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MAIJU KARHUNEN

STATUTORY INSPECTIONS OF SAFETY EQUIPMENT IN WIND TURBINES – THE DEVELOPMENT OF THE SERVICE PRODUCT AND ITS IMPLEMENTATION

Master of Science thesis

Examiner: prof. Jouni Kivistö-Rahnasto
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ABSTRACT

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Aim of thesis was to evaluate content and price of the service product Statutory Inspection of safety equipment. To determine inspection requirements for each identified safety equipment, a law-based definition was searched for equipment by analyzing a wide range of legislation and application guidelines. It was found that most of the equipment does not have a requirement of third party inspections, but inspection of equipment still usually requires special skills and knowledge, which can be obtained for example by participating in special training given by the manufacturer of the equipment.

In evaluation of pricing the cost based pricing, customer and competition based pricing and strategic goals and objectives based pricing factors were identified. The main cost factors were human resource related costs, cost of external services and use of work equipment. Order and competitive situation must be taken into account as usually in bidding pricing. Customers may also value this service product in a variety of ways whereby optimal pricing would be generated by pricing the customers. Also, the pricing of overall solution, where wind turbine as core product and advanced maintenance services have been considered, could be one way for strategic pricing.

Safety in the wind industry as well as in the target company is very important and so is the quality of this service. It was seen as practically possible to carry out inspections by in-house people, capacity purchase or outsourcing. Use of external manpower could be cheaper but requires additional management work to ensure their works safety and compliance. Third party inspection company would be objective, but not familiar with use of equipment. Investigating into own competence could be beneficial for the whole service business and continuous improvements could lower costs.

The evaluation of implementation alternatives was based on company's internal observations, interviews and grounded theory. Within this study, it was possible to identify advantages and disadvantages of various alternatives. However, for further analysis and evaluation of alternatives, more data would need to be collected.

TIIVISTELMÄ

MAIJU KARHUNEN: Tuulivoimalan turvallisuuslaitteiston lakisääteiset tarkastukset - teollisen palvelutuotteen ja sen toteutuksen kehittäminen
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Tutkimuksessa tavoitteena oli arvioida kohdeyrityksen palvelutuotteen - lainsäädännön mukaiset tarkastukset - sisältöä ja hinnoittelua. Jokaiselle tunnistetulle turvallisuusvälineelle etsittiin lainmukainen määritelmä analysoimalla lainsäädäntöä sekä sen soveltamisohjeita laaja-alaisesti. Tuloksena havaittiin, että suurin osa välineistöstä ei vaadi kolmannen osapuolen määräaikaistarkastuksia. Kuitenkin erityistä osaamista ja tietoja tarvitaan ja ne voidaan hankkia esimerkiksi osallistumalla laitevalmistajan antamiin käyttäjäkoulutuksiin tai muihin lisäkoulutuksiin henkilökohtaisen tarpeen mukaisesti.

Hinnoittelun arvioinnissa tunnistettiin kustannusperusteisia, asiakkaisiin ja kilpailijoihin sekä yrityksen omiin strategisiin päämääriin ja tavoitteisiin liittyviä tekijöitä. Tärkeimmät kustannustekijät olivat henkilöstöresurssien käyttöön, ulkopuolisiin palveluihin sekä eräiden työvälineiden käyttöön liittyvät kustannukset. Tilaus- ja kilpailutilanne olisi aina otettava huomioon tarjouskilpailussa. Optimaalinen hinnoittelu saattaisi syntyä myös asiakkaita tai kokonaisratkaisun hinnoittelemalla, jolloin palvelutuotteen hinnoittelussa otettaisiin huomioon asiakkaiden arvostukseen vaikuttavia tekijöitä sekä ydintuotteen ja huoltopalveluiden hinnoittelu.

Tuulivoima-alalla ja kohdeyrityksessä työturvallisuus on tärkeässä roolissa ja niin on myös tämän palvelun laatu. Kolme palvelutuotteen organisointivaihtoehtoa, joita olivat itsetekeminen, kapasiteettiosto ja ulkoistaminen, tunnistettiin ja vertailtiin. Ulkoisen työvoiman käytössä suorat kustannukset voisivat olla alhaisimmat, mutta voidakseen varmistua ulkopuolisen työn turvallisuudesta ja vaatimustenmukaisuudesta kontrollia tarvitaisiin. Kolmannen osapuolen käytössä toteutuisi varmimmin tarkastusten riippumattomuus. Sen sijaan koko huoltotoiminto voisi hyötyä investoinnista omaan osaamiseen

Toteutusvaihtoehtojen vertailu perustui kohdeyrityksen sisäisiin havaintoihin ja haastatteluihin sekä pohjateoriaan. Tässä tutkimuksessa voitiin tunnistaa eri vaihtoehtoihin liittyviä etuja ja haittoja. Kuitenkin tarkempaa analyysia ja vertailua varten tulisi kerätä enemmän dataa esimerkiksi tarkastusten kestosta ja kustannuksista.

PREFACE

This thesis was made for the company I was working for half a year before I started my thesis. I already knew the company when I had been working on a few safety issues with the company’s safety department. The statutory inspections were one of the issues and at that moment the development of service activities needed more attention than construction activities. I am thankful that I got such a technical and similarly practical subject where I was able to use my knowledge of safety as well as industrial management. Nordex's QHSE-manager Anna Lehtinen worked as my thesis supervisor.

I would like to thank my work community at Nordex for support. Everyone with whom I had conversations of this research and topic were really encouraging. So many provided their help in collecting the information necessary for the thesis. Special thanks to Anna and Juho. Thanks to my examiner, Professor Jouni Kivistö-Rahnasto for clear and precise feedback. Thanks to Vesa Kahilampi for helping me with language of my research report. Finally, my greatest thanks go to my family for a variety of support on my way.

In Helsinki, Finland, on 31th July 2017

Maiju Karhunen

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1. INTRODUCTION

1.1 Backgrounds of thesis

In the energy sector the competitive advantage of wind energy comes from the product, which is considered as green and environmentally good (EU-OSHA 2013). For that reason, wind energy might be considered as a responsible choice, but it doesn't automatically mean that it is a responsible choice from every aspect. Working in wind industry is always a high-risk job (Bayar 2014).

Good image and willingness to pay for green power is crucial for wind industry success. Even if wind energy as a clean and renewable energy source has been traditionally linked with strong public support, social acceptance is not obvious. Experience has shown that wind farms might be resisted by local communities and whole application processes have been delayed or blocked. (ETIPWind 2016.) Increasing social acceptance is necessary to increase market share of wind energy (European Commission 2016).

So far most of the safety procedures in the wind industry have been evolving by self-regulation when interested parties and organizations in the industry have been creating own standards and procedures for promoting best practices (Bayar 2014). The number of special wind turbine standards is still very low or standards for some special applications, even some safety devices, are missing entirely. All this can be explained by the rapid expansion of the wind energy sector and significant advances in the size and capacity of the wind turbine design. (EU-OSHA 2013.)

The safe and reliable operation of wind turbines over their whole operational life depends on the assurance of long term integrity of the assets. Inspections of safety equipment have an important role in this when functional or structural failure of these components could result in major health and safety risks. To the owner of the wind turbine, it is important to ensure that all required integrity maintenance work has been undertaken. (RenewableUK 2015.)

But in the current situation when there are still "very few" legal requirements around wind industry safety practices (Bayar 2014), identification of the requirements is challenging. In Europe, good operational wind industry practices are still forming while the wind industry is moving from design and build phase towards operational phase (EU-OSHA 2013). Finland is still behind many advanced European wind industry countries.

Wind power industry is still a young industry in Finland. It has been growing rapidly in recent years and in 2016 in Finland more wind power capacity was built than ever before. From the Figure 1.1 progress of industry can be seen.

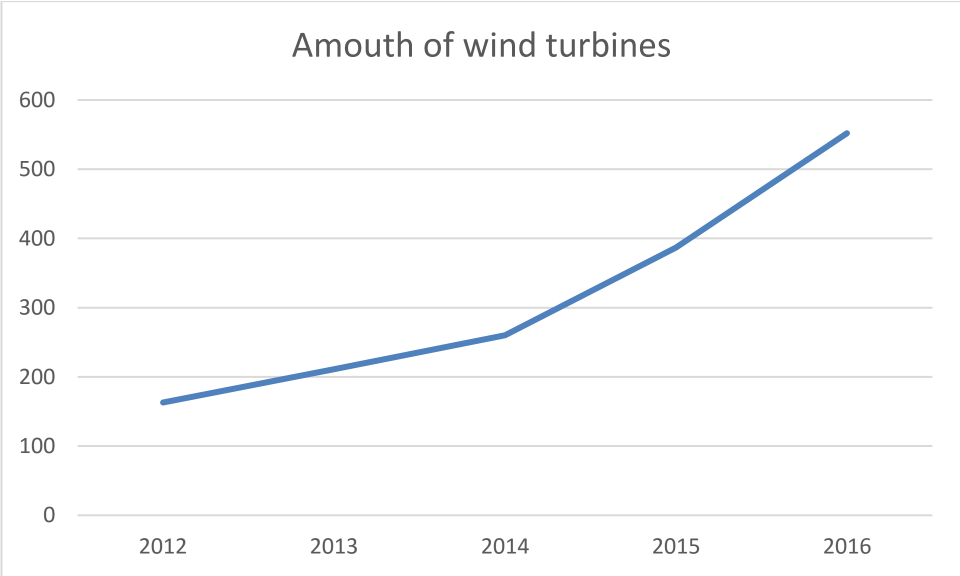

Figure 1.1. Amount of wind turbines in Finland 2012-2016 (Suomen Tuulivoimayhdistys ry 2016).

With last year's installed capacity of 570 MW, the capacity in Finland increased over 50 % and exceeded the total capacity of 1533 MW. In Finland, 81 % of total installed wind capacity has been built between 2012 and 2016. For comparison, in Europe only 32 % of total capacity has been built during the same years (EWEA 2015). In central scenario of capacity and electricity production in EU Member States, estimated installed capacity in Finland in 2030 will be 8,526 MW (EWEA 2015).

1.2 Aim and objectives of thesis

The case company operates globally in wind power industry as wind turbine manufacturer, provider of project services and maintenance services. Separate from maintenance services, the company provides a service called Statutory Inspection of the safety equipment. Company has operated for only few years in Finland and business has increased during the period in an upward trend. After-sale-services and their organization in larger scale is currently an important issue in the company's Finnish Branch. Statutory inspection of safety equipment as a safety related after-sale service and its organization is one of the services which needs evaluation.

Similar problems with a minority of wind turbine specific legislation can be found from the local legislation. National requirements also vary from European requirements, which set more challenges to the global activity when operational practices cannot be copied directly from one country to another. To offer the service product statutory inspections, current, local legislation needs to be identified to be able to continue identification of different operational alternatives. Also, special features of the industry and the case company need to be explored to identify and evaluate alternatives for service implementation.

Statutory inspections was originally priced in a situation where operational practices were still forming or there were no national practices at all yet. Anticipating the use of resources for the production is usually the most important but similarly the hardest part of the pricing (Laitinen 2007). Similarly, the pricing of statutory inspections in a situation where practices had been still forming has been a challenging task which have included uncertainty. Pricing should be re-evaluated when more information of recourses in actual use has become available.

The aim of this research is to help the case company define content and price of the service statutory inspection. Objective of this research is to find out and analyze different solutions for the practical implementation of the service product statutory inspection of the safety equipment in wind turbines. Research questions are

1. What does the service product statutory inspection contain?
2. How should the service product be priced?

To answer these questions and meet research objectives, machinery for inspections must be identified and defined to clarify machinery specific regulations. It is important to explore the industry and find out what criteria it sets for the solutions. Specifics of the company such as product and service portfolio as well as existing resources are factors which should be explored. One objective of the research is to evaluate costs and pricing of the service product. However, the focus is to find the factors which affect the costs and identify and evaluate a variety of pricing models.

There are some criteria for the solution. The case company invests in occupational safety and when the service product is a safety related after-sale service, it is important to find a solution which is safe, of high quality and complies with current legislation. Scope of the study is to focus on the Finnish legislation, the specific case company and company's single service product.

1.3 Content and structure of thesis

Second chapter presents the background and theoretical framework of the thesis. It introduces statutory requirements for inspections and theory of industrial service management. First section of the chapter introduces basic regulations for the machinery manufacturer and user. These two form the basis for inspection requirements. Requirements of inspection period and inspector qualifications are introduced more specifically in further subsections. Second section of the chapter contains a description of the industry and its special features. It is divided into Life cycle of wind turbines, Safety in the wind industry and Human resources management in the wind industry. At the end of the second chapter (third section), a theory of industrial services, their management and pricing is introduced.

Third chapter introduces the case company and research phases. Description of the case company tells what kind of product portfolio the company has and how the service product statutory inspection complements the portfolio. Research is divided into two phases, which have been opened in separate subsections. First subsection tells which phases have been done for defining the content of the service product. Second subsection describes what methodology has been used for defining the price of service product and how alternative implementation solutions have been identified and compared.

Results of the thesis have been introduced in chapter four. In the first section of the chapter, the machinery for inspection is identified and content of the service product defined. In the second section of this chapter, inspection requirements for all machinery are determined. The third section of this chapter contains analysis of the current state of service organizing. In the fourth section of the chapter, the factors which should be taken into account in pricing have been identified.

In the fifth chapter, discussion, there is analysis of the results' reliability and validity and comparison of alternative solutions for service implementation. It will be discussed what could be the best way to arrange inspection services for installed base of wind turbines. Sixth chapter is the final chapter and includes conclusions of the thesis. It contains the main result of the thesis and proposals for further research needs.

2. BACKROUND AND THEORETICAL FRAMEWORK

2.1 Statutory requirements for inspections

European Union directives on occupational safety are codes of conduct for national legislature. Directives contain minimum target requirements for the member countries. The methods for achieving the objectives set out in the directive have been defined at national level. Therefore, the directives are brought into force by national law. It is also possible to set a level of safety which is higher than the requirements of the directives. Occupational safety directives have been put into effect in Finland by the Occupational Safety and Health Act and government decisions or decrees issued under it. (Työsuojeluhallinto 2013.)

Machinery safety legislation in Europe is set out in two stages. Manufacturers of the machine are responsible for the machine's design and manufacturing process so that the machine will be safe when put into use. (McMullen & Caddick 2003.) The aim of the Machinery Directive and other product directives is to make possible the free movement of goods and remove trade barriers. Product directives define the products' characteristics for user health and safety, and requirements for the harmonization of the different product standards applied in the different Member States. (Työsuojeluhallinto 2013.) In Finland, *Directive 2006/42/EC on Machinery* has been put into effect by Government Decree on the Safety of Machines 400/2008 (later called Machinery Decree) (Decree 400/2008).

User legislation covers the operating procedures of work equipment. Equipment should be properly maintained and used in a safe manner. (McMullen & Caddick 2003.) Directive 2009/104/EC of the European Parliament and of the Council concerns the minimum safety and health requirements for the use of work equipment by workers at work. The directive gives basic regulations for each Member State, but each Member State shall determinate the conditions of inspections, as well as the meaning of competent person for doing inspections, in national law and/or practices (Directive 2009/104/EC). Member states are free to adopt more stringent requirements than the minimum requirements of Directive 2009/104/EC (Fraser et al. 2010).

In Finland, Directive 2009/104/EC has been put into effect by Government Decree on the Safe Use and Inspection of Work Equipment 2008/403 and Occupational Safety and Health Act 2002/738 (later OSH Act). User Decree 2008/403 is applicable on the same cases as Occupational Safety and Health Act (Decree 2008/403). User Decree has been given under the OSH Act, which means that certain sections of the OSH Act must be taken into consideration when applying the User Decree (Työsuojeluhallinto 2013).

Also, there might be other additional applicable decrees pertaining to structure, safe use or inspection of work equipment which must be taken into consideration. For example, Government Decree on the Safety of Construction Work 205/2009 and Government Decree on the Occupational Safety in Loading and Unloading of Ships 2004/633 are decrees concerning special works or working conditions. (Työsuojeluhallinto 2013.) If any provisions of the special decrees deviate from the user decree, those provisions must be applied instead of the user decree (Decree 2008/403). If the user decree and the special decree overlap, there is no conflict, because then the user decree will not apply. In questions concerning safety regulations, in the event of a conflict, the aim should be to find the safest possible solution. (Työsuojeluhallinto 2013.)

2.1.1 Manufacturer regulations

Machinery Directive/Decree concern machinery where linked parts and components, at least one of which moves, are joined together for special purpose and intended to be fitted with a drive system powered directly by other than human or animal effort, with the exception of machinery for lifting loads. It also concerns this kind of assembly ready to be installed on a building, structure or transport; connected to a separate source of energy or completed assemblies of machinery. (Decree 400/2008, Directive 2006/42/EC.)

Additionally, Machinery Directive/Decree applies to partly completed machinery, interchangeable equipment, removable mechanical transmission devices, lifting accessories, chains, ropes and webbings for lifting purposes. It also applies to safety components which are not a necessary part of machinery and therefore independently placed on the market, but which fulfil the safety function and failure of which endangers safety of users. (Decree 400/2008, Directive 2006/42/EC.)

