Improving Supply Chain and Logistics in the Wind Turbine Industry using Six Sigma

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Abstract

This paper presents the problem of Supply Chain Management and Logistics in the wind turbine industry, and a solution to the problem based on Six Sigma practices. The project consisted on analyzing the practices on one of the leading companies in the market and how to improve them. Siemens Gamesa Renewable Energies is a company based on Spain but with market share in the entire world. The practices in the United States market were analyzed and improved. The DMAIC Process tool was implemented to do so, divided into its 5 phases which include Define, Measure, Analyze, Improvement, and Control. After analyzing the project, it was finalized that many improvements can be done by the application of a new Kanban solution for the company worldwide to correlate orders with suppliers and resource allocation. This Kanban solution would be used as a perfect tool to analyze what the needs are, the cost of different suppliers and shipment, the customer location and its shipping cost, as well as the availability and capacity per weeks of each manufacturing plant to be able to fulfill the needs of the orders.

Keywords
Wind Turbine Industry, Six Sigma, Supply Chain Management, Logistics

1. Introduction
Wind energy is the conversion of air's motion into mechanical energy mostly for electricity generation. Wind energy gets the natural wind from environment and converts the air's motion into mechanical energy. Different locations are selected accordingly for wind energy generation. Wind speeds are higher in coast and offshore areas.

The machinery which converts air motion into electrical energy is a turbine. A turbine is a structure with several blades (spinning). These blades are connected to an electromagnetic generator which generates electrical energy when the wind helps the blades to spin. This energy was used for pumping water, but now it is commonly used to generate electrical energy. Now it is a most widely used energy. The advantage of wind is that it is a renewable and clean form of energy. However, wind energy faces many problems. The supply chain management and logistic departments are facing lots of problems due to inaccurate management.

Siemens Gamesa Renewable Energies is a leading supplier of wind power solutions to customers all over the world. A key player and innovative pioneer in the renewable energy sector, they have installed products and technology in many countries, with a total capacity base of over 89 GW and 23,000 employees.

Siemens Gamesa offers one of the industry's broadest product portfolios, with both offshore and onshore technology and industry-leading service solutions. The company was created in 2017 by the merge of Siemens Wind Power and Gamesa. With the vision: *To be the global leader in the renewable energy industry driving the transition towards a sustainable world.*

<u>Onshore Wind Power</u>
For the long-term success of onshore wind power project, they provide innovative solutions with geared technology including two platforms with modular design based on their proven track record and technological excellence. With their global reach they deploy a regional focus wherever they operate, with technology adapted to local needs.

Figure 1. Onshore Windmill

Figure 2. Offshore Windmill

Offshore Wind Power
When you are developing an offshore wind power plant, they strive to unlock the full potential of your project, while delivering a lower cost of energy. When you choose Siemens Gamesa as your offshore partner, they put nearly three decades of offshore experience, a mature value chain, and their extensive innovative capabilities at your disposal.

The logistic department and the supply chain managements are facing some of the problems in this turbine industry. We are going to solve this problem with the application of six sigma (DMAIC) methodologies.

2. Literature Review

The success stories for new logistics and supply chain management concepts implemented have been described in many previous publications.

Referring to the offshore-wind industry, Innovative purchasing and supply management practices can improve both firm and industry performance. A description of the offshore-wind supply chain, which remains understudied in academic literature, despite increasing global development of offshore-wind farms. These wind farm projects use larger turbines, which increase the difficulty of the supply chain. Innovative purchasing and supply management practices, designed to block this growing difficulty, can help companies to achieve the success. Innovative purchasing and supply management practices include decisions to make or buy, contract forms and local to global sourcing. These practices affect the success factors of the industry by improving competition, capabilities and control. (D'Amico, et al., 2017).

A maximum part of economic globalization has taken place in the form of different globalization policy. Off shoring and outsourcing of manufacturing activities from Western locations to Eastern Europe and the Far East are used to remain competitive. Such policies have implications for supply chain performance. The purpose is to explore whether supply chain performance is affected differently depending on the choice of globalization policy. This study shows different practices of managing supply chain performance in off shoring and outsourcing policies (Jan Stentoft, et al., 2012).

The literature on supply chain integration is to know the state of research in the various types of studied industries and manufacturing environments. The purpose is to identify academic discoveries that could provide offshore wind projects with means to overcome their present supply chain challenges. A literature review was conducted involving 162 articles. The papers were analyzed in terms of the dimensions of Supply Chain Integration, research methodology, unit of analysis, level of analysis, type of industry and manufacturing environment being studied, integrative practices, integrative barriers and the link between the Supply Chain Integration and performance. Scholars have over looked industrial contingencies by ignoring the differences between the studied industrial contexts, especially project-based manufacturing environments. The present review also reveals that no study of Supply Chain Integration has been conducted on the construction of renewable energy projects (Neri, et al., 2016).

