Examining the Capability of Lean and Agile Manufacturing Techniques to Address the Needs of Wind Turbine Manufacturers

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Abstract

Over the last few decades the wind power industry has grown very rapidly, and dozens of wind turbine manufacturers now operate all over the globe. Worldwide, installed capacity has increased tenfold in the last ten years, and the average rated power of the wind turbines available on the market has quadrupled in the same period (BWE 2010). However, in recent times wind turbine manufacturers have struggled to achieve profitable value performance, typically including wind turbine engineering, production, project management, logistics, installation, and commissioning (Knight 2012; McKenna 2012; Quilter 2012).

The wind energy industry is customer-driven and regulated by local laws and guidelines. Both have a strong influence on the technology of wind turbines. Wind turbine manufacturers attempt to provide wind turbines that fit the specific requirements of each market or customer exactly. This regularly leads to a high variety of products, which are designed to fit many different market and customer demands. Furthermore, in times of overcapacity, markets demand that product manufacturers are more responsive and provide short and reliable lead times for customer-specific products (Albrecht 1999). The wind turbine market currently faces these challenges (Knight 2012; McKenna 2012; Quilter 2012). In such market environments, an excellent strategy planning with innovative elements, e.g. in product development, manufacturing procedures, the supply chain or the sales channels is inevitably a key factor for companies looking to maintain and/or improve their competitive position and profit outlooks (Albrecht 1999).

The overall goal of this research is to investigate whether lean or agile manufacturing techniques can help manufacturers respond to these challenges. In particular, to evaluate whether lean or agile manufacturing techniques exist that have the capability to improve the value performance of wind turbine manufacturers and simultaneously enable sufficient product variety, as demanded by the different markets.

The evaluation of the identified manufacturing strategies, concepts and methods resulted in Mass Customization being chosen as most suitable for wind turbines, due to its capabilities for managing a large number of product variants and a reduction of inventory. Finally, the manufacturing concept Mass Customization was implemented in a single case study at a wind turbine manufacturer, in order to investigate the physical and organizational impacts caused by the implementation.

The research showed that there are lean and agile manufacturing techniques that address the needs of wind turbine manufacturers. The research further showed that the implementation of Mass Customization had a significant impact on the customer order process of a wind turbine manufacturer. Besides certain product preparations, a timely and comprehensive communication concept was required. The effects of both proper and poor project measures became evident in the case study. In summary, the research proved that Mass Customization has the capability to create corporate-wide and seamless communication on the product and customer order process at a wind turbine manufacturer, which can create the basis for an improved value performance.

Author´s Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those

Date ……………………………….

Acknowledgment

First and foremost, I want to thank my family, as I could not have completed this dissertation without their support and understanding. My wife Magdalena gave me much more than I could have asked of her. Her inner strength and everlasting optimism supported me in good and bad times. I am grateful for her support, understanding and love. I am also grateful for my two wonderful daughters, Madeleine and Lily. Both have given up time with me in order to allow me to complete this research. In the most recent, very demanding months, my five-year-old daughter Lily even prayed to God that Daddy´s dissertation would not be too hard for him. My nine-year-old daughter Madeleine always supported me in an exceptional way with deep belief in me and unfailing loyalty. I am now looking forward to enjoying more time with my family.

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1. Introduction

1.1 Research Background

In this chapter the current status and specific challenges of the studied business environment will be introduced. Firstly, the overall situation in the wind power industry is discussed. In the second part, the specific business situation at the company studied, PowerWind, is explained in more detail.

Over the last decade the wind power industry has grown rapidly and dozens of wind turbine manufacturers are now in existence all over the globe. Worldwide, installed capacity has increased tenfold over the last ten years, and the average rated power of the wind turbines available on the market has quadrupled in the same period (BWE 2010). Annually, wind-produced electricity represents 6.3 % of the EU´s total consumption (Wilkes, Moccia et al. 2012).
However, wind turbine manufacturers struggle to achieve profitable value performance, typically including wind turbine engineering, production, project management, logistics, installation and commissioning (Knight 2012; McKenna 2012; Quilter 2012). Although the expansion of green energy continues globally, many wind turbine manufacturers have difficulties becoming and staying profitable. Siemens Wind Power, for instance, stated that its loss in 2011 was due to higher R&D expenses, costs related to the expansion of the business in a highly competitive environment and increased price pressure (McKenna 2012). In addition, the world´s largest wind turbine manufacturer Vestas has announced to involve its suppliers in larger parts of the supply chain than it was in the past. The intention is to further increase the manufacturing flexibility and to reduce Vastas´capital requirement (Quilter 2012). In the course of the global economic crisis, generally believed to have been initiated by the insolvency of Lehman Brothers in September 2008, the wind power business began its downtrend in 2009 (Weinhold 2012). While the average annual growth of the European wind power market amounted to 13.6 % in the years 2005 to 2009, the market shrank annually by 1.2 % between 2009 and 2011 (Weinhold 2012). According to Weinhold (2012), the impact of the global economic crisis was amplified by overcapacity and declining prices, which are symptoms of an ongoing consolidation and maturation of the wind power industry. This

conclusion was also supported by the findings of the literature review carried out during this research.

In the interviews carried out by Weinhold (2012), most wind turbine manufacturers claimed to have problems in areas such as grid connections and bureaucratic approval for large projects, especially offshore projects, which make future planning difficult and impossible to calculate. The technical requirements for grid connections vary regionally in onshore projects. In the case of offshore projects, the grid operators have difficulties to realise the required offshore grid connections in time. Furthermore, many wind turbine manufacturers are expecting that the policy has to create uniform market conditions. Also, the compensation for electricity is not consistent. In Germany, only 9 cents per kWh is paid for generated onshore wind power. It is the cheapest form of electricity, when the follow-up costs like dismantling, renaturalization and final storage of nuclear waste are considered. However, these costs are not included in the basic cost of energy calculations for nuclear power, and the environmental impacts of coal power generation are not considered in these calculations either. In addition, in Germany there are still no uniform rules for planned offshore installations, and therefore many different bureaucratic obstacles have to be overcome. Other countries have different technical requirements for the connection of wind turbines to the public grid. In the US, for instance, wind turbines are treated like conventional electrical devices and have to be signed with the UL-label (Underwriters Laboratories). However, the independent safety company UL’s existing guidelines are not developed to regulate the technical characteristics of a wind turbine. That causes multiple technical challenges. The literature review of this research additionally indicated the beginning of the maturity phase within the product life-cycle of wind turbines, starting in the original nations using wind power in Europe. According to this, wind turbine manufacturers are currently facing the symptoms of the beginning of the maturity phase, such as steadily falling prices and worldwide overcapacity of wind turbines. Their costs for labour, logistics, energy and administration, as well as shareholders’ profit expectations, are disproportionate to the prices that can currently be achieved in the market (Knight 2012; McKenna 2012; Quilter 2012). In summary, even if the current situation in the wind industry is amplified by some special events, the general trend would be dictated by the industrial maturity phase, and this will require continuously increasing efficiency (BWE 2010). The consequences of this are discussed in more detail in chapters 2.3.1 and 2.3.2.

Sustainable strategy management and systematically planned products, typical for companies acting within the maturity phase of an industry (Dismukes, Miller et al. 2009), are currently seen as the main challenges in the wind power industry (Knight 2012; McKenna 2012; Quilter 2012). However, project opportunities and disturbing influences like local power networks, complex financial structures, and uncertain permitting and payment schedules are in fact the dominant concerns for many companies in the wind industry (Ozkan and Duffey 2011). Ozkan and Duffey (2011) also concluded in their study that the wind power industry is customer-driven and wind turbine technology is strongly influenced by local permitting regulations. This regularly leads to varying hub heights, rated powers, rotor diameters, electrical properties, aviation lights, and climatic adaptions. Wind turbine manufacturers attempt to provide wind turbines that fit the specific requirements of each market or customer exactly. The result is a wide range of products, with multiple technical features, that are designed to fulfil differing market and customer demands. In addition, many key components such as gearboxes, rotor blades and steel towers have a long delivery period, and it is a challenge to forecast how many units of each component type are needed, as this is influenced by the ordered turbine type. Both attributes, variety of products and long delivery periods of key components, can have a negative impact on the cash flow of the wind turbine manufacturer (Klepzig 2010).

However, in market environments with high competition density and low profit margins, superior strategy planning with innovative elements, e.g. in product development, manufacturing procedures, the supply chain or the sales channels is an inevitable goal for companies in order to maintain and/or improve their competitive position and profit outlooks (Albrecht 1999). Additionally, in times of overcapacity, which are currently faced by wind turbine manufacturers, markets demand that product manufacturers be more responsive by providing short and reliable lead times for market-specific products (Albrecht 1999). Wind turbine manufacturers, such as the researched company PowerWind, currently face these challenges. Finally, in the course of the energy transition, which recently started in Germany and will possibly soon follow in other industrial countries, each cost potential needs to be exploited to contribute to a lower energy cost.

Due to the increased expenses of the households related to energy transition, the public and political pressure on the reduction of electrical energy generated by wind power is continuously growing. This pressure is directly passed on to the manufacturers of wind turbines.

In summary, the wind power industry still aims to be profitable and sustainable. For this, the main challenges are

- the continuous need for cost reduction compared to other power generation technologies;
- the beginning of the industrial maturity phase;
- the large product variety, caused in particular by multiple specific market requirements and inconsistent regulations.

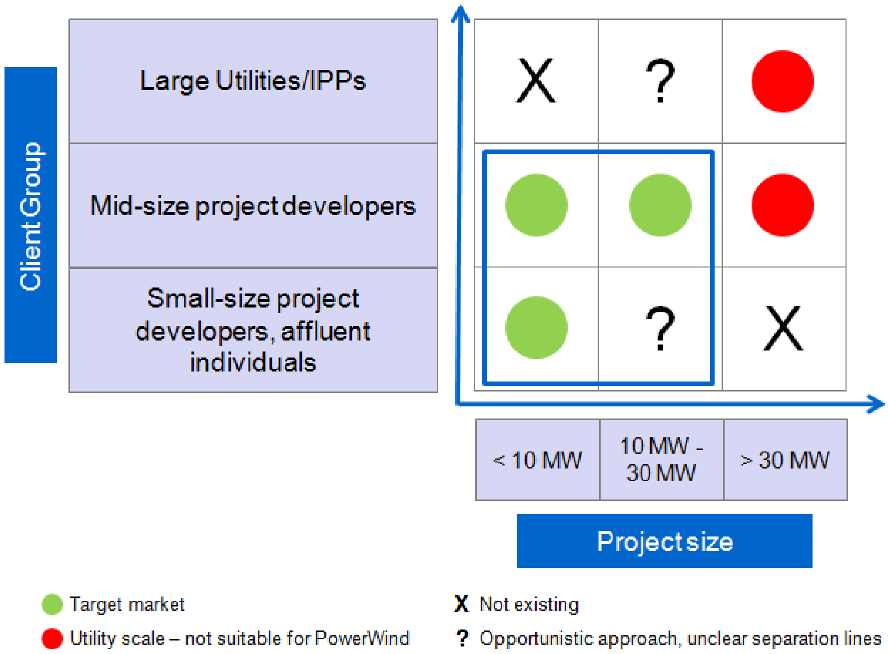
Out of this situation the following research questions arose:

1. Which lean manufacturing techniques are able to address the current needs of the wind power industry?
2. Which organizational impact should be expected following the implementation of an appropriate lean manufacturing technique?

Within the literature review, several manufacturing techniques were identified that could contribute to an improvement in the current value performance challenges faced by wind turbine manufacturers. However, the literature review also identified the need to differentiate between the terms “manufacturing strategy”, “manufacturing concept” and “manufacturing method”, which represent techniques applied at different business levels but are often used in a misleading way in the literature. Additionally, arising out of the literature review, evaluation criteria for analysing the suitability of different existing manufacturing strategies for the wind power industry had to be developed.

The study of the organizational impact caused by the implementation was based on a single case study conducted at the German wind turbine manufacturer PowerWind. In particular, the consequences for the product and the employees involved were studied. PowerWind was founded 2007 as a subsidiary of the renewable energy corporate group Conergy AG. The company was owned by a US finance investor for several years, but is now the property of a strategic investor from India. The research data were collected before the acquisition by the Indian investor. During this time, PowerWind employed around 200 employees covering the whole value chain of a wind turbine manufacturer. Besides general management, the organization consists of the following departments: Sales, Research and Development (R&D), Production, Product Management, Purchasing, Project Management, Service, Finance and Legal. However, a strong focus was laid on wind turbines designed in-house and intellectual property (IP). PowerWind offers two wind turbine platforms: a sub-megawatt platform (500 kW and 900 kW) and a 2.5 MW platform. Furthermore, PowerWind is focusing on providing wind turbines for a niche market, the so-called “community-scale”. PowerWind´s definition of the “community-scale” and “utility-scale” market segments is illustrated in Fig. 1, which summarizes the experience of PowerWind´s Sales employees gained in numerous discussions with customers and interested parties. The green dots within the blue frame illustrate the targeted markets, which are commonly summarized as “community-scale” markets.

Fig. 1: Relation of client groups to project size as defined by PowerWind



In opposition to “utility-scale” market segments, wind projects in the community market are characterized by

- a small number of turbines per wind park (often only single turbine projects),
- small- to medium-sized wind turbine capacities,
- difficult infrastructure,
- and usually customers with less wind power experience.

Such market characteristics regularly lead to individual projects equipped with customized wind turbine technology. The customized technology ranges from special transportation requirements with adjusted turbine designs, to individual electrical equipment, such as fire or ice detection systems, and controller software to meet the site-specific grid requirements or climate conditions. Besides that, smaller and mid-sized projects are more often located in so-called emerging markets, which have low wind energy experience and weaker infrastructure when compared to experienced wind markets like Denmark, Germany or the UK. That results in very specific site requirements and higher risks of miscommunication, due to less wind energy experience on the part of the local stakeholders. In these situations, PowerWind could be described as being an “engineer-to-order” wind turbine supplier, meaning that for each project, it is necessary to make technical adjustments to the wind turbines. As a consequence, the manufacturing of each wind turbine is not standardized. This makes it very difficult to calculate the real project costs and to work out benefits. Compared to wind turbine manufacturers which operate in the “utility-scale” market, with large wind farm projects, wind turbine manufacturers acting in the “community-scale” market should have a greater need for suitable product strategies and manufacturing processes. A “utility-scale” manufacturer only needs to adjust his turbine technology once for each project. That means that typically 10 to 30 identical wind turbines can be produced in series. However, in comparison to the amount of wind turbines produced annually, usually several hundred units, even 10 to 30 identical wind turbines are not much compared to typical manufacturers of serial products. Hence, even large wind turbine manufacturers need to increase their focus on sophisticated business processes and product strategies. This research, therefore, has also relevance for them.

1.2 Research Problem and Justification

Since the establishment of the company PowerWind in 2007, the company has faced difficult and complex operational challenges. A summary of these challenges, experienced between 2007 and 2012 at PowerWind and either reported by employees during the case study or expressed by directors during the weekly directors' meetings, is listed below:

- long-term project development, with variable demands on the wind turbine technology, e.g. different converter controllers due to local grid codes or frequency, varying cooling systems due to hot or cold climate versions, or differing requirements for aviation lights;
- commercial, technical and legal uncertainties over the entire project development process;
- country-specific and short-term product modification requirements from authorities or grid operators;
- many years of multidisciplinary new product development in a dynamic market environment;
- intensive input of R&D human resources in already realized projects, because technical requirements from building permissions, like shut-down behaviour of the wind turbine due to local grid situations were communicated too late;
- low range of vertical manufacture and therefore high supplier dependence through low supplier variety, as nearly all components are produced by suppliers and only assembled in the PowerWind factory;
- low project reliability combined with long component delivery period;
- high financial investment for materials and components;
- high variety of products caused by individual location requirements;
- worldwide market, even for small turbine manufacturers, therefore service and spare part expenses difficult to calculate.

As a result of the above memtioned situation, the General Management demanded the implementation of various measures. These measures included cost-out projects in the Purchase department, early warining indicators for the cash-flow in the Finance department, and a new product and manufacturing technique, which was the initial basis for this research.

Even if the above-listed challenges are very specific to PowerWind, several of them were also reported by other wind turbine manufacturers in the reviewed literature (Knight 2012; McKenna 2012; Quilter 2012; Weinhold 2012).

The nature of the studied business can be described by the manufacturing strategy “Engineer-to-Order” which is an evolution stage of “Craft Production” (Gardner 2009). Under this scenario, there is a high level of enginerering content and effort required for each order configuration. Only in very few cases the customer is willing to compensate this engineering effort. If there are enough manufacturers willing to fulfil all customer wishes at no additional charge just to win the project, a business environment with very low or no margins is created. That is probably one reason for the difficulties of the wind power industry reported in the articles above. A further characteristic of the wind power business is that the product wind turbine is an investment good. That means that the sales strategy follows a Business-to-Business (B2B) approach. The decision-making process for B2B products is usually much longer than for consumer goods, as more people are involved in the decision making process and the definition of technical details (Ulrich 1992). The combination of many technical features and relatively small batch-sizes lead to the fact that wind turbines can be defined as highly customized products.

These multiple challenges cannot be met by smart product development and lean manufacturing techniques alone. However, other industries, for instance automotive, have shown that lean manufacturing measures and the corresponding product modifications can contribute to a considerable level of improvement in business processes and profitability (Pine 1999). The automotive industry, however, is usally characterised by a higher volume of produced product units and therefore not directly compareable to the wind power industry. But during the literature review, only a small amount of research could be found that might help to determine the contribution of a lean manufacturing technique applied to wind turbines. Furthermore, no study could be found which investigated the implementation effort and organizational impact of a lean manufacturing technique on a wind turbine manufacturer. Therefore, the exploration of whether the implementation of an adequate manufacturing technique is reasonable, in terms of the effort caused by the change, was the main driver of this research. It could be anticipated that the implementation of a new manufacturing concept is an organizational change process that would result in a higher workload for and lower productivity of employees during the implementation phase. On the other hand, an improved and more reliable customer order process for the realization of the existing project pipeline could be expected. Such implementation experiences of wind turbine manufacturers were neither shared with the industry, nor have they been the subject of research to date.

1.3 Research Methodology

This research focused on existing lean manufacturing techniques and the required effort of implementing them at a wind turbine manufacturer. Possible tensions for the company departments involved during the implementation of the lean manufacturing technique and potentially decreased productivity and flexibility were considered. Prior to that, it was investigated how a lean manufacturing technique that is appropriate for a wind turbine manufacturer could be identified.

The research was conducted at a wind turbine manufacturer in Germany that has made an explicit commitment to improving its value performance. Beside the initiation of a cost-out project in the Purchase department and the introduction of early warning indicators in the Finance department, the implementation of a new lean manufacturing technique and the corresponding modification of the product architecture were decided by the General Management. The General Management allowed the investigation of the potential barriers and opportunities through the implementation of a new lean manufacturing technique by a research project. The research sought to capture and document the employees' experiences during the implementation of the new manufacturing technique.

As a large part of the research took place in an engineering context, the positivism paradigm, with its focus on objectivity and quantitative approach, was considered appropriate. The collection of quantitative data, and final decisions based on these data, are typical of the technical environment of the research. However, the positivist research paradigm was not adequate within the context of this research, the reason being that the nature of the research was exploratory and therefore not ideally suited to pure quantification (Zikmund 2003). Furthermore, little evidence of a previous research study covering lean manufacturing techniques applied within the wind industry was found. This meant that there was a scarcity of existing theories to be verified or falsified. Hence, the lack of research in this area provided the main motivation for conducting this study. Additionally, the research questions were not posed in terms of verification of a hypothesis, because the research focused on the organizational change of a given business rather than simply proving whether or not a lean manufacturing technique was effective. Finally, this research was not conducted empirically within a controlled environment, which is a key characteristic of studies within the positivist paradigm (Guba and Lincoln 1994).

The achievement of a holistic picture of the business environment affected by the implementation of a new manufacturing technique was a major motivation for this research. The investigated business case had a lot of interfaces, and involved many different departments and employees. Hence, the behaviour and perspectives of the people involved were significant for the investigation of the effort involved in the implementation of a new manufacturing technique. However, the people themselves were not objects to be studied in the style of natural science. Instead, the purpose of this study was to capture their behaviour within a single business system during an organizational change. For this reason, a research approach was designed that allowed the tracing of the flow of behaviour and motivation for employees involved in the implementation project. Such a research approach should provide for repeated data collection at the relevant implementation stages and identify trends across the whole lean manufacturing implementation project. To achieve this, a quantitative methodology alone would have been inappropriate. In order to realize such a fluent investigation, data collection was applied at three stages of the implementation project:

- prior to the beginning of the change project;
- at the beginning of the change project;
- at the end of the change project.

The data collection was designed to be capable of considering the independent actions of employees influenced by the implementation process. It should capture and investigate how a given business situation changed during the implementation project and how this influenced the participants in their day-to-day business environment. That was considered to be important, as the implementation of a new manufacturing technique would naturally generate costs and potentially reduce productivity during the organizational change. In summary, the chosen approach was designed to uncover potential predictors of certain behaviours at each stage, which could aid organizational leaders at each stage of future implementation projects.

1.4 Research Setting and Strategy

The research was carried out in the value chain domain of the wind turbine manufacturer PowerWind. The research project was carried out while the researcher was working as a project manager responsible for the implementation of the new manufacturing technique. As a part-time student working full-time in R&D and Production, the use of a case study as part of the research was an advantageous choice, particularly as the research related so closely to the researcher's daily workload. This predisposition to a particular research strategy, in this research a case study, is not only acceptable but actually quite common, and may be based on the research circumstances as well as the background of the researcher (Yin 2008). Since this was a real time project and because of the company size and available resources, it would not be viable to repeat or enlarge the scope of this research. Therefore, the application of a single case study was most appropriate to add value to the company and the research.

Leading the implementation project offered a great opportunity for awareness of potential adjustments and provided deep insights into the relevant organizational and technical changes. Therefore, a single case study appeared to be the best-suited method for this research. As no experience or guidelines for such a strategy implementation within the wind industry existed, it was expected that the processes of the implementation would have to be regularly adjusted. The interventionist and holistic nature of a single case study allowed both the implementation of the desired improvement approach for the company and additionally provided actionable knowledge in lean manufacturing practice.

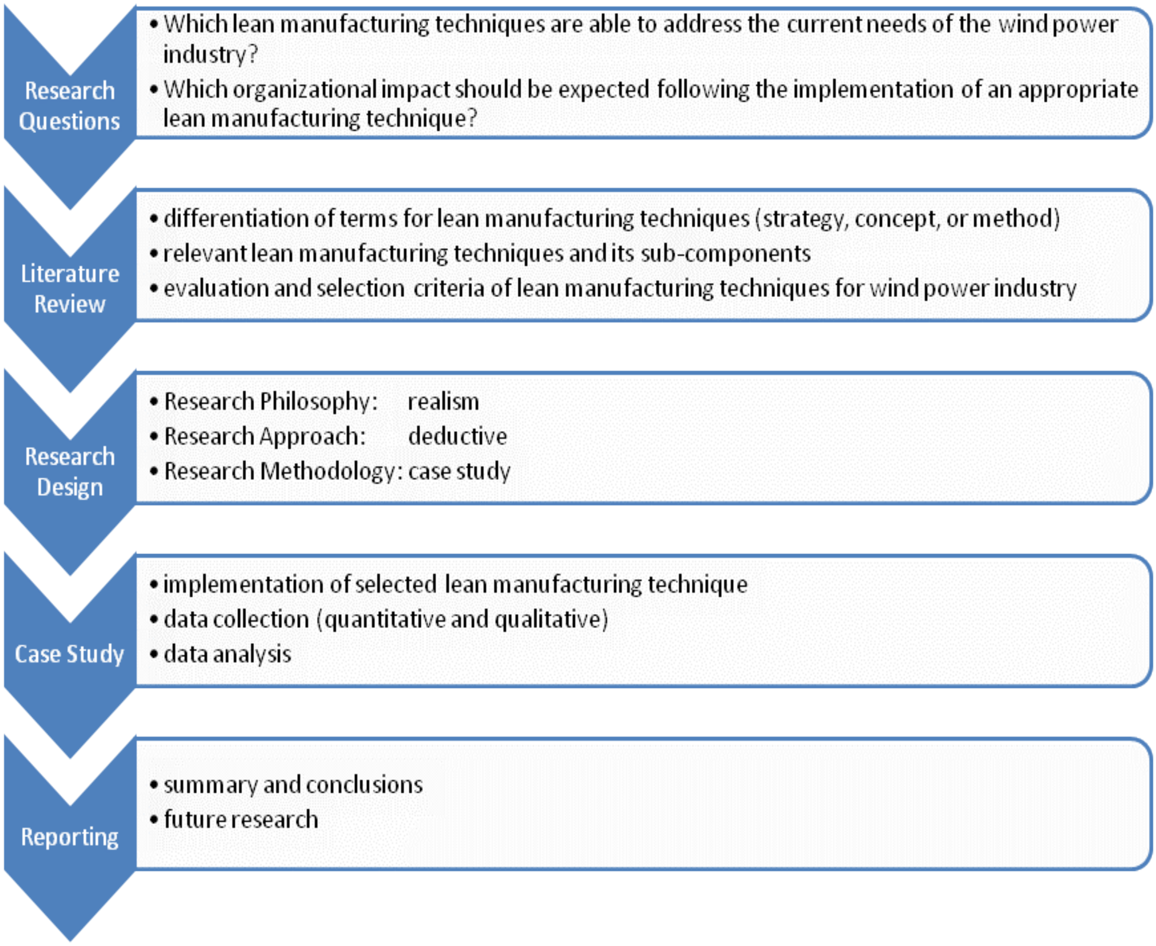
In addition, implementation effort and benefit were observed, based on the real case of the wind industry. In summary, a single case study research was beneficial because of its practical, problem-solving orientation and its ability to expand current scientific knowledge.
Even if the research seemed to be based in a technical context, it also covered commercial departments involved in the value chain and all organizational aspects touched by the implementation project. The research was designed to provide an understanding of the independent actions of all practitioners and departments influenced by the implementation of the new manufacturing technique.

Against this background, the following research steps were followed in the research project at PowerWind:

1. Identification and analysis of existing lean manufacturing techniques.
2. Development of evaluation criteria for the selection of a lean manufacturing technique appropriate for the wind power business.
3. Implementation of the selected lean manufacturing technique within a case study at PowerWind.
4. Investigation of the organizational impact and potential scale of benefits for value performance as a result of the implementation.
5. Evaluation of the implementation capabilities of the selected lean manufacturing technique at a wind turbine manufacturer.

An overview of the research design, developed for this research, is illustrated in Fig. 2.

Fig. 2: Overview research design



In summary, the basis for the research and the chosen research design (Fig. 2) came from the situation in the wind power industry (research background) and the corresponding challenges for wind turbine manufacturers (research problem and justification). The choice of the research methodology was mainly driven by the opportunity for organizational change in the researched wind turbine manufacturer PowerWind. The detailed research approach was influenced by the research questions and the existing research circumstances in the studied company.

2. Systematic Literature Review

2.1 Introduction

The identification of a need for a systematic review was determined by checking whether a similar review had been done previously. This was necessary to avoid duplication of research (Hart 2010).

Firstly, it was necessary to determine whether manufacturing techniques have been investigated in the selected industry (wind power industry). Secondly, the literature that deals with lean manufacturing technique approaches within other industries had to be reviewed. It might be assumed that lean manufacturing techniques used in the machinery or heavy machine industries, which most closely correspond to the wind turbine industry, should have been considered as well. In general, lean manufacturing techniques for products with comparable characteristics, offered as investment goods rather than consumer goods, in markets driven by business customers seemed to be suitable. In addition, the automotive and aviation industries offered a wide range of investigated and proven lean manufacturing techniques, as these industries are typically considered to be up-to-date and process-driven industries.

The identification of previous research involved database searches, selected Internet sites and experts in the field (e.g., librarians, academics, practitioners). In order to determine whether new research should be conducted, searches for journal articles in databases using the search strings: “manufacturing strategy”, “manufacturing technique”, “lean manufacturing/production”, “cost reduction”, “inventory/stock reduction”, “working capital” together with “wind turbine” and “wind power” were carried out. This resulted in eight results, two of which were relevant. However, neither of these two papers provided an overview of appropriate manufacturing techniques for wind turbines. They both focused on a single theory: Engineering Change Management and Supplier Supported Development.

In summary, little evidence of a previous research study on lean manufacturing techinques applied within the wind industry was found.

2.2 Planning the Literature Review

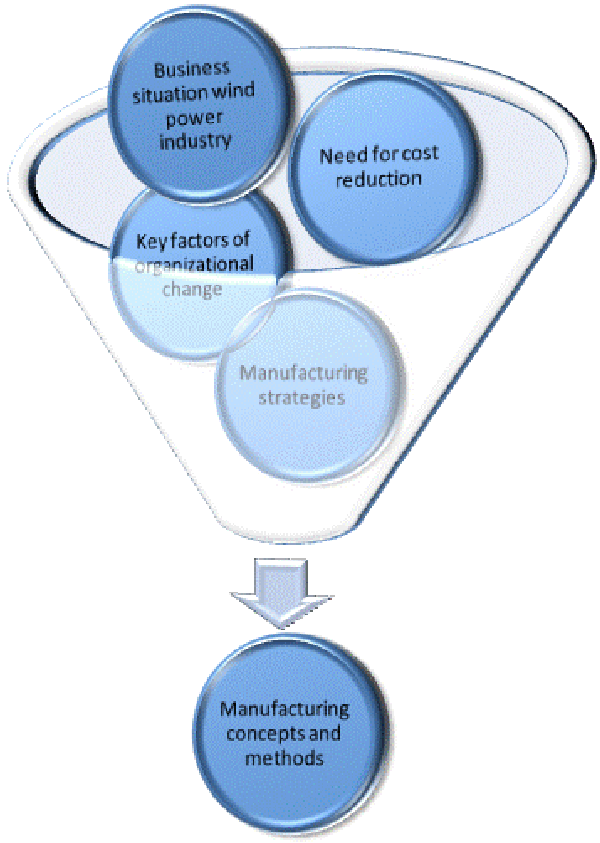
2.2.1 Search Strategy and Research Objectives

Starting with the analysis of the articles on lean manufacturing techniques and lean manufacturing strategies, and the attendant technical and human challenges in organizations, a decision was made to find patterns or models that describe the business situation in which the studied manufacturing strategy is applied. The reason for this was that, besides similarities in product type and market, the current phase of a product life-cycle was also important. Therefore, to reach the right conclusions and adapt correctly from other industries, it was important to understand which life-cycle phase the wind power industry was going through at the time. Research on product life-cycle has shown that different business and product strategies are applied if a product is in its pioneer or growth phase, rather than in its maturity phase. For this reason, a search was made for product life-cycle models that allowed the classification of a product or industry according to whether it was in the pioneer, growth or maturity phase. In addition, the deployment of other energy technologies and their product life-cycle status was compared. Eventually, several definitions and models for product life-cycles were found. Some research also investigates the different effects on the business in each life-cycle phase. For instance, most models state the need for cost reduction within a mature product life-cycle phase. Several studies allocate product manufacturing, especially its processes, with a high potential to contribute to cost reduction (Van der Zwaan, Rivera-Tinoco et al. 2012), e.g. by an improved manufacturing strategy. The term “manufacturing strategy” is widely used to describe business goals at the production level (Wildemann 1997).

However, it is also apparent that other terms are used for the description of manufacturing strategies. The term “strategy” is mostly used in the context of a higher business level, such as describing the overall strategy of an enterprise. Other terms, such as “manufacturing concept” or “manufacturing method” are common. In general, these three terms are not consistently used in the literature. Their usage changes depending on the business level being discussed, which ranges from global enterprise to operational level. Therefore, before the identification of the right manufacturing technique for this research, it was necessary to establish a logical path providing orientation concerning the different factors influencing a business and the corresponding manufacturing techniques. For a reliable comparison of business models and techniques in different industries, it was essential to know how to classify the status of the wind power industry compared to these industries. For instance, the need for cost reduction is a quite general requirement. Therefore, it was necessary to identify the different areas where cost reductions could be achieved and to concentrate on those that could be influenced by this research project. As the core objective of this research was the implementation of a new manufacturing technique and the study of the organizational impact caused by the implementation, a key factor was the consideration of corresponding organizational models and indicators describing employee behaviour. That meant the understanding of all relevant barriers and supportive factors during the implementation of a new lean manufacturing technique.

As a consequence, a thorough assessment of the business situation, the areas for cost reduction and the key factors in organizational change provided a basis for the identification of the appropriate manufacturing technique for the case study. Finally, the terms and content related to manufacturing strategies had to be investigated. As all these areas provided a wide range of literature to be reviewed, a framework for the search strategy seemed to be reasonable. Fig. 3 illustrates the framework for the literature review used in this research.

Fig. 3: Framework for literature review



The definition of a search strategy also helped to narrow the focus of the research. The next step was the definition of the review questions and the establishment of a protocol to answer these questions. Based on the initial business situation of the studied company, the established research design (Fig. 2) and the developed search strategy for the literature review (Fig. 3), the following review questions were defined:

1. Which lean manufacturing techniques are able to address the current needs of the wind power industry?
    1.1 Which manufacturing strategies, concepts and methods are described in the literature?
    1.2 How do they differ and what are their characteristics?
    1.3 Which evaluation criteria allow the selection of an appropriate lean manufacturing technique for the wind power industry?

Finally, based on the literature review framework (Fig. 3) and the review questions, a comprehensive literature review was conducted.

2.2.2 Search Sources

The definition of the search sources created the basis for the literature review. Peer-reviewed journal articles, scholarly publishing, as well as recognized literature and conference proceedings found in academic databases and business practice were chosen. This choice covered academic and public data sources, which increased the amount of potential literature and depth of covered perspectives. The considered data sources and databases are listed in Table 1.

Tab. 1: Data sources

Data Sources	Database Name
Electronic databases	EBSCO, Science Direct, SpringerLink, Internet (e.g. Google Scholar)
Conference proceeding and hand searches	Books, Conference papers, Newspapers, Theses

2.2.3 Inclusion and Exclusion Criteria

Before starting the review, the inclusion and exclusion criteria, determining whether a potential paper should be considered or not, had to be specified. The overview of the inclusion and exclusion criteria for this systematic literature review is shown in Table 2.

Tab. 2: Inclusion and exclusion criteria

Parameter	Inclusion Criteria	Exclusion Criteria
Content	Contributes to topics of conceptual framework (Fig. 3) or research questions	General opinion, poor arguments
Industrial context	Wind Power, Machinery, Automotive, Aviation	Chemical, IT, E-Business, Trading, others
Language	English or German	Other languages

The English and German literature was considered, as the variable use of terms for manufacturing strategies turned out to be complicated. Furthermore, several studies identified a strong focus on manufacturing strategy in English literature, whereas only a small amount of literature in other languages, e.g. German, deals with that topic (Blecker and Kaluza 2003). To keep the focus on the characteristics of the researched area (wind turbine development and manufacturing), literature from industries with significantly different production processes, such as chemicals, IT or E-Business, was excluded. Furthermore, as the field of manufacturing research belongs to a fast changing and dynamic research area (Blecker and Kaluza 2003), only literature from the past 20 years was defined as relevant.

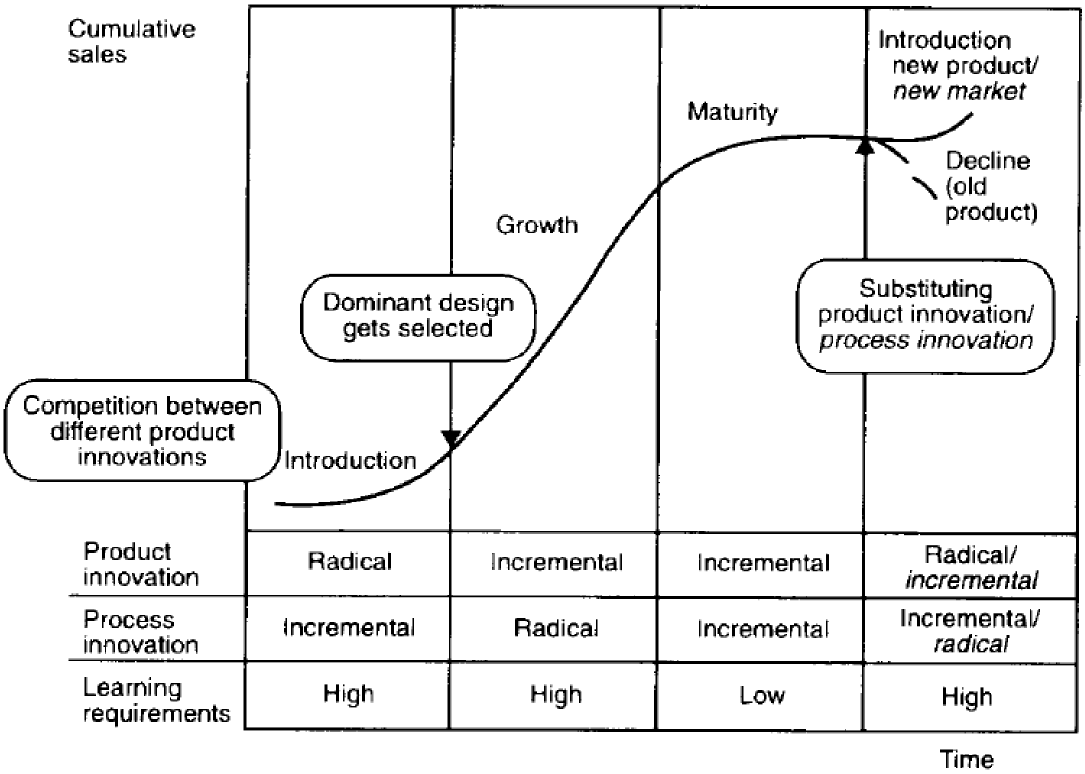
2.3 Conducting the Literature Review

2.3.1 Industrial Evolution of the Wind Power Industry

Within the current technical and organizational literature, several industrial evolution models for the life-cycle of a product are described. The Industry Life-Cycle Theory (ILCT) (Abernathy and Utterback 1978) is still relevant to industry development models. Abernathy and Utterback (1978) divide their industry model into three phases. In the fluid phase, many different product designs arise in small firms with no direct competition. During the transitional phase, the amount of tentative designs starts to decrease and companies start to focus on optimizing their existing products and processes. Finally, in the specific phase, the rate of product and process innovation slowly declines. The whole product life-cycle model is illustrated by an s-curve (*Fig. 4)*.

According to the dominant wind business indicators, the wind power industry is currently completing the growth phase. The process innovations are starting to exceed the product innovations, and the number of competitors is continuously decreasing (Weinhold 2012). However, according to Abernathy and Utterback (1978), the most important indicator for the classification of an industrial evolution stage is the appearance of a dominant design. The dominant wind turbine design had appeared by 1980. The so-called “Danish concept” is a three-bladed horizontal axis turbine on a tubular tower with lightweight composite rotor blades. According to Abernathy and Utterback’s life-cycle model (Fig. 4), the year 1980 marked the beginning of the growth phase of the wind power industry. Over the last 30 years, the establishment and successful expansion of the “Danish concept” has characterized the industry’s growth phase.

Fig. 4: Product life-cycle model acc. to Abernathy and Utterback (1978)

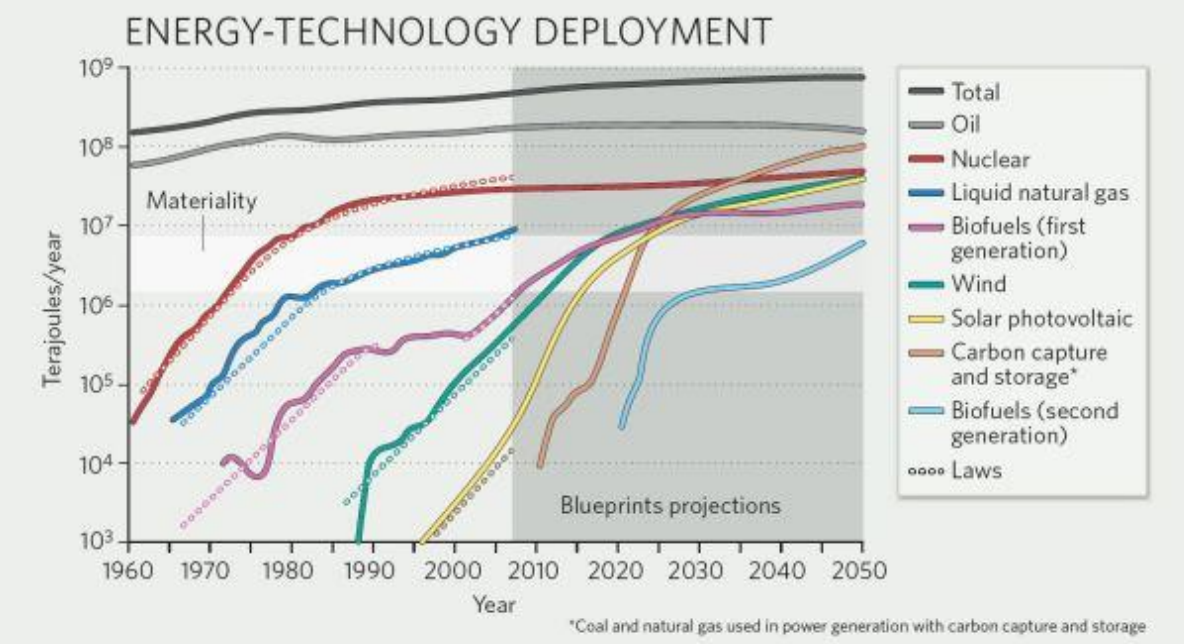


Recently, the Accelerated Rapid Innovation (ARI) model (Bers, Dismukes et al. 2009) was applied to the wind power industry (Dismukes, Miller et al. 2009). According to Dismukes (2009), the wind power industry is currently in the growth phase, but due to the long life-cycle of the wind turbines (20 years) this process could take several years, or even decades. Dismukes (2009) concludes that the maturity phase of the wind power industry will arrive worldwide in 2030, when the global wind industry reaches its maximum development. However, he expects regional differences, as pioneer countries like Denmark, Germany, the Netherlands and the UK will reach the maturity phase several years earlier. Most significant for the beginning of the growth phase, according to Dismukes (2009), is the decreasing number of product innovation launches. That is fully in line with the appearance of the dominant design, and the product life-cycle model according to Abernathy and Utterback (1978). The end of the growth phase, according to Dismukes, Miller et al. (2009), is characterized by a steady increase in process innovations. Products und industries in the advanced growth phase start to focus on cost reduction and process optimization, which are the basis for a successful entry into the maturity phase (Dismukes, Miller et al. 2009). In addition to Dismukes, Miller et al., recent business news (Knight 2012; McKenna 2012; Quilter 2012) also support the thesis that the wind power industry is in the advanced section of the growth phase.

