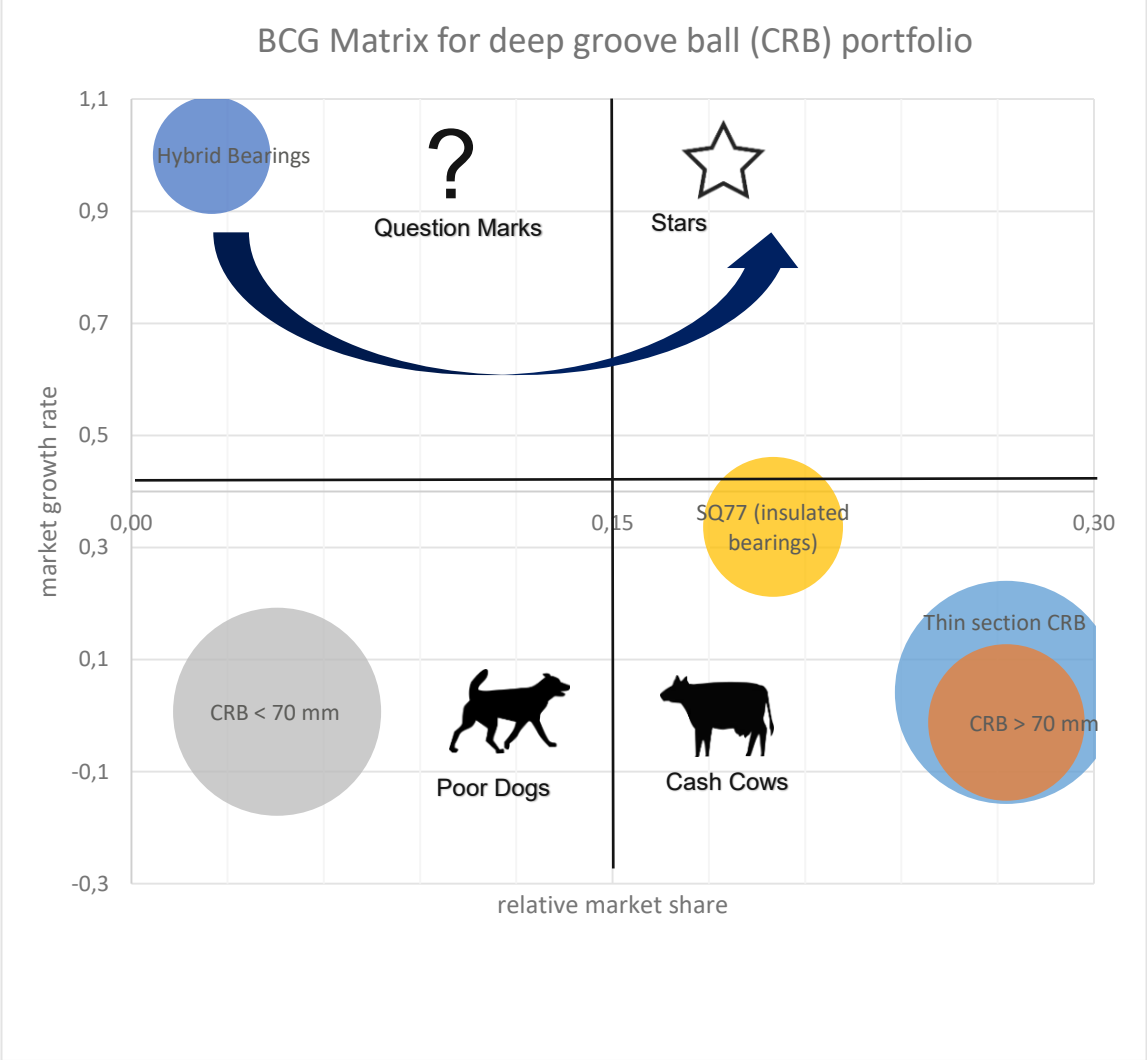


Figure 34: BCG Matrix Cylindrical Roller Bearings (own illustration)

By means of the BCG matrix it can be concluded that additional investments in the development of hybrid bearing cylindrical roller bearings are highly recommended. Investing in the development of this new product ensures that NKE remain competitive and capture a significant share of the overall market. Overall, because the outlook for this type of bearing is very promising, it can be expected that the hybrid bearing will move to a star product in the nearer future.

5.4 Build Business Plan, Stage II

The business plan for the project at hand is confidential. However, the business plan is structured as follows:

- Executive Summary
- Market Analysis
- General company description, mission and vision.
- Description of new product (NKE Cylindrical Roller Hybrid Bearing)
- Additional Services
- Pricing
- Marketing and Sales Plan
- Operational Plan
- Project Management Team Organization Chart
- Project Plan (GANNT Chart)
- Financials
- Appendix

5.5 Development of Cylindrical Roller Hybrid Bearings, Stage III

This chapter describes some of the most important insights of the development phase of cylindrical roller hybrid bearings. The overall engineering development of the cylindrical roller hybrid bearings can be considered as complex, as a complete new redesign of all components is necessary. This is because of the material combination of ceramic and steel. A steel to steel contact pattern is different than a steel to ceramic material. Further it has to take into account that the overall physical material characteristics, such as thermal expansion, weight, elastic modulus and hardness of steel and ceramic is different.

NKE already gained some knowhow in ceramic materials with the development of NKE Hybrid Bearings for the Wind Industry. Nevertheless, the overall design can be considered as completely different. For example cylindrical-shaped rolling elements require a certain profile on the roller in order to reduce edge-stresses within operation, while ceramic balls require a spherical shape. Even though NKE does not manufacture the rolling elements in-house it is important to point out that the manufacturing process of ceramic rollers and balls is significantly different. This means that the current supply chain for ceramic rolling elements have to be analysed as well. In general, the ceramic roller of a bearing can be considered as the cost driver of the product. Consequently, it is important to develop a reliable competitive supplier, who is able to meet NKE's technical specification.

Moreover, special quality control plans have to be implemented, in order to ensure highest quality for the end product. One have to distinguish between internal quality controls and quality controls at the supplier.

