EOSIM Simulate the assembly of offshore wind turbines

EOSIM – simulation tool for the assembly of offshore wind parks considering the weather conditions

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EOSIM – a tool to simulate the assembly of offshore wind turbines

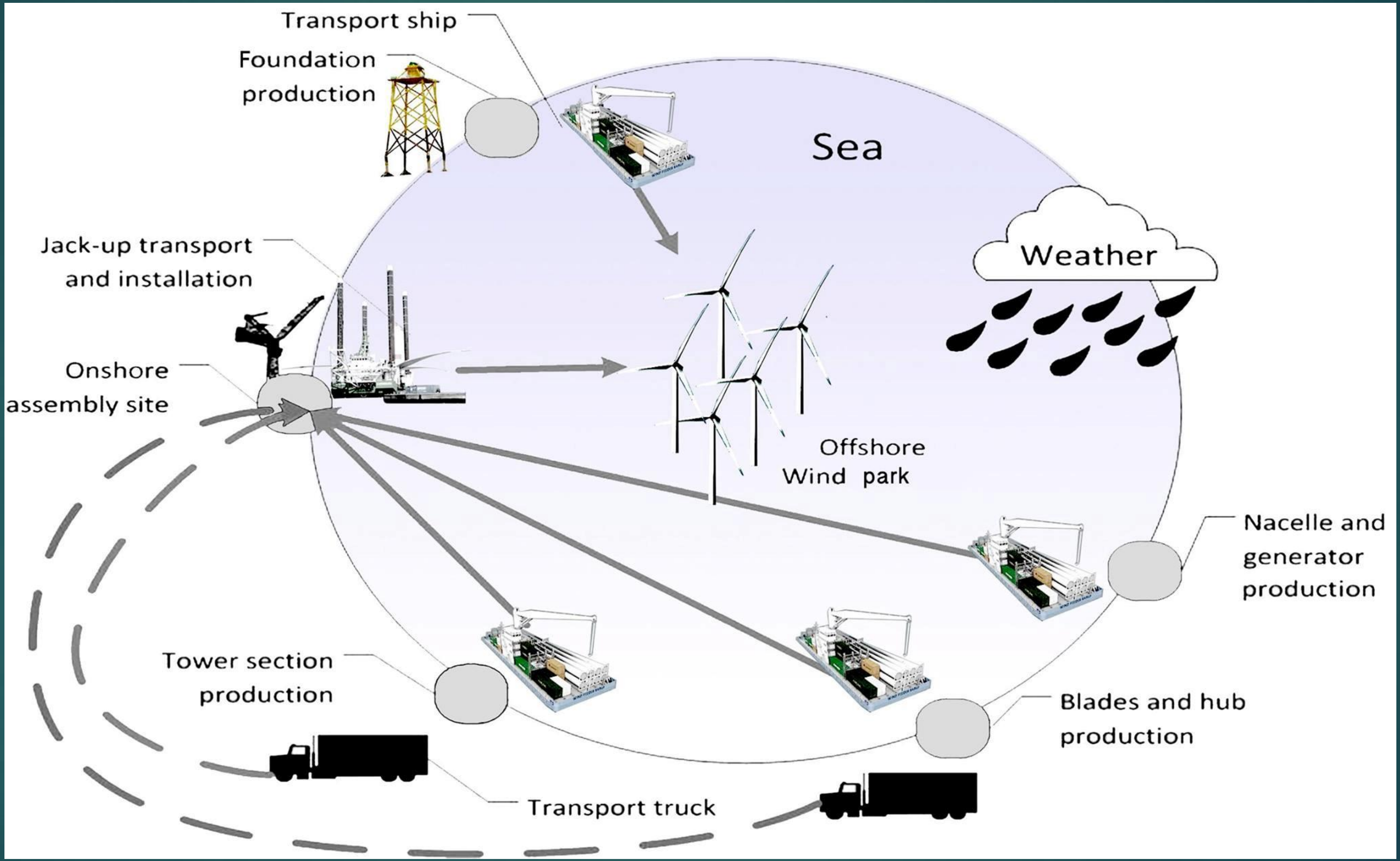
EOSIM (EOL OFFSHORE SIMULATION) is a software used to simulate the logistic chain related to the assembly of offshore wind turbine parks, from the components manufacturer's harbor until the offshore installation site, taking into account:

- ✓ The components: piles, foundations, blades, hubs, nacelles;
- ✓ The resources for the assembly: transport and installation ships, cranes and trucks;
- ✓ The weather data: real or statistic

- ➢ The final outcome of the project is to provide a decision support tool for the offshore wind industry, with which the companies in this field will be able to analyze different assembly strategies of offshore wind turbines.

- ✓ Financed by the Walloon region
- ✓ Developed with industrial partners.

EOSIM LOGISTICS LAYOUT AND STEPS (1/2)