Partly completed machinery is almost machinery, but it cannot itself perform a specific application even if it would be connected to the source of energy or installed on something. Partly completed machinery is intended to be incorporated into machinery or other partly completed machinery, in which case an assembly forms a machine which meets the definition of machinery in the machinery directive. For example, a drive system such as an internal combustion engine or a high voltage electric motor, could be considered as partly completed machinery. (Fraser et al. 2010.)

Assemblies of machinery mean machinery which consist of two or more machines, or partly completed machinery arranged and controlled so that they achieve the same end and function as an integral whole. In order to meet this definition, units of machinery should be assembled together to carry out some common function, operation of each unit must affect decently to the operation of another unit and separate units should have a common control system. If machines are connected to each other's functions independently of the others, the combination cannot be considered as an assembly of machinery. An industrial plant might consist of several assemblies of machinery. (Fraser et al. 2010.)

Machines defined in the Machinery Directive must be manufactured to conform with it. CE-marking on the machinery and the EC Declaration of Conformity drawn up and signed prove that work equipment fulfills the requirements of the directive and the manufacturer has performed the procedures for assessing the conformity with its essential health and safety requirements. If units of assemblies of machinery are marketed as complete machinery that could also be operated independently, those must bear the CE-marking. But if units are marketed as partly completed machinery, they must be accompanied with a declaration of incorporation and assembly instructions – not a CE-marking. The person responsible for the assembly of machinery is considered as its manufacturer. This person must carry out the conformity assessment procedure for the assembly. The person must take into consideration the safety of the assembly as a whole and hazards resulting from the interfaces between units. (Fraser et al. 2010.)

Machinery directive concerns each machine that isn't covered under any special directive, for example the lift directive or the tractor directive. Also several directives may concern some machines, and machines have to always fulfill all directives which concern them. In addition to the machinery directive, for example, the pressure equipment directive or the low voltage directive may concern machine. (Siirilä 2008, p. 28.)

Machinery directive defines principles of safety integration: "*Machinery must be designed and constructed so that it is fitted for its function, and can be operated, adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen but also taking into account any reasonably foreseeable misuse thereof.*" (Directive 2006/42/EC, section 1.1.2). Designer of the machine has to apply the following principles in the order given:

- First priority is to eliminate or reduce risk as far as possible and implement it by inherently safe machinery design and construction. An example of the first priority principle is to place hazardous parts, such as moving, sharp or hot parts, of machinery in inaccessible places.
- Second priority is to take the necessary protective measures in relation to risk that cannot be eliminated or sufficiently reduced by inherently safe design measures. Examples of technical protective measures are guards, protective devices, and enclosure of sources of hazard.
- Third priority is informing users of the residual risk and safe use of machine. Manufacturer should indicate particular trainings required, specify need of personal protective equipment, add warnings on the machinery in the form of symbols and pictograms, acoustic and light signs and important information of the machinery such as mass and restrictions on the use. (Fraser et al. 2010.)

Machinery directive defines the general requirements for the safe design of machinery. More specific details of requirements have been given by harmonized standards. (Siirilä 2008.) Standards support the directive and tell how a manufacturer may satisfy the safety requirements of the directive (RenewableUK 2015). Following a standard is not mandatory, but if a machine has been designed according to harmonized standards, it should fulfill the requirements of machinery directive. (Siirilä 2008.) The European Standardization Organizations CEN or CENELEC adopt the harmonized standards, and after that, such standards can be identified from the prefix "EN". If the standard has also adopted by The International Organization for Standardization (ISO), the standard has the prefix "EN ISO". (Fraser et al. 2010.)

Harmonized standards for supporting the machinery directive form a three-tiered system. On the top of the hierarchy are type A standards, which are general and concern all machines, for example SFS-ISO/TR 14121-2 *Safety of machinery. Risk assessment*. On the next level are type B standards, which concern some special hazard or safety related function, for example SFS- EN ISO *13850 Safety of machinery. Emergency stop function. Principles for design*. Type C standards concern special machines or groups of machines, for example SFS-EN ISO 144492-2 *Cranes. Power driven winches and hoists*. (Siirilä 2008.) Hierarchy of machinery can be seen in the Figure 3.1.

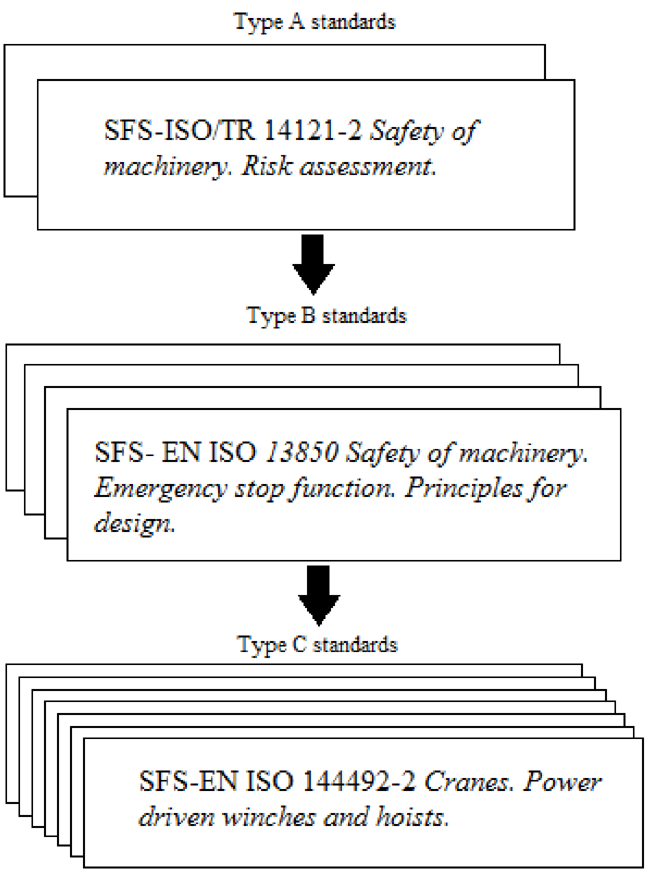

Figure 3.1. *Hierarchy of machinery standards (Siirilä 2008, p. 31).*

Some standards include different types (I, II, III), levels (A, B, C) or classes (1, 2, 3), which define different solutions (level) for the safety. Sometimes type C standard says which type/level/class of type B standard has to be chosen, but not always. Then the choice should be done through risk assessment. (Siirilä 2008.)

2.1.2 User regulations

The Decree on the Safe Use of Work Equipment designates all activities related to equipment, including selection, installing, transportation, start and stop functions, cleaning, use, maintenance, repairs, doing changes and inspecting. In many cases work equipment is a machine, but not necessarily. (Työsuojeluhallinto 2009.) Work equipment might be a machine, tool, technical device or their combination (Decree 403/2008).

It is important that hazards and safety of machines have been taken into account in the design stage, but there will always be some residual risks. Probability and seriousness of the residual risk depends on the user and organization using the machine. (Siirilä 2008.) Manufacturer of the machine is responsible for providing warnings and instructions for safe use of the machine, but how these precautions and measures have been taken to minimize risks depends on the user (Fraser et al. 2010).

In addition to a description of basic functions such as transportation, storing, installation and commissioning, normal use, maintenance and disabling, the user instructions should contain the following details:

- Content and frequency for the inspections of machine
- Information of any particular training required
- Information of how to avoid residual risk and act in emergency situations. (Directive 2006/42/EC)

Occupational Safety and Health Act says that work equipment and other devices in use must comply with the applicable provisions and be suitable for the work and working conditions. The use of machinery, work equipment or devices should not cause risk or hazard to the employees working with them or around. If the work may cause a serious risk of injury or illness, work should be done by a person who is competent and suitable for the task or by another person under the direct supervision of a competent person. (Act 738/2002.)

Employer has a liability all the time to monitor the safety of the working environment and this concerns also machines with CE marks. The employer is responsible for finding out and evaluating hazards concerning machinery, and for taking the necessary measures for minimizing and eliminating them. (KKO:2014:75.) For ensuring the safe working order of the machinery, the employer must do the necessary risk assessments for the machinery

(Siirilä 2008). Especially, the employer should evaluate hazards and risks caused by moving parts, external structures, physical and chemical properties, automatic functions and electricity of the machinery (Decree 403/2008).

The employer is responsible for providing the necessary training and user induction to ensure competence of employees who are working with machinery or working equipment (Siirilä 2008). For monitoring the safety of work equipment, the employer must define personal tasks, responsibilities and qualifications for the persons who are involved in it (Työsuojeluhallinto 2009). Also, the employer must always see to it that the manufacturer's instructions have been taken into account when carrying out any activities with the machinery or equipment (Decree 403/2008). Some manufacturers require that employees using equipment receive training through the original equipment manufacturer as a requirement for the product warranties (Duff 2010).

There are no similar EU standards for users of equipment as there is for the manufacturer. Standards made for the manufacturer of machines include the latest recommended solutions for the safety. Therefore, those solutions might be useful for the user of machinery for ensuring the safe working order of machinery over their lifetime. (Työsuojeluhallinto 2009.) However, the application of the user regulation should also be based on a risk assessment. The risk assessment must take into account not only the characteristics of the machine, but also the circumstances of the workplace and other relevant factors. (Työsuojeluhallinto 2013.)

The requirement to systematically ensure the safety of work equipment (machinery) means that there are utilitarian practices in the workplace that will ensure that the safety of all machines has been assessed. The risk assessment must be carried out at least at the time of purchase of machinery, in the conversion of machines or working methods, and periodically as seen necessary. (Työsuojeluhallinto 2013.)

2.1.3 Inspection period

The employer is responsible for keeping work equipment safe throughout its operational life by regular service and maintenance and if the equipment has a maintenance manual, it must be kept up to date. Before first use or after significant alterations, it must be ensured that work equipment has been installed correctly and it is in safe working order. Working order of the work equipment must be continuously monitored by inspections which include all necessary tests and measurements. (Decree 403/2008.)

According to Occupation safety law, if the installation or operating conditions of the machinery, work equipment or devices affect its safety, it must be inspected before first use and regularly after that. Doing inspections is important for ensuring that equipment has been correctly installed and it is in safe functional order before taking into use and over its lifetime. (Act 738/2002.)

User Decree defines three special types of work equipment inspections, which are:

> *"**An initial inspection** must be carried out before taking work equipment into use for the first time or after a significant alternation or after mounting it in a new place or when a machine is taken into use after being out of use for a long time.*
>
> ***Periodic inspection** must be carried out at one-year intervals after initial inspection or from the date when the employer took the work equipment into use. The inspection period can be extended if the use of the work equipment is minor and if the circumstances put only very slight strain on the equipment. Similarly, the inspection period must be shortened if the use of the work equipment or the conditions of the use put special strain on the working condition of the equipment, or if there is some other especially important reason to ensure that the equipment is safe to use.*
>
> ***Thorough periodic inspection** must be carried out when the designed limits defined for the lifting machinery by the manufacturer are drawing close. If those limits are not known, a thorough periodic inspection must be carried out within 10 years after the device was put into use for the first time." (Decree 403/2008 sections 33-35.)*

Initial inspections, periodic inspections and thorough periodic inspections must be carried out by the above defined intervals only for specific machinery groups, specified in Table 2.1.4 (Decree 403/2008). However, if the installation or operating conditions of any work equipment affect safety, the safe working order must be ensured before taking it into use (Act 738/2002). The objective of initial inspections is to check that machinery has been installed in the correct way in accordance with the user manual; walkways, ladders and maintenance/using places are in proper order; and control and safety devices work properly (Työsuojeluhallinto 2013).

Even if the above mentioned definition for periodic inspection concerns only specified machinery groups, any safety related work equipment should be subject to regular periodic inspection as well as initial inspection (Act 738/2002). For specified machinery groups (in Table 2.1.4), the extension or shortening of inspection period should be based on reliable analysis and evaluation (Työsuojeluhallinto 2013). Also, with unspecified work equipment, the reliable analysis and evaluation of inspection measures and intervals is sensible even when complying with the manufacturer's instructions.

Periodic inspections of work equipment could also be carried out as part of *a system for monitoring the condition of the equipment*, if the effects of the system correspond to the effects of periodic inspection. A system must be accepted by a competent body, which should assess the functioning of the system at least every three years with specified (in Table 2.1.4.) machinery groups. (Decree 403/2008.) In other cases the system doesn't need to be accepted, but system for monitoring the condition of the equipment might still be a useful system for keeping work equipment safe over its lifetime. Written description of the system should include appropriate actions (such as inspections, tests and measurements) and equipment for monitoring the working conditions as well as tasks, responsibilities and qualifications of persons involved in monitoring (Työsuojeluhallinto 2013).

Timing of thorough inspection should be based on comparing the actual use of machinery with the design limits of the machinery. Machinery has usually been designed by using design standards including design limits. The design limits of machinery should be found out and wrote down before initial inspection of machinery. After that, in every inspection the inspector should evaluate if the machinery has been used as it has been designed to be used. In that way, the inspector can compare the actual use and designed use. The main reason for the requirement of a thorough periodic inspection is to find out possible structural damage due to metal fatigue. There is a need to take into consideration the occurrence of fatigue disturbances, because crane design standards have traditionally been less stringent for fatigue design than general steel construction standards. (Työsuojeluhallinto 2013.)

Data of each inspection must be available for the whole operational life of work equipment, if specified in the Table 2.1.4. Data of inspections must be saved as *inspection reports*. An inspection report must include the description of the inspection course, all observations on the defects and deficiencies and instructions given to correct or eliminate them and an assessment of the dates of the next periodic and through periodic inspections. Also, data of all the repairs and other notices of conditions of equipment should be collected and used together with the inspection reports when performing through periodic inspection. (Decree 403/2008.) However, even if it is not mandatory to write documents of other working equipment inspections, it is recommended for the employer to document what has been done for keeping equipment in safe working order and how it has been ensured (Sosiaali- ja terveysministeriö 2008).

2.1.4 Qualified person for inspections

According to User Decree 403/2008 section 5, the employer must ensure that only *"a qualified person that is familiar with the structure and use of the work equipment can carry out the inspection and testing necessary to ensure the working order of the work equipment. When necessary, an outside expert must be used."*

The person carrying out the inspections (initial or periodic) must be familiar with the structure and use of the equipment. Also, he or she has to follow inspector requirements and manufacturer's instructions concerning the specific equipment. The inspector must be able to independently notice any defects of deficiencies of the equipment and assess how those affect the work equipment safety at work. (Decree 403/2008.) Initial and periodic inspections must be carried out by an approved, competent person or body if it's necessary according to legislation. (Decree 403/2008.) It is essential that equipment is properly identified before any inspection (McMullen & Caddick 2003).

Manufacturer of machine has to include into the machinery instructions the training requirements for the machine user. Manufacturer has to inform users if use of the machine requires special training. Normally, this concerns only machines for professional use. It is not mandatory to follow manufacturer training recommendations literally, but giving instructions for appropriate training contents help employers to provide appropriate trainings. (Fraser et al 2010).

The person who carries out the inspection should be able to notice and evaluate material defects of work equipment. This implies that the person must have sufficient knowledge about material engineering and how features of different components and materials affect the safety of equipment. Fatigue and corrosion of material are features which might affect the safety of machinery. (TVL 2003.) Inspector must be aware and able to use necessary inspection methods for assessing independently the working equipment safety at work. If it's necessary, person should disclaim from doing the inspection. Disclaiming is necessary if the inspector doesn't have enough professional skills or knowledge for evaluating safety of certain machinery in sufficient scope. (TVL 2005.) If there is no expertise on the workplace, an outside expert must be used (Työsuojeluhallinto 2013.)

In Finland, the employer must ensure that only an approved, competent person or competent body carries out initial or periodic inspections for certain specifically defined work equipment, which have been defined in annex of user decree (Finlex 2008/403). If specified work equipment has not been inspected properly, they are not allowed to be used. (Työsuojeluhallinto 2013.) Work equipment which needs inspection of competent body or person has been defined in Table 2.1.4.

Table 2.1.4 *Inspections of specific machinery groups (adapted from Decree 403/2008, annex).*

Machinery group	**Definition**	**Performers of initial, periodic or thorough periodic inspections**
Mobile crane	Any crane with wheels or tracks, can be freely moved from one location to another by using its own power or attaching it to another vehicle.	Competent body

Machinery for lifting persons (incl. **Machinery requiring installation for lifting person**)	Any power-driven device, fixed or mounted on a vehicle or a mobile platform, designed for lifting persons to perform work on the work platform of the machinery.	Competent person
Loading crane	Any crane mounted on truck, other vehicle, trailer or machine and primarily used for loading a vehicle.	Competent person
Loading crane, loading moment exceeds 25 tonne-meters	Crane intended to be used for loading, but primarily for other use than loading a vehicle	Competent body
Cranes and their tracks lifting more than 500 kg	Any power-driven lifting device, used for lifting, lowering and transferring loads, where load's movements are controlled only by lifting rope, chain or other similar mechanism.	Competent person
Builder hoist designed for lifting persons	Temporarily mounted lifting machinery used for construction work or equivalent, including a cage moving along a travel way guided by fixed equipment, designed to carry persons or goods between two or more landing levels within the maximum permissible load.	Competent body
Tower crane	Any crane with supporting structure of tower, which has a projecting boom at its top end, attached either to the top of the tower or to the foot of the tower with ropes that go through the top of the tower	Competent body
Lifting machinery for cargo-handling in vessels	Any power-driven lifting device of vessel	Initial inspection by competent body, periodic inspections by competent person
Vehicle lift, lifting height more than 0,5 m	Any power-driven device, designed for lifting or tilting vehicles to facilitate servicing carried out under the vehicle	Competent person

Those who carry out inspections of work equipment mentioned in Table 2.1.4 must be *a body* verified competent by an accreditation body or an independent *competent perso*n approved by a certification body which is verified by an accreditation body referred to in the Act on Verifying the Competence of Conformity Assessment Services (920/2005). Competent person or body must be able to present a certificate of their competence and a written description of their inspection methods. (Decree 403/2008.)