5.5.1 Bearing Design

As already before mentioned, it is crucial that the inner design of the current steel rolling element bearings is adapted as the ceramic material has different characteristics. The ceramic material is stronger and stiffer than steel, resulting in greater stresses on the rings as the contact ellipse is smaller. Consequently, Hybrid Bearings will lead theoretically to a reduction of the dynamic load capacity.

The following two international standards specify the

- *ISO 12297-2, Rolling bearings — Cylindrical rollers — Part 2: Ceramic rollers Boundary dimensions, geometrical product specifications (GPS) and tolerance values*[31]
- *ISO 20056-2:2017(en): Rolling bearings — Load ratings for hybrid bearings with rolling elements made of ceramic — Part 2: Static load ratings*[32]

However the optimal raceway profiles of all individual components, such as rollers, inner ring and outer ring, is specified by NKE Engineering. By means of the calculation software ROMAX an optimal profile specification have been developed, which leads to less contact pressure and highest service lifetime under typical operating conditions in traction motors.

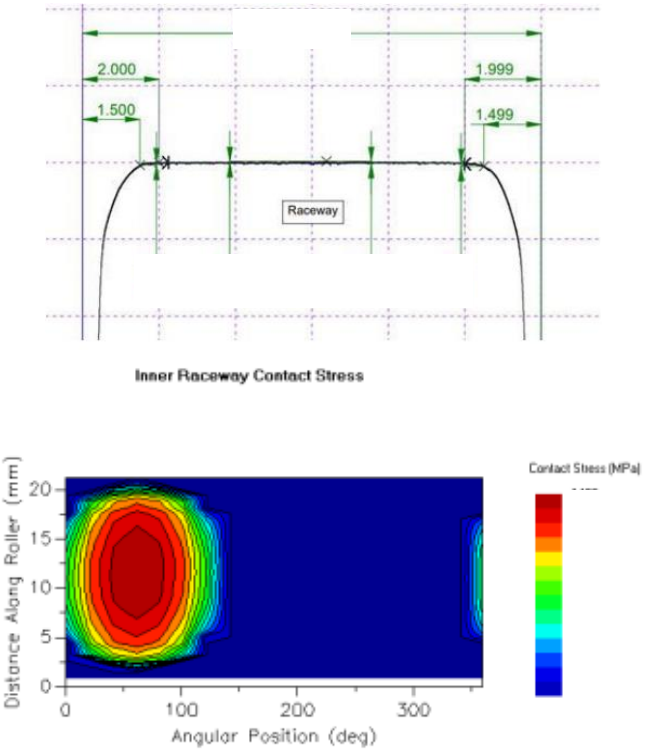


Figure 35: appropriate roller profile (left), inner raceway contact pressure (right), (own illustration)

During this design stage also the geometry of different competitor products are evaluated too. This kind of benchmark data have been also taken into account in the new

[31] *ISO 12297-2, Rolling bearings — Cylindrical rollers — Part 2: Ceramic rollers Boundary dimensions, geometrical product specifications (GPS) and tolerance values*
[32] *ISO 20056-2:2017(en): Rolling bearings — Load ratings for hybrid bearings with rolling elements made of ceramic — Part 2: Static load ratings*

product development. Also customers have shared their knowledge and experience with Hybrid Bearing Cylindrical Roller bearings with NKE. It turned out that one of

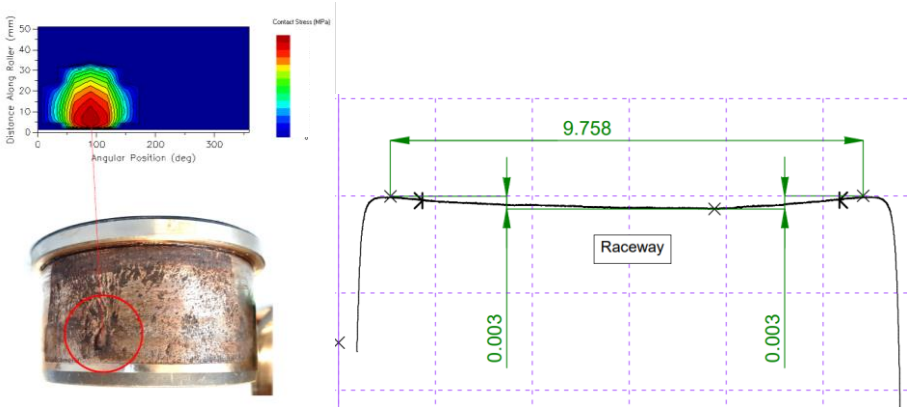


Figure 36: Concave roller profile leads to high edge stresses (own illustration)

NKE's customer had problems with a competitor Hybrid Bearing recently. The bearings have been investigated by NKE and it has been found out that some of the rollers show concave raceway profile, which leads to critical edge-stresses during operation.

In this phase a complete design instruction for the bearing geometry and the calculation of its performance data is carried out.

The design phase of the overall product is supported by a DFMEA.

5.5.2 Ceramic Material requirements

Ceramic material research has been quite popular in the bearing sector during the last decade. Previous research by rival rolling bearing manufacturers, universities, laboratories, and ceramic suppliers has revealed that silicon nitride is the best material for hybrid bearings. The ceramic rolling elements for hybrid bearings shall be produced in suitable quality according to hot isostatic (HIP) manufacturing process.

Furthermore, research has shown that there are two industrial standards, which specify the basic quality, physical/mechanical property requirements of silicon nitride rollers.

- *ISO 26602 Fine ceramics (advanced ceramics, advanced technical ceramics) – Silicon Nitride materials for rolling bearing balls and rollers*[33]
- *F2730/F2730M Silicon Nitride Cylindrical Bearing Rollers*[34]

NKE does not have any preferences for the blank material/powder used for the final product. The supplier must guarantee that the chosen raw-material provides the material characteristics to meet the specs of the required Material Classes and guarantee the homogeneity of the material properties between different batches and samples within the same batch. If requested, the supplier must disclose the information about the used raw-material.