Integrating the global enterprise using Six Sigma: Business process reengineering at General Electric Wind Energy: The study by Sanjay Goel, and Vicki Chen, focuses on the involvement of Business Process Reengineering when larger companies acquire smaller companies to sustain their growth. Being able to integrate different cultures is essential for a successful acquisition as well as consolidating processes to improve efficiency and reduce cycle times. The papers discuss the case of General Electric Energy's Wind Division, with the efforts of "defining metrics for redesign, identifying alternate tools and processes, and evaluating the alternatives through those metrics employing Six Sigma methodology" (Goel, et al., 2008) with the goal to demonstrate their "best practices for process integration across global engineering corporations developed over time" (Goel, et al., 2008). This case study that was developed to define the metrics and employ a metrics-driven methodology based on Six Sigma. It is used to reengineer risks the decisions that are made through the processes at each step. The methodology placed in work was a Decision-Making approach which was developed with a Table. This table is divided in three sections: Process Redesign, Tool Selection, and Security Analysis. The paper focuses thoroughly on a Case Study that analyzes how GE Energy "acquired several new wind turbine businesses and attempted to integrate business processes across different divisions" (Goel, et al., 2008). There are several tools that are used in this case study in order to proceed with this project, such as improvements on the BOM, Root Cause Analysis, Pareto Charts, and the invention of PLM/PDM as a new tool. All of these tools helped to reengineer "business processes across globally" (Goel, et al., 2008), and gives a statistical analysis to track the quality and performance.

Efficiency improvement on the multicrystalline silicon wafer through six sigma methodology: The study by S. Saravanan, Meera Mahadevan, Prakash Suratkar, and E.V. Gijo, focuses on the importance of applying a Six Sigma methodology into improving the efficiency of multicrystalline silicon wafer. This material, Crystalline silicone, has been the leading technology for the solar cell production (Saravanan, et al., 2012), according to the journal. There are many different processes to develop this kind of technology, however the one that has been the most dominant in the industry has been Screen Printed Solar Cells. This technology is recognized to be have a simple, robust, continuous and easily adaptable process (Saravanan, et al., 2012). The process that goes into developing a high efficiency solar cell is very complex, and there is a continuous need to research new ways to improve it. The process called ARC is considered a critical process as it “helps to reduce the reflection and to increase the passivation” (Saravanan, et al., 2012). It is for this reason that this study has been carried out in order to learn more about this science. It has been found that “plasma-enhanced chemical vapor deposition (PECVD) is the most efficient form of developing this technology” (Saravanan, et al., 2012). The study was carried out using a very well-known Six Sigma Methodology called DMAIC, and it refers to a cycle of improvement, optimizing, and stabilizing process and designs by the study of data within the system. The data was published using different tools such as Normal Probabilities, Process Capability Analysis, Cause and Effect Diagram, Cause Validation Plan, Main Effects Plot of Efficiency, and Run Charts that help with the outcome of the project. As a result, the “optimized process, the efficiency level of the solar cell improved significantly, which has been observed consistently. This study and the electrical results reveal the importance of the PECVD process in the conventional PV manufacturing processes” (Saravanan, et al., 2012).

Reducing cost of energy in the offshore wind energy industry: The study by Jan Stentoft, Ram Narasimhan, and Thomas Poulsen focuses on the importance of applying good techniques of Supply Chain Management in order to reduce the cost of the energy of offshore wind. In order to fulfill this project, the authors aim “to introduce a conceptual framework from a supply chain management (SCM) perspective, aimed at promoting the reduction of CoE in the offshore wind energy industry” (Stentoft, et al., 2016). Some of the findings on this project included the inclusion of “three interdependent aspects of reducing CoE – innovation, industrialization and supplier partnering – to guide the industry towards sources to reduce CoE” (Stentoft, et al., 2016).

3. Problem Statement and Objectives

The Problem Statement was established by the group as follows: “Wind Turbine Industry is not sufficiently efficient when producing and shipping the end product to the customer leading to higher production costs. Supply Chain Management and Logistics practices are phased out compared to other methodologies used in other industries.”

Also, the objectives were stablished:

- Apply Six Sigma to an emergent industry in growth with the application of few Six Sigma Methodologies.
- Reduce cost of Supply Chain Management and Logistics in the Wind Turbine Industry by 10% by the election of correct suppliers.
- Propose new ideas to Siemens Gamesa Renewable Energy (SGRE) for their future endeavors.

4. Methodology

Figure 3 shows the flowchart of the case study, that was also done initially to show the steps that the group was going to take in order to fully complete the task. The project was divided in 5 phases, which are as follows: Phase 1, Project Analysis, focuses on understanding the task assigned and finding the best proposal that we could find. Phase 2, Decision Process, focused on getting an agreement between the group members and getting it approved by the professor. Phase 3, Project Charter, stablished the Problem Statement and Goals, which was done right after the decision of the industry. Lastly, Phases 4 and 5, focused on the DMAIC Process and the Tools used in order to apply Six Sigma applications into this industry. In order to fulfill this project, a timeline was established with a scope that would lead it to completion.

The scope of the project was developed and instated into different phases, as follows:

- Conduct an in-depth research of Wind Turbine Manufacturers and Six Sigma applications to gain knowledge about current practices.
- Analyze the industry, specially concentrating in Siemens Gamesa Renewable Energy (SGRE) as the industry leader.
- Conduct interviews/discussions with current or former employees to gain knowledge of their practices.
- Apply Six Sigma to current practices to improve Supply Chain Management and Logistics in the company.
- Develop the Research Paper with analysis, findings and proposals.