An approved, competent person must be objective, which means that the inspector assessment must be based on independent knowledge and his / her own goals and affiliations should not affect the accuracy of his / her evaluation. Therefore, checking one's own lifting machinery should not be possible. The same person should also not undertake both maintenance and inspection in the employer community, so the aim is that no one inspects his/her own work. Instead, the inspector may be employed by the owner or holder of the lifting machinery. (Työsuojeluhallinto 2013.)

Inspections (especially if including maintenance) of *electrical work equipment* might also require electrical qualifications from the inspector. Before performing any electrical work activities (incl. repair and maintenance of electrical equipment) in Finland, the contractor must have formally notified the Finnish electrical safety authority Tukes. For that purpose, the contractor must have a responsible electrical supervisor having sufficient qualification certification given by an approved qualifications assessment body. Also, each worker working for the contractor must have sufficient qualifications or occupational skills as well as the necessary tools and electrical safety regulations to use. The person performing electrical works must be instructed in the specific task and be familiar with electrical safety requirements concerning the task (Act 1135/2016.)

In addition to electrical qualifications, some equipment or their parts might require inspections by *an approved inspection body for pressure equipment*. The inspection body must carry out periodic inspections (operation inspection, inside inspection and periodic pressure test) for *registered pressure equipment*. Pressure equipment that poses a significant risk must be registered. (Act 1144/2016.) In Government Decree on the Safety of Pressure Equipment 1549/2016, has been defined registration requirement for the equipment generating significant risks.

Inspection intervals for registered pressure vessels are 2-4 (+1) years for operation inspection and 2-8 (x2) years for inside inspection. Pressure test should be carried out at the same time with inside inspection, if the integrity and strength of the structure cannot be sufficiently ensured in the inside inspection. In a periodic inspection, the inspection body shall determine the type and time of the next periodic inspection. The decision should be based on the pressure equipment's type, manufacturer's instructions, operating conditions, maintenance and inspection results. In all cases, the pressure equipment (also unregistered) must be used and inspected so that it does not endanger anyone's health, safety or property. (Act 1144/2016.)

2.2 Description of the industry

Wind energy is part of the global energy sector. The whole sector is now in a big transformation and the biggest reason for that is the transition from fossil fuels to renewables. Change is inevitable and a result of the worldwide commitment to mitigate climate change with the one key objective of decarbonization of the power sector. As a political decision, many EU governments have set a target of increasing share of renewables in final energy demand. Over the last decade, wind energy has been the largest single technology of the added 224 GW of renewables, with an installed capacity of 110 GW. (WindEurope 2016.) The target is to increase wind energy capacity so that it will represent 27 % of electricity consumption in EU by 2030 (EWEA 2015).

Reason for transition is not only the result from the political decision of polluter pays principle, but over the last decade there have been significant innovations and cost reduction (ETIPWind 2016). The cost competitiveness of renewables has been increasing when there has been continuous cost reduction in technologies (WindEurope 2016). The wind power technology has been developing fast. Rotor blades have been enlarging to enable low wind applications. Also, blade developments have been focusing on noise and efficiency with improvements in material quality, structural design and aerodynamics. In the operational phase, improvements have been seen such as new forecasting technologies with innovative software tools, advances in predictive maintenance and use of stored operational data in maintenance activities. Also, improvements have been seen in quality plans, spare part management and other added-value functions. (WindEurope 2016.)

There are also still some challenges in the wind industry which makes future development and research necessary. At the current stage, the market design does not enable optimal integration of wind power and other renewables. Many countries are in the process of ending supportive measures such as feed-in-tariffs. (ETIPWind 2016.) In Finland, the feed-in-tariff supporting system for renewables launched in 2011 is going to end by end of 2017. (Suomen Tuulivoimayhdistys 2017). There is overcapacity in overall electricity production in Europe (WindEurope 2016) and price of oil, gas and coal are still at low levels (ETIPWind 2016). To achieve the growing targets set in EU, there is still need for some economic incentives and support mechanisms. At the same time, driving wind power costs down further is necessary. (ETIPWind 2016.)

To drive costs down, improvements in operation and maintenance are crucial. Traditionally, the focus in wind energy research has been in turbine design and technology development, but operating capacity is growing and needs more effort. To improve operation of wind farms, the challenge is to find an integrated approach to advanced operation of wind farms, to improve the control of wind farms to the advanced level and improve performance of wind turbines (European Commission 2016). When there is now a large amount of turbines in operation, the data has become available. Research in this area should be focused on developing data collection and big data analysis to get information to be used for improving machines, components and serving systems to achieve cost reduction in operational phase. (ETIPWind 2016.)

Economies of scale and developing effective value chains are one of the key enablers to reducing costs in the wind industry. Economies of scale can be achieved by taking advantages of the similarities of projects and operation with standardization of methods, products and concepts. However, it must be taken into account that national requirements might complicate the standardization on global level. (ETIPWind 2016.) By increasing economies of scale and developing more competitive supply chains, significant cost reductions of renewables might be achieved (WindEurope 2016.) It has been assessed that wind and solar energy technology costs will fall sharply, and by the end of 2020 these two technologies will become the cheapest ways of producing electricity in many countries. This will lead to a situation where renewables take the lion's share of future investments. (Bloomberg New Energy Finance 2016.)

2.2.1 Life cycle of wind turbines

Wind turbine generator system (WTGS) is "system which converts the kinetic wind energy into electric energy" (SFS-IEC 60050-415). It is a machine in the scope of the machinery directive 2006/42/EC because it contains energized moving parts (Co-ordination of notifies bodies 2011). Wind turbines are large, complex pieces of machinery. However, they should be seen as one machinery which only have been built from pieces. This is important detail and affect to the overall responsibility of the machinery. Manufacturer of the wind turbine is responsible of fitting all pieces of machinery together and conforming to requirements of machinery directive (RenewableUK 2016).

The life cycle of wind turbines can be divided into the following stages:

- Design and development
- Manufacture
- Transport
- Construction
- Operation and maintenance
- Decommissioning

The best possibility to affect usability of wind turbines throughout the life cycle of wind turbine is in the stage of design and development. Technical and structural decisions in this phase have lot of influence on operational safety. Decisions may influence the service and maintenance frequency, accessibility of the operating positions, the time a worker must spend in the wind turbine and how people can deal with the issues on the operational level. (EU-OSHA 2013.)

Procurement of a wide range of physical goods is a significant part of the manufacturing process, when wind turbine manufacturers purchase a lot of components and partly completed machinery from external suppliers. Decisions of component suppliers have a lot of influence on how and by who these components or heavier mechanical or electrical systems can be installed, commissioned, maintained, and inspected. (Renewable UK 2015.)

The movement of wind turbine components is a challenge for the logistics, when components are enormous (long, wide and heavy) and distances long (EU-OSHA 2013). The transport of large wind turbine components is more challenging on road trucks than marine vessels. The size of many turbine components is abnormal for road transportation. Special vehicles or vehicle combinations, as well as experienced specialized transport contractors are needed for transports, and routes must be planned well as enormous parts cannot go through every tunnel or cross every bridge (RenewableUK 2015.)

The construction phase is the most complicated phase on the turbines life cycle and the construction project itself consists of several stages such as project design, making foundations, construction, installation and commissioning. When a wind farm is actually built during the construction phase, the work undertaken on site influences the quality of the equipment installed and the rest of the life of the asset. Construction period can be more or less than a year depending on the project size. Construction phase is the most personnel-intensive phase in a wind farm construction project and it might involve hundreds of workers. (EU-OSHA 2013.) Majority of works have been undertaken by various contractors. (RenewableUK 2015.)

Commissioning is an important part of quality control in the wind farm construction phase and prepares a wind farm for operation. Commissioning activities may vary depending on the equipment installed in the wind turbine, but especially safety related equipment such as machinery for lifting purposes and each equipment for working at heights should be fully tested and commissioned prior to use (RenewableUK 2015.)

When a tower is up and a wind turbine is running, maintenance procedures become current. In operation, wind farms are essentially unmanned facilities where workers access only to perform maintenance and repairs. Wind turbine’s expected operational life is about 20 years, but for reaching its operational lifetime wind turbines need to be maintained regularly. Regular maintenance activities are usually needed on a yearly basis. (EU-OSHA 2013.)

There is both scheduled maintenance and unplanned condition-based maintenance. Objective is to avoid reactive unplanned maintenance by regular scheduled maintenance. Scheduled maintenance is preferred because maintenance work can be performed during good weather conditions such as summer time and with well-planned work force resources. Regular maintaining operations range from routine inspections to periodic major maintenance campaigns. (RenewableUK 2015.) Several parties, such as operator, WTG manufacturer, third party specialists and inspectors, may be involved in these activities (RenewableUK 2015).

The end stages of a component or turbines’ life is not yet well documented. The first wind turbine has been produced in 1979 and so far only few turbines have been decommissioned, as the operational life time of the turbine can be even 30 years or longer. Repowering has extended the intended life span of some wind farms. It is assumed that most of the wind turbine materials can be recycled at the end of the life cycle. (EU-OSHA 2013.)

2.2.2 Safety in the wind industry

Main hazards to the people working in or around onshore wind energy facilities are

- electrical incidents when working with high- and low-voltage equipment
- manual handling (Bayar 2014),
- weather conditions such as high wind, icing and lightning storms,
- falling from heights when working in high places
- falling objects when handling suspended loads (EU-OSHA 2013).

In the wind industry, the biggest consideration is typically given to the hazard of working at heights. (Duff 2010). Working at height cannot be totally eliminated, and especially in maintenance work, the risk of falling from heights is always left. Also, use of personal fall protective equipment is necessary for each person working in the wind turbine even if all possible collective protection systems to prevent falling have been implemented in the first place. Each wind turbine should be equipped with appropriate structures and means for working-at-height systems fitted. Emergency rescue plan must be in place and adverse weather conditions taken into account before entering the turbine. (IFC 2015.)

It has been seen as vital for the entire industry to share and promote best practices and harmonization of OHS (Occupational health and safety) regulations, training standards, safety rules and special applications (e.g. special rescue devices) for reducing risks to the wind industry workers (Bayar 2014, EU-OSHA 2013). Parties in the industry have also been proposing changes to OHS legislation and discussing at the EU level the suitability of the existing legislation for the wind industry (EU-OSHA 2013). This shows that the wind industry doesn’t just want to be reactive, but promote safety. (Bayar 2014.) Also, in future research the participation of wind turbine manufacturers and operators is expected (European Commission 2016) and sharing of OSH ideas and experience is even more necessary when the amount of experience in the operational phase increases (EU-OSHA 2013).

Each person working at heights must be trained and competent in the use of all special protective equipment as well as special rescue systems (IFC 2015). In the wind industry, it is widely recommended that each person working at heights has gone through special training for working at heights (Bayar 2014). Training, according to the standard of global wind organization, demonstrates correct use of personal fall protective equipment, correct identification of anchor points and correct use of evacuation and rescue devices in rescue situations (GWO 2016). Also, a special medical test for worker fitness (RenewableUK 2015) and first aid training (Bayar 2014) are widely recommended for people working in wind turbines.

In addition to the above mentioned trainings, there are also several other trainings which could be elements of a training program for workers in the wind industry (Duff 2010). Still, even if some special safety trainings are available for the industry, a practical wind energy training standard is missing. This has led to the situation where each individual wind energy company should interpret what is an adequate training standard. (EU-OSHA 2013.) This has again placed demands for the record keeping behind the defined training program. Trainings must be well documented to ensure compliance with the program requirements. (Duff 2010.)

For promoting safety of the wind industry, safety equipment has been developed and added to the wind turbines. One example of safety technology is a service lift fitted in the wind turbine. The tall structure of the tower section adds complexity to any repairs or maintenance. Service lift reduces implications to the worker's body caused by climbing, and improves safe access to the wind turbine. (EU-OSHA 2013.) With selection of correct equipment risk of musculoskeletal disorders leading to the shorter working life can be reduced, and at the same time enable employees to achieve a higher standard of work in a shorter time. This reduces labor costs and downtime. (RenewableUK 2015.)

New technologies, even safety related, may lead to new hazards (EU-OSHA 2013). Those must be considered in the risk assessment according to machinery user legislation. Modifications in technology create an on-going responsibility to ensure safety of working and maintenance procedures of wind turbines (EU-OHSA-2013). Certain equipment of wind power turbines, provided to ensure the safety of people, are therefore subject to time-based inspection schedules. The first inspection to the safety equipment, such as hoist, should be done after it has been installed, but before taking into use. Statutory periodic inspections often include inspections of

- Lifting equipment and lifts
- Pressure systems
- Equipment for work at heights: Fall arrest systems and anchor points, ladders, platforms, hatches
- Fire detection and suppression systems
- Emergency equipment: Rescue and evacuation equipment, emergency lighting and first aid equipment (RenewableUK 2015.)

Information for long term integrity management should include asset register data, inspection scope and frequency recommendations, decision-making criteria for different levels and types of defect and procedures for maintenance and repairs. Defined scopes and frequencies of activities and reporting requirements are basically defined in maintenance contracts. Contract should ensure that all statutory and other inspections have been carried out and identified corrective actions implemented on schedule. Also, it is important to ensure that there is all necessary competence available, keep record of inspection and receive managing reports from contractors. (RenewableUK 2015.)

The safety and effectiveness of the inspection program depends on the competence of people undertaking the work and effective communication and record-keeping. Effective record-keeping includes that the status of equipment on completion of inspection work as well as completed follow up actions have been recorded. Continuity of the workforce performing inspections helps technicians to know their sites and complete the tasks more effectively. Developing a wide range of competencies especially in inspection tasks can reduce the number of people involved in these tasks (RenewableUK 2015).

Procedures and checklists should be established to cover all parts of inspections and follow-up actions. Program should be reviewed periodically to address recurring problems and determine that scope and frequency of statutory inspections is appropriate. (RenewableUK 2015.) Equipment manufacturers should be contacted regularly to find out if there is updated information available of inspection requirements or safety alerts which should be taken into consideration in maintenance work. (RenewableUK 2015.)

2.2.3 Human resource management in the wind industry

Wind power provides 1.1 million jobs globally. China leads the way and provides almost half of the jobs. Germany and United States are also top players on the field. (IRENA 2016.) Europe owns one third of wind power jobs by employing 330,000 people (ETIPWind 2016). Wind energy is still a relatively new industry in Europe. The industry has been growing rapidly but so is the need for advanced, well-trained workers. It has been evaluated that in Europe, the industry would provide jobs for 446 000 wind industry workers by 2020. Given that the need of people was 192 000 in 2012, that means an increase of 57 percent in workforce in less than a decade. This speed could lead to skill gaps and difficulties to find experienced workers, who are able to work safely. (EU-OSHA 2013.)

As Europe’s wind industry is still moving from design and build phase towards operational phase, the biggest skill gaps in the future will be in the operational phase as maintenance and after sales operations (EU-OSHA 2013). When the total installed capacity grows, the skills shortage will increase sharply (ETIPWind 2016). In the European wind energy sector, there is currently a shortage of 7 000 qualified persons each year and that figure may even double by 2030 (EWEA 2013). For the wind industry, the use of subcontractors is typical (EU-OSHA 2013). Many tasks in the supply chain rely on procurement of services and goods from contractors and suppliers. The overall performance of the company depends on a wide range of contractors and their management. (RenewableUK 2015.)

It is necessary to appoint a suitable competent person especially to the key safety related roles. For that reason, it must be well enough ensured that when using contractors in the key safety roles in supply chain, their safety culture, performance and experience is at an acceptable level. Health and safety objectives of the contract should be clear from the start of tendering process. Also on this phase the arrangements for contractor performance monitoring in operation should be defined. (RenewableUK 2015.)

When assessing contractor's competence, the more effort should be given the bigger the risks of the task are. The main contractor is responsible for ensuring the competence of those whom they have appointed to undertake the tasks. (RenewableUK 2015). Like in-house employees, the employees of the subcontractors should be suitably skilled and receive adequate trainings and work instruction defined by the main contractor (EU-OSHA 2013). Effective competence assessment requires enough understand of the out contracted task. If necessary, competent advisers should be used for assessing contractors when the contracted task contains specialized and high risk works. Prior to appointing contractors, the client should do initial screening of potential contractors (RenewableUK 2015).

Selection of contractors should consider two different cases. Whether the contractor company is simply providing labour to work under client control, or whether they are providing own competent safety management or task supervision and managing the whole task more independently. However, it must be ensured by access control that each person who intends to work on site is authorised to work under site rules or are working under the supervision of an authorised person (RenewableUK 2015.).

