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A Study the Supply Chain Management and Logistics in the Wind Turbine Manufacturing

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Abstract - In this article, we discuss the issue of Supply Chain Management & Logistics in the production of wind turbines, as well as a possible solution based on Six Sigma methods. Among the tasks involved in this project was a thorough examination of current procedures at a market leader & recommendations for enhancement. The Spanish headquarters of Siemens Gamesa Renewable Energies boasts a global presence. Methods used in the American market were studied in order to make adjustments. This was accomplished by utilizing the DMAIC Process tool, which is composed of the following 5 steps: define, measure, analyze, improve, & control. After reviewing the data, it was determined that implementing a new Kanban solution for the organization globally would be beneficial in many ways, particularly in terms of improving the correlation between orders, suppliers, & resource allocation. This Kanban system would be ideal for calculating the availability and capacity of each production plant on a weekly basis & comparing these figures to the needs of the orders that need to be performed.

Keywords - Wind Turbine Manufacturing, Six Sigma, Supply Chain Management, Logistics

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INTRODUCTION

The generation of electricity from wind is the primary application of wind energy, which is the transformation of the kinetic energy of moving air into mechanical energy. Environmental wind is harnessed, and the air's kinetic energy is transformed into useful mechanical work. Various spots are chosen to maximize wind power potential. Highest wind speeds occur near the coast and out at sea. A turbine is the piece of equipment that changes mechanical energy from moving air into electrical energy. An example of a machine having blades is a turbine (spinning). When the wind blows, it helps spin these blades, which in turn spins an electromagnetic generator, which produces electricity. Once employed for pumping water, this source of energy is now more typically put to use creating electricity. It has quickly become one of the most popular sources of power. Wind power has the benefit of being a sustainable and environmentally friendly alternative to traditional energy sources. Many obstacles stand in the way of the widespread adoption of wind power. Both the logistics & supply chain management teams are struggling under the weight of poor leadership.

The wind power solutions provided by Siemens Gamesa Renewable Energies are among the most sought after in the global market. They have approximately 89 GW of installed capacity and 23,000 employees, making them a major player and an industry pioneer in the renewable energy field.

When it comes to manufacturing, Siemens Gamesa has one of the most comprehensive product lines available, including everything from offshore to onshore technology and service. In 2017, Siemens Wind Power and Gamesa merged to form the current company. With the goal of becoming the most prominent producer of renewable energy worldwide, thereby accelerating the shift toward a more sustainable global economy.

Onshore Wind Power: Their track record & technological prowess allow them to offer cutting-edge solutions with geared technology, such as two platforms with a modular design, to ensure the long-term success of onshore wind generating projects. They have a global presence, but their operations are always locally oriented, and the technology they use is always tailored to the specifics of the area in which it is being used.

Offshore Wind Power: Offshore wind power plant developers aim to maximize your project's potential while reducing your energy costs. Siemens Gamesa has been working in the offshore industry for nearly three decades, and when you choose them as your offshore partner, they will make available to you their mature value chain & wide inventive capabilities.

Some of the challenges in this turbine production can be traced back to the logistics team & SCM.

Figure 1. Onshore Windmill

Figure 2. Offshore Windmill

PROBLEM STATEMENT

The Problem Statement: "Wind Turbine Manufacture is not sufficient while creating & distributing the finished product to the client, resulting in higher production costs." When compared to approaches employed in other sectors, SCM & Logistics methods are being phased out."

OBJECTIVES

- To Integrating a small number of Six Sigma Techniques into a rapidly expanding manufacturing operation.
- To choose the right suppliers for Wind Turbine Production's SCM & Logistics to cut costs by 10%.
- To suggestions for Siemens Gamesa Renewable Energy's (SGRE) new initiatives.

METHODOLOGY

The group's initial case study flowchart is depicted in Figure 3 to demonstrate their planned procedures for completing the assignment. The project can be broken down into the following five stages: In the first stage, "Project Analysis," we try to learn as much as possible about the mission at hand and then select the most suitable solution. Phase 2 of the decision making process involved reaching a consensus between group members and gaining approval from the instructor. After the manufacturing decision was made, the next phase, the Project Charter, established the Problem Statement & Goals. And last, in Phases 4 & 5, we looked at the DMAIC Process & Tools that we'd be using to implement Six Sigma techniques into this production setting. This project's timetable and scope were laid out in order to bring about its realization.

