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Risk variables in wind power supply chain

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Abstract

The demand of global investments in renewable energy projects requires a deep understanding of various risks faced by the utility and project developers. This paper analyzes risk variables between different actors of supply chain and identifies problems encountered in wind power projects through public procurement procedure. The authors were involved in a wind power project obtained through a structured process achieved in stages: research, development and final implementation of a wind power. The analysis of the issues reported by literature combined with the application of the analytic hierarchy process (AHP) tries to eliminate risk factors in wind power supply chain.

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1. Introduction

Wind power is no longer a simple idea, it has developed into a major and dependable source of energy. The key to success of the wind power industry is to construct the supply chain. The financial crisis has led to a decrease in demand in the short term, but long-term demand will likely rebound due government policies that support renewable energy, the recovery of the credit markets, and the return to the market of tax equity investors. There are several impediments to further wide scale deployment of wind turbines, but manufacturers are moving ahead with planned investments in production in the expectation that the market will grow in the long term. Wind power developers have to stay focus in identifying suppliers that can provide special equipment and quality material on time. Certain key component in completion of the project should be taken into account such as special technology, special teams that have a good knowledge in this industry, choosing the right spot where the wind farms will be located. From an economic standpoint, the development of wind facilities and use of wind

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energy has a lot to offer. The benefits of wind power can solve the issue of growing power consumption with insufficient distribution facilities. Wind power bring not only economic benefits but also help to protect the environment that is becoming increasingly precarious due to globalization (Blanco, 2009). The environment will be the first thing to benefit from a shift to wind power. The amount of global warming gases that can potentially be reduced is tremendous. As wind technology improves, more can be done to learn about the best way to incorporate wind turbines into the environment, with little to no negative impact. Researchers must turn their attention on how enterprises have started to develop their supply chain for assembling wind turbines and install at the site place where they function. This involves a good timing for the whole collaborative supply chain so that the actors could eliminate encountered risk variables that can provide failure of project. Wind turbine supply chain consists of a combination of in-house production and outsourcing with many suppliers strongly positioned in the supply chain. Most manufacturing want to localize important pieces of the supply chain in order to reduce transportation costs and logistical difficulties, avoid import duties, and mitigate the risks associated with currency fluctuations (Sun, Matsui & Yin, 2012). Because of the multimodal nature of most wind turbine shipments, control over the process is important. Shippers, consignees, and transportation and logistics partners are all engaged in the planning and routing. It is critical that transportation concerns are an integral part of project planning from its earliest stages. The booming demand for wind energy projects puts pressure on the supply chain. The rapid growth in global demand in the last few years strained the wind turbine supply chain. In response, some actors expanded and diversified their supply chain while others enhanced in-house production capabilities through investments in new manufacturing facilities or purchases of major component suppliers.

The objective of this paper is trying to present from the perspective of a public procurement risk factors encountered in wind power project and propose a strategy for improving relationships between project developers, supply chain actors, manufacturers, all involved in successful completion of a project. The relationships between manufacturers and their component suppliers have become increasingly crucial, and have come under increasing stress in the past years as soaring demand has required faster ramp-up time, larger investments and greater agility to capture value in a rapidly growing sector. Supply chain issues have dictated delivery capabilities, product strategies and pricing for every component. Manufacturers have sought to strike the most sustainable, competitive balance for full component outsourcing to fit their wind turbine designs (Karuranga, Frayret & D' Amours, 2008).

2. Wind Power project developers and supply chain collaboration issues

Collaboration in supply chain could be define as being the cooperation between partners sharing the greater information in order to avoid interruptions in logistics flows. The buyer- supplier relationship must be characterized by trust, commitment and long term time horizons. The process of collaboration involves a good partnership amongst supply chain partners through exchange of information, resources and allocation of specific roles in order to enable mutual risk management. Collaboration is based on a mutual objective, and is a process in which organizations will participate only if it contribute to their own survival. Collaboration is focused on relationship between all supply chain members and it requires the availability of integrated information and high level of motivation and trust. Regardless of the way in which researchers are studying wind power supply chain, it is never easy to predict its evolution, nor the context in which it change and develops.

