University of Strathclyde Engineering

TECHNOLOGY & INNOVATION CENTRE

Cost Benefit Analysis of Mothership Concept and Investigation of Optimum Operational Practice for Offshore Wind Farms

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* Presenter

Presentation Outline

- Problem Identification
- Potential Solutions
- StrathOW-OM Methodology and Tool Interface
- Case Study
- Results
- Conclusion
- Future Work

Problem Identification

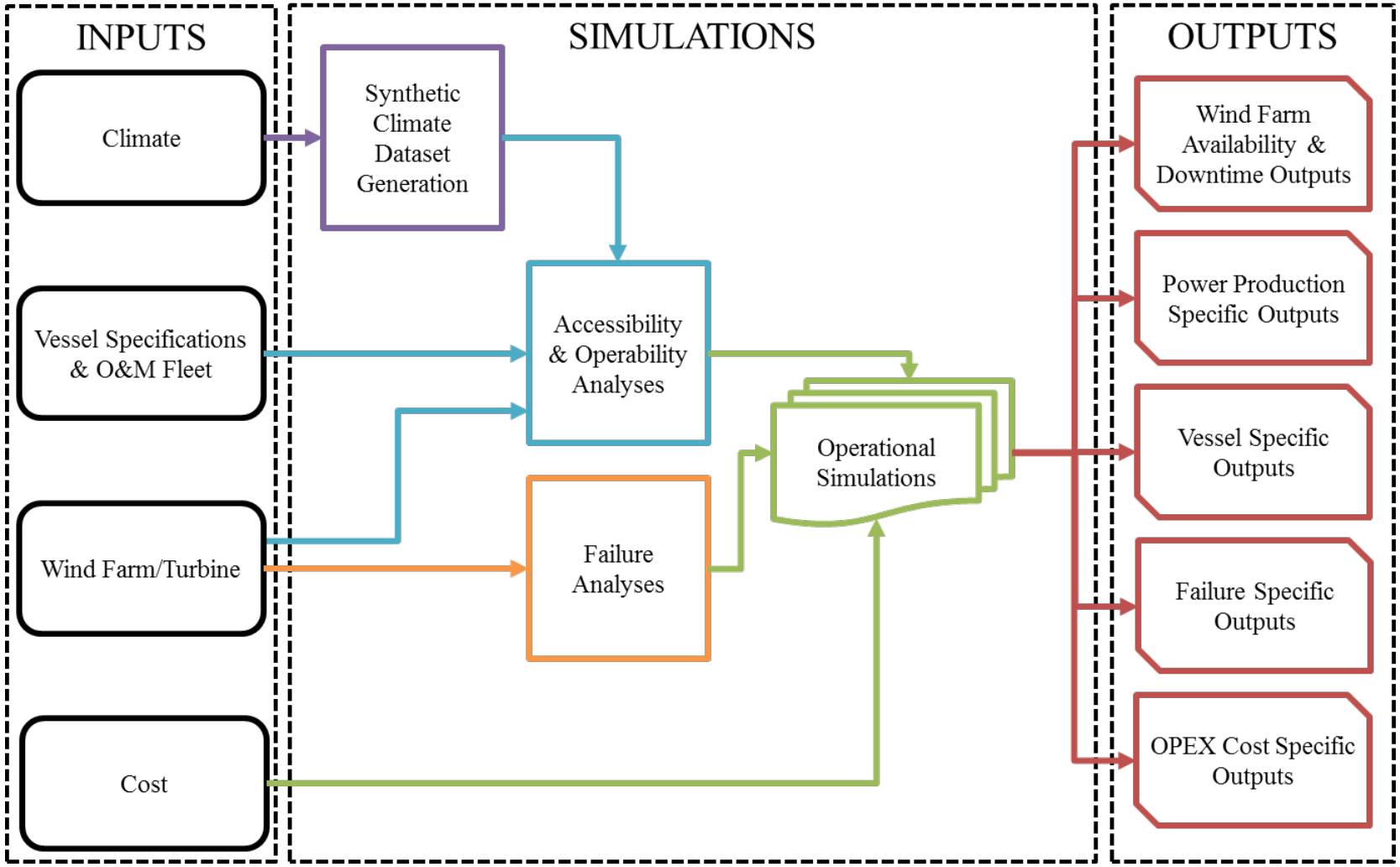
New Generation Offshore Wind Farms

- Moving far offshore (>50 nautical miles)
- Occupying larger area
- Very long transit time
- Limited actual productive time
- Long reaction time to failures
- Increasing downtimes
- Very high O&M/MWh costs

Potential Solutions

- Design and build advanced vessels
- Increase the size of O&M fleets
- Build O&M ports on islands
- Install a fixed offshore platform
- Purchase/charter a mothership
- Cancel the projects

StrathOW-OM Methodology



Methodology

- Climate Dataset Generation

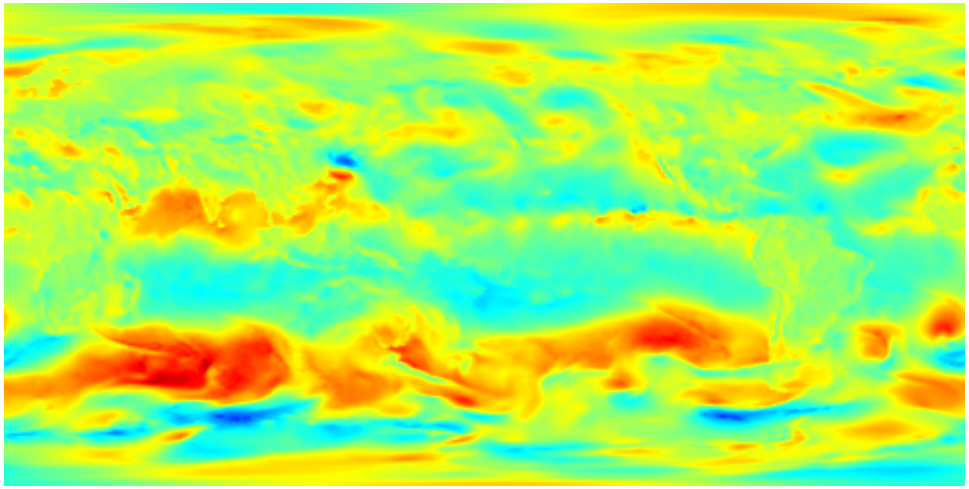
➢Analyse Meteorological time series.