The ARI model (Bers, Dismukes et al. 2009) states that there are three great challenges involved in shifting from the growth to the maturity phase: scientific and technological challenges, business and organizational challenges, and market and social challenges. According to that classification, the wind power industry is going to face these challenges in the foreseeable future.

As well as the ARI model, an s-curve model describing the deployment of new energy technologies was published few years ago (Kramer and Haigh 2009). This model for the deployment of new energy technologies was based on the analysis of past rates of technology deployment. It showed that new energy technologies typically start with a period of exponential growth, increasing by approximately an order of magnitude per decade. When new energy technologies reach around 1 % of world energy supply, their growth becomes more linear (Fig. 5). It takes some decades for energy technologies to build up the scale of industry necessary to provide 1 % of the world´s energy. Then, typically long replacement cycles in the energy sector (between 20 and 40 years) and competition with the incumbent infrastructure limit the rate of further growth (Kramer and Haigh 2009). This study indicates that similar life-cycle rules apply to energy technologies and other products, with the special characteristic that due to the usually long life-cycle of energy technologies the maturity process could take several decades. Based on the experiences of PowerWind and the reported situations of other wind turbine manufacturers (Knight 2012; McKenna 2012; Quilter 2012), there are strong indicators that confirm the validity of the ARI model for the wind energy industry.

Fig. 5: Energy-Technology deployment



All energy technologies conformed well or very well to the s-model. This study also supports the thesis that the wind power industry (Fig. 5, green line) is in the final stage of the growth phase. In 2011, a strategy consulting company conducted an international study on the situation in wind power (Hader and Weber 2011). The very clear result of the study was that the global wind power boom is tailing off. Especially in Europe, the onshore segment is particularly flat because the onshore market is getting saturated. This and the growing competition from Asian players, are forcing wind turbine manufacturers to significantly cut costs. Hader and Weber predict a large wave of consolidation in the wind power industry, which will bring with it a need for cost reductions of 25 - 40 %.

All the observations published in the newspapers, journals and studies (Hader and Weber 2011; Knight 2012; McKenna 2012; Quilter 2012; Van der Zwaan, Rivera-Tinoco et al. 2012) are logical indicators that the current restructuring of the wind power industry is a consequence of the increasing maturity of wind turbine technology. Hence, the wind power industry would be well advised to intensify their process innovations and to start focusing on cost reduction and process optimization, in preparation for a successful entry into the maturity phase.

2.3.2 Need for Cost Reduction

In the recent past, several articles and studies have dealt with the reduction of wind energy costs and cost-of-energy (Fuglsang, Bak et al. 2002; Junginger, Faaij et al. 2004; Ozkan and Duffey 2011; Van der Zwaan, Rivera-Tinoco et al. 2012). The recent increase in papers dealing with topics related to cost reduction, as well as product and process optimization, significantly confirms the industry status of wind energy as described in the models of industrial evolution (chapter 2.3.1).

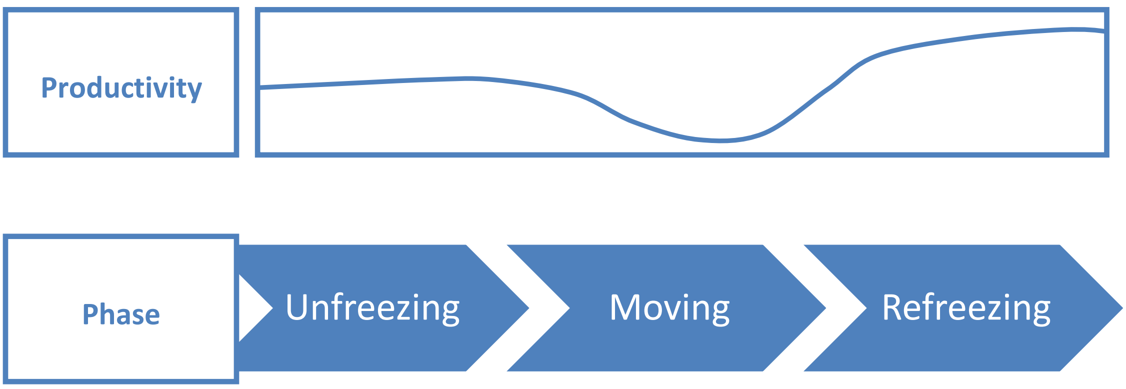
Fuglsang, Bak et al. (2002) highlight the individual site properties and environmental complexity of each wind turbine project as specific challenges. According to them, these are the main drivers for further technical adjustments of wind turbines. In addition, Ozkan & Duffey (2011) describe the financial risks of wind projects resulting from policies, power network regulations, complex financing structures and uncertain permitting and payment schedules. They recommend the deployment of legal regulations to contribute to the reduction of cost-of-energy. Amongst others, Junginger, Faaij et al. (2004) suggest that the standardization of wind turbines and the activation of economies of scale for wind turbine production could be key factors for cost reduction. Van der Zwaan, Rivera-Tinoco et al. (2012) recommend that wind turbine manufacturers return to the laboratory to undertake research and development with a renewed focus on “learning-by-searching”. By this they mean that the wind turbine manufacturers should increase their effort in investigating new materials and innovative components to reduce the wind turbine weight and replace costly materials and components. It is a contribution to an overall cost reduction due to an imptoved product design.

Even if these research findings indicate the potential for cost reduction through improved manufacturing, product design and product strategy, none of them is about a specific concept, method or approach. Furthermore, they do not specify a level of concrete benefits or saved costs. The main reason for this is that they lacked internal information, such as organizational set-ups, business processes, component prices, delivery times, real project pipelines, etc. Usually, wind turbine manufacturers do not share such information. Moreover, no information on the experience and effort involved in the implementation of a new manufacturing technique by a wind turbine manufacturer was found. It could be expected that such organizational change would have a significant impact on the productivity of an organization and its employees. However, it was essential to quantify all the necessary effort and cost involved in such an implementation, in order to identify the real contribution of a lean manufacturing technique to cost reduction. The key factors of organizational change are investigated in the following chapter.

2.3.3 Key Factors in Organizational Change

The first and still widely used model of change process phases was developed by Lewin (1947). He assumes that before each change within an organization, a stable organizational status existed. This stable status would need to be disrupted in order to get a change process started. After completion of the change process, the recreated states and structures should be strengthened and become stable again (Lewin 1947). Therefore, Lewin defines the phases of his model as unfreezing, moving and refreezing. He assumes that changing and stabilizing forces are always active, and the impulse for change is generated if the balance of these forces tips in one direction or the other. Lewin´s model for organizational changes is shown in Fig. 6. His model also states that productivity and employee motivation can decrease during the moving phase.

Fig. 6: Change phases acc. to Lewin (1947)



Several authors have claimed that most modern organizations are continually in flux and that no stable status exists (Schreyögg and Noss 1995).

However, as this research project dealt with change processes within a defined time frame, the definitions unfreezing and moving could be applied because, at the very least, the project had to achieve a new organizational state within a given time period.

A completely different concept of organizational change is described by Greiner (1972). His model of organizational development considers organizations as steadily growing enterprises that pass through predetermined phases. The essential attribute of his model is the interaction between the evolutionary and revolutionary periods of a change process. Evolutionary phases with continuous adjustments lead to crises, which cause revolutionary phases with volatile and discontinuous changes (Greiner 1972).

Lievegoed (1974) also differentiates three phases in his model, in which the impulse for organizational development is again initiated by the appearance of a crisis. During the pioneer phase, the enterprise is led by its founder. The differentiation phase is characterized by standardization and automation, in order that the original processes of an organization should be improved. Finally, in the integration phase, social aspects come to the fore, and an attempt is made to integrate the social into the technical system (Lievegoed 1974). According to Lievegoed, social aspects are strongly influenced by organizational culture. In addition, his model strongly corresponds with the product life-cycle models described in chapter 2.3.1. This made his change model appear favourable for this research project. Therefore, Lewin's and Lievegoed's models were used as a framework for the set-up of the project phases of the studied implementation project, in particular for the moving phase, where the most significant organizational effects were expected (Fig. 6).

The organizational impact caused by the implementation of the new manufacturing concept was measured by the change in employee behaviour. Several studies have shown a strong correlation between readiness for change and supportive behaviour during the change (Kraus 1995; Cooke and Sheeran 2004). There is also a corresponding correlation at the other end of the scale. A resistance to change leads to low supportive behaviour during a change project (Herscovitch and Meyer 2002). Therefore, the development of readiness for change was chosen as a key factor for evaluating the organizational impact in this research. Firstly, the initial readiness for change was captured, prior to the moving phase. Secondly, the development of readiness for change was observed and investigated as fluently as possible during the moving phase.

2.3.4 Manufacturing Strategy

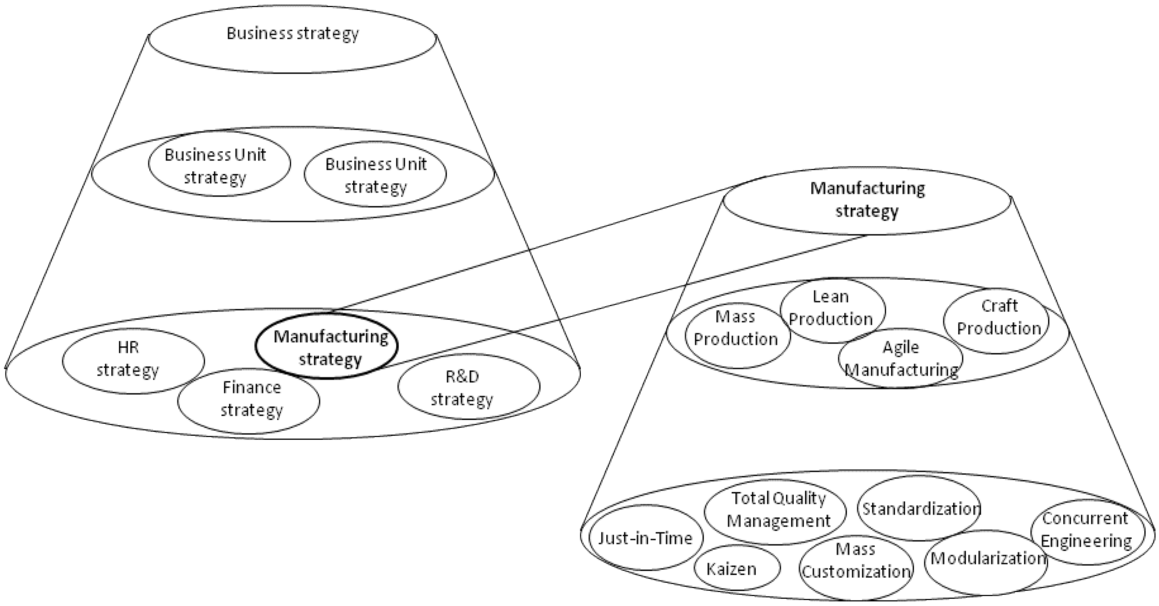
One of the first findings of the literature review on manufacturing strategies was that the term “manufacturing strategy” is used in differing ways within the economic literature. Often the same term was used, even though the studies dealt with different business levels. A clear definition, as well as an explicit differentiation of the term, was often missing, even though that would have allowed better comparability amongst the existing literature (Blecker and Kaluza 2003). In contrast to most other authors in this subject area, Blecker and Kaluza (2003) rank the terms relating to manufacturing strategy in three levels: manufacturing strategy, manufacturing concept, and manufacturing method. This hierarchy also formed the basis for this research, as it simplified the overview and supported later classification and evaluation of the relevant studies. It is of significant importance whether strategy research is conducted on the enterprise level, within production or at the product level in the R&D department (Fig. 7). Within this research, that was taken into account by the use of the following hierarchy-specific terms: manufacturing strategy, manufacturing concept, and manufacturing method. The generic term for all three was: manufacturing technique.

The term “manufacturing strategy” can often be found in the English language literature. Skinner (1984), who is seen as a founder of the research of manufacturing strategies, describes manufacturing strategies as "the competitive leverage required of - and made possible by - the production function […]. And it spells out an internally consistent set of structural decisions designed to forge manufacturing into a strategic weapon" (Skinner 1984). Skinner (1984) highlights the importance of manufacturing strategies for the entire company and ranks them on a high business level. Other researchers approach this differently and discuss manufacturing strategies in the context of supply chain or production management. They partly define the term "manufacturing strategy" (Skinner 1984; Zahn 1988; Wildemann 1997; Zäpfel 2000; Blecker and Kaluza 2003).

Thus, Wildemann (1997) defines a manufacturing strategy as a guideline for the conversion of the enterprise aims into production targets, in order to increase the customer value. According to Zäpfel (2000), a manufacturing strategy fixes the creation and preservation of the capabilities and potentials in the value chain, so that the value chain can contribute to the competitiveness of the overall enterprise. Hayes and Wheelwright (1984) define manufacturing strategy as "a sequence of decisions that, over time, enables a business unit to achieve a desired manufacturing structure, infrastructure, and forms a set of specific capabilities as a basis for a later occurring systematization". All these definitions differ in the kind of systematization or the kind of derivation of the manufacturing strategy. However, the different definitions of manufacturing strategy have one thing in common: decisions on the application of a manufacturing strategy have significant influence on a company´s technology, performance, operational added value and production locations. In contrast, the extent of clear definitions for manufacturing concepts or methods was lower in the relevant literature.

One coherent definition of the relationship between manufacturing strategy, concepts and method was developed by Zahn (1988). He classifies them according to their contribution to business processes. Based on his definition, a hierarchy of manufacturing strategy, concept and method, and their relation to each other, as well as his classification in the overall system of operational strategies, is illustrated in Fig. 7. The illustration, in the form of a strategy cone, offers a good overview of the hierarchical classification of the different manufacturing techniques. According to this strategy cone, a manufacturing strategy is a functional strategy in the overall system of operational strategies. As stated in most of the reviewed literature, discussions about manufacturing strategies take place in the highest business levels of an enterprise. Overall, the strategy cone (Fig. 7) is important to understand the evaluation and choice of the appropriate manufacturing technique for the researched case study.

Fig. 7: Business process hierarchy based on Zahn (1998)



Taking into account the definitions in the reviewed literature, the term "manufacturing strategy" was defined in this research as follows: a manufacturing strategy serves to achieve the overall aims of an enterprise and to maintain or improve its competitiveness. In order to reach these goals, manufacturing concepts and manufacturing methods such as Just-in-Time, Kaizen or Standardization are to be used. Derived from the overall enterprise or business strategy, a manufacturing strategy offers a functional view of long-term business goals. Furthermore, a manufacturing strategy is considered as an area of business which is situated in the very early phase of a product's development and that takes into account other similarly valued business areas such as sales and customer relationships, finance, and human resources. This in turn means that manufacturing concepts and manufacturing methods are sub-components of manufacturing strategy, which itself is a route to achieve the overall goals of an enterprise. A detailed definition of the sub-components manufacturing concept and manufacturing method is given in the following chapter 2.3.5.

As the project took place in the operational domains of a business value chain, the research had to concentrate on manufacturing concepts and methods. The management board had already decided to introduce Lean Production as a manufacturing strategy. In more detail, the choice of Lean Production as a manufacturing strategy was mainly due to the need for cost reduction, considering the amount of wind turbines produced per year, the diverse customer requirements and sufficient project flexibility. The following chapters explain the different manufacturing strategies and their sub-components, manufacturing concepts and methods in more detail.

2.3.4.1 Overview of Manufacturing Strategies

As mentioned previously, few previous systematic reviews or literature dealing with manufacturing strategies in the wind power industry were found. Thus, the search was undertaken in comparable industries. The automobile industry is usually characterized by a high degree of both product and process innovation (Pine 1999). Many existing manufacturing strategies, methods and concepts have their roots in the automobile industry and are applied by different automobile manufacturers (Blecker and Kaluza 2003). The best-known manufacturing strategies are Craft Production, Mass Production and Lean Production (Fig. 7).

Craft Production offers customers individual products with long lead times and a difficulty in obtaining additional units (Gardner 2009). Gardner describes Craft Production as a manufacturing strategy that mainly employs human craft techniques with few, or no, tooling machines, etc. According to him, it is difficult to achieve great efficiency under a Craft Production paradigm. This could be a reason that no relevant studies, in the context of Craft Production and corresponding manufacturing concepts and methods, could be found.

Mass Production was originally designed and industrially introduced by Henry Ford (Gardner 2009). According to Gardner (2009), Mass Production offers great economies of scale but has the issue of not being able to support much in terms of variety. Furthermore, he points out that an increase of product variability in a Mass Production strategy could be likely to lead to greater inefficiency within a manufacturing process and possibly result in increased costs in the whole value chain of an enterprise.

Lean Production respectively Lean Manufacturing also originated in the automobile industry, but significantly later. Lean Production is described as an innovation of Japanese enterprises and is confronted with the investigations of dominating systems of Mass Production as well as Craft Production (Ohno

1988). Within the research programme “International Motor Vehicle Program (IMVP)”, which was coordinated by the Massachusetts institutes of Technology (MIT), the term Lean Production was further developed as a manufacturing strategy (Krafcik 1988). The competitive superiority of Japanese enterprises could be substantially traced back to the introduction of Lean Production (Womack and Jones 1994). However, the authors consider Lean Production as neither specific to Japanese enterprises nor as a manufacturing concept specific to cars. They see its essential principles as universally transferable and Lean Production as a concept generally applicable to all industrial production (Womack and Jones 1994). Lean Production is seen by Womack and Jones as the worldwide standard manufacturing strategy of the twenty-first century and a worthy substitute for Craft Production and Mass Production. That is probably the reason that by far the greatest number of manufacturing studies deal with an environment characterized by Lean Production.

Additionally, in the last decade the term Agile Manufacturing was increasingly used as the next step after Lean Production in the evolution of production methodology (Bala 2012). The most prominent description of the difference between Lean Production and Agile Manufacturing was given by Goldman, Nagel et al. (1995). According to them, the key difference between the two is like between a thin and an athletic person, Agile Manufacturing being the latter. One can be neither, one or both (Goldman, Nagel et al. 1995). With regard to manufacturing strategies, Agile Manufacturing applies in environments where customised, configurable, or specialized orders offer a competitive advantage (Sanchez and Nagi 2001; Bala 2012). According to Bala (2012), Lean Production is a strategy that focuses on the efficient use of resources and continuous elimination of waste. In contrast, Agile Manufacturing is associated to an organization that has created the processes, tools, and training to enable it to respond quickly to customer needs and markt change while still controlling costs and quality (Gunasekaran 2001). A simplified definition is provided by HAQ AND BODDU (2014): Lean Manufacturing is a response to competitive pressures with limited resources. On the other hand, Agile Manufacturing is a response to complexity caused by constant changes in the business (HAQ AND BODDU 2014). SHARIFI and ZHANG (2001) state that the concepts belonging to the Agile Manufacturing strategies at least need to follow two basic objectives: responding to changes in appropriately, and exploiting changes and taking advantages of opportunities. In several studies they observed an enhancemenent of marketing, operational and financial performcane of the firms which have properly implemented an Agile Manufacturing concept (SHARIF AND ZANG 2001). In a further study Dubey and Gunasekara (2015) have developed an Agile Manufacturing framework to check the effects of Agile Manufacturing on technology, empowerment of employees, customer focus, and supplier relationship. They finally conclude that Agile Manufacturing is one of the operational strategies which organizations have to adopt to beat business uncertainties resulting from global economic recession, shortening of product life cycle, supplier contraints, and obsolete technologies (Dubey and Gunasekaran 2015). Wang and Koh (2010) explain the increasing prominence of Agile Manufacturing due to the recent business decentralization and outsourcing. According to them, both decentralization and outsourcing have led to a multi-tier supplier structure with numerous small-to-medium-sized enterprises involved. As a consequence enterprise networks are formed and broken dynamically in order to deal with issues of logistics and supply chain management (Wang and Koh 2010). They consider these consequences as uncertainties for Agile Manufacturing and recommend organizations to invest more effort in the development and application of advanced information technology. Even more than Lean Production techniques, the application of Agile Manufacturing requires a comprehensive and fast exchange of information through the organization (Xiaoli and Hong 2004). Within their study of a company applying Agile Manufacturing, they identified the challenge to exchange and communicate data at different stages of the product development lifecycle. Especially if the departments involved in the different stages of a product development use different software for their purpose. Xiaoli and Hong (2004) developed and implemented a customized communication system and describe this as a major organizational change which significantly influenced the employees and their familiar business setting. Even if the authors report a great effort in integrating the communication system, they saw alternative to achieve the company´s objective to offer products faster and with more unique customer specifications.

Overall, Agile Manufactruing enables organizations to attain a certain level of flexibility that will allow them to appropriately respond to changes in the business environment in order to survive and grow. Many researches describe this as an ongoing organizational change process. Therefore, Agile Manufacturing can also be seen as a new term for organizational change which fits into the Lewin´s second and third step (chapter 2.3.3). However, as Lewin´s change model (1947) was developed in a very different business environment, in particular a relatively more stable and less global environment than toady, the theories of Agile Manufacturing are better suited for the current business environment. Nevertheless, even if the change model of Lewin (1947) appears very simplified against the background of today´s dynamic business environment, his description of the key change stages was never proven wrong. In this research the clear stages of Lewin´s change model are mainly used as a framework for data collection. For this prupose its application appears to be reasonable.

In summary, Lean Manufacturing techniques focus on eliminating of waste and non value-added activities, while Agile Manufacturing techniques enable to detect and respond to uncertain changes of markets and business environments. Additionally, Agile Manufacturing is stronger related to customer satisfaction and rapid adaption or change of products than Lean Manufacturing (Gunasekaran 2001). As this research is about customised and configurable products with the aim to improve the customer order process and become more responsive to quickly changing customer and market needs, Agile Manufacturing is better suited as collective term for the sub-components lean manufacturing concept and lean manufacturing method which are investigated in this research. Furthermore, the topicality of Agile Manufacturing naturely provides a better link to recent information and communication technology which is seen as a key factor for successful implementation and application of Agile Manufacturing (Xiaoli and Hong 2004; Wang and Koh 2010). The need for the development of an appropriate communication concept also played an important role in this case study, which confirms the decision to implement a manufacturing concept from the group of Agile Manufacturing techniques.

Whereas Lean is related to a higher efficiency of production and use of material, Agile enables more flexibility of the production and overall organication.

However, both Agile Manufacturing and Lean Production meet the basic definition of a manufacturing strategy and can make use of the same sub-components: lean manufacturing concepts and methods (Blecker and Kaluza 2003) (HASSAN AND SHARIF (2015). According to Dubey and Gunasekara (2015), Lean is a collection of operational techniques focused on productive use of resources and Agility collects techniques enabling higher flexibility and information processing. Several techniques fulfill both requirements and can be classified either in the group of Lean or Agile. Recent literature even identifies an increasing trend in combining Agile with Lean Manufacturing to achieve even better performance by securing efficiencies resulting from Lean and flexibility from Agile. The commonly used trem for this combination is leagile (HASSAN AND SHARIF (2015). The different lean manufacturing methods and concepts, as used in this research, can be applied either under a Lean Manufacturing or Lean Manufacturing strategy.

In the following chapter a general definition of the sub-components manufacturing concept and manufacturing method, as well as their relationship to a manufacturing strategy, is given.

2.3.5 Manufacturing Concepts and Methods

As discussed in the sections above, a manufacturing strategy consists of the sub-components of manufacturing concept and manufacturing method. They can be defined as follows:

<u>Manufacturing concept:</u>

Within the literature, the term “manufacturing concept” is often confused with the term “manufacturing strategy”. For instance, literature was found which mentioned “manufacturing strategy” in the subtitle, but predominantly dealt with “manufacturing concepts”. On the other hand, studies based on manufacturing strategy do not separate manufacturing strategy and manufacturing concept clearly (Hitomi 1997).

Blecker and Kaluza’s definition (2003) formed the basis for the further research approach: a manufacturing concept defines the main production parameters and the tools to reach the required business goals. Hence, manufacturing concepts can be considered as fairly comprehensive compared to manufacturing methods.

Manufacturing method:

Manufacturing concepts can define the manufacturing methods needed for the realization of a required manufacturing strategy or manufacturing concept. Just-in-Time or Kanban, for example, are not manufacturing concepts but manufacturing methods that define best practice in manufacturing worldwide (Clark 1996). They are considered to be tools for the operational implementation of a manufacturing concept, used for the final realization of a manufacturing strategy. Hence, manufacturing concepts make use of manufacturing methods and are more highly ranked in the business hierarchy. Fig. 8 gives an overview of the most common manufacturing methods and their hierarchical classification, with the business processes (Zahn 1988).

Manufacturing strategies can be applied by combining suitable manufacturing concepts and methods (Blecker and Kaluza 2003). They do not necessarily need to be realized by commonly used manufacturing concepts.

According to this definition, manufacturing strategies break overall business strategies down to the production level (Fig. 7). Cost reduction of a product is one overall objective of many companies, and production costs can be a significant part of the general product costs. The reduction of production costs can be achieved by several manufacturing strategies, for instance Mass Production or Lean Production. They are the most common examples of manufacturing strategies. Manufacturing concepts and manufacturing methods can be distinguished by their relationship to each other; manufacturing concepts make use of manufacturing methods and are therefore more highly ranked (Blecker and Kaluza 2003). Accordingly, a manufacturing concept has a more comprehensive character than a manufacturing method. One or more manufacturing methods support a manufacturing concept in achieving its objectives. Therefore, manufacturing concepts are always composed of one or more adequate manufacturing methods. Eventually, manufacturing concepts cover more areas of a value chain, while manufacturing methods focus on a certain aspect within it. Also, manufacturing methods do not fall back on other manufacturing methods or even manufacturing concepts (Blecker and Kaluza 2003).

In summary, manufacturing concepts cover a more holistic scope, while manufacturing methods are rather directed at a certain aspect (Zäpfel 2000).

2.3.5.1 Overview of Lean Manufacturing Concepts and Methods

This chapter gives an overview of the found lean manufacturing concepts and methods that seemed to be relevant for the wind power industry and this research. To start with, their main attributes are introduced. In the following chapters the identified manufacturing concepts and methods are mapped and evaluated according to the evaluation criteria developed for the needs of the wind power industry.

In recent years, many studies have been conducted in the area of Lean Production. Womack and Jones (1994) designate Lean Production clearly as a manufacturing strategy in their study. In their research case, Lean Production is a Toyota manufacturing strategy, developed by Toyota between 1950 and 1970. Hitomi (1997) divides Lean Production into its individual components. According to Hitomi (1997), the core components of Lean Production are the manufacturing concepts Just-in-Time and Kaizen, which confirms the hierarchy of Zahn (1988) (Fig. 8). Further researchers support this theory. For example, according to Ohno (1988), Just-in-Time and Kaizen are manufacturing concepts that contribute to the manufacturing strategy Lean Production. Therefore, it is considered crucial to investigate not only the characteristics of the different lean manufacturing concepts and methods, but also their hierarchical classification within the business processes. The lean manufacturing concepts and methods most discussed in the literature are set out below and described according to their main attributes and business level classification:

Just-in-Time was developed in the early 1950s to improve the material flow within production and between several productions plants at Toyota in Japan (Wildemann 1997). Just-in-Time includes the absolute focus on quality in all manufacturing stages. In this context the zero-buffer and zero-mistakes orientations provide a permanent challenge for improvement activities (Hitomi 1997). According to Wildemann, Just-in-Time is both a logistical concept as well as an organizational development approach for the restructuring of the value chain. Arising from the material flow, Just-in-Time seeks to optimize the logistical supply chain with the aim of focusing all value chain activities on the success factors productivity, time and quality (Wildemann 1997). Most important is the just on demand procurement, production and delivery to customers (Zäpfel 2000). Zäpfel (2000) splits Just-in-Time into two blocks: just-in-time procurement and just-in-time production. Just-in-time production is limited to the internal material and goods flow, while just-in-time procurement considers the value chain stages outside the enterprise (Zäpfel 2000). The basic element of Just-in-Time is to have the right product in the right quantity at the right time and in the right place for each order (Meybodi 2003). Also, Meybodi states that inventory stocks have to be avoided and lead times are to be kept as short as possible. To avoid inventory stocks, the product may only be produced, provided or transported when it is required by the customer. Hence, Meybodi (2003) concluded that in addition to quantity and delivery date, the quality of the delivered parts is also a key aspect. In summary, he defines the following main goals of Just-in-Time:

- reduction of stock inventory,
- reduction of lead times,
- reduction of set-up times,
- increase of productivity,
- increase of flexibility in the readiness for delivery.

Therefore, Just-in-Time could be also appropriate for this research project, as it covers the main goals of the studied business environment.

<u>Kaizen</u> is a term that is composed of the Japanese words Kai (change or turn) and Zen (for the better). As a manufacturing concept, Kaizen became well known in industrialized countries outside Japan in 1986 (Imai 1986). Differing to Just-in-Time, which mainly focuses on material and work flows, Kaizen describes improvement processes brought about by the comprehensive involvement of the employees. The main characteristic is a general orientation at all levels of the organization towards considering even the smallest improvement potentials and developing corresponding improvement solutions (Ohno 1988). Ohno describes Kaizen as an improvement process with small

steps that continuously eliminate failure. That is in contrast to big and comprehensive innovations that are introduced suddenly and that are typical for Western industrial nations. Specific to Western industries are short-term improvement measures which do not exploit all the potential for improvement (Imai 1986). According to Imai, all technical and organizational functions can be worked on in order to improve product quality and productivity. Specifically, he names the optimization of operational processes, the better utilization of resources like workforce, machines or material, the reduction of rejects and failure costs as well as the improvement of planning and control.

Kaizen is based on a kind of process-oriented thinking, which stands in contrast to the more innovation- and result-oriented thinking of Western nations (Ohno 1988). Ohno defines Kaizen as a manufacturing concept that requires a continuous analysis of existing standards, in order to reach the zero-mistake objective. As a main component of this permanent and systematic improvement approach, he defines all the working and experience areas for all the employees in an enterprise.

Kaizen appears to be a corporate culture or philosophy. It stimulates a general shifting of the management and employee mindset and seems appropriate to supplement change projects as a long-term philosophy of process-oriented thinking.

Kanban is the Japanese word for card or indication sign. The original industrial application was also realized at Toyota, in the 1950s (Berkley 1992). Its principal purpose is decentralized planning and control of the raw material flow according to easy rules. In Japan, it was recognized early that, due to raised market dynamics and rising flexibility requirements, low inventory stocks, high delivery reliability and low lead times are priority aims (Suzaki 1993). Suzaki defines the basic idea of Kanban as being that the need for a product is determined by the actual consumption. This means that a product or part is only produced when the quantity of needed products sinks, due to consumption, to a certain level.

Kanban requires a production that follows the assembly-line principle, i.e. that two production steps following each other are linked together by a self-controlled process that allows decentralized quantity control of produced products and raw material (Ohno, Nakashima et al. 1995). Consequently, Ohno,

Nakashima et al. define Kanban as material consumption control of several series-connected production steps. Hence, a so-called pull-control has to be established, meaning that one production place only receives a production order when the following production place signals a need. The direction of the demand signals is downstream. This means that the Kanban cards are control instruments that serve on the one hand as part and material identification for the material containers and on the other hand for placing the orders (Suzaki 1993). Suzaki distinguishes between transportation-Kanban and production-Kanban. Transportation-Kanban manages the material flow between the production place where the material is used and the material buffer stock upstream. Production-Kanban manages the material flow between the production place and the material buffer stock downstream (Suzaki 1993). Hence, the necessary amount of material must be requested by the production place, by sending a control impulse to the material flow. Production as a whole is managed by a self-controlled system, which synchronizes the material flow.
Suzaki defines several rules that enable the correct functionality of this manufacturing method:

- production may only produce the required parts if an impulse is given by the production-Kanban.
- only standard containers may be used, which are filled with a defined amount of raw material.
- for each part, one container exists, containing a defined amount of material, and for each container there are two types of Kanban card.

In summary, the main objectives of Kanban are the reduction of inventory stock and the acceleration of production processes, with a simultaneous fulfilment of the delivery dates (Berkley 1992, Ohno, Nakashima et al. 1995). Compared to Kaizen, Kanban is clearly operation-oriented. As it requires an assembly-line principle, Kanban is commonly seen as an appropriate manufacturing method to support the manufacturing strategy Mass Production.

Total Quality Management in turn forms a comprehensive approach for quality management in an enterprise. On the one hand, the whole enterprise is involved in the fulfilment of quality standards and, on the other, customers and suppliers also are involved in the quality processes (Logothetis 1992).

Logothetis describes the basic idea of Total Quality Management as a consideration of all enterprise areas and the achievement of motivation of all participants by exemplary behaviour on the part of the executives. Furthermore, the raising of customer satisfaction is a core element of Total Quality Management (Fox 1994). Fox further describes that product quality is a core element of Total Quality Management, as is the ability of an enterprise to remain high quality, even if customer requirements change quickly. The intention is the continuous improvement of the enterprise for the employees and therefore also for the customers. To achieve this, significant rationalization of the internal processes, the creation of conditions for substantially improved compliance with the delivery dates as well as a reduction of new product development times have to be achieved (Logothetis 1992). He further concludes that through the implementation of Total Quality Management an enterprise is able to gain competitive advantage and to compete even in narrow markets.

The continuous improvement of product quality, together with the ability to fulfil the changing wishes of customers, is stated as being important in all Total Quality Management literature. Total Quality Management does not have the objective of maximizing quality, but rather of finding the right balance between customer and market needs (Fox 1994). A level of quality that is neither desired nor rewarded by the customer is waste of resources and therefore should be avoided. Again, Total Quality Management is a kind of enterprise philosophy. As a manufacturing concept, Total Quality Management offers orientation for the business goals of a company. In order to achieve them, suitable manufacturing methods must be selected.

<u>Concurrent Engineering</u> is another manufacturing method acting on an operational level. Concurrent Engineering follows the trend of combining different theories and handling several product design processes simultaneously. Its main objective is the reduction of product development times (Savci and Kayis 2006). Savci and Kayis define product development, as well as production, as a central functional area of an enterprise, in which customer needs and requirements are adapted into new products. As early as during the concept and development phase of new products, many characteristics are created that determine the efficiency and performance of the production phase

(Hasenkamp, Adler et al. 2007). As a result, Hasenkamp, Adler et al. conclude that it is important for the produced products to be very well standardized, as well as covering a range of very different customer needs. Savci and Kayis recognize a successfully implemented Concurrent Engineering if, during the product development, close contact between production and suppliers exists that enables fast development and preparation of the production. In summary, they identified the aims of Concurrent Engineering as the reduction of the time from product idea to market launch, the reduction of development and production costs and the improvement of the product quality. By the collective product development carried out by the manufacturer and the suppliers, and the simultaneous development of production technology and processes, Concurrent Engineering promises a reduction of information gaps and a quicker marketability of innovative products (Schmidt 1997; Stelian 2009).

Concurrent Engineering is considered as a useful method for developing products that suit different manufacturing strategies and concepts. Its general characteristics allow use within the manufacturing strategies Mass Production and Lean Production.

Computer Integrated Manufacturing is a further method for the realization of lean manufacturing concepts. Computer Integrated Manufacturing is described as the integrated data management of economic and technical processes of an industrial company (Koening 1990). Koening further defines Computer Integrated Manufacturing as an overall enterprise method for the integration of all information flows within an enterprise. The main emphasis is placed on the use of synergy effects (Gunasekaran 1997). Gunasekaran points out that synergy effects can be achieved by the avoidance of duplication, e.g., the repeated input of product information during a production process or the rebuilding of products due to a lack of information at a current production step. Furthermore, synergy effects can arise in general management with the development of new possibilities in management and decision-making supported by an improved management of information (Kramer, Chibnall et al. 1992).

Computer Integrated Manufacturing bases itself on single modules that already exist in enterprises. Those modules are: Computer Aided Design (CAD), Computer Aided Planning (CAP), Computer Aided Manufacturing (CAM), Computer Aided Quality Assurance (CAQ), and the Production Planning and Scheduling System (PPS) (Gunasekaran 1997). Computer Integrated Manufacturing encloses the interaction of these modules based on IT. The economic tasks are tracked by the PPS and include elements such as order prices, order release, production scheduling and dispatch control.

Computer Integrated Manufacturing contributes to an increase in customer value due to the achievement of higher quality, quicker order realization and production of customized product variations (Blecker and Kaluza 2003). They highlight that the implementation of Computer Integrated Manufacturing

- increases productivity and flexibility,
- reduces lead times,
- decreases inventory and reject rate,
- and provides a higher flexibility of production.

In summary, the whole enterprise is able to react faster to changing customer requirements. Similar to Concurrent Engineering, Computer Integrated Manufacturing is a supportive method for the realization of all types of manufacturing strategies and is appropriate in businesses that have to manage a large amount of data.

<u>Mass Customization</u> is defined as an enterprise-wide manufacturing concept (Davis 1997; Pine 1999; Gardner 2009). At the centre of this concept is the product architecture. The product basis is ideally realized by a product platform and additional options that are designed as add-ons. The combination of product platforms and different options creates the required product variants. Under Mass Customisation there is a significant upfront effort to engineer the essential features of the product and determine how different modules can be recomposed into specific order configurations (Gardner 2009).

Dealing with disturbing factors and a dynamic market environment is also a main attribute of the Mass Customization method (Gardner 2009). Mass Customization became well known due to its successful implementation at the technology company Hewlett-Packard (Feitzinger and Lee 1997). Feitzinger and Lee define reduced inventory stock and material waste, increase of cash flow and faster responsiveness to market with many simultaneous product variants as the main benefits of Mass Customization.

Mass Customization is very well suited to realize a Lean Production strategy. It involves several business areas in an enterprise, in particular sales, production, R&D and procurement. This holistic approach enables the leverage of potentials from different departments that have influence on the production. Both the holistic approach and the presumed benefits made Mass Customization very favourable for this research project.

Postponement is a further type of manufacturing concept that supports the implementation of a Lean Production strategy. Postponement focuses on the supply chain and manufacturing processes. That is its main differentiation from Mass Customization, which is significantly more focused on the product (Van Hoek 2001). According to Van Hoek (2001), Postponement improves the agility of the supply chain and the value performance processes. Furthermore, by postponing production until customer orders are received, there is lower forecasting risk compared to when products are made to stock. There is an increase in flexibility and scalability because it is possible to respond more quickly to market trends (Yang, Burns et al. 2004).
The characteristics and benefits of Postponement made it an attractive manufacturing concept for the researched case. However, even with the close similarities to Mass Customization, Postponement has a lower focus on the product and the management of its variants.

Standardization approaches in production are described in several studies within many industries. Standardization makes it easier for parts to be pulled into an assembly process, instead of ordering and waiting (Anderson 2004). Anderson highlights the need to reduce the number of part types to the point where the remaining few standard parts can be delivered via demand-pull just-in-time deliveries. His main identified benefits, cost reduction and flexibility, are achieved by ordering in large quantities and having parts available at all points of production. Further benefits are the improvement of product quality and a higher responsiveness to market and customer needs (Ulrich 1992). Standardization can contribute to several approaches for the achievement of Lean Production. Hence, it can be classified as a manufacturing method.

Modularization is another powerful method for contributing to the realization of Lean Production. Modularization is seen as the foundation for tailoring a product to the needs and requirements of the customers (Feitzinger and Lee 1997). Ulrich (1992) describes an important difference between standardization and modularization. While standardization may seem attractive from a cost and quality perspective, it can constrain choices and lead to conflicts with marketing and customers. Modularization starts by understanding where variety is needed and where a company wishes to drive lean product development. Only when this is understood can a company move forward with modularization. Modularization embraces market complexity, while still allowing for standardization (Ulrich 1992). Furthermore, modularization is essential for the realization of platform families, as they are a combination of subsystems and modules (Feitzinger and Lee 1997). This attribute means that Modularization is particularly suitable for the application of Mass Customization.

The literature review provided an overview of the most common lean manufacturing concepts and methods. The study of each concept and method helped to identify the main attributes and characteristics of each of them. However, to evaluate the concepts and methods according to the needs of a wind turbine manufacturer, suitable evaluation criteria had to be developed. The development of the evaluation criteria and finally the mapping of the review results are described in the next chapter.