One of the most famous practices of Six Sigma, is the usage of the DMAIC Process which analyzes the problem that is being analyzed and finds different tools in order to fix and control it in the future. It is an essential tool for companies to assure success in the future of the company. DMAIC stands for Define, Measure, Analyze, Improve, and Control. The different phases are analyzed.

<u>Define:</u> The actual problem is defined in order to improve. Project charter is to define the focus, scope for the improvement of the system. An overall view of the business process is defined by thorough study and customer feedback. This face analyzes what is required to meet customer need.

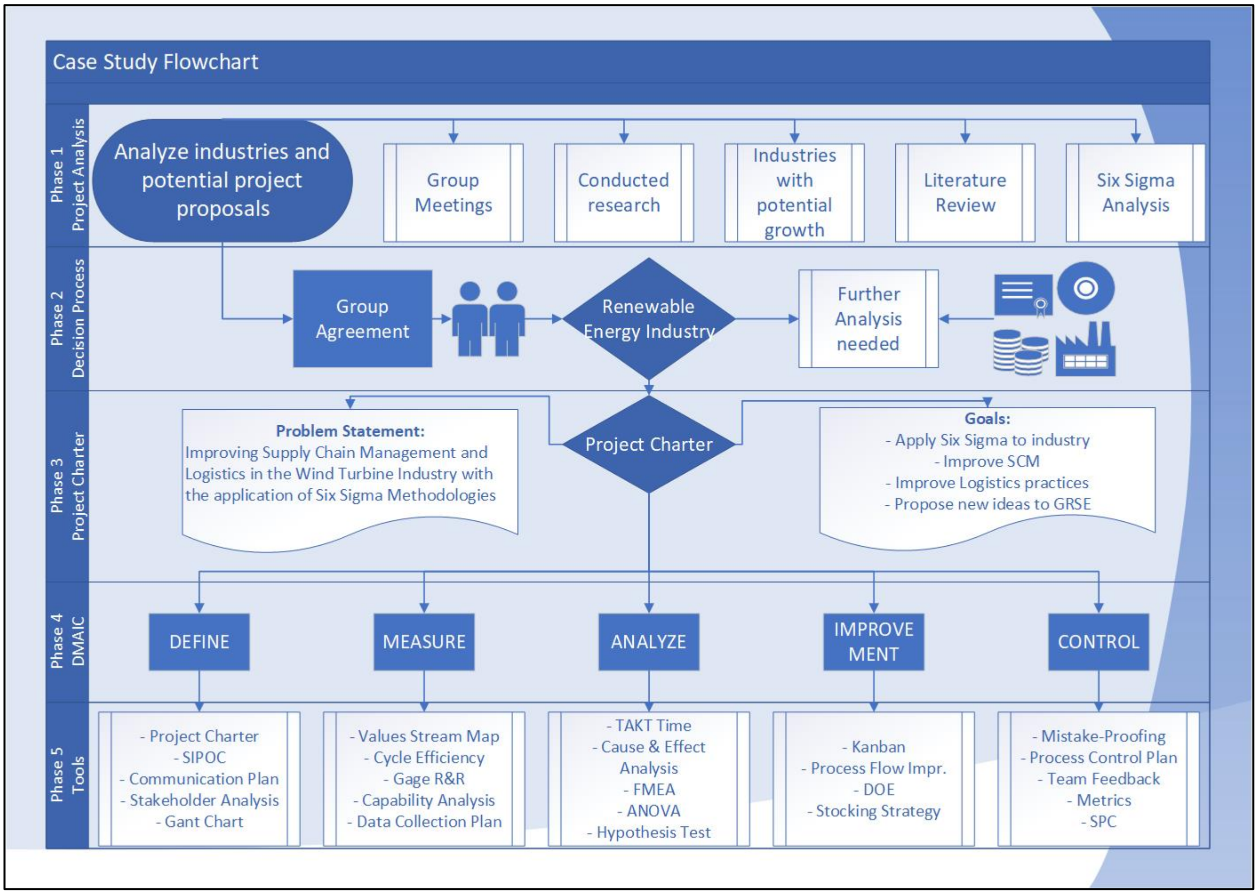

Figure 3. Case Study Flowchart

<u>Measure:</u> Process mapping is done to know the performance of the system. Here all the measures are analyzed to find the solution for the process to meet the customer expectations. Fishbone diagrams are constructed to measure the problem.

<u>Analyze:</u> This process helps to find the root cause of the problem. Analysis is done to solve the problem in the system. Six sigma tools are used to determine the root cause.

<u>Improve:</u> This process helps to eliminate the root cause. Design of experiments (DOE) is used to improve the system. Improvement of current practices helps to meet the customer need satisfaction.

<u>Control:</u> In this phase the future process performance is controlled. Statistical Process Control (SPC) is used to control the entire process. Control plans are set up to control the improved system.

5. Applications of DMAIC Tools

This project was fulfilled by the implementation of DMAIC, which it was explained above. There are five total phases on this project, which are fully explained below.