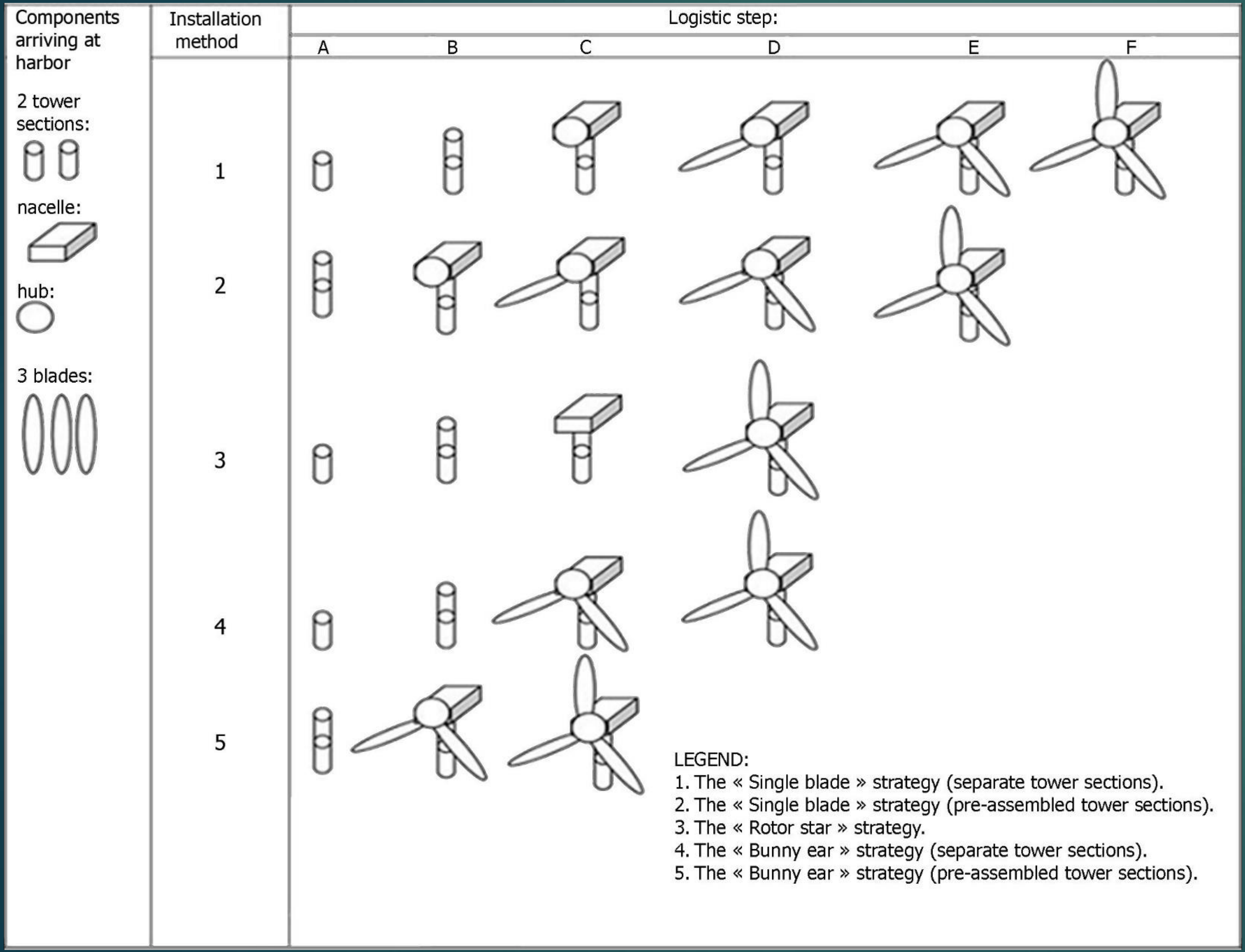


EOSIM LOGISTICS LAYOUT AND STEPS (2/2)

Example of logistic chain (using the rotor star strategy):

- Loading the piles on the transport ship.
- Transport of the piles from the producer to the offshore park, with the transport vessel.
- Transfer of the piles from the transport ship to the jack up vessel.
- Jacking up the vessel.
- Driving the piles.
- Loading of the jacket foundations on the transport ship.
- Transport of the jacket foundations from the producer to the offshore park, with the transport vessel.
- Jacking up the vessel.
- Installing the jacket foundations from the barge.
- Jacket foundation grouting.
- Loading the wind turbine components (lower tower section, upper tower section, nacelle, hub, blades) onto the transport ship.
- Transport of the wind turbine components from the producer to the onshore site (harbor).
- Unloading of the wind turbine components to the onshore site (the harbor).
- Pre-assembly of the rotor (3 blades and one hub), by means of the crane on the onshore site.
- Loading of the jack-up vessel with the wind turbine components (lower and upper tower sections, nacelle, rotor).
- Transport of the wind turbine components from the onshore site to the offshore park, with the jack-up vessel.
- Jacking up the vessel.
- Installing the wind turbine, element by element. First the lower tower section, then upper tower section, then the nacelle, and lastly the rotor.

THE ASSEMBLY STRATEGIES



1. "**Single blade**" method: the elements of the turbine are transported and installed independently.

2. Same as the 1st, except that the tower sections are already installed onshore and then transported with a vessel to the intermediate harbor.

3. "**Rotor Star**" method: the components of the wind turbine are transported independently between the suppliers and the harbor. But unlike the 1st method, the rotor is pre-assembled in the harbor.

4. "**Bunny ears**" method: the difference compared to the third is the fact that only two blades and the hub are assembled in the harbor, the third blade is installed in the wind park, independently.

5. The only difference of this method is that the tower is already assembled onshore.

COMPARISON FOR REAL AND STATISTIC WEATHER DATA (1/3)

The first step is to have the complete set of weather data (real measured or statistic).

- For the **real weather** measurements, we need to find the "workability", a criterion that verifies whether or not a certain real weather parameter exceeds the working limitation.
- Next, we need to find the time window. A criterion which finds out for how long will the weather parameters be smaller than the working limitations.

ID	Time	Year	Month	Day	Hour	Minutes	Wind speed_V1(m/s)	Wind speed_V2(m/s)	Wave_Height_Hs_(m)
1	01-01-10	2010	1	1	0	0	13,38	13,38	2,43
2	01-01-10	2010	1	1	0	10	13,14	13,14	2,42
3	01-01-10	2010	1	1	0	20	13,99	13,99	2,42
4	01-01-10	2010	1	1	0	30	13,62	13,62	2,42
5	01-01-10	2010	1	1	0	40	13,5	13,50	2,41
6	01-01-10	2010	1	1	0	50	14,03	14,03	2,41

Sample of real weather data used as input in EOSIM.

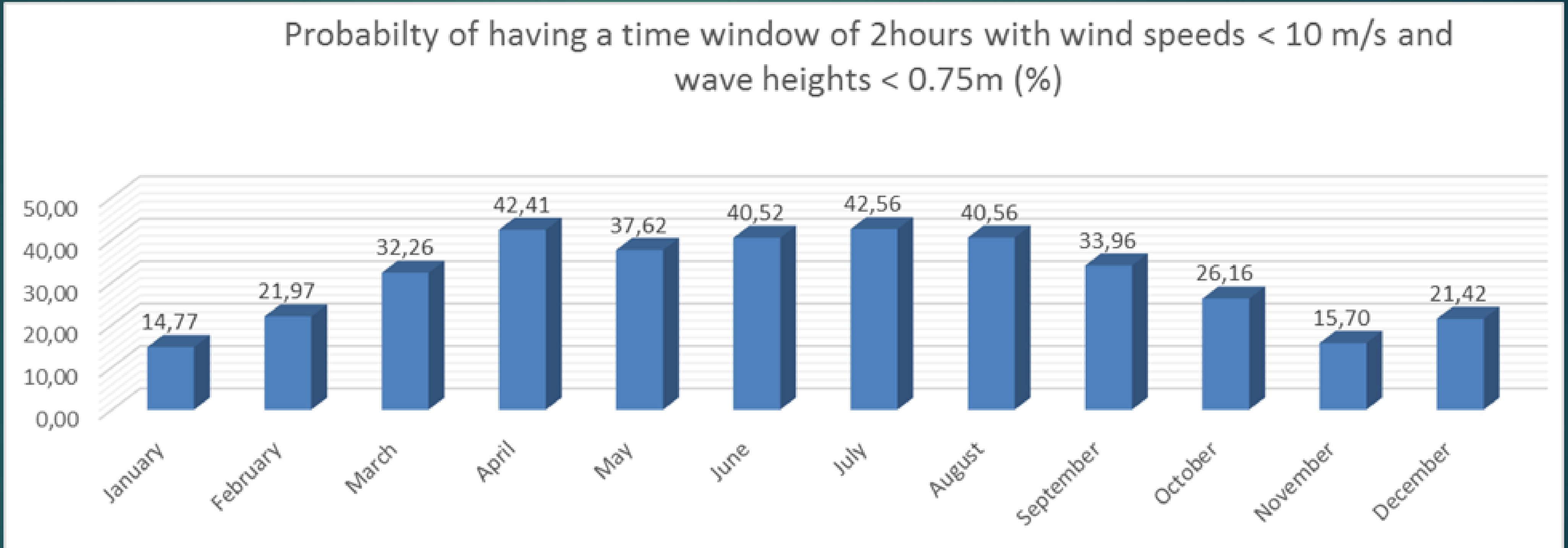
COMPARISON FOR REAL AND STATISTIC WEATHER DATA (2/3)