2.3.6 Implementation of Lean Manufacturing Concepts or Methods

In the current literature there is little evidence of previous research studies dealing with the implementation or application of lean manufacturing techinques in the wind power industry. An Engineering Change Management (ECM) approach was applied and investigated at a wind turbine manufacturer during the design project of a wind turbine cooling system (Fei, Gao et al. 2011). Their paper presented an advanced ECM to help designers to trace, analyse, and evaluate engineering changes occurring in the product design phase. In a further research the application of Six Sigma at a wind turbine manufacturer to improve the quality during the erection of wind turbines was investigated (Gijo and Sarkar 2013). However, both research studies focus only on a small area of the value chain of a wind turbine manufacturer: the design of a wind turbine component and the influence of infrastructure on the quality of wind turbine erections. Furthermore, they do not consider the manufacturing area and its influence on the customer order process. In summary, no relevant literature on the implementation of a lean manufacturing strategy or concept in the wind power industry was found. Therefore, recent literature and studies sharing lean or agile implementation experience from other industries were reviewed. The most interesting findings of the reviewed researches were the implications on organizational change, required efforts, and achieved benefits as a consequence of implementing lean manufacturing techniques. However, only some of them address such potential success factors and barriers during the implementation of lean or agile manufacturing concepts. One of the best-known literatures on sharing implementation experience of Mass Customization is from Feitzinger and Lee (1997). However, in their case study on printers at Hewlett-Packard they mainly report the benefits of a successful implementation of Mass Customization. On the other hand, they describe only little the implementation implications and efforts. Feitinger and Lee (1997) introduce briefly the challenge to involve employees from several departments of a company because each department has its own measures of performance. All of those employees, however, have to support an effective Mass Customization program and have to be willing to make compromises. Thomas, Barton et al. (2009) describe the implementation of an integrated lean and six sigma model at a small engineering company in UK. Their case study resulted in a successful implementation. They conclude that the implementation approach developed a culture towards continuous improvement throughout the whole organization. According to them, the abailty to change the company´s culture is the most important success factor. However, they conclude that the soft culture transition in their case study was mainly enabled by the small size of the studied company (Thomas, Barton et al. 2009). Hodge, Goforth et al. (2011) conducted a lean implementation research at a textile manufacturer in United States. The overall objective of the textile manufacturer was the elimination of waste and non-added activities to reduce production costs. The authors observed change resistance of both the shop floor employees and top management. A deeper investigation also identified a disturbed comunication among the employees from Marketing, Sales, and Product Development during the implementation project. Furthermore, a poor integration of the shop floor personal was found which was mainly explained by too many not native English speakers in the shop floor (Hodge, Goforth et al. 2011). Overall, the main implementation barrier was a missing communication at all business levels. Chowdhury, Haque et al. (2015) studied the implementation of lean manufacturing at a large furniture manufacturer in India. The main objective of the lean implementation project was the improvement of productivity and flexibility. The authors report a successful implementation reflected by a significantly improved working capital and reduced processing time. They identified the exemplary behaviour and positive attitude of the top management, and a good information flow as main success factors (Chowdhury, Haque et al. 2015). Rymaszewska (2014) conducted a case study at a furniture manufacturer in Finland. She uncovered an insufficient readiness for change of the furniture manufacturer to implement lean manufacturing and identified several challeneges that hindered a smooth lean transition. According to her research, the main challenges are: the motivation and skills of employees, the challenge of managing the workflow during the change process, the challenge of becoming a learning organization, and the challenge to preserve a long-term lean philosophy (Rymaszewska 2014). Roh, Hong, at al. (2014) have studied the implementation of a responsive supply chain strategy in global complexity at a diversified industrial corporation. They conclude that the key factors that influence the success of implementation of lean manufacturing strategies are the size of firms and particularly the industry characteristics with their specific customer and supplier relationships (Roh, Hong et al. 2014). In addition, Salem, Musharavati et al. (2015) have discovered that there are differences on the levels of awareness, recognition, and appreciation of lean concepts in different industrial sectors. They based their results on implementation data from several companies and organizations from various sectors like oil and gas, academic institutions, and services sectors. They recommend further sector-wise researches to gain deeper understanding about barriers and success factors of lean and agile implementation in respective industries (Salem, Musharavati et al. 2015). Therefore, literature on the implementation of a lean or agile manufacturing technique in industries with similar characteristics like the wind power industry was reviewed. A widely discussed research on lean manufacturing implementation in the machinery industry was conducted at Lantech, a manufacturer of customized stretch wrapping equipment, by Womack and Jones (1996). One of the challenges, which they identified at the very first stage of the implementation, was also the consolidation of several departments to work together. Lantech experienced communication barriers between the different departments. Especially the information flow was highly difficult from Sales and Marketing to Production and Engineering (Womack and Jones 1996). A strong focus on organizational change caused by the implementation of lean manufacturing was also laid in a case study of two plants in the aerospace industry by Crute, Ward et al. (2003). They describe as main challenge the conflict to mange the implementation activities and the caused change implications at the same time. Eventually, they conclude that the organizations need to be thoroughly prepared for the lean transformation to reduce the risk of later consequences (Crute, Ward et al. 2003). In further case studies, conducted in ten small and medium size manufacturing companies (Achanga, Shehab et al. 2006) and six manufacturing companies (Elnadi and Shehab 2015) in the United Kingdom, the success factors and challenges during the implementing of lean manufacturing techniques were studied. Both research studies identified the following key success factors: the need for a certain degree of communication throughout the company, a proactive organizational culture, the belief in the new lean concept, and well skilled employees with willingness to learn. In a case study on lean manufacturing implementation at a German manufacturer of wood processing machines, three main success factors were found: communication at every organizational level, readiness for change of the organizational cultre, and consequent following of the new practices and principles (Czabke, Hansen et al. 2008). In a further research, based on case studies in multinational automotive and aeronautic manufacturing companies, Larteb, Haddout et al. (2015) identified the following success factors: top management engagement and commitment, balanced allocation of time and resources, strong communication and leadership of the project manager. In contrast, when these success factors are not pronounced enough the implementation progress is disturbed (Larteb, Haddout et al. 2015), Nordin, Deros et al. (2012) carried out case studies on lean implementation at three automotive component manufacturing firms. Their research identified a poor management of the change process during a lean manufacturing transformation as main reason for failure of lean implementation. They propose the use an information system to provide the employees a better understanding of the change process and a clear guidance to minimize the resitance and conflicts during the lean transition (Nordin, Deros et al. 2012). Furthermore, strong leadership skills of the orpject manager are requested.

In summary, no significant differences on benefits, success factors, and barriers for lean implementation in the different industries, as decribed by Roh, Hong, at al. (2014) and Salem, Musharavati et al. (2015), were found. Almost all reviewed researches indicate that the main benefits of lean implementation are reduction of waste and inventory, improved flexibility, and increase of productivity and efficiency. The results of the identified barriers and success factors for a lean implementation provide a clear picture as well. Most mentioned barriers for lean implementation are: insufficient top management involvement, employee´s motivation, poor communication, and inadequate skills of employees and project management. Based on these results, it can be concluded, firstly, to spend enough time on the investigation and analysis of the considered business area, as well as the organizational characteristics and capabilities like cultre, resources, and skills. Secondly, the establishment of an effective communication concept or information system is recommended. Both measures require a deep understanding of the considered organization and business environment because prior to the start of the lean implementation project.

Even if no literatue on lean manufacturing implementation in the wind power industry was found, several identified researches showed comparable initial business situations with PowerWind and probably many other wind turbine manufacturers: quickly changing customer and market needs, no adequate processes to meet this challenge, and dissatisfaction with the current state. For this reason, similar lean manufacturing objectives, like reduction of inventory, improved flexibility and increase of efficiency, were targeted by the studied companies.

Therefore, the organizational implications, potential barriers, and achieved benefits caused by the lean manufacturing implementation in those researches can serve as a benchmark for the findings of this research.

2.4 Mapping of Review Results

2.4.1 Identification of Possible Evaluation Criteria

In order to identify the most appropriate manufacturing technique for the case study, evaluation and selection criteria needed to be developed. For this purpose, a further literature review on evaluation criteria of manufacturing techniques was conducted. In general, multiple evaluation criteria for manufacturing techniques are discussed within the current management and technology publications both academical and professional.

Wheelwright (1978) describes quite general performance criteria for manufacturing strategy such as

- efficiency,
- dependability,
- quality,
- and flexibility (Wheelwright 1978).

Skinner (1984) describes more detailed evaluation criteria for manufacturing strategies:

- short delivery cycles,
- superior quality and reliability,
- dependable deliveries,
- fast new product developments,
- flexibility in volume changes,
- and low cost (Skinner 1984).

Later, Hayes and Wheelwright (1984) delineate four basic competitive priorities: cost, quality, dependability and flexibility (Hayes and Wheelwright 1984). Krajewski and Ritzman (1987) further identify five operations competitive priorities: cost, high performance design, consistent quality, on-time delivery, and product and volume flexibility (Krajewski and Ritzman 1987). In a comprehensive review of the literature on manufacturing competitive priorities, Leong, Snyder et al. (1990) contend that five priorities are the most critical: quality, delivery, cost, flexibility and innovativeness (Leong, Snyder et al. 1990).

In general, many studies strongly suggest the inclusion of criteria such as cost, delivery, flexibility and quality as the key components of manufacturing strategy. However, a strategy making process would also benefit from the inclusion of other factors such as company structure or culture.

Blecker and Kaluza (2003) also develop comparable assessment criteria for the manufacturing strategy sub-components manufacturing concepts and manufacturing methods. They distinguish between four further categories of manufacturing concepts and manufacturing methods:

- technical targets,
- economic targets,
- social targets, and
- ecological targets.

Social targets mainly consider the employees perspective, in particular the securing of jobs, health and safety, and fair pay (Rumel, Schendel et al. 1979). Rumel, Schendel et al. list the following social evaluation criteria:

- securing of jobs,
- health and safety,
- right of co-determination,
- fair pay,
- flexible working time,
- personal development of skills and work content.

In general, Rumel, Schendel et al. define all the aims of members of an economically active community that consider the social and ethical environment as social targets. The inclusion of social targets amongst the key contribution towards the strategic decision making would by definition introduce a tension between the technical considerations and the social, but on the other hand would likely lead to more realistic organisations´ aims and objectives.

As ecological criteria, Rumel, Schendel et al. (1979) list

- extraction of mineral resources,
- pollution of air and water,
- reduction of waste.

All the different evaluation criteria for manufacturing techniques can be clustered into two main categories: formal targets and competitive targets (Porter 2004). Porter (2004) defines competitive targets as: costs, differentiation and concentration. In more detail, he highlights the aim of achieving cost leadership, a higher product differentiation to stand apart from competitors and concentration on increasing business efficiency. He defines formal targets as: social, technical, economic, political and ecological. These are commonly summarized as STEP analysis and focus on the quantitative and qualitative properties of the manufactured product. Social targets take into account the employees' perspective, while the technical targets consider the technical and functional properties of the product. Economic targets deal with costs and the profitability of product portfolios and production processes. Political targets consider legal and public frameworks. Ecological targets attempt to protect the environment and contribute to moderate use of natural resources (Porter 2004).

As mentioned earlier (chapter 2.3.5), manufacturing concepts and manufacturing methods are additionally differentiated by their application and classification in the business hierarchy. Hence, the classification of the applied business level is also an important selection criterion.

2.4.2 Selection of Evaluation Criteria

Gathering all these different criteria together helped to define suitable evaluation criteria for this research project. Firstly, all identified lean manufacturing techniques were categorized according to their business strategy level (manufacturing strategy, concept or method). Thus, the procedure to find the right manufacturing concept or method for the case study was a top-down approach. In order to select the right lean manufacturing technique, it was important to define whether the application of a manufacturing strategy, concept or method was required by the given business situation. Otherwise a selected manufacturing technique might not have been adequate (too powerful or too focused) for the given business project. Furthermore, a comparison between a manufacturing strategy and a manufacturing method would have been pointless and would have biased the results.

For the achievement of a holistic evaluation, formal and competitive targets according to the STEP analysis of Porter (2004) appeared suitable for this research. Both targets created the basis for the development of evaluation criteria for identifying an appropriate lean manufacturing technique for this study and possibly other for wind turbine manufacturers.

As derived from the literature review, the most significant challenges for the researched wind power industry case were the increasing market maturity, with its higher demand for process excellence, the ongoing need for cost reduction and multiple product variants. The demand for increased process excellence is quite general and therefore not suited as a specific evaluation criterion for a lean manufacturing technique. On the other hand, the managing of multiple product variants is very specific and clearly a technical target. Therefore, the capability to manage a large amount of product functions and variants was selected as the first evaluation criterion. The improved handling of many product variants should free up engineering resources that could be used in increased innovation which is an inherent part of developing new products and augmented product features. According to Porter (2004), the need for cost reduction is a competitive target. To create an evaluation criterion out of this competitive target, the cost reduction area needed to be defined more specifically. The investigated value chain area at PowerWind required a significant amount of components and parts to fulfil customer orders. That in turn led to large inventory stock and a negative impact on the working capital. Consequently, the capability of inventory stock reduction was chosen as a competitive target and second evaluation criterion.

In the following chapter, all identified lean manufacturing techniques are classified and evaluated according to these criteria:

1. Classification:
Differentiation between manufacturing strategy, manufacturing concept and manufacturing method.

2. Evaluation:
Fulfilment of the formal target “capability to manage product variants” and the competitive target “capability to reduce the inventory stock”.

2.4.3 Classification of Manufacturing Strategies, Concepts, and Methods

In this chapter the identified manufacturing strategies, manufacturing concepts and manufacturing methods are classified according to the business level they apply to.

Manufacturing strategies:
In general, three manufacturing strategies are discussed in the literature: Craft Production, Mass Production and Lean Production (Gardner 2009). All these strategies have significant characteristics and are useful for certain products and markets. As manufacturing strategies are located high up in the business process hierarchy (Fig. 7), they have a strong influence on the overall business of a manufacturing enterprise. In addition, they have the aim of defining and shaping the philosophy of the whole enterprise. Therefore, the selection of the right type of manufacturing strategy has to be done very carefully. In contrast, a manufacturing concept, which is located one level below the manufacturing strategy, is a more operational objective and aims to influence the culture of an organization or business unit, e.g. the quality culture. In this case study, a Lean Production strategy was decided on by the management board. However, for the realization of Lean Production, the appropriate lean manufacturing concept or method had to be selected from the many different types of manufacturing concepts and methods.

Manufacturing concepts:

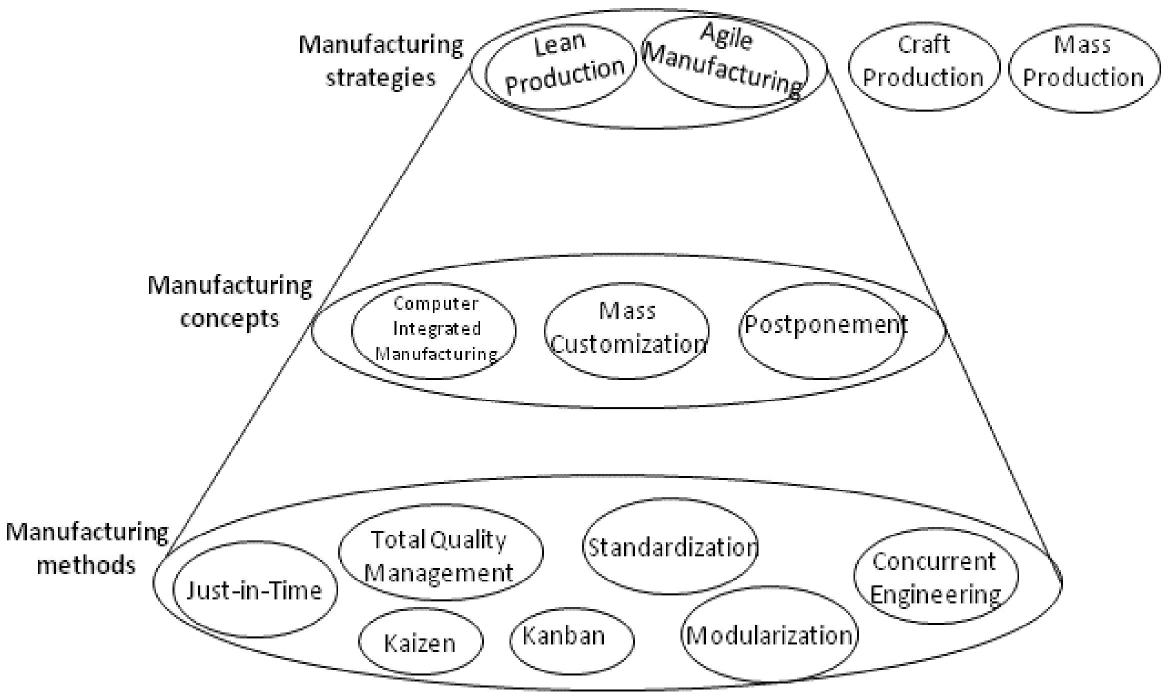
According to Zahn (1998), manufacturing concepts and manufacturing methods are classified in a lower operational business level than manufacturing strategies. In addition, manufacturing concepts and manufacturing methods are distinguished by their correlation to each other (Zahn 1988). Thus, manufacturing concepts make use of manufacturing methods and are positioned more highly in the business process hierarchy. Manufacturing concepts have the objective of influencing or even changing the organizational culture. Meanwhile, manufacturing methods are the functional and organizational instruments to realize these objectives. Therefore, manufacturing concepts and manufacturing methods can be differentiated by the impact they have on the overall enterprise. Manufacturing concepts have a rather comprehensive perspective, while manufacturing methods are directed more at a certain aspect (Blecker and Kaluza 2003). According to this definition, Kaizen, Postponement, Mass Customization and Total Quality Management have the status of manufacturing concepts. They have a holistic perspective and a leading idea of creating, steering and developing production systems that have the aim of improving the competitiveness of an enterprise. All four of these manufacturing concepts can use different manufacturing methods to realize their goals.

Manufacturing methods:

In contrast, Just-in-Time, Kanban, Computer Integrated Manufacturing, Concurrent Engineering, Standardization and Modularization focus only on a part of a business system or value chain, e.g. the Production or R&D department (Blecker and Kaluza 2003). For example, Just-in-Time and Kanban concentrate on the improvement of the material supply for production. Concurrent Engineering and Computer Integrated Manufacturing have the objective of collecting and providing the best product information during product development or manufacturing. Standardization and Modularization support purchase and production by reduced material variety and simplified product platforms. None of these aim to cover a wide range of company departments. Therefore, they can be classified as manufacturing methods.

Based on these classification results, a hierarchical overview of manufacturing strategies, concepts and methods was developed (Fig. 8).

Fig. 8: Classification of manufacturing strategies, concepts, and methods



As mentioned previously, Lean Production was chosen as the manufacturing strategy by the management board prior to the implementation of a corresponding manufacturing concept or method. Therefore, only the identified manufacturing concepts and methods were the subject of further evaluation.

2.4.4 Evaluation of Manufacturing Concepts and Methods

As derfined in chapter 2.4.2, the evaluation criteria for the chosen lean manufacturing techniques are:

- "capability to manage product variants" (formal target)
- "capability to reduce the inventory stock" (competitive target)

In this chapter, the identified manufacturing concepts and methods are evaluated according to these criteria. In the next chapter, the results and conclusions of the evaluation are presented and displayed in an overview.

The principal purposes of the production method Just-in-Time are the reduction of inventory stock and production lead times. Lowered inventory stocks lead to cost reductions in the form of a reduced need for working capital. Also, flexibility is increased with regard to the short-term readiness for delivery (Meybodi 2003). This supply chain aspect is independent of the number of product variants.

Similar results are achieved by Standardization. Costs are reduced by orders of large quantities (economies-of-scale), less material overhead and spontaneous resupply, which in turn improves flexibility (Anderson 2004). The aim is to use as many similar parts as possible for many different sub-assemblies. Standardization requires a detailed and structured bill of materials, which in turn promotes the handling of product variants.

Modularization considers the whole product and the functionality of its sub-assemblies. The sub-assemblies are separated according to their functionality. This requires a more holistic view of the product and an understanding of its market requirements (Feitzinger and Lee 1997). The function-based definition of the sub-assemblies is well suited for the generation of product variants. A reduction of inventory is only achieved in combination with advanced business and production processes.

Kanban puts the main focus on the reduction of inventory stock. However, this method also aims to accelerate the production processes by an improved material flow and a guaranteed delivery date for materials (Ohno, Nakashima et al. 1995). Costs are lowered by the reduced inventory stock and the corresponding lower need for working capital. The acceleration of the production processes and reliable material delivery dates increase productivity. A Kanban system is independent of the number of product variants.

The core target of Kaizen, a zero mistake objective throughout the whole enterprise, increases productivity and quality by avoiding mistakes (Imai 1986). In addition, the avoidance of failures leads to a reduction in rework and post-processing costs. Kaizen aims to influence the organizational attitude and may be applied to both a low and high number of variants.

Total Quality Management moves customer satisfaction to the centre of an enterprise’s activities. Also central are the quality of the products and the flexibility of the enterprise in terms of how fast it can react to changing customer wishes. These quality and flexibility aims are achieved through improved production processes and optimized product development processes (Fox 1994). That is positive, in terms of managing many product variants. Total Quality Management is not purely focused on a low inventory stock; by aiming to improve production processes it automatically contributes to efficient production and a certain level of inventory reduction.

Using Concurrent Engineering, the final product quality is already positively influenced during the product development phase. This aim is achieved by the avoidance of construction-conditioned failures that could lead to raised costs due to necessary rework during the later production phase (Savci and Kayis 2006). This supports an improved and more efficient production. However, there is no direct focus on inventory reduction. The quality perspective alone does not support the efficient handling of many product variants during the product development phase.

Computer Integrated Manufacturing leads to higher productivity, as well as raised quality and flexibility, due to the integration of all information flows in an enterprise (Blecker and Kaluza 2003). Productivity is increased by shorter processing times as a result of the improved information flow. Furthermore, cost reduction is achieved by lower inventory stock, resulting from the improved material flow. Good information flow also allows a higher level of flexibility in production and with it the improved ability of the enterprise to adapt to changing customer requirements. Good information flow is also a good basis for the handling of many variants during product development, even if Computer Integrated Manufacturing does not provide a direct approach for the managing of product variants in a company´s value chain.

Mass Customization is realized by upfront engineering of product platforms and add-on options (Gardner 2009). This creates a strong capability for the managing of product variants. The clearly structured and market-aligned product design allows a reliable product configuration in the earliest product phase. This leads to efficient material and production planning. Along with others, Feitzinger and Lee (1997) define reduced inventory stock and material waste as main benefits of Mass Customization.

The key for a successful implementation of Postponement is the design of product platforms that delay the completion of production until customer orders are received. By doing this, it is easier to plan the inventory and lower the risk of products being made to stock. Product platforms designed for Postponement are not automatically best suited to an efficient handling of product variants. However, the Postponement design approach does provide a good basis to consider product variants as well.

2.5 Results and Conclusion

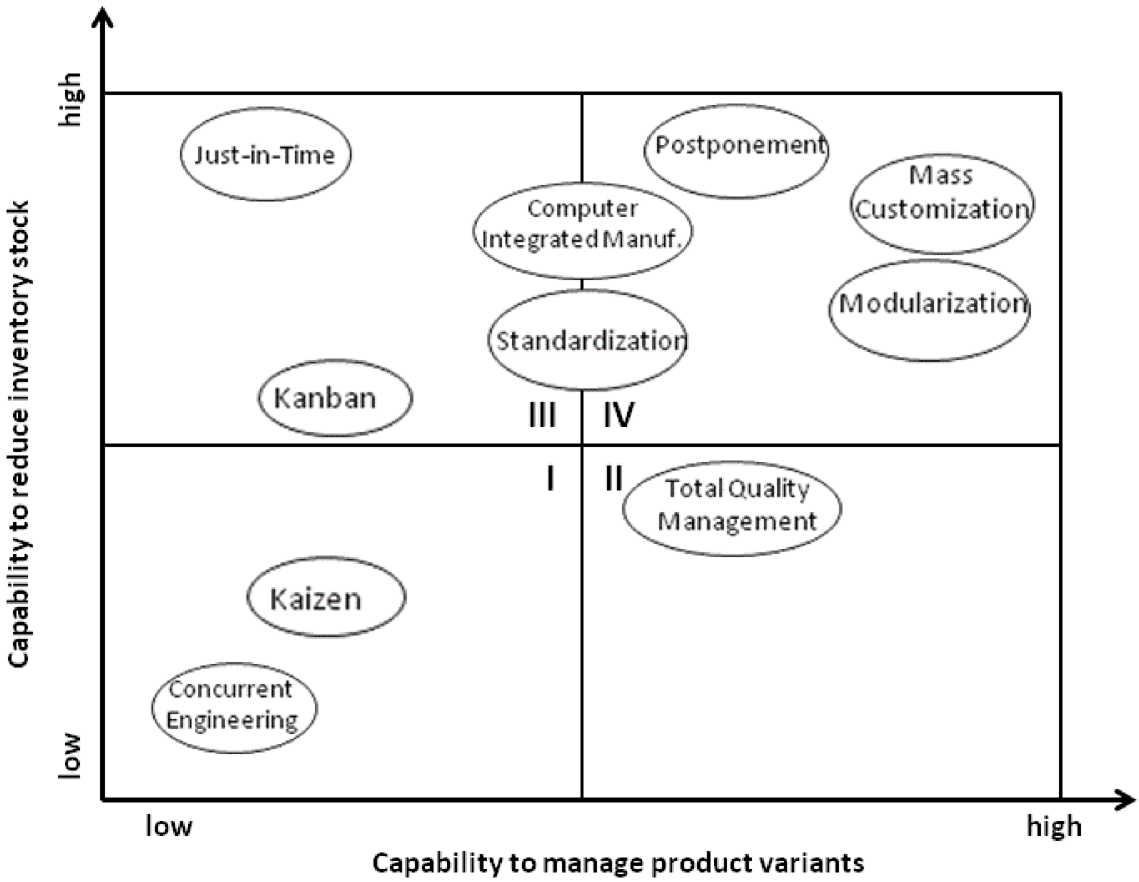
The aim of the Literature Review was to establish a broad overview of the existing manufacturing strategies and their sub-components of manufacturing concepts and methods. Following this, the criteria for the classification and evaluation of the manufacturing strategies, concepts and methods were developed. Besides the establishment of an overview, a clear definition for manufacturing strategy, concepts and method was developed. This allowed a classification according to the business process hierarchy, where the different manufacturing techniques were applied. This was important for further evaluation, as high-level business strategies have to be distinguished from methods applied in a department or team environment. Finally, the developed evaluation criteria enabled the investigation of which manufacturing concept or method was most suitable for the case study and possibly for other wind turbine manufacturers. Manufacturing strategies can be divided into Craft Production, Mass Production and Lean Production, but the choice of a manufacturing strategy was not the subject of this case study; only the identified manufacturing concepts and methods were evaluated further. To achieve a holistic evaluation, formal and competitive targets according to the STEP analysis of Porter (2004) were used. Based on a formal and a competitive target, and the investigated value chain area, the following evaluation criteria were applied:

- "capability to manage product variants" (formal target)
- "capability to reduce the inventory stock" (competitive target)

One key result was that all concepts and methods have clear diversities, but also several commonalities. Within this, the overlaps of the formal targets were most significant. Also, the applicability for different company types and sizes was remarkable. Various manufacturing concepts make use of the same manufacturing methods. That means that a manufacturing method can be a sub-component of different manufacturing concepts. However, certain core characteristics of each manufacturing concept and method exist and could be evaluated according to the established criteria.

To provide a better overview, the evaluation results are presented in a diagram (Fig. 9). The evaluated manufacturing concepts and methods were classified according to their capabilities of reducing inventory stock (y-axis) and managing multiple product variants (x-axis).

Fig.9: Evaluation matrix of manufacturing concepts and methods



Quadrant I includes lean manufacturing techniques, which provide only little support for the handling of product variants. Furthermore, the techniques classified in quadrant I have no special focus on the reduction of inventory stock. Kaizen and Concurrent Engineering are to be found in this quadrant. Both techniques consider new product input during the product development process and offer a rapid adaption of this input into the product. Manufacturing techniques in quadrant II have the capability to manage many product variants, without focusing on a significant contribution to the reduction of inventory stock.

Due to the correlation of these attributes, this combination is seldom found. Therefore, the only manufacturing technique in quadrant II is Total Quality Management. Manufacturing concepts and methods with a higher capability of inventory stock reduction are placed in quadrants III and IV. At the same time, quadrant IV includes manufacturing concepts and methods with a high capability of managing product variants. This combination of capabilities, with slightly different intensity, is only fulfilled by Mass Customization, Modularization and Postponement. According to this classification, Mass Customization, Modularization, and Postponement are the most favourable manufacturing strategies for the wind power industry.

As Mass Customization seems to have the highest capabilities under both criteria, this manufacturing concept was selected to provide the basis for the case study. However, the relevant attributes of Postponement and Modularization could be also considered during the implementation project, if reasonable. Besides Modularization, some attributes of Standardization may be needed during the adjustment of the product architecture that seems to be required for the implementation of Mass Customization.

In general, it is of significant importance whether a business process project is conducted on the enterprise level, within a business unit or on department level. This influences the selection of the right lean manufacturing technique: manufacturing strategy, concept or method. If this is not taken into account, a selected manufacturing technique could turn out to be inadequate (too powerful or too focused) for a given business project. As the researched case study covered the core value chain of PowerWind and involved several departments, the selection of a manufacturing concept was required. Hence, also from this perspective, the selection of the manufacturing concept Mass Customization was reasonable.

3. Research Methodology

3.1 Introduction

The overall objective of this research was to examine the capability of existing manufacturing techniques to reduce wind turbine production costs. The intention of the first research question was the investigation of whether one or more of the existing lean manufacturing techniques could address the current business needs of the wind power industry. As a first step, the existing manufacturing techniques were searched and reviewed in the literature. It soon became apparent that different terms for similar types of manufacturing techniques were in use. As the various types of manufacturing techniques act at different business levels, they had to be assigned to the corresponding business level. Therefore, the different manufacturing techniques needed to distinguish between manufacturing strategies, concepts and methods (Fig. 8). Subsequently, the main characteristics and differences of the found manufacturing techniques were identified. Thereafter, evaluation criteria relevant to the wind power industry were developed. This resulted in the formal criterion “capability to manage product variants” and the competitive criterion “capability to reduce the inventory stock”. Finally, the identified manufacturing concepts and methods were evaluated according to these criteria. The second research question was related to the organizational impact caused by the implementation of a suitable lean manufacturing technique at a wind turbine manufacturer. It was expected that such an organizational change project would influence the behaviour of the employees involved, which in turn could reduce the productivity of the organization (Fig. 6, Lewin (1947)). To answer this question as holistically as possible, the selected lean manufacturing technique was implemented at a wind turbine manufacturer.

In this chapter, various research methodologies and methods are investigated for their suitability in providing an appropriate connection between the research objective and the method of research. For that purpose, several research types and approaches are discussed against the background of the research objective. Finally, the selected research methodology and approach for answering the research question are described and justified.

3.2 Research Design

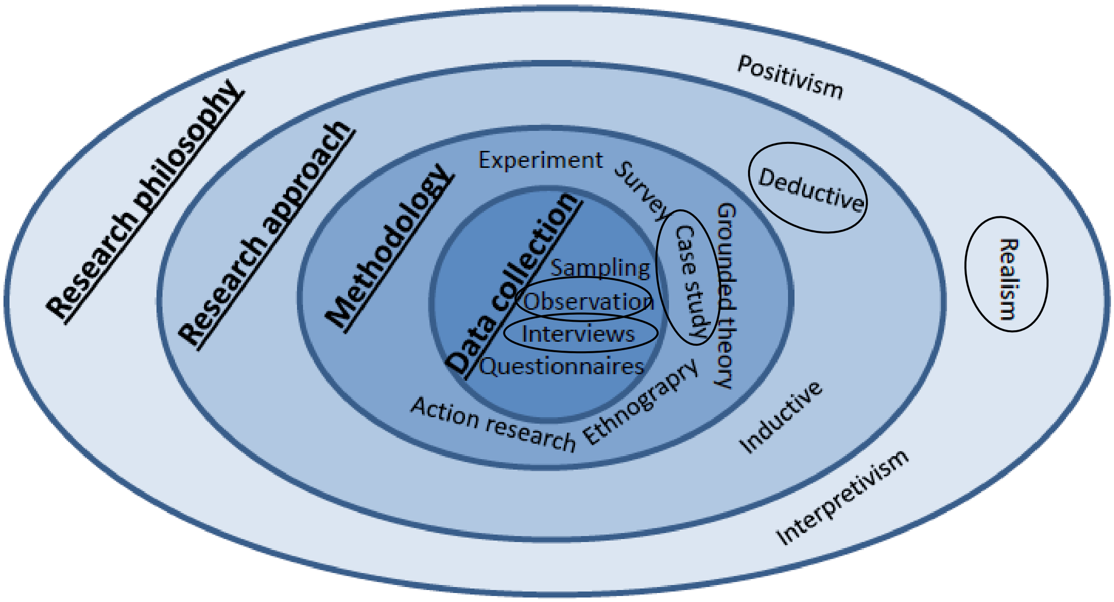
As a first step, the scope of the research design was defined. Within the literature, several proposals for a research design within a business context exist (Easterby-Smith, Thorpe et al. 2002; Saunders, Lewis et al. 2003; Zikmund 2003; Crotty 2011). Two of them were investigated in more detail:

According to Crotty (2011), a research design should follow the path of considering four main aspects:

1. Epistemology - describing the way knowledge is created
2. Theoretical perspective - creating the individual basis for the methodology of the research
3. Methodology - the strategy to achieve the research objective
4. Methods – describing the applied techniques and procedures

Saunders, Lewis et al. (2003) visualize the research approach with an onion model (Fig. 10). The outer layer deals with the question of the research philosophy. This layer establishes a framework for the whole study. The second layer considers the subject of the research approach, which is influenced by the research philosophy but is also the starting point of the research (theory or phenomenon). The third layer is the research strategy, similar to the methodology used by Crotty (2011), which is strongly influenced by the first two outer layers. The fourth layer is the intended time horizon and finally the data collection method, which creates the core of this onion model.

Fig. 10: Research design model acc. to Saunders et al. (2003)



The model of Saunders et al. (2003) offers many alternatives for collecting data to answer the research questions and a clear process of how to choose and justify the appropriate data collection. Therefore, the explanation and justification of the applied research design was based on the research design model acc. to Saunders et al. (2003). The circled terms in Fig. 10 show the choices of research philosophy, research approach, research methodology and type of data collection used in this research.

3.3 Research Philosophy

In the chosen model for the research design (Fig. 10), the definition of the research philosophy is seen as the first decision on the way to answer the research questions (Saunders, Lewis et al. 2003). The terminology for this fundamental research assumption varies within the literature. Besides research philosophy (Saunders, Lewis et al. 2003), the notations ontology (Crotty 2011) and paradigm (Easterby-Smith, Thorpe et al. 2002) are commonly used. All describe the researcher´s perspective or view of the world and how she or he thinks about the world. The research philosophy also depends on the way a researcher thinks about the development of knowledge. And this in turn affects the way the researcher conducts a study (Saunders, Lewis et al. 2003). Within the literature, different types of research philosophies are discussed.

Saunders et al. (2003) define three philosophical views on management research: positivism, interpretivism and realism. Guba and Lincoln (1994), as well as Perry, Reige and Brown (1999), contended that scientific research is conducted within four key paradigms, although they differ in the terminology used to describe the second paradigm: positivism, realism (Perry, Riege et al. 1999) or post-positivism, critical theory, and constructivism (Guba and Lincoln 1994). Crotty (2011) differentiates even more types of research paradigm.
Saunders et al. (2003) direct their literature at postgraduate students and practitioner-researchers, which made it best suited to this research. Their definition of research philosophies is as follows:

Positivism:
Within the positivist paradigm, questions and hypotheses are proposed by the researcher and subjected to empirical testing within a controlled environment that ensures the research outcomes are not influenced by uncontrolled impacts (Guba and Lincoln 1994). The positivist researcher assumes that natural and social sciences measure independent facts about a single understandable reality composed of discrete elements, whose nature can be known and categorized (Perry, Riege et al. 1999).
The corresponding research methodology is primarily quantitative and consists primarily of controlled experiments, tests and surveys conducted on representative samples. Hence, the nature of positivism seems to be suitable for research within the engineering context.

Interpretivism:
The interpretivism paradigm views reality as being socially constructed. People are influenced by their environment and also seek to make own interpretations. This complex world creates unique situations that cannot be reduced to laws or generalisations. However, the Interpretivist argues that generalizability is not of crucial importance (Saunders, Lewis et al. 2003).
The nature of this subjective research paradigm is exploratory and involves the perspectives of all research participants. Therefore, the application of qualitative methodologies is mostly appropriated within the interpretivism paradigm.

Realism:

Realists believe that a reality exists that is independent of human thoughts and beliefs. In the context of business studies this can indicate that people interpret their environment without being aware of social forces and processes that affect them (Saunders, Lewis et al. 2003). To understand this subjective reality, the social forces, structures and processes that influence people's behaviour and interpretations have to be considered. Saunders et al. (2003) therefore conclude that realism shares some philosophical aspects with positivism, but people themselves are not objects to be studied in the style of natural science. The appropriate research methodology is primarily quantitative, but can include qualitative elements such as case studies, experiments or interviews.

As a large part of this study was based in the engineering context, the positivism paradigm, with its emphasis on objectivity and quantitative approach, seemed to be appropriate. However, there are also several arguments indicating the opposite. First of all, the nature of this research was exploratory and therefore not ideally suited to pure quantification (Zikmund 2003). Additionally, the research questions were not posed in terms of verification of a hypothesis. Finally, the research was not conducted empirically within a controlled environment. The investigated business case had a lot of interfaces, involved many different departments and was not within a controlled environment. Rather, the behaviour and perspectives of the people involved were important for the investigation of the implementation of the new manufacturing concept. To consider this a quantitative methodology alone would have been inappropriate.

In general, the exploratory nature of the research and the involved practitioners perspectives made it well suited to the qualitative methodological focus of the interpretivism paradigm (Zikmund 2003). However, the research aim was not only the investigation and interpretation of the different participant´s perspectives on a given business situation. Participants provided an important contribution to the business situation, but further focus was also laid on the value chain performance affected by the new lean manufacturing concept within a complex business situation.

To consider both the participants' behaviour in the investigated business situation and the performance evaluation of the new manufacturing concept, a mixed approach consisting of qualitative and quantitative methods appeared reasonable. This combination created an atypical mixture of methodologies within the interpretivism paradigm (Saunders, Lewis et al. 2003). Furthermore, in some literature general doubts exist about whether interpretivism is an appropriate paradigm within which to conduct business research (Hunt 1991). Hunt concludes that the interpretivist approach does not engage with the economic and technological aspects of business. But that was exactly the core topic of this research: the effects of the implementation of a new technology-based manufacturing concept.

To investigate the organizational effects caused by the implementation of the new manufacturing concept, the dynamics of experiencing change in everyday organizational life had to be captured. These dynamics were studied in a defined business environment. All the social forces, structures and processes that influence the people in this business environment had to be considered. Even if the world outside the investigated business case had influence on the researched business environment and each participant, the realism paradigm allowed a disentanglement of the small “business world” from the world outside. Of course, a dominant reality outside the studied business case existed, but it could only be partly influenced by human beings and had to be adapted by the business environment since it could not be controlled. However, the realism paradigm allowed the disentanglement of the investigated small “business world” from the world outside. In addition, the realism paradigm allowed the use of quantitative and qualitative methods. For these reasons, the realism paradigm appeared to be suited for this research.

3.4 Research Approach

Within the literature, the research approach is differentiated by inductive and deductive approaches. If the research questions are theory-driven, i.e. investigating the performance of a theory in a business context, the research approach is deductive. Otherwise, if the research questions are phenomenon-driven, i.e. starting from a given business phenomenon with the goal to describe this phenomenon by a theory, the research approach is inductive (Saunders, Lewis et al. 2003).

In this research, a lean manufacturing concept, already established in other industries, was applied to a defined business environment. The overall research objective was to confirm or falsify whether this strategy has the potential to improve the value performance of a wind turbine manufacturer and to find out which organizational impacts should to be expected. However, the research questions were not posed in terms of verification or hypothesis. Instead, it was more interesting to balance the organizational impacts caused by the change process and the benefits for the value performance. Based on this, the research approach was clearly deductive. In contrast, if the research started from a phenomenon, with the research objective to develop a theory, the research approach would have been inductive.

From the already existing, and in other industries established, lean manufacturing techniques, one selected manufacturing concept was applied at a wind turbine manufacturer. The focus was on the situational activities triggered by the implementation project and its relation to the overall value performance. In order to explore this, the selected manufacturing concept needed to be implemented, applied and the effects analysed holistically.
Zikmund (2003) defines exploratory research as a way of gaining greater understanding of a concept or clarifying issues. According to him it has three primary purposes: i) diagnosing a situation; ii) screening alternatives; and iii) discovering new ideas (Zikmund 2003). This supported the setting of this research, which included an in-depth diagnosis of the wind power industry, the screening of potential techniques for improvement, and potential practical advice based on the research results. Typically, exploratory research is conducted with the expectation that additional research will also be undertaken in order to provide conclusive proof of the identified phenomenon. Furthermore, it is predominantly qualitative by nature (Zikmund 2003). All these aspects agreed with the characteristics of this research.

