

GE Energy Wind Turbine Supply Chain Modeling

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GE Energy



Outline

- 1 Introduction
- 2 Optimization Model
 - Objective Function
 - Constraints
- 3 Results
- 4 Conclusions
 - Summary of Findings
 - Future Possibilities



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Introduction

Project Scope

- GE is one of the world's leading wind turbine suppliers with over 8,400 worldwide wind turbine installations comprising more than 11,300 MW of capacity.
- GE assembles 1.5 to 3.6 MW complexes worldwide.
- Customers are almost exclusively utility companies.
- As of last year, GE Wind Energy is a \$2-2.5B enterprise per year.



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- Need a strategic tool to bridge the gap between wind turbine supply and demand.
- Optimization engine to automate assignments.
- Implications: database and GUI design to integrate business intelligence and optimal resource allocation.
- Adaptive interface to contend supply chain network uncertainties.



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Wind Turbine

Turbine



Hub



GE Energy



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Objective Function

$$\text{Min: } z = \text{TotalTransportationCosts}_{s,w,p} + \text{TotalLDCosts}_p$$

where

$$\text{TotalTransportationCosts}_{s,w,p} = \sum_{s \in \text{Supplier}} \sum_{w \in \text{Week}} \sum_{p \in \text{Project}} \text{Supply}_{s,w,p} \cdot \text{TransportationCost}_{s,p}$$

and

$$\text{TotalLDCost}_p = \sum_{p \in \text{Project}} \text{LDCost}_p$$

for supplier s , week w , and project p .

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Constraints

Net Inventory Constraint

$$\begin{aligned} \text{ExcessNetInventory}_{p,w,c} - \text{NetInventoryShortage}_{p,w,c} = \\ \text{ExcessNetInventory}_{p,w-1,c} - \text{NetInventoryShortage}_{p,w-1,c} + \\ \text{ArrivingInventory}_{p,w,c} - \text{Demand}_{p,w} \end{aligned}$$



Quantity Arriving at Customer Base p at Week w

$$\text{ArrivingInventory}_{p,w,c} = \sum_{s \in \text{Supplier}} \tau_{s,p,w}$$


where

$$\tau_{s,p,w} = \begin{cases} \text{Supply}_{s,w - \text{LeadTime}_{s,p,p}}, & \text{if } w - \text{LeadTime}_{s,p} \geq 1 \\ 0, & \text{otherwise} \end{cases}$$



Constraints

For each customer, the total inventory arriving must exceed the total demand.


$$\sum_{w \in \text{Week}} \text{ArrivingInventory}_{p,w,c} \geq \sum_{w \in \text{Week}} \text{Demand}_{p,w}$$

Production must be kept within production capacity specifications.

$$\text{Production}_{s,w} \leq \text{ProductionCapacity}_{s,w}$$

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Constraints

$$\text{SupplierInventory}_{s,w} = \text{SupplierInventory}_{s,w-1} + \text{Production}_{s,w} - \sum_{p \in \text{Project}} \text{Supply}_{s,w,p}$$

$$\sum_{p \in \text{Project}} \text{Supply}_{s,w,p} \leq \text{Production}_{s,w} + \text{SupplierInventory}_{s,w-1}$$



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$$\sum_{p \in \text{Project}} \text{Supply}_{s,w,p} \leq \text{Production}_{s,w} + \text{SupplierInventory}_{s,w-1}$$

Constraints

Maximum Early Delivery

$$\text{ExcessNetInventory}_{p,w,c} \leq \sum_{w'=w+1}^{\Omega} \text{Demand}_{p,w'}$$

where $\Omega = \min\{w + \text{MaximumEarlyDelivery}, \omega\}$ and $\omega =$ the week number of the GE's horizon^a.

^aFor our project, GE's horizon is defined as week #104

Supplier Stock Inventory Capacity

$$\text{SupplierInventory}_{s,w} \leq \text{StorageCapacity}_s$$

Energy



Constraints

Maximum Early Delivery

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Constraints

The Switch_p would capture the liquidated damages costs per project into the portion below the cap and the portion above.



$$\text{LDCap}_p + \text{Switch}_p = \text{LDRate}_p \times \sum_{w \in \text{Week}} \max_c \{ \text{NetInventoryShortage}_{p,w,c} \}$$

Constraints



$$\text{LDCostPerProject}_p = \text{BinarySwitch} \cdot \text{LDCap}_p + (1 - \text{BinarySwitch}) \cdot \text{LDCostPerProject}_p$$

where $\text{BinarySwitch}_p = \mathbb{I}_{\{\text{Switch}(p) \geq 0\}}$

$$\text{LDCostPerProject}_p \leq 4 \cdot \text{LDCap}_p$$



Constraints

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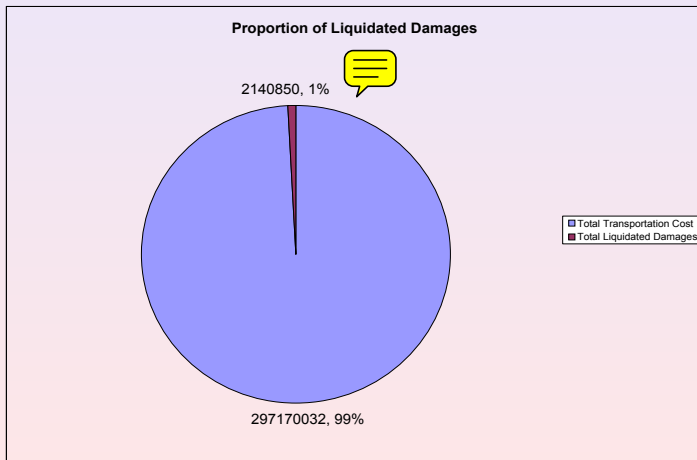
$$\text{LDCostPerProject}_p \leq 4 \cdot \text{LDCap}_p$$



