6 CONTACT DRIFT MODEL

A drifting collision is the result of an event that cannot be stopped by the crew on board, which causes a ship to lose power and starts drifting. The engine failure can occur on any position at sea. After the failure, the disabled ship starts drifting in a direction with a certain drift velocity depending on the environmental conditions, like wind speed and current.

A drifting ship can be a threat to an (fixed) object on the sea. When the ship is drifting in the direction of the object and the problem cannot be fixed in time, the ship can drift against the object. Usually the ship will drift at low speed, so the impact will occur with low energy, but still a lot of damage can be done to the object and the ship.

6.1 Global description of the model

In the SAMSON-model ships are assumed to sail from one waypoint to another waypoint over so-called links. When an engine failure occurs it is assumed that a ship starts drifting in the direction of the wind. So not all ships that have an engine failure will eventually drift against the object, even when the engine failure cannot be repaired for a very long time. So there are parts of the link on which the ship can never reach the object when it starts drifting and there is a part where it can.

Therefore the first step in determining the number of ships that drift against an object is to determine on which part of a link a ship will drift against the object when an engine failure occurs of infinite duration, given a certain wind direction (drift direction). This part of the link is called the danger part of the link, see Figure 6-1. This danger part depends on the coordinates of the waypoints connected by the link, the co ordinates, dimensions and the orientation of the object, the length of the ship and the drift direction.

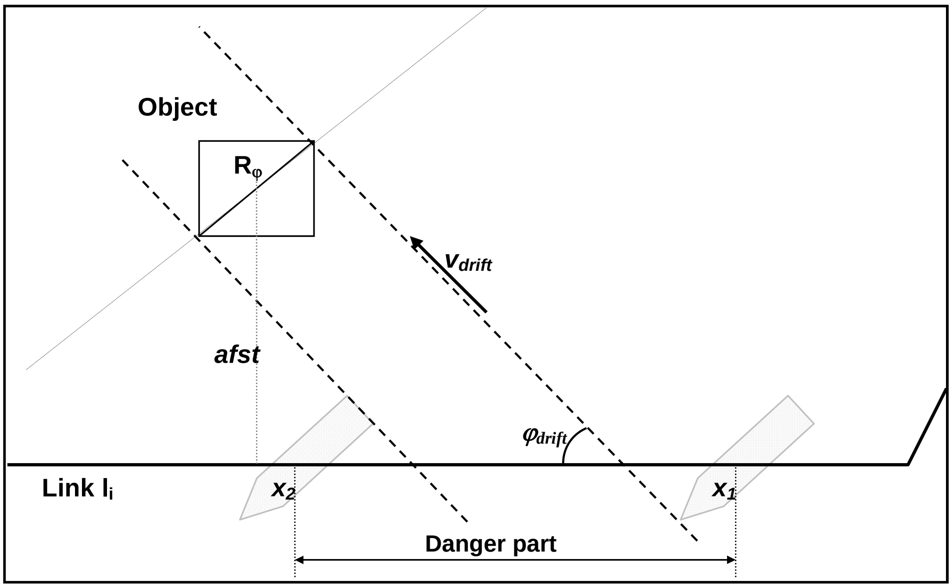


Figure 6-1 Figure of the danger part of a link.

Second, the drifting distance from the link to the object is determined for all positions on the danger part of the link. The link is always represented by a straight line, the distance between the position on the link and the object is given as a function of that position on the link.

A ship will only drift against the object if it takes more time to repair the engine failure than it takes to drift from the link to the object. So it is necessary to know the drift velocity of the ship (third step). This drift velocity depends on the wind, wave and current speed. The drift direction is assumed to be equal to the wind direction.
Using this drift velocity, the drifting time, necessary to drift from a point on the link to the object, is calculated.

The fourth step is to determine the probability that the calculated drifting time is larger than it will take to repair the engine failure. Using casualty data from Lloyds and data collected by the Dutch Coastguard concerning drifting ships, a so-called repair function is defined. This repair function is a probability function for the duration of an engine failure:

$$P_{EF}(t > t_s) \qquad \text{(Eq. 6-1)}$$

where:
$P_{EF}(t>t_S)$: probability of an engine failure of t_S hour or longer

So the probability for a ship to drift against the object from a certain point of the danger part ($P_{DRIFT}(x)$) is given by:

$$P_{DRIFT}(x) = P_{EF}(t > t(x))$$
$$t(x) = \frac{r(x)}{v_{drift}} \qquad \text{(Eq. 6-2)}$$

where:
$P_{EF}(t>ts)$: probability of an engine failure of ts hour or longer
$t(x)$: drifting time from point x on the link
$r(x)$: distance between point x on the link and the object.
v_{drift} : drift velocity.