3.5 Research Methodology

As the nature of this research was exploratory and a real-time approach was selected to study everyday organizational situations, a qualitative methodology, i.e. a case study, was well suited. A case study is also a key method in the realism paradigm. Moreover, a mixture of qualitative and quantitative methodologies is possible within this paradigm (Zikmund 2003). The research objective was to capture the organizational efforts and benefits of a newly implemented manufacturing concept. To get a holistic overview and understanding of the relevant organizational efforts and benefits, an in-depth single case study approach appeared to be most reasonable. Understanding could be facilitated with a case study approach, by studying individuals in their natural settings. Moreover, a single case study approach allowed in-depth understanding of a real life phenomenon by considering important, contextual conditions (Yin 2008), which is important in the complex business environment studied. According to Yin (2008), a single case study is most promising, and even necessary, when examining real-time mechanisms that organizational members may show when they interact on an everyday basis in their natural setting.

Another argument for choosing a single case design is by conducting a mixed methods approach. In investigating how the organizational change affects employee motivation and productivity, discussions and interpretations of their behaviour provide the main source of data. A combination of both quantitative and qualitative methods can provide the most comprehensive analysis of such complex research problems (Creswell and Plano Clark 2011). According to Yin (2008), a mixed methods study can allow researchers to address more complicated research questions and collect richer and stronger results than by any single method alone. Therefore, a mixed methods study was designed using an explanatory sequential approach that was applied in two distinct phases. As a mixed methods approach can generate a huge amount of data, the data collection and interpretation was a key element of this research approach. According to Creswell and Plano Clark (2011), in a mixed methods study the researcher thinks through the research problem and the research questions in order to select the appropriate research design.

That was also reflected by the sequencing and mixing of strategies to achieve the necessary rigor for the overall interpretation of the results. Creswell and Plano Clark (2011) divide their sequential mixed methods design into a quantitative and qualitative phase. The order of the two research phases is sequential, which means the results of the first phase are used in the second phase and eventually both sets of data are considered. Following this pattern, in this research the quantitative data collection and analysis also occurred before the qualitative data collection and analysis. The quantitative data provided the status of the initial business situation prior to the implementation of a new lean manufacturing concept. This was about capturing a fixed picture and so a quantitative method was suitable. In the course of the project, qualitative methods were applied at points where fluent data collection during a potentially dynamically changing business situation appeared more appropriate. This was designed to allow the measuring of the trend of the changing business and employee behaviour caused by the implementation project.
As a particularly important attribute of the sequential research design, the quantitative data analysis guided the development of an interview guide for the subsequent qualitative data collection.

Even if the low generalizability of single case research is often criticized, in context-specific, real-time research with a focus on obtaining detailed and enhanced knowledge for refining and developing existing theory, the issue of generalization becomes less relevant.

3.6 Data Collection

The case study approach allows the application of different data collection methods, while many existing studies use sociological and anthropological field methods, such as observations, interviews and narrative reports (Saunders, Lewis et al. 2003). In this research, an ethnographic approach for collecting the data was followed. The chosen case study approach combined participant observation, semi-structured group interviews and an initial questionnaire as a source of information. The data collection took place between August 2012 and December 2012. The participation in the implementation project allowed a direct relationship with the participants, while staying in the natural environment of the studied culture. Observation is a very promising and indeed necessary way to study the real-time behaviour that members of an organization exhibit while they interact in their natural setting on an daily basis (Gobo 2008). It is important to investigate the real perspectives, standpoints and day-to-day actions of the employees in the context of their observed behaviour. Participant observation allows not only the observation of the mechanisms of change itself but also a means of learning and understanding how and why certain statements and answers are given during the interviews. Such background knowledge is particularly important for the interpretation of data in a way that respects the specific features of the researched business environment.

The implementation of a new manufacturing concept is a significant change project within a product manufacturer. The changed core business process has an effect on employees from several departments. As a reduction of productivity is expected (Fig. 5) (Lewin 1947), the impact on the employees is an essential parameter for the overall balance of efforts and benefits. Change projects are characterized by the fact that they always have influence on human beings. That is mainly caused by changed working procedures (Coch and French 1948). Even though human beings naturally possess a pioneering and investigative spirit, it is also typical that they strive for safety, hold on to the tried and tested, and therefore tend to be reluctant to change (Lewin 1947; Watson 1971). Compared to pure product development projects, change projects have a stronger influence on working procedures and practices and therefore have to face more emotional resistance. This potential human resistance, possibly changing over the course of the project, needed to be considered in the determination of the overall implementation effort of the new manufacturing concept.

In order to capture a picture of the organizational impacts that was as comprehensive as possible, data from three implementation phases were collected. For that purpose, the selected data collection methods were oriented towards the three phases of the Lewin model (1947): unfreezing, moving and refreezing. Due to limited time and resources, this research covered the unfreezing phase, as well as the beginning and the end of the moving phase. A reliable investigation of the refreezing phase would have required additional months, probably one business year, to gain a representative picture and that was beyond the scope of this research. However, according to the models of Lewin (1947) and Lievegoed (1974), the strongest influence on employee productivity and behaviour is expected during the moving phase (Fig. 6).

In summary, the project phases and corresponding data collection covered by this research were as follows:

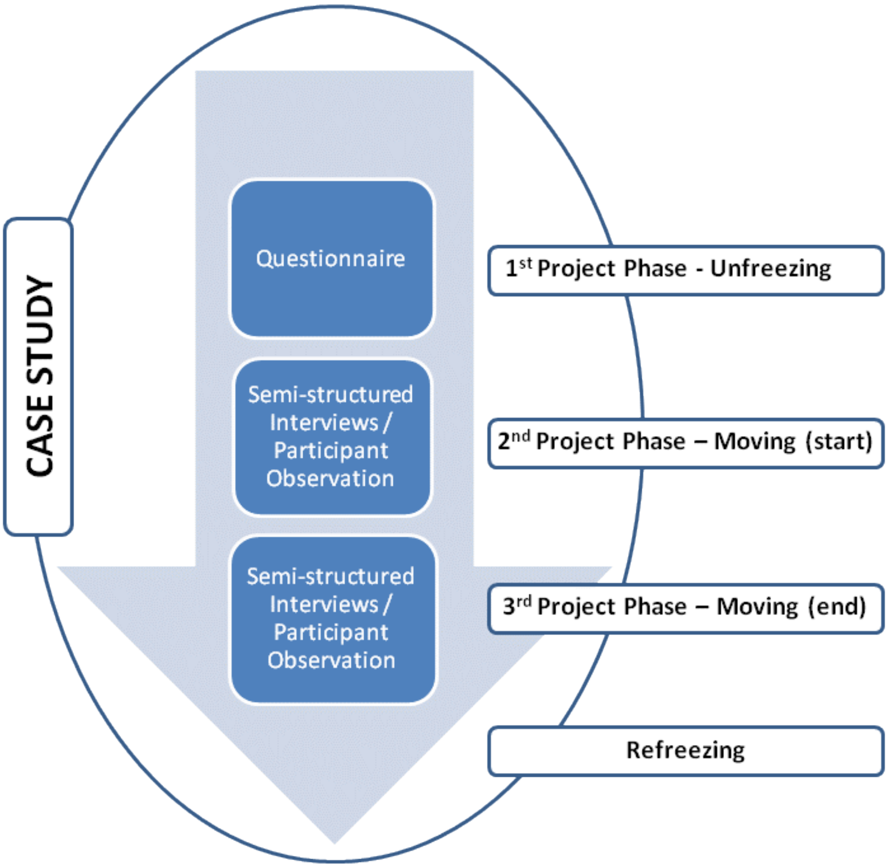
1. In the unfreezing phase, employees and management were prepared for the change project. They received rational information and objectives concerning the change project. It was the first time that the change objectives were introduced to the employees. Prior to that, their expectations and motivations for change were collected using a questionnaire. This was mainly done by asking them for their view on the current business and product situation. In brief, the initial situation of the studied business environment was analysed.

2. During the beginning of the moving phase, the implementation of the new manufacturing concept took place. The employees and their departments had to face different challenges and needed adequate support. This situation, which was likely to be complex, was investigated through semi-structured interviews. Furthermore, the participants were observed during the meetings and their daily work. Semi-structured interviews and participant observation of the involved groups was flexible and quick enough to collect the right data at the right time.

3. At the end of the moving phase, the employees experienced several weeks of the implementation project. Certain changes to the project approach and changed working procedures had to be experienced in the day-to-day business. To capture that, the behaviour and potentially changed attitude of both the individuals and the departments at the end of the implementation was of interest. Therefore, the same employees were interviewed again, using the same semi-structured interview guidelines as during the first interview session.

Fig. 11 provides an overview of the considered implementation phases in the case study and the corresponding methods for data collection.

Fig. 11: Data collection in different case study phases



3.6.1 Questionnaire

Prior to the start of the implementation of the new manufacturing concept, a questionnaire was constructed, as well as tested for validity and reliability with a small group of selected colleagues. Finally, the questionnaire was administered to the participants. The overall aim of the questionnaire was to capture and analyse the initial situation of the business environment and the employees' readiness for change. As the position of the researcher, as a colleague and direct supervisor, could have influenced the answers, direct questions about motivation and readiness for change were avoided. Instead, an attempt was made to get information about these topics by using indirect questions. For instance, questions were asked about the perception of the current manufacturing and value chain performance, as well as about expectations of a new manufacturing concept. The answers to these indirect questions provided an indication of the level of readiness for change.

The results of the questionnaire served as a basis for measuring the existing mood, motivation, opinion regarding the current strategy and readiness for change. A solid snapshot of the initial situation was essential for the evaluation of potential changes in employee attitude later in the project. It marked the starting point of the employees' mood and motivation and was the benchmark for the measurement of further development of mood and motivation. As a rather static picture was taken, the use of a questionnaire was sufficient.
The objective was to gain a representative overall result, as well as department-specific results that considered the different perspectives of the departments involved. Therefore, four departments, mainly involved in the customer order processes of PowerWind, were considered: Sales/Marketing, R&D, Purchasing, and Production. Besides the members of the implementation project, further employees from these departments also participated in the questionnaire. Furthermore, the questionnaire considered junior- and senior-level employees of PowerWind.

An initial questionnaire has, against the background of the researched project phase, the following main advantages (Popper 2004):

- large amounts of information can be collected from a large number of people in a short period of time,
- the results of the questionnaires can usually be quickly and easily quantified,
- the results can be analysed more scientifically and objectively,
- the quantified data can be easily ordered by the different departments, used for comparisons and provide a good preparation for the development of the qualitative data collection (interviews).

These advantages met the research needs at the beginning of the implementation project exactly. As the aim was to capture a rigid picture of the initial readiness for change, the application of a questionnaire for initial data collection appeared to be more appropriate than the use of interviews. Furthermore, the existing mood, motivation and relevant concerns of the employees were unclear at the beginning of the research project. Therefore, a clear direction for asking questions did not yet exist. After the analysis of the quantitative data, potential characteristics and anomalies could be identified and these led to a better understanding of the given situation and made it possible to develop appropriate interview questions for the later project phases.

The main disadvantage of questionnaires is that people may read different meanings into each question and therefore reply based on their own interpretation of the question. However, the splitting of questions into shorter and more easily understandable questions can avoid this bias. Furthermore, the use of specialized and overly sophisticated terminology was avoided. As already mentioned, the avoidance of misinterpretation and misunderstandings was tested with a small group, consisting of trusted colleagues who were not directly involved in the implementation project.
Popper (2004) additionally claims that one possibly fruitful piece of information resulting from emotions, behaviour, feelings etc. of the participants is not considered by questionnaires. However, the consideration of emotions, behaviour and feelings caused by the implementation of a new manufacturing concept was covered by the interviews in the qualitative research phase. The purpose of the questionnaire prior to the implementation of the new manufacturing concept was to capture the initial business situation and employee mood as accurately as possible. This organizational snapshot provided the starting point for the approach to further research.

Questionnaires are structured ways of collecting quantitative data from a population or a sample of a population (Easterby-Smith, Thorpe et al. 2002). The questionnaire was sent out by email and self-administered using the online tool Q-Set. Therefore, the layout needed to be well produced. According to Easterby-Smith et al. (2002), the following questionnaire principles are good practice:

1. Short covering letter, explaining the purpose of the research
2. Brief introduction explaining how to complete the questionnaire
3. Keep similar types of questions together in bunches
4. Start with simpler factual questions, moving on to opinions or values later

These principles created the basis for the initial questionnaire. After the definition of the objectives, uses, participants and principles of the questionnaires, a decision had to be made on whether the questions should be open- or closed-ended.

Open-ended questions can typically broaden the scope of possible responses and assist in formulating other, more specific, questions. They therefore tend to provide more qualitative data. In contrast, closed-ended questions provide a limited scope of responses. A limited scope of responses supports the consideration of a large amount of respondents and an easy scaling of interesting parameters. The participation of many employees in the departments involved was important, as it was not clear whether the readiness for change was the same in each department. Both the large group of participants and the catalogue of interested attributes led to the decision to use closed-end questions with similar scale categories.

As suggested by Easterby-Smith et al. (2002), the questionnaire started with simpler factual questions, such as ‘How do our product variants and features cover the customer needs?’ Then, questions on the valuation of PowerWind´s value chain processes and the contribution of the current manufacturing concept were asked. Finally, opinions on the ability of a manufacturing concept to support the customer order process and the overall value performance were gathered. As already mentioned, direct questions about the attitude of the employees to the change project were avoided, as they knew that the questionnaire was organized by their Project Manager, and that could have caused bias in their answers. Asking about the existing value performance and the expectations of the results of the change was designed to allow the employees to answer more honestly.

It was expected that, at the very least, a rating of the current value performance and the contribution of the existing manufacturing concept would be received. The result of this rating reflected the given satisfaction of the employees in terms of the business process and an indication of their readiness for change. Alongside other factors, the initial mood and motivation of the employees contributed to the generation of the interview guide for the qualitative research phase.

The final questionnaire consisted of the following 10 questions:

1. Question: I am an employee of the following department:
   1=Purchase, 2=Production, 3=Project Management, 4=R&D, 5=Sales/Marketing

2. Question: How well do our products meet customer requirements?

3. Question: How well can our products and product features be communicated to customers?

4. Question: How do you rate the general processing of customer orders in your company?

5. Question: How high is the failure rate in the procedures for processing customer orders?

6. Question: How fast is the speed of each working step during the processing of customer orders?

7. Question: How do you rate the flexibility of the product portfolio in reacting to short-term customer needs?

8. Question: What influence does the product portfolio have on the processing of customer orders?

9. Question: What influence does the product portfolio have on the cash flow of a wind turbine manufacturer?

10. Question: What influence does the product portfolio have on the manufacturing concept of a wind turbine manufacturer?

The results, obtained and summarized by the online tool Q-Set, are shown in Appendix 1. Q-Set is an online tool which enables the creation and analysis of questionnaires. The invited participants receive a link to the questionnaire by email and are guided through the questionnaire by the online tool.

3.6.2 Semi-structured Interviews

The further development of employee mood and motivation was captured using semi-structured interviews during the qualitative research phase. Semi-structured interviews as a research method have several advantages. Semi-structured interviewing, according to (Bernard 2006), is best used when more than one chance to interview is available. When conducted after the regular meetings of the working groups, semi-structured interviews allow the capture of opinions from many participants at different stages of the change project, within a relatively short timeline. That allows the capturing of a fluent situation and enables the identification of possible trends. Furthermore, the interactive character means that it is possible to recognize whether or not a question and the context are well understood. Moreover, a semi-structured interview approach offers the possibility of controlling and adjusting the questions according to the understanding of the interviewee.

During the interviews, an interview guide was used containing a list of questions and topics that needed to be covered during the conversation. The semi-structured interview guide provided a clear set of instructions for the interviews, supporting the reliability and comparability of the gathered qualitative data. Even if the questions were listed in a particular order, a semi-structured interview allows a certain flexibility to follow topical trajectories in the conversation and change the order if appropriate. According to Bernard (2006), semi-structured interviews are often preceded by observation, informal and unstructured interviewing in order to allow the researchers to develop a keen understanding of the topic of interest, which is necessary for developing relevant and meaningful semi-structured questions.

The interviews were embedded into regular working meetings and had the character of a normal working discussion. This gave the interviewed employees the freedom to express their views and feelings in their own terms and within a relatively comfortable atmosphere. Each interview was conducted with a paper-based interview guide that had enough space for notes next to each question and topic. Notes were also taken to capture characteristic non-verbal cues and observations. In order to control bias, a full record of the interviews was developed shortly after the event, in the format of transcripts, to develop familiarity with the raw data (Saunders, Lewis et al. 2003).

The interview questions allowed the capture of the development of readiness for change during the project progress. Within the literature, several personal and situational indicators for readiness for change are described. Trust in the organization and the supervisor is often mentioned as a situational indicator (Armenakis, Harris et al. 1993; Lines 2004). Some studies deal with personal indicators such as dispositional resistance (Oreg, Bayazıt et al. 2008) and job satisfaction (Cunningham, Woodward et al. 2002). Both indicators, personal and situational, were studied within the implementation project:

- situational indicators:
  - trust in supervisor
  - trust in organization
- personal indicators:
  - dispositional resistance
  - job satisfaction

Here again, the employees were not asked directly about these indicators, as there was a risk of bias. In particular, the question about trust in the supervisor was sensitive, as the project manager was the researcher. Therefore, the appropriateness of the selected manufacturing concept was questioned. As the concept was chosen by the project manager, the answers showed a certain trust or mistrust in the project manager and his choice. Comparably difficult was the question about the dispositional resistance of each individual. As some could have had barriers to giving direct statements about their own resistance during the group sessions, a question about the need for a new manufacturing concept was asked instead. According to Oreg (2008), individuals with resistance to change are seeking routine and would prefer to find arguments stating that there is no need for change. Trust in the organization was checked by the question about organizational capabilities, and job satisfaction was monitored by asking about the employee’s current motivation for the implementation project.

In summary, the interview guide contained questions addressing the following areas:

1. Need for new manufacturing concept
2. Appropriateness of new manufacturing concept
3. Organizational capabilities for implementation
4. Motivation of employees for implementation

The complete interview guide is included in Appendix B.

3.6.3 Participant Observation

Participant observation combines the controversy of having to participate in the natural setting of the actors observed, while at the same time keeping sufficient distance to neither influence the behaviour of the actors nor lose the ability to see the phenomena from the outside, through the eyes of a stranger (Gobo 2008). According to him, the conducting of participant observation allows the involvement of a direct relationship with the actors, as well as staying in the natural environment of the culture being studied. Easterby-Smith, Thorpe et al. (2002) define different roles for participant observation in the context of organizational research. They differentiate between four roles:

1. researcher as employee
2. research as explicit role
3. interrupted involvement
4. observation alone

The role of “researcher as employee” was ideally suited to this study. Within this role, the researcher works within the organization, alongside others, to all intents and purposes as one of them (Easterby-Smith, Thorpe et al. 2002). This role is appropriate when the researcher needs to experience the work and to collect the data at first hand. This was considered important to this research, as the implementation of the new manufacturing concept would affect several different departments. Only prompt and direct conversation with the employees could allow a holistic understanding of their perspectives and standpoints on the newly implemented manufacturing concept. It allowed not only the observation of mechanisms of change, but also a means to learn and understand how and why certain problems and reactions occurred during these mechanisms. Such background knowledge was particularly important to interpret the data in a way that respected the specific features of the researched business environment. However, being aware of the impact and change that could have been induced because of the presence of the researcher as project manager, an attempt was made to minimise awareness that a researcher was present during the project. Bias caused by involvement can be minimised if, during day-to-day business, the employees in the study think of the researcher as their colleague or supervisor, rather than as a researcher. This situation is easier if the researcher is a long-term employee and has been in their role for many years. Regular discussions on this issue with familiar colleagues helped prevent such bias. Furthermore, the regular distribution of meetings allowed the observation of possible changes in the perception of the organizational members.

Besides the regular project meetings, there was also the opportunity to attend several meetings in other departments where the change project was also discussed. Additionally, employees were regularly visited at their working place during the completion of the tasks resulting from the change project. During these events, comments, mood, and motivation were observed and noted.

3.6.4 Data Collection Occasions

The quantitative and qualitative data was collected within a period of about three months. Based on the implementation project, three teams were established. Each team consisted of 6 - 7 employees. In total, 16 employees from three departments (Sales/Marketing, Purchase, R&D) were involved in the implementation project and participated in the semi-structured interviews. Prior to that, 25 employees from five departments (Sales/Marketing, Purchase, R&D, Production, and Project Management), directly involved in the customer order process of PowerWind, participated in the questionnaire. The first implementation team mainly consisted of sales employees. The main task of this team was the collection of all relevant customer and market requirements. Another team, consisting of sales and technical employees, discussed the technical rationalization of these requirements. This team had to find the corresponding technical solution or feature to realize the customer´s wishes. The last team had the task of developing a variant manager to make the product configurable. It was a mixed team consisting of R&D, Sales and Purchase employees. During the three months, all three teams had weekly meetings to work and report on the project progress. Once a month, a big informal meeting with all three teams was scheduled. The semi-structured interviews were conducted during the first and the last meeting of each team. That meant that each team was interviewed two times directly after the regular team meeting. Generally, the whole data collection was based on two organizational change phases according to Lewin (1947): unfreezing and moving. Whereby, the questionnaire was conducted during the unfreezing phase (1^{st} project phase) and the semi-structured interviews during the beginning and the end of the moving phase (2^{nd} and 3^{rd} project phase). In total, 6 semi-structured interview sessions were conducted. The interviews were conducted as group interviews of 6 - 7 employees, during which each employee had the opportunity to answer the questions and to give comments.

The following table gives an overview of the formal occasions for data collection (Tab. 3).

Tab. 3: Formal occasions for data collection

Data collection method	Occasion
<u>1st Project Phase - Unfreezing:</u>	
Questionnaire	Questionnaire (25 participants) conducted prior start of implementation project (between 17th August and 3rd Sept. 2012)
<u>2nd Project Phase - Moving:</u>	
1st Semi-structured interviews/ Participant Observation	10th September 2012: Team Product Rationalization
	26th September 2012: Team Technical Feasibility
	19th October 2012: Team Product Configurator
<u>3rd Project Phase - Moving:</u>	
2nd Semi-structured interviews/ Participant Observation	29th October 2012: Team Product Rationalization
	24th October 2012: Team Technical Feasibility
	9th November 2012: Team Product Configurator

In summary, the qualitative data was collected during the first and last meeting of each working group, using semi-structured interviews and participant observation. This rigid approach meant it was possible to see precisely which events led to which consequences and to preserve a chronological flow that allowed the identification of possible organizational changes during the progress of the project. That was designed to support data analysis and the achievement of fruitful explanations. By applying this approach it also became possible to go beyond initial conceptions and to generate or revise conceptual frameworks (Miles and Huberman 1994).

3.7 Research Data Analysis

The quantitative and qualitative data were triangulated to find the answer to the second research question: how can a lean manufacturing concept contribute to the reduction of production costs and retain project flexibility? Triangulation means that different data collection techniques are used in order to get a full understanding of the observed situation. It is a tool for cross-comparison of the data collected by different techniques (Creswell and Plano Clark 2011). For this research, this means that conclusions, which were initially drawn from the questionnaire, also led to the development of an interview guide and eventually to the coding system for the qualitative data analysis. To this end, it was investigated to what extent wind turbines can be standardized or modularized and simultaneously provide sufficient variety for the diverse market and project requirements. Furthermore, it was important to explore how much effort was needed for the adjustment of the wind turbine product architecture, in order to implement a lean manufacturing strategy in the organization. Finally, it was relevant to obtain results regarding the potential benefits (e.g. reduced working capital) that could be achieved, based on a real project pipeline.

To answer this question, the chosen lean manufacturing concept was implemented at a wind turbine manufacturer. The implementation project of the new manufacturing concept was the core source for data collection and the following data analysis provided answers to the research question. Prior to the implementation project, a questionnaire was conducted amongst the employees involved in the implementation project. The main objective of the questionnaire was the establishment of an interview guide for the subsequent semi-structured interviews. The semi-structured interviews were conducted during the implementation project at PowerWind. This mixed methods approach required quantitative and qualitative data analysis. Both types of data analysis in this research are introduced in the following chapters.

3.7.1 Quantitative Data Analysis

Both types of research data, quantitative and qualitative, contributed to the achievement of the research objective: a holistic evaluation of the business impact and effort caused by the newly implemented manufacturing concept, as well as department-specific results. Hence, the participants of the questionnaire were employees from the R&D, Purchasing, Production and Marketing/Sales departments. All chosen participants from these departments were strongly involved in the business value chain process and the implementation project of the new manufacturing concept. In total, 25 co-workers were asked to fill in the questionnaire. Each department was represented by employees with different experience levels. Department directors were included, as well as senior- and junior-level employees. This allowed a more independent view on value performance. The questionnaire design was structured. A multiple-choice form with five scale categories for each question was used. This allowed sufficient assessment precision, with a minimum risk of becoming too detailed. The simple form structure was designed to motivate the participants to answer all ten questions. The specific analysis of quantitative data depends on the survey design and the scale type of replies (nominal, ordinal, interval, ratio, etc.) (Kitchenham and Pfleeger 2003). Due to the fact that a five-scale-based questionnaire was used, the results are ordinal data. As the questionnaire only served to capture a picture of the initial business environment and to establish an interview guide for the qualitative data collection, this simple approach of quantitative data analysis appeared to be sufficient.

3.7.2 Qualitative Data Analysis

The collection of data concerning the organizational impact caused by the implementation of the new manufacturing concept during the 2nd and 3rd project phases ("moving phase") was realized by semi-structured interviews and participant observation. After the capture of data relating to the initial organizational situation, particularly the mood and readiness for change of the employees, the further development of these factors was captured through statements from, and the actions and behaviour of the employees during the following two project phases.

Within the literature, several approaches for qualitative data analysis and interpretation are described. According to Creswell and Plano Clark (2011), the handling and interpretation of comprehensive and numerous data requires a structured and systematic data analysis. Punch (2005) defines three different components for a systematic data analysis process:

- data reduction,
- data display,
- drawing and verifying conclusions.

However, conclusions are drawn not only after the analysis of data but also partially during it. The subsequent analysis is usually based on a common set of principles (Miles and Huberman 1994):

- transcribing the interviews;
- immersion within the data to gain detailed insights into the explored phenomena;
- development of a data coding system;
- linking to codes or units of data to form overarching categories or themes which may lead to the development of theory.

According to Patton (2002), approaches for undertaking qualitative data analysis can be divided into three categories:

- the story-telling approach, exploring the use and meaning of language such as discourse and conversation analysis;
- the theory-developing approach, typified by grounded theory;
- the analytical approach, describing and interpreting different participants' views by content, thematic or framework analysis.

Thematic and content analysis are common methods for qualitative data analysis and are widely described in the literature. They consist of interpretive processes in which data are systematically searched for patterns, in order to provide an insightful description of a studied phenomenon (Miles and Huberman 1994). The framework approach has many similarities to thematic and content analysis, particularly in the initial stages when recurring and significant themes are identified. However, a framework analysis emphasizes even more strongly the transparency in data analysis and the links between the different stages of the data analysis (Smith and Firth 2011). Analytical approaches, such as content, thematic or framework analysis are gaining popularity because they systematically and explicitly apply the principles of undertaking qualitative analysis to a series of interconnected stages that guide the process (Smith and Firth 2011). Analytical frameworks are based on categories that the analyst defines, based on the collected data. According to Patton (2002), these can be processes, key issues, interview questions or sensitizing concepts.

To handle the amount of data collected in this research and to draw rigorous and relevant conclusions from it, a systematic and disciplined approach to data analysis was considered appropriate. Such an approach also correlated best with the chosen research paradigm. Furthermore, the entire process, from data to conclusions, should be traceable and transparent for readers and further researchers (Punch 2005). Therefore a framework analysis was considered as best suited to this research.

As a first step, the collected data should be reduced in order to identify the most relevant meanings. For this purpose, the qualitative data should be categorized based on core consistencies and meanings (Patton 2002). Within this research project, an interview guide was developed, based on the analysis of a questionnaire amongst the employees who were most involved with PowerWind´s customer order process (Appendix B). The interview guide constituted a descriptive framework for both the qualitative data collection and analysis. Consequentially, the answers from the different respondents were classified according to the topics in the interview guide.

All the semi-structured interviews were carried out in German. The protocols were, as a result, all written in German. However, all the codes were in English, and all quotes used in the dissertation have been translated into English. Quotes relevant to defined topics were written down in an Excel spreadsheet and a few initial keywords describing the specific quotes were written next to the quotes.

The classification categories were based on the question areas of the interview guide (3.6.2):

1. Need for new manufacturing concept;
2. Appropriateness of new manufacturing concept;
3. Organizational capabilities for implementation;
4. Motivation of employees for implementation.

The keywords from each answer were classified according to these categories. By comparing and contrasting the keywords with each other it was possible to formulate different valuations for each category.

Table 4 provides an overview of how the collected data were analysed. The interviewee numbers “S1”, “P1”, etc. refer to the department and person interviewed. Instead of the employee´s name these acronyms were used, to enable both their privacy and the traceability of their participation in the working groups and interview sessions. For instance, all Sales employees were abbreviated by the letter “S” following a number, correspondingly all Purchase employees by “P”, all Engineering employees by “E”, etc.

The quote lists the statements the interviewee made (translated into English). The last three columns show the keywords, category and valuation that describe and evaluate each quote.

Tab. 4: Examples of qualitative data analysis

Inter-viewee	Quote	Keywords	Category	Valua-tion
S1	"I did not know that we have such difficulties in manufacturing our wind turbines. For me it is a problem of R&D and production. The production will always have issues with the headquarter in Hamburg because of the distance (note editor: 180 km) to their facility in Bremerhaven."	No difficulties in manufacturing, problem of R&D and production because of long distance	Need for Implemen-tation	No need
P1	"It is good that the new manufacturing concept covers all involved departments. I hope that this will avoid the process and communication failures within our value performance."	All departments involved, avoidance of communication failures	Appropria-teness of manu-facturing concept	Appro-priate
E1	"We have to distribute the implementation effort over all involved departments and not left everything at the R&D department. Otherwise I have serious doubt whether we can manage this project in the defined timescale."	Distribute implementation effort, doubts on timeline	Capability of organization	Moderate capability
E2	"The reduction of disturbing factors during our daily work is my motivation. I hope that this will happen when all department involved in the value performance are disciplined enough to follow the process."	Reduction disturbing factors, discipline and reliable processes	Motivation of employees	Motivated

The codes represent the facts described in the qualitative data and support an objectivistic approach. They can be treated as surrogates for the quotes and the analysis can focus on the codes instead of the full quotes. The reduction from quotes to codes allowed the analysis of the qualitative data, the categories and their valuation.

3.8 Limitations of Research Methods

Qualitative research methods, such as case studies, participant observation and in-depth semi-structured interviews do not only bring advantages; they also come with some form of limitation. One aspect to consider in individual interviews is the high level of influence that the researcher can have on the respondents (Saunders, Lewis et al. 2003). In particular, the working relationship between participants and the researcher poses a potential risk of interviewees being reluctant to disclose their true feelings and views. To avoid this phenomenon, the research purpose was thoroughly explained to the participants prior to the project and the anonymity of collected data during the case study and the interviews was emphasized. An attempt was made to identify any signs of unease or reluctance around particular questions during the interviews. That was particularly necessary during the first interview session with the Sales and Purchase employees who were not yet familiar with the researcher as he was not their supervisor in the daily business. The application of semi-structured interviews supported the creation of an environment in which the participants became more relaxed, felt free to voice their opinions, and built trust in the group. Finally, this approach contributed to a reduced risk of bias.

Although the analysis followed a defined framework, some risk of personal interpretation remains. Conducting a questionnaire and detailed kick-off meeting prior to the start of the implementation project and the semi-structured interviews contributed to a reduction of this risk. Furthermore, it had to be taken into consideration that the outcomes are interpreted from a personal point of view. Regular personal reflections on this risk and reflective discussions with management colleagues on subjective perception helped to reduce this risk.

In addition, participant observation is subject to the biases of the observer. However, that was counteracted by the use of multiple methods to gather data. While participant observation was used to collected data by observing the actions and behaviour of the organizational members, the semi-structured interviews found out what they were thinking.

Both data collection methods, observation and interviews, should show a certain correspondence in order to provide reliable data. This approach allowed a cross-validation of the collected data.

Furthermore, the conducting of a questionnaire had certain limitations. In particular, the registration of emotions and feelings was not possible. Also, there was no way to recognize whether the responses were truthful. The first disadvantage was outweighed by the advantage that many responses could be collected and therefore employees from all departments involved in the value chain were considered within a relatively short time period. In addition, as the intention was to capture an initial business situation and obtain a benchmark for further data analysis, the conducting of a questionnaire appeared to be appropriate. The risk of untruthful responses was reduced by the use of non-direct questions.

Finally, all research findings were based on a single case study. Therefore, the research findings cannot necessarily be generalized without further research. However, it was possible to draw a number of conclusions from the case study and to contribute to building the basis for sector-wide research on lean manufacturing strategies in the wind industry. The depth of the answers to the research questions was expected to be greater. Further case studies that focus on the implementation and application of new manufacturing strategies could help to increase the reliability and validity of this research.

3.9 Ethical Considerations

As the research was conducted within a business environment, several ethical issues had to be considered. Any information solicited was gathered only on the basis of informed and organizational consent. As the research topic was based on data that may be perceived to be confidential in nature, the following arrangement was made: before conducting the interviews, the voluntary participation each interviewee, confidentiality and anonymity were assured.

As well as being voluntary, no form of incentive or reward was given to encourage individuals to participate. When approaching colleagues within the organization to see if they would participate in interviews, individuals were granted the right to privacy and were not pressurized or coerced in any way to participate. Also, interview questions were formulated sensitively with the intention to avoid causing any discomfort or stress to the interviewee.

4. The Case Study

4.1 Quantitative Data Analysis – 1st Project Phase “Unfreezing”

At the beginning of the implementation project, the “unfreezing” phase according to Lewin´s (1947) model, quantitative data were collected (Fig. 13). The quantitative data were collected using a questionnaire conducted between 17th August 2012 and 3rd September 2012 at the company headquarters, located in Hamburg, Germany. The questionnaire was sent out to 25 employees who were involved in the implementation project for the new manufacturing concept. The questionnaire contained 10 questions (appendix A) with a corresponding multiple-choice answering system. Following (Likert 1932), each question could be answered with a five-point rating.

In the first question, the employees had to say which department they belonged to. The evaluation of the answers to the first question led to table 5, which provides an anonymous overview of the participating employees and their departments. Furthermore, a statement about their response in the questionnaire is given. In total, 23 valid responses were collected, which corresponds to a response rate of 92 %.

Tab. 5: Overview participants in questionnaire

No	Date	Department	Completed: YES	Completed: NO	Missing answers
1	17/8/2012	Production	X		Q2
2	20/8/2012	Purchase	X		Q2, Q3
3	20/8/2012	Purchase	X		
4	20/8/2012	Purchase	X		
5	20/8/2012	Project Manage.	X		
6	20/8/2012	R&D	X		Q4
7	20/8/2012	Production	X		
8	20/8/2012	Purchase	X		
9	20/8/2012	Project Management	X		
10	20/8/2012	Production	X		
11	20/8/2012	?		X	
12	20/8/2012	R&D	X		
13	21/8/2012	Project Manage.	X		
14	21/8/2012	Production	X		
15	21/8/2012	Sales/Marketing	X		
16	21/8/2012	R&D	X		
17	21/8/2012	Sales/Marketing	X		
18	22/8/2012	R&D	X		Q2, Q3, Q4, Q6, Q7
19	22/8/2012	Sales/Marketing	X		
20	23/8/2012	Sales/Marketing	X		
21	24/8/2012	?		X	
22	27/8/2012	Sales/Marketing	X		
23	27/8/2012	R&D	X		
24	27/8/2012	R&D	X		
25	3/9/2012	Sales/Marketing	X		

The collected data were distributed over the departments as follows:

1. Purchase: 4 responses (17.4 %)
2. Production: 4 responses (17.4 %)
3. Project Management: 3 responses (13.0 %)
4. Research & Development: 6 responses (26.1 %)
5. Sales/Marketing: 6 responses (26.1 %)

In general, it is positive that a very high response rate was achieved, with relatively few invalid answers. That offered a balanced distribution across all departments involved in the researched value chain. The highest number of responses came from the Sales/Marketing and R&D departments, which corresponds to the impact and effort the new manufacturing method was expected to cause in those departments.

The remaining questions 2 to 10 were answered as follows:

Question 2:
How well do our products meet customer requirements?

very well	0
well	15
medium	5
poorly	0
very poorly	0
total	**20**

In general, the PowerWind employees were very confident in the wind turbines they manufacture. Throughout all departments, a significant identification with the products existed. That is the main reason why the employees felt that the wind turbines they offer cover the market and customer requirements.

Question 3:
How well can our products and product features be communicated to customers?

very well	0
well	7
medium	12
poorly	2
very poorly	0
total	**21**

There was only an average level of confidence that the products and features offered can be easily communicated to the market. The rating of the capability of technology communication was one level lower than the rating of the technology itself. Two employees even had the feeling that the technology could only be communicated poorlyly. Compared to the good rating of the product and product features, there was room for improvement in communication capability.

Question 4:
How do you rate the general processing of customer orders in your company?

very well	0
well	1
medium	8
poorly	11
very poorly	1
total	**21**

The question concerning the performance of customer order processing delivered significant information. More than half of the employees rated the process from order to delivery as poorly or very poorly. Especially in the Purchase and R&D departments, where 75 % of the employees rated it as poorly or very poorly, the existing customer order process was seen negatively. On the other hand, five out of six Sales/Marketing employees valued the customer order process at a medium level. Even if this was also an inadequate result, it showed that the first part of the value chain (Sales/Marketing) valued it more highly than the subsequent parts (R&D, Purchase, Production, Project Management). It could also be concluded that the poor value chain performance after the sales activities was not visible to the sales employees. That in turn would mean that no seamless value chain existed and the tracking of sold wind turbines, as well as the communication between the sales department and the departments involved later, was insufficient.

Question 5:

How high is the failure rate in the procedures for processing customer orders?

very high	1
high	5
medium	14
low	3
very low	0
total	**23**

The failure rate was also valued highly by employees in the Purchase department. Three out of four employees valued the failure rate as high.

Question 6:

How fast is the speed of each working step during the processing of customer orders?

very fast	1
fast	3
medium	14
low	3
very low	1
total	**22**

The question about speed delivered a balanced result. In general, the speed of customer order processing was seen medium.

Question 7:

How do you rate the flexibility of the product portfolio in reacting to short-term customer needs?

very high	3
high	5
medium	10
low	3
very low	0
total	**21**

Production employees mostly rated flexibility in relation to short-term customer needs as high or very high. Three out of four Production employees answered "high" or "very high" to this question. This evaluation was probably based on their daily experience of modifying wind turbines spontaneously due to customer requests. This modification work was often done without released R&D documentation.

Question 8:
What influence does the product portfolio have on the processing of customer orders?

very large	8
large	5
medium	9
low	1
very low	0
total	**23**

The answers to this question provided a picture of the expectations the employees had for a modified product structure and architecture. They clearly correlated the poor performance of the customer order process with the product itself. It was recognized that the existing product architecture and structure of the bill-of-materails did not match the process requirements of the given markets. The employees had the feeling that most of the sold product variants were not fully engineered and had gaps in their documentation. Even four of the six R&D employees, who are responsible for the product design, recognized this correlation.

Question 9:

What influence does the product portfolio have on the cash flow of a wind turbine manufacturer?

very large	7
large	8
medium	5
low	3
very low	0
total	**23**

The correlation between the production architecture and the cash flow situation of the wind turbine manufacturer was seen as even more important. Two-thirds of the participating employees saw a large or very large influence on cash flow caused by the product architecture.

Question 10:

What influence does the product portfolio have on the manufacturing concept of a wind turbine manufacturer?

very large	11
Large	9
medium	1
Low	2
very low	0
Total	**23**

Finally, a very strong relationship between the product architecture and the manufacturing concept was recognized by the employees (87%). This showed that the employees involved in the change project understood the need for a change of manufacturing strategy. Furthermore, they had already shown an understanding of the correlation between the manufacturing strategy and possible consequences affecting the product architecture. Based on this, the planned implementation approach and its possible consequences for the business and the product could be easily communicated in more detail during the project kick-off meeting on 3rd September.

In general, the answers showed that the employees had a good understanding of the value performance at PowerWind and the main factors that affect the customer order process. This was highlighted by the answers to the questions regarding the correlation of the manufacturing concept and the value performance. Furthermore, there was significant dissatisfaction with the existing value process and room for improvement (question 4). Both the dissatisfaction with the status quo and the expectation that a new manufacturing concept could be a key solution indicated a readiness for change. Even in the R&D department, where the change project probably caused the largest amount of work, most employees saw the need for change. From this, it can be stated that a low dispositional resistance to the change project existed, although a certain resistance was seen amongst the employees of Sales/Marketing. In summary, the positive attitude of the employees could be an indication of high employee motivation regarding the implementation of a new manufacturing method. That in turn meant that, even with the dissatisfactory value performance, a good level of job satisfaction existed amongst the employees.

The questions about the appropriateness of the selected method and capabilities of the organization, which could result in the situational opinions about trust in supervisor and organization, could not have been asked in the questionnaire because the selected manufacturing method was explained in detail after the questionnaire phase, in a project kick-off meeting on 3rd September.