When using a lot of contractors and suppliers as in the wind industry, the contracting strategies should be defined. The selection of the strategy is influenced by the characteristics of the client and potential contractors:

- Which activities the contractor is capable to undertake.
- Who should carry the financial risks?
- Does the main contractor want to keep the control itself?
- Is the main contractor looking for strategic partnership or a one-off contract? (RenewableUK 2015.)

Strategic decision will determine the responsibilities, resource levels and competence requirements for both parties. Contracting strategy should ensure that most important outcomes of the delivery, such as safety, quality and balance of initial / whole lifecycle cost will be reached. Contracting strategy should be part of overall human resource management of the manufacturer company. The long-term maintenance strategy should be considered when planning human resources. (RenewableUK 2015.)

In Finland, if one employer is the main authority at a workplace, where several employers or self-employed workers are operating simultaneously or successively and the work may affect other employees' safety or health, all work performers have a duty to exercise care of others. This kind of workplace is called "a shared workplace", where each work performer must, with mutual cooperation and information sharing, ensure that their work activities do not endanger other work performers' safety and health. (Act 738/2002.)

On the shared workplace, the employer, who is exercising the main authority, is liable to ensure that each external employer and workers get all necessary information of hazards and risk factors at the workplace. As part of workplace introduction, the necessary information on action with fire control, first aid and evacuation must be given. (Act 738/2002.) If the use of subcontractors is recurrent in the shared workplace, the main employer should create permanent procedures for giving health and safety introduction for all new external workers. With an approved occupational safety card, a worker can demonstrate to have basic knowledge of safe working habits, but the card does not show that the worker has knowledge of hazards and risk of the particular workplace. (Työsuojeluhallinto 2013.)

The main employer must also coordinate the activities of external work performers at a workplace and organize the general planning of the workplace, including traffic and movements, general order and cleanliness and safety and health of working conditions and environment. (Act 738/2002.) In the wind industry, it is typical that the main contractor receives the Risk Assessment and Method Statement (RAMS) of the contractor for getting knowledge of hazards of subcontractor work tasks and to know how the contractor is going to undertake, monitor and control its works. Main contractor accepts the RAMS of the contractor and monitors that the contractor will follow it. This is the way how the main contractor takes care of its responsibility to manage co-ordination between different companies and monitor their works. (RenewableUK 2015.)

In Finland, "Act on the contractor's obligations and liability when work is contracted out" forces the contractor having *a subcontract on a certain work against compensation* to check that its contracting partner is taking care of its social responsibilities. This check must be done if the work relates to the normally performed task in contractor's operations and work is performed on the work site which is controlled by the contractor. (Act 1233/2006). This concerns also the services provided on the user's premises (Regional State Administrative Agency 2015). Before assigning a contract, the contractor must ask from the contracting partner certain documents which show that the enterprise is fulfilling its duties to pay taxes and employee related statutory payments. (Act 1233/2006.)

Under the Aliens Act, if a Finnish employer uses foreign external manpower as temporary agency workers or subcontractors, it must ensure the employees' right to work in Finland. This means that employee has a residence permit or the employee doesn't need it. (Act 301/2004.) Under the "Act on the Posting of Workers", if the contractor is using posted workers in Finland, it must ensure that the posting company selects a representative in Finland and reports the posting of the workers to the Finnish authorities (Act 447/2016). The requirement of reporting is entering into force in the fall of 2017 (Työsuojeluhallinto 2017).

2.3 Industrial services

The profits from the products are decreasing when the global competition in the manufacturing industry intensifies. Because of this, in addition to the physical product, the manufacturers provide value-added services which can add value to the product. (Zhang et al. 2015.) Support and maintenance services may generate even twice as much profit as do sales of original single product (Kim, Cohen & Netessine 2007). The shift by manufacturers to selling services coupled with products as the basis of their competitive strategy is called servitization (Baines et al. 2009).

Servitization has been changing the nature of the relationship between manufacturer and customer. From the "sale of product", there has been a shift to "sale of use", and when a customer pays for using an asset, it reduces operating costs, risk and investment, all linked with ownership. At the same time, risk and costs have been moved to the manufacturer, which has to deal with them by technological and operational methods, such as remote monitoring. The main reasons for servitization in manufacturer companies are "providing more value to the customer and gaining their loyalty", "increasing sales revenue" and "differentiating from competitors". (Baines et al. 2009.)

Advanced services are known as capability, availability or performance contracts, where manufacturer delivers services which are critical to the customer's core business processes. Some features are typical to these services: long-term contractual agreements, penalties if the product fails to perform in service and revenue payments structured around product usage. (Baines & Lightwood 2014.)

With advanced services the customer are delivered the desired outcome from the product. In this process, the communication between the customer and the manufacturer plays an important role. The outcome of the service process is, that the product should be seen to be returned available for use rather than repaired. The relationship which these services engender between customer and manufacturer differ. Strong relationships through the life-cycle of the service offering has been seen a necessity for service delivery rather than a feature of the offering. Advanced services are integrated into a wide range of customer touch-points, which enables strong inter-organizational relationships. (Baines & Lightwood 2014.)

Part of relationship building is that the value of service should be demonstrated. It is important that customers see what they get. That is why there should be regular communication about actions and interventions, and also well-presented and organized maintenance facilities, which demonstrate capability and expertise of the manufacturer company. Also customers want to see the following things: that there is focus on outcomes from product use rather than delivery and sale; that the outcomes are specific for the single customer; and that there is on-going performance rather than a single transaction. (Baines & Lightwood 2014.)

While the relationship building seems to be in an important role with advanced services, it defines the skills for the people involved in the service delivery. Important skills which lead to the customer oriented behavior are flexibility, relationship-building, service-centricity, authenticity, resilience and technically adeptness. The servitization demands innovations in the way people are skilled and organized. (Baines and Lightwood 2014.)

Three types of customers who buy both product and services may be identified: "customers who want to do it themselves", "customers who want us to do it with them" and "customers who want us to do it for them". First type owns and repairs the product themselves. They rely on the manufacturer only to supply the product and spare parts. The second type does the maintenance themselves, but relies on the manufacturer on significant repairs and overhaul. Third type of customer only uses the product and wants the manufacturer to take care of everything else. (Baines & Lightwood 2014.)

An industrial service product is a set of activities created to generate a certain added value for corporate customers. Professional implementation of services defines certain principles. The service concept, i.e. the content, value, implementation and service experience of the service are known (at least partly) by the company and the customer. The service is implemented with limited available expertise and tools, which means that anyone cannot do it without any significant investment. To provide and reproduce a high-quality service experience, the company should have a clear system for the delivery of services, i.e. structures, competencies, processes and systems for implementing services. (Martinsuo 2016.)

2.3.1 Operations management

Companies perform certain *value activities* to do their business and create value to customers. These activities form a *value chain*. The *value* indicates how much the customers are willing to pay for a product or service. The created value must exceed the cost of performing value activities to make business profitable. If a company wants to gain a competitive advantage over its rivals, it must perform these activities at a lower cost or perform activities in a special way that creates more value to the customer, and customers are willing to pay premium price for the product. (Porter & Millar 1985.)

A company's value activities divide into a few categories. Primary activities mean those which directly involve the product's physical creation, marketing, delivering, after sale services and support. Support activities allow the primary activities to take place by providing inputs and infrastructure. Inputs such as human recourse, technologies and purchased inputs are needed for performing value activities. Infrastructure, including general management, legal work and accounting, are needed for supporting the entire value chain. (Porter & Millar 1985.)

Activities in the value chain are connected by linkages. "Linkages exist when the way in which one activity is performed affects the cost or effectiveness of other activities". For example, a more costly product design may reduce the costs of after sale service. The optimization may require trade-offs, but also coordination of activities. Linkages concern also the value activities outside the company, if there are suppliers who provide inputs (such as materials, components or purchased services) to the company's value chain and if there are interdependencies between these two. To create competitive advantage, optimizing and coordinating links to the outside is necessary. (Porter & Millar 1985.)

Each value activity towards fulfilling buyer needs is a potential source of a cost advantage and differentiation. Cost advantages may be exceeded by identifying and influencing the cost drivers of value activities. Many of the company's value activities contribute to differentiation, not only the primary product of the company. Company's other activities, such as logistics or after sale services, may also impact the fulfillment of the buyer's needs. (Porter & Millar 1985.)

Value activities always have both a physical and an information-processing component, which may be either simple or complex. The physical component includes physical tasks, and information processing includes steps such as capture, manipulation and channeling of data. Information of some kind is always used for every value activity. A service activity, for example, uses a service request to schedule calls and parts, and generates information on product failures to develop product design and the manufacturing process. The information processing component, in addition to a physical component, affects the competitive advantage of the value chain. (Porter & Millar 1985.)

In the decision making of the operations ownership, the company must take into account the competences of the other company. In this context, the *operations* mean the whole process where inputs and resources are processed into outputs. Outputs are all the products and services which the company produces. *Competitive competence* separates the company from its rivals and leads to the competitive advantage if the company is able to increase its market share because of competence. *Distinctive competence* separates the company from the other companies in the same value chain. It affects the decision of vertical integration. Level of *vertical integration* means how big a share of value activities in the products' value chain the company does itself. (Heikkilä & Ketokivi 2013.)

There must be a connection between the company's strategy and operations, so that operations could increase the competitiveness of the company. In the strategic decision making the company must do selection. The decision is not strategic if the choice is obvious. The strategic selection might be for example the selection between low-costs and high quality. The company might choose one of these specialized strategies or a broad, generalist strategy which is between these two strategies. In broad, strategy costs cannot be as low as possible nor quality as high as possible. (Heikkilä & Ketokivi 2013.)

There are many factors, which should be considered when planning the content of the operations. The Figure 2.3.1. shows these factors and how they affect the operations.

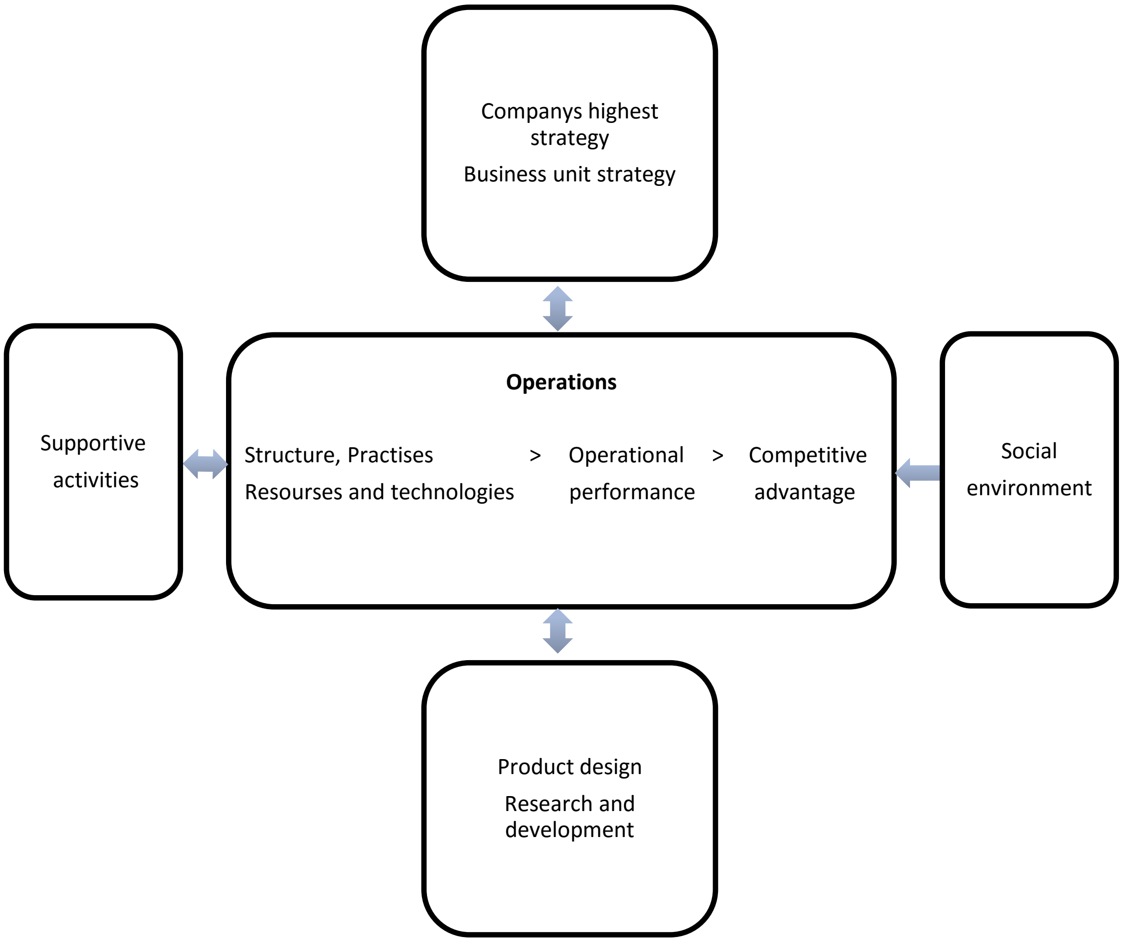

Figure 2.3.1. *Causalities in operations' decision making (adapted from a four-level model of strategic operations and a model of operations strategic management, Heikkilä & Ketokivi 2013).*

Decisions about operations have been made at various levels of the companies. The highest level is the *strategic level* of the company, where the decisions of importance of operations and operational competence have been made. Close to the highest strategy of the company is the *business unit strategy*, which means the same as highest strategy in the one business companies. On the business unit strategy, there is a question about operations role in business unit strategy. Operations role depends on the decisions of the product's competitive strategy. (Heikkilä & Ketokivi 2013.)

In the middle level of the decision making hierarchy, decisions have been made about *functions* and *operations*. On the *function decisions,* the question is about coordination of main value activities, both primary and supportive activities, inside and outside of the company. Defining corporate boundaries is important, but so is also the co-organization between activities no matter if they are in or outside of the company. On the *operations,* the decisions have been made about operations organizing in operational units so that they implement the higher strategy of the company. Operations objectives, ways and means to achieve targets set and measurement of performance should be defined on this level. (Heikkilä & Ketokivi 2013.)

Operation system can be divided into three phases: *organizational structure*, *operational practices* and *recourses including technologies*. On phase of *organizational structure* it has been defined how the operations have been organized, who owns responsibilities of different tasks and productivity, how co-organization with other activities has been taken into account and how reporting has been designed to do. On the *operational practices* the main operational processes, how operations are managed and planned, have been defined. On the phase of *resources* has been defined which are the main technologies, who provides them, where is the main expertise and information in the organization. (Heikkilä & Ketokivi 2013.)

How things are organized in the operation system affect the *operational performance* of the system. Factors of the operational performance are, for example, productivity, flexibility, quality and delivery time. Companies choose which are their main objectives, and which factors of operations system lead to the objectives set. For example, the most important factors leading to the productivity could be organizational structure and managing network of subcontractors, or the most important factors leading to the high quality could be own special operational practices and competent personnel. (Heikkilä & Ketokivi 2013.)

The third link inside the operations level considers the connection between operational performance and *competitive advantage*. This connection is always not self-evident, but it is important to know what is the role of operations in the formation of competitive advantage. When analyzing this connection, for example the following questions are important: how costs of operations affect the price of the product, can the delivery time lead to the competitive advantage, does the operations affect the quality and performance of the product. (Heikkilä & Ketokivi 2013.)

On the right in the middle level is the *social environment.* The social environment and institutional things such as local legislation, culture, norms of social responsibility and good practices of governance, may sometimes even have significant influence to the operations system and decisions about it (Heikkilä & Ketokivi 2013).

The *features of the product* define the structure of the operations. The products can be divided into two main categories for operations management. *Functional products* are "basic products" which have long life cycles, a relatively narrow range of variety and received, foreseeable demand. Competition keeps selling prices low as well as gross profits. There is competition of the costs, and to the operations system committed costs affects particularly to the competitiveness of the company. (Heikkilä & Ketokivi 2013.)

Innovative products instead are new, having usually short life cycles and wide range of products. Products have a short sales season, because of fast technology development or seasonal changes on the weather for example. Product novelty makes it possible to set higher prices, but quite often the costs are high and there is risk of lost sales of the product. (Heikkilä & Ketokivi 2013.)

The nature of supply chain must be different for functional products than for innovative products. Functional products require *a cost-effective supply chain*. The aim of the cost-effective supply chain is to satisfy the foreseeable demand of the product as efficiently as possible. For achieving this, the capacity utilization should be maximized, stocks should be minimalized, and unnecessary operational activities and the flow of information should be reduced. In a cost effective supply chain, the selection of supplier should be based on sufficient quality and low prices. (Heikkilä & Ketokivi 2013.)

Innovative product requires a *reactive supply* chain, which is able to respond to uncertain demand. Reactive supply chain includes features such as free capacity, the stockpile keeping, investing into shortening turnaround times, and modular product design. From the suppliers a reactive supply chain requires quality, speed and flexibility. (Heikkilä & Ketokivi 2013.)