- For the **statistic weather** data, we follow the same procedure but instead of having real time windows we have probabilities to work for the different resources. The end results will be the same, lead times and activity distribution.
- The percentage of having wind speed and wave height under the limitations for specific time windows for the STATISTIC weather data corresponding to the real data from 1994 until 2008.

Wind_Speed (m/s)	Time window (hours)	1	2	3	4	5	6	7
	Wave_Height (m)	1	2	3	4	5	6	7
5	0.5	6.48	5.45	4.89	4.23	3.85	3.23	3.26
5	0.75	10.05	8.46	7.55	6.77	6	5.38	5.08
5	1	11.51	9.77	8.63	7.71	6.99	6.24	6.02
5	1.25	12.3	10.5	9.25	8.46	7.75	6.72	6.4
5	1.5	12.6	10.7	9.49	8.64	7.97	6.83	6.52
5	1.75	12.85	10.99	9.7	8.92	8.15	7.15	6.77
5	2	12.89	11	9.76	8.92	8.15	7.15	6.77
5	2.25	12.91	11.04	9.78	8.96	8.2	7.15	6.84
5	2.5	12.92	11.04	9.78	8.96	8.2	7.15	6.84
5	2.75	12.94	11.06	9.78	8.96	8.2	7.15	6.84

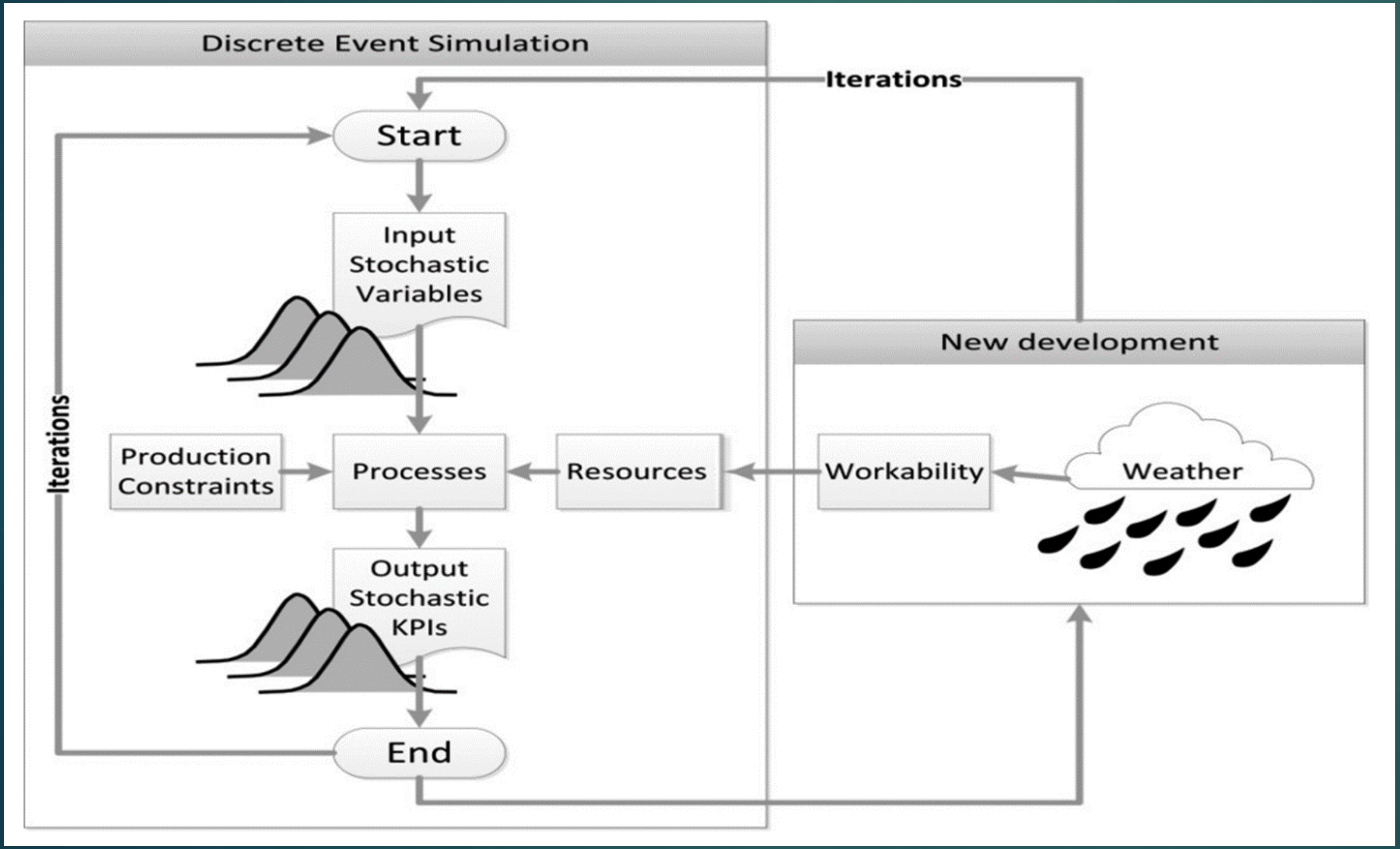
Example in orange: the probability of having wind speeds less than 5m/s and wave heights less than 2m, for a time window of 3 hours is 9.76%.