4.2 Qualitative Data Collection – 2nd and 3rd Project Phase "Moving"

The qualitative data collection was conducted with semi-structured interviews and participant observation to explore the development of the quantitative results. The quantitative data identified that the employees were convinced that the wind turbines they develop, produce and offer to the market cover the needs of customers and markets. However, they did not believe that the product technology could be sufficiently communicated to the market. They were also not satisfied with the existing customer order process. Furthermore, the results showed that the employees working in the later phases of the value chain

(Production) were more dissatisfied than those working at the beginning (Sales/Marketing). That in turn indicated that the customer order process was not seamless or supported by good communication, which would allow the employees to have a more holistic view on the process.
On the other hand, the quantitative data indicated that the close relationship between the overall value performance and the manufacturing concept was well understood by the employees. Furthermore, as the employees believed the new manufacturing concept could improve the customer order process, a high readiness for change could be assumed.

The following semi-structured interviews were designed to capture the evolution of readiness for change during the progress of the project. As developed in chapter 3.6.2, the interview guide used included questions that captured situational indicators (trust in supervisor and trust in organization) and personal indicators (dispositional resistance and job satisfaction). This led to the underlying questions regarding:

1. Need for new manufacturing concept (dispositional resistance);
2. Appropriateness of new manufacturing concept (trust in supervisor);
3. Organizational capabilities for implementation (trust in organization);
4. Motivation of employees for implementation (job satisfaction).

Finally, the guide for the semi-structured interviews was established as follows:

1. Need
   - 1.a What do you think about the need to implement a new manufacturing concept?
   - 1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

2. Appropriateness
   - 2.a What do you think about the choice of the implemented manufacturing concept?
   - 2.b What strategic advantages for the company do you see in the implementation of a new manufacturing concept?

3. Capability

    3.a What do you think about the organization's capability to implement the new manufacturing concept?

4. Motivation

    4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?

4.2.1 The Implementation Project

After the decision to implement Mass Customization at PowerWind, a strategy for the implementation was prepared. According to (Gardner 2009), the main attributes of Mass Customization are as follows:

1. Offers customers product configurations derived from standardized product modules,
2. Maintains a listing of standardized product modules, as well as any rules for combining the product modules into fully configured products,
3. Provides a means to seamlessly share the same understanding about product configurability across the enterprise,
4. Extends the capability to create order configurations and explore alternatives to the customer.

Most important was the introduction of a new design rule at the R&D department. All required product features needed to be designed as "add-ons" which can be simply added to a generic wind turbine platform. Such a generic platform had to be described by a neutral bill of materials which allowed the adding of a defined amount of product features. To achieve that, the product features, required by the customer, needed to be identified and the rules for their possible combination defined.

The achievement of these attributes in turn led to the following project steps:

1. Product Rationalization:
   Identification of the essential product options that the market will require.
2. Technical Feasibility:
   Check of the technical feasibility of combining the product modules and definition of rules for combining them.
3. Product Configuration:
   Development of an adequate product configurator.
4. Bill of Materials:
   Rework of existing bill of materials and create link to product configurator.

While the bill of materials was generated in the ERP system SAP, the product configurator should provide a list of sub-assembly numbers based on the sold product variant. Such a list of sub-assemblies aimed to simplify the creation of the assembly documentation required by the Production.

One week before the start of the interviews, a detailed explanation of the selected manufacturing concept and all relevant terms was given to the employees during the project kick-off meeting (3rd September). Furthermore, the project plan, including all project steps, was introduced to the project members. Therefore, the project start was marked by an initial presentation, followed by an intensive question and response session. The following chapters describe the implementation approach, based on the defined project steps.

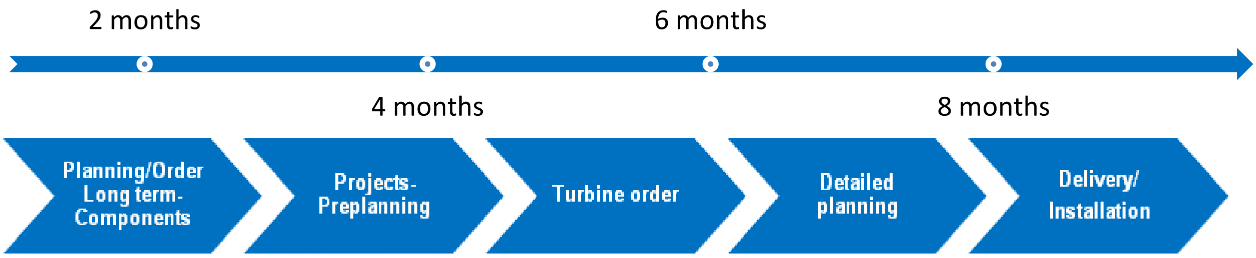
4.2.1.1 The Project Kick-Off

Monday 3rd September 2012 was the official start of the implementation project. The questionnaire, with 25 participants, was conducted before the initial kick-off, between 17th August and 3rd September 2012. Therefore, all the employees involved were also already informed about the research project and the role of the researcher as employee and project manager.

All project members and other interested employees were invited to the kick-off meeting to listen to the initial presentation and to participate in the first discussions. In total, about 30 employees attended this meeting. The main aim of the meeting was to reflect on the existing business situation, to introduce the characteristics of Mass Customization as a new manufacturing concept and to discuss the next steps of the project.

In the beginning, PowerWind´s existing customer order process was shown as workflow (Fig. 12) and discussed against the background of the experienced operational challenges.

Fig. 12: General customer order process at PowerWind



In spite of the existence of a clear customer order process, there was a general manufacturing dilemma at PowerWind. One major reason for this was the difficultly in order planning for long-term components such as gearboxes, steel towers and rotor blades (Fig. 12). Due to long delivery times, the amount of long-term components must be fixed in the first phase of the customer order process. The definition of the amount of long-term components has to be defined by the Purchase department about eight months before the possible delivery and installation date of the wind turbine.

Prior to that, the General Management and Sales departments have to define the planned production volume for a period of approximately one year. This information is also important for the Production department, as resource planning has to be completed for a period of several months. Moreover, an even production utilization is targeted. But, as the amount of wind turbine installations is not usually equally distributed over the year, in times of few deliveries anonymous production of wind turbines is started. This means that the production of wind turbines that have not yet been assigned to an order is started. In these cases, the biggest challenge is that the final variant of the wind turbine is unknown. Wind turbines that can be assigned to a customer order are configured in this phase as well, and a production order is generated.

In the Preplanning phase, specific customer requests are already processed. This phase is led by the Sales department and is supported by the department project management and R&D. Besides the establishment of the most reliable time schedule for each project request, possible technical modifications of the wind turbine are discussed with the R&D department. The main part of this is the evaluation of the technical feasibility of given customer and site requirements. In cases where the evaluation of technical feasibility results in further development and engineering effort, the acceptance of a project is discussed. All this information provides the basis for the Sales department to sign the contract with the customer and place an order. At this stage, very often about four to five months after the planning and order of long-term components, the final wind turbine variant and configuration is known.

During the Master Planning, the time schedule and remaining material planning is finalized. The wind turbines under construction are firmly assigned to the corresponding project. In some cases, wind turbines under construction, which were started without having been allocated to a customer, need to be modified by Production. This uncertain rework effort has to be handled by the production management. In cases where a technical modification was promised to the customer, the engineering work is started in the R&D department. It is fairly common that, due to time constraints, the production of a modified wind turbine has to start before the engineering work is completed.

The consequences that arise from this approach stress the whole customer order process, as well as the collaboration between the involved departments.

The final stage of PowerWind´s internal customer order process is the delivery of the completed and tested wind turbine from the production facility. This step does not mark the end of the overall value chain of a wind turbine manufacturer, as typically several important project steps like transportation, installation and commissioning follow. However, as this research focused mainly on manufacturing and product strategies, these later stages were not considered further in this study.

After a discussion regarding the existing situation, the following major operational challenges of PowerWind were identified:

- the R&D department is overwhelmed supporting individual order demand,
- Production lacks the ability to efficiently produce individual orders,
- reliance on individual knowledge,
- lack of assembly procedure documentation,
- items missing in bill of materials discovered during manufacturing process.

During the reflection on the existing situation, the operational challenges for highly configurable products, as described by Gardner (2009), were introduced. It was very interesting to realize that many challenges that were experienced by Gardner in the fire/rescue vehicle industry were also recognized at PowerWind by the employees involved. It seems that managing a business in the fire/rescue vehicle industry has certain similarities to the wind power business. In both industries, the customers have individual product requirements and ecpectations. The Sales employees are interested in the fulfilment of all customer wishes in order to increase the amount of sold products and to receive higher bonus packages. Such incetitive packages facilitate the dilemma of highly customized products with low profitability. However, the incentitive system is not seen as the root cause for the operational problems of highly customized products. The overall goal of an appropriate manufacturing strategy is the enabling of a sufficient amount of product variants to cover the market needs with a simiulteanous capability to process the orders adequately through the organization. Ideally, the Sales employees have still a sufficient amount of product variants in their portfolio to achieve their sales goals.

After the reflection of the initial situation, the main attributes of Mass Customization, such as the involvement of several departments in the value chain and its influence on the product architecture, were introduced. Furthermore, the classification of Mass Customization as a manufacturing concept was explained. Most relevant for the attendees was the introduction of project goals, time schedules and working packages.

Hence, the four main working steps were presented:

1. Product Rationalization;
2. Technical Feasibility;
3. Product Configurator;
4. Bill of Materials.

In general, the atmosphere during the meeting was positive and very constructive. It could be felt that the identified process challenges had stressed each attendee at least once. In particular, the comments from employees from the R&D and Production departments signalled that it was high time for process improvement and that they had high expectations of the results. Purchase employees were rather reserved and neutral in their comments. A similar reaction was shown by Project Management employees. Their main expectation was that the delivery dates of the wind turbines should become more reliable. In the past, they had seen that discussions and miscommunication during the manufacture of wind turbines would arise and that this caused some delivery delays. More critical comments came from Sales and Marketing employees. On the one hand, it appeared that the problems were not seen to be so big by this group of employees, but the other, some Sales employees worried about losing their freedom in regard to selling future wind turbines. The background to this was that selling wind turbines has become more and more difficult recently.
A reason for the reserved reaction of the Purchase, Project Management and Sales/Marketing employees might have been a lack of trust in the project manager. The project manager was a supervisor in the R&D and Production department and therefore was possibly more trusted by the employees from R&D and Production.

Before getting into deeper reporting and analysis of the project progress in the different working groups, it is necessary to introduce the main components of a wind turbine, in particular the “PowerWind 56”, in order to understand the actions that resulted from the implementation project.

The product “PowerWind 56”:

In general, the product wind turbine is assembled from numerous mechanical and electrical sub-assemblies and components. The wind turbine PowerWind 56 represents a typical wind turbine of the type “Danish concept”, which is explained in chapter 2.3.1. In general, a wind turbine of the “Danish concept” type consists of four main sub-assemblies: the machine house (nacelle), the rotor consisting of three rotor blades, the tower and a transformer for the grid connection (Fig. 13). The nacelle consists of several main mechanical and electrical components. In the case of the wind turbine PowerWind 56, the nacelle includes 14 main components (Fig. 14). The PowerWind 56 has a rated power of 900 kW, a rotor diameter of 56 m and is offered on two tubular steel towers, achieving a hub height of either 59 m or 71 m.

Fig. 13: Overview main sub-assemblies of the PowerWind 56

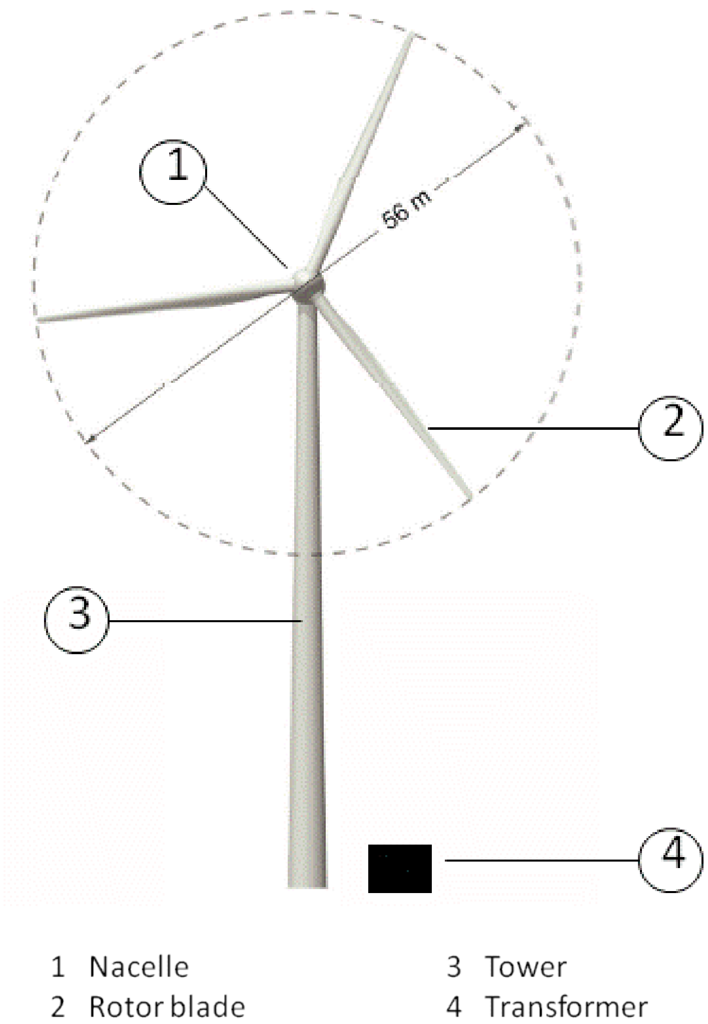
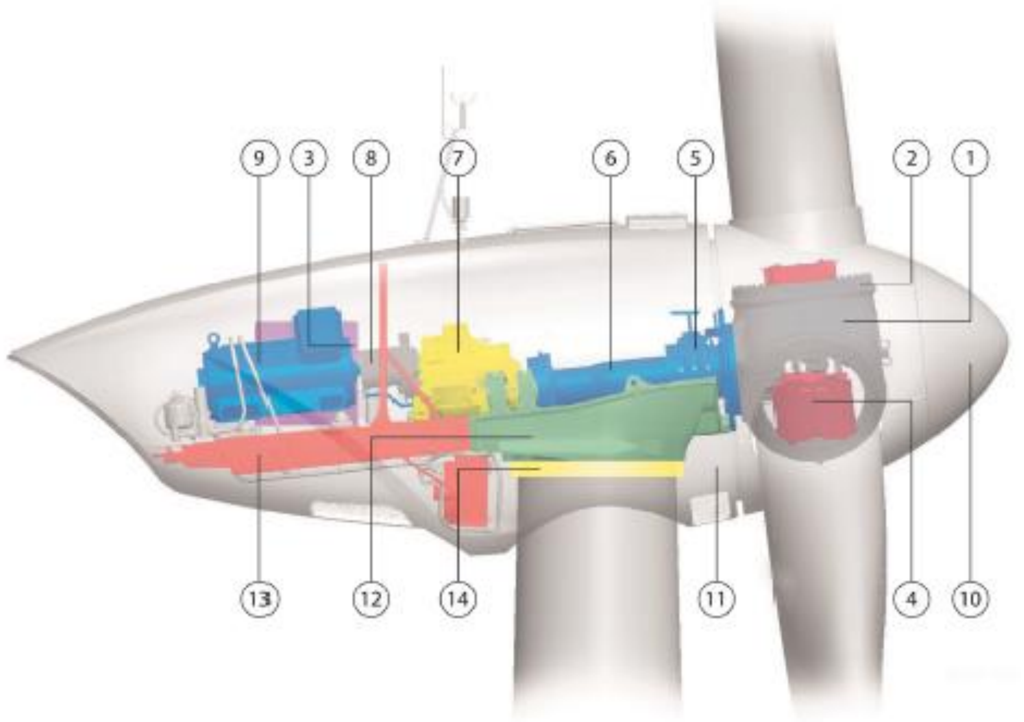


Fig. 14: Overview characteristic components inside the nacelle of the PowerWind 56



1 Hub
2 Pitch bearing
3 Control cabinet
4 Pitch control
5 Main bearing
6 Main shaft
7 Gearbox
8 Coupling and brake
9 Generator
10 Hub cover
11 Nacelle cover
12 Machine frame
13 Generator frame
14 Yaw bearing

4.2.1.2 Product Rationalization – Interviews 2nd Project Phase

The first meeting with a working group was a meeting with the product rationalization team on 10th September 2012, during the 2nd project phase. The team consisted of four employees from the Sales/Marketing department. In the first and during some following meetings of this team, the Head of Sales/Marketing also participated. Furthermore, one R&D and one Purchase employee belonged to the team. The aim of the product rationalization team meetings was the identification of the relevant wind turbine characteristics and product features to cover market needs. The product rationalization meetings took place on 10th, 17th and 24th September. A last team meeting took place on 29th October in the final implementation phase (3rd project phase). The semi-structured interviews were conducted during the first (10th September) and the last (29th October) meeting.

Seven participants in first product rationalization meeting, 10th September 2012:

Sales	R&D	Purchase
S1	RD1	P1
S2		
S3		
S4		
S5		

Responses and observations from the first meeting, 10th September 2012:

As the sales employees were the most sceptical project members during the discussion at the initial meeting, the aim of the new manufacturing concepts was explained to them again.

The “Need” questions were answered as follows:

1.a What do you think about the need to implement a new manufacturing concept?

Only two of the five sales employees recognized the need for the implementation of a new manufacturing concept.

One sales employee mentioned:

“I did not know that we have such difficulties in manufacturing our wind turbines. For me it is an R&D and Production problem. Production will always have issues with the headquarters in Hamburg because of the distance (note editor: 180 km) to their facility in Bremerhaven.”

Another Sales employee said:

“I have heard from some colleagues that they are unhappy with the processes. But I thought that this was caused by the fact that PowerWind still is a young company and many processes are simply not established enough.”

Two Sales employees summarized what represented the majority opinion of the Sales team at the start of the project:

“We are afraid that the implementation of the new manufacturing concept will limit our options in terms of offering multiple wind turbine solutions. This measure will make the situation worse at PowerWind.

1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

One Sales employee mentioned:

“Is it reasonable to implement the whole concept at once? It could reduce the operational performance to a minimum. We would be hindered in serving our customers”

Another Sales employee said:

“I think that the R&D department will have difficulties meeting the requirements of the Production and Purchase department. There is a common understanding of the process between Purchase and Production, but the R&D department is not able to deliver.”

The R&D employee replied:

“It is not an R&D issue alone. The stated Sales opinions reveal our biggest challenge: there is no consistent communication, starting at the Sales department and ending at Production. To overcome this challenge is our biggest barrier.”

The “Appropriateness” questions were answered quite consistently. In general, the new manufacturing concept appeared to be very big and complex.

2.a What do you think about the choice of the implemented manufacturing concept?

Most responses to this question expressed the concern that the Sales team would lose its flexibility and the amount of possible projects would decrease due to missing product features.

A typical answer to this question was:

“The PowerWind wind turbines are of interest to the customer because we are able to react to special site requirements. In general, the “community-scale” markets, as targeted by PowerWind, are characterized by multiple requirements.”

The Head of Sales added:

“I have serious concerns that this manufacturing concept is too complex for PowerWind. It seems that the main processes of all departments have to be modified. Is there no smaller concept available which better fits our company´s size?”

The attending Purchase employee added:
“An alternative could be to focus on certain departments, e.g. starting with the most faulty.”

2.b What strategic advantages for the company do you see in implementing a new manufacturing concept?

Most of the Sales employees recognized the capabilities of the new manufacturing concept, but they believed that most benefits could only be achieved in theory. Furthermore, they had doubts that all the advantages could be achieved at PowerWind.
A typical answer was:
“If the concepts would really run there could be capabilities to reduce our lead times and working capital. That would be a big advantage. On the other side, we are afraid that the amount of sold wind turbines would shrink, due to reduced product flexibility.”
Most of the responses from the Sales employees can be represented by this statement:
“I have the feeling that we make many mistakes during the customer order process. All the additional costs resulting from these failures have to be borne by PowerWind. This has to be avoided if we want to succeed in the long term.”
The R&D employee reported the causes of failures from his perspective:
“Many failures occur due to bad communication and the lack of time for the completion of the engineering work. It would be a big advantage if we could get the process to be more stable and reliable.”

The “Capability” question was answered as follows:

3.a What do you think about the organization’s capability to implement the new manufacturing concept?

The Sales employees expressed doubts about the capabilities of PowerWind to implement the manufacturing concept. Besides the amount of interfaces and departments involved, which would all have to be aligned, they saw a lack of human resources.
One Sales employee made a representative statement for the Sales employees:

“I am not sure if this additional work can be done by the engineers. I always have the impression that they are overloaded with daily work. They are not even able to react to the small requests and questions that we raise.”

The R&D employee confirmed the overload, but saw the reasons for it differently:

“I think that many people in our organization have different views and expectations of a completed R&D task. I consider a design to be completed when all the drawings are released and the full bill of materials is entered into the ERP system. Many others see the engineering work as being completed much earlier, and this is causing failures. If we are not able to align this, our capabilities could indeed be limited.”

Finally the “Motivation” question was answered as follows:

4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?

Even if the Sales employees rated the general processing of customer orders as medium (question 4), several of them mentioned that they were partly unsure what can be offered to customers. Several reported mistakes in sales contracts and the corresponding costs of which are usually borne by PowerWind. The avoidance of failures was the most mentioned motivation.

One Sales employee reported an interesting situation, which according to him was no exception:

“An engineer from the R&D department attended a sales meeting with an important customer. Suddenly the engineer noted quietly: I see you have promised the customer the fulfilment of a special grid requirement, but I cannot find the additional costs for this technical feature in the binding offer! I learned at this point that this feature is an add-on and not standard. Of course, it was too late to change this particular sales contract.”

The Purchase employee added:

“That is one reason why we lose money and why so often new materials are suddenly required from the erection sites. When we order new materials this quickly we are not able to generate the best conditions. A more structured approach is my biggest motivation.”

The data collected during the first meeting of the Product Rationalization Team generally confirmed the results (personal indicators) of the questionnaire. The employees of Sales/Marketing and Purchase expressed their resistance to change once again. They also showed less satisfaction with the work required to implement the new concept. By expressing their concerns about the appropriateness of the chosen concept and organizational capacity, they also displayed situational indicators (trust in supervisor and organization) against the change project. Besides doubts regarding the organizational capacity, the R&D employees displayed positive personal and situational indicators.

4.2.1.3 Product Rationalization – Results 2nd Project Phase

In summary, the Sales team, assigned to identify the relevant product characteristics and features, made good progress in its meetings. After a discussion and the elimination of some concerns in the first meeting, the following meetings were very productive. It took three full-day meetings with five Sales employees, supported by the Head of Sales/Marketing during two meetings, to create the product properties described and listed below:

The Sales team underlined that PowerWind´s target customers can be classified as community-scale customers (Fig. 1). Typical clients in this group are affluent individuals, as well as small- and mid-size project developers. The project sizes range from single wind turbines with a total capacity of 0.9 MW to about 30 MW, which corresponds to 33 PowerWind 56 units. The high number of single clients naturally leads to many individual customer requests regarding the product. PowerWind´s target markets are: Italy, UK, Poland, USA, Romania, Bulgaria and Germany. These countries have different regulations for wind power generation that also influence the product technology. Countries with a longer wind power history, such as Germany and USA, have even issued technical standards for single wind turbine components or whole wind turbines. However, each of the other countries has a regulation for at least the grid connection or feed-in of power, which could have an influence on the wind turbine. The definition of targeted markets and the naming of relevant technical and grid standards was a major task of the first meeting.

Based on the targeted markets, the technical characteristics and features of PowerWind 56 had to be defined in the following meetings.

Tower:

As already explained in chapter 1.2 and shown in Fig. 1, PowerWind target markets are the so-called community-scale markets. Over the years, the Marketing and Sales departments at PowerWind have learned the main requirements of these markets. In general, the Sales employees underlined that the wind turbine PowerWind 56 has a large rotor diameter of 56 m compared to other wind turbine types in the sub-megawatt segment. As large rotor diameters are the most important parameter to generate as much power as possible from the wind, many customers appreciate this attribute. As many of PowerWind´s small “community-scale” projects are closer to buildings and other infrastructure than large wind farms are, a maximum height of 100 m, from the ground to the blade tip, is very often required by the authorities. Due to the existing rotor diameter of 56 m, the maximum hub height is limited to 71 m, which leads to a total height of 99 m. In some cases, the maximum height is even more limited. Especially in urban areas, or sites close to a local airport, very short towers are required. Hence, the Sales department required three possible hub heights: 44 m, 59 m, and 71 m. That in turn meant that three tower variants, with different lengths, are required.

Power Frequency:

In Europe, the electrical grid works at a frequency of 50 Hz. However, the electrical grid in the USA operates at a frequency of 60 Hz. As the USA is one of PowerWind´s targeted markets, sales employees required that both frequency variants, 50 Hz and 60 Hz, had to be offered.

Power Quality:

In recent years, the quality requirements of electricity generated by renewable sources have been increasing steadily. The reason for this is the massive expansion of renewable power sources in power generation. Renewable power generation is volatile by nature and cannot be manually regulated in the same way as conventional power plants. Especially in more mature wind markets, like Germany, grid codes have appeared to regulate the quality of electricity fed into the public grid. However, all countries have their own regulations for the operation of their electrical grid and the feed-in of electrical power. They regulate the characteristics of electricity generated by wind turbines. Besides the ability to decrease or even shut down power production remotely, wind turbines have to be connected to the grid, even if the grid has failures lasting in the range of milliseconds. Typical failure types that wind turbines have to cope with are frequency fluctuations and short voltage drops. For this, an electrical solution has been developed by the industry, called “Fault-ride-through” (FRT). That means the wind turbine is able to remain connected to the grid, even if the grid is not able to receive the generated power for time periods up to 3000 ms. The electrical power generated during the time period of the failure has to be blown out by the wind turbine using special components called choppers, managed by a more sophisticated controlled power converter. Italy, as one of PowerWind´s main markets, requires a failure time period of 500 ms, while Germany requires 3000 ms. As there are still some countries which do not require this costly technology, the Sales department required three power quality variants: FRT 3000, FRT 500, and without FRT.

Transformer:

The transformer is the interface of a wind turbine and the electrical grid. Therefore, the specification of the transformer is very project-specific. Usually, PowerWind offers a standard transformer that is located outside of the wind turbine, on the ground next to the tower entrance. In cases where a project-specific transformer is required, the customer becomes responsible for the supply of the transformer and its installation outside the tower. In recent years, several countries, including Italy and the UK, have formulated the requirement that the transformers have to be placed inside the wind turbine tower. The main arguments for this were the reduction of negative visual and environmental impacts. For that reason, PowerWind also had to engineer a solution where a standard transformer is located inside the tower. Hence, three transformer variants were required by the Sales team: outside, inside and customer specific.

Switch Gear:

Similarly to the transformer, project-specific requirements for the switch gear also exist. The switch gear is a wind turbine component that is connected to the transformer. The main task of a switch gear is to switch the medium-voltage electrical power of the wind turbine into high-voltage grid power. The switch gear is located in the tower base of a wind turbine. While local grids operate with a high voltage of 6 - 20 kV or 30 - 60 kV, regional transmission grids operate with 110 kV. Depending on the project-specific grid connection point, different types of switch gears are required. As the Sales team prefer to have more flexibility in terms of connection points, they required at least a 2-pole and a 3-pole switch gear with voltage levels of 11 kV, 15 kV, and 20 kV. According to most Sales employees, this would cover the majority of existing customer sites.

In total, the Sales team identified six customer- or market-specific needs to be covered by the wind turbine:

1. Tower: 44 m, 59 m and 71 m hub height
2. Power Frequency: 50 Hz and 60 Hz
3. Power Quality: FRT 500, FRT 3000 and without FRT
4. Transformer location: customer delivered, inside or outside the tower
5. Transformer performance: 11 kV, 15 kV or 20 kV high-voltage
6. Switch Gear: 2- or 3-pole

4.2.1.4 Technical Feasibility – Interviews 2nd Project Phase

The team for the checking of technical feasibility met for the first time on 26th September, just after the completion of the customer requirements by the Sales team, and was confronted with the results of the product rationalization. The technical feasibility team had five full-day meetings on 26th September, 2nd, 10th, 17th and 24th October). Their task was to identify possible product modules to meet the market needs and to define rules for combining them. The technical feasibility team consisted of three experienced R&D Engineers and three senior Purchase employees with a good overview of possible component suppliers. This was important because many wind turbine components are developed and supplied by external suppliers. Furthermore, due to a historical more-supplier strategy, at least two different suppliers for each main component exist.

In several cases, these components have slightly different mechanical or electrical interfaces.

The semi-structured interviews were conducted during the first (26th September) and the last (24th October) meeting.

Six participants in first technical feasibility meeting, 26th September 2012:

Sales	R&D	Purchase
	RD2	P2
	RD3	P3
	RD4	P4

Responses and observations from the first meeting, 26th September:

The R&D and Purchase employees were most critical of the existing customer order process. Furthermore, they revealed higher expectations of the new manufacturing method. Therefore, the atmosphere was open-minded and highly attentive. During the meeting, however, several tensions between the departments came up. The atmosphere became slightly tense later on.

The “Need” questions were answered as follows:

1.a What do you think about the need to implement a new manufacturing concept?

In the questionnaire, the employees from the R&D and Purchase departments rated the customer order process at PowerWind as poorly, or even very poorly (question 4). Furthermore, the employees from the Purchase department in particular claimed that there was a high failure rate during general processing (question 5). They backed up this position with corresponding statements during the interview in the first meeting. The R&D employees mostly claimed that the large work overload and the chaotic input of new engineering requests were the problem, but also claimed that some failures were due to the Purchase department.

One Purchase employee mentioned:

“It is difficult to order larger quantities at our suppliers in order to achieve a considerable economy of scale. I always have the impression that the bills of materials, which are most relevant for the purchase of parts and components, are permanently changing. We need more structure in our processes and more efficiency in our Engineering department. They are evidently too slow.”

On the other hand, one R&D employee reported an interesting story that also identified failures in the Purchase department:

"Last month a colleague from the Purchase department mentioned that he had finally found a second supplier for the yaw bearing. He was happy because of the quality and the price. After checking the drawing of the yaw bearing, I realized that the new yaw bearing was not geometrically identical to the original. The new bearing is 8 mm higher. This small deviation would require a redesign of the main frame and the yaw drives!"

Thereupon a Purchase employee answered:

"This is an example of the inadequate documentation that we receive from the R&D department."

1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

The controversial discussion after the first question was partly continued during the answering of the second question. Several potential barriers were identified on both sides.

One R&D engineer mentioned:

"We need more support from other departments. Sometimes we have to generate documents that should be the responsibility of other departments, e.g. the Service department. The biggest issue is that we have to deal with everything alone."

Another R&D employee added:

"I think it is more of a resource problem. If we had more engineers in our team then we could manage it."

A Purchase employee confirmed:

"That is right. The R&D department has a resource problem. Potentially, they are not skilled enough. My feeling is that they make too many mistakes, either caused by an overload of work or a lack of knowledge."

In contrast, another Purchase employee stated:

"The biggest barrier is time. I think it will take a considerable amount of time to get the new manufacturing method running. We cannot wait too long with the order of the critical long-term components. Otherwise, Production will have to stop the assembly of wind turbines due to missing components."

The “Appropriateness” questions were answered differently by the individual team members. While most R&D employees judged the chosen manufacturing method as appropriate for PowerWind´s needs, some Purchase employees were afraid that their requirements were not fully covered by the new manufacturing concept.

2.a What do you think about the choice of the implemented manufacturing concept?

The answers to this question differed widely. In particular, the Purchase employees expressed differing views on the chosen manufacturing concept.

While one Purchase employee mentioned:

“It is good that the new manufacturing concept covers all the departments involved. I hope that this will avoid process and communication failures within our value performance.”

Another Purchase employee added:

“I am not sure whether we have several sources of failures. From my perspective most failures are caused by insufficient R&D documentation. Maybe a method should be applied which gets a handle on this problem.”

Contrary to this, one R&D employee answered as follows:

“We need to at least involve the Sales department, as both departments need to have the same understanding of what we are producing. Furthermore, the process owner has to control communication between the Sales department and Production. From this perspective, the chosen manufacturing methods seem to be appropriate.”

The other R&D employees answered similarly. One of them added a prime example of misleading communication during the value performance:

“Several days ago, a Production employee told me that three days previously they had received an instruction from the Sales department to deliver the next wind turbine with a grid fault-ride-through feature. However, he could not find the corresponding bill of materials for this feature. I said, sorry, but we only got the order to start development of this feature yesterday!”

2.b What strategic advantages for the company do you see in implementing a new manufacturing concept?

The answers of the Purchase employees mainly dealt with delivery times and component costs.

“We have difficulties in planning the orders for long-term components. This is the very first phase of our customer order process, but it has significant impact on the following phases and the inventory stock. Here we need more certainty and reliability. That would be a beneficial advantage to us.”

Another answer from a Purchase employee was:

“In addition, it would be great to make more use of economies of scale. Our suppliers regularly offer us better prices for higher-volume orders, but we are limited due to our low standardization.”

One R&D employee answered:

“From my perspective, the biggest advantage would be if the R&D department could get their work completed. My colleagues and I are overwhelmed by supporting all these individual order demands. Last month, a Sales manager told me with pride that he had been able to sign a new contract for a wind turbine. And the best news was that it was allegedly a standard turbine. The only non-standard feature the Sales manager had accepted was a slightly different transformer housing: a thin-walled glass-fibre housing instead of our standard thick-walled and solid concrete housing. However, this small difference cost me 30 hours redesign for the cooling pipes, 20 hours for the cables, 15 hours for the brackets and, finally, required a new bill of materials. This was a nice gift for the customer but a massive engineering effort for us.”

Another R&D employee added:

“I can confirm that we often face situations where we do not have enough time to complete our work. Sometimes orders that are not fully configured are prematurely loaded to the backlog, causing a lot of difficulties. I have even found out that Production have generated their own bills of materials in order to get wind turbines assembled.”

The “Capability” question was answered as follows:

3.a What do you think about the organization’s capability to implement the new manufacturing concept?

During this phase of the meeting, the discussion was very intense, but fruitful, as many situations that had been experienced were discussed. There was certain feeling of doubt around the statements made by the team members, probably caused by hearing about the impressive process failures other team members had experienced and the ideas about the changes required.

One R&D engineer started with following comment:

“We have to distribute the implementation effort over all the departments involved and not leave everything to the R&D department. Otherwise, I have serious doubts about whether we can manage this project in the defined timescale.”

A Purchase employee added:

“What happens if further project steps are necessary? It could be that we discover further failures and challenges during the implementation phase. The time schedule could be critical.”

Finally, the team was asked the motivation question:

4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?

An engineer answered spontaneously:

“I would like to focus on innovative solutions to make our product more competitive.”

Another engineer added:

“That is right. We have a long list of required product improvements and innovations that cannot be started due to the daily demand-driven workload. I hope that the new manufacturing concept can contribute to a reduction of this kind of workload.”

One Purchase employee stated his motivation:

“I would be glad if we could achieve the best possible component prices. Furthermore, it would help me if I had a reliable amount of required long-term components as far in advance as possible.”

Another Purchase employee added:

“A reduction of incorrect orders would help as well. I have too many corrections of purchase orders, either due to a wrong amount or incorrect component type. This has a negative impact on trust and the relationship with our suppliers. My motivation is the establishment of a reliable and sustainable relationship with our suppliers.”

The responses and actions of the team indicated again that the Purchase employees had a certain resistance to the implementation project. They furthermore showed less trust in the chosen concept, with respect to the supervisor, than the R&D employees. However, both employee groups were motivated to work for the change project, even if the Purchase employees had less trust in the organizational capabilities.

4.2.1.5 Technical Feasibility – Results 2nd Project Phase

The product feasibility team created a very motivated atmosphere at the beginning of their working group. This changed a little during the interview phase, as most team members reflected very critically on the current status of the customer order process. Furthermore, several examples of poor process performance that they had experienced were discussed, and different views on the root causes became apparent. However, the team was very productive during the following meetings. Their task, to examine the product features defined by the Sales team and to identify possible product modules to realize them, was fully fulfilled. It was important to have a mixed team, consisting of R&D and Purchase employees, as it was not only technical rules that needed to be evaluated. Due to a historical more-supplier strategy, at least two different suppliers for each main component existed. Knowledge about the importance and continuation of each supplier relationship was to be found mainly in the Purchase department. In several cases, these components had slightly different mechanical or electrical interfaces. This applied in particular to: the generator/converter system (ABB and TheSwitch), the gearbox (JAKE and Moventas), the pitch drives (Bonfiglioli and Comer) and the yaw drives (Bonfiglioli and Comer). These components were identified as strategic components and the corresponding relationships to their suppliers as important.

In summary, it took four full-day meetings with three Purchase employees and three R&D employees to identify the technical feasibility requirements, as listed below:

Tower:

The technical feasibility team discussed the requirements for the hub heights intensively. The need for three different tower heights required the design and maintenance of three different steel tower designs and the corresponding tower internals. Moreover, the technical feasibility team identified the need for different steel materials to cover the requirements of Europe and the USA. The towers of wind turbines are considered as buildings and have to fulfil the building and construction rules of each country. While the building standards of European countries are widely aligned, different requirements are stated in US standards, especially in terms of materials. Therefore the 44 m, 59 m and 71 m towers needed two different designs to satisfy European and US standards. Furthermore, the purchase department also wanted to use an older version of the 71 m tower, because the production of this tower type had recently started at a new supplier.

Controller:

Due to the increasing demands on the generated power, sophisticated components and solutions are required. In addition to normal operational controls, which are mainly influenced by wind speed and wind directions, the turbine has to react to changes in the electrical grid. To “ride” a turbine through faulty grids, special controller algorithms are required, as well as the previously mentioned additional electrical components such as choppers. Therefore, additional turbine commands have to be implemented in the turbine controller. As the original controller of the PowerWind 56, supplied by Mita, has no open software code, a new supplier of the controller hardware had to be found that allowed PowerWind to use their own modified controller software. That supplier was found in Bachmann. Therefore, all turbines offering a sophisticated grid feature had to be equipped with a Bachmann controller.

Nacelle Cover:

The use of gearboxes from two suppliers also had an impact on the nacelle cover. The nacelle cover is the enclosure of the machine and is made of a lightweight glass-fibre composite. As the cooling systems for the two gearboxes are not located at the same place, the openings in the nacelle cover had to be designed differently. Furthermore, one nacelle cover had to be slightly higher, due to the larger height of one gearbox assembly.

In general, all market needs defined by the product rationalization team could be confirmed. However, some features can only be reached by new developments or the use of further components. Despite starting with team members in a good mood and having high motivation, the work in the technical feasibility team soon became hard and the discussions intensive. To keep an overview, the different features and components had to be drawn into an overview plan. This plan had to be changed several times. The atmosphere soon became quite tense.

Following the five product characteristics and features defined by the Sales team (tower, power frequency, power quality, transformer, switch gear), an additional six were identified by the feasibility team to solve the product feature issues and to fulfil the supply chain requirements:

Defined by the product rationalization team:

1. Tower: 44 m, 59 m, and 71 m hub height
2. Power Frequency: 50 Hz and 60 Hz
3. Power Quality: FRT 500, FRT 3000, and without FRT
4. Transformer location: customer delivered, inside or outside the tower
5. Transformer performance: 11 kV, 15 kV, or 20 kV high-voltage
6. Switch Gear: 2- or 3-pole

Defined by the product feasibility team:

7. Generator/Converter: ABB or TheSwitch
8. Gearbox: JaKe or Moventas
9. Pitch drive: Bonfiglioli or Comer
10. Controller: Mita or Bachmann
11. Yaw drive: Bonfiglioli or Comer
12. Nacelle cover: version A or B

In total, the two teams identified a total of 12 feasible product characteristics and features of the PowerWind 56. Table 6 gives an overview of all product characteristics and features, as well as their corresponding variants.

Tab. 6: Overview product characteristics and features PowerWind 56

		A	B	C	D	E	F
1	**Tower**	59 m US	59 m EU	71 m old	71 m US	71m EU	44 m
2	**Gen./Converter**	TheSwitch	ABB				
3	**Gearbox**	JaKe	Moventas				
4	**Transformer**	Inside	Outside	Customer			
5	**Pitch drive**	Bonfiglioli	Comer				
6	**Frequency**	50 Hz	60 Hz				
7	**Voltage**	15 kV	20 kV	11 kV			
8	**Switch gear**	2-pole	3-pole				
9	**Controller**	Mita	Bachmann				
10	**Yaw drive**	Bonfiglioli	Comer				
11	**FRT**	500	3000	none			
12	**Cover**	A	B				

In general, most of these characteristics and product features can be combined. The technical feasibility team also identified the combinations that cannot be realized due to technical reasons, e.g. the above-mentioned need for a Bachmann controller in combination with a FRT solution.

The possible combinations resulted in numerous possible product variants. That was one significant result. In total, 14,976 product variants are technically possible (Tab. 7). That high number of possible combinations surprised all team members. It became evident that the amount of variants needed to be reduced. Otherwise, the R&D department would need months for the generation of the usually absent bills of materials. The role of the product configurator became much more important than originally planned. Before the start of the development of a product configurator, and the corresponding configurator rules, the company had to decide which product variants were really needed in the future.