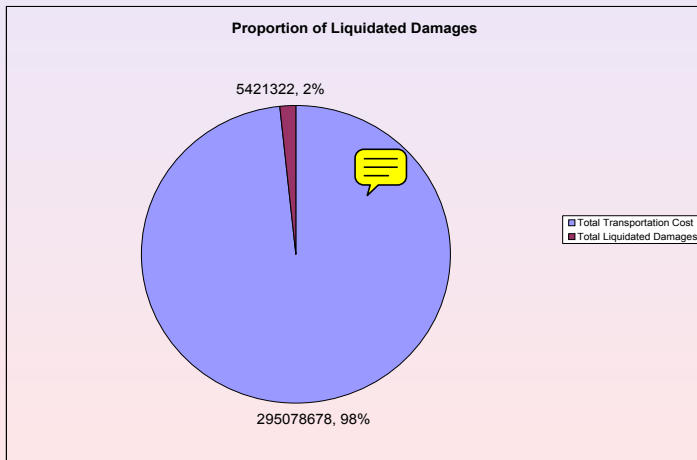
User Interface Demonstration



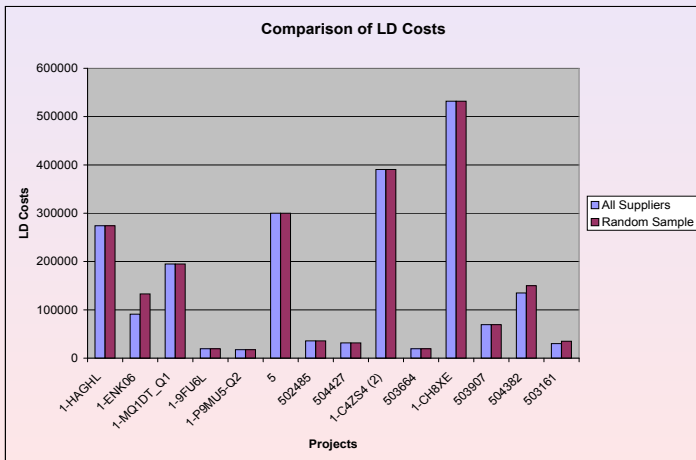
Breakdown of Costs



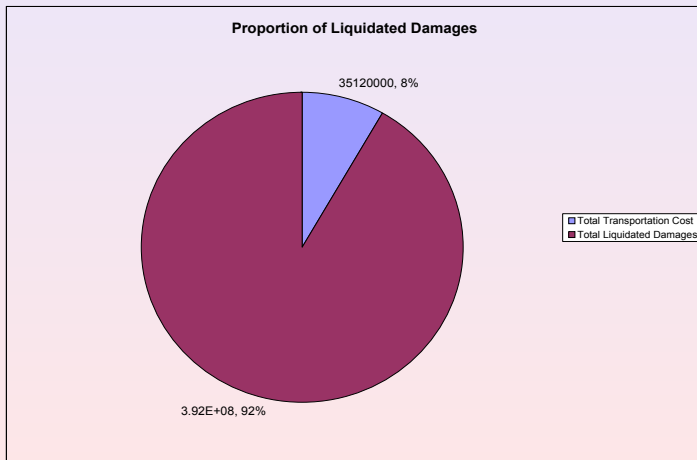
Breakdown of Costs—After Random Supplier Removed



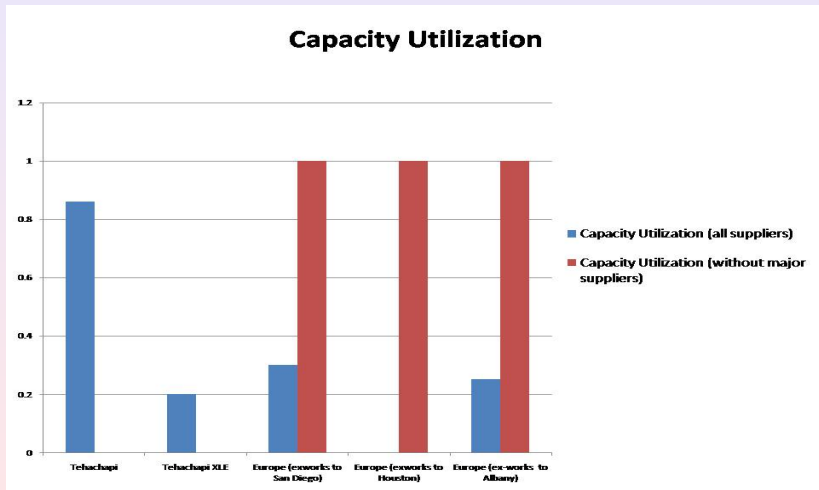
Supplier Shortages



Breakdown of Costs—After Major Suppliers Removed in CA and FL



Capacity Utilization Adjustments



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Summary of Findings

- Optimization module complete. Able to effectively allocate resources to minimize costs.
- Developed a GUI to incorporate business strategy to make better decisions from optimal results.
- Google Earth application to provide spatial visualization to aid in manual assignment of resources.
- Application is robust to business growth.



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- Tracking function to store manual changes made over time.
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Questions?



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Thank You