COMPARISON FOR REAL AND STATISTIC WEATHER DATA (3/3)



Exemple: the monthly working probability in April for a time window of 2 hours referring to this distribution is 42.41%

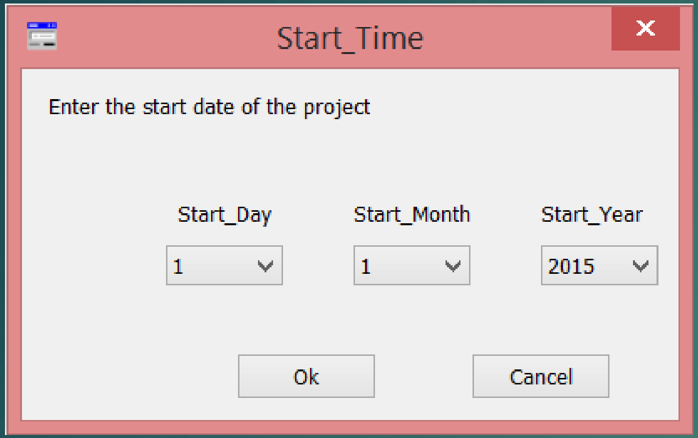
THE MODEL'S WORKFLOW (1/4)



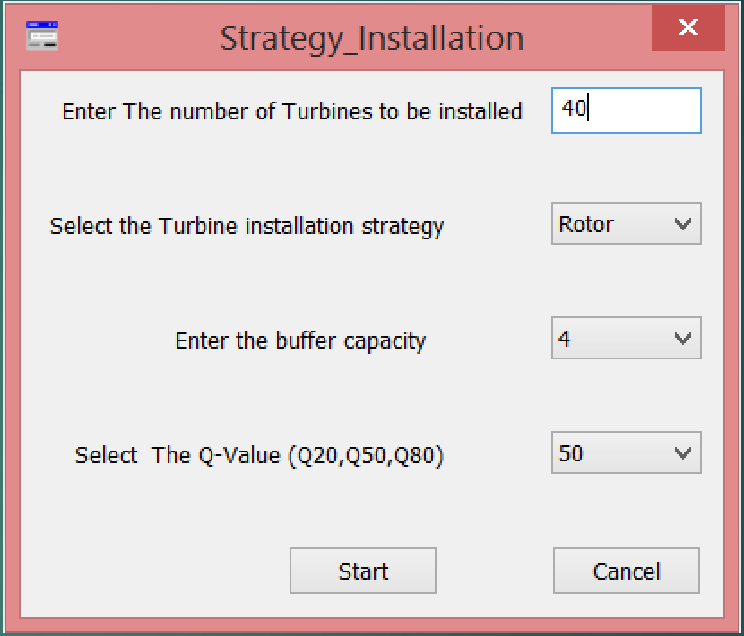
Legend:

- **Weather**: Real or statistical measurements;
- **Workability**: A criterion that verifies if the resources are under the weather limitations;
- **Resources**: Ships, cranes or trucks.
- **Processes**: Loading, unloading, transport, installation, etc.
- **Production constraints**: For example, the jack-up vessel has priority when it arrives at the intermediate harbor.
- **Input/Ouput Stochastic Variables**: A normal distribution for the input values (such as the duration of the installation of the wind turbine parts).
- **Iterations**: The simulation runs.

THE MODEL'S WORKFLOW (2/4)

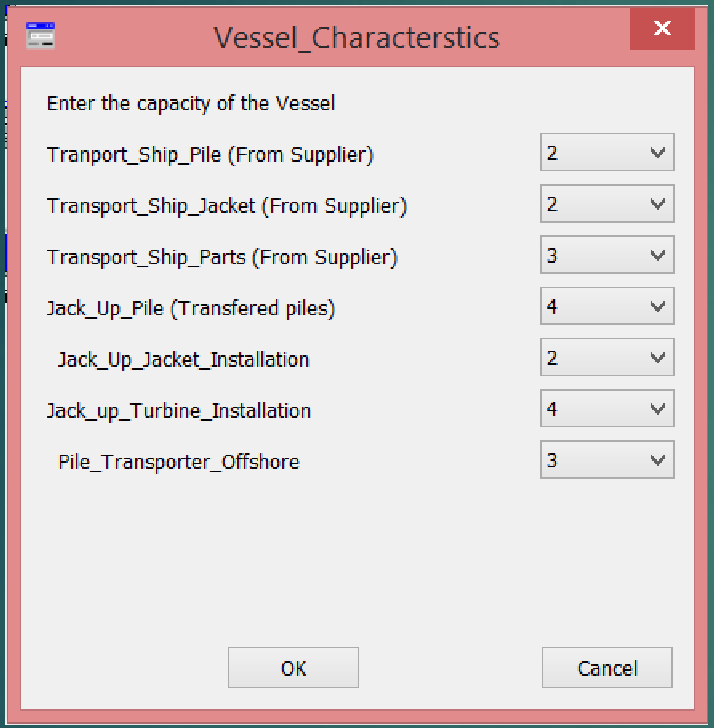


1. Defining the starting date of the project

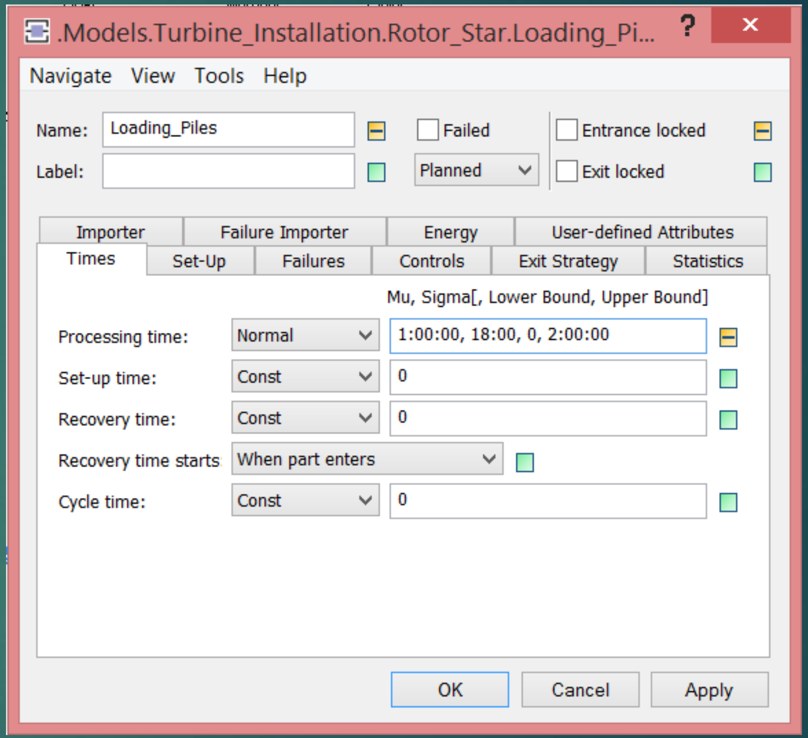


2. Defining the number of wind turbines, the assembly strategy, the buffer for the piles and for the foundations, the percentiles (Q20, Q50 or Q80) in order to choose the weather scenario (optimistic, neutral, pessimistic)