Tab. 7: Overview of technically possible variants of the PowerWind 56

	1A	1B	1C	1D	1E	1F	2A	2B	3A	3B	4A	4B	4C	5A	5B	6A	6B	7A	7B	7C	8A	8B	9A	9B	10A	10B	11A	11B	11C	12A	12B
1A	X						X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1B		X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1C			X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1D				X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1E					X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1F						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2A	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2B	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3A	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	x	X	X
3B	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	x	X	X
4A		X	X	X	X	X	X	X	X	X	X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
4B	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4C	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5A	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5B	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
6A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
6B	X	X	X	X	X	X	X	X	X			X	X	X	X		X	X	X	X	X	X		X	X	X		X	X	X	X
7A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X
7B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X
7C	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X
8A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
8B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
9A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X		X	X	X
9B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
10A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
10B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
11A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X			X	X
11B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X		X	X
11C	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
12A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
12B	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X

Each cross marks a possible combination of the identified product characteristics and component types. That in turn represents a possible product variant of the PowerWind 56. More than fifty of the possible product variants were indeed realised by PowerWind in the last three years.

4.2.1.6 Product Configurator – Interviews 2nd Project Phase

Based on the results of the technical feasibility team, it became clear that the work of the product configurator team would be more important for the implementation project than was assumed and planned at the start. Before the establishment of the configuration rules, the wind turbine had to be divided into some basic platforms, ideally assigned to certain countries or markets. For that reason, the Sales team needed to be involved again. Therefore, the original team composition was extended to include two employees from the Sales department. In total, six employees belonged to the product configurator team: three R&D employees, two from Sales, and one Purchase employee. The first meeting of the product configurator team was scheduled for 19th October. Three further meetings followed on 26th October, 2nd November and 9th November. That was one meeting more than initially planned. Originally, the main task of the product configurator team had been the collection and definition of rules for allowable product configurations, based on technical feasibility.

According to Gardner (2009), under Mass Customization, Engineering´s role shifts to working with Sales or/and Product Management to define the modules and manage the configuration rules that govern how the modules can ultimately be combined into saleable order configurations. However, due to the substantial number of possible product variants, the wind turbine PowerWind 56 needed to be reduced to a few platforms.

The first semi-structured interview was conducted during the initial meeting on 19th October.

Six participants in first product configurator meeting, 19th October 2012:

Sales	R&D	Purchase
S1	RD2	P2
S6	RD5	
	RD6	

Responses and observations from the first meeting, 19th October:

From each department (Purchase, R&D, Sales) one employee had already been a member of the previous two teams and was being interviewed for a second time. The two remaining R&D employees and one Sales employee were attending a working group and a semi-structured interview for the first time. The new members seemed to be more curious about what the next steps of the implementation project would be, as they had already discussed possible working tasks just before the meeting started. The team members who had already participated in the product rationalization or technical feasibility team behaved in a more reserved way.

The “Need” questions were answered as follows:

1.a What do you think about the need to implement a new manufacturing concept?

One of the R&D employees attending for the first time mentioned:

“I very often get calls from my Production colleagues claiming that assembly information is missing, e.g. drawings or bills of materials. Furthermore, they often require the speedy completion of additional engineering work, even if this is not in compliance with the processes. Therefore, I think there is a big need for improvement."

The R&D employee participating in an interview for the second time added:

"Last time I already mentioned the large workload we have, but I am not sure whether this project is able to reduce it. When I look at the high number of possible variants, my concern is that the workload could increase dramatically."

The Sales employee mentioned:

"The current status of the product variants is clear evidence that we need a new product and manufacturing concept."

1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

The R&D employee attending for the second time answered:

"Last month I considered the resource issue as the most critical. The R&D department is simply overwhelmed supporting individual order demand. However, facing this huge amount of variants I now see this barrier as even worse."

The Sales employee added:

"To avoid this, the whole organization has to contribute to the solution. We have to solve an enterprise-wide challenge. Therefore, I think that a new collaborative and organizational culture has to be introduced. That could be the biggest difficulty."

A Purchase employee saw a further barrier:

"As the project seems to be very comprehensive and complex, I see the time schedule as the biggest barrier. We have to keep in mind that we are not able to stop the business during the implementation project."

The answers to the "Appropriateness" questions were relatively consistent. In general, the given business situation was considered as complex and, therefore, the chosen manufacturing concept would be reasonable in order to cover all aspects.

2.a What do you think about the choice of the implemented manufacturing concept?

One of the R&D employees attending for the first time mentioned:

"It is good that the Sales department is involved as well. From my perspective, it is important that they have sufficient understanding of our products and technology. Otherwise, we have permanent miscommunication."

The R&D employee who participated in an earlier working group added:

"It sounds great for me that we will focus more on innovation in the future. However, there is a long road ahead of us. The ultimate basis of this concept is the availability of bills of materials for all variants and modules. If we are not able to reduce the possible product variants, we will work for years to complete this."

The Purchase employee gave the following statement:

"Besides the misleading communication issue, we also need a solid customer order process. If we manage to solve this successfully then the new manufacturing concept could be appropriate for PowerWind. Ideally, the whole customer order process could be implemented in our ERP system."

Finally, the Sales employee added:

"Yes, if all these requirements can be fulfilled, and we still have enough options to cover the individual needs of our customers, then the manufacturing concept can be considered as appropriate."

2.b What strategic advantages for the company do you see in implementing a new manufacturing concept?

Typical answers from the R&D employees mentioned avoiding permanently reactive actions.

One of the R&D employees said:

"We need a priority list for our work. Without the disturbances due to changing demands we could increase our efficiency. That would be strategic advantage."

Another R&D employee mentioned the problem of reliance on tribal knowledge and explained:

"One current disadvantage is that a lot of process steps are discussed personally. It seems that the Production employees have one R&D employee for each technical problem. Besides the disturbance of the daily work, this leads to poorly documented solutions that only exist in the heads of individual employees. That in turn means that the company has to rely on individual knowledge. From the company's strategic perspective, that should be avoided."

The Sales employee highlighted the need for customer satisfaction:

“In the end, we need to achieve a high level of customer satisfaction. We can achieve this by fulfilling individual customer needs and high product quality. Furthermore, we have to avoid process failures to reduce costs and lead times. These could be the most interesting strategic advantages.”

The Purchase employee added:

“One strategic advantage is also cost reduction. Besides the deliverability of wind turbines with customer-friendly product features, we have to offer competitive prices. Only then will our customers remain happy, and we will remain profitable.”

In the next step, the capability topic was discussed.

3.a What do you think about the organization’s capability to implement the new manufacturing concept?

One R&D employee started:

“If the Sales and Purchase departments are able to reduce the amount of variants caused by numerous options and suppliers, then I see the capability to manage this challenge.”

Another R&D employee added:

“Furthermore, we have to get our engineering change process under control. We need clearly identifiable individuals responsible for the products, who then avoid uncontrolled product changes. Otherwise I do not see the ability for fast progress.”

The Purchase employee mentioned more general doubts:

“I have certain doubts whether the organization, especially the general management and the Sales department, are disciplined enough to control the sales process more strictly. It seems that many projects are firstly opportunity-driven and the impact on the product is considered later. We need supportive systems to handle this issue.”

The Sales employee countered:

“In general, I see a strong capacity to meet the needs of the processes. The customer order process has not been fully covering the Sales needs so far, but I am sure that a commonly agreed customer order process can be established within the organization.”

At the close of the interview, the team were asked the motivation question:

4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?

The Purchase employee said:

“It would be great to achieve stable processes and reduce failures in the value process. We have to rely on our customer order process and avoid reliance on individual knowledge. To contribute to this achievement is my biggest motivation”

An engineer described his view as follows:

“The reduction of disturbing factors during our daily work is my motivation. I hope that this will happen when all departments involved in the value performance are disciplined enough to follow the process.”

An R&D employee added:

“And a reliable list of work, without being in a permanent state of change, is my motivation. That would allow work on necessary product improvements, which in the past was something that had to be interrupted regularly.”

Finally, one of the two Sales employees reported his motivation as follows:

“From my perspective, it would be good to achieve a better atmosphere in the organization. Currently we are facing a lot of discussions and mutual accusations. This is also caused by a lack of knowledge and of appropriate contact persons.”

The responses in this meeting indicated a decreasing level of trust on the part of the R&D employees, relating to both the project manager and the organization. Most significant was the amount of product variants identified and the corresponding workload. On the other hand, the Sales/Marketing and Purchase employees gave comments that indicated an increase in trust. The motivation of all employee groups was still positive, even if the resistance to change from the R&D employees had started to increase.

4.2.1.7 Product Configurator – Results 2nd Project Phase

The product configurator team had to be extended prior to the start of their working phase. The reason was the huge amount of variants identified by the earlier working groups. This huge amount had to be reduced, as a first step. However, the main goal of the team, the creation of a product configurator by defining all allowable product variants and corresponding configuration rules, was followed as well. Besides the increase in team members, additional team meetings were also required. Finally, the working group consisted of new project members and employees who had already attended the earlier working groups. The atmosphere was slightly different between these two types of participants. While the employees attending for the first time actively discussed the expected group work, the employees attending for the second time behaved in a very reserved way. It took a certain amount of time to get the team working productively. The increasing resistance from the employees attending for a second time began to cause resistance amongst the other employees. However, the initial semi-structured interviews and related critical discussions about the project helped to get all team members more deeply involved and better prepared to give their input in this important project phase. Starting with very incremental progress, the generation of useful results proceeded quickly in the following meetings.

In summary, it took four full-day meetings with three R&D employees, two from Sales, and one Purchase employee to reduce the amount of allowable product variants and define the relevant platforms of the PowerWind 56.

As a first step, the working group decided to define a basic or standard variant of the PowerWind 56. The 12 product characteristics identified previously by the working groups were reduced to five main assemblies, or cancelled altogether.

<u>Tower:</u>

Initially three tower hub heights were proposed by the product rationalization team. Most efficient for a wind turbine, however, is the realization of the highest possible hub height. Wind speed increases with height, as does the generated electrical power. In many countries, the maximum allowable height of wind turbines is 100 m (from ground to blade tip). As the half rotor diameter of the PowerWind 56 amounts to 28 m, the difference between 100 m and 28 m can be used for the hub height. Therefore, the use of the 71 m tower, which results in a total height of about 99 m, was decided unanimously. In the past, the 44 m and 59 m towers were used at sites where the local buildings regulations required maximum heights below 100 m. Those sites were defined as special and, therefore, the 44 m and 59 m towers were removed as option. This was decided mainly by the Sales employees.

Power Frequency:

Due to the different grid frequencies in Europe and the USA, the PowerWind 56 is offered in 50 Hz and 60 Hz versions. As the company decided to continue to serve both continents, 50 Hz and 60 Hz variants need to be offered. Nevertheless, in order to contribute to a reduction of possible variants, it was decided that the 60 Hz version would not be combined with further grid options like the ability to “ride through grid faults” (FRT). The Sales employees had no issue with that, as the grid requirements in the US currently do not require sophisticated grid support of installed wind turbines.

Power Quality:

For the PowerWind 56, three different grid features were requested by the Sales employees: FRT 3000, FRT 500 and without FRT. This is largely due to the continuously increasing requirements of grid operators, as the amount of electricity generated by renewable sources has grown rapidly in the last few years. More and more countries are setting up new rules with corresponding requirements. Therefore, the team decided to offer the already developed grid features. It was even concluded that further features will follow in the future. Due to the rules of Mass Customization, those will have to be developed as add-on features. Here could no reduction of variants be realized.

Transformer:

Three transformer variants were originally required: outside, inside and customer specific. The main reason being that countries like Italy and the UK want to reduce the visual impact of wind turbines by placing the transformer inside the tower. Other countries, especially in Eastern Europe, prefer a transformer outside the tower due to the reduced wind turbine costs. As both markets and regions are defined as target markets in the future, the transformer variants “inside” and “outside” were retained. The specific customer option, however, was cancelled. In future, two instead of three transformer variants will be offered.

<u>Switch Gear:</u>

As for the transformer, several grid requirements were defined for the switch gear by the earlier working groups. However, for the switch gear, even more combinations were requested. Besides the general differentiation of 2-pole or 3-pole, three voltage levels (11 kV, 15 kV, and 20 kV) depending on the project-specific grid connection point, were suggested. Even if the coverage of as many local grid requirements as possible was emphasized by the Sales employees, the different grid requirements turned out to be the main source of product variants. Hence, a reduction in the combinations offered was essential. After intensive discussions, the offering of a 2-pole switch gear version was deleted. On the other hand, it was decided that all three voltage levels had to be supplied, in order to be competitive. However, the different voltage levels should only have an impact on the bill of materials if a transformer inside the tower is chosen. The realization of different voltage levels outside the tower should be realized by the customer, supported by a clear interface offered by PowerWind. These two reduction decisions reduced the total amount of transformer and switch gear combinations to four. Additionally, the Sales employees still had the feeling that they had enough options to cover the majority of existing customer sites.

<u>Controller:</u>

In the past, two controller types were used for the PowerWind 56. Originally the wind turbine was equipped with a system from the supplier Mita. This system was a cost-efficient and sufficient solution. Due to the requirement to offer more grid options, a second supplier (Bachmann) was added. The Bachmann system allowed more programmable options. However, as markets with a focus on prices and higher grid requirements are still served, the working group decided to continue with both options.

<u>Nacelle Cover:</u>

Over time, two nacelle cover variants (A and B) were developed and in put into use. As a smaller modification of the new cover version (B) would allow use with all variants, the working team decided to initiate an engineering change project for the nacelle cover B and to only use version B in the future.

Finally, there were four main components (generator/converter, gearbox, pitch drive, yaw drive), each supplied from two suppliers and with impact on the bill of materials, due to geometrical or electrical differences. The discussions about phasing out some suppliers, mainly driven by the Purchase employees, led to the consensus that the pitch and yaw drives should be purchased from only one supplier in the future; in this case, from the supplier Bonfignoli. The drives from the supplier Comer would be phased out. On the other hand, the more strategic components of generator/converter and main gearbox should continue to follow a two-supplier strategy. The future aim, however, is to negotiate at least with the gearbox suppliers to modify their gearboxes in a way that would make them geometrically identical.
In summary, the intensive reduction approach of the product configurator team led to the options listed below. The options in bold will be used in future for the PowerWind 56 and are applied in the product configurator.

Defined by the product rationalization team:

1. Tower:	44 m, 59 m, and **71 m** hub height
2. Power Frequency:	**50 Hz** and **60 Hz**
3. Power Quality:	**FRT 500**, **FRT 3000**, and **without FRT**
4. Transformer location:	customer delivered, **inside** or **outside** tower
5. Transformer performance:	**11 kV**, **15 kV**, or **20 kV** high-voltage
6. Switch Gear:	2- or **3-**pole

Defined by the product feasibility team:

7. Generator/Converter:	**ABB** or **TheSwitch**
8. Gearbox:	**JaKe** or **Moventas**
9. Pitch drive:	**Bonfiglioli** or Comer
10. Controller:	**Mita** or **Bachmann**
11. Yaw drive:	**Bonfiglioli** or Comer
12. Nacelle cover:	version A or **B**

Even if the intensively discussed compromises only led to a modest number of reductions, the effect on the total number of possible product variants was significant. Table 8 gives an overview of the consolidated variants of the PowerWind 56.

The overview includes the possible combination of the main components, as well as the countries where each variant is offered (right column). In total, 14 product configurations of the wind turbine PowerWind 56 are possible, as well as 16 variants of the “down tower assembly”, which is influenced by the electrical grid components and installed in the tower base. Compared to the initial 14,976 product variants, the product consolidation result was a great achievement for the working group.

Tab. 8: Overview of consolidated variants of the PowerWind 56

Assumptions: only 71m, only Bonfignoli, only 3-pole switch gear, only nacelle cover B, no customer trafo

	Configuration	Machine frame	Hub	Tower	Down tower assy	Base platform	Country
PowerWind 56 BASIS	1	ABB, Moventas, Mita	OAT	71 V4	ABB 20 kV inside	1	D, IT, RO
	2	ABB, JaKe, Mita	OAT	71 V4	ABB Trafo outside	2	D, AZ, PL
					TheSwitch 20 kV inside	3	IT
	3	TheSwitch, Moventas, Mita	OAT	71 V4	TheSwitch 15 kV inside	4	PL
	4	TheSwitch, JaKe, Mita	OAT	71 V4	TheSwitch Trafo outside	5	IT, PL
	5	ABB, Moventas, Bachmann	OAT	71 V4	ABB 20 kV inside	6	IT, D, RO, BG
	6	ABB, JaKe, Bachmann	OAT	71 V4	ABB Trafo outside	7	IT, D, RO, BG
					The Switch 20 kV inside	8	IT
	7	TheSwitch, Moventas, Bachmann	OAT	71 V4	The Switch 11 kV inside	9	UK
	8	TheSwitch, JaKe, Bachmann	OAT	71 V4	The Switch 15 kV inside	10	PL
					The Switch Trafo outside	11	IT
PowerWind56 RT500	9	TheSwitch, Moventas, Mita	OAT	71 V4	TheSwitch RT5 20 kV inside	12	IT
	10	TheSwitch, JaKe, Mita	OAT	71 V4	TheSwitch RT5 Trafo outside	13	IT, PL
PowerWind56 RT3000	11	ABB, Moventas, Bachmann	OAT	71 V4	ABB RT3 20 kV inside	14	D, RO
	12	ABB, JaKe, Bachmann	OAT	71 V4	ABB RT3 Trafo outside (bisher kein Bedarf)	15	???
PowerWind56 60Hz	13	60 ABB, Moventas, Bachmann	OAT	71 V4	ABB 60 Kunde outside	16	USA, 60Hz countries
	14	60 ABB, JaKe, Bachmann					USA, 60Hz countries

The next step for the working group was the development of a product configurator based on these consolidated product variants.

4.2.1.8 Product Rationalization – Interviews 3rd Project Phase

After the first interview, during the initial team meeting on 10th September 2012, a second interview took place on 29th October. At this time the implementation project was already at an advanced stage (3rd phase). Again, the team consisted of five employees from the Sales/Marketing department, including the Head of Sales/Marketing. In addition, one R&D and one Purchase employee were on the team. The original aim of the product rationalization team was the identification and definition of the relevant wind turbine characteristics and product features to cover the market needs. During three meetings (10th, 17th and 24th September), the team was able to present the relevant product features against the background of targeted markets. During the last team meeting on 29th October, the final semi-structured interviews were conducted.

As in the first interviews, seven employees participated in the meeting and semi-structured interviews on 29th October:

Sales	R&D	Purchase
S1	RD1	P1
S2		
S3		
S4		
S5		

Responses and observations from the last meeting, 29th October 2012:
The atmosphere was quite relaxed, as no new input needed to be added. Rather, the intention was to reflect on the handling of their input during the implementation project and the progress of the overall project. In the project kick-off meeting, the Sales employees were the most sceptical project members. However, in the course of the project and team meetings their attitude became more productive and optimistic.

The "Need" questions in the second interview session were answered as follows:

1.a What do you think about the need to implement a new manufacturing concept?

Compared to the first meeting, where only two of the five sales employees saw the need for the implementation of a new manufacturing concept, there was a small increase of acceptance registered.

Hence, one Sales employee mentioned:

“The discussions helped me to understand the claims of the manufacturing employees in Bremerhaven. These are not mainly caused by the distance between our headquarters and the production facility. Although it seems to be a customer order process problem, I am still not sure whether the new manufacturing concept is able to solve this.”

On the other side, another Sales employee concluded:

“In the course of the implementation project I became confident that implementation of the new manufacturing concept was really needed. In particular, it can possibly close the gaps that currently exist in the customer order process. Also, the consolidation of variants does not necessarily result in a lack of flexibility.”

Another Sales employee supported this statement, but with certain restrictions:

“That is true. However, up to now it has cost more effort than expected and led to postponed wind turbine deliveries.”

The attending R&D employee added:

“I have the feeling that the Sales department learned more about our products during the weeks of the project than in all the years before. This alone highlights the need for the implementation.”

1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

The first response came from a Sales employee:

“The reduced performance of the organization was evident over the last few weeks. We have to ramp up our productivity again, as the last quarter of a year is usually characterized by the highest delivery rate. Our barriers are the limited resources, which are now tied-up in the implementation project”

Another Sales employee said:

“The biggest issue was and is the alignment of sold wind turbine variants and the variants offered in the future. Even if some variants are not offered in the future, we have to support those customers who have ordered those variants recently. For instance, we have one customer who expects more support for his customer-specific transformer than the delivery of an interface. That is a real issue at the moment."

The R&D employee commented on this as follows:

"This example is quite typical for our business and highlights our main difficulties. We allow too many customer requests for engineering support. The realization of so many individual requirements costs a lot of effort and investment. I am pretty sure that the customers are not willing to pay for this."

The "Appropriateness" topic was also discussed intensively. During this, different views on appropriateness came to light.

2.a What do you think about the choice of the implemented manufacturing concept?

Compared to the responses in the first meeting, there were fewer concerns from the Sales team about losing its flexibility due to fewer product features. However, there were still opinions that the chosen manufacturing concept could be too complex.

Hence, one response to this question was:

"The future will show whether PowerWind can react flexibly enough to special site requirements. I would still prefer to introduce a smaller process package and to test its impact before changing too much."

In contrast, another Sales employee responded:

"In the beginning I had serious concerns about whether this manufacturing concept was too complex for PowerWind. In particular, when we started to reduce our product variants dramatically. However, when the consolidation results and the possible product variants were presented, I changed my mind. Furthermore, I have seen the first results from the new product configurator. It can really contribute to improvements in all the departments involved."

2.b What strategic advantages for the company do you see in implementing a new manufacturing concept?

The theoretical advantages of the new manufacturing concept were already understood in the first interview session. However, certain doubts about the practical realization existed during both interview sessions.

One common response was:

"Of course, the organization will have more detailed information about the sold wind turbines sooner. It is not certain, however, whether this information alone will reduce our process failures and production lead times."

Most responses from the Sales employees were about the current situation:

"Up to now, we have been implementing the new concepts for two months. During this time, we have produced less than half the number of the wind turbines that we usually produce. Furthermore, we have almost no engineering support for internal and external requests. Therefore, we have currently no advantage."

On the other hand, the attending Purchase employee added:

"The implementation phase is not representative. I have also seen the first results of the product configurator team. As we can now get such clear and valuable information, our communication and process failures should be reduced massively."

Finally, one Sales employee highlighted:

"We have also taken into account that the implementation project produced subliminal results. We are sitting together as mixed team, having an intensive exchange of different perspectives and information. This was not practiced earlier and will surely have a positive impact on the future of the business."

The "Capability" question was answered as follows:

3.a What do you think about the organization's capability to implement the new manufacturing concept?

The Sales employees saw their views confirmed regarding PowerWind's capability to implement the manufacturing concept, especially due to the lack of human resources.

One typical response from the Sales employees was:

"It became evident that this additional amount of work could not be handled by the engineers. We have had practically no engineering support during the implementation phase. We are afraid that this situation will last longer than originally estimated."

The attending R&D employee confirmed:

"Even after the reduction of product variants, we still have a lot of work on the bills of materials. Some of the main assemblies are newly configured and in addition, several options have to be designed as “add-ons”. This requires a more sophisticated design for the corresponding interfaces. The problem of low human resources remains.”

At the end of the interviews the “Motivation” question was discussed:

4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?

Even though the Sales employees had issues with the current situation, they still had a certain amount of motivation.

One Sales employee explained:

“My biggest motivation is the improved communication. Since we started the implementation project, understanding of the different opinions about our work improved. We have learned what is driving and hindering the work in the different departments. Furthermore, I have a better understanding of our product, which makes it easier for me to negotiate with customers. This achievement motivates me to continue with the project.”

Another Sales employee gave a different view:

“However, the current performance is not sufficient. If the implementation project lasts longer we will have serious problems in the important last quarter of the year.”

The Purchase employee added:

“In general, we have to work on our organizational culture. When we have a better understanding of each department´s perspective, we can start speaking a common language. In the past we had more of a silo mentality.”

During the second interview session, the employees’ behaviour and attitudes had changed. Firstly, all of the resistance from the Sales/Marketing employees was reduced, even if some claimed that organizational productivity had reduced due to the implementation project. Most employees saw the need for a new concept. Furthermore, motivation and job satisfaction had increased to a higher level. The same happened with trust in the project manager. The Sales/Marketing employees expressed more confidence in the chosen manufacturing concept. On the other hand, all participating employees claimed there was a lack of organizational capability.

4.2.1.9 Product Rationalization – Results 3rd Project Phase

At this stage of the project, no further input from the product rationalization team was planned. The aim of the last meeting was to reflect on the project's progress and to check whether the defined product characteristics had been processed correctly. In summary, the Sales team confirmed the originally defined product characteristics and their proper consideration in the course of the project.

4.2.1.10 Technical Feasibility – Interviews 3rd Project Phase

The technical feasibility team met for the last time, close to the end of the implementation project, on 24th October. During this meeting, the second semi-structured interviews were conducted. As in the meetings before, the team consisted of three experienced R&D engineers and three senior Purchase employees. Their original task was the identification of possible product modules to meet market needs and to define rules for combining them. As these product modules and rules were already under implementation in a product configurator, no further input was necessary to this task. Due to the fact that the team consisted of experienced R&D and Purchase employees, the team was given the task of designing a modified customer order process, based on the already existing process (Fig. 14) and the results of the implementation project achieved so far.

In the second interview session, on 24th October, six participants attended, as listed below:

Sales	R&D	Purchase
	RD2	P2
	RD3	P3
	RD4	P4

The modification of the customer order process was supported by the Head of Sales/Marketing and a further Sales employee. Both were interviewed in other team meetings and therefore did not participate in this interview session.

Responses and observations from the meeting of 24th October:

The members of this team had intensive discussions, and experienced certain tensions, during the first meeting, as the employees of the R&D and Purchase departments saw different reasons for the poor performance of the customer order process. During this meeting, different viewpoints on the project came into light. However, the modification of the process was carried out with high motivation from both groups.

The "Need" questions were answered as follows:

1.a What do you think about the need to implement a new manufacturing concept?

In general, the Purchase employees felt that there is an immense need for a process change, justified by the ongoing implementation project. They highlighted the many examples of failures from all the departments as evidence for that. The R&D employees, however, expressed certain concerns. That was detected for the first time in this project.

One Purchase employee responded:

"It was interesting to hear of the different difficulties from each department, but it was also difficult to imagine that this was caused by incorrect processes. I am keen to see whether the new manufacturing concept and process modifications result in an improvement or if the R&D department requires performance improvements."

A further Purchase employee reported a recent example of failures in the current value performance and communication:

"During the commissioning of a wind turbine, a Sales manager announced that he had received the final grid acceptance from the operator. At same time, the grid operator required an additional hard-wired control connection of the wind turbine to the transfer station. However, the site manager responsible reacted with surprise and said that they had already filled in the 800 m long line trench. That meant that the workers had to dig out the trench again to insert one cable. This additional work could have been avoided by reliable processes and better communication."

One of the attending R&D employees stated:

“There was definitely a need for better communication and performance, but I am not sure whether we needed to change so many bills of materials. Maybe the existing product variants were sufficient, or a more restrictive process for the Sales employees would have been a solution. Now, we have still a huge amount of work ahead of us.”

1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

Following a short discussion after the first question, several potential barriers were identified from both sides.

One R&D employee reported his experience:

“A positive element is the fact that, during the project, several areas for improvement were uncovered. Additionally, the open work packages are clearer now. However, even if we can prioritize the work, the largest portion of it still has to be done by the Engineering department.”

Another R&D engineer added:

“Possibly we have to proceed with the reduction of product variants. It depends how the progress of the completion of the missing bills of materials goes.”

One Purchase employee confirmed:

“Due to limited resources, we possibly need to wait a little bit longer to get all the bills of materials completed, but we now have a better idea what is finished or when it will be finished. The required resources and time are now easier to calculate.”

The employees from R&D and Purchase evaluated the “appropriateness” of the selected manufacturing concepts differently again. However, this time the Purchase employees saw the business needs as being covered by the concept.

2.a What do you think about the choice of the implemented manufacturing concept?

The first response came from a R&D employee:

“I am still convinced that we need to involve the Sales department more strongly in the customer order process, and this is supported by this concept. However, I did not expected that we would need so many different modules, which is causing us a lot work.”

A second R&D employee added:

"The concept contributes not only to better communication but also makes our complex situation and the workload transparent."

One Purchase employee mentioned:

"One big advantage is that we get a higher degree of standardization, which should increase our economies of scale in the purchase of components. That is also claimed by our suppliers when we request lower prices. The aim should be to have as many product features as possible designed as add-ons. The remaining components would then create a platform that is valid for all variants. By doing that, a neutral bill of materials could be generated."

Another Purchase employee added:

"If this concept contributes to a larger neutral bill of materials, then it is the right choice."

2.b What strategic advantages for the company do you see in implementing a new manufacturing concept?

In general, both groups of employees saw the standardization effect as a possible advantage. Compared to the last interview, where reduced delivery times and component costs were mentioned in particular, this was a significant change. However, some critical opinions were also expressed.

One Purchase employee said:

"We can reduce our planning difficulties with component purchase and inventory stock when we are able to start anonymous production without the risk of major rework due to project changes. Balanced utilization was not possible up to now."

Another Purchase employee added:

"It would be best if the concept allowed a link to the payments made by the customers. We would customize the turbine only if a certain payment had been made. That would improve our working capital situation as well."

On the other side, one R&D employee responded:

"However, I do not see a strategic advantage for the R&D department for a long period. The aim, to have more time and resources for innovation, has not yet been achieved."

The "Capability" question was responded to as follows:

3.a What do you think about the organization's capability to implement the new manufacturing concept?

Compared to the first questions, no major differences in the employees' answers were noted in the "capability" question. The most significant difference was observed in the group atmosphere. During the first interview session the atmosphere was a little bit more loaded and the discussions more intense. In the second interview session, the mood was more relaxed and the responses more factual.

The Purchase employees generally answered:

"I have seen the timeline as critical from the very beginning. Not only due to the resource situation in the R&D department but also because of unexpected project steps like the handling of a huge number of product variants."

One R&D employee added a response that was representative of all participating R&D employees:

"The last weeks of the project have shown that the work is becoming more and more concentrated on the R&D department. That is what we were afraid of at the beginning. For that reason, I see our capabilities critically."

Finally, the motivation question was responded to by the team as follows:

4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?

An engineer responded:

"I still hope that we can start to focus more on innovative solutions for our product. Even if the work packages are more structured now, there is still a huge amount of work ahead of us engineers. But my motivation is decreasing."

Another engineer added:

"I think further measures like reduction of product variety and complexity are unavoidable. At this project phase, the workload is higher than before the implementation project."

One Purchase employee described his motivation:

"I still feel motivated to get the project completed - even more than at the beginning of the project. In particular, the potentially increased rate of standardization motivates me to get more out of it."

A second Purchase employee added:

"For me, the ability to modify the customer order process further is the biggest motivation. We can balance the utilization of the production and the required components and in addition reduce our inventory stock."

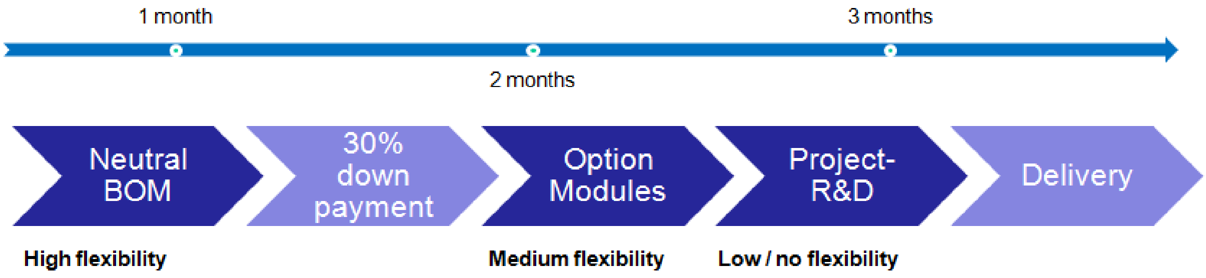
In summary, a positive trend could be registered amongst the Purchase employees and a rather negative one for the R&D employees. The personal indicator "job satisfaction" increased for the Purchase and decreased for the R&D employees. Furthermore, a lower resistance to change and higher trust in the project manager was observed amongst the Purchase employees. On the other side, the R&D employees expressed more doubts about the project. Both groups had in common the opinion that the organizational capabilities are not sufficient.

4.2.1.11 Technical Feasibility – Results 3rd Project Phase

The final task of the technical feasibility team was the modification of the existing customer order process (Fig. 12), based on the results of the implementation project and the capabilities of the new product configurator. In general, the objective was to postpone the assembly of the project-specific equipment for each wind turbine as far as possible in the assembly process. Such an approach is also a main characteristic of the manufacturing concept Postponement. The basic idea is also to link customer payment to the assembly progress of the wind turbines. Ideally, the project-specific features are assembled when the customer has made at least a down payment for the wind turbine.

In a very motivated and constructive atmosphere, the product feasibility team created a modified customer order process, as shown in figure 15.

Fig. 15: Modified customer order process at PowerWind



Based on a neutral bill of materials, which should be as comprehensive as possible and should ideally cover wide areas of the wind turbine, the assembly of wind turbines is started. This high flexibility for change even allows anonymous production of wind turbines, without the risk of rework due to specific project requirements. Wind turbines that are produced based on a neutral bill of materials could even be assembled to stock. These wind turbines could then be used for different projects without any rework. Only after receiving a down payment would production start to assemble the optional ordered modules. In this process phase, the contract with the customer would be signed and the technical requirements fixed, because with the start of such customization, the flexibility for further change decreases.

Several projects are so specific that project R&D is unavoidable. Such technical features, which are usually engineered to order, reduce the flexibility of the production to a minimum. Ideally this process step is accompanied by a further down payment from the customer.

This approach means that the risk of an uncontrolled rework of the production and engineering work should be minimized. If the supply chain is quick enough, and properly linked to this process, inventory stock could be increased as well. For instance, the optional modules are ordered in the course of production and only after the signing of a contract with the customer. In a more advanced version of such a process, the optional modules could be outsourced as sub-assemblies to the suppliers and just ordered and added after a wind turbine is sold. This would contribute additionally to a reduced inventory stock.

Furthermore, anonymous production could be equally distributed over the whole year, which would also contribute to a lower inventory stock of parts and components that belong to the neutral bill of materials.

4.2.1.12 Product Configurator – Interviews 3rd Project Phase

Before starting the development of the product configurator, it was necessary to reduce the number of product variants. Hence, the development of the product configurator was started in the 3rd project phase. After the reduction of variants, started on 19th October, three further meetings followed. During the last team meeting, on 9th November, the second interview session was conducted. The product configurator was to be set up in such a way that either an automatic configuration is created based on the chosen features, or the features are manually selected. Again, six employees belonged to the product configurator team: three R&D employees, two from Sales, and one Purchase employee:

Sales	R&D	Purchase
S1	RD2	P2
S6	RD5	
	RD6	

The following responses and observations were noted during the last meeting on 9th November:

After the productive meetings for the reduction of product variants, the team gave the impression of being very motivated. Right at the start of the meeting, two employees presented their ideas for the selection of product characteristics.

The “Need” questions were answered as follows:

1.a What do you think about the need to implement a new manufacturing concept?

One of the R&D employees started to respond:

“The fact that we have not had enough time to react to spontaneous change requests is an indicator of the need for a new manufacturing concept. I have the feeling that this was recognized throughout all departments, although it has meant that some colleagues have temporarily had a higher workload."

Another R&D employee added:

"It was a matter of time before the failures caused by incorrect documents led to serious damage. Therefore, it is good when we achieve a reliable documentation basis and communication platform."

The third R&D employee expressed his doubts for the need:

"My concerns regarding the higher workload have been confirmed. We have an immense workload ahead of us. Therefore, I have doubts whether this change was needed."

The Purchase employee mentioned:

"I believe that the benefits outweigh the disadvantages. Once the system is fully established, we can significantly increase our efficiency."

1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

The attending Sales employee stated:

"I believe that existing human resources are really an issue. However, I also see that a supportive attitude exists throughout the whole organization. For that reason, I think that we can handle this bottleneck."

An R&D employee added:

"There is no reliable guideline for such an implementation. That makes the time and resource planning unpredictable. Furthermore, low process experience exists amongst the employees."

One Purchase employee confirmed:

"I think the uncertainty contributes additionally to the reduction of performance. If the planning were more reliable then the attitude of the employees would be more positive."

The answers to the "Appropriateness" questions were congruent throughout all employee groups. It was seen as positive that the concept is acting on all points of the value performance, as the sources of failures are multiple.

2.a What do you think about the choice of the implemented manufacturing concept?

One of the Sales employees responded:

“The manufacturing concept already provided transparency and improved the communication basis. Our Sales colleagues also learned a lot about our technology and the constraints of R&D. Therefore, I now think that the choice was appropriate.”

One R&D employee confirmed:

“That is right, we are now more aware of the motivations and difficulties of the departments involved. Furthermore, the Purchase and Sales colleagues were able to improve their technical understanding of our wind turbines.”

The Purchase employee added:

“The selection seems to be good. I will be sure of that when we can link the concept to material and cash flow. That can probably be realized using the modified customer order process.”

Finally, the Sales employee added:

“I think it is an appropriate choice, even if I had certain doubts about whether it would slow us down to a complete standstill. The seasonal timing is not so good, due to the increasing amount of deliveries at the end of the year. The reduced performance has already been noticed by the customers.”

2.b What strategic advantages for the company do you see in implementing a new manufacturing concept?

Transparency and reliability in the process were named by employees from all departments.

The Sales employee stated:

“I hope that the implementation is completed soon and the modification of the customer order process established. The product configurator could become an important tool; if it works as planned we could become clearer, faster and more reliable in our negotiations.”

An R&D employee added:

“And with that, you should increase customer satisfaction as well. It is better that we offer less features, but deliver reliably, than making promises that cannot be achieved or that cause unreasonable effort.”

Another R&D employee explained:

“The transparency that we get in the Engineering department is also strategically important. Even if the responsibility for each sub-assembly and add-on is now assigned to one engineer, the defined design rules and documentation will avoid individual knowledge, especially as it is no longer possible to make personal arrangements for change."

The "Capability" question was answered during the second interview session as follows:

3.a What do you think about the organization's capability to implement the new manufacturing concept?

One R&D employee expressed his doubts on whether the purchase strategy was exploited enough:

"The two-supplier strategy should be reconsidered. And if this decision remains unchanged then the supplier should be forced to deliver exactly the same components, electrically and mechanically. There is still untapped capability."

The attending Purchase employee saw limitations in the professional experience and process thinking of several employees:

"Furthermore, we have to get our engineering change process under control. We need clearly identifiable responsible persons for each product, in order to avoid uncontrolled product changes. Otherwise, I do not see the ability to make progress quickly."

The Purchase employee mentioned more general doubts:

"Many R&D employees have not been involved in processes outside of engineering. Therefore, I see certain limits in their capability. On the other hand, they should be flexible enough and able to learn fast."

The Sales employee countered with the view that everything is moving in the right direction:

"Even if several difficulties came up during the project, I have the feeling that, each time, a solution was developed quickly. We should have enough experienced employees to guide the younger ones."

As in all previous interviews, the last question was about the employees' motivation:

4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?

A Sales employee reported his motivation first:

“If we succeed in developing a product configurator that enables seamless communication from quotation to payment, as planned, I am sure that we will significantly improve our profits. The development of this product configurator is currently my motivation.”

One R&D engineer added that this would lead to a reduction of interpretation errors and, in the end, less rework of already assembled wind turbines:

“I would like to have less confusion during our day-to-day business. In particular, fewer calls from Production where I have to explain technical issues because they were incorrectly entered into the order process.”

The Purchase employee added:

“If the modified customer order process is stable enough, and used in a disciplined manner, then these kinds of failure should be eliminated. Even though my experience with new processes in this company demotivated me, the prospect of achieving the set goals using a new customer order process has motivated me again.

Finally a further R&D employee reminded the others that:

“We should not forget that we wanted to achieve more capacity for product innovation, with the aim of producing better products and having more customers.”

Most significant was the fact that employees from all the departments gave positive comments about the chosen manufacturing concept and expressed their trust in the project. This positive attitude possibly led to the overall high motivation and relatively low resistance to change. The Sales/Marketing employees even gain confidence in the organizational capabilities, while the R&D employees remained sceptical on this point.

4.2.1.13 Product Configurator – Results 3rd Project Phase

Based on the reduced number of product variants during the 2nd project phase, the development of the product configurator was started in the 3rd project phase. The product configurator had two main objectives.