Moreover, a strategic partnership with the University Leoben and the University RWTH Aachen has been established. The input of those cooperation partners were

[33] *ISO 26602 Fine ceramics (advanced ceramics, advanced technical ceramics) – Silicon Nitride materials for rolling bearing balls and rollers*
[34] *F2730/F2730M Silicon Nitride Cylindrical Bearing Rollers*

crucial for the implementation of an internal NKE technical specification for material requirements of ceramic rollers. Of course this standard is continuously reviewed and updated.

More specific requirements are not shared due to confidential reasons.

5.5.3 Quality controls for NKE Hybrid Cylindrical Roller Bearings

The finished Ceramic rolling elements are very sensitive but also the production processes are very demanding. Already small deviations within the overall process can lead to critical deviations, like imperfection of the material surface. During the development phase also several suppliers have been visited in order to gain more insights about the manufacturing process and the subsequent quality controls.

The following industrial standards of quality controls for ceramic rolling elements are applicable and have to be considered at NKE:

- *ISO 14627 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for fracture resistance of silicon nitride materials for rolling bearing balls at room temperature by indentation fracture (IF) method.*[35]
- *ISO 14704 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for flexural strength of monolithic ceramics at room temperature.*[36]
- *ISO 14705 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for hardness of monolithic ceramics at room temperature.*[37]
- *ISO 17561 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for elastic moduli of monolithic ceramics at room temperature by sonic resonance.*[38]
- *ISO 17562 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for linear thermal expansion of monolithic ceramics by push-rod technique.*[39]
- *ISO 18754 Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of density and apparent porosity*[40]
- *ISO 20501 Fine ceramics (advanced ceramics, advanced technical ceramics) — Weibull statistics for strength data.*[41]

[35] *ISO 14627 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for fracture resistance of silicon nitride materials for rolling bearing balls at room temperature by indentation fracture (IF) method*
[36] *ISO 14704 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for flexural strength of monolithic ceramics at room temperature*
[37] *ISO 14705 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for hardness of monolithic ceramics at room temperature.*
[38] *ISO 17561 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for elastic moduli of monolithic ceramics at room temperature by sonic resonance*
[39] *ISO 17562 Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for linear thermal expansion of monolithic ceramics by push-rod technique*
[40] *ISO 18754 Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of density and apparent porosity*
[41] *ISO 20501 Fine ceramics (advanced ceramics, advanced technical ceramics) — Weibull statistics for strength data.*

- *ASTM C 1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature*[42]
- *ASTM C 1198 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance*[43]
- *ASTM C 1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics*[44]
- *ASTM C1421 Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperatures*[45]
- *ASTM E831 Test Method for Linear Thermal Expansion of Solid materials by thermomechanical Analysis.*[46]
- *ASTM E 165 Test Method for Liquid Penetrant Examination*[47]
- *ASTM E 1417 Practice for Liquid Penetrant Examination*[48]

At least the suppliers have to be aware about all those standards and follow them or must explain why they do not follow a specific one. The frequency of the individual controls, sample sizes and additional quality controls, such as 100% FPI (Fluroscentic Penetration Inspection) are defined by NKE.

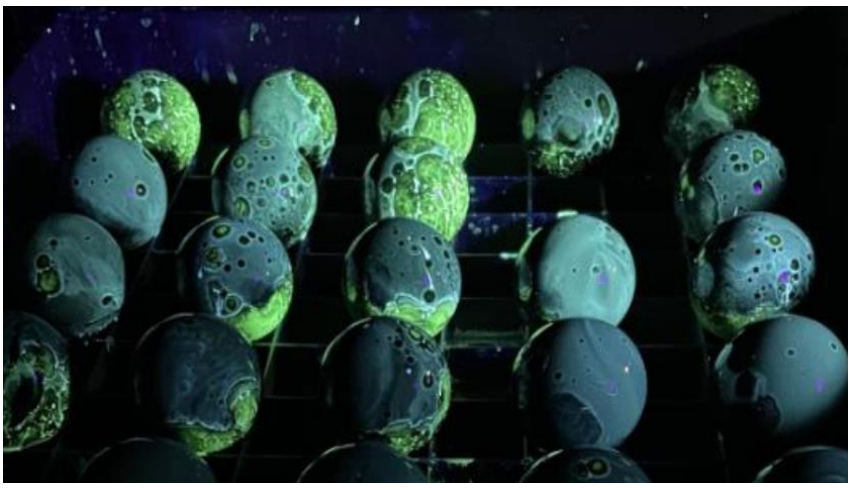


Figure 37: FPI Inspection of balls at NKE (own illustration)

Nowadays, the visual, non-destructive quality control by FPI inspection is the most important control of the finished ceramic rolling elements. FPI is used to detect very small cracks and surface imperfections by applying a. The main limitation of the FPI inspection is the cost efficiency. At the time being conventional FPI inspection is done 100% manually by naked eye inspection. The throughput is very low. However, the industry is already working on camera-based crack detection systems or other

[42] *ASTM C 1161 Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature*
[43] *ASTM C 1198 Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio for Advanced Ceramics by Sonic Resonance*
[44] *ASTM C 1327 Test Method for Vickers Indentation Hardness of Advanced Ceramics*
[45] *ASTM C1421 Test Methods for Determination of Fracture Toughness of Advanced Ceramics at Ambient Temperatures*
[46] *ASTM E831 Test Method for Linear Thermal Expansion of Solid materials by thermomechanical Analysis.*
[47] *ASTM E 165 Test Method for Liquid Penetrant Examination*
[48] *ASTM E 1417 Practice for Liquid Penetrant Examination*

technologies such as, ultrasonic based technologies. In order to minimize production costs those technologies should be carefully analysed.