➢Remove deterministic seasonal and diurnal trends in climate data

➢ Estimate distributions of climate data.

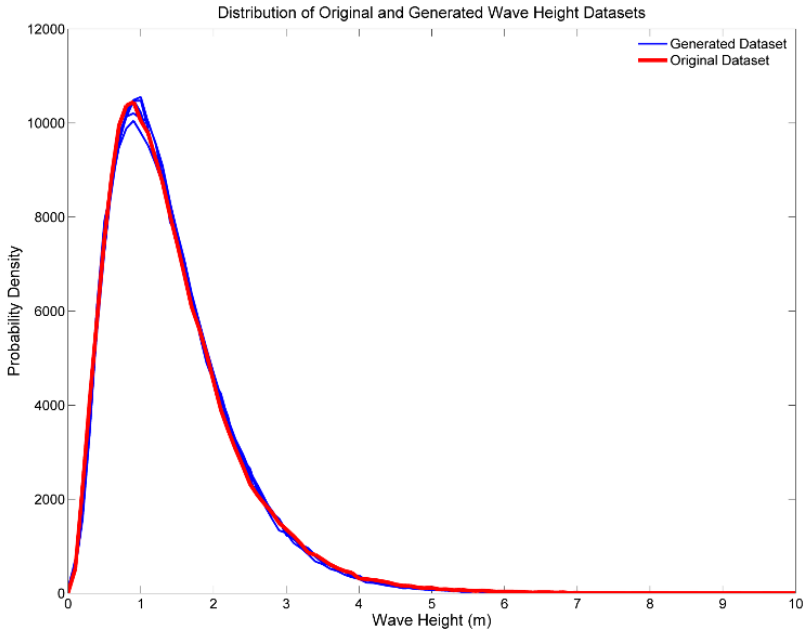
➢Sample from the distributions

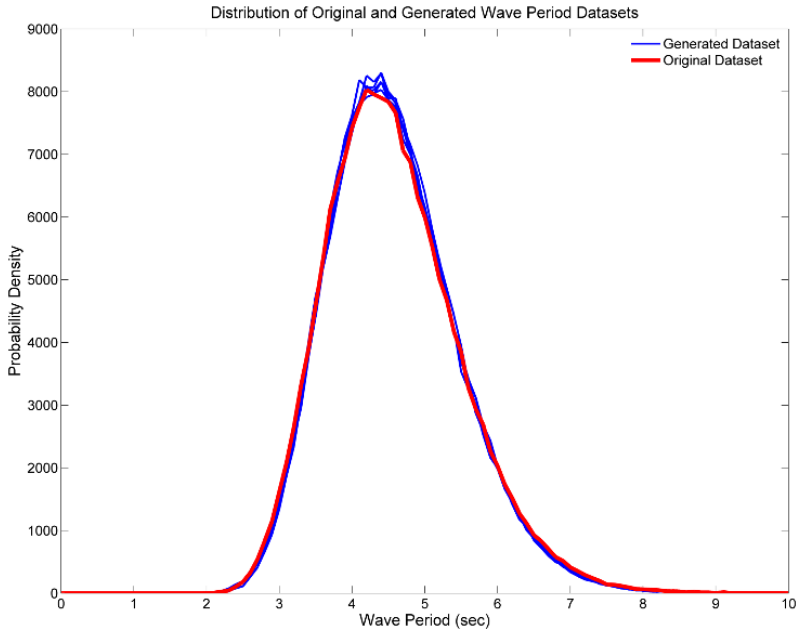
➢Re-apply deterministic trends



Methodology

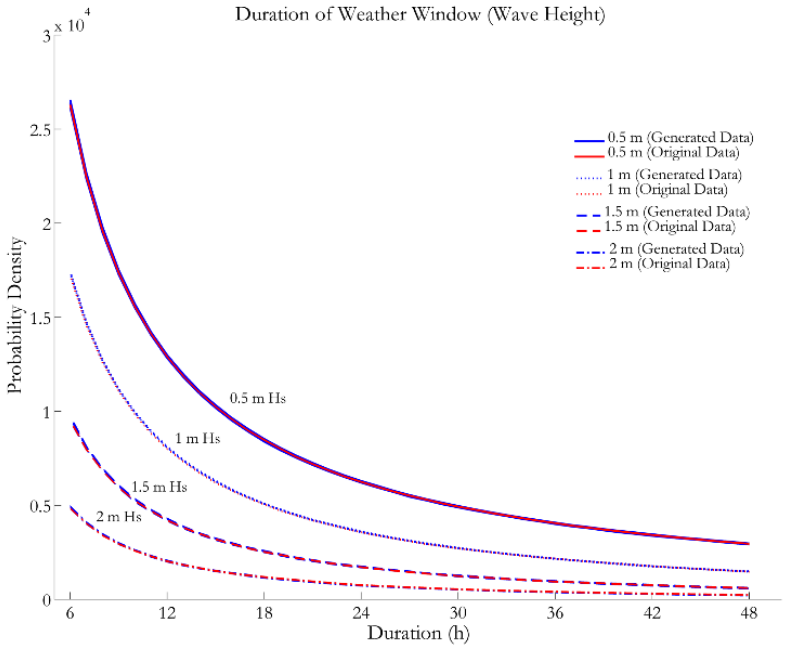
- Climate Dataset Generation

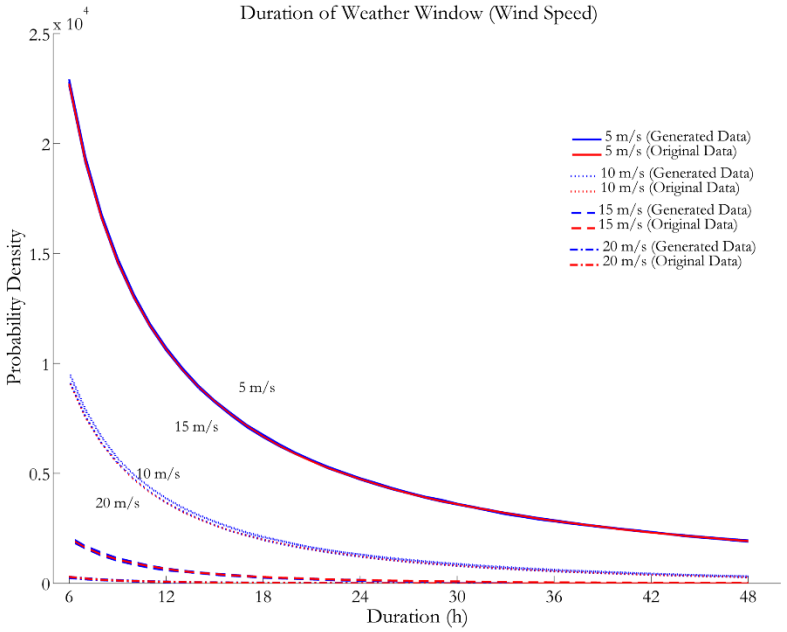




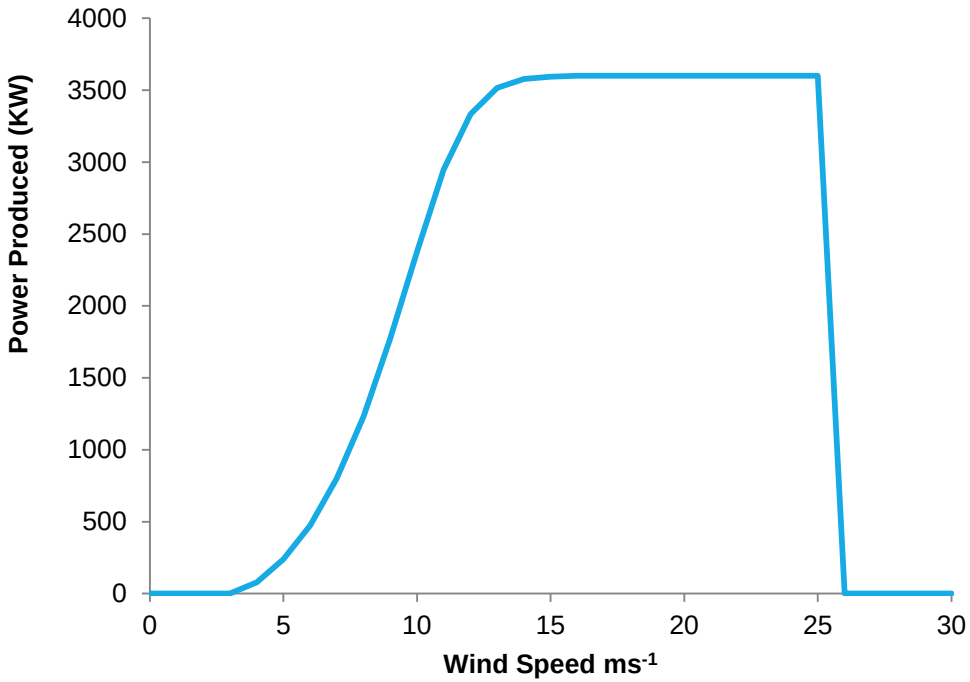
Methodology

- Climate Dataset Generation





Wind Turbine Behaviour



Failure Type
