

Comparison of Weather Window Statistics and Time Series Based Methods Considering Risk Measures

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Abstract

Offshore activities, like the installation of offshore wind farms, consist of a number of different and often weather dependent activities. These activities and their relations are defined in project schedules which have to be assessed for weather effects before the project realization. Here often Weather Window Statistics are used as a statistical method. Another possible approach is the Weather Time Series Scheduling (WaTSS) method which combines the given project schedule, weather restrictions and historical weather time series data, often for several decades. The aim of this paper is a comparison of the two approaches especially when it comes to risk analysis with percentile values or related risk measures. Therefore, we create project schedules, including parallel process chains. Weather data is used both as basis for the Weather Window Statistics and the WaTSS analysis. We calculate weather downtimes for each task as well as for the total project and apply the risk measures Value at Risk (VaR), Conditional Value at Risk (cVaR) and Upper Partial Moments (UPM). This is followed by an analysis of the results from Weather Window Statistics and the WaTSS method considering their applicability and consistency.

Introduction

The assessment of weather delays is imperative for project risk management. The weather delay times can be calculated with different methods. We compare these methods considering the application of risk measures. Therefore we create project plans with certain weather restrictions and calculate the corresponding delay times using Weather Window Statistics and WaTSS method. As a first step, we give a short insight in the different methods. In Weather Window Statistics, the weather data is analyzed considering weather windows. As a result one gets the relative frequency of weather windows from different length for every month. In WaTSS method, which is implemented in the Fraunhofer IWES COAST tool, we use the total project schedule with the given predecessor-successor-structure combined with historical weather data. We model the project plan starting at different times and check the corresponding weather data for weather windows to execute each task. The delay times from the different simulation runs give a distribution of delay times for each task and for the whole project plan.

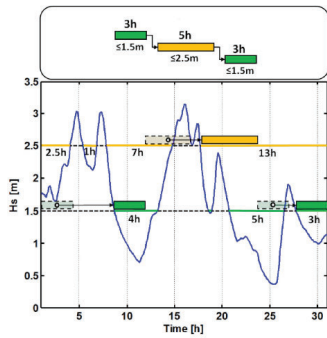


Figure 1: Exemplary Illustration of a Project Schedule in WaTSS method comp. [1]

Methodology

Project Plan Specification

- $m = 55, 42, 28$ tasks with duration and minimum weather window length $d = 6, 8, 12$
- finish-start predecessor structure
- project start: 1st, 8am, in every month

Weather Data Specification:

- ERA5 model for location FINO1
- $n = 40$ years historical data
- restricted on significant wave height lower equal than threshold $T = 1.5$

Calculation of Delay Times

Weather Window Statistics: Using Weather Window Statistics we calculate for each month a sample of size n with task delay times $y = \{y_1, \dots, y_n\}$ and total project delay times $Y = \{Y_1, \dots, Y_n\}$.

WaTSS method: From WaTSS method we get a sample of delay time of the whole project plan $X = \{X_1, \dots, X_n\}$ as well as m samples for every task i $x_i = \{x_{i1}, \dots, x_{in}\}$.

Risk Measurement

We take into account *Value at Risk*, *Conditional Value at Risk* and *Upper Partial Moments*.

Definition 1 (Value at Risk). The Value at Risk of a sample Z for confidence level p , called $\text{VaR}_p(Z)$, is defined as the p -Quantile-Value of Z .

Definition 2 (Conditional Value at Risk). Let Z be a sample. The Conditional Value at Risk for confidence level p is defined as

$$\text{cVaR}_p(Z) := \mathbb{E}[Z \mid Z > \text{VaR}_p(Z)].$$

VaR and cVaR are calculated for confidence niveaus $p \in \{0.75, 0.95\}$. Using the definitions, we calculate $\text{VaR}_p(Y)/\text{cVaR}_p(Y)$ and $\text{VaR}_p(X)/\text{cVaR}_p(X)$ for total project delay as well as $\text{VaR}_p(y)/\text{cVaR}_p(y)$ for task wise delay in Weather Window Statistics. For task delay VaR/cVaR in WaTSS method, we define the calibration factor ρ_i as