2.3.2 Contracting services

The important questions in operations organization are: what are the activities the company performs itself and what are the activities the company acquires from external suppliers. There are two main reasons why some companies want to purchase or outsource operations. First reason is that the company doesn't want to own all its capacity and makes a purchase for using the other company's operational capacity. *Capacity purchase* is often used in the situation where a company wants to add to its flexibility and answer fluctuations in demand by purchasing capacity. Purchase is made in the situation where current demand exceeds own operational capacity. (Heikkilä & Ketokivi 2013.)

Another reason is the decision of vertical integration of the company. This decision is called by *outsourcing*. Normally this decision is based on distinctive competence of the company, which means that a company outsources the whole part of its operations where it doesn't have distinctive competence. When a company outsources the whole part of its operations, it trusts another company's knowledge and resources fully, at the same time stop developing its own operational competence in this area. (Heikkilä & Ketokivi 2013.)

However, often the decision of the outsourcing is not only the decision about company's distinctive competence. The outsourcing often makes possible to use lower labor costs of the manpower or service provider, but when outsourcing operations, the need of control may increase when operations will be transferred out of the company's ownership. In outsourcing, there is a risk that strategically significant activities fall outside the company's control. That is why the availability of trusted subcontractors with sufficient qualifications must be evaluated. (Heikkilä & Ketokivi 2013.)

In many cases, industrial services are delivered through external third party providers as service contracting, even though services are strategically important to the manufacturing-based organization (Owida et al. 2016). When the organizations become in this way more dependent on their suppliers, the significance of the purchase function and importance of the purchase decision increase. At the same time, consequences of poor decision making of the supplier become more severe. (Boer, Labro & Morlacchi 2001.)

The selection of service suppliers is a multidimensional problem with many different variables, such as quality, price, payment terms, lead time and reliability (Owida et al. 2016). The situational factors, such as the number of available suppliers and the importance of the purchase or the supplier relationship, might be determinative in the process. In the efficient purchase decisions, it is important that the purchaser is

- solving the "right problem" and avoiding feeding the supplier with incorrect or outdated information,
- taking satisfactory criteria into account, especially long-term consideration when deciding on make-or-buy,
- storing data of the purchasing decision making process, supplier evaluation and the outcomes of processes for later decision making. (Boer, Labro & Morlacchi 2001.)

Companies usually have many different relationships in their supply network varying from short corporate relations, which base on single purchases, to the more essential strategic partnerships (Heikkilä & Ketokivi 2013). The change towards performance based advanced services has caused confusion among suppliers of after-sales support services. The complex systems require more sophisticated relationships between service buyers and suppliers. (Kim, Cohen & Netessine 2007.) It has been shown that in after-sales field repair services, a long-term partnership including collaborative evolvement and process improvement over the contract life-cycle is beneficial (Owida et al. 2016).

2.3.3 Pricing industrial services

Costing system provides information of how much products use resources and how much the use of resources costs. The relation between product and use of resources reveal the effectiveness of operations. This systematic relation is called “production function”. When use of resources is transformed into costs (valuation), the relation between cost and number of products can be demonstrated. This systematic relation is called “cost function” and it measures the average unit cost of the product. Average price of the product instead is measured by studying relation between revenue and amount of the sold products. This systematic relation is called “revenue function”. (Laitinen 2007.)

With these basic functions, organizations are able to evaluate and manage their processes. Functions are related to the effectiveness of operational process as well as to the monetary process of the organization. If an organization combines information of the cost function and revenue function, it can evaluate the profit. (Laitinen 2007.)

In costing, there are three basic problems to solve:

- Registering problem means difficulties to register all cost data. Cost resources such as direct material, direct machine or labor time are possible to register automatically, but following all cost factors is not economic.
- Allocating problem means difficulties to allocate indirect cost to the products. The choice of correct allocation base and driver affect the reliability and functionality of the costing system.
- Scope problem means problem to choose cost resources which should be allocated to the product. This decision affects the coverage of the calculation system, but also the laboriousness/effectiveness of the system. (Laitinen 2007.)

It must also be decided how exactly, and on what basis, the cost resources should be defined in the bill of resources. The more indirect cost resources there are, the more difficult it is to measure costs directly. Therefore, resource aggregating makes measuring more economic. In the Table 2.3.3 classification of different cost resources is demonstrated. Measurement is harder at lower levels of the classification. (Laitinen 2007.)

Table 2.3.3. *Classification of the resources and direct measurability (Laitinen 2007).*

	Classification of the resources	

1.	Raw materials for the production	Easy to measure
2.	Immediate work	
3.	Accessories for the production	
4.	External services	
5.	Machinery and equipment for the production	
6.	Facilities for the production	
7.	Energy for the production	
8.	Other (indirect) work	
9.	Other materials	
10.	Other external services	
11.	Other machinery for the production	
12.	Other facilities for the production	
13.	Other energy for the production	
14.	Financing	
15.	Other resources	Hard to measure

In many situations, indirect cost resources have not been allocated to the product even if there is causality between cost factor and product. Different ways of costing motivate the organization in different ways. In *variable costing,* the costs which change in relation to change of output number are calculated. It motivates companies to minimize changing costs of the product. In *direct costing* only direct costs are allocated to the product and all indirect costs are unallocated. In *full costing* the fixed cost are also added in the calculation. Calculation includes all direct and indirect costs. It motivates organization to minimize also the use of fixed cost factors. (Laitinen 2007.)

From the company's point of view, the cost is an important factor in the price. The higher the costs are, the higher the price should be for covering all the costs. The customer instead is not interested about costs directly, but it wants to maximize its own utility. In a buying situation, a customer compares price of the product in relation to the utility of the product. If the product provides greater utility than competing options in relation to the amount of money used, the customer is in principle willing to buy it. (Laitinen 2007.)

Cost-based pricing is often a good starting point for finding the optimal price for the product. However, usually market conditions are not suitable for using cost-based pricing only. If the price is wrong for the market, it might lead to the situation where demand is too low or too high. If the price is too low, there is excess demand on the market. In this situation the company could have sold design volume at a higher price and got more profit. Contrarily, if the price is too high, demand remains too low. Then the company doesn't get enough revenue from the product and profit is too low. So for finding an optimal price to the product, also demand and competition must be taken into account. (Laitinen 2007.)

In a traditional pricing situation, the price is set to maximize the profit in the current competitive situation. However, the target of pricing should be to support the whole strategy of the company. In addition to looking for direct profit, companies might want to achieve targets related to growth or market share. If a company is in a situation where it wants to grow the market share, it might set the price low at first and increase it gradually. This is called market penetration pricing. (Laitinen 2007.)

Different customers get utility from different things and feel also the value of the product differently. This might make possible to differ price of the product in different customer segments. (Laitinen 2007). In the pricing of customers, some customers pay more than others. In practice those customers who are willing to pay more for the product, pay part of other customer's payments. But when some customers may get higher utility from the same service, according to value based thinking, the pricing of customers is justified. (Sipilä 2003.) It should be also considered that the value of the product is not always the same even for one customer. For example, if the company needs to repair the machinery fast, it might be willing to pay extra for repair. If the same company is later in a financial crisis, the value of the money is higher, which affects the purchasing decisions. (Laitinen 2007.)

Bidding pricing is a challenging task to the company where competitors' bids are often unknown. Too low a price makes the bid unprofitable, and too high a price leads to the loss of order. The bids are normally based on cost of the company, but costs must be able to be predicted reliably. Also, own targets to growth and profitably must be taken into consideration. In situations where the company has a lot of free capacity and the company wants to increase sales revenue, the offer is cheaper than otherwise. If the company's strategy is to maximize profits, not increase sales revenue, the bid is higher. Also the level of differentiation between various offers affects the winning bid and pricing. (Laitinen 2007.)

If the company has a product line where demand of different products affects each other's pricing, optimizing is more challenging. Company should look for a solution which is best for the whole product group, not just for demand of one product. In this case, optimal prices for the line products might vary significantly from the optimal prices for the single products. (Laitinen 2007.)

The pricing of service products is different than pricing of physical products (Laitinen 2007), but there are still the same three main bases, which all usually affect the pricing:

1. cost-based pricing,
2. market competition and customer based pricing
3. own strategic targets and objectives as base of pricing (Sipilä 2003).

Intangibles of the services lead to the situation where for the customer it is hard to see what it pays for. Service is created as a joint result of the service provider and the customer and value is related to the experience of the customer at the time of service. The quality of the service may vary very much depending on the service provider. That is why the reputation and image of the service provider are the key pricing principles of the services. (Sipilä 2003.)

The image is more important with services than with physical products. That is why the pricing should be based more on the marketing output than cost accounting. When the customer cannot see the service product very clearly beforehand, the customer must get to try out the service. For making one try the service, the price should be set lower or other customers should convince the new customer that the service is worth buying. When reputation of the company increases, the price can be set higher quickly. Price might become a symbol of service quality. (Sipilä 2003.)

The price of the service demonstrates often the valuation of different professions. The valuation of doctor work is high and valuation of cleaner is not equally high. There is a clear distinction between services and professional services. Valuation affects the image of the price. Also, the image of the price is affected by price information clarity, frequency of use of the service, craftsmanship of the service, public image of the service and the fact how well the customer would have performed the service itself. The price-quality ratio is an important factor affecting the price picture. By influencing the price picture and image of the service, the company may affect the valuation of the service. By offering a service package which includes also physical parts, the value of the service is easier to demonstrate to the customer. (Sipilä 2003.)

The market price, based on price image, does not always meet the costs of the service. Usually when the manpower is the main resource of service, the customer might think that the salary of the service performer is the only cost of the service. Providing services, however, requires a lot of other resources and generates a wide range of costs. Other costs are, for example, other manpower related costs than salary, cost of facilities and work equipment, unused capacity costs, research and development cost, administrative costs and value-added tax. In practice, prices should be 2.5 - 5 times higher than the gross salary of a person. This means that service worker whose monthly salary is 2000 euros should earn a monthly return of 6000-8000 euros for the employer. (Sipilä 2003.)

3. THE CASE COMPANY AND THE RESEARCH PHASES

3.1 Description of the company

The case company Nordex Group is global provider of multi-megawatt onshore wind power systems. Company has been operating on the market for more than 30 years and expanded with alliance of Acciona Windpower in 2016. The product portfolio of the company has form around wind turbines. Company offers turbine systems for several customer segments: turbines for markets with limited land and for regions with limited grid capacities, turbines for all wind classes (strong, moderate and low) and the project services for the implementation of wind farms. The noise level of Nordex turbines are best-in-class and turbines can be outfitted with Nordex Anti-icing system and air-traffic warning lights. (Nordex SE 2017.)

Company offers its customers services, ranging from maintenance services and inspections to spare part delivering, customer training and further technical development. Company's contract portfolio can be tailored to the customer's specific needs - varying from basic package, with optional elements, to premium contracts, which comprise the entire range of turbine-related services. Service contracts preserves long-term relationships between Nordex and its customers. (Nordex SE 2017.)

In the end of 2016 Nordex Group had 5,129 employees worldwide. Company has own production facilities in Germany, Spain, Brazil, India and the United States and own technology centre for rotor blade development in Denmark. In own facilities Nordex produces nacelles and hubs, as well as substantial share of rotor blades for wind powers systems. A large share of the systems components is sourced externally. Sourced components are for example gearboxes, generators and converters. (Nordex SE 2017.)

The core of company's quality management is comprehensive management of Healthy, Safety and Environment HSE. The principles of company's HSEQ-management are:

- employee's awareness of quality and a customer centric approach,
- regular and systematic training and briefing of employees,
- continuous improvements to quality in company's day-to-day activities,
- high standards,
- a broader focus on high safety and environmental standards,
- clearly delineated organizational structures and defined processes. (Nordex SE 2017.)

Nordex see itself as ”a technology-focused producer of power generation plants”. In addition to building turbines it offers also downstream services, which are crucial for the business by giving higher margins. Margins of the services are especially important in the situation where volumes of building project are becoming volatile in many business areas. Despite of this situation, company’s strategy is continuing to focus on investing in new competitive products, which mean the highest-performance and most cost-efficient turbines. Company’s own ”Cost of Energy” programme purpose is develop more efficient turbines and try to make all operations in entire life cycle of the wind farms more cost-efficient. The strategy of expanded market coverage and corresponding product range has reinforced the position of the Nordex Group as an innovative and profitable provider of onshore wind turbines. (Nordex SE 2017.)

Nordex Services are provided by local network of its own experts. Purpose of this is to allow short response times and high quality level for maintain and repair services. Intelligent digital system is used for condition monitoring and data management to enhance process efficiency and avoiding downtimes. Nordex has around 230 service points in more than 30 countries. This means a total capacity of 13 GW under contract worldwide. (Nordex SE 2017.) In Finland, there is around ten service points which serve around 200 wind power systems.

3.2 Research methods

This research use inductive approach, which means that data is collected and analyzed for developing theory and not the other way. Inductive approach is usually intended to gain a close understanding of the research context. The purpose of this study is exploratory. Exploratory studies are means of clarifying understanding of a problem and finding out what is happening. Three principal ways of conducting exploratory research are *a search of a literature*, *talking to experts in the subject* and *conducting focus group interviews*. In the exploratory study strategy, the focus is initially broad, but it becomes progressively narrower as the research progress. (Saunders et al. 2000.)

It is typical for the inductive approach to collect qualitative data rather than quantitative data. Also the theory building is widely used in inductive approach. In the method of grounded theory, data collection starts without the formation of theoretical framework. The theory built from the data generated by observations. Grounded theory is used to understand wider particular context around the research subject and analyzing results of research. When the grounded theory will be used for decision making in this particular time and/or in the future, it sets time constrained to the research and makes the research cross-sectional. (Saunders et al. 2000.) Both primary and secondary literature are used for the theory building.

As typical for exploratory research the interviews are used for collecting data. In an exploratory study in-depth interviews can be helpful to collect qualitative data and find out what is happening. This kind of exploratory discussion are not to understand only "what and "how", but also "why". In-depth interviews are usually also known as unstructured interviews. This mean that interviewer does not have predetermined list of questions, but a clear idea about things interviewer want to explore. The interview situation gives interviewee situation to tell freely about the topic. Typically, in-depth interviews happen in face to face and there might be one or more participants at the same time. (Saunders et al. 2000.)

In this research is used non-probability sampling technique, more specifically purposive sampling. Purposive sampling is typically used when following the grounded theory approach and when working with small samples. When research topic is special the best strategy for the purposive sampling is extreme case sampling. In this strategy data will be collected from the extreme outcomes. This enables to learn the most from the area of study and meet the research objectives effectively. (Saunders et al. 2000.) In practice this means that people who has best knowledge of this special subject will be chosen.

3.2.1 Defining content of the service product

At first it was studied how content of statutory inspections was defined elsewhere. Within this literature research, the aim was at first to identify all machinery, components and devices in wind power turbine, subject to any statutory inspection. In the literature review it was investigated in publications concerning the industry, recommendations of Finnish insurance companies and internal database of the company including general instructions for performing statutory inspections and other guidelines. In addition to this it was also studied the safety instructions of the wind turbine and the agreements concerning service product.

Identified inspection targets was listed and sorted out in appendix 1. After identifying targets for inspection, it needed to be sorted out which equipment should be subject to the statutory inspection and which inspections should be part of the maintenance program. The service agreements, company's instructions and interviews of case company workers was used. Interviews with the case company personnel were mainly short unstructured discussions. Discussions were held with the regional service manager, lead technician with inspection qualifications, specialized technician, sales personnel and workers of project organization.

One of the interviews was wider and length of it was about three hours. Interviewed person was company's lead technician, with good technical knowledge of maintenance and inspections of wind turbine. In this interview, there was discussion about technical details of machinery and manufacturer's instructions. There was also discussion about service organization in current state: how inspections are organized, what are the costs, what are the advantages of different implementation options and where is room for improvements.

After finding out which safety equipment are target for inspections in scope of the statutory inspection, it was time to define qualifications for inspector and inspection intervals for each equipment. Every equipment or part of the machinery, subject to the inspection, was explored separately. The literature as directives, legislation, legislation application guides and guides of supervising authorities were widely used when looking for correct definition. Familiarizing with the properties of the equipment based on user instruction, pictures and the design standard of the machinery. The technicians and other workers of the case company, more familiar with details and actual use of machinery, were interviewed. It was not possible to go to observe machinery inside the wind power turbine.

Inquiries of expert and authorities were used for gathering information in unclear situations. Finnish supervising authorities the Finnish Safety and Chemicals Agency (TUKES) and Regional State Administrative Agencies (AVI) were contacted to ask few specified questions. After all a few topics (hoists, pressure equipment, emergency equipment) were discusses via e-mail with few experts of various fields. Also manufacturer of one equipment was contacted and asked for giving a further clarification of inspection requirements by e-mail.

Finally, the own evaluation of qualification criteria and sufficient inspection interval was done. The significance of manufacturer given training was evaluated in relation to how challenging certain inspection task is. Need of other additional trainings was also evaluated. Design use of equipment was evaluated with actual use of it. Also TOT (Investigated fatal occupational accidents in Finland) -reports and the safety notices of certain machinery, found from the case company database, was taken into account while evaluating risks of machine and adequacy of the qualification criteria.