Required Repair Time - Calender Hours
Required Technicians
Vessel Type
Cumulative or Single Repair Window
Global Failure
Percentage of wind farm production impacted (%) (0-100)
Percentage of turbine production impacted (%) (0-100)
Failure Model Type

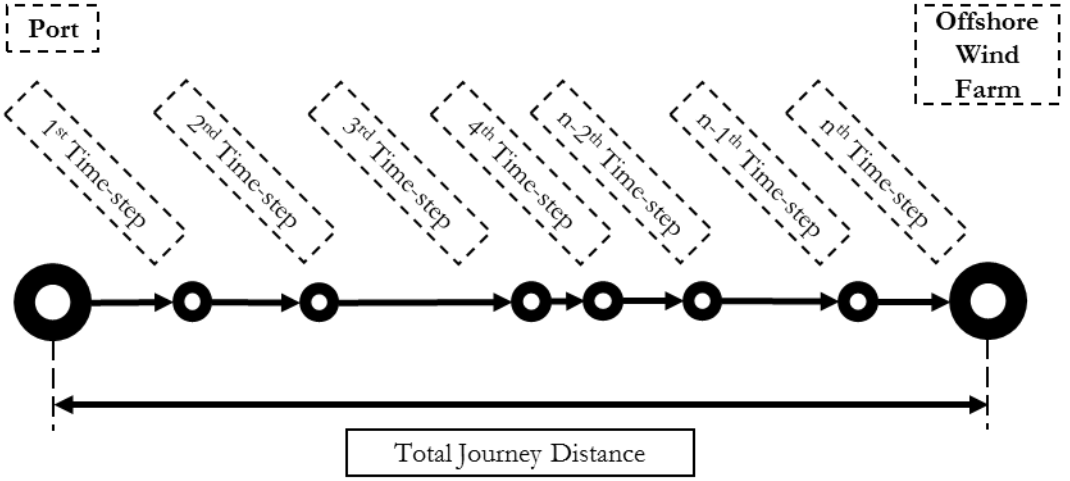
StrathOW-OM Methodology

- Accessibility and Operability

- Calculation of total calm water resistance
- Calculation of additional wave resistance
- Calculation of total resistance
- Calculation of speed loss in wavy sea
- Calculation of transit time