Forms of change are varied and are becoming faster. This incorporates uncertainty like a parameter for motivating project developers and represents an issue which has a new dimension and can limit the vulnerability of supply chain (Karuranga, Frayret & D' Amours, 2008). But working in an environment where uncertainty is a constant stimulant to develop operating rules, methods, tools and adequate mechanisms can provide rather an active coordination in a collective manner than an isolation made only to improve supply chain, respectively, resources and customer satisfaction or over time reducing risk (Chopra & Sodhi, 2004).

According to Chopra and Sodhi potential risk factors that may be the cause of crisis in supply chain are categorized in 9 groups: (1) disruptions of natural disasters, terrorism, war, (2) delays and inflexibility of supply source, (3) systems information infrastructure breakdown, (4) inaccurate forecast and bullwhip effect, (5)

intellectual property, (6) procurement and exchange rate risk, (7) receivables and number of customers, (8) inventory holding cost, demand and supply uncertainty, (9) capacity. Through structured discussions and after an intensive searching in the present literature research team has identified 13 risk factors most present in the recently journals and articles in supply chain management (Chopra & Sodhi, 2004). Main objectives analyzed include risk factors in supply chain encountered in *equipment manufacturers, service suppliers, key component manufacturers, procurement and environment.* Managing supply chain risks are complicated because sometime risks are often interconnected. Disruption caused in supply chain it refers to the risks which affect the movement of efficient process of information, materials and products among different parts of the supply chain.

Divulging vulnerabilities or reporting an incident can have a negative reaction from the stockholders. Supply chain managers should be taking active measures to reduce future disruption, their primary role is to make the project successful.

A challenge for wind power project developers are the obstacles that they encounter in their way when implementing product specifications. They also must analyze all the situations that could jeopardize the project.

Most common situations encountered by developers in the wind power project were:

- Developing a project plan, which includes defining project goals, how task and objectives will be achieved
- What resources are need, and associating budgets and timelines for completion, implementing the project plan, and ensure that the plan is being managed according to the project.
- The process of obtaining necessary permits and approvals is laborious and time-consuming and construction works sometimes can be atypical, hampered by placement location without power supply and water. Weather conditions also can influence the development work in the field.
- The analysis and research of the cost reduction possibilities, through diversification and simplification of the equipping, multiple usages of the components
- The necessary financial funds, various reorganizations and restructurings are necessary to complete the project in time and achieve the desired goals.
- It can been difficult finding companies that have the ability to achieve some different materials elements of high precision. In addition the selection of suppliers must be transparent, fair and give equal opportunities to all potential suppliers, but at the same time ensuring that high standards of equipment as designed precision

From the perspective of supply chain we try to identify most common problems encountered by project developers in choosing components from wind turbines suppliers.

Taking each of the main components of a turbine in turn it is possible to identify where bottlenecks are occurring and how these are likely to be resolved.

- *Blades*. A crucial component requiring sophisticated production techniques, global supply is dominated by independent blade maker.
- *Gearboxes*. Most turbine manufacturers have traditionally outsourced their gearboxes to a shortlist of six or seven independent companies. Gearboxes are nonetheless the component for which most shortages of supply have occurred: the limited number of production facilities tailored to the wind market, a shortage of large bearings and a bottleneck caused by unexpected repairs to operating gearboxes, including the replacement of bearings.
- *Bearings*. There are particular shortages of large bearings used in gearboxes and the main shaft. One reason for the shortage is that the boom in the wind industry has coincided with a generally increased level of activity across all heavy industry. For bearing manufacturers wind represents only a small fraction of their business.
- *Generators*. Supplied to the wind industry by a number of large companies and dedicated suppliers. No shortage of supply.
- *Cast iron and forged components*. This includes the main frames used to support the rotor hub and nacelle, the hubs themselves and the main shaft which links the rotor to the gearbox. The market here has again been affected by the high level of activity in the heavy industry sector, with increased demand for both forged steel and cast iron.

- *Towers*. Most turbine towers are made of rolled steel, although some manufacturers are turning increasingly to concrete as a cheaper alternative. Although manufacturing a wind turbine tower is an increasingly sophisticated process, the basic expertise is more widely available than for other components. It therefore often makes sense for suppliers to source towers locally to the eventual project.