Together with different suppliers and research institutes the following imperfection categories of ceramic rolling elements have been defined:

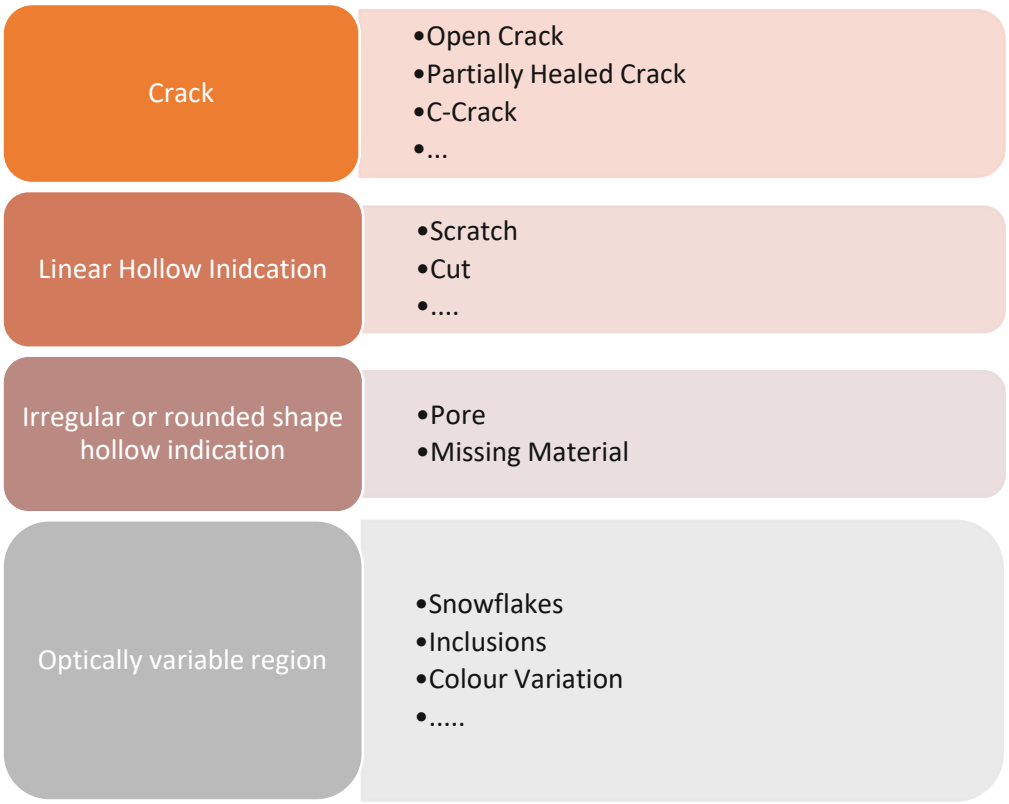


Figure 38: Ceramic rolling element imperfection categorization (own illustration)

NKE Hybrid Bearings are used in very critical and demanding customer applications. Any kind of critical imperfection of the ceramic rolling element represents a risk in the final application. The presence of a surface imperfection might or might not have an impact on the actual function and performance.

It is important to learn about how specific deviations behave during operation. This makes it possible to set certain acceptance limits for deviations. One major problem for manufacturers is still that there are no appropriate models for the damage-tolerance of ceramic bearing. Some surface flaws are so little that they have no effect on the performance or service lifetime of a bearing, but because manufacturers don't know where the permissible limits are, a conservative approach is applied and components are rejected. This means that components are rejected that may have operated flawlessly in service. Step by step NKE is implementing an imperfection catalogue of common deviations with specific limits.

Deviation	Samples pictures	Limits of Max size (µm)
C Cracks		Not Accepted.
….	….	….

Figure 39: Catalogue of common deviation and acceptance limits (own illustration)

Finally NKE defines an overall quality control plan, listing all the inspections which have to be carried out at the sub-supplier(s) and those which have to be carried in-house at NKE. The quality controls are not focusing only on the ceramic rolling elements, even though those are the most critical sub-component. Also the other components and the overall assembled bearing is checked.

5.5.4 Scouting and evaluation of suppliers

The current supply chain for the cage components and the rings remain. But it is very important to find and develop a strong supplier for ceramic rollers. For this purpose competitors supply chain have been analysed. Furthermore, a detailed analysis of potential suppliers on the market has been conducted. However, there are only a few promising suppliers which have to be evaluated by certain criteria. It is a very common problem that manufactures struggle to find suppliers that meet specific criteria. The following evaluation criteria have been defined:

- Reputation: i.e. overall market reputation. Is the supplier already established in the bearing industry? Does the supplier have already references?
- Reliability:
- Costs:
- Technical Service:
- Roller Quality
- Flexibility:
- Readiness for strategic partnership
- Delivery Time:

Despite the fact that all of these characteristics are of relevance, it is crucial to prioritize in order to find the best supplier. A pairwise comparison is used for this. This tool is a basic and easy task for entity resolution and decision making. Pairwise comparison is a good approach when having too many options. This could be overwhelming. Essentially, each accessible single criterion is compared to all of the other criteria. Finally, a list of the most significant to least important criteria is given, which is represented by the ranking in the green column. (see below figure)

Pairwise comparison

Comparison of the criteria	Reputation	Reliability	Costs	Technical service	Ball quality	Flexibility	Attitude	Delivery times	Sum (Weighting)	Ranks
Reputation		0	0	0	0	0	0,5	0,5	1	8
Reliability	1		0,5	0,5	0	0,5	1	0,5	4	4
Costs	1	0,5		0,5	0,5	1	1	1	5,5	2
Technical service	1	0,5	0,5		0,5	1	1	0,5	5	3
Roller Quality	1	1	0,5	0,5		1	1	1	6	1
Flexibility	1	0,5	0	0	0		0,5	0,5	2,5	5
Readiness for strategic partnership	0,5	0	0	0	0	0,5		0,5	1,5	7
Delivery time	0,5	0,5	0	0,5	0	0,5	0,5		2,5	5
1... row more important than column										
0,5... row and column equally important										
0... column more important than row										