$$Distance_i = Time\ Step\ Interval \times V_{A_i}$$

$$Total\ Distance = \sum_{0}^{i} Distance_i$$



StrathOW-OM Methodology

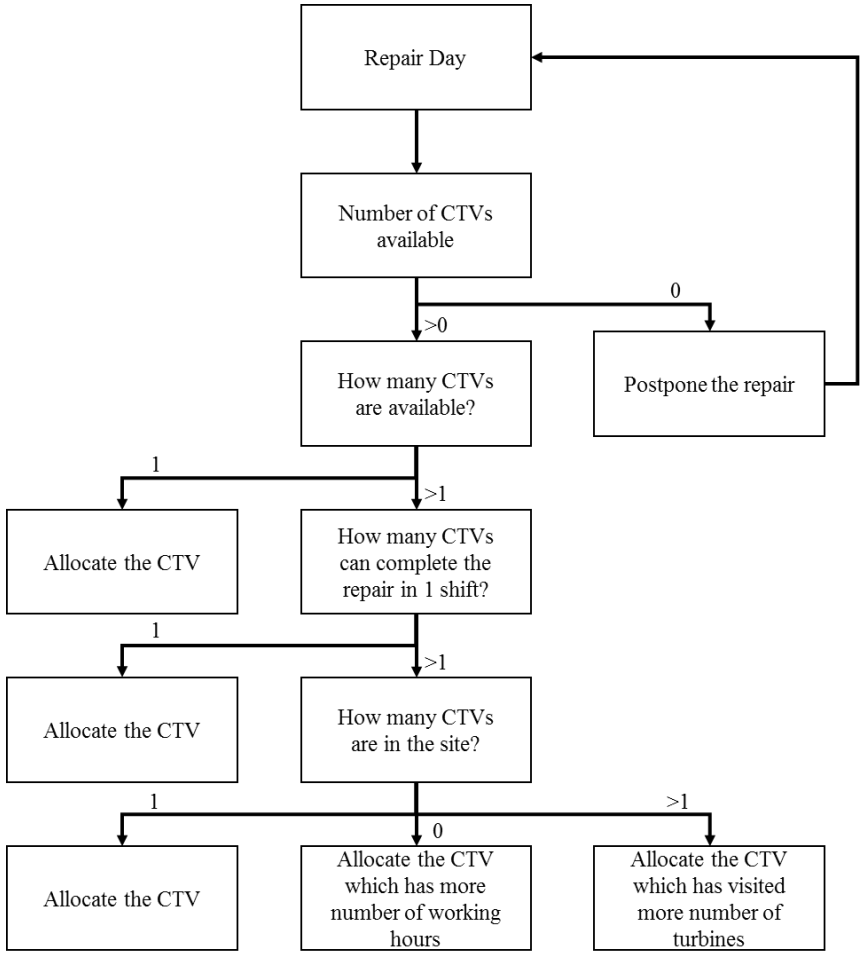
- Failure Analyses and Simulation

➢ Monte-Carlo Simulation

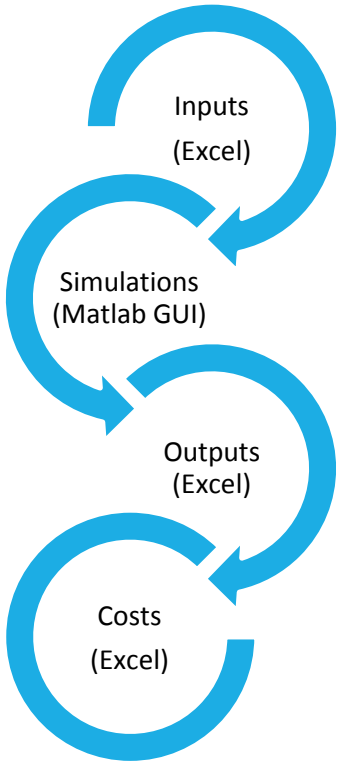
➢ Random Number Generation, R

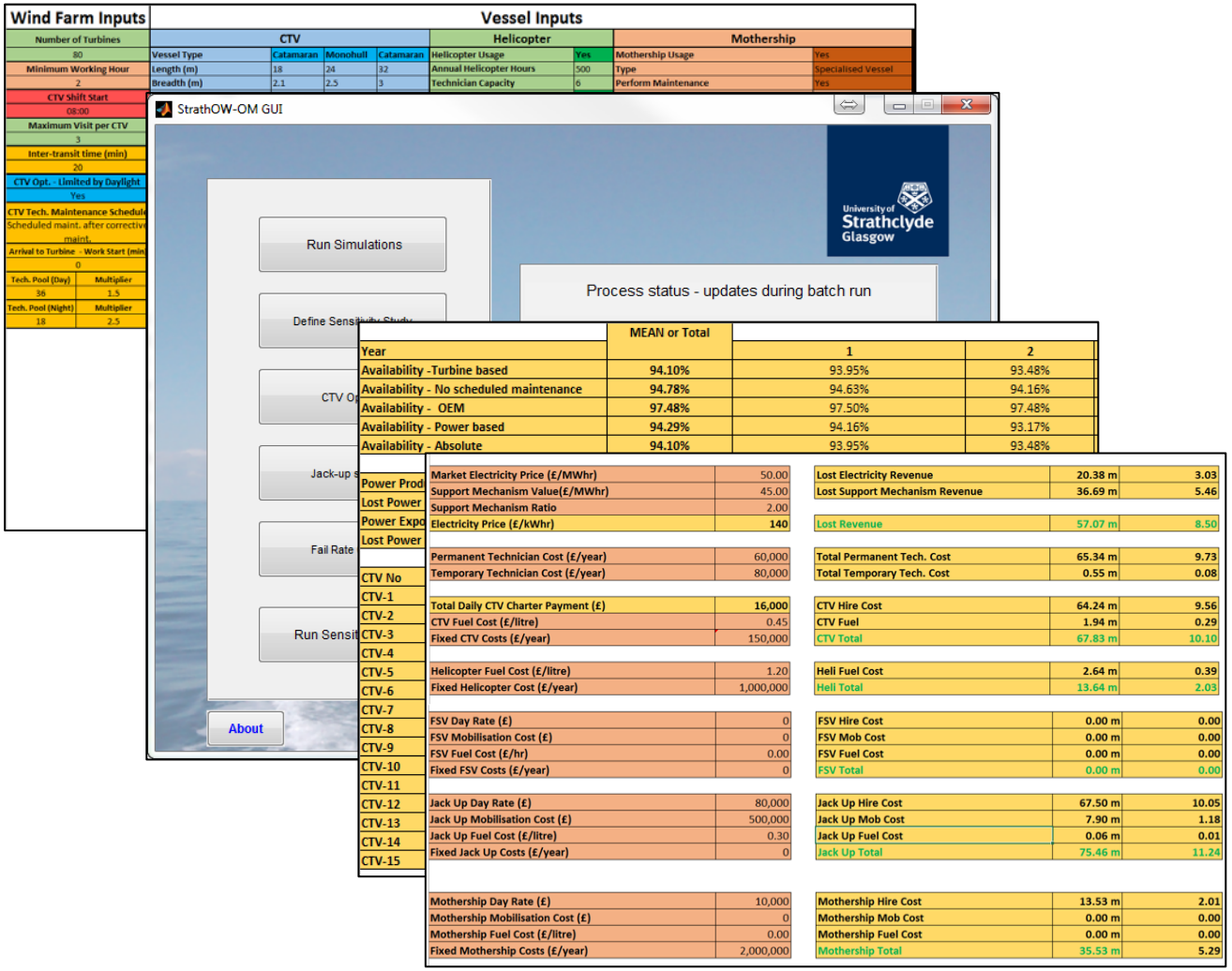