Making turbine by the supplier requires the execution of a sequential chain of operations and time duration (this involves realization of matrix, metal inserts, walls palette, pasting, filling with foam, static load testing). Some operations can be meticulous and it is possible that the supplier has no experience or specific technology of wind turbines. Improper organization of tasks and supply malfunction turbine can cause delays in delivery components for implementing the project. These issues are closely related, because behaviour of the actors in supply chain can have a direct impact on the risks they face. This refers to risks affecting the smooth running of information processes, materials and products between different parts of the supply chain within manufacturers and other suppliers (Sun, Matsui & Yin, 2012). The most difficult situation for project developers in implementation of the wind power project is the fact that when they purchase components through public procurement. For public procurement project managers must select those suppliers who fulfils all the requirements of product specifications.

Application of Analytic Hierarchy Process (AHP) method can be used to detect which is the most common risk in choosing a supplier in case of his contracting was made through public procurement and assessing these risk around the five alternative: *Transportation and on-site assembling and installation, Price, availability and quality of raw materials*, *Technology and machinery investment, Manufacturing of mechanical components, Fabrication design, test of electronic devices*. Through structured discussions following an action research approach the research team has identified risk variables most present in the recently journals and articles in supply chain management. The analytic hierarchy process (AHP) methodology was then used to formulate a decision model for evaluating the importance of each risk variables and then ultimate determinate what is the alternative that is most predictable to risk and can harm a good implementation of the project.

3. Research methodology

3.1. Application of Analytic Hierarchy Process

The application of analytic hierarchy process has attracted the interest of many researchers mainly to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The multi-criteria programming made through the use of the analytic hierarchy process a technique for decision making in complex environments where many variables or criteria are considered in the prioritization and selection of alternatives or projects (Triantaphyllou & Mann, 1995).

The comparison between two elements using AHP can be done in different ways. However, the relative importance scale between two alternatives suggested by Saaty is the most widely used. Attributing values that vary from 1 to 9, the scale determines the relative importance of an alternative when compared to another alternative (Schoenherr, Tummala & Harrison, 2008).

Usually, AHP is being employed with the following four steps:

- Elaborate the decision hierarchy: the decision is decomposed into its independent elements (Fig. 1.);
- Determine the importance of attributes and sub-attributes: pairs of attributes are evaluated on a 9 point scale (Table 1);
- Evaluate the performance of each alternative (Table 3);
- Control the consistency of the subjective evaluations.

Table 1. Saaty Scale of Relative Importance (Saaty, 2005)

Numerical value	Verbal meaning for risk factor evaluation	Verbal meaning for alternative evaluation
1	Equally important	Equally preferred
2	Equally to moderately more important	Equally to moderately preferred
3	Moderately more important	Moderately preferred
4	Moderately to strongly more important	Moderately to strongly preferred
5	Strongly more important	Strongly preferred
6	Strongly to very strongly more important	Strongly to very strongly preferred
7	Very strongly more important	Very strongly preferred
8	Very strongly to extremely more important	Very strongly to extremely preferred
9	Extremely more important	Extremely preferred

When all the comparisons has been made, and the relative weights between each one of the criteria has been evaluate and establish, the numerical probability of each alternative is calculated. The probability determines that the alternative has to fulfill the expected goal. The higher the probability, the better chances the alternative has to satisfy the final goal of the presented problem. The useful of AHP is especially important when uncertain aspects need to be assessed.

4. Case Study: Components public procurement- delay implementation in wind power

The biggest challenge of the project analyzed was financing the project from funds, money allocated for research projects, which has generate several risk variables. The necessary financial funds came late due to delayed reimbursements, various reorganizations and restructurings was necessary to complete the project in time and to achieve the desired goals. This constraint assume that the project implementation has to be done through public procurement procedure therefore project developers were unable to work with specialized suppliers because of the difficulties imposed by the product specification, and their selection was done in terms of risk, a risk which may involve malfunctions in development and final implementation of the project.