The project's scope was modified & implemented into its current iteration, which consists of the following stages:

- Learn about existing procedures by doing in-depth research on Wind Turbine Manufacturers & Six Sigma implementations.
- Conduct an in-depth examination of the production process, with a focus on the industry leader Siemens Gamesa Renewable Energy (SGRE).
- To learn more about the company's methods, interview current & past workers.
- Use Six Sigma to revamp the company's present methods for SCM & Logistics.
- Create an analysis, results, & suggestions section for the research paper.

The DMAIC Process is widely recognized as one of Six Sigma's most prominent methods, as it examines the issue at hand, identifies potential solutions, and establishes ongoing monitoring & control. The use of this technology is crucial for businesses to ensure their continued success. Define, measure, analyze, enhance, & control is the DMAIC method's five-step process. Each stage is broken down and examined.

Explain: The source of the issue is identified & recognized. The goal of a project charter is to outline the parameters within which the system will be enhanced. Comprehensive research & input from clients define the big vision of any organization. This side explores the essentials for satisfying the consumer.

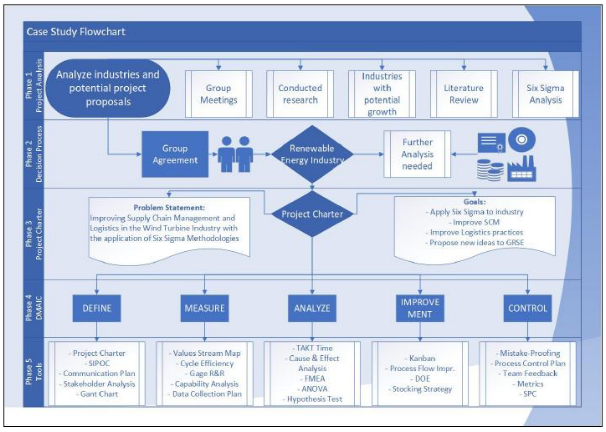

Figure 3. Case Study Flowchart

Measure: In order to assess the efficacy of a system, a process map must be created. In this stage, we evaluate all available data in search of a method that will allow us to deliver results that exceed our customers' expectations. To evaluate the severity of an issue, a fishbone diagram is drawn.

Analyze: The source of the issue can then be investigated further. In order to fix the issue in the system, analysis is performed. Tools from the Six Sigma methodology are utilized to focus the source of the problem.

Improve: This procedure aids in eradicating the underlying problem. To better the system, we employ a method called design of experiments (DOE). Adapting to changing consumer demands requires a commitment to continuous process improvement.

Control: Here, the process's future performance is controlled. The whole operation is monitored and managed with the help of Statistical Process Control (SPC). To regulate the new, enhanced system, a set of controls has been established.

Applications of DMAIC Tools

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

Define Phase

In the first stage, known as the Define Phase, the main goals are to establish a clear vision for the project & identify the fundamental requirements for completing it. Methods include investigating the source of the issue, researching the manufacture of your goods, and surveying and assessing potential clients & distributors. In order to execute new strategies and arrive at a solution, you must first have a thorough familiarity with your firm and how it operates. A Project Charter and SIPOC Diagram were created to complete this stage.

Project Charter

To begin, we analyzed the issue at hand and considered some potential solutions. Creating a project charter was the first step, and it helped clarify the project's purpose, as well as the steps that would be taken to achieve it, including the expected outcomes and schedule. Detailed in Figure 2 are the Problem Statement, Goal Statement, Scope, Outputs, Timeline, & Team Members. In the first step, we defined the problem, and in the second, we developed a strategy to solve it. It was agreed that two process engineers would complete the work in the next three months.

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

SIPOC Diagram

The product development process was broken down into its component parts using a SIPOC diagram. This device identifies the company's inputs & outputs, breaks down the manufacturing process, and maps out its distribution network. All aspects of the project's execution can be analyzed with the use of this handy tool. Once this is grasped, subsequent actions can be performed to realize the project's objectives.

Measure Phase

In the Measure Phase, the project's processes & company's current methods of operation are examined in detail. Solving the project's problems requires first doing a thorough analysis of the status quo, which will shed light on how things are done & serve as a benchmark for future improvements. A Network Map was drawn up to finish this section.

Network Map

The Network Map is a visual representation of the connections between the company and its many customers & suppliers. Siemens Gamesa Renewable Energies has four distinct business verticals in the USA, as shown in Fig. 4. To cover the entire country, it is split up.