Cost utility analysis

Criteria \ Suppliers	Weighting	Nominal weighting	Supplier A	Supplier B	Supplier C	Supplier D
Reputation	1	3,6%	4	2	3	1
Reliability	4	14,3%	3	3	3	4
Costs	5,5	19,6%	1	3	2	4
Technical service	5	17,9%	1	2	3	4
Ball quality	6	21,4%	4	0	1	4
Flexibility	2,5	9,9%	1	2	2	4
Readiness for strategic partnership	1,5	5,4%	1	3	2	4
Delivery time	2,5	8,9%	3	3	2	2
Total value:			221,4	205,4	214,3	371,4
Rank			2	4	3	1

0...requirement not fulfilled
...
4...requirement fulfilled

Figure 40: Pairwise comparison and cost utility analysis – Supplier evaluation (own illustration)

Next a (cost) utility analysis is carried out to find the most suitable supplier of NKE. In total four suppliers, named: Supplier A to Supplier D have been evaluated. The utility analysis is taking into account the criteria and ranking of the previous performed pairwise comparison. Using the prior ranking, each criterion can be assigned an individual weighted in percentage. This individual weighting, paired with a scoring system of 0 to 4, results in an overall ranking for every supplier. The most appropriate supplier is the one with the biggest score, followed by ranks two, three, and four. In the case at hand, the supplier D is nominated as most suitable supplier for the project at hand.

Based on the research and the findings of the cost-utility analysis, it can be concluded that, for the time being, Supplier D is the best supplier for the project, followed by Supplier A, Supplier C and Supplier B.

Nonetheless, because conditions change, it is strongly recommended to perform supplier selection procedure on a regular basis. Furthermore, in order to be more flexible and independent, NKE is still looking for new ceramic rolling element suppliers.

5.6 Testing and Validation, Stage IV

NKE follows a testing strategy with different levels from V to I. In general this process is aligned to the concept described in the industrial standard "*ÖNORM M 8121-1*"[49].

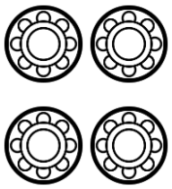
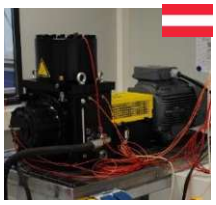
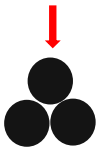
NKE Testing Strategy for Hybrid Bearings Cylindrical Roller Bearings				
Category	**Type of test**	**Illustration**	**Done by**	**Respons.**
Goal: Release an internal technical standard for NKE hybrid bearings				NKE
I	Bearings mounted in application		Customer field	End user/customer
II	Test of test bearings in the field	  4 test samples	Customer testing in field test centre	
III	Rig test with real bearing but simplified arrangement		CRB 	NKE	Bearing manufacturer (NKE)
IV	Rig test with modified test bearing		CRB 	NKE	
V	Simple tests – Material analysis…		Supplier D ….	NKE (can be outsourced) e.g. universities, laboratory	

Figure 41: Testing strategy (own illustration)

First of all, basic tests are carried out focusing on the individual components. A special focus is on the component testing of the ceramic rollers. Those tests are carried out together with different research institutes and also internally. Next prototypes are assembled, which are tested on test rigs.

[49] *ÖNORM M 8121-1:Tribotechnik: tribologische Prüfung; Kategorien*

After a successful test rig test, test samples are provided to the end-customer in order to do internal tests at his facilities. The last stage of the testing strategy is represented by the field test at the customer. Here the bearings are already mounted in the final application.

In order to minimize the overall test time on the internal test rigs, the testing conditions are selected appropriate. Generally speaking, the overall testing conditions can be considered as very challenging compared to the common operating conditions within the final application.

Application operating conditions	Testing conditions
Speed: max. 6000 rpm. Nominal: 4500 rpm	Speed: 9000 rpm
Load: C/P = 20	Load: C/P = 4
Re-greasing: 45.000 hours	Re-greasing: every 300 hours
Service Lifetime: 120.000 hours	Lifetime target: 2000 hours

Figure 42: Application operating conditions vs. testing conditions (own illustration)

A very important aspect of the testing process is also the lubrication. At the case at hand the test is carried out with grease lubrication, as traction motor applications are usually lubricated by grease. However due to the very demanding operating conditions, such as very high speeds and high loads, the grease service lifetime is dramatically shorter in the test than in the final application. In order to ensure that the performance of the bearing is tested and not the performance of the applied grease, it is mandatory to remove old grease and re-lubricate the bearing frequently. A re-greasing interval of about 300 hours = 12,5 days has been defined as appropriate.

The below sketch shows the basic testing setup. One cylindrical roller bearing is mounted as test bearing and loaded by a hydraulic cylinder in radial direction. The two deep groove ball bearings are so called slave bearings, which carry the reaction forces.

The condition of all three bearings is monitored continuously by vibration sensors and temperature sensors. The limited vibration levels are set accordingly.

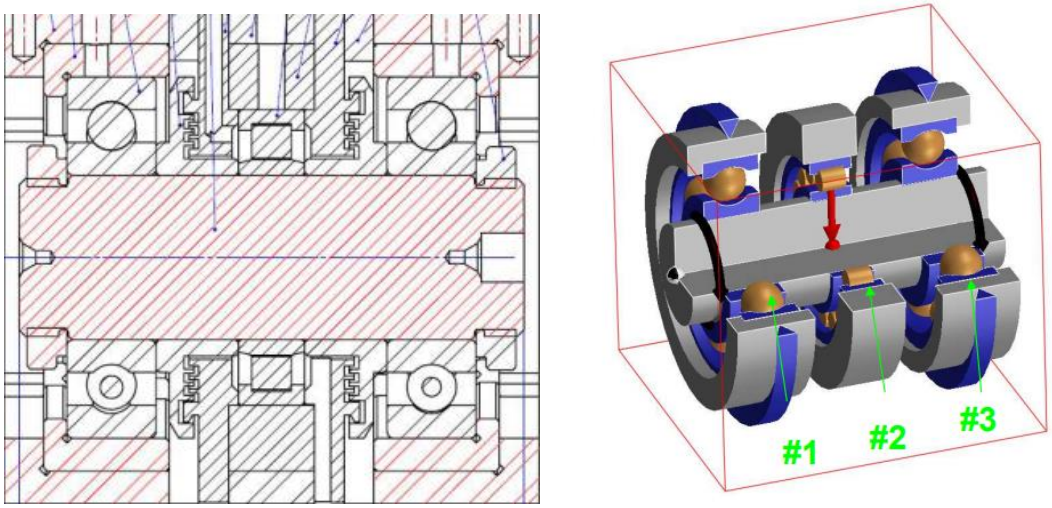


Figure 43: Test setup of Hybrid Cylindrical Roller Bearing (NKE Austria, 2023)