3.2.2 Defining pricing of the service product

After finding out the content of the service product and defining inspector qualifications and inspection intervals, it was time to find out how much resources are needed for organizing all inspections and what could be different implementation alternatives. While having interviews and discussions with several people inside the case company (as introduced in previous section) it was also discussed what strength and weaknesses the current way of operation has or should the case company do something in other way. Implementation alternatives in the current situation were identified and analyzed. Also, the researcher's own observations, which were made while her other work duties (subcontractors' guidance, documentation), were used in the analysis.

The cost factors of different alternatives was identified. However, the objective of costing was identifying only the most significant factors and not give too much effort to the cost accounting. Therefore, identified cost factors were easy measurable, direct costs. In the interview, it was estimated how many working days inspecting one turbine takes and how many people should be participated. Maintenance of safety equipment was included into calculation.

Amount of *working days* for inspecting one turbine *(d)* was multiply by amount of wind turbines *(t)* to get amount of *working days (D)* needed for all statutory inspections of the case company.

$$d \times t = D \quad (1)$$

For calculating how many *persons* (*p)* company needs to do all inspections, *days needed for statutory inspection (D)* was divided by *annual working days* of one employee *(a)*.

$$D/a = p \quad (2)$$

Statistics were used to calculate annual working days of employee. In the manufacturing and construction sector, it is done on the average of 1660 working hours per person per year. This has been calculated by reducing yearly annual leaves and sick leaves from the full hours. (OSF 2014.) On working days this is 1660 h / 8 h/d = 207, 5 working days yearly. And when there is at least 10 days annual training per year for wind industry inspector, the evaluation for net yearly working days for wind industry worker (y) is 200 days.

Annual costs factors were clarified to be able to estimate annual pricing. In addition to costs, also factors related to the customers and competitive situation as well as case company's strategic target and objectives, which should be taken into account in pricing, was identified and analyzed. This analysis based mainly on grounded theory of pricing, advanced services and wind industry. Extensive market analysis could not be done within this research.

4. RESULTS

4.1 Content of the service product

Nordex's wind turbines comprises four main components which are Foundation (incl. anchor cage), Tower with tower installations (incl. converters, service lift, bottombox transformer, vertical ladder), Nacelle with nacelle installations (incl. main gearbox, generator, cooling system, wind sensors, lightning protection, on-board crane and chain hoist) and Rotor with extensions and installations (incl. rotor blade, bearings, rotor hub, rotor lock, pitch drives, anti-icing system). Wind turbines' declaration of conformity applies to complete WT including any installed components, parts, machinery and incomplete machinery. (Nordex SE 2015.)

The service statutory inspections of safety equipment is part of Nordex's wider product portfolio. It is optional service which customer can choose on the top of maintenance contract package. Statutory inspection concern inspections of the safety equipment but not all statutory inspections of the wind turbine. Inspections of special, operationally critical parts of the turbine, such as inspections of blades, tower, generator, lightning protection and ice detection system, are included in service contract packages even if those are also related to the safety.

Targets for the statutory inspection were identified from the list of wind turbine inspection targets (appendix 1). First four (1-4) target for inspections are lifting equipment of wind turbine. The following three (5-7) comprise the parts of wind turbine machinery allowing the safety movements inside the turbine. The rest of the inspection targets are rescue equipment (8-12). The wind turbine is a modular product that means that each turbine does not consist of all the same components. Also the set-up of safety equipment inside a wind turbine may vary (for example, there is no automatic fire extinguisher system in each wind turbine). Therefore, the content of the inspections varies slightly according to the customer and the wind farm.

The safety equipment, target to the periodic statutory inspections, should be also target to the initial inspection. Initial inspections however are carried out on construction phase and that is why those might be seen as content of construction/supply of wind turbine rather than content of the service product statutory inspections. However, when there are same requirements for inspector qualifications of initial and periodic inspections, the same results may be used to select the initial inspector.

4.2 Defining machinery

When defining the work equipment and machinery, there are some important details and features which affect to the definition. Who is doing the definition task should pay attention to the following details (check from the user manual, but consider also actual use of equipment):

- purpose of the machinery
  - lifting *humans* or lifting *loads*,
  - for *public use* or for *work*,
  - for allowing *access to workplace*, for being *work platform* or for fulfilling *safety function*
- machinery work independently or it is intent to assemble as part of machinery or transport/building/structure
  - does it has *EC Declaration of Conformity* or *Declaration of Incorporation*
- movements
  - *lifting, lowering, horizontal movements*
  - is there only *moving parts* or does the whole *machinery move*
- maximum capacity
  - *load, electricity, pressure*
- drive system
  - *electricity, hydraulics, human effort*
- design standard used
- actual use and functions of the equipment

There are certain steps to be taken to define inspection requirements and to continuously improve the maintenance system.

1. First you must define equipment.
   - Observe the work equipment. Pay attention to the above listed details and the actual use of the equipment.
   - Check the user manual of equipment, often there is list of standards and directives it fulfils. If you can find name of c-type standard it is good starting point for definition.
   - Machinery directive and its application guide give names and definitions for specific equipment and help define machinery more specifically.
   - Application guide also contain list of specific directives (as directive on lifts, pressure equipment, personal protective equipment) which concern certain machinery more specifically than machinery directive.
2. Look for appropriate user legislation to find out general and special inspection requirements (inspection period and inspector qualification)

- A priority is in national legislation. In particular, it must be taken into account that each European union member country is obligated to determine sufficient qualification for inspector.
- Note that several decrees might be applicable similarly.
- Occupational safety law sets the basic requirements for inspections and must be followed in all safety relevant cases in principle.
- The design directive refers to the correct specific user legislation.
- For emergency equipment apply Rescue Equipment Act 10/2007 and series of decrees which are submitted within its scope.
- Also there are some decrees concerning special working conditions and their inspection requirement.

3. Look for manufacturer’s instructions
   - The manufacturer's instructions on the inspection interval and other measures to ensure the working condition of the equipment must be followed.
   - It should be checked what user manual says about inspector training and qualifications.
   - If something is unclear, it is recommended to turn to the manufacturer.
4. Risk assessment
   - Evaluate equipment actual use with its design use.
   - Analyse how equipment affect to the people safety.
   - Identify possible failures and their consequences.
   - Identify the safety-critical features of equipment to analyse what kind of skills inspector needs.
   - Take in to account opinion of inspector because the inspector must believe that he or she has the necessary skills and knowledge.
   - The employer is in the end responsible for ensuring that the inspector has sufficient information and skills. Employer determine need of further trainings (manufacturer training, any other optional training).
5. Maintenance system
   - Write down inspection periods, methods and qualifications for inspections as well as other methods keeping work equipment in safe working order. Decide how actions will be documented.
   - Manage and plan resources
6. Follow the performance of the system as well as safety technology and legislation development – make improvements if necessary.
   - Contact manufacturer regularly to find out if it has given new recommendations. Take into account newsletters concerning machinery if manufacturer send those.

- Follow new releases of standards concerning certain machinery. Adopt improvements of new standard if necessary to ensure higher level of safety. Collect inspection data and analyse it. Also information of near misses, accidents and other matters related to the certain equipment should be analysed.

4.2.1 Turbine lift

Turbine lifts have become common parts of the wind turbine and it is todays expectation that wind turbines with a tower higher than 60 m will be equipped with a lift. No matter of the name of this equipment, lifts installed in wind power plants are subject to the machinery directive rather than the Lifts Directive (Renewable UK 2015). Also, Finnish *Act on Lifts and Safety Components for Lifts* excludes "*3§ 8) lifting equipment, which is part of machinery and which is intended exclusively for access to work station including maintenance and inspection points of machinery."* (Act 1134/2016.)

The turbine lift is example of equipment which has been designed to promote safety of the service work in the wind turbine, but which currently has no European standard even if it would be beneficial. Several terms of the turbine lift, which all have special meaning in the European machinery directive, has been used. Terms as lift, elevator and vertical transport carrier all have different meaning and inspection regulations in the legislation. About this issue has been discussed in the European level between wind turbine industry stakeholders and authorities. After all it is recommended to define turbine lift as vertical transport carrier (EU-OSHA 2013.)

Turbine lift can also be seen as machinery serving fixed landings. Guide to application of the machinery directive define: *Machinery serving fixed landings is machinery intended to move good, or both goods and persons between pre-determined levels or floors of a building, a construction or a structure. It includes lifts connected to machinery such as, for example tower cranes or wind generators, for access to workstation.* Machinery serving fixed landings must be separated from machinery intend to provide access to position at a height if access to and from the carrier is only foreseen at one level which is usually the ground level. (Fraser et al. 2010.) So even if turbine lift is meant to move persons it is not defined as machinery for lifting person because works has not been performed on platform of machinery and access to and from the carrier does not happen at one level.

When turbine lift should be assumed as vertical transport carrier / machinery serving fixed landings rather than machinery for lifting person (as defined in Table 2.1.4), lift according to lift act/directive or temporary builder hoist (as defined in Table 2.1.4), there is no specific inspection requirements given by legislation. Inspection of lift must be carried out by qualified person, and manufacturer requirements must take into account when defining sufficient inspection interval and training needs for the inspector.

Hailo is the supplier of *ladder guided Toplift service lift* and it has recommended that maintenance work (incl. inspection) may only be carried out by authorized Hailo employees or other employees who have been suitably trained and certified by Hailo. According to instructions of Hailo, qualified person who is able to carry out inspections, is person who due its profession and experience and completion of a separate manufacturer training has the necessary specialist expertise to inspect equipment, and who has been certified and authorized by the manufacturer. The inspection of the power components (hoist, block stop) requires a separate expert training provided by the power component manufacturer (Hailo 2013.) Power component manufacturer Dual lift and service lift supplier Hailo both provides their own inspector trainings, which are valid for two years.

A scheduled inspection of the drive components, ropes and block stop (safety device) must be performed annually and inspection and maintenance of the carrier (service lift) at interval of one or two years. Additional inspection and maintenance is required if the service lift or other parts of the system are damaged due to improper use. Such an additional check or maintenance is required after collision or adhesion cracking. Special inspection/maintenance (thorough) for drive components, ropes and block stop must be carried out after 4 years or 200 hours of use. (Hailo 2013.) It is recommended to send block stop and hoists for the thorough inspection / maintenance (after 4 years or 200 hours) to the manufacturer.

Inspector of service lift should be also electrician (having profession which enable to perform work on electrical installations) for performing all inspection activities of service lift. (Hailo 2013.) By Finnish regulations, company performing electrical works should be registered as electrical entrepreneur and all electrical works should be performed under company’s responsible electrical supervisor.

4.2.2 Electrical chain hoist

The essential legislation of Machinery Directive includes the requirement to the manufacturer to minimize ergonomic risk to the users of the machinery. Therefor in addition to turbine lift, lifting equipment for lifting, lowering and moving loads have been added to the nacelle for avoiding manual handling and its possible consequences to the worker physical health and ergonomics (RenewableUK 2015).

An electrical chain hoist of Nordex's WTGS has been deigned under Machine directive 2006/42/EC by following harmonized c-type standard DIN EN 14492-2 Cranes – Power driven winches and hoists. Also, Low Voltage directive concern this machine. (Star Liftket 2012.) The electrical chain hoist is anchored into a fixed point in NX’s wind turbine nacelle. Therefore, the hoist only lift and lower loads, but it does not transfer them. It cannot be crane defined in the Table 2.1.4. and it does not need to be inspected by an approved competent person. Hoist should be inspected by qualified person.

Because electrical chain hoist is a lifting machinery it is important that the possible physical failures of it, such as breaking of a component, should be considered with special care. (Työsuojeluhallinto 2013.) Manufacturer of the hoist offers the training for inspector and prefer that inspector has participated in the training. The training provided by the manufacturer was considered to be very useful and provided important information on the inspection of this particular equipment.

According to user manual of electrical chain hoist, inspection of hoist should be repeated annually or more often and hoist should be overhauled after 10 years (Start Liftket 2012). Because the hoist is designed for daily use and in WTGS it has been used quite seldom, there is no need to shorten the inspection period. Because electric cable and power cable are inspection targets in annual inspection, inspector should be working under contractor with electrical registration and supervisor.

4.2.3 Chain hoist

In according to general rule of machinery directive, manually powered machinery is excluded from the definition of the machinery. Only exception to this rule is manually powered machinery for lifting loads. This machinery might lift goods or persons or both and be for example manually powered hoist, crane, jack, lifting table or mobile elevating work platform. (Fraser et al. 2010.) When this machine has been not defined in the Table 2.1.4. it should be inspected by qualified inspector.

Chain hoist in the Nordex's wind turbines' is *The deck crane EBK 1000 – 3.2* manufactured by Taucha company. Machinery is also called as overhead crane and it is able to lift, low and transform loads. Machinery consist of lift support beams and tralift. Tralift with maximum capacity of 1000 kg is supplied by Yale. As crane manufacturer Taucha recommends that machine should be inspected annually by qualified person. (Mechanik Taucha Fördertechnik GmbH.) Also, instructions of Yale says that lift should be inspected initially prior to operation and at least once per year, but repairs should be carried out only by a specialist workshop using original Yale spare parts (Yale Industrial Products GmbH 2010).

Even though the manufacturer of chain hoist has not made special training recommendations, for example, Finnish training organizations AEL provide available optional training for inspection of manual hoist. Necessary of this or any other additional training should be evaluated on a case-by-case basis for each inspector separately. Inspector's previous trainings and expertise in inspections should be taken into account when making decision of personal training needs. Optional inspector training is necessary if inspector cannot ensure safety of equipment otherwise.

4.2.4 Rescue device

Wind turbines has equipped with rescue device: Skylotec Descender - Rescue-Device with Lifting function. It has been engineered in according to standards EN 341:2011/1A and EN 1496/2006/A. Skylotec rescue device is intend to use for descending and lifting person. Its only power source is directly applied human effort, it consists of linked components and one of them is moving part. Device can be defined as manually powered machinery for lifting loads and machinery directive applies to it (Fraser et al. 2010). This work equipment has not been specified in the Table 2.1.4. It should be inspected by qualified person in according to manufacturer's instructions.

In user manual of Skylotec rescue device it's said that a manufacturer check is required at least after 6 years but, if device is used as part of emergency equipment and have been specially sealed and packed, inspection periods can be extended. Otherwise longer inspection periods must be defined by the manufacturer on a case to case basis and take into account storage and packing. If device has been used it must be checked by manufacturer or a repair shop which is authorized by manufacturer. (Skylotec 2014.)

Each Nordex's wind turbine has been equipped with Skylotec rescue device. Device is packed in aluminum seal pack. Manufacturer has defined in special SEAL PAC instruction that in case of emergency equipment which is packed in special aluminum SEAL PAC, inspection of equipment must be done by manufacturer only after 10 years. However, device should be checked visually by reading the moisture indication once per year and in case of humidity exceeds 50 % or if the device has been used, the full inspection of the manufacturer or repair shop authorized by the manufacturer is needed. (Skylotec 2014.) Anyone can perform this visual check of emergency equipment.

4.2.5 Ladders, fall arrester system and anchor points

"Parts of the machinery where persons are liable to move about or stand must be designed and constructed in such a way as to prevent persons slipping, tripping or falling on or off these parts" (Directive 2006/42/EC). This requirement applies to the footboards, work platforms, walkways, ramps and ladders. If after fitting necessary enclosures, guard rails and toe plates there is still a residual risk of falling, anchorages for attaching PPE against falls from a heights shall be fitted to the machinery. When choosing type of anchorage, need of move by the operator must be taken in to account. There might be need for several kind of anchor point, rails and so on. (Fraser et al. 2010.)

Ladders, rails and anchor points of the wind turbine are part of machinery which enable access from one place of use to another. Those parts affect to the safety of users and must be target for the periodic inspection by qualified inspector as required by manufacturer. Practically all component suppliers has recommended to check each of these parts of machinery annually.

The ladder manufacturer offers and recommends its own inspector training. Ladders are provided by Hailo company, which is the same company as supplier of turbine lift. Fall arrester rail is added on to the ladders as part of fall arrester system. Fall arrester system consist of the fall arrester rail and the fall arrester. The fall arrester is used as personal protective equipment. Both fall arrester system providers, Avanti and Haca, provides their own courses for inspector of their fall arrester systems. However, Avanti also recommends that each Avanti fall arresters should be sent annually for the inspection of Avanti.

When assessing the integrity of the anchor the manufacturer of the anchor device should be consulted for advice. (RenewableUK 2015.) In NX WTGS's the anchor points are supplied by RUD company. By RUD instructions "a technical expert should control at least once a year the appropriateness of the anchor point". Also after any special incident or event of damage the inspection must be done by expertized person. General inspections should be done before each usage. (RUD 2016.)

4.2.6 Lifting accessories and personal fall protective equipment

Lifting accessory is equipment which is placed between the holding device of the lifting machinery and the load or only on the load itself when its function is hold the load during lifting. Load devices incorporated into lifting machinery, such as hooks, are not to be considered as lifting accessories. Also slings and their components are lifting accessories. (Fraser et al. 2010.)

Lifting accessories are covered by machinery directive as well as user decree of work equipment. In the user degree, there is no special inspection requirement for lifting accessories. But when failure or deficiencies of this equipment may affect to the safety of its user, a safety of equipment must be ensured by sufficient measures. Equipment has to be inspected regularly by qualified person.