THE MODEL'S WORKFLOW (3/4)



3. Setting of the vessels' storage capacity



4. Imposing the stochastic input to the resources (the piles loading time is given by a normal distribution function (mean value and standard deviation)

THE MODEL'S WORKFLOW (4/4)

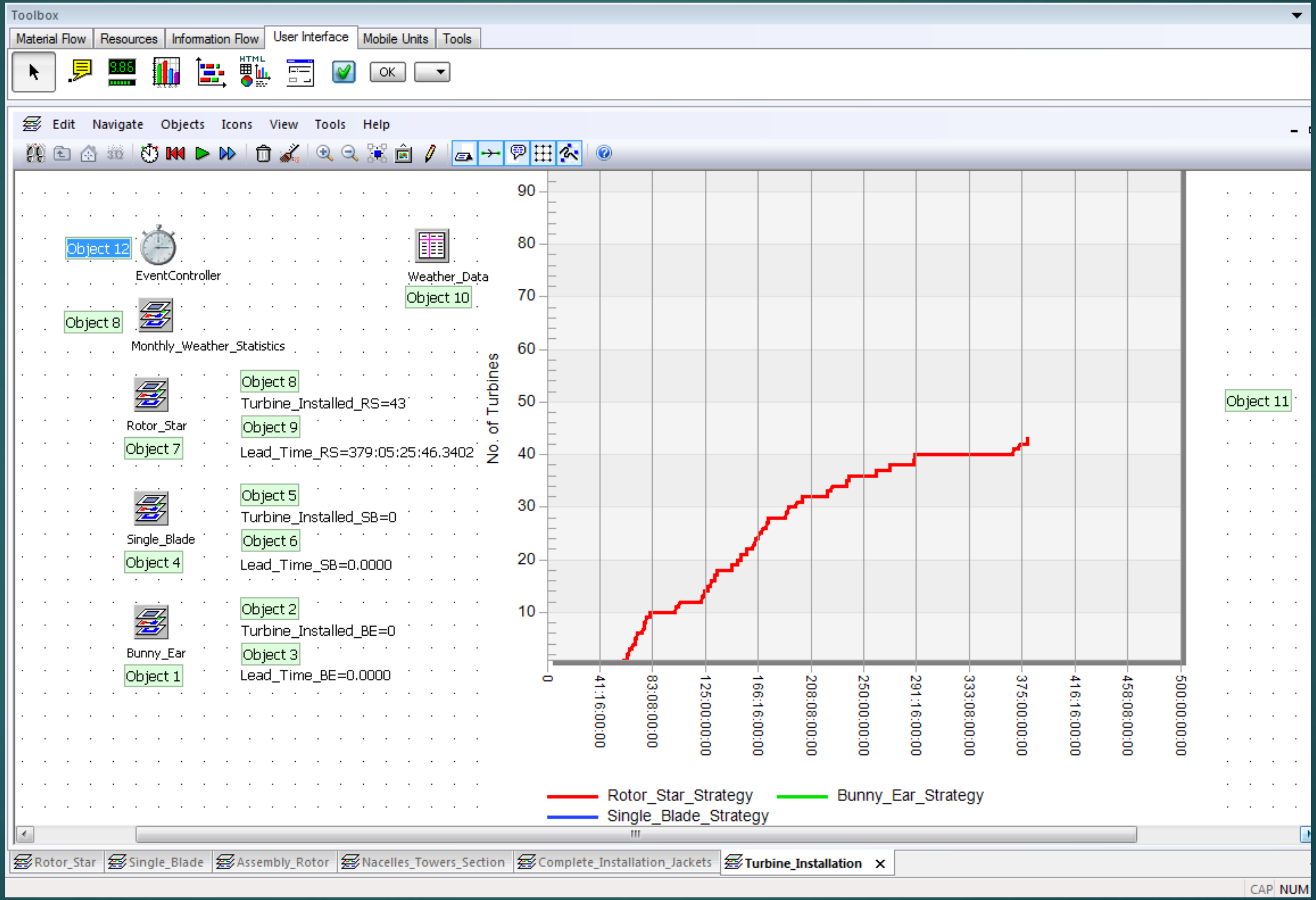
Name	Distance_Covered_(Km)
Transport_Ship_Supplier	500
Jacket_Transporter_Supplier	500
Jackup_Vessel_Turbine_Installation	55
Crane	
Pile_Transporter_Supplier	500
Pile_Jackup_Vessel	55
Jacket_Installation_Vessel	55
Pile_Transporter_Offshore	55

5. Setting of the distances between each important point of the project

6. Next, we will run the simulation, which will undertake all the logistical steps of the project

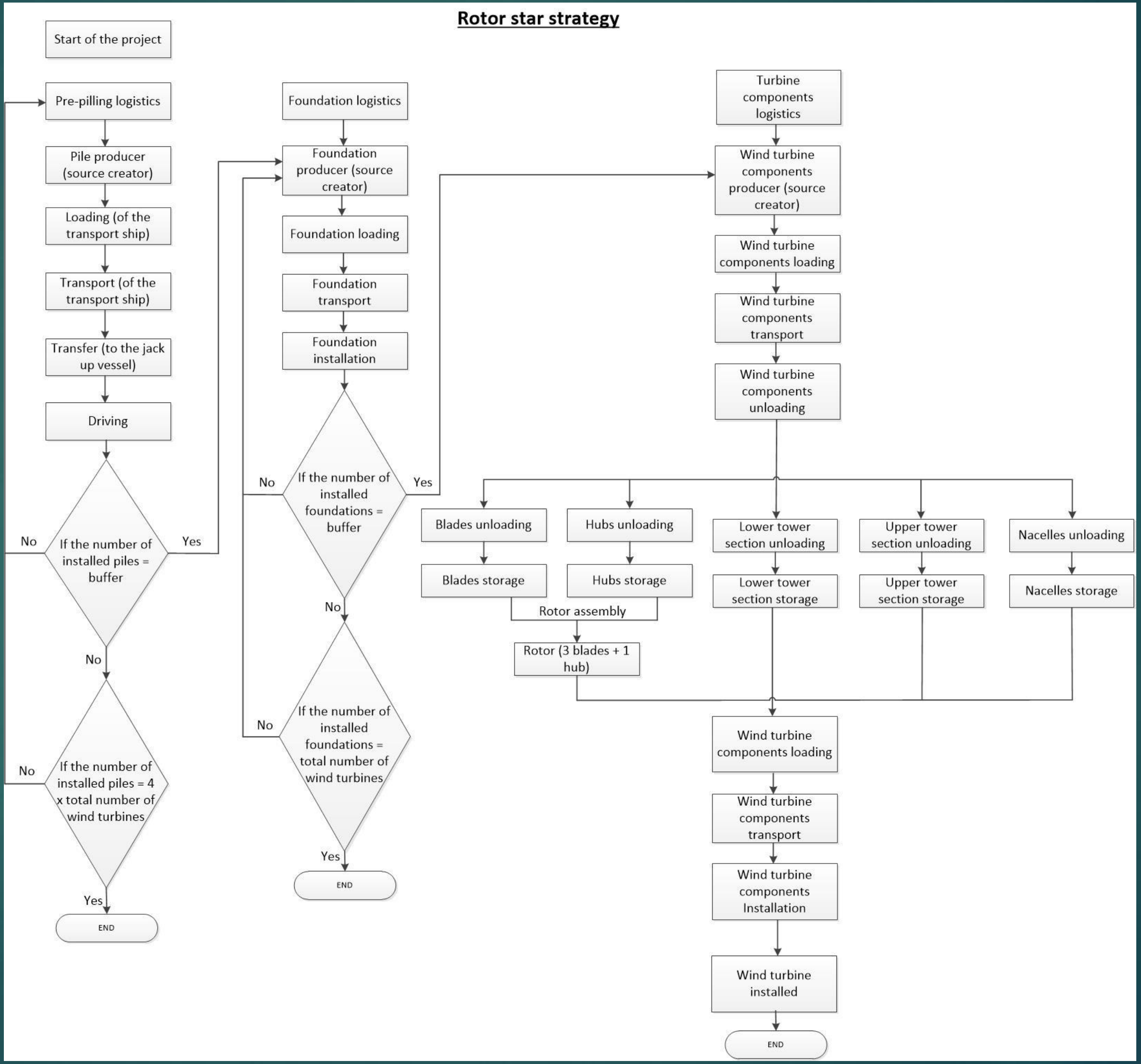
7. And in the end we will get the simulation's results such as lead time for the whole project or activity distribution for each activity.