Integrating this function over all points of the danger part gives the total possible threat for drifting of the link to the object given an engine failure.

$$P_{DRIFT} = \int_{x_1}^{x_2} P_{DRIFT}(x)dx \qquad \text{(Eq. 6-3)}$$

with x_1 and x_2 the boundary points of the danger part.

Finally the Danger Mile (DM) for a certain link (l_i) is given by the total number of ships (per type and size) that will drift against an object given an engine failure:

$$DM(l_i) = P_{DRIFT}(l_i) * N_{SHIP}(l_i) \quad \text{(Eq. 6-4)}$$

The final step in determining the number of ships that will drift against the object is multiplying the Danger Mile for a specified link (l_i) and with the probability of an engine failure. Then adding all contributions of all links will give the total possible ships that will drift against a given object.

$$N_{DRIFT} = \sum_{l_i} DM(l_i) * P_{ENGINE\_FAILURE} \quad \text{(Eq. 6-5)}$$

with

$N_{DRIFT}(l_i)$:	Number of ships that will drift against the object from link li
$P_{ENGINE\_FAILURE}$:	Probability of an engine failure
$N_{SHIP}(l_i)$:	Number of ships of specific type (length) and size on link li

The different steps in the calculation will be further explained in the next subsections.

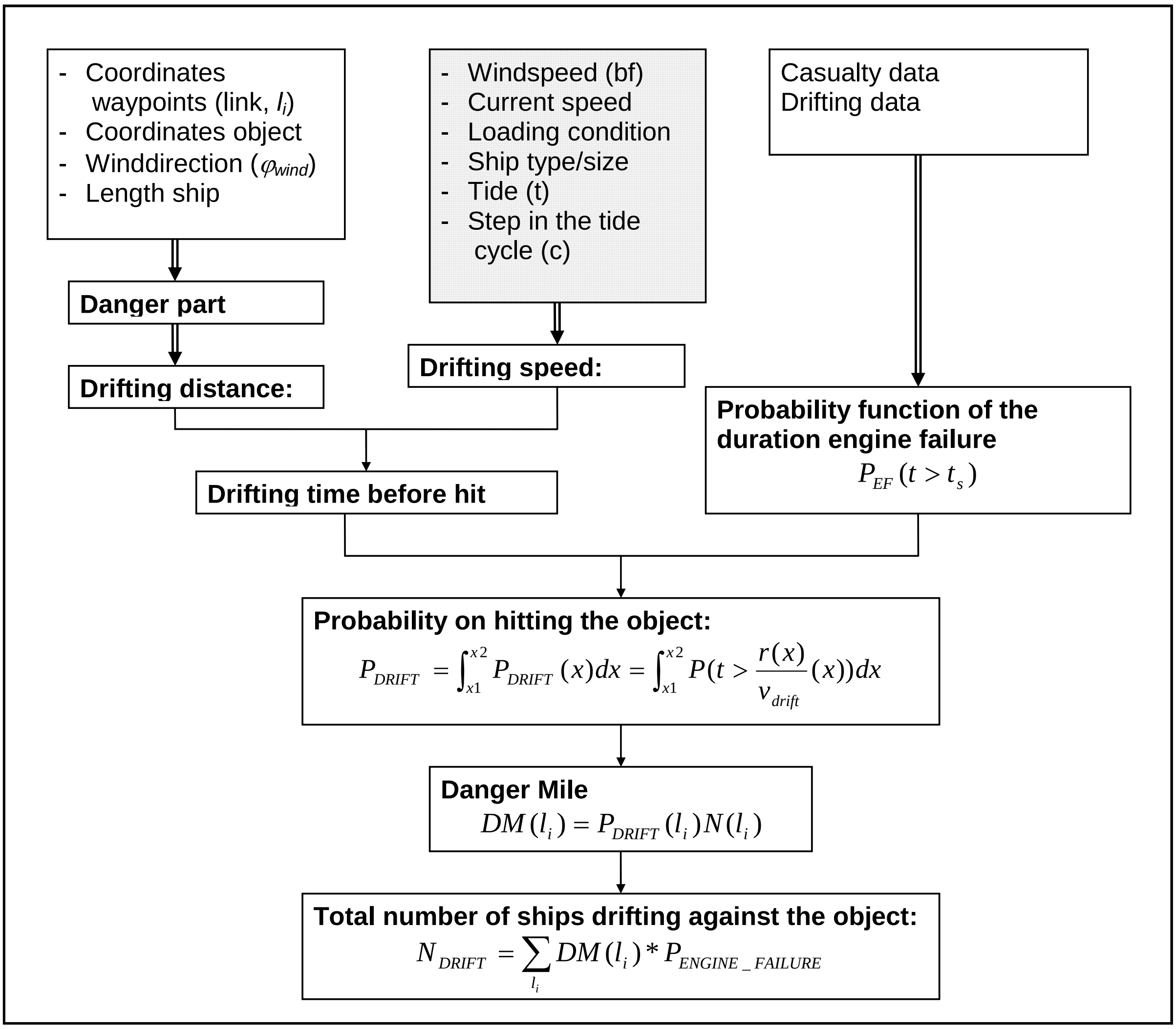


Figure 6-2 Short calculation plan: contact drift model

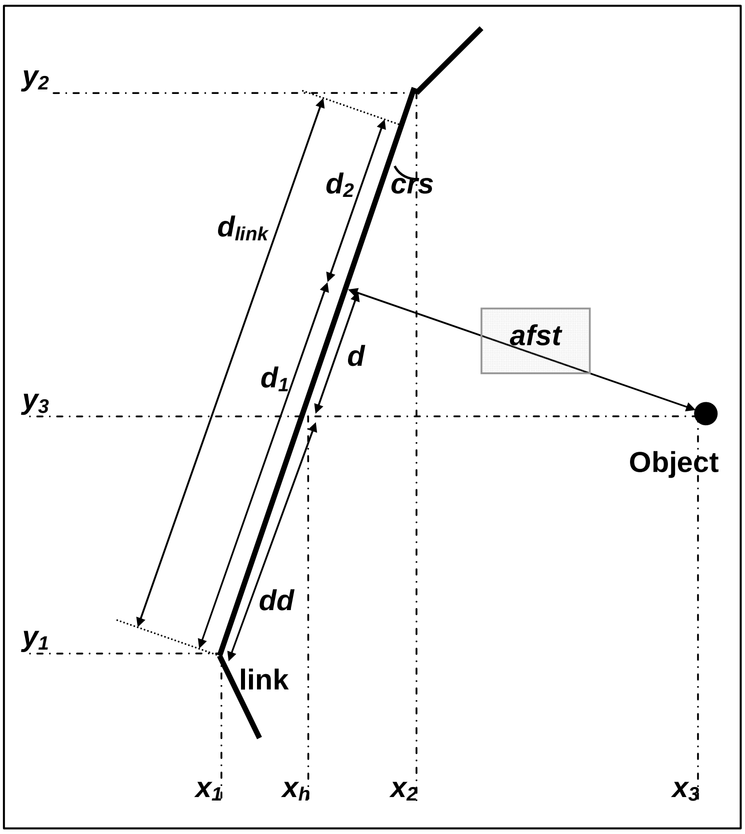
6.2 Danger part

The traffic database of the SAMSON-model consists of different waypoints connected by different links. In the database it is known how many ships sail on each link per ship type and size.