Traditionally lifting accessories has been inspected annually by expert who is familiar with structure of equipment as well as necessary test methods and assessment criteria. In order to ensure working order of equipment, employer may carry out inspection by own expertized employee or outside expert. However, in all cases inspection once per year as one-off measure is not sufficient alone. The condition of the device should be viewed continuously and each people who use equipment should know the rejection criteria for the device. Especially it should be recognized by anyone if equipment breaks in use and it is not in safe working order anymore. Safe working order of lifting accessories in construction work must be checked also prior taking equipment into use at construction site and in the regular site inspections. (Työsuojeluhallinto 2010.)

Personal fall protective equipment (PFPE) as harnesses and ropes must be inspected regularly. The manufacturer of machinery defines inspection period and it can be checked from the user manual of equipment. Most often the interval is one year, but in difficult conditions interval may be shorter. Inspection must be carried out by qualified inspector. Worker is qualified if he or she is familiar with structure and use of equipment. (Työsuojeluhallinto 2015.)

At Nordex, inspections of the whole set of PFPE has been carried out annually. Internal inspectors of lifting accessories and personal fall protective equipment has been participated in specific inspection trainings to become more familiar with necessary inspection methods. Internal inspectors are internally authorized and not allowed to inspect their own equipment. Procedure of participating in additional training and authorization has been seen necessary when conditions of these equipment use are difficult and their failure would affect to the safety of people in a very significant way.

4.2.7 Emergency equipment

As part of safety integration of wind turbines, the risk of fire must be considered when there is always presented main fire hazards as oxygen (windy places) and ignition source (electricity). The risk cannot be adequately reduced and complementary protective measures, as fitting machinery with fire detection, alarm and extinction systems, shall be taken. (Fraser et al. 2010.)

Each Nordex's wind turbine has been equipped with two portable fire extinguishers and fire alarm or detection systems. According to Rescue Equipment Act 10/2007 *portable fire extinguishers* shall be inspected in a manner ensuring their reliability and safety. Prior to commencing inspection of fire extinguishers firm/business (performing inspections) shall submit a notification to the Safety Technology Authority TUKES. (Act 10/2007.) Extinguishers shall be inspected at intervals of no less than one year if extinguisher has been stored in a place where the factors as moisture, vibration or changes in temperature may impact its working conditions. (Decree 917/2005.) Each of these factors may be presented in wind turbine so portable fire extinguisher in wind turbine must be inspected at least annually.

Wind turbines has been usually equipped only with fire alarms (not detection system). A fire detection system is available option. Only fixed fire detection systems which must be installed in building under an act, a provision or decision by an authority or which are linked via data link to an emergency response centre shall be inspected by registered inspection company. (Act 10/2007.) Fire detection system in wind turbine has not been linked to an emergency response centre. It is optional equipment and must not be installed under an act or provision. Fire detection system or fire alarm should be inspected in a way which ensure its reliability in case of fire. It is the company's own responsibility to assess the adequacy of these actions.

Exit routes must be marked with exit signs in workplaces, production facilities, storage facilities where people work and in other areas where the exit is difficult or where exit arrangements are unusual (Sisäasiainministeriö 805/2005). In case of emergency, the exit from wind turbine must sometimes happen from inside the building even if there is rescue equipment for external emergency exiting. The tall structure of the wind turbine and climbing makes evacuations difficult and therefor wind turbines has been equipped with exit signs.

Exit signs must always be illuminated. The additional illumination of the exit route must be started when ordinary electric lighting failure. Emergency lighting must work for the time required for safe evacuation. Reliability of signs and lighting of escape routes must be ensured by regular maintenance. The actions taken should be either recorded in the maintenance program or in a separate register. (Sisäasiainministeriö 805/2005.)

4.2.8 Automatic fire extinguisher system

Automatic fire extinguisher system (AFES) is a rescue equipment under rescue equipment act like portable fire extinguisher and fire detection system. Also, the same basic requirements apply to its inspections: an inspection are aimed at ensuring safety and reliability of equipment (Act 10/2007). Similarly, as with the fire detection system, if automatic fire extinguisher system must have been installed in building as condition for building permit, the inspector firm must be approved and registered by TUKES. This inspection body should be functionally and financially independent. A person who owns the equipment to be inspected or is their manufacturer, supplier, designer, installer or serviceman or who is their representative, cannot be considered as independent party (Sisäasiainministeriö 2000).

Automatic fire extinguisher systems installed in Nordex wind turbines are gas fire extinguisher system with volume of 67,5 L and maximum pressure of 200 bar. However, when AFES is not condition for building permit of wind turbines, systems can be inspected by the person who is competent and possess the necessary information to ensure safety and reliability of the equipment (Sisäasiainministeriö 2000.) The manufacturer provides separate additional training which necessity must be assessed on a case-by-case basis.

Automatic fire extinguisher system contains also pressurized parts as vessel and piping. But when pressure vessel (cylinder containing extinguishing agent) are transported in pressurized form (eg at or out of the filling station), ADR (European Agreement concerning the international carriage of Dangerous goods by Road) agreement is applicable to them. Such cylinders are excluded from the scope of the Pressure Equipment Directive, but TPED (Transportable Pressure Equipment Directive) is applicable to them. If the pressure cylinders are not transported under pressure, but filled and/or refilled at the site of installation they are within the scope of the Pressure Equipment Directive. The pipelines of the automatic fire extinguisher system are subject to the Pressure Equipment Directive when their content is inert gas and maximum allowable pressure PS exceed 0,5 bar. (PED application guidelines 2017.)

Gas cylinder, if it is transportable pressure equipment, and piping for fire extinguishing equipment do not need to be registered (Tukes 2012). Transportable pressure equipment which is used as part of extinguisher and which maximum volume is 150 L shall be subject to the periodic inspection no later than 11 years after the last inspection. Periodic inspection shall be carried out by a VAK (transport of dangerous goods) Inspection Body approved by the Finnish Safety and Chemicals Agency. (Act 1144/2016.) Pressurized cylinders must be transported for inspection as required by the transport regulations for dangerous goods. (Tukes 2012.) The transportable pressure equipment cannot be kept or transported under pressure if the last inspection carried out on the pressure equipment has passed the maximum allowable interval (Finlex 1144/2016).

4.3 Organization of the services in current state

For getting guarantee of the wind farms performance, premium contract has been reasonable choice for many customers. It is even more reasonable choice in countries with a feed-in-tariff system, which guarantees raised target prices for electricity produced (valtiontalouden tarkastusvirasto 2017). In Finland support period is 12 years (valtiontalouden tarkastusvirasto 2017) during which the wind turbine creates more value to its customers than otherwise. As most customers want to buy statutory inspections for each turbine, there is now about 200 wind turbines under annual statutory inspection of Nordex Finnish Branch.

From the point of resource planning statutory inspections approach to functional product when the demand is steady and content is “basic”. Steady demand of the product enables maximizing the capacity utilization by reducing unnecessary activities and information flow (Heikkilä & Ketokivi 2013). Increased efficiency may lead to the cost reduction which is one goal of Nordex as well as the whole wind energy industry.

The demand of the service product is easy to forecast when it can be directly derived from the demand for wind turbines. The contract of this service have been usually made at the same time as contract of building and maintaining wind turbines. Also, these contracts have been made for several years at a time which makes easier to know how many wind turbines will be under the service for following years. For this service product also forecasting of annual workload should be relatively easily by collecting data from duration of previous inspection when the content of inspections remains the same. The annual workload of whole maintenance work instead is harder to forecast when the number of unforeseen service visits cannot be known in advance. Sometimes maintenance work may take the capacity from inspections.

It has been estimated that inspection of one turbine takes 1,5 working days from team of two workers. There must be always team of at least two workers working in wind turbine because of safety reasons. Inspecting 200 wind turbines annually takes

1,5 working days/turbine x 200 turbines = 300 working days (1)

and when there is estimated 200 working days during a year, the number of teams needed for inspections:

300 working days / 200 working days = 1,5 (2)

So, need of inspection teams is two which means that minimum of four people should be performing statutory inspections of safety equipment.

At the moment Nordex has already in Finland three qualified inspectors, who have participated many necessary trainings given by specific machinery manufacturers and few other optional trainings as well. They are also experienced wind turbine technicians and certainly able to evaluate safety of wind turbine's safety equipment. However, they are not only carrying these inspections but also maintaining wind turbines, supporting in construction activities or working as lead technicians. Therefore, they cannot handle all the inspections of wind turbines along their other tasks.

Finland has been divided into three service areas, led by local service manager. On each area, there is one qualified inspector. The inspections have been performed in teams of two wind turbine technicians. One of the technicians has inspection qualifications and he carry out responsibility of inspections. Another technician helps to carry out inspection and maintenance activities related to the safety machinery. The inspection data has been saved inside wind turbine where all the necessary machinery documentation, as user manuals, maintenance manual and inspection reports has been saved on one place.

For some inspections of safety equipment have been used third party inspection company in service and construction phase. Subcontractors have also been used to carry out inspections. In the construction phase, the subcontractors handle most of the work activities and Nordex does not even have all necessary competencies to carry out all construction activities. On service activities Nordex has invested into own competencies and it is carrying out most of service activities itself. In the service phase, external workforce (capacity purchase) has been used if the required capacity has exceeded own available capacity. Mainly the same subcontractors have been used in the operational phase as during the construction phase.

Nordex itself has a quality certificate and therefore requires the quality certificate or otherwise high quality from its subcontractors. In according to good wind industry practises Nordex ask its subcontractors to provide beforehand work method statement and risk assessments, which must be accepted by Nordex site management before works of external company can be started. In addition to quality certificates and RAMS, Nordex check that company has necessary approvals for example doing electrical works and company is carrying out their social responsibilities (under contractor's obligations law).

When using external companies, Nordex go through the personal documentation of each external employees. Each person working in wind turbine must have necessary valid safety training certificates and task related machinery specific assemble, use, maintenance and inspection certificates. Certificates validity and works of subcontractors has been monitored in necessary way. Nordex has also special permission system for certain work activities and it gives workplace induction for each employees. All these activities has been done to ensure the quality and safety of wind turbines and people working there.

Availability of wind industry workforce is regionally distributed and many specialized wind industry workers come from wind industry forerunner countries. Therefore, the use of foreign subcontractor companies from other European countries is typical. When foreign European companies send their employees working in Finland there is obligatory actions they must do before sending the employees and acting in Finland. The company who order the service work must inform and ensure that subcontractors are carrying out their duties before they can start working in Finland.

It is typical that employees of foreign companies change quite often. One reason for that is that foreign employees don't want to pay taxes in Finland which is necessary if they stay in Finland for more than six months or more than 183 days within the time period of tax treaty (tax administration 2011). Experience of the case company has shown that in longer contracts with foreign companies new employees are coming all the time and the turnover of workers is quite high. It has been seen laborious to follow who is coming, who has get induction and if there are all necessary personal certificates in place always for everyone.

The experience has shown that advising and following subcontractors to fill all the requirements take lot of time. All these activities should be performed at various levels at the company, but it is not easy for everyone to recognize their own responsibilities in the management of these tasks. It has been seen that foreign companies need lots of advising to meet Finnish requirement, but they know better the common wind industry requirements. For the local companies instead, it is easier to meet Finnish local requirements, but only few has been specialized with wind industry good practices as providing copies of training certificates, work method statement and risk assessments.

However, the more external companies and people change the more extra work it has causes to Nordex. In the use of third party inspection companies, there has sometimes also been a problem that company has sent inspectors without valid safety certificates for working at heights. In this case, two employees of Nordex with valid certification and experiment must have gone to the turbine with inspector. This is procedure to ensure visitors safety, but it means that in addition to work of outside expert, inspection has required attendance of two Nordex service technician. It is never the safest solution to let people work in wind turbine without medical check-up and safety trainings for working at heights.

When the wind industry has grown so fast that there has occasionally been lack of professional wind industry workers, the availability of subcontractors has sometimes caused problems. When there are less suppliers on the market than which is a demand, there is always not so much choice of subcontractors. Also, because of sending workforce into high regulated Finland is not very easy, some companies don't want to do it at all. It has been seen that some companies have decided to not come into Finland after finding out all national requirements. Undersupply could also lead to the higher prices of subcontractors.

4.4 Pricing of the services

The pricing of this service product has been annual fee per turbine. The price has been defined for the service product for several years at the time of the bid of wind turbine supply. Easily measurable cost factors of the service, mainly direct, are shown in the Table 4.4.

Table 4.4. *Identified cost factors for inspections.*

	Types of resources	Cost factors
1.	Immediate work	Work of inspector, communication to the customer, data saving, labor costs (plus additional training costs)
2.	External services	Annual inspection of portable fire extinguishers by specific inspection body and rarely some other external inspections
3.	Facilities for the production	service point, use relatively small, not allocated
4.	Machinery and equipment for the production	Tools and gauge, Service car to access wind farm
5.	Energy for the production	Fuel for car, no other significant energy costs
6.	Raw materials and supplies for the production	Oil, use of raw materials low, rarely spare parts

Immediate work consists of work for inspection, communicating to the customer about actions and findings and saving data from inspections. Moving into isolated wind farms causes extra working hours for employees. Annual labour costs for inspections can be calculated from the working hours needed for inspections when the average price of one working hour is known. Training cost for inspectors are higher than average training cost in Finland and those must be added to the average costs.

Inspectors cannot perform all inspections of safety equipment themselves. Fire extinguishers must be transported to the authorized inspection company for annual inspection. This external service causes additional cost. External services are needed also for inspection of automatic fire extinguisher systems when system’s gas bottle must be inspected by competent inspection body every 11 years. Also, some equipment is recommended to be sent to the manufacturer for thorough periodic inspections/maintenance. The use of external service as well as sending part of machinery to another country for inspection causes more additional costs.

Inspections are carried out mainly inside the wind turbines. Other facilities has not been used very much. Inspectors use service points sometimes for doing some office work and storing accessories for inspections. Service points are serving one or few wind farms. Most of service work is maintenance work, and the service points have been made mainly for that purpose. There would be the same costs of the facility even if customer did not purchase the service statutory inspections. When this does not affect the decision-making of this research, facility costs have not been allocated now.

When wind farms have been located in isolated places, inspector team needs to use service car everyday quite much. Even if inspectors would not go home daily, the nearest hotel might be at a distance of tens of kilometres away from the wind farm. Using the car as work equipment and/or staying overnight close to wind farms causes costs. Also some tools and gauges are needed for inspections.

If necessary, some system components need to be cleaned, oiled or replaced along inspections. Use of materials does not have significant impact on the costs. Sometimes also replacements of spare parts are needed and those cause some additional costs. However, it is not defined, if the maintenance work and/or repairs of safety equipment should be part of inspection content. It is also unclear if the cost of small maintenance activities such as oiling, replacement of spare parts or sending equipment to the manufacturer’s thorough inspections should be assigned to the statutory inspection. Another option would be assign costs to the maintenance services or even charge separately.

It has been said that repairs and replacements identified as part of statutory inspection shall be entitled to invoice customer in addition to the annual fee. Additional cost could be however problematic for the reputation when some customers may think that they are already paying for overall solution. Most of the customer are paying for premium contract, including replacements of spare parts. They might see that the maintenance activities of safety equipment are in content of maintenance contract.

As value adding service the service product statutory inspections cannot be handled separately from the core product - Wind turbine. Wind turbine create value to the customer by producing energy. The more energy wind turbine is able to produce the more valuable it is to the customer who gets more return to its investment by selling more energy. The purpose of maintenance services is to add value by increasing reliability of wind turbines. As advanced services, the maintenance services create a lot of additional value for the core product. Advanced maintenance services have so much impact on product performance that some customers may even keep these services as core product rather than physical wind turbine.

The safety equipment makes it more efficient to maintain wind turbines and at the same time decrease their down times. For example turbine lift carry people to the high maintenance places multiple times faster than climbing. The electrical chain hoist and manual chain hoist makes it easier to lift and transfer loads needed for maintenance work. Some safety equipment are necessary for moving safely inside wind turbine or mandatory for emergency situations. Maintenance works cannot be performed if the safety equipment has not been inspected correctly. This makes inspections of safety equipment valuable, but in this situation the service does not create value directly but indirectly.

Statutory inspection can be seen as standard product which means that differentiation is hard or even impossible. The law requires certain measures to be taken, so as long as minimum requirements of the law has been fulfilled and safety equipment work in a way that nothing happen, improvements are useless when customers cannot get more value. When an acceptable level for safety (quality) has been set by the legislation, following it is self-evident not source for differentiation. Lower quality would lead to the loose of reputation. Customers are usually not willing to pay standard product very high prices.

Primary product, Wind turbine, instead is the innovative product, which represent the latest technology. This kind of product costs are high, but the product novelty and desirability of properties makes possible to set higher prices (Heikkilä & Ketokivi 2013). However, cost of energy has been reducing when the technology has been developing and industry growing. This has set pressure to drive costs and prices down in the wind industry. To achieving cost-efficiency is challenge in fast developing markets towards rivals. (Nordex SE 2017.)

Statutory inspections is part of overall solution that Nordex provides to its customers. The pricing of the statutory inspection and other products (primary and value-adding) in company’s portfolio could be strategically sensible to be optimize. This means that if customer cannot see the cost based value of the statutory inspection when it creates value indirectly, the price of statutory inspection could be set lower and price of the primary or other value-adding services higher to covering costs and profit expectations of statutory inspections. This could lead to the higher revenue than pricing each product separately.