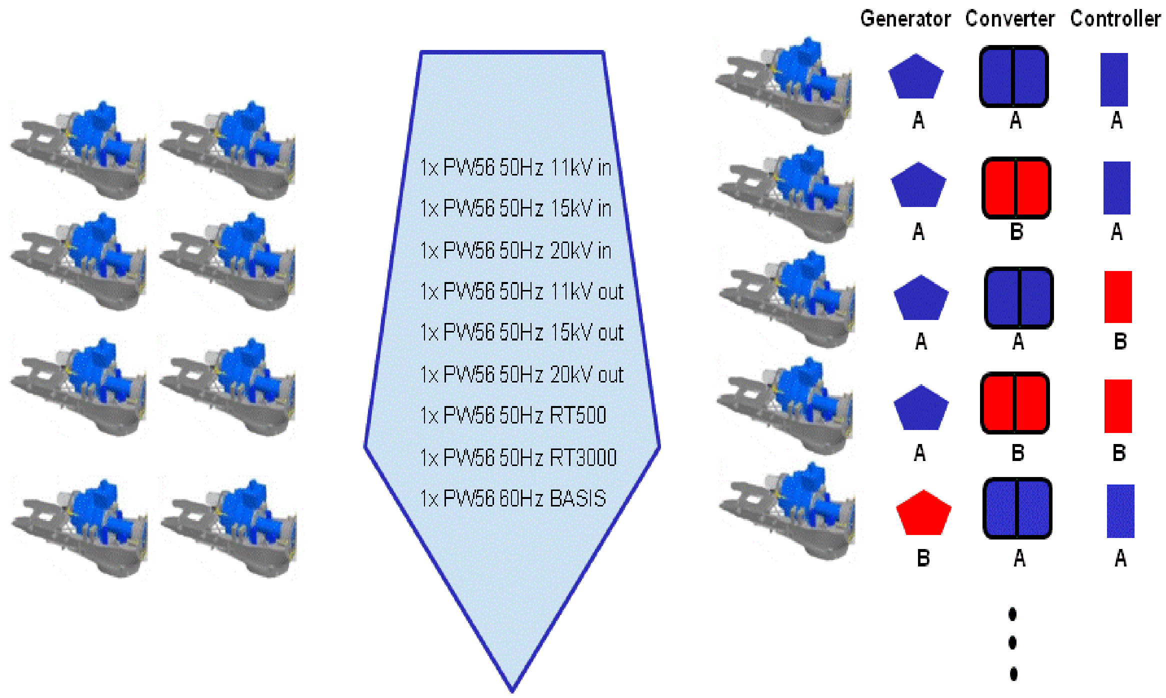
The generation of

1. internal reports, with all material numbers necessary for the assembly
2. external reports, with an overview of selected wind turbine features for the customer

The product configurator was set up in such a way that either an automatic configuration is created, based on the chosen features, or the features can be manually selected. When using manual selection, only allowable combinations are possible. In the automatic mode, the wind turbine variants are configured corresponding to the country of the project. As already described, several countries have specific technical requirements. These requirements, and the corresponding rules, are considered by the product configurator. For instance, a wind turbine configured for Italy automatically selects the option of having the transformer inside the tower. Based on the input and the programmed rules, the correct product variant is configured. Furthermore, optional equipment can be selected that is designed as an add-on and therefore fits all product variants.

Based on the postponement approach developed by the product feasibility team, the product configurator also considered the new product architecture, which consisted of a neutral bill of materials, pre-engineered modules and optional equipment. Figure 18 gives a systematic overview of how, based on a neutral bill of materials, in combination with pre-engineered modules, the requested product variants were realized. In general, the drive train (blue), mainly consisting of the gearbox, main shaft, and main bearing, as well as the main frame and generator frame (both grey), made up the neutral bill of materials. Basically, by combining the variable modules generator, converter and controller, the required product variants were achieved. These basic rules, and multiple further detailed rules, have been programmed into the product configurator and no longer depend on individual knowledge.

Fig. 16: Basis for product configurator and neutral bill of materials of the PowerWind 56



The arrow in the middle of Fig. 16 lists the different product variants of the PowerWind 56 as requested by the customer. According to the design rules of Mass Customization, the greatest possible neutral bill of materials was created. This was mainly realized by a similar machine and generator frame (in grey pictured components) and gearbox (in blue pictured components). The generic wind turbine platforms can be produced anonymously as they can be used for all later product variants (Fig. 16 left side). In a later step, the different sub-assemblies are added to the generic platform to achieve the requested product variant. In this case, different generators, converters, and controllers (versions A or B) can be differently combined with the generic platform to achieve the requeted wind turbine variant.

The product configuration results in two reports, listing the chosen wind turbine variant and its main components. The internal report additionally includes the material numbers of the components and the bill of materials for the ERP system SAP. This information can be used directly in the customer order process. Furthermore, an indication of the purchase costs is displayed, which is valuable for Sales employees when calculating an adequate sale price. In addition, the expected manufacturing lead time is shown, which also supports the Sales department during negotiations. Both pieces of information are highlighted by symbols:

- green symbol: positive indicator (low purchase price / short lead time)
- red symbol: negative indicator (high purchase price / long lead time)
- blue symbol: neutral indicator (average purchase price / average lead time)

An example of a description of a configured wind turbine is shown in Fig. 17. In Fig. 18, an external customer report is shown, and Fig. 19 shows the corresponding internal report.

Fig. 17: Example of description of configured wind turbine

Product Configuration

Project
Project UK

Customer
University of Gloucestershire

Product Type
PowerWind 56

Salesmanager
Thomas Korzeniewski

Date
29.05.2015

Fig. 18: Example of external report of configured PowerWind 56

Requirements for this WEC

Rated Power:	900 kW
Country:	UK
Tower height:	71 m
Ride through capabiltiy:	None
Transformer voltage:	11 kV
Transformer:	Inside of Tower

Main configuration

Component	Selection
Tower:	Hub Height 71 m
Down Tower:	Converter: ABB, FRT: None, Control: PowerWind
Nacelle:	Generator: ABB, Gearbox: Moventas
Transformer:	Inside Tower (11KV)

Optional equipment

Option	Selection
Aviation Lights:	DAY + NIGHT 2 BEACONS RED/WHITE
Shadow Casting / Bat	SHADOW CASTING WITH BAT
Smoke Detection:	MINIMAX SMOKE DETECTION
Ice Detection:	ICE DETECTION
Logo:	POWERWIND LOGO
Wind Speed and	ULTRASONIC ANEMOMETER
Power Meter:	CALIBRATED
Day Marking:	ACC. TO PW COLOUR SPEC C27
Grid Protection:	G59 GRID PROTECTION

Fig. 19: Example of internal report of configured PowerWind 56

PowerWind **WEC configuration**

Internal Document for Project: Project UK / Target Date: 29.05.2015

Customer:	University of Gloucestershire		
Created:	29.05.2015	Created by:	*Thomas Korzeniewski*

Requirements for this WEC

Rated Power:	900 kW
Country:	UK
Tower height:	71 m
Ride through	None
Transformer	11 kV
Transformer:	Inside of Tower

Main configuration

Component	Selection	SAP-#
Tower:	TOWER NH71M-V4	2300001618
Down Tower:	DT ABB BACHMANN	2300001592
Nacelle:	NAC. ABB MOVENTAS BACHMANN	2300001599
Rotor:	ROTOR 56m	2300001258
Transformer:	TRAFO SWITCH GEAR 11KV	2300001400
Nacelle Lighting:	NAC. LIGHTING 50 HZ	2300001322
Supplies:	SUPPLIES PW56/60	2300001403
Consumable Supplies:	CONSUMABLE SUPPLIES	2300001434
ET - Cables Down Tower:	ET DT ABB IN	2300001549
Country Package:	CP UK	2300001371

Optional equipment

Option	Selection	SAP-#
Aviation Lights:	DAY + NIGHT 2 BEACONS RED/WHITE	2300001354
Shadow Casting / Bat System:	SHADOW CASTING WITH BAT	2300001350
Smoke Detection:	MINIMAX SMOKE DETECTION	2300001345
Ice Detection:	ICE DETECTION	2300000499
Logo:	POWERWIND LOGO	2300001366
Wind Speed and direction:	ULTRASONIC ANEMOMETER	2300000460
Power Meter:	CALIBRATED	2300001358
Day Marking:	ACC. TO PW COLOUR SPEC C27	9990000000
Grid Protection:	G59 GRID PROTECTION	999999

Necessary components for optional equipment: 2300001639, 2300001632, 2300001633, 2300001337

4.3 Qualitative Data Analysis

As expected, a considerable amount of data was collected during the implementation project. In order to draw rigorous and relevant conclusions from it, a systematic and disciplined data analysis method was chosen. In this case, a framework analysis was considered as best suited.

In the first step, the collected qualitative data was categorized based on core consistencies and meanings. The interview guide constituted a descriptive framework for both the qualitative data collection and analysis. As developed in chapter 3.6.2, the interview guide that was used included questions that captured situational indicators (trust in supervisor and trust in organization) and personal indicators (dispositional resistance and job satisfaction). This led to underlying questions about:

1. Need for new manufacturing concept (dispositional resistance);
2. Appropriateness of new manufacturing concept (trust in supervisor);
3. Organizational capabilities for implementation (trust in organization);
4. Motivation of employees for implementation (job satisfaction).

The keywords of each answer were classified and evaluated according to these categories.

It was expected that, with the implementation of a new company-wide manufacturing concept, the different employee groups would have fairly different opinions and attitudes towards the implementing process, as well as multiple reasons for their different views. Moreover, different levels of motivation and readiness for change were expected. As readiness for change correlates to supportive behaviour during a change project (Kraus 1995; Cooke and Sheeran 2004), it was important to capture the readiness for change during the different project phases, in order to evaluate the organizational impact of the lean manufacturing concept implementation.

4.3.1 Qualitative Data Analysis – 2nd Project Phase

In the 2nd project phase, three working groups (a product rationalization team, a technical feasibility team and a product configurator team) were interviewed during their first group meetings. According to Lewin (1947), this phase of the project (2nd phase) marks the beginning of the “moving phase”. In total, 19 employees were interviewed, with three of them participating in two groups and being interviewed twice. Their arguments were summarized down to one statement from each employee.

As two questions dealt with the need for the implementation of a new manufacturing concept, 38 answers were given on this topic. However, some answers included more arguments for or against the need for implementation. Therefore, to summarize, 47 arguments were noted and classified according to their core statement, as described in chapter 3.8.2 (Tab. 4). The percentage of the reasons given is related to all registered statements (47) and the total amount of interviewed employees (16). Table 9 gives an overview of the summarized core statements and their occurrence.

Tab. 9: Need for implementation of lean manufacturing concept – 2nd project phase

Reasons for need or no need for implementation of new manufacturing concept	Valuation	Occurrence	Percentage of statements/ employees
Failures in existing process	Need	12	25.5 % / 75.0 %
Overload of R&D	Need	10	21.3 % / 62.5 %
Lack of product/assembly documentation	Need	7	14.9 % / 43.8 %
Simplicity and flexibility of existing process	No need	5	10.6 % / 31.3 %
Knowledge of R&D	No need	4	8.5 % / 25.0 %
Limited time	No need	4	8.5 % / 25.0 %
Attitude of production	No need	3	6.4 % / 18.8 %
Organizational culture (not supportive)	Need	2	4.3 % / 12.5 %

The responses to the question about the need for the implementation of a new manufacturing concept should provide a picture of the resistance to change amongst the employees. Compared to the “unfreezing phase” (1st project phase), the opinion that there was a need for this implementation decreased at the beginning of the "moving phase" (2^{nd} project phase). In total, 66 % of the registered statements indicated that the company had a need for a new manufacturing concept. 34 % of all statements denied that there was a need for the implementation. In particular, the Sales employees did not recognize the need for the implementation of a new manufacturing concept; only 40 % of Sales employees identified this need. The remaining Sales employees had not seen the difficulties caused by the old concept and customer order process. Their doubts regarding the "complexity of the new manufacturing concept" and their fear of "losing product flexibility" were summarized in the no-reason argument: "simplicity and flexibility of existing process". Further arguments were insufficient "knowledge of R&D" and poor "attitude of production" workers towards an efficient customer order process.

On the other hand, 83 % of the R&D employees and 75 % of the Purchase employees interviewed stated the need for a new manufacturing concept. The main argument of both groups was the poor performance of the old customer order process. Statements like "reliance on individual knowledge", "people-dependent process", "failures of purchase" and "failure of sales" were classified in the core need-argument "failures of old process". Furthermore, a typical argument from the Purchase and R&D employees in favour of the implementation was the "lack of product/assembly documentation".
However, the reason given most often for the need for a new manufacturing concept was the existing "overload of R&D". This reason was mentioned equally often by employees from all the departments represented.

It was significant that 12 of 16 employees (75 % of all interviewed employees) stated that the performance of the existing customer order process was not satisfactory. On the other hand, five of 16 (31 %) praised the "simplicity" of the existing process. The majority of employees expressing this opinion (four of five) were from the Sales department. Even if most of them also found negative aspects to the existing customer order process, they saw the root causes in other areas, rather than the existing manufacturing concept. The Sales employees were mostly responsible for the claim that a lack of "knowledge in the R&D" department was the problem; 75 % of those making this statement were from the Sales department.

Furthermore, a certain reluctance from the Sales employees was detected. 67 % of them mentioned that they are concerned about implementing a new manufacturing concept because they fear becoming more limited in the multiple solutions they can offer to their customers ("simplicity and flexibility of existing process"). Only 33 % of the interviewed Sales employees said that they were positive about the prospect of getting a new product and manufacturing system. The R&D employees had the opposite view: only 17 % had purely negative opinions about the implementation of the new manufacturing concept. Their biggest concern was that the new processes could disrupt their tasks and reallocate the work from other departments to R&D ("overload of R&D").

In summary, it can be stated that the Sales employees had a high resistance to change and the Purchase and R&D employees a lower resistance at the beginning of the "moving phase". One possible explanation could be that the Sales department is involved in a very early phase of the customer order process and therefore less affected by process failures. That was highlighted by the different opinions about the given business situation coming from the Sales and R&D employees.

Two questions were also asked with regard to the appropriateness of the selected manufacturing concept. Hence, the 16 interviewed employees gave a total of 38 answers on appropriateness. In total, 45 arguments were noted, as some answers included more statements on this topic. Again, the statements were classified according to their central argument, as described in chapter 3.8.2 (Tab. 4). The percentage of the given arguments relates to all registered statements (45) and the total number of interviewed employees (16). Table 10 gives an overview of the summarized central arguments and their occurrence.

Tab. 10: Appropriateness of selected lean manufacturing concept – 2nd project phase

Reasons for appropriateness of selected manufacturing concept	Valuation	Occurrence	Percentage of statements/ employees
Improves communication	Approp.	12	26.7 % / 75.0 %
Reduces process failures in value chain	Approp.	9	20.0 % / 56.3 %
Reduces flexibility	Not approp.	6	13.3 % / 37.5 %
Improve R&D efficiency	Approp.	5	11.1 % / 31.3 %
Increases product understanding	Approp.	4	8.9 % / 25.0 %
Positive financial influence	Approp.	4	8.9 % / 25.0 %
Too complex and time-consuming	Not approp.	3	6.7 % / 18.8 %
No advantages achievable in practice	Not approp.	2	4.4 % / 12.5 %

In general, the appropriateness of the chosen manufacturing concept was seen positively at the beginning of the “moving phase”. In summary, 75.6 % of the registered statements indicated that Mass Customization as the selected manufacturing concept was appropriate to cover the needs of PowerWind. Only 24.4 % of all statements said the opposite. The responses regarding appropriateness should give an indication of the level of trust in the project and moreover in the project manager, who prepared the project and selected the implemented manufacturing concept. Even though it was not as significant as in the need questions, the main differences in views on appropriateness were again found between the Sales employees and the employees from the Purchase and R&D departments. 50 % of the Sales employees mentioned doubts on whether the chosen manufacturing concept was appropriate for PowerWind. Their main argument was potentially reduced flexibility in offering the required wind turbine features. Furthermore, they claimed that the complexity of the chosen concept and the limited human resources, especially in the R&D department, would be a problem for the implementation. More than half of the Sales employees who expressed doubts asked if the new manufacturing concept could not be implemented in part. Others suggested an extended timeline for the implementation.

On the other hand, the R&D employees welcomed a manufacturing concept that covered all the departments involved in the value performance. 67 %

valued the chosen manufacturing concept as appropriate. Their main arguments were improved knowledge and better communication with the Sales employees. From the R&D perspective, they simply did not have enough knowledge about the technology they were selling. This led to offering wind turbine features that were not yet fully engineered. Furthermore, the R&D employees expected that the chosen concept would improve efficiency in the R&D department (11.1 % of all given statements). In particular, they hoped to get more free time for necessary product innovations. Most Purchase employees also expressed a positive opinion about the selected manufacturing concept. 75 % of the Purchase employees considered the chosen lean manufacturing concept as appropriate for PowerWind. They mainly based their positive opinion on the company-wide approach of the concept. Through this they expected to reduce communication and process failures during the value performance. They additionally expected a positive financial effect caused by more process certainty, higher standardization, reduced inventory stock and shorter lead times. Some Purchase employees said that PowerWind had grown to a size where a more formalized customer order process was simply essential. In general, the concept´s focus on seamless communication over the whole value performance was the most-mentioned attribute (given by 75 % of all interviewed employees). In particular, the product configurator was seen as a unifying communication tool that could help the different departments to talk to each other in a language they all understood, rather than having a clash between Sales and Production language.

In summary, the trust in the project and the project manager was highest amongst the R&D employees, followed by the Purchase employees and relatively low for the Sales employees. Here again, the order of the value chain could be responsible, but the closer relationship of the project manager to the R&D employees was the reason for a higher level of trust amongst the R&D employees.

In a further question, the group was asked about the expected organizational capability for the implementation project. The 16 interviewed employees gave 19 answers as to the capability of their organization. In total, 33 statements were noted. Again, the statements were classified according to their central arguments, as described in chapter 3.8.2 (Tab. 4). The percentage of the given arguments is related to all registered statements (33) and the total number of interviewed employees (16). Table 11 gives an overview of the summarized central arguments for and against the organizational capability and their occurrence.

Tab. 11: Capability of organization for implementation project – 2nd project phase

Reasons for capability of organization	Valuation	Occurrence	Percentage of statements/ employees
Limited human resources	Not capable	9	27.3 % / 56.3 %
Timescale	Not capable	7	21.2 % / 43.8 %
Reliability of processes	Not capable	5	15.1 % / 31.3 %
Motivation of employees	Capable	4	12.1 % / 25.0 %
Capabilities of employees	Capable	3	9.1 % / 18.8 %
Organizational culture	Not capable	3	9.1 % / 18.8 %
Unexpected barriers	Not capable	2	6.1 % / 12.5 %

The opinion regarding the organizational capability for the implementation of the new manufacturing concept, as a situational indicator of readiness for change, was very negative at the beginning of the “moving phase”. Only 21.2 % of all given statements indicated that the company was capable of implementing the new manufacturing concept within the set timescale. A total of 78.8 % of the registered statements were negative about organizational capability. In this question, the frequency of positive and negative answers over all the participating departments was equal. There was no specific department with a significantly positive or negative opinion. The bulk of employees (56.3 %) said that there was a lack of human resources to implement the whole concept. This statement was made by employees from all departments. The second most frequent response described the set timescale as too ambitious. Most purchase employees (75 %) did not believe that the implementation could be completed within the timescale. The defined time schedule was also a typical argument from the R&D employees (50 %) who saw it as critical for a successful implementation. 31.3 % of the employees claimed that existing processes were a potential barrier to the implementation. In particular, the R&D employees mentioned that the organization was opportunity-driven and not disciplined enough to comply with the existing engineering change process. Three employees also mentioned the present organizational culture. This specific claim, which was also made in response to the need questions, was not classified as a process failure and got its own category. The employees who made this statement added that there is a general lack of sharing the workload or supporting each other. A particularly low level of support between different departments was reported. Furthermore, two employees were afraid that further unexpected and unspecified barriers could occur during the implementation. They felt this could happen because so many departments and employees were involved. Such projects are complex in nature and therefore not easy to control completely. One employee mentioned the huge amount of possible product variants that suddenly became evident during the project and increased the amount of work unexpectedly. On the other hand, there were a few positive opinions about the organizational capability to successfully implement the new manufacturing concept. 25 % of all employees recognized a good level of motivation amongst the employees. For instance, the great interest in the big introduction meeting highlighted the level of motivation. Finally, some employees (18.8 %) believed in the capabilities of the employees involved in the implementation project.

The responses to the capability question were surprisingly negative when compared to the need and appropriateness questions. Even if the employees understood the need for change and the main attributes of the selected concept, they disclosed a significant uncertainty about implementing Mass Customization. The natural fear of implementing change was certainly increased by the occurance of so many possible product variants and the corresponding workload for getting them designed and managed. This aspect needs to be considered in future plannings of Mass Customization projects at wind turbine manufacturers.

Finally, the employees were asked about their personal motivation to implement the new manufacturing concept. Again, 19 responses were given by the 16 interviewed employees, with the answers from the three employees who were interviewed twice being combined into one statement. In total, 25 statements were noted and classified according to their central arguments, as described in chapter 3.8.2 (Tab. 4). The percentage of the given arguments relates to all registered statements (25) and the total number of interviewed employees (16). Table 12 gives an overview of the summarized central arguments for and against organizational capability and their occurrence.

Tab. 12: Motivation for implementation of new manufacturing concept – 2nd project phase

Reasons for motivation or no motivation of implementation	Valuation	Occurrence	Percentage of statements/ employees
Reduction of failures	Motivated	7	28.0 % / 43.8 %
Improved communication	Motivated	5	20.0 % / 31.3 %
More innovations	Motivated	4	16.0 % / 25.0 %
Additional work	Not motivated	3	12.0 % / 18.8 %
Improved order planning	Motivated	3	12.0 % / 18.8 %
Doubts about efficiency	Not motivated	2	10.0 % / 12.5 %
Cost reduction	Motivated	1	5.0 % / 6.3 %

The motivation of the employees should provide a statement as to “job satisfaction” as a personal indictor of readiness for change. The motivation of the employees involved in the implementation project was high at the beginning of the “moving phase”. In total, 78 % of the collected statements highlighted a motivated opinion about the implementation project. Only 22 % of all statements suggested an unmotivated attitude. The most mentioned reason for motivation was the “reduction of failures”. 43.8 % of all interviewed employees raised this argument. This matched the responses to the need and appropriateness questions where the argument “reduction of process failures” was the most (need question) and the second most (appropriateness question) mentioned. The same applied to the second most given reason for motivation: “improved communication” (31.3 % of all employees). The attribute “improvement of communication” was also associated with Mass Customization during the appropriateness question. Both reasons, “reduction of failures” and “improved communication”, were mentioned by employees from all departments. There was no specific department arguing for them in particular. The opposite applied to the argument “more innovation”. All the employees who stated that the idea of more time for innovation is motivating them to implement the new manufacturing concept belong to the R&D department. Some of them gave examples for required product improvements and innovations that cannot be started due to other priorities. The prospect of a reduced daily workload caused by regular engineering-to-order or product modification was significant for the responses of R&D employees. Significant for the responses of the Purchase employees was the argument "improved order planning". All those in favour of this argument were from the Purchase department. In total, 75 % of the interviewed Purchase employees stated that this was a reason for their motivation. In particular, they hoped to improve the relationship with the suppliers by avoiding order failures and to finally achieve reduced component prices. Only one employee, belonging to the Sales department, expected reduced costs for the whole company. She argued that this would happen because of higher standardization and lower inventory stock. However, there were also negative voices that indicated low motivation. Two employees simply expressed doubts about the efficiency of the new manufacturing concept. From their perspective, the promised advantages were too theoretical and could not be achieved in practice. They argued that business environments are more complex and individual than general models can cover. Three more negative statements included the argument "additional work". The prospect of the implementation work against the background of the current workload simply demotivated them.

4.3.2 Qualitative Data Analysis – 3rd Project Phase

In the 3rd project phase (the end of the "moving phase") the same three working groups (the product rationalization team, the technical feasibility team and the product configurator team) were interviewed. The semi-structured interviews were conducted during the last meeting of each team. Again, a total of 19 employees were interviewed. Three employees (S1, RD2, and P2) participated in two groups and were interviewed twice. Their arguments, if different in their interviews, were summarized to one statement per employee.

On the "need" subject, two questions were asked of 19 interviewees, which resulted in a total of 38 responses. In summary, 42 arguments for or against the need for implementation were noted in the statements and classified according to their core statement as described in chapter 3.8.2 (Tab. 4). The percentage of the given reasons is related to all registered statements (42) and the total number of interviewed employees (16). Table 13 gives an overview of the summarized core statements and their occurrence.

Tab. 13: Need for implementation of lean manufacturing concept – 3rd project phase

Reasons for need or no need for implementation of new manufacturing concept	Valuation	Occurrence	Percentage of statements/ employees
Failures in existing process	Need	8	19.0 % / 50.0 %
Improved communication	Need	7	16.7 % / 43.8 %
Limited resources	No need	7	16.7 % / 43.8 %
Limited time	No need	6	14.3 % / 37.5 %
Knowledge of R&D	No need	4	9.5 % / 25.0 %
Reduced performance	No need	4	9.5 % / 25.0 %
Lack of product/assembly documentation	Need	3	7.1 % / 18.8 %
Overload of R&D	Need	2	4.8 % / 12.5 %
Simplicity and flexibility of existing process	No need	1	2.4 % / 6.3 %
Attitude of production	No need	0	-
Organizational culture (not supportive)	Need	0	-

The opinions about the need for the implementation, as a personal indicator for resistance to change, continued to decrease from the “unfreezing phase”, through the beginning of the “moving phase” up to the end of the “moving phase”. That in turn meant that the resistance to change increased over the course of the project. In total, only 47.6 % of all registered statements indicated that the company had a need for a new manufacturing concept. Compared to the interview sessions at the beginning of the “moving phase”, where 66 % saw the need for implementation, this was a reduction of nearly 20 %. The distribution of the opinions over the employee groups changed as well. While, during the last interview sessions, the majority of Sales employees (60 %) saw no need for implementation, this time most of the R&D employees expressed doubts as to whether the new manufacturing concept was necessary. 83 % of the R&D employees mentioned that the human resources were too limited for this project. However, the most stated reason for a need for implementation, "failures in existing process", remained the same. In addition, seven of 16 employees registered the potential of "improved communication" in the new manufacturing concept. The statements about communication were significant during the second interview session, compared to the first meeting, and are therefore listed in their own category (43.8 %). In a strict sense, the registration of "improved communication" could be classified in the category "failures in existing process", which would make this argument even more dominant as a reason for the need for implementation. The concerns about "limited resources" were not mentioned in the context of "need for implementation" during the first session either. "Limited resources" were expressed by 43.8 % of all employees as an argument for "no need" during the second interview session. A further new argument for "no need" was "reduced performance". 25.0 % of all interviewed employees noted reduced performance during the implementation. At the beginning of the implementation nobody mentioned this. On the other hand, the need for a new manufacturing concept due to the work overload in the R&D department was mentioned by 62.5 % of interviewees in the first interview session. During the second interview session, this justification had only minor relevance (12.5 % of all interviewees). It seems that this argument had no value anymore, as the amount of work had increased rather than decreased during the implementation project. Other statements like the "no need" argument and "simplicity and flexibility of existing process" received considerably fewer nominations (6.3 % instead of 31.3 %) or were not mentioned at all ("attitude of production", "organizational culture").

In summary, the change of opinions amongst the R&D and Sales employees was most significant. While, at the beginning of the implementation of Mass Customization, it was mainly the Sales employees who showed a high resistance to change, at the end of the implementation project many R&D employees indicted increased resistance. The most evident reason was the significantly higher workload for the R&D department. The "no need" argument of "limited resources" was given mostly by R&D employees. In contrast to that, the attitude of the Sales employees changed from negative to positive. The main reasons were the uncovering of deficiencies in the old customer order process during the implementation project and the realization that even after the consolidation of product features they would still have enough flexibility to offer different wind turbine options. The attitude of the Purchase employees remained basically unchanged. Although there was a certain degree of doubt, they saw the need for a new manufacturing concept at the beginning and the end of the implementation project.

In the next step, two questions were asked regarding the appropriateness of the selected manufacturing concept. These questions indicated to what extent the employees had trust in the project and the project manager. In total, 32 responses were collected from the 16 interviewees. Within these responses, 41 arguments on appropriateness were noted and classified according to their central statement, as described in chapter 3.8.2 (Tab. 4). The percentage of the given arguments relates to all registered statements (41) and the total number of interviewed employees (16). Table 14 gives an overview of the summarized central arguments and their occurrence.

Tab. 14: Appropriateness of selected lean manufacturing concept – 3rd project phase

Reasons for appropriateness of selected manufacturing concept	Valuation	Occurrence	Percentage of statements/ employees
Improves communication	Approp.	13	31.7 % / 81.3 %
Positive financial influence	Approp.	8	19.5 % / 50.0 %
Increases product understanding	Approp.	7	17.1 % / 43.8 %
Too complex and time-consuming	Not approp.	7	17.1 % / 43.8 %
Reduces process failures in value chain	Approp.	5	12.2 % / 31.3 %
Reduces flexibility	Not approp.	1	2.4 % / 6.3 %
Improve R&D efficiency	Approp.	0	-
No advantages achievable in practice	Not approp.	0	-

Just like at the beginning of the “moving phase” (2nd project phase), the appropriateness of the selected manufacturing concept was seen as positive at the end of the “moving phase” (3rd project phase) as well. In summary, 80.5 % of all statements indicated that Mass Customization was appropriate for PowerWind. This had increased compared to the last interview session (75.6 %). During the second interview session, only 19.5 % of all statements included the opposite opinion. Most significant was the change of reasons for this evaluation. Although the most frequently mentioned argument “improves communication” was confirmed, the second most frequently stated argument was the “positive financial influence” (given by 50.0 % employees instead of 25.0 %). Most employees reasoned that the “positive financial influence” was due to a higher degree of “standardization”, “economies of scale”, “reduced lead times” and “reduced inventory stock”. Furthermore, the ability to work with a neutral bill of materials was seen as a big financial opportunity. Such a neutral bill of materials would allow the assembly of wind turbines to an advanced stage without the need for project-specific changes. In contrast to that, during this interview session what was most significant was the many negative comments about how complex and time-consuming the manufacturing concept was. Seven employees used this argument during their statements (43.8 %). This time, five of them were R&D employees, while during the first interview session most of them were from the Sales department. Their main argument was that the chosen manufacturing concept was “too complex and time-consuming”. They underlined their statements with claims about the increased workload due to reengineering of the product. Several sub-assemblies had to be engineered as add-on modules. Even after the consolidation of variants, a considerable number of bills of materials for possible product variants had not been completed. This also uncovered gaps in the documentation and led to a certain level of frustration amongst the R&D employees. This change of attitude amongst the R&D employees was also underlined by the statement “improve R&D efficiency”. This statement was given by 31.3 % of all employees during the first interview session. Most of them were R&D employees. During the second interview session the argument “improve R&D efficiency” was not relevant anymore. Due to the continuous workload, nobody saw improved R&D efficiency as a potential result of the implementation project.

The implementation of Mass Customization led to increased transparency and therefore possibly contributed to the view that it is possible to “reduce process failures in the value chain”. On the other hand, during the “moving phase”, an unexpected degree of complexity (huge number of variants) and failures in the value chain came into light, which gave the employees the impression that Mass Customization could not contribute to a reduction in complexity. Only 31.3 % of the interviewees gave this argument, compared to 56.3 % at the beginning of the implementation project. The concerns about “reduced flexibility” in the first interviews, mainly expressed by the sales employees, were no longer an issue. The frequency of this statement dropped from 37.5 % to 6.3 %. The “not appropriate” argument “no advantages achievable in practice” even dropped from 12.5 % to zero. It seems that the implementation process contributed to the view that concepts and models can be proven in practice.

Overall, the trust in the project and project manager increased at the end of the “moving phase”. This was driven mainly by an increasing level of trust from the Purchase and Sales employees. However, it also became evident that the trust of the R&D employees in the project and the project manager decreased during the “moving phase”.

At the end of the “moving phase”, opinions regarding organizational capability were sought from the three teams for a second time. Again, one question was asked regarding this topic. In total, 34 statements were noted from the 16 interviewed employees. The statements were classified according to their central arguments as described in chapter 3.8.2 (Tab. 4). The percentage of the given arguments is related to all registered statements (34) and the total number of interviewed employees (16). Table 15 gives an overview of the summarized central arguments for and against organizational capability and their occurrence.

Tab. 15: Capability of organization for implementation project – 3rd project phase

Reasons for capability of organization	Valuation	Occurrence	Percentage of statements/ employees
Limited human resources	Not capable	11	32.4 % / 68.8 %
Time scale	Not capable	8	23.5 % / 50.0 %
Motivation of employees	Capable	7	20.6 % / 43.8 %
Capabilities of employees	Capable	5	14.7 % / 31.3 %
Unexpected barriers	Not capable	2	5.9 % / 12.5 %
Reliability of processes	Not capable	1	2.9 % / 6.3 %
Organizational culture	Not capable	0	-

In general, the opinions on organizational capability with respect to the implementation of Mass Customization improved over the course of the implementation project. Even if, in total, 64.7 % of all given statements included the message that the organization has a poor capability to manage the implementation in a proper manner, this was a clear improvement in comparison with the first interview session (78.8 %). This means that, at the end of the implementation project, 35.3 % of statements indicated that the organization has sufficient capability for such an implementation. However, the first two ranked arguments were negative once again. The frequency of these two statements actually increased since the first interviews. Again, the most frequent reason given for a lack of capability was “limited human resources” (32.4 % of all statements, instead of 27.3 % in the first interview session). The second most mentioned reason for a lack of capability was the set “timescale”. The frequency of this argument increased from 21.2 % to 23.5 %. A remarkable differentiation between the first and the second interview session was found in the evaluation of employee motivation and capability. Both of these factors contributed to the overall improvement of opinion regarding the organization´s capability. The frequency of positive statements about the “motivation of employees” increased from 12.1 % to 20.6 %. The frequency of positive statements about the “capabilities of employees” increased from 9.1 % to 14.7 %. In contrast to that, the argument “reliability of processes” was no longer considered to be a reason for poor capability in the organization. While five of 16 interviewed employees were concerned about this potential barrier, during the second interview session only one employee saw this as possible obstacle. A further potential barrier, the “organizational culture”, was no longer an issue either. The frequency of this argument dropped from 9.1 % to zero. The argument “unexpected barriers” remained at a low level of frequency. Only two employees gave this argument during both interview sessions.

Again, there was no specific department with a significant positive or negative opinion. Positive and negative opinions were distributed amongst employees from all departments. The majority of employees still had the feeling that there are not enough human resources available to implement the whole concept (68.8 % of asked employees). That is particularly critical against the background of the set timescale (mentioned by 50.0 % of the employees).

The responses to the capability question were surprisingly negative during the first interview session. However, this improved in the second interview session. Several potential barriers, such as "reliability of processes", "organizational culture" and "unexpected barriers", which were mentioned during the first interview session, no longer played a role. The project progress after the first interview seemed to convince the employees that these were needless concerns, potentially caused by a lack of information about the detailed effects of such an implementation. On the other hand, two main concerns remained throughout the whole "moving" phase: "limited human resources" and the given "timescale". These results sent out a clear message from the employees involved.

Finally, the employees were asked for a second time about their personal motivation to implement the new manufacturing concept. In total, 26 statements were noted for the 16 interviewees and classified according to their central arguments, as described in chapter 3.8.2 (Tab. 4). The percentage of the given arguments is related to all registered statements (26) and the total number of interviewed employees (16). Table 16 gives an overview of the summarized central arguments for and against organizational capability and their occurrence.

Tab. 16: Motivation for implementation of new manufacturing concept – 3rd project phase

Reasons for motivation or no motivation of implementation	Valuation	Occurrence	Percentage of statements/ employees
Improved communication	Motivated	8	30.8 % / 50.0 %
Additional work	Not motivated	6	23.1 % / 37.5 %
Improved order planning	Motivated	4	15.4 % / 25.0 %
Reduction of failures	Motivated	3	11.5 % / 18.8 %
More innovations	Motivated	3	11.5 % / 18.8 %
Cost reduction	Motivated	2	7.7 % / 12.5 %
Doubts about efficiency	Not motivated	0	-

Compared to the beginning of the implementation phase (2nd project phase), the percentage of statements expressing a high degree of motivation did not change significantly in the 3rd project phase. In total, 76.9 % of the collected statements, instead of 78 % in the 2nd project phase, indicated a high motivation towards the implementation project. Only 23.1 % of all statements pointed to a lack of motivation (instead of 22 % in the 2nd project phase). What changed significantly were the reasons for motivation levels. While seven of 16 employees considered the “reduction of failures” as their biggest motivation at the beginning of the implementation, at the end eight of 16 employees mentioned “improved communication” as their most achievable objective. The argument “improved communication” was mainly expressed by the Purchase and Sales employees. “No silo mentality”, “same view on products” and “speaking common language” were the reasons most frequently given. The Purchase and Sales employees also said they were motivated by “improved order planning”. This statement was the third most frequently mentioned during the end of the implementation project. In contrast to that, the motivating factor “reduction of failures” became significantly less relevant, because several employees still felt there was a high level of complexity in their work. Statements such as “further measures like reduction of product variety and complexity are necessary” were typical. Such statements were mainly given by R&D employees, who saw high complexity and a high workload in their working environment. This situation also resulted in an increase in the “not motivated” argument “additional work”. Five of six R&D employees mentioned this argument, which was in total the second most given statement (23.1 % of all statements). Compared to 12.0 % in the 2nd project phase, this was a significant increase during the 3rd project phase. In correspondence to that, the earlier motivating factor for the R&D employees, “more innovations”, dropped from 16.0 % to 11.5 %. A certain frustration was detectable amongst the R&D employees. Finally, the reduction of costs was still considered less relevant by the employees. This time, two employees mentioned it, compared to only one in the first interview session. The “doubts about the efficiency” of the new manufacturing concept as a demotivating factor were not mentioned at all.

5. Summary and Conclusion

The purpose of this research study was to examine whether existing lean manufacturing techniques are capable of contributing to the reduction of wind turbine production costs. Besides the identification of potential lean manufacturing techniques, their appropriateness for the wind power industry needed to be evaluated. For this purpose, evaluation criteria had to be developed that met the needs of a wind turbine manufacturer. Based on this, a systematic literature review relating to lean manufacturing techniques and the evaluation of their attributes created the basis for this research. Subsequently, the attributes that characterize a suitable lean manufacturing technique for wind turbines were identified and the corresponding evaluation criteria for the selection of a lean manufacturing technique were developed. The following evaluation resulted in the selection of Mass Customization as the lean manufacturing technique most appropriate for the subsequent case study. The aim of the case study was a holistic investigation into the required implementation effort for Mass Customization. For this reason, the consideration of physical events and employee behaviours affected by the implementation project appeared to be necessary.

Conducting such in-depth and holistic research using multiple case studies would have required extensive resources and time beyond the means of a single researcher. Furthermore, it appeared unlikely that two organizations would be considering implementing a new lean manufacturing technique in a similar time period for the same reason and with comparable scope. Therefore, after careful consideration, conducting a single case study seemed to be the most appropriate method for studying the organizational impact caused by the implementation of Mass Customization in its natural setting. Within the case study, the employees were observed and interviewed during the implementation and adoption of Mass Customization at different project stages. The research approach was an explanatory single case study utilizing sequential mixed methods. During the qualitative phase, all relevant project meetings, as well as necessary project and product changes were studied, which provided an extensive contextual analysis and in-depth insight into the case.

In summary, the research consisted of a single case study utilizing quantitative and qualitative methods for data collection. The core element of the case study was the implementation of Mass Customization at the wind turbine manufacturer PowerWind. Data collection was oriented according to the three organizational change phases during an implementation project, as described by Lewin (1947): unfreezing, moving and refreezing (Fig. 6 and Fig. 11). Prior to the implementation project, a questionnaire was distributed to 25 employees from all the departments involved in the value performance. This 1st project phase marked the “unfreezing” phase, according to Lewin (1947). The quantitative data from the questionnaire contributed to an interview guide that was used in the following two project phases (2nd and 3rd project phase). During both phases, semi-structured interviews were conducted based on the interview guide. The first semi-structured interviews were conducted with 16 employees involved in the implementation project, at the beginning of the concept implementation – the 2nd phase of the project. This phase corresponds to the beginning of the “moving” phase, according to Lewin (1947). The second semi-structured interviews were conducted with the same interviewees at the end of the concept implementation (3rd project phase), which corresponds to the end of the “moving phase”, according to Lewin (1947).

The aim of this chapter is to analyse the results and provide conclusions about the study. This chapter includes discussions on the following topics:

1. Summary overview of results,
2. Conclusions concerning the findings and implications for practice,
3. Limitations and suggestions for future research.

5.1 Overview of Results

In the first stage, the literature on existing lean manufacturing techniques was reviewed. The literature review identified the need for a differentiation between the terms manufacturing strategy, manufacturing concept and manufacturing method, which are mainly used in the context of lean manufacturing literature. Their main differentiation is the business level where they are applied (Fig. 8). Otherwise, the comparison and evaluation of the different strategies, concepts or methods can be distorted. In the next stage, the evaluation criteria for lean manufacturing techniques needed to be developed. For that, the current status and challenges of the wind energy industry were analysed. Based on that, the lean manufacturing techniques identified were classified according to their "capability to manage product variants" (formal target) and their "capability to reduce the inventory stock" (competitive target) (Fig. 9). From this, the manufacturing concept Mass Customization was selected as the most suitable technique to be implemented in the case study at the German wind turbine manufacturer PowerWind. During the implementation project at PowerWind, quantitative and qualitative data were collected as described above.

