Description of a `Problem` Object

A `Problem` object represents a terminal and stevedoring status. It is associated with the current time and the planned schedule at this time. Further, it is defined through the cargo units' and tugs' information. Table 1 summarizes the statuses cargo units and tugs can have.

Table 1 Description of Cargo and Tug Statuses.

Category	Status	Description
Cargo Processing Status	`initial`	The cargo is at its departure position.
	`selected`	A tug selected the cargo as the next operation.
	`in_process`	The tug started handling the cargo.
	`finished`	The tug finished the operation, the cargo is at its destination position.
Cargo Predecessor Status	`blocked`	At least one predecessor has processing status `initial`.
	`pred_selected`	No predecessor has processing status `initial`, and at least one predecessor is in processing status `selected`.
	`available`	All predecessors have status `in_process` or `finished`.
Tug Status	`idle`	The tug is idle.
	`moving_to_task`	The tug selected a cargo unit and moves to its departure position.
	`arrived_at_cargo`	The tug arrived at the selected cargo's departure position.
	`delays_start`	The tug delays starting the operation as predecessors are not in progress yet, or it delays the (import) operation to allow the buffer time to the cargo's predecessors to pass.
	`handling_cargo`	The tug handles the cargo (coupling, moving, uncoupling).
	`delays_end`	The tug delays completing the (export) operation to allow the buffer time to the cargo's predecessors to pass.
	`broken`	The tug is broken and cannot handle any further cargo.

Tugs. The tug status determines whether it is idle or busy and at what stage of handling an operation it is. When in process, they have a "time left" to complete the operation. This study neglects travel paths, so tugs are either located at their cargo's

departure or destination position, or they are currently traveling between positions and thus are not associated with a specific position.

Cargo. The cargo units have a *processing status* that defines their current progress, and a *predecessor status* that determines whether a tug can move them, given precedence constraints. Cargo units have a departure and a destination position. Further, they are associated with vessel and yard positions. For import (export) cargo, the vessel position matches the departure (destination) positions, and the yard position matches the destination (departure) position. A cargo's current location is either its departure or destination position, or it is currently in transfer.

Times. A `Problem` object contains *expected* processing times for each cargo operation as well as *expected* travel times between any two cargo units' destination and departure positions. These times are computed from the travel distances and the average tug speed.

Before stevedoring, Monte Carlo simulation is used to draw a set of random factors from a shifted log-normal distribution to compute the *real* times to apply in the analog twin (AT) simulation. The set of times resulting from multiplying random factors and expected times is stored in the `Problem` object. The underlying distribution $\mathcal{LN}(\mu, \sigma^2)$ is modeled such that the minimal possible value is 0.5 and the average is 1, i.e., with a given standard deviation σ, it follows $\mu = \ln(0.5) - 0.5 \cdot \sigma^2$. Given the average factor of 1, the expected and real times are, on average, equal. The lower bound of 0.5 accounts for an assumed maximal achievable tug speed.

Finally, once a cargo unit is `in_process`, it is linked to its realized starting time. Once `finished`, it is associated with its realized completion time.