Further, the testing process at NKE is supported by Weibull Distribution methodology. Due to confidential reasons no more insights are given in this thesis. However at the time being about 1200 hours of the test are completed successfully. The lifetime target is 2000 hours. The following pictures have been made during the re-greasing process after 1200 hours. The inner ring raceway track and the rolling elements functional surface are in a mint condition. No significant wear patterns can be noted.

Only some fretting corrosion on the bore diameter is notable. This fretting corrosion can be considered as normal as the bearing is disassembled and assembled multiple times during the re-greasing process.

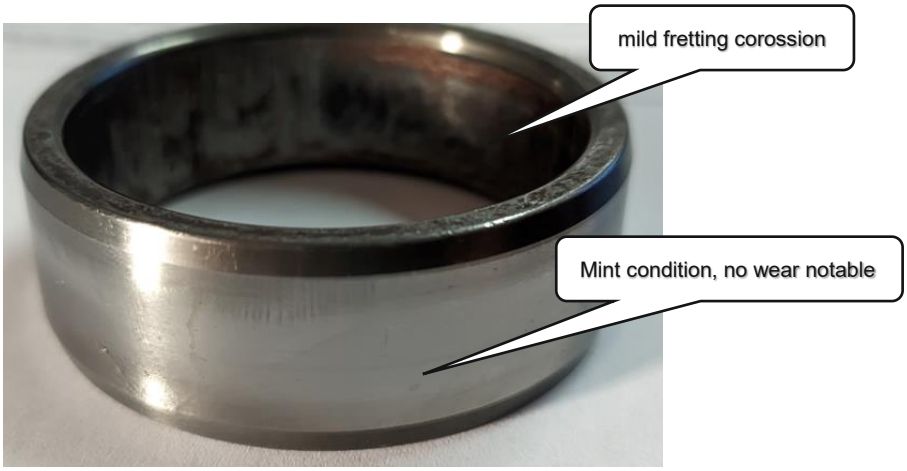


Figure 44: Inner ring of Cylindrical Roller Hybrid Bearing Prototype (NKE Austria, 2023)

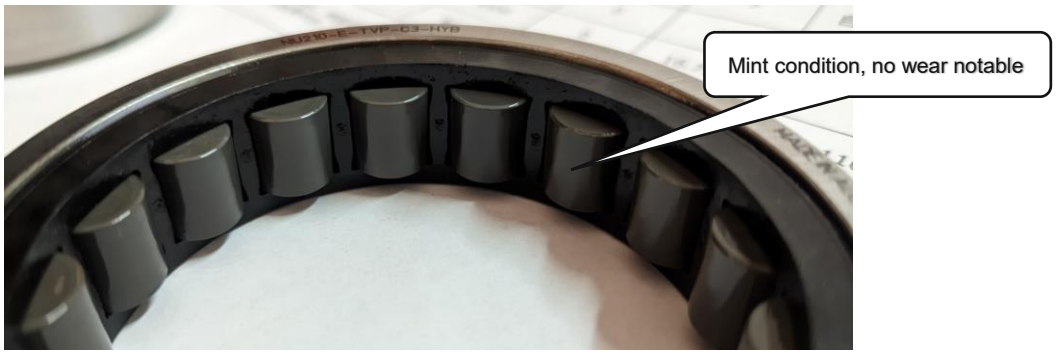


Figure 45: Outer ring with rollers and cage of Hybrid Prototype (NKE Austria, 2023)

The overall test is documented in a Design Validation Plan Report (DVP&R) template. It can be summarized that the intermediate test results are very good.

After this test a controlled test at a railway customer is planned.

5.7 Market Launch, Stage V

As the testing and validation process in not competed yet the last phase, the market launch is still pending. However, the following aspects should be considered when launching the product.

- Marketing Strategy (Exhibition, information material, …)
- Manufacturing Ramp-up plan
- Positioning in the market
- Internal training of the team (mainly sales)

6 Innovative service concepts for Wind Generator Bearings

The following chapter represents some ongoing innovation project in the service area shortly. In this case just a rough explanation about the scope of the individual projects is given and not the overall development is described. NKE focuses on several service innovations to increase customer's satisfaction and create a bond between the customer and the brand NKE. All those projects have been initiated during the development of this master thesis.

6.1 An innovative App for wind bearing installations

At the time being the majority of NKE's customers do not keep track of specific individual bearing data. For instance, customers do not document the individual batch code of the bearing and link it to their internal job i.e. repair job or maintenance job. This means that in the event of any issue i.e. bearing failures which are batch related, it is not possible to make a serious statement which bearings are mounted in which application. It is even more difficult as aftermarket customers often do not apply a First in First out (FIFO) logistics principle. The service technicians often claim that this essential information is still documented handwritten by using too complicated templates.

In order to solve this issue, NKE's idea is to build a simple mobile application for Android and iOS devices that will help its customers and their technicians to collect maintenance details of their windmill bearings and also offer the possibility to identify fake bearings.