The following is a summary of the data analysis. First of all, the quantitative data resulted in the capture of the initial business situation. The results served as a benchmark for the further development of the business situation. The quantitative data collection aimed to register the personal indicators for readiness for change: dispositional resistance and job satisfaction. In summary, a low dispositional resistance towards the change project was registered. A certain resistance was identified amongst the employees of Sales/Marketing, but the general positive attitude of the employees was an indicator for a high level of motivation amongst employees regarding the implementation of a new manufacturing method. That in turn meant that, despite the unsatisfying value performance, a good level of job satisfaction existed amongst the employees. Besides the two personal indicators for readiness for change, the qualitative data analysis aimed to capture the development of the situational and personal indicators for readiness for change: trust in the project manager and trust in the organization. For this purpose, underlying questions regarding the topics need (resistance for change), appropriateness (trust in project manager), capability (trust in organization) and motivation (job satisfaction) were developed.

An awareness of the need for implementation was registered in 66.0 % of all given statements, in total 31 comments, at the beginning of the implementation project (2nd project phase). The arguments "failures of existing process", "overload of R&D" and "lack of product/assembly documentation" could be found in 29 comments. That picture changed over the course of the implementation project. At the end of the implementation project (3rd project phase), only 47.6 % of all noted comments indicated a need for the implementation of a new manufacturing concept. In total, only 20 comments registered a need for implementation. The need argument "overload of R&D" was no longer an issue. Only two statements included this argument, compared to 10 during the first interviews. Instead, the employees who acknowledged the need for implementation gave "improved communication" as a reason. Table 17 summarizes the development of the need opinion in the course of the implementation project.

Tab. 17: Development of opinion on "need" for implementation

Phase	**2nd project phase**	**3rd project phase**
Frequency	66.0 %	47.6 %
3 most frequent arguments for need	1. Failures of existing process	1. Failures of existing process
	2. Overload of R&D	2. Improved communication
	3. Lack of product/assembly doc.	3. Lack of product/assembly doc.

Corresponding to that, at the end of the project (3rd phase), 52.4 % of all given comments indicated that there was no need for the implementation. The most prevailing arguments against the need for a new manufacturing concept were: "limited resources" (seven comments), "limited time" (six comments) and "knowledge of R&D" (four comments). During the first interviews (2nd project phase), only 34.0 % of all given statements included a "no need" message. Most mentioned, especially by the Sales employees, was the reason "simplicity and flexibility of existing process" (five comments). That argument played no major role during the second interview session. Table 18 provides an overview of the development of the "no need" opinions.

Tab. 18: Development of opinion on "no need" for implementation

Phase	**2nd project phase**	**3rd project phase**
Frequency	34.0 %	52.4 %
3 most frequent arguments for no need	1. Simplicity and flexibility of existing process	1. Limited resources
	2. Knowledge of R&D	2. Limited time
	3. Limited time	3. Knowledge of R&D

Most significant was that the "need" argument "overload of R&D" changed to a "no need" argument over the course of the project, this was mainly expressed by the statements "limited resources" and "limited time". This was due to disillusionment amongst R&D employees with the idea that the new manufacturing concept could reduce their workload. This did not happen, as the implementation required a huge amount of reengineering work and changes to the product architecture. Furthermore, the huge number of variants that came to light overwhelmed employees from all departments. The employees continued to work on the project, but were not as convinced as they were at the beginning of the implementation project. In contrast to the negative development of R&D employee opinion, the opinion of the Sales employees became more positive. While, at the beginning of the implementation project, the Sales employees mostly saw no need for the implementation, over time most of them became convinced of the need for the project. The main reasons for this were the uncovering of deficiencies in the old customer order process and the realization that even after the consolidation of product features they still would have enough flexibility to offer different wind turbine options. In general, the attitude of the Purchase employees remained unchanged. Despite having certain doubts about the implementation project, they saw the need for it throughout the project.

The positive opinions about the appropriateness of the selected manufacturing concept, Mass Customization, developed from 75.6 % to 80.5 % over the course of the project. In particular, the capability of Mass Customization to contribute to "improved communication" was recognised by the bulk of employees during both project phases. During the second interview session, the additional reasons "positive financial influence" and "increase of product understanding" were mentioned. Table 19 summarizes the development of opinions on appropriateness during the course of the implementation project.

Tab. 19: Development of opinion on "appropriateness" of Mass Customization

Phase	2nd project phase	3rd project phase
Frequency	75.6 %	80.5 %
3 most frequent arguments for appropriate	1. Improves communication	1. Improves communication
	2. Reduces process failures in value chain	2. Positive financial influence
	3. Improves R&D efficiency	3. Increases product understanding

In general, the opinion on the appropriateness of Mass Customization became slightly more favourable over the course of the project. The arguments against it were "reduction of flexibility" and "too complex and time-consuming". At the end of the implementation project, only one comment was noted that contained concerns about a "reduction of flexibility". However, the mentions of complexity and time-consumption increased from three to seven comments. Table 20 provides an overview of the development of the "inappropriateness" opinions.

Tab. 20: Development of opinion on "inappropriateness" of Mass Customization

Phase	2nd project phase	3rd project phase
Frequency	24.4 %	19.5 %
3 most frequent arguments for not appropriate	1. Reduces flexibility	1. Too complex and time-consuming
	2. Too complex and time-consuming	2. Reduces flexibility
	3. No advantages achievable in practice	-

The contribution of Mass Customization to seamless communication was introduced comprehensively during the kick-off meeting for the implementation project. That may have led to the positive opinions of employees on communication at the beginning of the implementation. However, that opinion was actually strengthened over the course of the project. On the other hand, there was a low level of confidence in the likelihood of retaining flexibility after the introduction of Mass Customization. The systematic approach of this concept is probably the reason why the employees believed that there would be a negative influence on business flexibility. That belief also highlighted the employees' concerns about the complexity of the concept, which emerged during the project.

In summary, it can be concluded that an intensive introduction to Mass Customization´s capabilities was worthwhile. Advantages like “improved communication” could be easily explained to the employees. On the other hand, more emphasis should have been placed on measures and explanations that could have avoided the idea that flexibility would be lost, or complexity increased. In particular, the impression of increasing complexity was important as it tended to increase over the course of the implementation of Mass Customization.

Similar to the positive development of opinions regarding appropriateness, opinions on the organization’s capabilities also improved during the project. However, the assessment of the organization’s existing capabilities was very low at the beginning of the project. At that time, only 21.2 % of all registered comments indicated that the organization was considered to be capable enough to implement Mass Customization. This picture did change a little, as at the end of the project 35.3 % of the statements included arguments that saw the organization’s capabilities positively. The employees, however, found only a few reasons why their organization could be considered capable of implementing Mass Customization. The only arguments they mentioned were the existing “motivation of employees” to change their situation and the “capabilities of the employees”. In general, they trusted the experience of some of the senior employees and the innovative spirit of some of the younger employees. Table 22 summarizes the development of opinions on capability over the course of the implementation project.

Tab. 21: Development of opinion on “capability” of organization

Phase	**2nd project phase**	**3rd project phase**
Frequency	21.2 %	35.3 %
3 most frequent arguments for capability	1. Motivation of employees	1. Motivation of employees
	2. Capabilities of employees	2. Capabilities of employees
	-	-

In summary, there was a pessimistic view on the capability of the organization throughout the project. The most frequently mentioned reason for insufficient capability, in both project phases, was limited resources. The occurrence of this statement actually increased from nine to 11 times during the project. Table 22 gives an overview of the development of the “no capability” opinions.

Tab. 22: Development of opinion on “no capability” of organization

Phase	**2nd project phase**	**3rd project phase**
Frequency	78.8 %	64.7 %
3 most frequent arguments for no capability	1. Limited resources	1. Limited resources
	2. Time scale	2. Time scale
	3. Reliability of processes	3. Unexpected barriers

The responses to the capability question were clearly negative compared to the need and appropriateness questions. Even if this attitude improved during the project, the majority of comments remained negative. It can be concluded that although the employees understood the need for change and the main attributes of the selected concept, they felt significant uncertainty about implementing the new manufacturing concept. The employees were probably not clear enough about the detailed project approach and the work packages behind it. Even if it is difficult to plan the stages of such a complex project in detail, it can be concluded that a considerable effort needed to be invested in detailed and realistic work packages prior to the implementation of Mass Customization. Possible barriers, such as a huge number of product variants or immense changes of the product architecture, should not be underestimated.

Unlike the opinions on the organization’s capabilities, the motivation of the employees was positive during both of the project phases that were investigated. From the very beginning, the responses of the employees indicated a high level of motivation. 78.0 % of all statements included positive arguments for motivation. This picture changed only slightly. During the second phase 76.9 % comments were still positive. The most significant difference between the two interview sessions was the different reasons given for motivation. While, during the first interviews, most comments indicated the belief that the failure rate in the value chain could be reduced, in the second interview session improved communication was clearly seen as the biggest motivating factor. Furthermore, the wish for more time for innovations, in particular expressed by the R&D employees, was no longer relevant by the end of the implementation project. They probably lost their belief in this driver of motivation. Table 23 summarizes the development of the motivation of the employees over the course of the implementation project.

Tab. 23: Development of "motivation" for implementation

Phase	2nd project phase	3rd project phase
Frequency	78.0 %	76.9 %
3 most frequent arguments for motivation	1. Reduction of failures	1. Improved communication
	2. Improved communication	2. Improved order planning
	3. More innovations	3. Reduction of failures

In general, only very few comments were registered that included negative statements about motivation. From the very beginning, the additional work was seen as the most demotivating factor. Doubts about the potentially poor efficiency of the new concept, mostly from Sales employees, were only an issue at the beginning of the implementation project. The Sales employees seemed to become convinced over the course of the project that the new concept also had the potential to fulfil their need for flexibility. On the other hand, the decreased frequency of this argument led to an increase of the frequency of the argument "additional work". The frequency of this demotivating factor grew from 12.0 % to 23.1 %. Table 24 gives an overview of the development of the opinions for "no motivation" during the project.

Tab. 24: Development of "no motivation" for implementation

Phase	2nd project phase	3rd project phase
Frequency	22.0 %	23.1 %
3 most frequent arguments for no motivation	1. Additional work	1. Additional work
	2. Doubts about efficiency	-
	-	-

In summary, the bulk of employees involved in the implementation project had a motivated attitude after the kick-off meeting. There were just a few doubts about the concept´s efficiency and the additional work that could not be ruled out. However, an increasing level of frustration was registered, mainly amongst the

R&D employees. Their hope to gain more time for innovation could not be fulfilled during the implementation. Even if it may not have been realistic to try and achieve this so quickly while a change project was in progress, certain measures should be considered in order to try and avoid such a rapid change of attitude. Better preparation and analysis of the potential impact on product variety could probably help to avoid such frustrations. It was observed that many employees were simply shocked by the huge number of potential product variants. At first, the R&D employees in particular thought that they were facing an unsolvable task.

5.2 Conclusions and Implications for Practice

The overall objective, to examine the capabilities of existing lean manufacturing techniques to address the needs of wind turbine manufacturers, required the development of appropriate evaluation criteria. Prior to the evaluation, the existing lean manufacturing techniques had to be classified according to the business level they are applied to. Based on the found need for classification, it is recommended that an organization that is considering the implementation of a lean manufacturing technique is aware of their targeted organizational results, the business level where the results should be generated and, finally, the scope of organizational changes. Based on that, it can then be decided whether a manufacturing strategy, manufacturing concept or manufacturing method needs to be implemented. Out of these three groups of techniques, the appropriate technique needs to be selected in the next step. For that purpose, further evaluation criteria, generally based on the individual business situation and market environment, have to be applied. In the case of the studied wind power business environment, the evaluation criteria “capability to manage product variants” and “capability to reduce the inventory stock” corresponded best to the identified needs of the wind power industry. An analysis of several lean manufacturing techniques identified according to these evaluation criteria led to the results illustrated in Fig. 9. From this analysis, the lean manufacturing concept Mass Customization was considered best suited for implementation at the researched wind turbine manufacturer PowerWind. The implementation of the new lean manufacturing concept resulted in organizational change that had significant impact on employee behaviours and on the product.

In the case of implementing Mass Customization at a wind turbine manufacturer, the following conclusions can be drawn from this research:
This research confirmed that Mass Customization significantly affects all departments involved in the customer order process. Furthermore, the case study showed that wind turbine manufacturers have to be aware of the consequences of implementing Mass Customization, not just in regard to the employees, but also in regard to the strategy, structure and culture in their different departments. Therefore, an initial analysis should be carried out in all departments affected by the organizational change. The research showed that different opinions about the given business situation existed in the different departments. In particular, the employees of the Sales department were not aware of the difficulties which the following departments had in the customer order process. Corrispondigly, the discussions about the need of a new manufacturing concept should be started earlier in the Sales department than in other departments. A proper analysis of the ruling paterns and opinions in the different departments should provide the basis for the right timing and order of priority. In general, the discussions about the given business situation of a company, and the required changes, should be started as early as possible to achieve a balanced level of information in all departments. This was only partly considered in the researched case study. In particular, significantly different perspectives on the business situation were found in the Sales and R&D departments. That became particularly evident through the different opinions on the need for a new manufacturing concept and the resistance to change. As the Sales department is usually located at the very beginning of a customer order process, they might not see potential difficulties in the following process stages, if no proper exchange of information exists. It can therefore be concluded that the discussions on the current situation of the company, and the need for the implementation of Mass Customization, should be started as early as possible, and with more intensity in the departments involved in the early stage of the customer order process. Here especially, more time to prepare and inform the Sales employees is suggested.

In addition, the fact that the project manager belonged to the R&D department led to a lower level of trust in the project and the project manager on the part of employees from the Sales and Purchase departments, compared to the R&D employees. This could have been avoided by more intensive preparation for departments that were not already familiar with the project manager. Furthermore, the creation of alliances with senior employees in these departments prior to the implementation would have reduced the effort involved in convincing the rest of employees, as the case study showed that their resistant behaviour had a strong influence on other colleagues. Both measures could have led to more efficiency at the beginning of the implementation project and a balanced view on the need for implementation throughout all departments. In general, the intensive introduction of the concept´s capabilities during the kick-off meeting was recognized as helpful in increasing employee trust. Therefore, it can be stated that an intensive introduction of Mass Customization is worthwhile prior to an implementation. Furthermore, in the case of Mass Customization, it is advantageous to highlight the concept´s communication capabilities (seamless corporate-wide communication). Within the PowerWind case study, this was the most motivating argument for increasing acceptance of the change project amongst the employees at the beginning of the “moving” phase.

In the course of the implementation of Mass Customization, the risk of demotivation amongst the R&D employees was recognized. Mass Customization has the capability to create transparency on required product variants, but it also aims to treat even the smallest product difference as a product variant. That is a core element of Mass Customization and is necessary for the achievement of reliable and seamless communication about the product and customer orders amongst all the departments involved in the value chain. However, that transparency on multiple product variants led to an unexpectedly huge number of product variants. Furthermore, the strict requirement of Mass Customization to treat product features as modules that need to be designed as add-ons, and to create a basic product platform, led to considerable reengineering of the product architecture. The bills of materials for the newly defined options and modules were not completed during the studied period. It was estimated that this work would take a further four to six months. The employees, in particular the R&D employees, should have been better prepared for these consequences and the additional work, in order to avoid the quick rise in their levels of frustration. One possibility could be a pre-analysis of potential product variants with selected team members. Based on this, the development of detailed work packages, an appropriate level of human resources and realistic timescales could be possible.

A further aspect that should be considered in the implementation of Mass Customization is the time selected to begin the implementation project. The main implementation activities required a time period of about three months. Several employee statements indicated that the delivery of wind turbines was reduced by about 50 % during this time. In addition, nearly all R&D resources were tied-up in the project. The Sales employees had to do without the usual level of engineering support for both internal and external purposes. The conclusion to be drawn from this is that similar implementation projects should ideally be performed at less busy times of year.

In summary, this research has shown that implementing Mass Customization at a wind turbine manufacturer causes compareable implications as the implementation of other lean manufacturing techniques at companies in industries with similar characteristics. No significant differences on the success factors and barriers for lean implementation, as decribed by Roh, Hong, at al. (2014) and Salem, Musharavati et al. (2015), were found between the different industries and the researched wind turbine manufacturer. In general, the same main success factors and barriers for lean implementation apply. However, the order of importance of each success factor and barrier differs in each individual case and is also very specific in this case study. The most frequently mentioned success factor in the literature on implementation of lean manufacturing techniques in the different business environments is the suggestion to plan enough time for a prior analysis of the required process improvement and the existing organizational capabilities like cultre, resources, and skills. Secondly, the establishment of an effective communication concept or information system is recommended by almost all researchers. Hereby, the involvement of employees with deep knowledge and understanding of the overall organisaition appears to be advantageous as the priority of each of those measures differ in the individual organizations. The results of this research confirm these recommendations also for the case of a wind turbine manufacturer. However, many responses in this case study indicated that Mass Customization appeared to be a particularly complex and massive concept from the perspective of the employees. It became evident that the communication regarding the studied implementation project missed out several important elements. The results showed that, at the beginning of the implementation project, the R&D employees had more information about the given situation and were better prepared for change. This can mostly be explained by their closer relationship to the project manager, who was their regular supervisor. However, the reasons for change were not so clear to the Sales and the Purchase departments. Further elements of a communication concept could include a detailed introduction to the project stages, information about potential consequences and the corresponding working packages. These elements were not communicated sufficiently in the researched study, and many employees, from the R&D department in particular, lost trust and motivation in the project for that reason. Therefore, in the case of the wind turbine manufacturer PowerWind the establishment of an appropriate communication concept, prior and during the implementation of Mass Customization, is the most relevant recommendation to be considered. A seamless communication between all departments involved in the value performance became apparent during all project stages. It turned out that a company-specific product conficgurator is an appropriate communication tool within the business envirornment of a wind turbine manufacturer. It proved to be fast and flexible enough to meet the expections of the sales employees regarding the dynamic markets. On the orther hand, the product configurator allows the Product Management and R&D employees to control the marketrable product variants. The configurable product variants, the delivery dates of new product features or the deadlines for the phase-out of old product features can be easly communicated by this tool.

Particularly in the case of Mass Customization the handling of product variants can be a challenge as a proper application of Mass Customization can create a huge number of product variants, which in turn leads to an increased workload. However, the concerns about insufficient human resources could have been reduced by a more detailed description of the consequences of the project and the working packages. Consequently, the recommendation for an intensive

analysis of the organizational capabilities prior to an implementation project, as also found in the literature review, resulted in the second most important recommendation in the case of implementing Mass Customization at a wind turbine manufacturer. Such an analysis would support the definition of detailed working packages and corresponding resources against the background of the existing organizational culture as well as available human resources and skills.
The last recommended implementation element to be considered is the continuous and regular exchange of information durch the change process. The conducting of team meetings and the corresponding exchange of information led to an improvement of trust and a reduction of resistance amongst the Purchase and Sales employees. Therefore, an intensive continuation of communication in all organizational levels has to be considered the project manager and General Management.

On the other hand, Mass Customization has the capability to offer a very good basis for the improvement of communication, which can led to an overall high level of acceptance for the concept. In this research, the communication improvement was mainly achieved by the introduction of the product configurator. The introduction of the product configurator, and its effects, were easily understood by the employees. That led to the employee belief that Mass Customization was appropriate for their organization and was the main motivating factor in the implementation of the concept. Over the course of the project most employees recognized that a wind turbine is suited to management through a product configurator. Many Purchase and Sales employees reported that they had a significantly better understanding of the product after the development and introduction of the product configurator. Mass Customization, and in particular the product configurator, also offer a good basis for a Postponement strategy in Production. This method of thinking in “modules” and “add-ons” was quickly achieved by the employees. As a consequence, the modification of the customer order process based on the restructured product architecture could easily be achieved, simultaneously to the development of the product configurator.

The research showed that lean manufacturing techniques appropriate to the needs of a wind turbine manufacturer do exist. This was proven by a detailed analysis of existing lean manufacturing techniques and the development of classification and evaluation criteria based on the current need in the wind power industry. Such an investigation has not been the subject of previous studies. The evaluation showed that the manufacturing concept Mass Customization fulfilled the evaluation criteria most successfully. The subsequent implementation of Mass Customization in a case study showed that it had a significant impact on the customer order process of a wind turbine manufacturer. Therefore, intensive project preparation is required to avoid uncontrolled physical and organizational consequences. In particular, a timely and comprehensive communication concept, consisting of reasons for change, detailed project steps, consequences of change and regular exchange of information, is required during an implementation project. On the other hand, the research proved that Mass Customization has the capability to create seamless corporate-wide communication about the product and the customer order process. The achievement of better product understanding amongst all departments, less reliance on individual knowledge and a faster product configuration led to broad acceptance by the employees and trust in the more reliable processes, which had significantly reduced failure rates. The introduction of a product configurator as a communication tool for all departments involved in the customer order process proved to be appropriate for wind turbine manufacturers and showed its ability to improve communication.

5.3 Limitations and Suggestions for Future Research

In general, single case studies are criticized for offering a low degree of generalization without further research. However, due to the corporate-wide impact of such an organizational change project, a holistic business analysis was required to capture all the relevant effects. Such an in-depth study is very time-consuming and therefore was only possible with a single case study.

In addition, the challenge of managing so many product variants could be distinct to PowerWind. However, the high product variety in relation to the number of produced units is significant for wind turbine manufacturers, compared to other products in series production. As no literature could be found sharing the experience of similar implementation projects within the wind power industry, the results of this research can contribute to building up a basis for sector-wide research on lean manufacturing techniques in the wind power industry. Therefore, one suggestion for future research is the collection of further data resulting from other implementation projects of lean manufacturing techniques at wind turbine manufacturers. This could help to increase the reliability and validity of this research. Furthermore, the investigation of the “refreezing” phase and adaption of Mass Customization would be fruitful. The results of such studies could be linked to the results of this research and could allow the ability to trace the flow of motivations and attitudes from the “unfreezing” to the “refreezing” phase. Finally, future studies could focus more on the benefits and impacts on production. For that purpose, the effects of Postponement could be investigated in a production environment. Both manufacturing concepts, Mass Customization and Postponement, have comparable overall objectives. But, while Mass Customization is more engineering oriented, Postponement is more focused on production and in particular on optimized material flow. The link between the two concepts is the neutral bill of materials, and therefore further research on a postponed production of wind turbines would be a fruitful supplement to Mass Customization studies.

6. References

Abernathy, W. and J. Utterback (1978). "Patterns of Industrial Innovation." Technology Review.

Achanga, P., E. Shehab, et al. (2006). "Critical Success Factors for Lean Implementation within SMEs." Journal of Manufacturing Technology Management **17**(4): 460-471.

Albrecht, R. (1999). Szenariogesteuertes Innovationsmanagement - Scenario-Driven Innovation Management. Wirtschafts- und Sozialwissenschaften. Hamburg, Hochschule für Wirtschaft und Politik Hamburg.

Anderson, D. M. (2004). Build-to-Order & Mass Customizatiom. Cambria, CA, CIM Press.

Armenakis, A. A., S. G. Harris, et al. (1993). "Creating organizational readiness for change." Human Relations **46**: 681-703.

Bala, R. (2012). "Relationship Between Agile Manufacturing & Just-In-Time." International Journal of Physical and Social Sciences **2**(3): 89-94.

Berkley, B. J. (1992). "A review of the Kanban production control research literature." Production and Operations Management **1**(4): 392-411.

Bernard, H. R. (2006). Research Methods in Anthropology - Qualitative and Quantitative Approaches. Lanham, Alta Mira Press.

Bers, J., J. Dismukes, et al. (2009). "Accelerated radical innovation: Theory and application." Technological Forecasting & Social Change.

Blecker, T. and B. Kaluza (2003). Forschung zu Produktionsstrategien (Research on Production Strategies) College of Business Administration. Klagenfurt, University of Klagenfurt.

BWE (2010). "Statistik 2010."

Chowdhury, S., K. A. Haque, et al. (2015). "Implementation of Lean Strategies in a Furniture Manufacturing Factory." Journal of Mechanical and Civil Engineering **12**(1): 45-50.

Clark, K. B. (1996). "Competing through Manufacturing and the New Manufacturing Paradigm: Is Manufacturing Strategy Passe?" Production and Operations Management **5**(1): 42-58.

Coch, L. and J. R. P. French (1948). "Overcoming resistance to change." Human Relations **1**: 512-532.

Cooke, R. and P. Sheeran (2004). "Moderation of cognition-intention and cognitionbehaviour relations: a meta-analysis of properties of variables from the theory of planned behaviour." British Journal of Social Psychology **43**: 159-186.

Creswell, J. W. and V. L. Plano Clark (2011). Designing and Conductiong Mixed Methods Research. Thousand Oaks, Sage.

Crotty, M. (2011). The Foundations of Social Research. London, SAGE Publications Ltd.

Crute, V., Y. Ward, et al. (2003). "Implementing Lean in Aerospace - Challenging the Assumptions and Understanding the Challenges"." Technovation **23**(12): 917-928.

Cunningham, C. E., C. A. Woodward, et al. (2002). "Readiness for organizational change: a longitudinal study of workplace, psychological and behavioral correlates." Journal of Occupational and Organizational Psychology **75**: 377-392.

Czabke, J., E. N. Hansen, et al. (2008). "A Multisite Field Study of Lean Thinking in US and German Secondary Wood Products Manufacturers." Forest Products Journal **58**(9): 77-85.

Davis, S. (1997). Future Perfect. New York, NY USA, Perseus Books Group.

Dismukes, J., L. Miller, et al. (2009). "The industrial life cycle of wind energy electrical power generation: ARI methodology modeling of life cycle dynamics." Technological Forecasting and Social Change.

Dubey, R. and A. Gunasekaran (2015). "Agile manufacturing: framework and its empirical validation." The International Journal of Advanced Manufacturing Technology **76**(9): 2147-2157.

Easterby-Smith, M., R. Thorpe, et al. (2002). Management Research London, SAGE Publications Ltd.

Elnadi, M. and E. Shehab (2015). "Main Enablers and Factors for Successful Implementation of Lean in Product-Service Systems " International Journal of Agile Systems and Management **8**(3-4): 332-354.

Fei, G., J. Gao, et al. (2011). "A Model-driven and Knowledge-based Methodology for Engineering Design Change Management." Computer-Aided Design and Applications **8**(3): 373-382.

Feitzinger, E. and H. L. Lee (1997). "Mass Customization at Hewlett-Packard: The Power of Postponement." Harvard Business Review **January-February**: 115-121.

Fox, M. J. (1994). Quality Costs: Their Impact on Company Strategy and Profitability (TQM Practitioner). Lincoln, UK, Nelson Thomas Ltd.

Fuglsang, P., C. Bak, et al. (2002). "Site-Specific Design Optimization of Wind Turbines." Wind Energy **5**(4): 261-279.

Gardner, D. J. (2009). Mass Customization - An Enterprise-Wide Business Strategy. Silicon Valley, California USA, HappyAbout.

Gijo, E. V. and A. Sarkar (2013). "Application of Six Sigma to Improve the Quality of the Road for Wind Turbine Installation." The TQM Magazine **25**(3): 244-258.

Gobo, G. (2008). Doing Ethnography. London, UK, Sage.

Goldman, S. L., R. N. Nagel, et al. (1995). Agile Competitors and Virtual Organizations: Strategies for Enriching the Customer. New York, Van Nostrand Reinhold.

Greiner, L. E. (1972). "Evolution and revolution as organizations grow." Harvard Business Review **50**(4): 37-46.

Guba, E. G. and Y. S. Lincoln (1994). Competing Paradigms in Qualitative Research Thousand Oaks, SAGE Publications Ltd.

Gunasekaran, A. (1997). "Implementation of Computer-Integrated-Manufacturing: A Survey of Integration and Adaptability Issues." International Journal of Computer Integrated Manufacturing **10**(1-4): 266-280.

Gunasekaran, A. (2001). Agile Manufacturing: The 21st Century Competitive Strategy. Oxford, Elsevier.

Hader, M. and M. M. Weber (2011). Wind Turbine Manufacturing - A Case for Consolidation. Hamburg, Roland Berger Strategy Consultants.

Hart, C. (2010). Doing a Literature Review: Releasing the Social Science Research Imagination. London, SAGE Publications.

Hasenkamp, T., T. Adler, et al. (2007). "Robust Design Methodology in a Generic Product Design Process." Total Quality Management.

Hayes, R. H. and S. C. Wheelwright (1984). Our Competitive Edge - Competing Through Manufacturing. New York City, John Wiley & Sons.

Herscovitch, L. and J. P. Meyer (2002). "Commitment to organizational change: extension of a three-component model." Journal of Applied Psychology **87**: 474-487.

Hitomi, K. (1997). "Manufacturing strategy for future production moving toward manufacturing excellence." International Journal of Technology Management **14**(6/7/8): 701-711.

Hodge, G. L., R. K. Goforth, et al. (2011). "Adapting lean manufacturing principles to the textile industry." Production Planning & Control **22**(3): 237-247.

Hunt, S. D. (1991). Modern Marketing Theory: Critical Issues in the Philosophy of Marketing Science Cincinnati, South-Western Pub.

Imai, M. (1986). Kaizen: The Key to Japan's Competitive Success New York, McGraw-Hill Higher Education.

Junginger, M., A. Faaij, et al. (2004). "Cost Reduction Prospects for Offshore Wind Farms." Wind Engineering **28**(1): 97-118.

Kitchenham, B. A. and S. L. Pfleeger (2003). "Principles of Survey Research. Part 6: Data Analysis." SIGSOFT Software Engineering Notes **28**(2): 24-27.

Knight, S. (2012). Siemens and GE struggle in German market. Windpower Monthly. London.

Koening, D. T. (1990). Computer Integrated Manufacturing: Theory and Practice. New York, Hemisphere Publishing Corporation.

Krafcik, J. F. (1988). "Triumph of the Lean Production System." Sloan Management Review **30**(1): 41-52.

Krajewski, L. J. and L. P. Ritzman (1987). Operations Management: Strategy and Analysis. Reading, USA, Addison-Wesley.

Kramer, G. J. and M. Haigh (2009). "No quick switch to low-carbon energy." Nature **462**(3): 568-569.

Kramer, T. J., J. T. Chibnall, et al. (1992). "Managing Computer Integrated Manufacturing (CIM): A Review of Themes, Issues, and Practices." Journal of Business and Psychology **6**(4): 415-442.

Kraus, S. J. (1995). "Attitudes and the prediction of behavior: a meta-analysis of the empirical literature." Personality and Social Psychology Bulletin **21**: 58-76.

Larteb, Y., A. Haddout, et al. (2015). "Successful lean implementation: The systematic and simultaneous consideration of soft and hard lean practices." International Journal of Engineering Research and General Science **3**(2): 1258-1270.

Leong, G. K., D. Snyder, et al. (1990). "Research in the process and content of manufactruing strategy." OMEGA **18**(2): 109-122.

Lewin, K. (1947). "Frontiers in group dynamics." Human Relations **1**(2): 143.

Lievegoed, B. C. J. (1974). Organisationen im Wandel. Bern, Haupt.

Likert, R. (1932). "A Technique for the Measurement of Attitudes." Archives of Psychology **140**(55).

Lines, R. (2004). "Influence of participation in strategic change: resistance, organizational commitment and goal achievement." Journal of Change Management **4**: 193-215.

Logothetis, N. (1992). Managing for Total Quality: From Deming to Taguchi and SPC. New York, Prentice Hall.

McKenna, J. (2012). Siemens posts €48 million renewables loss. Windpower Monthly. London.

Meybodi, M. Z. (2003). "Using Principles of Just-in-Time to improve New Product Development Process." Advances in Competitiveness Research **11**(1): 116-138.

Miles, M. B. and A. M. Huberman (1994). Qualitative Data Analysis - An Expanded Sourcebook. Thousand Oaks, SAGE Publications.

Nordin, N., B. M. Deros, et al. (2012). "A framework for organisational change management in lean manufacturing implementation." International Journal of Services and Operations Management **12**(1): 101-117.

Ohno, K., K. Nakashima, et al. (1995). "Optimal numbers of two kinds of kanbans in a JIT production system." International Journal of Production Research **33**(5): 1387-1401.

Ohno, T. (1988). Toyota Production System: Beyond Large-scale Production. Portland, Oregon, Productivity Press.

Oreg, S., M. Bayazıt, et al. (2008). "Dispositional resistance to change: measurement equivalence and the link to personal values across 17 nations." Journal of Applied Psychology **93**: 935-944.

Ozkan, D. and M. R. Duffey (2011). "A Framework for Financial Analysis of Offshore Wind Energy." Wind Engineering **35**(3): 267-288.

Patton, M. Q. (2002). Qualitative Research & Evaluation Methods. Thousand Oaks, SAGe Publications.

Perry, C., A. Riege, et al. (1999). "Realism's role among scientific paradigms in marketing research." Irish Marketing Review

Pine, J. B. I. (1999). Mass customization: The new frontier in business competition. Bosten, MA USA, Harvard Business School Press.

Popper, K. R. (2004). The Logic of Scientific Discovery. London, Taylor & Francis.

Porter, M. E. (2004). Competitive Advantage: Creating and Sustaining Superior Performance. New York City, Free Press.

Punch, K. F. (2005). Introduction to Social Research: Quantitative and Qualitative Approaches. London, Sage.

Quilter, J. (2012). Vestas in turmoil - the stories. Windpower Monthly. London.

Roh, J., P. Hong, et al. (2014). "Implementation of a responsive supply chain strategy in global complexity: The case of manufacturing firms." International Journal of Production Economics **147**(B): 198-210.

Rumel, R. P., D. E. Schendel, et al. (1979). Evaluation of Strategy: Theory and Models. Strategic Management: A New View of Business Policy and Planning. Boston, MA, Little, Brown & Company. **1:** 196-217.

Rymaszewska, A. D. (2014). "The challenges of lean manufacturing implementation in SMEs." Benchmarking: An International Journal **21**(6): 987-1002.

Salem, R., F. Musharavati, et al. (2015). "An empirical study on lean awareness and potential for lean implementations in Qatar industries." The International Journal of Advanced Manufacturing Technology: 1-19.

Sanchez, L. M. and R. Nagi (2001). "A Review of Agile Manufacturing Systems." International Journal of Production Research **39**(16): 3561-3600.

Saunders, M., P. Lewis, et al. (2003). Research Methods for Business Students. Harlow, Pearson Education Limited.

Savci, S. and B. Kayis (2006). "Knowledge elicitation for risk mapping in concurrent engineering projects." International Journal of Production Research.

Schmidt, R. (1997). "The implementation of simultaneous engineering in the stage of product concept development: A process orientated improvement of quality function deployment." European Journal of Operational Research.

Schreyögg, G. and C. Noss (1995). "Organisatorischer Wandel: Von der Organisationsentwicklung zur lernenden Organisation." Die Betriebswirtschaft **55**(2): 169-185.

Skinner, W. (1984). "Operations Technology: Blind Spot in Strategic Management." Interfaces **14**: 116-125.

Smith, J. and J. Firth (2011). "Qualitative Data Analysis: The Framework Approach." Nurse Researcher **18**(2): 52-62.

Stelian, B. (2009). "Concurrent multifunction deployment (CMFD)." International Journal of Production Research.

Suzaki, K. (1993). The New Shop Floor Management - Empowering People for Continuous Improvement. New York, The Free Press.

Thomas, A., R. Barton, et al. (2009). "Applying lean six sigma in a small engineering company - a model for change." Journal of Manufacturing Technology Management **20**(1): 113-129.

Ulrich, K. T. (1992). The Role of Product Architecture in the Manufacturing Firm. Cambridge, MA, Massachusetts Institute of Technology. **1**.

Van der Zwaan, B., R. Rivera-Tinoco, et al. (2012). "Cost Reductions for Offshore Wind Power: Exploring the Balance Between Scaling, Learning and R&D." Renewable Energy: An International Journal **41**: 389-393.

Van Hoek, R. I. (2001). "The Rediscovery of Postponement: a Literature Review and Directions for Research." Journal of Operations Management **19**: 161-184.

Wang, L. and S. C. L. Koh (2010). Enterprise Networks and Logistics for Agile Manufacturing London, Springer.

Watson, G. (1971). "Resistance to Change." American Behavioral Scientist **14**(5): 745-766.

Weinhold, N. (2012). Belastungsprobe. Neue Energie. Berlin, Bundesverband WindEnergie e.V.

Wheelwright, S. C. (1978). "Reflecting Corporate Strategy in Manufacturing Decisions." Business Horizons(February): 57-66.

Wildemann, H. (1997). Fertigungsstrategien. Munich, TCW.

Wilkes, J., J. Moccia, et al. (2012). Wind in power - 2011 European statistics. Brussels, European Wind Energy Association.

Womack, J. P. and D. T. Jones (1994). "From Lean Production to the Lean Enterprise." Harvard Business Review **72**(2): 93-103.

Womack, J. P. and D. T. Jones (1996). "Beyond Toyota: How to Root Out Waste and Pursue Perfection." Harvard Business Review **74**(5): 140-144, 146, 148-152, 154, 156, 158.

Xiaoli, Q. and Y. Hong (2004). Perspectives from Europe and Asia on Engineering Design and Manufacture - A Development on Manufacturing Information Communication in Agile Manufacturing with STEP and XML. Amsterdam, Springer.

Yang, B., N. D. Burns, et al. (2004). "Postponement: A Review and anIntegrated Framework." International Journal of Operations & Production Management **24**(5): 468-487.

Yin, R. K. (2008). Case Study Research: Design and Methods London, SAGE Publications Ltd.

Zahn, E. (1988). Produktionsstrategie. Wiesbaden, Hirschgraben.

Zäpfel, G. (2000). Strategisches Produktions-Management. Munich, Oldenbourg.

Zikmund, W. G. (2003). Business Research Methods 7th ed. Bosten, South-Western College Pub.

Appendix A
Results Questionnaire

Seite 1, Frage 1: PowerWind-spezifisch:
Ich bin Mitarbeiter aus dem folgenden Fachbereich:
23 Teilnehmer

1 = Einkauf	4
2 = Produktion	4
3 = Projektmanagement	3
4 = R&D	6
5 = Sales/Marketing	6

Seite 1, Frage 2: PowerWind-spezifisch:
Wie gut decken unsere Produkte die Anforderungen unserer Zielkunden ab?
20 Teilnehmer

1 = sehr gut	-
2 = gut	15
3 = durchschnittlich	5
4 = eher schlecht	-
5 = sehr schlecht	-

Seite 1, Frage 3: PowerWind-spezifisch:
Wie gut lassen sich unser Produktprogramm und unsere Produktfeatures dem Kunden kommunizieren?
21 Teilnehmer

1 = sehr gut	-
2 = gut	7
3 = durchschnittlich	12
4 = eher schlecht	2
5 = sehr schlecht	-

Seite 1, Frage 4: PowerWind-spezifisch:
Wie bewertest Du allgemein die Abläufe bei PowerWind zur Abarbeitung unserer Kundenaufträge?
21 Teilnehmer

1 = sehr gut	-
2 = gut	1
3 = durchschnittlich	8
4 = eher schlecht	11
5 = sehr schlecht	1

Seite 1, Frage 5: PowerWind-spezifisch:
Wie hoch ist die Fehlerrate bei den Abläufen zur Abarbeitung unserer Kundenaufträge?
23 Teilnehmer

1 = sehr hoch	1
2 = hoch	5
3 = mittel	14
4 = eher gering	3
5 = sehr gering	-

Seite 1, Frage 6: PowerWind-spezifisch:
Wie hoch ist die Geschwindigkeit der einzelnen Arbeitsschritte bei der Abarbeitung unserer Kundenaufträge?
22 Teilnehmer

1 = sehr hoch	1
2 = hoch	3
3 = mittel	14
4 = eher gering	3
5 = sehr gering	1

Seite 1, Frage 7: PowerWind-spezifisch:
Wie hoch schätzt Du die Flexibilität unseres Produktprogramms ein auf kurzfristige Kundenwünsche zu reagieren?
22 Teilnehmer

1 = sehr hohe Flexibilität	3
2 = hohe Flexibilität	6
3 = mittelere Flexibilität	10
4 = eher geringe Flexibilität	3
5 = sehr geringe Flexibilität	-

Seite 2, Frage 8: Allgemein:
Welchen Einfluss hat das Produktprogramm auf die Abläufe zur Abwicklung von Kundenaufträgen?
23 Teilnehmer

1 = sehr großen Einfluss	5
2 = großen Einfluss	8
3 = mittleren Einfluss	9
4 = geringen Einfluss	1
5 = keinen Einfluss	-

Seite 2, Frage 9: Allgemein:
Welchen Einfluss hat das Produktprogramm auf den Cash-Flow eines Herstellers von Windenergieanlagen?
23 Teilnehmer

1 = sehr großen Einfluss	7
2 = großen Einfluss	8
3 = mittleren Einfluss	5
4 = geringen Einfluss	3
5 = keinen Einfluss	-

Seite 2, Frage 10: Allgemein:
Welchen Einfluss hat das Produktprogramm auf die Fertigungsstrategie eines Herstellers von Windenergieanlagen?
23 Teilnehmer

1 = sehr großen Einfluss	11
2 = großen Einfluss	9
3 = mittleren Einfluss	1
4 = geringen Einfluss	2
5 = keinen Einfluss	-

Appendix B
Interview Guide

1. Need (dispositional resistance)
    - 1.a What do you think about the need to implement a new manufacturing concept?
    - 1.b What difficulties or barriers do you foresee in implementing a new manufacturing concept?

2. Appropriateness (trust in project and Project Manager)
    - 2.a What do you think about the choice of the implemented manufacturing concept?
    - 2.b What strategic advantages do you see in implementing a new manufacturing concept will bring the company?

3. Capability (trust in organization)
    - 3.a What do you think about the organization's capability to implement the new manufacturing concept?

4. Motivation (job satisfaction)
    - 4.a What personally motivates you to adopt or not to adopt the new manufacturing concept?