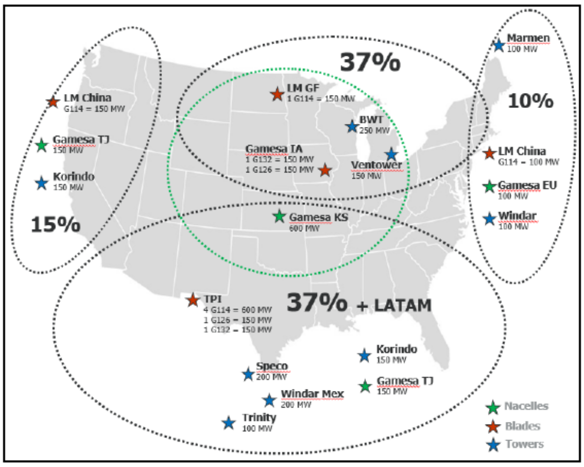

Figure 6. United States Market Opportunities & Suppliers

Figure 7 below depicts maps of various industrial facilities in the USA, Mexico, & Canada, as well as suppliers from other countries outside of North America, such as Spain & Korea. It sources not only from its own production facilities but also from third-party manufacturers of essential components.

Although the majority of blades are manufactured in China, several American manufacturers do exist. Since the corporation does not have its own towers production facilities, it must rely on third-party vendors for all of its tower needs. Most nacelles are produced in Spanish factories, however other American manufacturers also supply this part. The production cost & logistics cost must be known before deciding on a supplier.

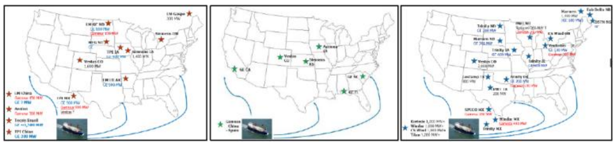

Figure 7. Suppliers for Blades, Nacelles, and Towers, respectively, in USA

Suppliers Election

In order to determine the most cost-effective configuration of blades, nacelles, & towers for mass producing wind turbines, a comprehensive assessment of suppliers including production cost & logistics cost was done. Installation of wind turbines in the U.s was analyzed, with products sourced from a variety of countries including the United States, Mexico, & Asia because these are the most competitive markets for producing for the United States. Figure 8 shows that compared to producing blades in the United States, manufacturing them in Mexico results in a savings of $90K; when logistics are factored in, the total cost is even lower. Producing in Mexico is 16% cheaper than producing in the United States.

Central USA Mfg (KS)	Cost Estim.	Imported Mex to USA	Cost Estim.
Materials	429K	Materials	339K
Opex USA	30K	Opex LCC	10K
Logistics Inland	20K	Logistics Inland	50K
Logistics Ocean	20K	Logistics Ocean	20K
TCO	499K	TCO	419K

Figure 8. Blades price comparison USA vs. Mexico

Siemens Gamesa compared the costs of producing the nacelles in the United States, Mexico, & Asia before making their final decision. Figure 9 shows that the cost of manufacturing nacelles in Asia is 4% lower than in both Mexico & United States. Finally, a comparison of the towers market in Mexico & United States revealed that Mexico's costs were 15% lower than the United States', because to a $60K save in raw materials.

Central USA Mfg (KS)	Cost Estim.	Imported Mex to USA	Cost Estim.	Imported Asia to USA	Cost Estim.
Materials	630K	Materials	630K	Materials	605K
Opex USA	30K	Opex LCC	10K	Opex LCC	10K
Logistics Inland	20K	Logistics Inland	50K	Logistics Inland	40K
Logistics Ocean	20K	Logistics Ocean	20K	Logistics Ocean	30K
TCO	710K	TCO	710K	TCO	685K

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

Central USA Mfg (KS)	Cost Estim.	Imported Mex to USA	Cost Estim.
Materials	270K	Materials	210K
Opex USA	30K	Opex LCC	10K
Logistics Inland	20K	Logistics Inland	50K
Logistics Ocean	20K	Logistics Ocean	20K
TCO	340K	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

At the outset of the project, we wanted to select the most cost-effective manufacturers & SCM partners so that we could cut our expenses by 10%. The target was reached by manufacturing the wind turbines for $1,394,000, or 10.01 percent less than the company's original practice of manufacturing in the United States.

Analysis Phase

In the third stage, known as Analysis, the problem's origins are investigated. Though crucial, this step is rarely given the full focus it deserves. The right answers can be found by doing a thorough analysis of the underlying issues. A Process FMEA was performed to complete this stage.

The FMEA, or Failure Modes and Effects Analysis, is a method for assessing the impact of potential problems with a process. Potential logistical problems with suppliers & customers were analyzed in this project. Once possible failures are identified, a thorough investigation into their origins, consequences, & detection tool to address the problems is required. Based on the study's findings, the organization should prioritize addressing the most pressing issues first.