5.1 Define Phase

The first phase, which is the Define Phase, focuses on the project overall and finding the initial needs to overcome the project successfully. It consists on analyzing the problem, learning more about the processes that go into the production of your good and analyzing suppliers and customers. In order to find the solution of the problem, you must first understand your company and how it functions, which will allow you to implement new techniques. In order to fulfill this phase, a Project Charter and a SIPOC Diagram were conducted.

5.1.1. Project Charter

It was first started by analyzing the problem and possible ideas to solve it. The first step was to develop a project charter where an initial idea of the goal was found and how to approach the project with deliverables and a timeline. As it can be seen on Figure 2, there are six different parts which include the Problem Statement, Goal Statement, Scope, Outputs, Timeline, and Team Members. The Problem Statement was stablished initially, and then the plan was set to overcome the proposal. The project was stablished to be done in the following three months, and conducted by two process engineers.

Project Charter

Problem Statement
Wind Turbine Industry is not sufficiently efficient when producing and shipping the end product to the customer leading to higher production costs. Supply Chain Management and Logistics practices

Goal Statement
- Apply Six Sigma to an emergent industry in growth with the application of few Six Sigma Methodologies. - Improve Supply Chain Management in the Wind Turbine Industry. - Improve Logistics practices in the Wind Turbine Industry. - Propose new ideas to GRSE for their future endeavors.

Scope In/Out	
1st Process Step	Analysis of the Industry and Literature Review.
Last Process Step	Develop Research Paper and Submission to SGRE and Lawrence Technological University.
In Scope:	Research, Analysis, and Implementation of Six Sigma Methodologies.
Out of Scope:	SGRE denies to give confidential information.

Outputs
Improvements in Supply Chain Management and Logistics in an industry with continuous growth and the ability to share information with Siemens Gamesa Renewable Energy for their future growth.

Timeline		
Phase	Planned	Actual
Define:	02/26/2019	02/26/2019
Measure:	03/08/2019	--
Analyze:	03/18/2019	--
Improve:	03/26/2019	--
Control:	04/02/2019	--

Team Members			
Position	Person	Title	% of Time
Team Member	Abhishek Ashtagi	Process Engineer	50%
Team Member	Pablo Ripodas	Process Engineer	50%
Sponsor	Ahad Ali	Supervisor	0%

Figure 4. Initial Project Charter

SIPOC Diagram

Suppliers	Inputs	Processes	Outputs	Customers
Who supplies the process inputs?	What inputs are required?	What are the major steps in the process?	What are the process outputs?	Who receives the outputs?
LM WIND POWER	BLADES	BUY COMPONENTS	WIND TURBINE	IBERDROLA
TECSIS		LOGISTICS TO GET PRODUCTS TO LINE		
KORINDO	TOWERS	MANUFACTURE THE PRODUCT	WIND FARMS	EDF
WINDAR		LOGISTICS TO SEND TO WIND FARM		
ACCIONA	NACELLE	PLACEMENT IN WIND FARM	SERVICES	EDP
GAMESA (DIFFERENT LOCATIONS)		INTERNATIONAL PAPERWORK		

Figure 5. SIPOC Diagram

5.1.2. SIPOC Diagram

A SIPOC Diagram was developed in order to analyze the steps that are taken to develop the product. This tool determines the suppliers, and inputs, understands the processes that goes into creating the product, and determines the outputs of the company as well as its customers. This tool helps analyzing the whole process of the project. Once this is understood, the next steps can be taken in order to fulfill the goals of the project.

5.2 Measure Phase

The second phase, which is the Measure Phase, focuses on the understanding what the processes are in the project and how things are currently done in the company. In order to find the solution to the project, a fully study of the current practices must be done, which would lead to understanding the processes correctly and will be the comparison point once some changes are made. In order to fulfill this phase, a Network Map was created.

5.2.1. Network Map

The Network Map consists of a map that contemplates the different markets in which the company operates and the different suppliers that provide the needs to make the parts. Figure 4, shows the four different areas in which Siemens Gamesa Renewable Energies operates in the United States. It is divided in order to provide service in the whole country.

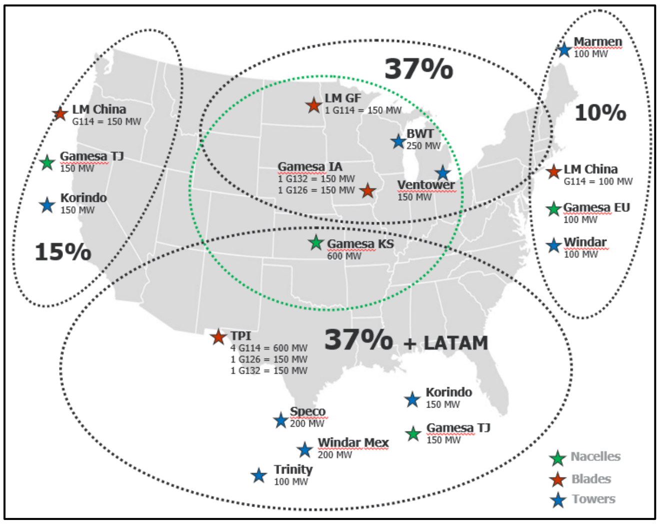

Figure 6. United States Market Opportunities and Suppliers

The following maps, see Figure 7, represents the different manufacturing plants in the United States, Mexico, and Canada, as well as other suppliers that come from outside North America from different places of the world, for instance Spain and Korea. The company does not only supply from their own plants but also from other companies that manufacture on key areas.