➢ Hazard Rate h(t)

$$R > (1 - h(t)) \cdot \frac{\Delta t}{8760}$$



StrathOW-OM Tool Interface



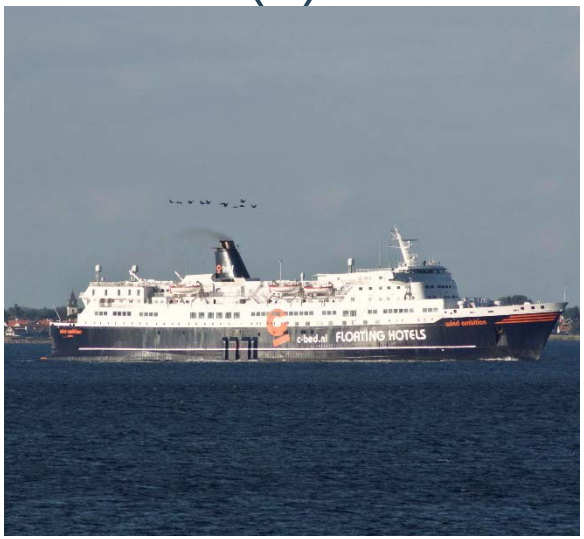


Case Study

- A fixed accommodation platform concept (A)
- A floating hotel mothership concept (B)
- A pro-active mothership concept (C)

(A)

(B)



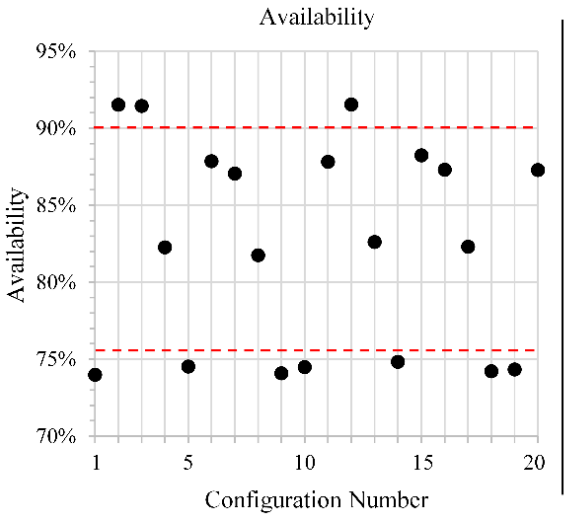
(C)