EOSIM – THE INTERFACE

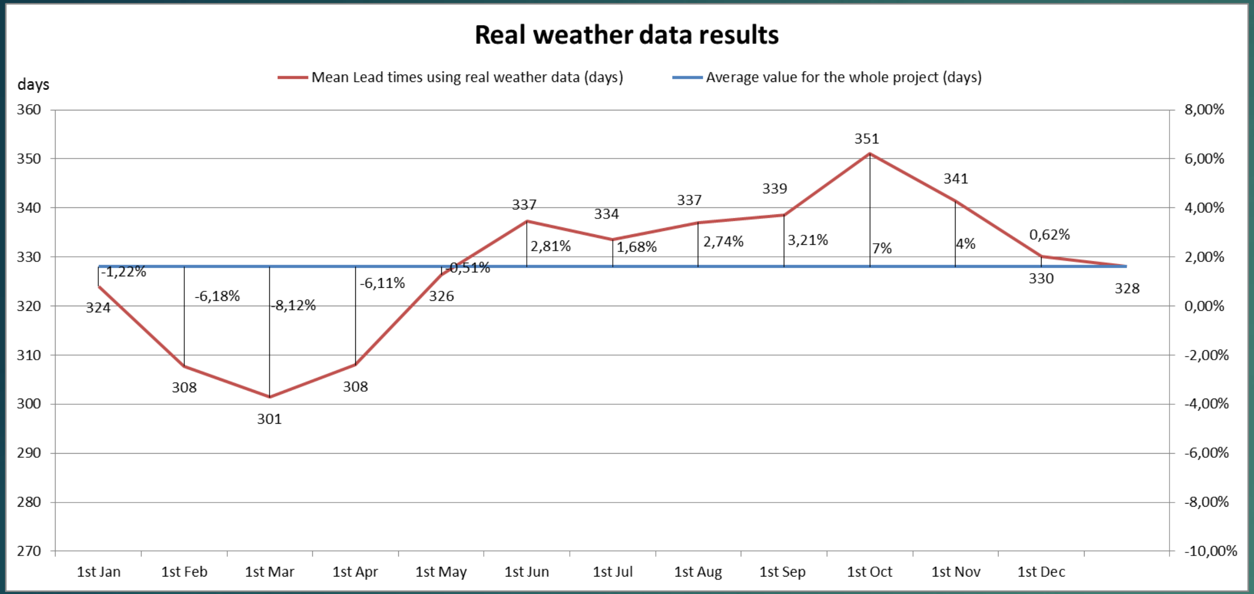


MODEL ARCHITECTURE OF THE ROTOR STAR STRATEGY

The software architecture for both real and weather data.



EXEMPLES OF RESULTS (ROTOR STAR STRATEGY)

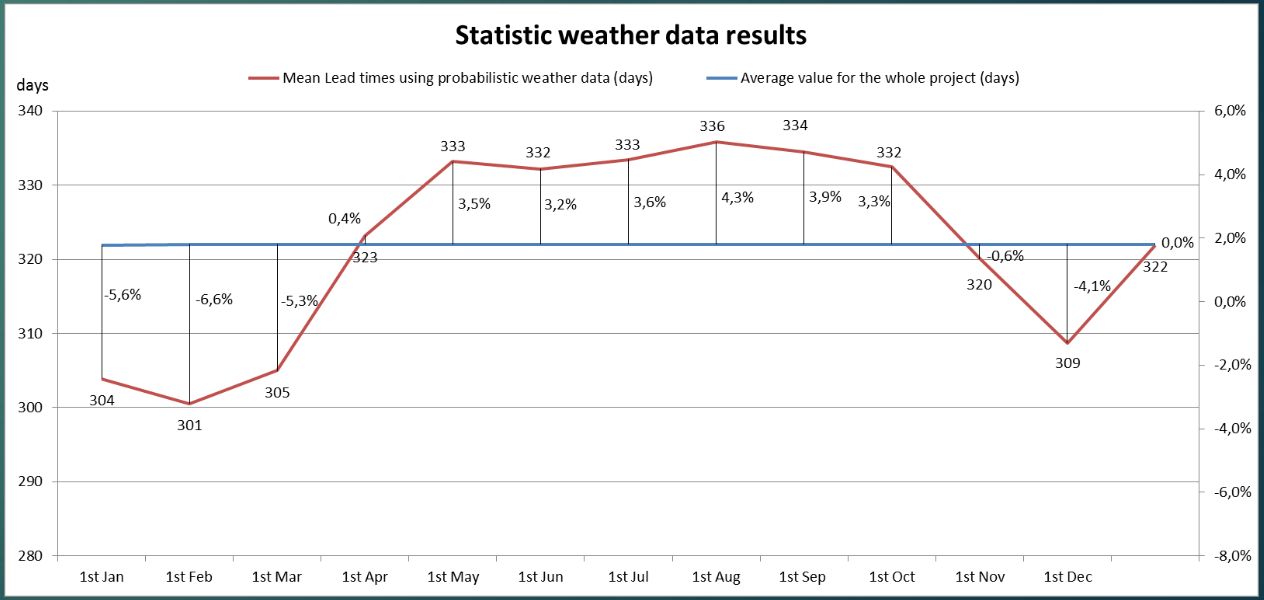


Real weather data (wind speed on 2 directions and specific wave height)