Most of the blades are made in China, however there are some other suppliers in United States. The company does not own towers manufacturing plants, so everything is outsourced from different companies. Most of the nacelles come from the plants in Spain, however there are different suppliers in United States. In order to select the supplier, one has to understand both the cost of production and the cost of logistics.

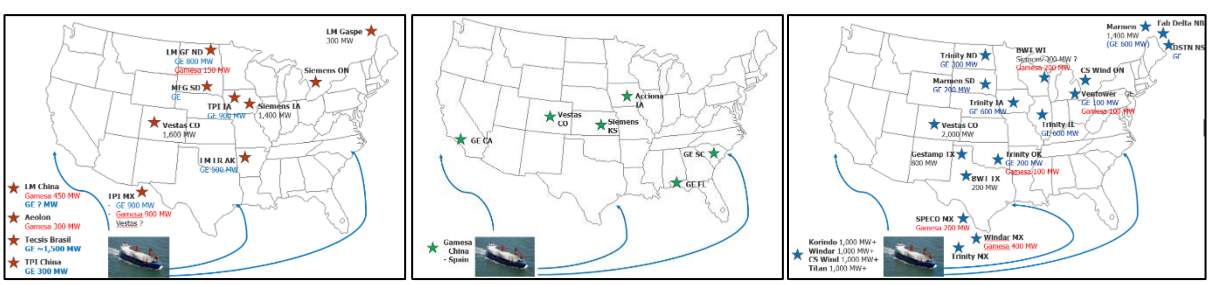

Figure 7. Suppliers for Blades, Nacelles, and Towers, respectively, in USA

5.2.2. Suppliers Election

A full study of the suppliers with the production cost, as well as the logistics cost was conducted in order to find the best combination of blades, nacelles and towers; to produce the wind turbines at the lowest cost. The analysis was conducted for the installation of wind turbines in the United States with products coming from different suppliers in USA, Mexico and Asia; as those are considered the most competitive markets when producing for United States. When looking at the manufacturing of blades, as it can be seen in Fig. 8, manufacturing in Mexico has a $90K saving over manufacturing in the United States; and adding the logistics, the price still is lower. There is a reduction of cost of 16% when producing in Mexico over in USA.

Central USA Mfg (KS)	Cost Estim.
Materials	429K
Opex USA	30K
Logistics Inland	20K
Logistics Ocean	20K
TCO	499K

Imported Mex to USA	Cost Estim.
Materials	339K
Opex LCC	10K
Logistics Inland	50K
Logistics Ocean	20K
TCO	419K

Figure 8. Blades price comparison USA vs. Mexico

In order to decide where the nacelles are going to be manufactured, Siemens Gamesa did a full analysis of the price and a comparison between United States, Mexico and Asia. As it can be seen in Figure 9, the lowest cost is the production of nacelles in Asia, over Mexico and USA which have the same cost, by a 4%. Lastly, the towers market was analyzed between Mexico and USA, and Mexico had a lower cost by 15%, due to a $60K reduction on the cost of materials.

Central USA Mfg (KS)	Cost Estim.
Materials	630K
Opex USA	30K
Logistics Inland	20K
Logistics Ocean	20K
TCO	710K

Imported Mex to USA	Cost Estim.
Materials	630K
Opex LCC	10K
Logistics Inland	50K
Logistics Ocean	20K
TCO	710K

Imported Asia to USA	Cost Estim.
Materials	605K
Opex LCC	10K
Logistics Inland	40K
Logistics Ocean	30K
TCO	685K

Figure 9. Nacelles price comparison USA vs. Mexico vs. Asia

Central USA Mfg (KS)	Cost Estim.
Materials	270K
Opex USA	30K
Logistics Inland	20K
Logistics Ocean	20K
TCO	340K

Imported Mex to USA	Cost Estim.
Materials	210K
Opex LCC	10K
Logistics Inland	50K
Logistics Ocean	20K
TCO	290K

Figure 10. Towers price comparison USA vs. Mexico

PRICE COMPARISON				
	Blades	**Nacelles**	**Towers**	**Total**
Manufacture in USA	$499.000	$710.000	$340.000	**$1.549.000**
Manufacture in Mexico	$419.000	$710.000	$290.000	**$1.419.000**
Manufacture in Asia	--	$685.000		
% Cost Reduction	16%	4%	15%	
Total Cost Cheapest	$1.394.000			
% Cost Reduction	10,01%			

Figure 11. Towers price comparison USA vs. Mexico

The goal was to reduce the cost of SCM and logistics by a 10% at the beginning of the project, by picking the right suppliers in order to find the lowest manufacturing cost. This goal was obtained by producing the wind turbines at a price of $1,394,000, which is a 10.01% cheaper than producing in United States, which were the initial practices of the company.