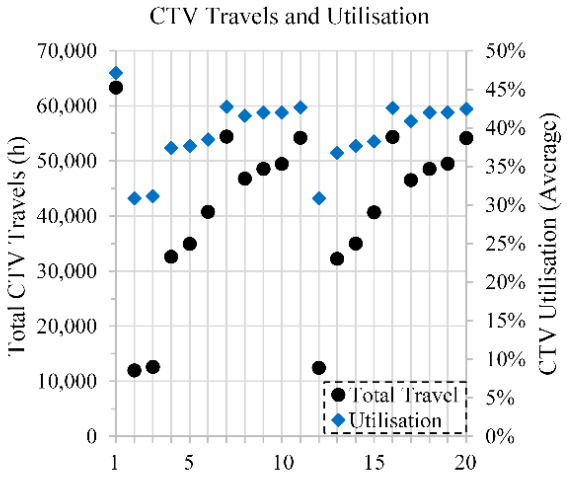
Case Study

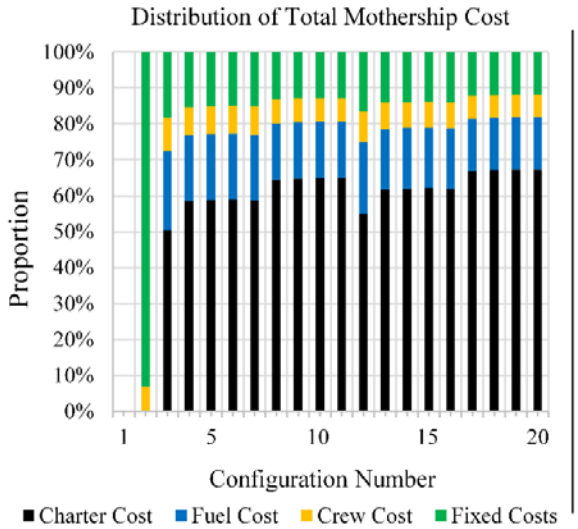
No	Configuration	Charter Type	Start Month	Final Month	Period	Daughter craft
1	No mothership	N/A	N/A	N/A	N/A	N/A
2	Fixed platform	N/A	N/A	N/A	25 years	N/A
3	With mothership	Continuous	N/A	N/A	25 years	N/A
4	With mothership	Seasonal	Jan	Jun	6 months	N/A
5	With mothership	Seasonal	Apr	Sep	6 months	N/A
6	With mothership	Seasonal	Jul	Dec	6 months	N/A
7	With mothership	Seasonal	Oct	Mar	6 months	N/A
8	With mothership	Seasonal	Jan	Mar	3 months	N/A
9	With mothership	Seasonal	Apr	Jun	3 months	N/A
10	With mothership	Seasonal	Jul	Sep	3 months	N/A
11	With mothership	Seasonal	Oct	Dec	3 months	N/A

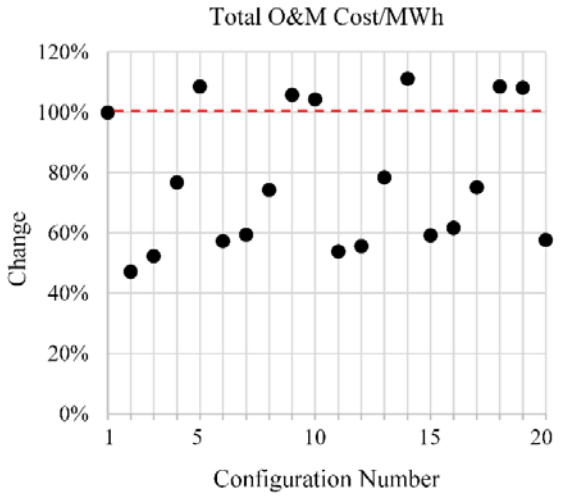
No	Configuration	Charter Type	Start Month	Final Month	Period	Daughter craft
-	-	-	-	-		-
-	-	-	-	-		-
12	With mothership	Continuous	N/A	N/A	25 years	3
13	With mothership	Seasonal	Jan	Jun	6 months	3
14	With mothership	Seasonal	Apr	Sep	6 months	3
15	With mothership	Seasonal	Jul	Dec	6 months	3
16	With mothership	Seasonal	Oct	Mar	6 months	3
17	With mothership	Seasonal	Jan	Mar	3 months	3
18	With mothership	Seasonal	Apr	Jun	3 months	3
19	With mothership	Seasonal	Jul	Sep	3 months	3
20	With mothership	Seasonal	Oct	Dec	3 months	3

Results


Availability
95%
90%
85%
80%
75%
70%
Availability
1
5
10
15
20
Configuration Number


CTV Travels and Utilisation
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Total CTV Travels (h)
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
CTV Utilisation (Average)
Total Travel
Utilisation
1
5
10
15
20


Distribution of Total Mothership Cost
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Proportion
1
5
10
15
20
Configuration Number
Charter Cost
Fuel Cost
Crew Cost
Fixed Costs

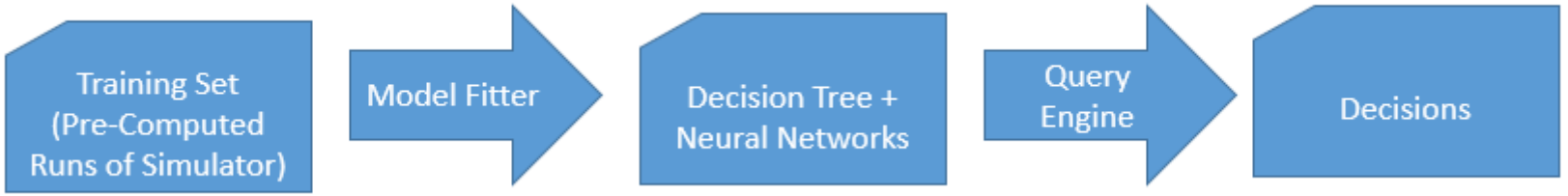

Total O&M Cost/MWh
120%
100%
80%
60%
40%
20%
0%
Change
1
5
10
15
20
Configuration Number