The following resources are considered in the example:

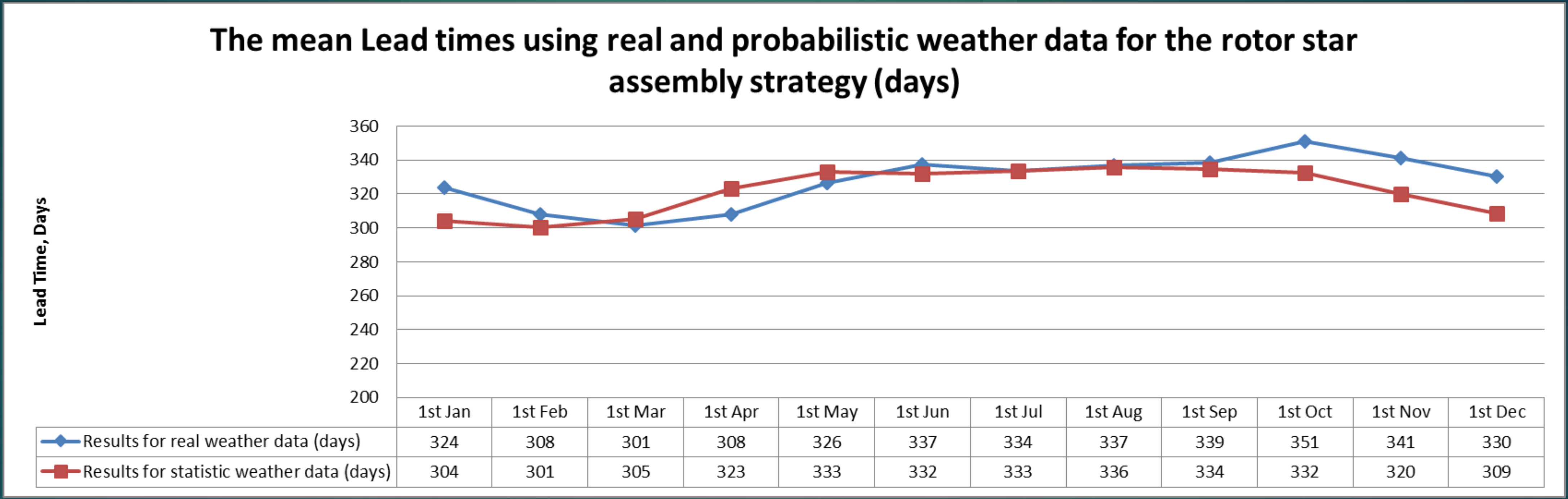
- 3 transport ships
- 1 jack-up vessel for the jacket foundations
- 1 jack-up vessel for the wind turbine components
- 1 jack-up vessel for pre pilling

- The **mean lead times**, in the red line (the difference in time between the last installed wind turbine and the first delivered one) starting the simulation the 1st of every month. The lead times are the mean value of the lead times obtained for all the years (from 1994 until 2008).
- The **difference between the monthly and the annual mean lead time (%)**, from 1994 until 2008, in the vertical lines.



Statistic weather data

EXEMPLES OF RESULTS (ROTOR STAR STRATEGY)



	1st Jan	1st Feb	1st Mar	1st Apr	1st May	1st Jun	1st Jul	1st Aug	1st Sep	1st Oct	1st Nov	1st Dec
Results for real weather data (days)	324	308	301	308	326	337	334	337	339	351	341	330
Results for statistic weather data (days)	304	301	305	323	333	332	333	336	334	332	320	309

Mean Lead times using real and probabilistic weather data for the rotor star assembly strategy (days)

EXEMPLES OF RESULTS (ROTOR STAR STRATEGY)

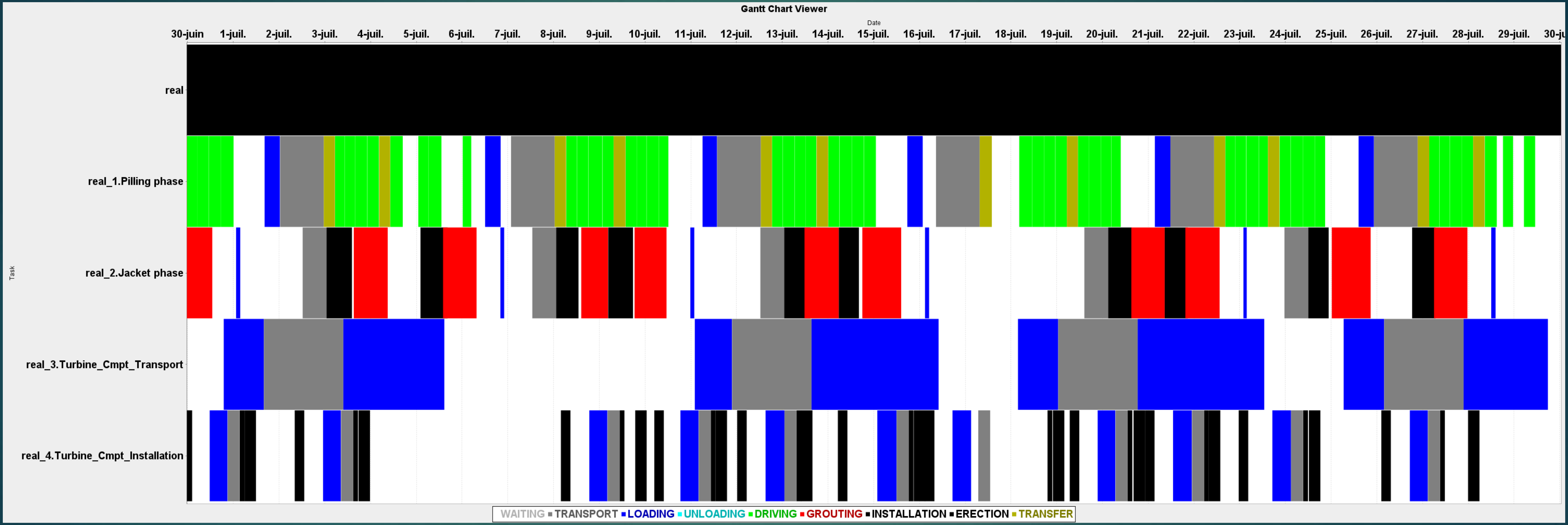
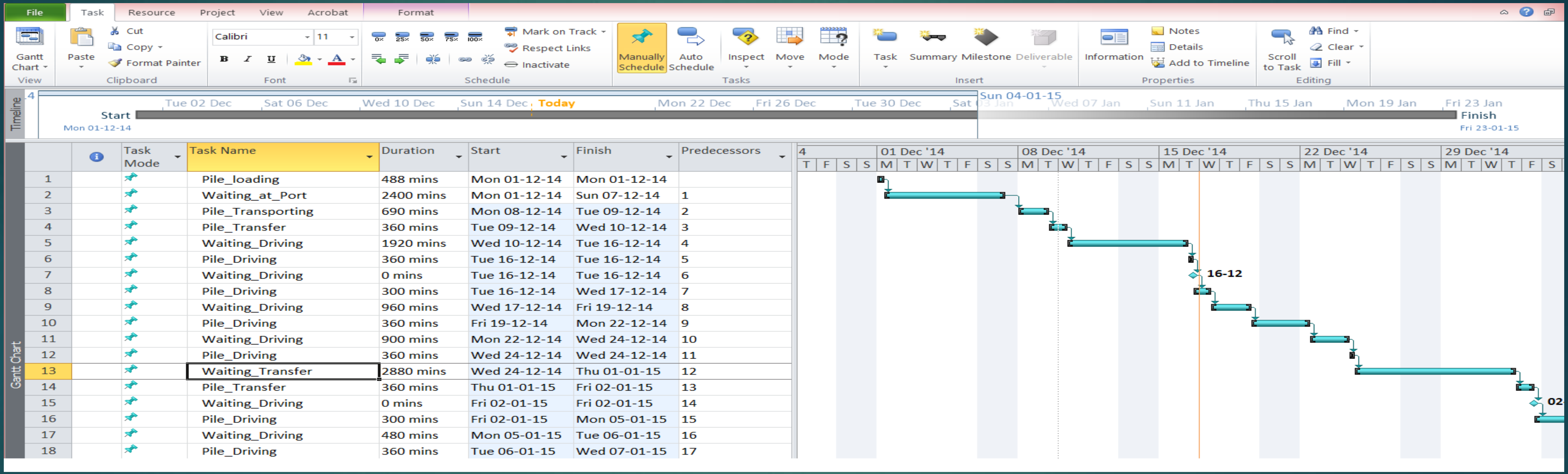