5.3 Analysis Phase

The third phase, which is the Analysis Phase, focuses on understanding the root causes of the problems. This phase is essential; however, it is usually not given enough attention. Analyzing the root causes properly will lead to finding the proper solutions. In order to fulfill this phase, a Process FMEA was carried out.

5.3.1. FMEA

Failure Modes and Effects Analysis is a tool that analyzes the different potential failures on different process. In this project, the analysis was done with the possible issues that could arise with suppliers and customers based on the logistics. Once the potential failures are found, a full study has to done including the potential effects of the failure, the causes and a detection tool to fix the issues. The study analysis which ones are the most important problems to focus on, and that's where the company has to first start working on fixing those.

Logistics FMEA

SIEMENS Gamesa RENEWABLE ENERGY

Item:Wind Turbine | Prepared by: A. Ashtagi; P.Ripodas | Created: 04/06/2019
Team: LTU Master Eng. Management

Function	Potential Failure Mode	Potential Effect(s) of Failure	S	Potential Cause(s) of Failure	Preventive Actions	O	Detection Actions Cause	D	RPN
Process Element: Supplier									
Issues with Supplier	Late shipment of supplies	Delay on order	6	Issues on our communcation system and mistakes on our study of future needs	Create a chain of communication to improve all conunnications	2	Kanban	2	24
		Lost of client	10						40
	Early shipment of supplies	Too much inventory	5	Issues on our communcation system	Create a chain of communication to improve all conunnications	2	Kanban	2	20
		Change in design and inventory is too old	8	Production of parts is offset with Engineering Revolutions					32
	Defective Parts	Not being able to build parts, and delays on order	7	Problems on design and shipment	Improve shipment material	4	Buy better material and training to employees	3	84
Process Element: Customer									
Issues with Customer	Late shipment of supplies	Delay on order	6	Issues on our communcation system and mistakes on our study of future needs	Create a chain of communication to improve all conunnications	2	Kanban	2	24
		Lost of client	10						40
	Early shipment of supplies	Customer is not ready to handle the incoming orders	5	Issues on our communcation system	Create a chain of communication to improve all conunnications	2	Kanban	2	20
	Defective Parts	Not being able to build parts, and delays on order	7	Problems on design and shipment	Improve shipment material	4	Buy better material and training to employees	3	84

Figure 12. Company Organization Map

5.4 Improvement Phase

The fourth phase, which is the Improvement Phase, focuses on facing new ways to fix the problems and the outcome of the proposals. Brainstorming solutions, implementing them, and collecting data to confirm the solutions are the steps for a correct outcome of the phase. In order to fulfill this phase, a Kanban system was created.

5.4.1. Kanban

Kanban is a “visual system for managing work as it moves through a process. Kanban visualizes both the process (the workflow) and the actual work passing through that process. The goal of Kanban is to identify potential bottlenecks in your process and fix them so work can flow through it cost-effectively at an optimal speed or throughput.” The idea that we have is to create a software that would match the new projects and the needs of it with the best fits of factories that the company owns based on location and resource allocation.

Siemens Gamesa has over 50 sales offices in 39 different countries in the world, as well as 7 Service core Competence Centers. Also, there are several factories to produce Nacelles and Blades around the world as shown in the map. The Towers are always outsourced and the company does not owned factories to produce them. Figure 13, shows the organizational map of the company which shows the different manufacturing plants that the company owns for in the world. It does not show the different outsourced suppliers that the company has.

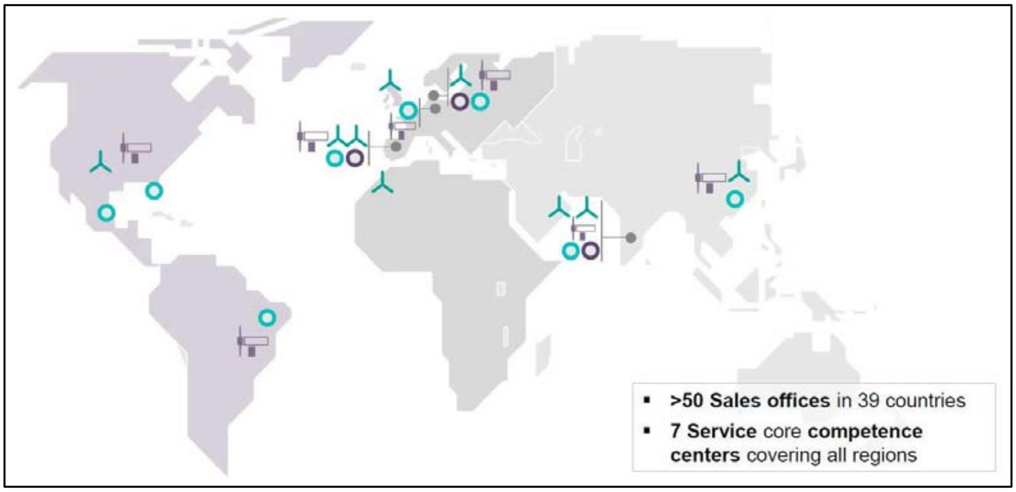

Figure 13. Company Organization Map

Siemens Gamesa has the goal to become the by 2020 the leader in the main markets. Figure 14, shows the goals for each specific market. In order to fulfill this goal, Siemens Gamesa must be a leader on efficiency practices on logistics in order to minimize the cost and maximize the outcome. A new Kanban system will be the perfect tool in order to correlate orders and production practices on each country.