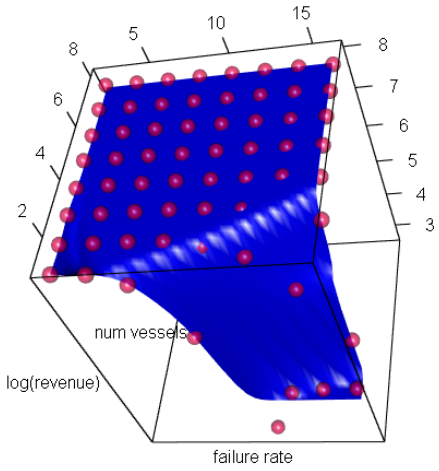
Emulator

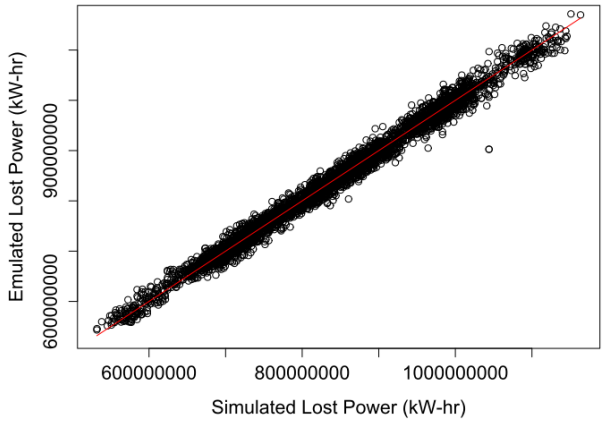
- Monte-Carlo convergence requires hundreds to thousands of runs of the simulator, which can take several hours.
- In order to allow quick decisions and automated optimisation, we need a continuous function approximation of the simulator's response.
- Hence we have developed such a model. We call it the "emulator" of the simulator.
- Emulator does not try to represent the internal state of the real world phenomenon, and instead tries to replicate the input-output behaviour.

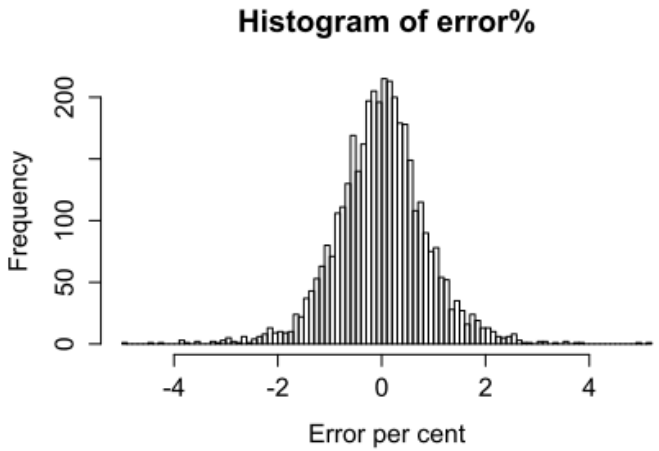
Emulator for StrathOW-OM

- The emulator “learns” from a given set of simulation results.
- Essentially it is a mixture of interpolation, multivariate approximation (using neural network), and decision tree.
- Decision trees are needed because of non-numerical (ordinal) variables.
- Neural Networks learn the mapping of numerical (cardinal) variables.