To illustrate the difficulties that project developers in wind power encounter in implementing a project through public procurement procedure we considered necessary to present a case which describes in detail the problems that block on time the development of activities. If the components supplier it is selected by public procurement procedure, by offer request type, this may delay implementation of the project, as this procedure can take 3-4 weeks in case there are no appeals. Appeals may extend this period or may cancel the entire procedure and this involves the risk that the entire procedure have to be restarted from the beginning (Vagstad, 1995). Also it is a risk that the bidders not be present, given the specialization needed to achieve the required product: mechanic requirements, technologic equipment and electronic devices. Some operations can be meticulous and it is possible that the supplier has no experience or specific technology to achieve special components using quality materials and new technologies to operate equipment. Finding suppliers that have the capability of performing specialized parts can also often be difficult due to the particularly designed equipment. In addition the selection of suppliers must be transparent, fair and give equal opportunities to all potential suppliers, but at the same time ensuring that high standards of equipment as designed precision. From here it is necessity to realize specifications extremely sharp and detailed. Another problem encountered represents the way in which parts sent from the supplier arrive in safe conditions at wind turbines site location. Due to the size of wind turbines components, transportation can be a difficulty in absence of special machines or they may break due to various risk factors produced during movement.

5. Application methodology of AHP

The decision hierarchy is a graphical representation of the decision goal, the main objectives, the risk factors (attributes), and the alternatives. This hierarchic frame and decomposition represent a succinct summary of the decision problem and for clarity of the presentation the links to and from risk factors and alternatives have been

omitted in the representation (Fig. 1.). This part demonstrate how AHP can be used to assess risk factors and alternatives as part of the framework to facilitate and to support project developers to stay focused in eliminate risk barriers for choosing a supplier in case of his contracting was made through public procurement.

Fig. 1. Framework for assessing risk factors in wind power supply chain

While the results provided in Fig. 1 offer interesting and useful information, the main goal of the AHP evaluation was to determine which alternative can produce a high risk, from the part of the supplier contracted through public procurement, for the research team to identify maximum sources of risk in order to achieve the final project implementation in safety conditions. A formal data collection process was necessary for the evaluation of the risk factors. For ensures that data gathered are defined and accurate the research team analyzed the present literature (Blanco, 2009; Chopra & Sodhi, 2004; Schoenherr, Tummala & Harrison, 2008; Archer & Jacobson, 2005) and then based on valid arguments of all recent articles in wind power supply chain, risk factors identified in the experimented reality of project were evaluated using matrices on 9 point scale (Triantaphyllou & Mann, 1995).

Table 2 Final weight of risk factors

Risk factor	Overall weight
Transportation risk	0.147
Demand risk	0.137
Technology risk	0.124
Receivable risk	0.084
Disruption risk	0.080
Logistic risk	0.074
Material quality risk	0.068
Outsourcing risk	0.062
Construction risk	0.060
Delay risk	0.059
Man-made risk	0.044
Guaranty risk	0.029
Order fulfilment risk	0.023
Total all weights	1.000

To determine the relative importance of the risk factors the research team evaluated pairs of these factors (attributes) on a 9 point scale (Table 1.), which is more reliable than an evaluation of all criteria or alternatives at once. Overall, 26 pairwise comparisons were conducted and the final weight for each risk factor corresponding were represented. Each risk factor representing its relative importance, is provided in Table 2 final weight of risk factors identified. The results presented in Table 2 highlights the fact that in order to reduce the blockage in supply chain it is important to include an in-depth analysis of all operations that provides a better knowledge about *transportation risk* (0.147) and *demand risk* (0.137) operations involved in managing the flow of inventories from supplier to end users or consumers. *Technology risk* (0.124) can influence smooth running of goods creating transportation issues, for that cooperation have to minimize accidents in supply chain and ensure getting goods safety to and from destinations. Most important aspect in this category was sub-technological interfacing of different engineering fields: mechanical sub-projects, electronic sub-projects and sub-projects of automatics.

The evaluation of the 5 alternatives (the third level of Fig. 1.) was conducted in a similar way as the comparison among risk factors. The research team identified 13 risk variables most present in the literature and 5 alternatives used to detect issues that have predictability to put obstacle in choosing a supplier. Matrices were created with the rows and columns being labeled with the 5 alternatives. A modified 9 points scale (Table 1) was used to make the 10 *pairwise* comparisons per matrix, resulting in total 130 evaluations.