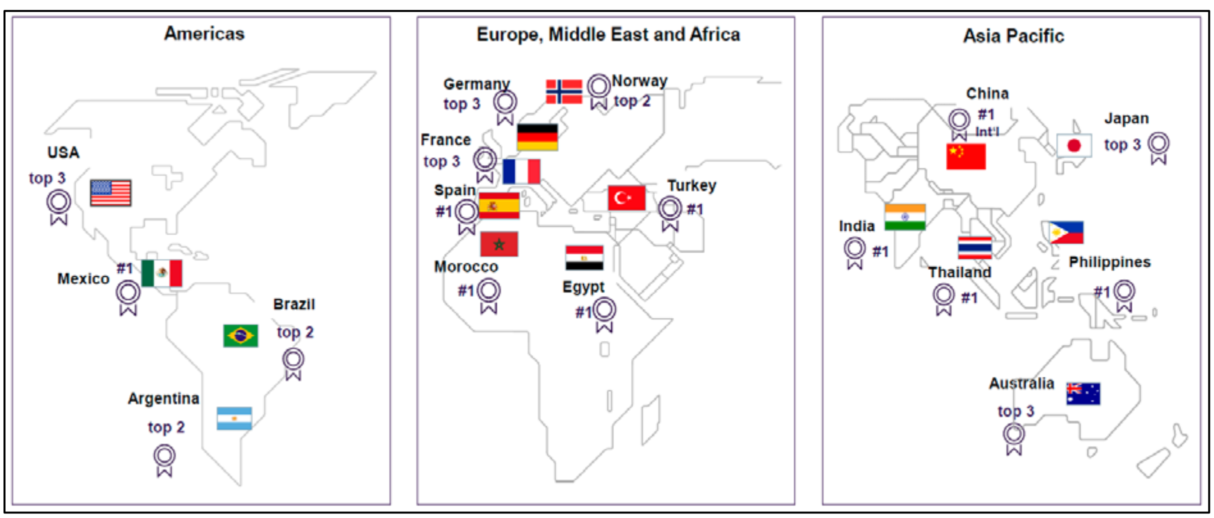

Figure 14. Business Market Map

5.5 Control Phase
The fifth phase, which is the Control Phase, focuses on ensuring that the process is properly managed and monitored. There are several other key steps such as documenting the processes, apply the same improvements into other areas, share and celebrate the success, as well as continuously improve using lean principles. In order to fulfill this phase, a Mistake Proofing Analysis and an Operating Rhythm Chart was developed.

5.5.1. Mistake Proofing
Mistake Proofing, also known as Poka Yoke, is a Japanese tool that was instated in order to identify human errors and how to mitigate them. By creating a perfect flow of the process, many human errors can be stopped, for instance by color-coding the process, or by creating a better flow on the making of the parts in the assembly line. In this project, the main processes that could lead into problems were related to late and early shipments to both suppliers and customer as well as defective parts. Figure 15, shows that thinking process that was carried out in order to fulfill this phase of the project.

Process or Function Name: Improving Supply Chain Management and Logistics in the Wind Turbine Industry with the application of Six Sigma Methodologies			**Date:** 04/10/2019
POKA YOKE			
Process	**Contact Method (Testing Characteristics)**	**Fixed-Value (Specific Number of Movements)**	**Sequence Method (Procedure)**
Late/Early Shipment of Supplies	Work different routes before analyzing best one, and getting information on borders	Have specific routes of shipment and tracking to assure perfect delivery. Understanding borders to pass products through them.	Software to detect errors on orders that do not correlate with the needs of the company
Defective Parts from Supplier	Assure full quality and inspections of different kinds at different parts of process to guarantee perfection	Quality control on every station	Set a proper line and proccedure in accordance with suppliers to have same working structure
Late/Early Shipment of Orders	Work different routes before analyzing best one, and getting information on borders	Have specific routes of shipment and tracking to assure perfect delivery. Understanding borders to pass products through them.	Software to correlate orders with status of needs of orders
Defective Parts for Customer	Different controls on the line to continuously check errors on the line	Quality control on every station	Set a proper line and proccedure in accordance with customers to have same working structure

Figure 15. Poka Yoke Chart

5.5.2. Operating Rhythm Chart
An Operating Rhythm Chart is a tool that sums up all the communication that needs to go into the perfect functioning of the company. It analyses every communication between employees, the recurrence of the communication, as well as the contents of the information. It can be seen on Figure 16, the overall review of the chart with every element included on it.