$$\rho_i := \frac{\bar{x}_i}{\bar{X}}, \quad (1)$$

where \bar{x}_i is the Mean of task i delay time, thus $\bar{x}_i = \frac{1}{n} \sum_{j=1}^n x_{ij}$, and \bar{X} describes the Mean of total project delay time. Using this we calculate the VaR and the cVaR for each task i with

$$\text{VaR}_p(x_i) = \rho_i \text{VaR}_p(X) \quad \text{and} \quad \text{cVaR}_p(x_i) = \rho_i \text{cVaR}_p(X). \quad (2)$$

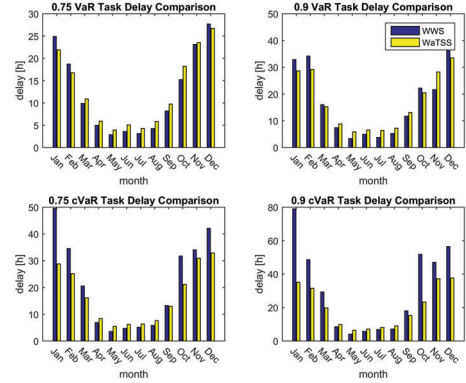


Figure 2: VaR and cVaR for Project with 12-Hour-Tasks

Definition 3 (Upper Partial Moments). Let Z be a sample. The Upper Partial Moments for benchmark c and order k is defined by

$$\text{UPM}_k(c, Z) = \mathbb{E}[\max(Z - c, 0)^k]$$

where we set $0^0 := 0$

The order k gives different results for UPM:

- $k = 0$: $\text{UPM}_0(c, Z)$ gives the probability to exceed the threshold c

- $k = 1$: $\text{UPM}_1(c, Z)$ gives the average exceeding height

We calculate the UPM for order 0 and 1 for each sample Y, y, X, x_i using its mean as benchmark.

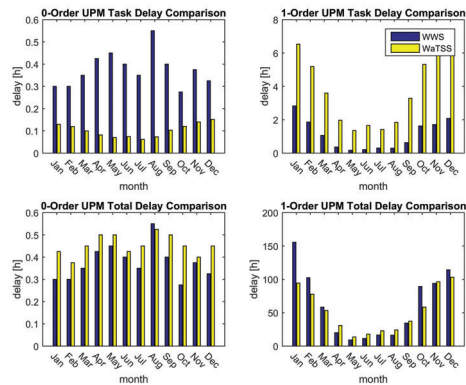


Figure 3: UPM for Project with 6-Hour-Tasks

Results

VaR and cVaR (Figure 2):

- Summer: WaTSS tends to be a little higher than WWS
- Winter: extremely high values for WWS esp. for higher percentiles

UPM (Figure 3):

- Taskwise Delay: WaTSS low 0-Order, high 1-Order
- Total Delay: WWS has lower 0 order, higher 1-Order

A reason for the difference might be the way VaR and cVaR are calculated in WaTSS method. We use the total project risk and the calibration factor for calculation. Thus, we provide the impact of Knock-On Effects. We make sure to not overvalue occasionally occurring huge task delays, that do not affect the total project delay due to following tasks not having any delay at all.

The task wise UPM results show that there are only a few delay values for a task that exceed the mean, but these few values are very high. The Knock-On Effect also attributes this. In total project delay, the effect is vice versa - especially in winter months. This shows that the distribution of total project delay times in WaTSS method is more concentrated around the mean while the one from WWS tends to have heavier tails.

All in all, one should always keep in mind that the method, that was used to calculate the delay times, has a big impact on the results. To provide realistic risk values, one has to specify whether a total complex project is analyzed or whether only a few independent tasks are considered. For the latter we recommend Weather Window Statistics, but for complex offshore installation projects a risk analysis calculated with WaTSS method models certain effects and therefore should be used in that case.

References

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