Diagram showing the activities' duration of the whole project on a time span of one month: waiting/transport/loading/unloading/driving/grouting/installation

The pilling phase, jacket phase, the transport and installation of the other wind turbine component are displayed on separate rows.

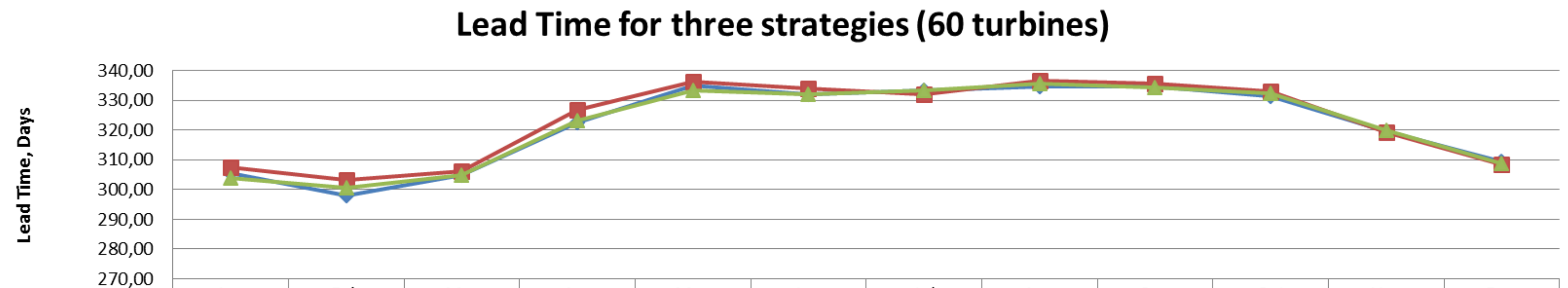
EXEMPLES OF RESULTS (ROTOR STAR STRATEGY)



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Pile_loading	488 mins	Mon 01-12-14	Mon 01-12-14	
2		Waiting_at_Port	2400 mins	Mon 01-12-14	Sun 07-12-14	1
3		Pile_Transporting	690 mins	Mon 08-12-14	Tue 09-12-14	2
4		Pile_Transfer	360 mins	Tue 09-12-14	Wed 10-12-14	3
5		Waiting_Driving	1920 mins	Wed 10-12-14	Tue 16-12-14	4
6		Pile_Driving	360 mins	Tue 16-12-14	Tue 16-12-14	5
7		Waiting_Driving	0 mins	Tue 16-12-14	Tue 16-12-14	6
8		Pile_Driving	300 mins	Tue 16-12-14	Wed 17-12-14	7
9		Waiting_Driving	960 mins	Wed 17-12-14	Fri 19-12-14	8
10		Pile_Driving	360 mins	Fri 19-12-14	Mon 22-12-14	9
11		Waiting_Driving	900 mins	Mon 22-12-14	Wed 24-12-14	10
12		Pile_Driving	360 mins	Wed 24-12-14	Wed 24-12-14	11
13		Waiting_Transfer	2880 mins	Wed 24-12-14	Thu 01-01-15	12
14		Pile_Transfer	360 mins	Thu 01-01-15	Fri 02-01-15	13
15		Waiting_Driving	0 mins	Fri 02-01-15	Fri 02-01-15	14
16		Pile_Driving	300 mins	Fri 02-01-15	Mon 05-01-15	15
17		Waiting_Driving	480 mins	Mon 05-01-15	Tue 06-01-15	16
18		Pile_Driving	360 mins	Tue 06-01-15	Wed 07-01-15	17

Diagram showing the activity distribution of the whole project, in MS Project. The results can easily be exported into MS Project (where they can be edited by the user).

COMPARISON OF RESULTS



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average_SB	305,39	297,94	304,72	322,42	335,05	332,11	333,25	334,75	334,66	331,35	319,68	309,58
Average_BE	307,59	303,27	306,14	326,91	336,38	333,96	332,16	336,50	335,61	332,89	319,33	308,37
Average_RS	303,91	300,54	305,00	323,18	333,20	332,20	333,45	335,79	334,49	332,46	320,08	308,69

The mean lead time values (days), starting the simulation every month, for the 3 strategies « Rotor star », « Bunny ears » and « Single blade »

EOSIM
Simulate the assembly of offshore wind turbines

EOSIM – CONTACT

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LOCATION ON MAP