OPERATING RYTHM CHART				
WHO	**HOW**	**WHEN**	**WHAT**	**WHY**
Audiences	**Format**	**Consistency**	**Content**	**Purpose**
Board of Directors	Monthly Email Updates	Beginning of month	Report Progress, secure approvals	Maintain Board informed and New Projects Proposals
Local Directors	Weekly Meetings	End of the Week	Progress Reports	Further Decisions need to be made based on current status of projects
Engineers	Daily Emails and Meetings	Beginning of the day	Analyze previous day and Plan of Action for the day	Mantain all operations running correctly
Director of Operations in Manufacturing Lines	Weekly Meetings	End of the Week	Progress Reports	Further Decisions need to be made based on current status of projects
Engineers in Plants	Daily Emails and Meetings	Beginning of the day	Analyze previous day and Plan of Action for the day	Mantain all operations running correctly
Line Workers	Scrum Meetings	Beginning of the day	Analyze previous day and Plan of Action for the day	Analyze Quality of the production and how to improve practices
Suppliers	Daily Emails	Throughout the day	Needs of the company	Assure a proper communication for the success of the collaboration
Consumers	Daily Emails	Throughout the day	Orders Updates	Assure a proper communication for the success of the collaboration

Figure 16. Operating Rhythm Chart

6. Conclusion
The Wind Turbine Industry is not efficient when producing and shipping the product to the customer leading to higher production costs, Logistics practices and supply Chain Management are phased out compared to other methodologies

used by other industries. As a conclusion, by implementing the Six Sigma tools (Project Charter, SIPOC Diagram, Failure Modes and Effects Analysis, Kanban system, Mistake Proofing that is Poka Yoke Chart & Operating Rhythm Chart), the company will be able to improve the process of Supply Chain Management and the Logistics greatly by creating a new Kanban tool Kanban, which is a visual system for managing work flow as it moves through a process. Kanban visualizes both the process (the workflow) and the actual work passing through that process. The goal of Kanban is to identify the bottlenecks in the process and fix them so that work can flow through it cost-effectively at an optimal speed that will better correlate needs with location of resources and price of different suppliers, including shipment costs. This tool can then be fully controlled with different tools in order to assure efficiency and excellence in the delivery of the product. The project had as a goal to decrease the cost of the production of the wind turbines by 10%, which was successfully completed electing the right suppliers. Once this was completed, it is essential to control the processes and have different tools in order to do so. This was a very successful project, which analyzes better practices for a leading company in the world.

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Biographies

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Pablo Ripodas is currently a graduate student enrolled in the Masters of Engineering Management in Lawrence Technological University. He graduated from his Bachelor of Science in Mechanical Engineering with Magna Cum Laude honors. During his time as an undergraduate student, he was involved in many organizations including the foundation of various. His efforts to make an impact at Lawrence Tech provided him with many recogntions such as the Ed Donley Award (2018) as the Graduate of the Year per the Alumni Association and Student Leader of the Year (2018) per Student Government. During his senior year, he also participated on a research with collaboration of Eaton engineers as his Senior Project. The purpose for this project was to design a system that could replicate an automotive cooling system and evaluate the concept of direct contact heat exchange to recover waste heat from the automotive cooling system. His experience includes a full year internship in a top manufacturing automotive interior company worldwide. Pablo is very passionate and aims to become a great leader in this challenging and changing world. His dream is to become the CEO for an important company and be able to make an impact on other people's life.

Ahad Ali is an Associate Professor and Director of Industrial Engineering Program and Director of Smart Manufacturing and Lean Systems Research Group, A. Leon Linton Department of Mechanical, Robotics and Industrial Engineering at the Lawrence Technological University, Southfield, Michigan, USA. He earned B.S. in Mechanical Engineering from Khulna University of Engineering and Technology, Bangladesh, Masters in Systems and Engineering Management from Nanyang Technological University, Singapore and Ph.D. in Industrial Engineering from University of Wisconsin-Milwaukee. Dr. Ali was Assistant Professor in Industrial Engineering at the University of Puerto Rico - Mayaguez, Visiting Assistant Professor in Mechanical, Industrial and Manufacturing Engineering at the University of Toledo and Lecturer in Mechanical Engineering at the Bangladesh Institute of Technology, Khulna. He received an Outstanding Professor Award of the Industrial Engineering Department, University of Puerto Rico -Mayaguez, (2006-2007). He has published 50 journal and 121 conference papers. Dr Ali has conducted research projects with Chrysler, Ford, DTE Energy, New Center Stamping, Whelan Co., Delphi Automotive System, GE Medical Systems, Harley-Davidson Motor Company, International Truck and Engine Corporation (ITEC), National/Panasonic Electronics, and Rockwell Automation. His research interests include manufacturing systems modeling, simulation and optimization, intelligent scheduling and planning, artificial intelligence, predictive maintenance, e-manufacturing, and lean manufacturing. He has successfully advised seven doctoral students. Dr. Ali has involved with many international conference committees. He is serving as an Executive Director of IEOM Society International and Conference Co-Chair of the International Conference on Industrial Engineering and Operations Management and hold events in Dhaka, Kuala Lumpur, Istanbul, Bali, Dubai, Orlando, Detroit, Rabat, UK, Bogota, Paris, Washington, DC, Pretoria, Bangkok, Pilsen, Toronto, Costa Rica, Sao Paulo and Riyadh. Dr. Ali has visited 20 countries for professional events. He is a member of IEOM, INFORMS, SME and IEEE.