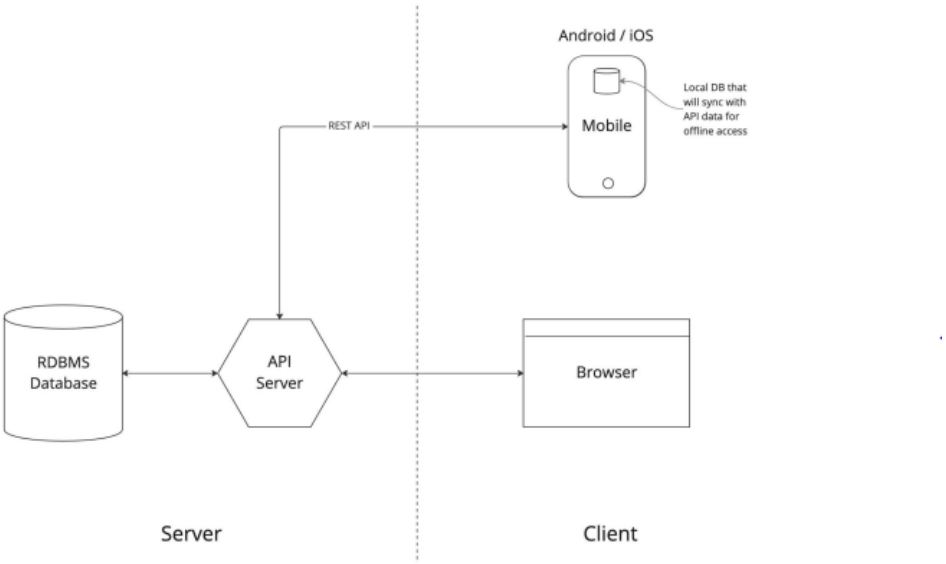


Figure 46: Architecture of App (NKE Austria, 2023)

One of the main idea of this app is to provide to NKE's customers a clear differentiation to the rest of the competitors. Further, the overall maintenance data is key in order to improve the existing products and create new products with new features. The app is also collecting valuable data which can be used to make strategic business decisions. In a later stage the app should be used also as information channel to approach customers with news of NKE.

Currently the app is in the development stage. However, the idea is that a customer has their own common customer account. In addition also the service technicians have their own individual account. The app offers the possibility to save notes and photos of the repair job.

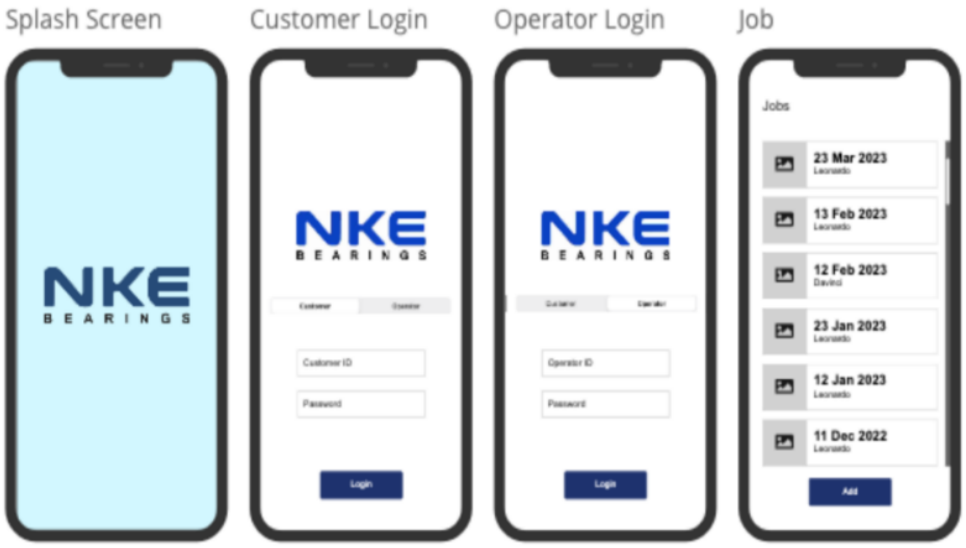


Figure 47: Concept of Wind Generator Bearing App 1/2 (NKE Austria, 2023)

In general, depending on the customer account login, specific customized templates are shown. Those templates are created together with the customer in order to meet his requirements. General information about the repair job, like Wind Park, Wind Turbine Number, Bearing Designation and Batch code have to be filled out. Data like the batch number can be scanned by the smartphones camera. Also the location of the Windturbines is set by the GPS information of the phone.

Figure 48: Concept of Wind Generator Bearing App 2/2 (NKE Austria, 2023)

In order to identify fake products and implement specific bearing data details very easily to the app, from now on every NKE Wind generator bearing is featured with a Data Matrix Code (DMC), which is positioned next to the conventional bearing designation.

Figure 49: Data Matrix Code Traceability (NKE Austria, 2023)

The app is going to be introduced to key customers by the end of May 2023.

6.2 An innovative packaging solution with shock sensors

Large sized Hybrid Bearings are very sensitive and have to be protected well. However, especially oversea transportation is very rough and inventible entail a risk for a potential product damage.

Customers regularly inform NKE that the palette of goods is damaged, but obviously often the individual bearing boxes within the palette are not damaged. However, there is no doubt that an impact load which is absorbed by the palette is also transmitted to a certain extend to the individual boxes. Huge impact loads can lead to a product damage of the bearing. It is very tricky to assess a bearing is in good condition or not, as those small damages, like cracks within rolling elements, are not visible without disassembling the bearing.

Consequently, NKE developed a special, reinforced bearing box which can absorb impact loads to a certain extend. But the heart of the new bearing box is a shock sensor which is applied to every single bearing box and which status is readable through a viewing window on the side of the box.

Figure 50: Innovative Packaging solution with shock sensor (NKE Austria, 2023)

If the sensor turns red the box have been hit by a critical impact load and the bearing have to be shipped back to NKE for inspection purposes.

Furthermore the packaging is adapted to the industry's needs as it fits perfectly in common wind lifting bags, is equipped with handles to provide best handling feeling and even offers the option to grease the bearing within the packaging. During a customer visit it has been noted that the former packaging have been removed already within the facilities and grease was applied to the bearing. The bearing have not been put back into the original packaging box. Instead the greased bearing have been put into a plastic bag, which do not offer any protection at all.

With the new packaging and features NKE meets the customer's requirements, ensure highest quality deliveries and increase customer's satisfaction.