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 comunnications	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 comunnications	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 comunnications	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 comunnications	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

Improvement Phase

The Improvement Phase, the fourth, examines potential solutions to the issues identified in the previous phases & results of the proposals made. In order to reach a successful conclusion to this stage, it is necessary to first generate ideas for potential solutions, then put those ideas into action, and last, to collect data to verify the effectiveness of the solutions. A Kanban system was developed to help with this stage.

Kanban

A "visual approach for managing work as it progresses through a process," Kanban is a tool for keeping track of tasks as they are completed. Kanban is a method of visualizing not only the workflow but also the process itself. With Kanban, you can optimize the speed & efficiency with which work moves through your system at the lowest possible cost. We propose developing a program to determine which of the company's factories, given their location and resource capacities, are best suited to handle each new project and its requirements.

More than 50 sales offices and 7 Service core Competence Centers are spread throughout 39 countries for Siemens Gamesa. As can be seen from the map, there are also several locations where Nacelles and Blades are manufactured. The Towers are never manufactured in-house but rather are contracted out to outside vendors. Manufacturers owned by the corporation are depicted on an organizational map (see Figure 13) across the globe. Not all of the company's contracted vendors are reflected.

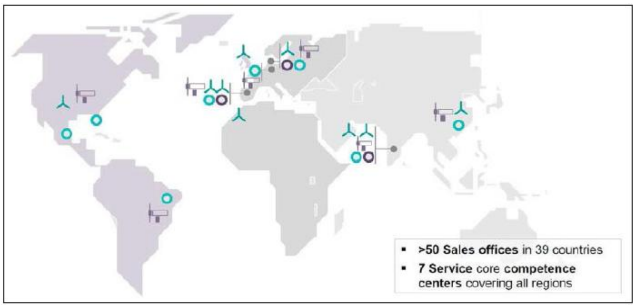

Figure 13. Company Organization Map

Siemens Gamesa plans to establish itself as a market leader by 2020. Specific market objectives are depicted in Figure 14. To achieve this objective, Siemens Gamesa will need to take the lead in developing and implementing logistics efficiency strategies that reduce costs while increasing output. Orders & production methods across countries can be correlated with the use of a brand-new Kanban system.

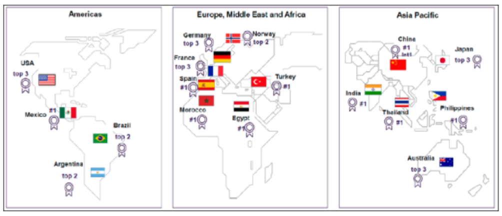

Figure 14. Business Market Map

The fifth stage, "Control," is dedicated to checking sure everything is under control or being monitored thoroughly. In addition to this, it is essential to keep track of the processes, replicate the gains in other areas, spread the good news, and revel in the fruits of your labor. A Mistake Proofing Analysis & Flowchart of Normal Operations were created to help with this step.

Mistake Proofing

Poka Yoke (also called as Mistake Proofing) is a Japanese technology for detecting and reducing the effects of human error. Many human mistakes can be avoided by establishing a smooth process flow, such as by the use of color coding or by improving the assembly line's method of producing individual parts. There were a few key processes that may cause issues in this project, and they all had to do with deliveries: being either too late or too early for the supplier or the customer, or including faulty components. The steps used to complete this part of the project are depicted in Figure 15.

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 procedure 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 procedure in accordance with customers to have same working structure

Figure 15. Poka Yoke Chart

Operating Rhythm Chart

An Operating Rhythm Chart is a useful instrument for summarizing all the necessary communication for smooth business operations. It examines the frequency and content of all internal company communications. Figure 16 provides a view of the entire diagram.

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

CONCLUSION

Logistics methods & SCM are being phased out in the wind turbine industry, leading to higher manufacturing costs & inefficient product delivery. In conclusion, the company will be able to greatly improve SCM & Logistics process by developing a new Kanban tool by utilizing the Six Sigma tools (Project Charter, SIPOC Diagram, FMEA, Kanban system, Mistake Proofing that is Poka Yoke Chart & Operating Rhythm Chart). Kanban is a visual approach for monitoring and controlling the flow of work in a production line. Kanban is a method of visualizing not only the workflow but also the process itself. With Kanban, you can better link needs with the location of resources & pricing of multiple suppliers, including shipping costs, all while maintaining an efficient work flow & reducing costs. To ensure efficiency & perfection in product delivery, this instrument can be fully controlled by a variety of other tools. The project's aim was to reduce wind turbine manufacture costs by 10%, and that goal was met through careful supplier selection. Once this is done, other tools will be needed for process control. This study, which examines best practices for a global leader, was a huge success.

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