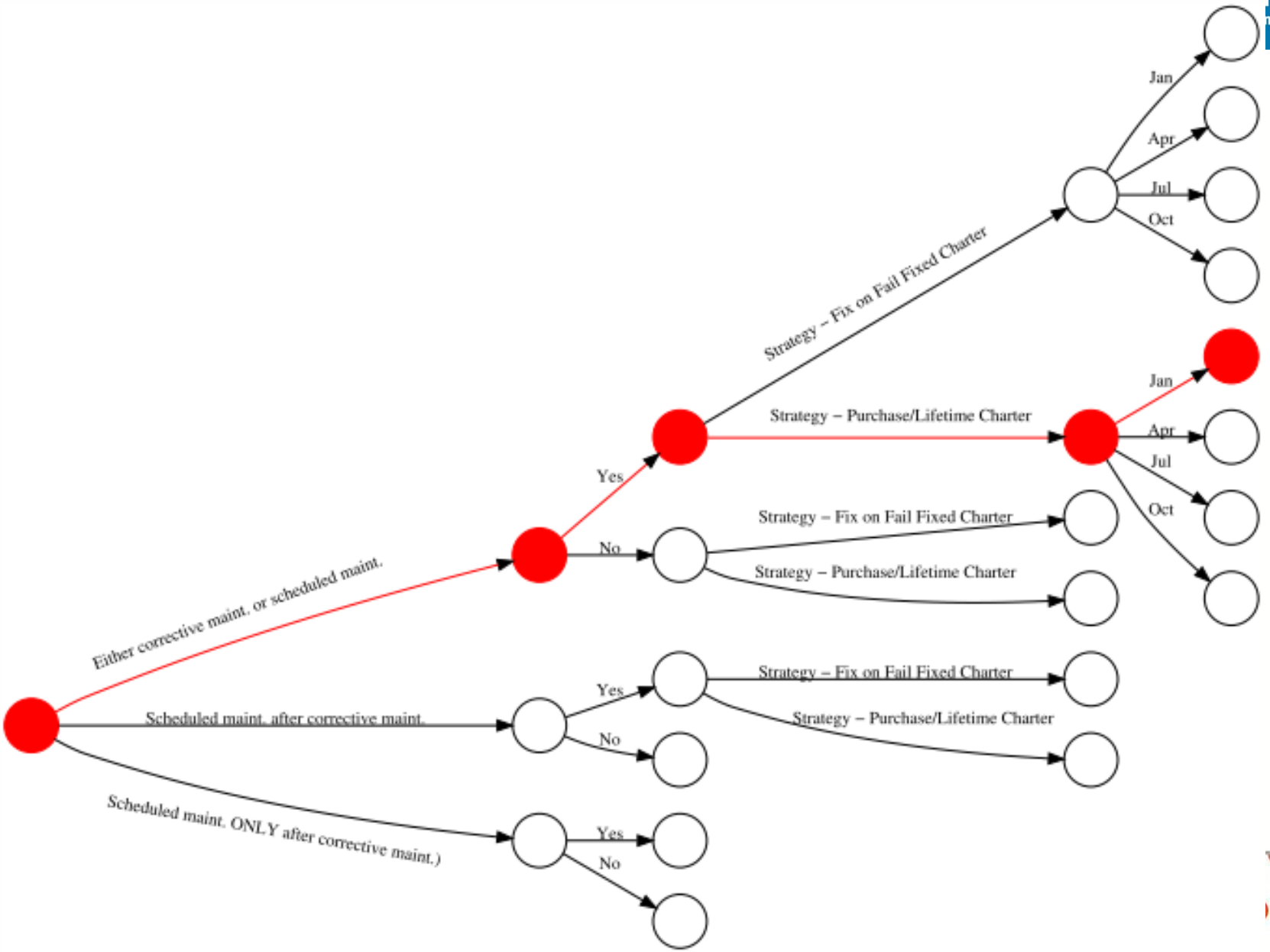




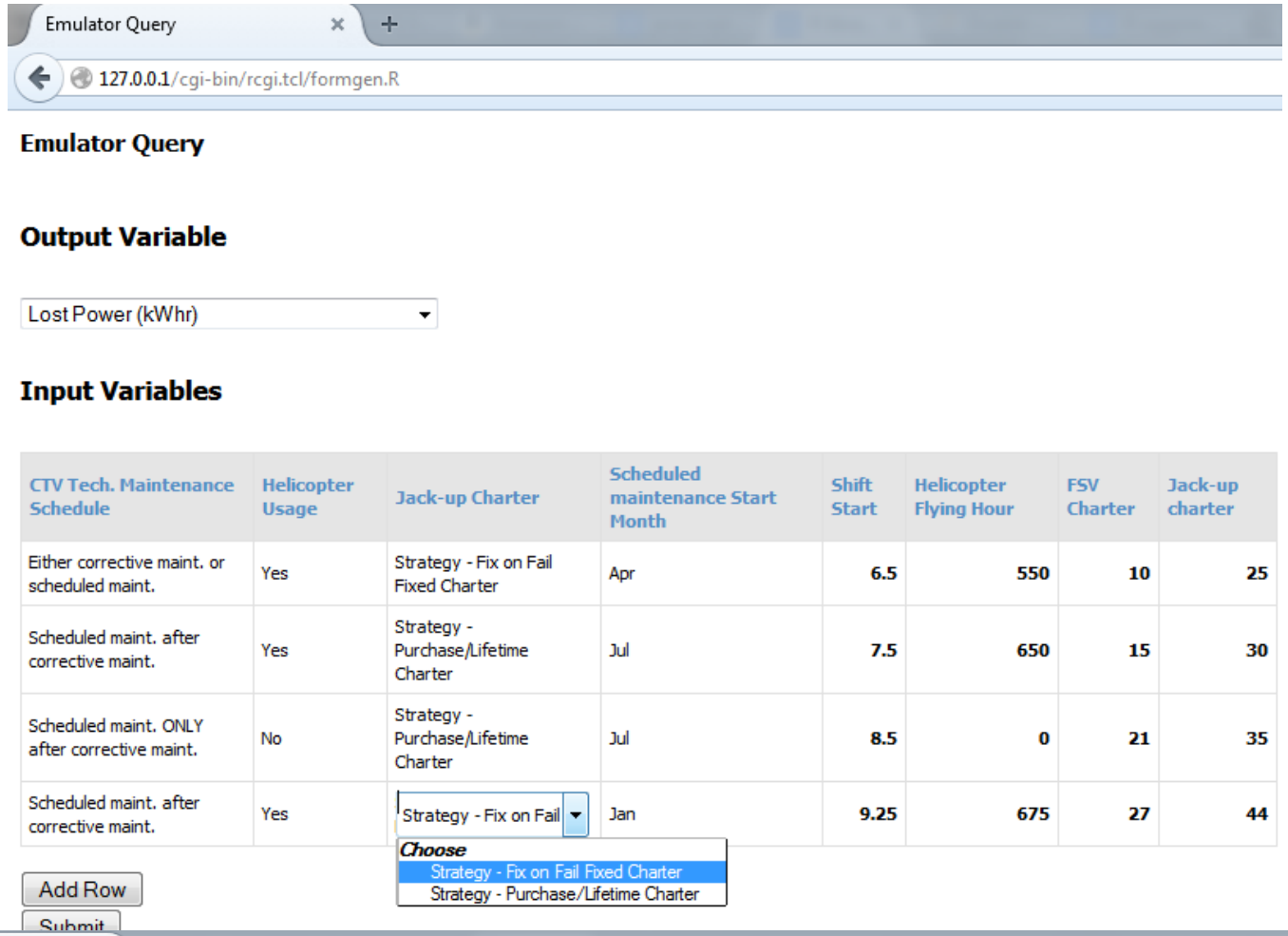




Ordinal Variables in the Emulator



Web Interface to Emulator



Conclusion

- Mothership concepts can bring a considerable advantage when the distance between offshore wind farm and port is long (>50 nautical miles).

- Fixed platforms can be considered in shallow waters; however, for deeper waters, mothership concepts are expected to be considered in offshore wind O&M fleets.

- Mothership concepts increase winter availability more than summer availability. If a mothership is not chartered for winter, productive period is expected to be significantly short.

- The most favourable alternative is significantly dependent on the climate, distance, water depth, failure rates, CTV fleet size, turbine capacity and wind farm size. Therefore each case should be investigated individually.

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