6.3 Augmented reality trainings and remote support via smart glasses

Recently, NKE is also focusing on the development and the application of augmented reality tools in order to support customers and perform technical trainings. The idea is to support also the on-boarding process of new employees at NKE but also at the customer.

The below pictures represents the first prototype augment reality tools, which visualize and explains the induction heating process for NKE Hybrid Bearings step by step.

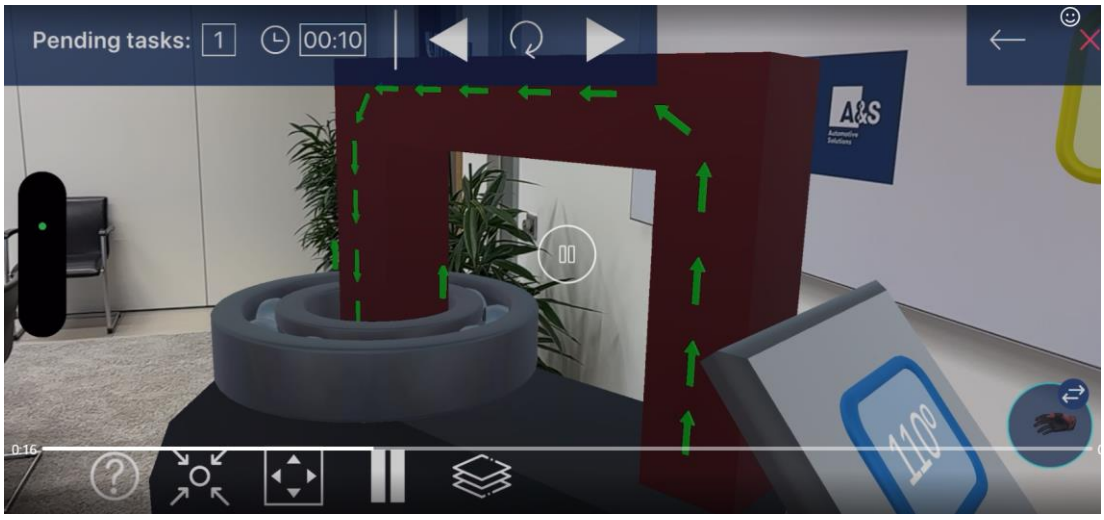


Figure 51: Augmented Reality Bearing installation training concept (NKE Austria, 2023)

Further NKE is working on an innovative remote customer care service, which is assisted by smart glasses. The smart glasses allow NKE to transfer a live video stream from the customer on-site to the back office at NKE.

7 Summary and Outlook

In conclusion the thesis creates a general framework for a medium sized bearing manufacturer company to be able to design and offer new innovative products and services.

The company's overall strategy has been analysed by common tools, such as the five forces model of Porter and a SWOT Analysis. Thereby inputs of different stakeholders have been analysed thoroughly and taken into account. The Porter and SWOT analysis support the strategy to focus on NKE's strengths and develop aggressively the niche markets: railway and wind bearing solutions.

In order to succeed in a very competitive market, it is mandatory to build up and invest also in the necessary organizational structure to support the growth. In order to grow the two niche markets, railway and wind, it is highly recommended to set up two strategic, cross functional project teams. Further, on the engineering level it is mandatory to invest in new resources and focus more on the development of innovative solutions. The proposal has been shared to launch a new department within the Engineering area, which is named "Advanced Engineering". This team will be relieved from the day-to-day business and pushes the development of strategic innovative projects. Moreover, those resources should be responsible for innovation management throughout the entire company. Because innovation is often associated with new product development, but innovation can also occur in services and processes within different areas. As projects may require specific capabilities and resources beyond the possibilities of the FERSA Group, it is important to focus also on the development of an innovation network, including strong industrial partners, renowned research institutes and universities. A proposal of a potential suitable network is given in this thesis.

Moreover, the concept of the innovation funnel is introduced. It is also highly recommended to create an idea generation platform, which allows employees of the entire organization to share ideas in an easy way. In order to select the best ideas of the idea pool a qualitative and quantitative screening is implemented. The innovation funnel is linked to a new innovation process for product developments.

The NPD is based on a stage gate process with 5 phases and 5 stages. The tailored process model is described and common deliverables for each phase are defined. The process is underpinned by a case study.

The individual process steps are discussed based on the development project of Hybrid Cylindrical Roller Bearings for Traction Motors in the railway industry. This product family is of high interest for the customer but also of highest relevance from the company's strategical point of view. A SWOT analysis shows that there is big opportunity for NKE to be one of the key players in this segment, but at the very same time it is a very challenging project as NKE does not have deep knowledge in the processing of ceramic materials, especially ceramic rollers. Further, the input of the customers and also market research confirm that Hybrid Cylindrical roller bearings are expected to have a significant market growth. This is also represented in the performed BCG analysis, in which Hybrid Cylindrical Roller Bearings have been identified as Question mark product and are expected to move to a start product. Also a business plan is briefly outlined but due to confidential reasons not published within this paper. Also some of the most important development actives are described. In particular the technical specification for the overall bearing design, the ceramic rollers and

the related quality controls are highlighted. By means of the tools pairwise comparison and a cost utility analysis the most suitable ceramic supplier has been defined. Next a prototype of Cylindrical Roller Bearing with polyamide cage has been assembled and is currently under validation. The testing conditions and strategy has been defined within the thesis too. Even though the product has not been entered the last phase “Market Launch” yet, some key aspects are already outlined in the thesis. All in all, the development of Cylindrical Roller Hybrid Bearings have been managed properly till the testing and validation phase.

During this Master thesis some more innovation projects have been initiated by the author and his team. Among others an innovative packaging for large sized Hybrid bearings with implemented shock sensors have been developed. Also an app which is supporting the tractability of bearing installations in wind turbines is in the process. Recently, NKE is also focusing on the implementation of augmented reality tools in order to support customers and perform technical trainings.

The output of this master thesis was to create and show a suitable basic framework which supports the development of innovative solutions within NKE. It is expected that this framework supports the overall long term success of the company.

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