Also, when we are talking about service product we should take into account how people usually see the value of services i.e. what is the image of the price. The wind power professions might be seen more special than average service professions, because inspections concern specific, high-technology machinery. Therefore someone could keep this professional service rather than normal. However, it is very important that customer see the customer-oriented and professional behavior of service workers and has been informed about actions and interventions for having higher image of price via customer experience.

When customers of advanced services may vary from “customers who want to do it themselves” to “customers who want to do it for them”, these customer groups valuate the service differently (Baines & Lightwood 2014). Customers who can do it themselves do not want to pay service lot more than it would cost them to do it themselves. The other customer instead might be willing to pay more for overall solution if it does not have own possibilities/resources to perform task. For that reason, the pricing of customers might be reasonable and when the selling of wind turbines base on bidding, the prices anyway base on individual customer.

On the bidding, the price should also be based on competitive and ordering situation (Laitinen 2007). When we are talking about huge, high technology machinery and customized orders of wind farms, it is obvious that there is no possibility to deliver wind turbines unlimited amount annually. Nordex should have set the target for annual sales and reserved capacity to answer objective demand such as manufacturer of any other innovative products. Prices must be based on order situation so that expected sales and thus the high capacity utilization will be achieved.

5. DISCUSSION

5.1 Reliability of the results

As this research was done from a safety perspective, the most important objective was to look for the correct inspection qualifications and inspection periods, so that the target company would be able to carry out inspections in a manner which meets the requirements of safety legislation. The legislation was thoroughly and diversely explored and probably the most significant observations of the legislation were done. However, the interpretation of the legislation was challenging, when there were not many precedents available.

The defining task was more difficult with some safety equipment. In those cases, the definition of equipment was close to some specific machinery definition and it was necessary to think very carefully whether the difference was large enough or not. In these cases the opinions of the official authorities' leading experts were asked. These discussions were profound and provided support for the interpretation of the legislation.

Possible mistakes in the definitions would have more likely to be due to missing some important details of equipment, than the incorrect interpretation of the law. The analyses of correct definitions were made on the basis of the user instructions of the equipment and the conversations with the users. In the conversations, people could not possibly remember all the details when they had not paid attention to them earlier. The instructions, instead, did not tell about the actual use of equipment. The observations of equipment would have been an important part of definition process but those could not be carried out.

The current state analysis based on discussions and researcher's own observations. The review of current state helped to take into account the most important things, but did not gave the most accurate picture of the subject. Instead of only one larger interview, it would have been valuable to interview more people. The sample would have been more comprehensive if there were people from different geographical areas and premises. Once the sample was so small, there is increased risk that the bias of interviewee or researcher have affected the results. It might also be possible that the safety centricity of the researcher has guided the study more than what was needed.

The assessment of pricing was not profound. Quantitative data on the cost factors would have provided additional information. For example, the data of inspection duration, average travel time and available net time for inspection could have been collected with the help of accounting department. Market analysis would have provided more information of competition and in-depth strategic analysis would have been important part of profound analysis as well.

The results of the study correspond to the research questions. However, further studies would be needed to make the answers more unambiguous. The results of the study can not necessarily be used extensively. It must be taken into account that the definitions correspond to the requirements of Finnish legislation. Also the differences exist between the wind turbines of different manufacturers. However, even if results can not be fully used elsewhere, some of the results are more general. For example description of the defining process could be used more widely.

5.2 Evaluation of implementation alternatives

Findings show that it is possible to carry out inspections by Nordex itself, look for subcontractors with necessary qualifications or outsource inspections. However, it is necessary to ensure high quality of service outcome and experience. This means that the requirements set for inspector's qualification as well as inspection periods has been followed and people working on customer interface have customer-oriented and professional behaviour.

The value of service must be shown to the customer by continuous communication. Regular communicating of service actions is very important when looking for stronger customer relationships and better image. Communicating of inspections and improvements demonstrate the value of services. It signals to the customer how much effort and experience it requires to inspect and maintain the wind turbines. This could lead to the higher valuation and extension of service contracts.

The question of make or buy is one of the most important question related to the service implementation. However, there is no simple answer to that question. This decision should base on the main goals of Nordex business: Is it the quality which distinguish Nordex from its competitors? Is there some other factor which specialize Nordex? Or does Nordex compete more on costs and productivity? These strategic decisions influence to the objectives of operations and optimization of implementation.

Use of subcontractors is possible source of cost savings. However, it doesn't necessarily lead to the cost savings even if manpower would be cheaper. Using external manpower lead to the increased need of management. As in the wind power industry, it is usual that operations of subcontractors are much controlled as part of Good wind industry practices. Lot of attention has been paid especially safety management of subcontractors. Therefore use of subcontractors causes at least following administrative or control activities in the contracting company:

- advance review of subcontractor, including check of quality management system and check under contractor's obligations act
- tendering process, contracts making
- receiving and going through work method statement and risk assessment
- checking personal documentation and relevant training certification
- giving workplace instructions incl. safety instructions
- following that subcontractors are working according to own work method statement (for example there is responsible foreman in place if there should be).
- collecting inspection documents from subcontractors
- contractors' evaluation, auditing
- billing, incl. tax payment

All control and administrative work require use of manpower resources from Nordex and the more often the subcontractors change the more extra work it causes to the Nordex. In use of subcontractors, the capacity purchase should be done well in advance to be able to evaluate subcontractors beforehand and choose the best alternative. Nordex's own skilled workers should be involved in defining requirements and evaluate subcontractors beforehand and afterwards. It would be good to try to avoid single purchases and develop cooperation with subcontractors with sufficient quality. Also, it might not be even possible to find out subcontractors with correct qualifications within a fast timetable.

Subcontracting controls should be further developed to ensure the reliability and efficiency of these activities. However, despite of subcontracting control, there might still be a greater risk of poor safety and quality when control of individual external employees it is not in own hands. Risk of poor quality lead to the increased reputation and legal risks for the Nordex company. There might be also risk that contracting will deteriorate service experience when it is difficult to control that a person with sufficient social skills and customer oriented behavior has been chosen to the task. However, workers of subcontractors are not necessarily working in customer interface if communication to the customer takes place through Nordex.

Nordex should keep and save documentation of inspection (and maintenance) activities performed in each wind turbine. The information of inspections and maintenance activities (done by in-house or external workers) should be recorded in one place where anyone (managers, other technicians) could reach the information easily and find out when the next inspection should be performed. Otherwise if someone of the inspectors are not available, there is no information available elsewhere than only inside the turbines. From the point of information management this would be very important and decrease risk of losing information inside the company.

If outsourcing this task entirely, the own competence might disappear over time. It would make evaluation of subcontractors, their competencies and work more difficult. In the outsourcing, management of certain activity might fall outside the company's control

(Heikkilä & Ketokivi 2013). When control of certain activity is no longer in ownership of the company the risk of poor quality might increase. Control activities lower risks of poor quality, but still contractor cannot manage activities of subcontractor as much as own activities. In longer relationship or in partnership it might be possible to develop cooperation and improve quality.

When Nordex is carrying out wind turbine maintenance activities and similarly works as main user of wind turbines it must always control the overall safety. That is why Nordex cannot desist all control activities even in case of outsourcing. It has been discussed if Nordex could buy inspection entirely from another company. This would probably be the local company because the qualified persons should be available through the year and people turnover should be minimized.

External company would be objective party for carrying out inspections. But use of third party only for inspections (not maintenance) would be almost impossible when the maintenance instructions of service lift, for example, has been written in a way that maintenance and inspection activities would have been performed similarly. It might be ineffective to carry out these two activities separately continually. But if there is need for objective inspections, outside experts could also be used only occasionally.

The problem in the use of external company for carrying out inspection, is the requirement that qualified person should be familiar with use of certain equipment. Actual use of equipment should be informed to the external inspector so that he or she could be able to evaluate equipment actual use with design use. It may even be necessary for the equipment user to participate in the external inspection. Own employees instead have seen the actual use of equipment and if they worked as inspector, there would be no need for additional informing or extra participants.

If Nordex choose to do inspections by in-house people, it should decide how own performance should be measured and how it could be improved. By developing own activities Nordex might be able to increase own performance and cost-effectiveness. Also by carrying out statutory inspections itself the competences inside the company would increase. It would be investment in own expertise and specialization. The competence with inspections could lead to the extension of service contracts. Utilization of own facilities (service points) would also increase if Nordex carried out more service tasks itself.

Data for optimization of capacity utilization is easier to collect if company own the activity i.e. perform it. With operations performance information, it is easier to strive to continuous improvements. The cost-effective supply chain can be achieved also by contracting if selection of subcontractors is based on low prices and sufficient quality (Heikkilä & Ketokivi 2013). But if sufficient quality is high, the optimization of own operations might be better option than pay semi high prices for the contractor and still perform large amount of control activities to ensure sufficient quality.

When the demand of statutory inspections is very regular, inspections should be able to schedule carefully to achieve high capacity utilization. Because of foreseeable use of capacity, the capacity purchase in resourcing of statutory inspection does not look like a justified choice. However, if we are looking for the overall need of manpower capacity, we can see that the use of capacity in projects and unforeseen maintenance is more uncertain. When capacity is transferred within the company (for example from maintenance to construction activities) the capacity purchase can still become reasonable if capacity for inspection is easier to purchase than capacity for construction or maintenance activities.

It might be that Nordex does not have enough capacity to perform all inspections and maintenance works at the moment. For that reason, it could be necessary to hire new employees to perform all inspection activities in addition to service activities. But in the situation when there has occasionally been lack of skilled wind industry workers, it is necessarily not easy to find skilled wind industry worker to hire. However, inspector may not even need to be a wind service technician, but also people with electrical and mechanical skills could be able to handle inspections after participating necessary trainings.

Machinery statutory inspections have also been carried out on construction phase. Construction phase inspections might not belong on scope of service product statutory inspection, but the requirement for inspector qualifications are the same for periodic and initial inspections. When the capacity purchase and outsourcing is widely used for construction of wind turbines, someone could argue that same party should not handle both construction/assembly and initial inspection of machinery. When construction/assembly has been purchased from external company, it would be reasonable choice to have own inspectors for inspecting work of subcontractors. The service workers already support the construction projects in the final states of construction phase. It could be possible that same internal inspectors could handle both the service and construction phase inspections.

6. CONCLUSIONS

The most important objective of the study was to find the proper inspector qualifications and inspection periods for the safety equipment of the wind turbine. As a result, in most inspections the inspector should be a qualified person who is following manufacturer instructions. This person must be able to use necessary inspection methods and own an understanding of defects and deficiencies to evaluate the condition of work equipment (Decree 403/2008). Except for the general rule, the inspection of portable fire extinguishers must be annually carried out by an approved inspection body (Act 10/2007) and the inspection of the transportable pressure vessel of the automatic fire extinguisher system by a VAC inspection company once in every 11 years (Act 1144/2016).

Probably the best solution is to carry out inspections annually for each safety equipment. Most of manufacturers and general guidelines set the inspection interval at one year and handling all inspections simultaneously would be effective. However, inspection once per year as a one-off measure is not enough with most of the equipment. The condition of the equipment should be reviewed continuously and each user should know the rejection criteria for the equipment (Työsuojeluhallinto 2010).

It was discovered that the company's own evaluation of adequate measures for keeping machinery in safe working order could not be ignored. It might be easily forgotten, but it is very important to evaluate how the actual conditions and use may affect the need of inspections. Also, own inspection procedure should not be evaluated only sporadically, but try to observe the functionality of condition monitoring regularly. This kind of own evaluation was left in a minor role in this study. For further analysis, Nordex should start collecting data of all inspections, save it in one place and analyse it. With this analysis, it could be possible to improve the system to better meet Nordex's operating conditions.

It was seen as very important that the company should be able to show how it has carried out inspection and taken care of its obligations (Sosiaali ja terveysministeriö 2008). The company should be able to justify why it has chosen to carry out inspections in a certain way, and demonstrate by documenting what has been done to ensure the safe working order of certain equipment. As a result of this research, the important factors which affect the definition of machinery were identified. The phases of the identification process and the condition monitoring system were also established.

The steady demand of the product makes it possible to schedule inspections in a way which leads to the high capacity utilization. This fact does not support capacity purchase. By performing inspections by in-house people, the development of own inspection competencies could lead to improvements in effectiveness and quality of services. When control of activity would be in one's own hands, it would be easier to collect performance data and make improvements. Also, when performing the inspection itself, the maintenance activities of safety equipment could be performed along with inspections. When the own staff know actual use of equipment, it makes this information easy to use in inspections.

Contracting causes extra work to Nordex when it must ensure subcontractors' compliance, quality and safety at work. Their works and qualifications monitoring is laborious. However, the use of subcontractors may be effective if there is: use of same subcontractors, longer contracts, early purchases, evaluations in many stages and communication. By taking into account these things, it is also possible to continuously improve the work of subcontractors and reduce the risk of poor quality. So even if use of subcontractors involves more risks, their use may be justified if they are generally cheaper and their quality is sufficient.

The use of an outside inspection company (outsourcing) would lead to higher objectivity of inspections. At the same time, outsourcing would lead to a situation where own competence and control of this activity decrease (Heikkilä & Ketokivi 2013). The outsourcing, with the aim of a log-term relationship, could likely be a more expensive solution than capacity purchase, but if the quality of the external inspection company would be high, this solution could be-come worthwhile.

In this study, it was concluded that for the customer, it might be difficult to see the value of this service, when inspections create value indirectly. That is why value of the service should be demonstrated to the customer by communication. On the pricing of this service product, the pricing of the core product and advanced maintenance services, as well as how different customers valuate the service, should be taken into account. If a company would like to optimize pricing, it should optimize pricing of the overall solution (wind turbine supply + maintenance contract + statutory inspection) and price the different customers differently. Also, the competitive and order situation should be taken into account as usually in bidding pricing (Laitinen 2007).

Based on this study, it is impossible to say which implementation alternative is the best solution. However, the study succeeded in highlighting issues that should help in decision-making and guide the further analysis of options. There is still need for more accurate analysis of different solution's cost implications. Also, for more accurate pricing, more data should be collected and analysed. The main direct cost sources and factors affecting pricing were identified, but it was not possible to determine precise costs for pricing.

In further evaluation of pricing, the competitors should be taken into account much better. By market analysis someone should find out: What do competitors offer? Do they offer advanced services or statutory inspections? How do they compete? And how do we really differ from them? In further costing more quantitative data should be collected. For example, the data of inspection duration, average travel time and available net time for inspection could have been collected and general costs allocated to the inspections. Strategy and competitive strategy of Nordex should also be analysed more specifically to make strategically right decisions.

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APPENDIX A: LIST OF INSPECTION TARGETS

List of identified inspection targets:

	Inspection target	Source	Target for
1.	Turbine lift	NX guidance, Renewable UK 2015	Statutory Inspection
2.	Electric chain hoist	NX guidance, Renewable UK	Statutory Inspection
3.	Chain hoist	NX guidance, Renewable UK 2015	Statutory Inspection
4	Fall arrester rail	NX guidance	Statutory Inspection
5.	Anchor points	NX guidance, Renewable UK 2015	Statutory Inspection
6.	Platforms and hatches	Renewable UK 2015	Statutory Inspection
7.	Lifting accessories	NX guidance, Renewable UK 2015	Statutory Inspection
8.	Fire extinguishers	NX guidance, OP Vakuu-tus 2015	Statutory Inspection
9.	Automatic fire extin-guisher system	NX guidance, OP Vakuu-tus 2015	Statutory Inspection
10.	Inspection of the fire detection system	OP Vakuutus 2012	Statutory Inspection
11.	Emergency abseiling equipment	NX guidance, Renewable UK 2015	Statutory Inspection
12.	Emergency lighting	Renewable UK 2015, Safety manual NX	Statutory Inspection
13.	Personal safety / pro-tective equipment	NX guidance	Statutory Inspection

14.	First aid box / kit	NX guidance, Renewable UK 2015	Statutory Inspection
15.	Blades	OP Vakuutus 2012	Inspection under maintenance contract
16.	The main axle and the main laurel	OP Vakuutus 2012	Inspection under maintenance contract
17.	Checks on the gearbox	OP Vakuutus 2012	Inspection under maintenance contract
18.	Generator controls and electrical measurements	OP Vakuutus 2012	Inspection under maintenance contract
19.	Checks for lubrication and hydraulic oil systems	OP Vakuutus 2012	Inspection under maintenance contract
20.	Checking the braking and stopping device of the wings rotation	OP Vakuutus 2012	Inspection under maintenance contract
18.	Converter inspection	OP Vakuutus 2012	Inspection under maintenance contract
19.	Inspections of tower structures and foundations	OP Vakuutus 2012	Inspection under maintenance contract
20.	Electrical protection inspections and testing	OP Vakuutus 2012	Inspection under maintenance contract
21.	Lightning protection inspection and testing	OP Vakuutus 2012	Inspection under maintenance contract
22.	Icing detection system	NX manual	Inspection under maintenance contract
23.	Inspection and testing of condition monitoring equipment	OP Vakuutus 2012	Inspection under maintenance contract

24.	Pressure systems	Renewable UK 2015	Inspection under maintenance contract