The final weights of alternatives across risk factors (Table 3) provide information about the relative performance of the 5 alternatives across each risk factor, higher values signify more favorable relative performance. According to a total number of 156 *pairwise comparisons* being conducted, 26 comparisons to develop the weights for the risk factors, 130 comparisons to develop the weights for each alternatives performance relative to the risk factors. The major manifestations of supply chain system in this case include Bullwhip effect, break of supply, increase cost and energy crisis which cause major delays, seriously affecting the timing of project implementation to the final level of testing and stabilization. When the crisis is transmitting on an entire chain, the harms and negative influences will be obvious, and therefore, analyze the causes of supply chain crisis in details will take some time to repair the damages (Liu & Wang, 2011).

To obtain final evaluation of alternatives has been achieved assessing all risk factors according to the 5 alternatives (Table 3). As an example: construction risk (0.060) multiplied by the alternative construction risk across *Transportation and on-site assembling and installation* (0353), *Price, availability and quality of raw materials* (0104), *Technology and machinery investment* (0.180) *Manufacturing of mechanical components* (0224), *Fabrication design, test of electronic devices* (0137). The result will be gather (vertical columns) to get the outcome of each alternative (Table 4).

Table 3 Final weights of alternatives across risk factors

Risk factor	Alternatives				
	Transportation and on-site assembling and installation	Price, availability and quality of raw materials	Technology and machinery investment	Manufacturing of mechanical components	Fabrication design, test of electronic devices
Construction risk	0.353	0.104	0.180	0.224	0.137
Receivable risk	0.312	0.094	0.194	0.208	0.190
Guaranty risk	0.322	0.244	0.140	0.185	0.106
Order fulfilment risk	0.208	0.194	0.190	0.094	0.312
Logistic risk	0.322	0.140	0.106	0.185	0.244
Delay risk	0.251	0.241	0.209	0.156	0.141
Technology risk	0.295	0.147	0.182	0.189	0.147
Outsourcing risk	0.179	0.209	0.211	0.249	0.149
Material quality risk	0.214	0.242	0.210	0.142	0.189
Demand risk	0.244	0.153	0.190	0.196	0.214
Transportation risk	0.314	0.194	0.194	0.102	0.194
Disruption risk	0.205	0.258	0.246	0.099	0.189
Man-made risk	0.198	0.200	0.187	0.191	0.222

The final results presented in Table 4 demonstrate that most of the risk problems that developers encounter are in *Transportation and on-site assembling and installation*. It is a challenge for project developers to manage transportation risk. This fact demonstrate that cooperation between project developers and components suppliers have to minimize accidents and ensure safety getting goods to and from destinations. Transportation becomes an issue when the project is expand or it is establish a site where is built not a good road. Moving or re-locating costly and oversized wind turbines or blades from the manufacturer, requires experienced shippers who have a dedicated focus on wind transportation

Table 4 Final weights of alternatives in wind power supply chain

Alternative	Weight
Transportation and on-site assembling and installation	0.240
Technology and machinery investment	0.183
Fabrication design, test of electronic devices	0.179
Price, availability and quality of raw materials	0.170
Manufacturing of mechanical components	0.161
Total all weights	1.000

6. Conclusions

The model and the study case presented have implications to academic as well as to policy makers and practitioners in the field of supply chain and project implementation in order to be more efficient and effective. Project managers in wind power can prevent potential blockage in supply chain if they carefully choose their collaborators, without being constrained by the requirements that public procurement procedure has. Despite the above difficulties it is useful to re-examine public procurement for wind power project, so that the project developers respect the deadlines in time and fulfill requirements for an optimal function of wind power. The AHP methodology utilized demonstrate that risk variables can be asses as part of the framework to facilitate and support project developers to identify the main blockage in implementation of the project. The model applied provide immediate responses therefore assessing all risk factors around 5 alternatives allow project developers to examine the relationships between suppliers and manufacturers, between points of risks and value and what these parties may offer in term of risk within the context of transportation and technology for a future project. All the activities presented in the project are basically decision process and all decision taken by developers may include some risk. The last part illustrates the efficient use of the application approach in wind power supply chain and can provides immediate answers for future project managers in finding a good linkage between suppliers for improving supply chain collaboration in wind power.

The wind power project in present improves overall performance, does not ensure only economic benefits by facilitating the movement of energy but also protect and help the environment.

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