The danger part of a link is the part of the link from which a (specific) ship will drift against an object when an engine failure of infinite duration occurs, given a certain drift direction (assumed to be equal to the wind direction).
Calculating the danger part of a certain link, object and drifting (wind) direction and ship type (ship length) consist of three steps.
First, the minimal distance between the object and the link is calculated using the coordinates of the waypoint connected by the link, the coordinates of the object (see block 1, Figure 6-3).

Using the minimal distance, the dimension and orientation of the object and the drift direction, the two boundary points (x_{1a} and x_{2a}) of the danger part can be calculated (step two, see Figure 6-4). The drift direction is assumed to be equal to the wind direction. In the model the current will only have an influence on the drift velocity because the contribution of the current vector in the wind direction is added.

Finally the length of the ship is included. So the danger part is defined by the two boundary points x_1 and x_2. If a ship of the specified length has an engine failure (of infinite duration) between the points x_1 and x_2 the ship will drift against the object for the given wind direction.



Block 1:
Calculate the minimal distance between the object and the link

$$crs = \tan^{-1}\left(\frac{x_2 - x_1}{y_2 - y_1}\right)$$

$$d_{link} = \frac{y_2 - y_1}{\cos(crs)}$$

$$x_h = x_1 + (y_3 - y_1)\left(\frac{x_2 - x_1}{y_2 - y_1}\right)$$

$$afst = (x_3 - x_h)\cos(crs)$$

$$d = (x_3 - x_h)\sin(crs)$$

$$dd = \frac{y_3 - y_1}{\cos(crs)}$$

$$d_1 = -(d + dd)$$

$$d_2 = d_1 + d_{link}$$

Figure 6-3 Calculation block 1 for determining the danger part of a link.

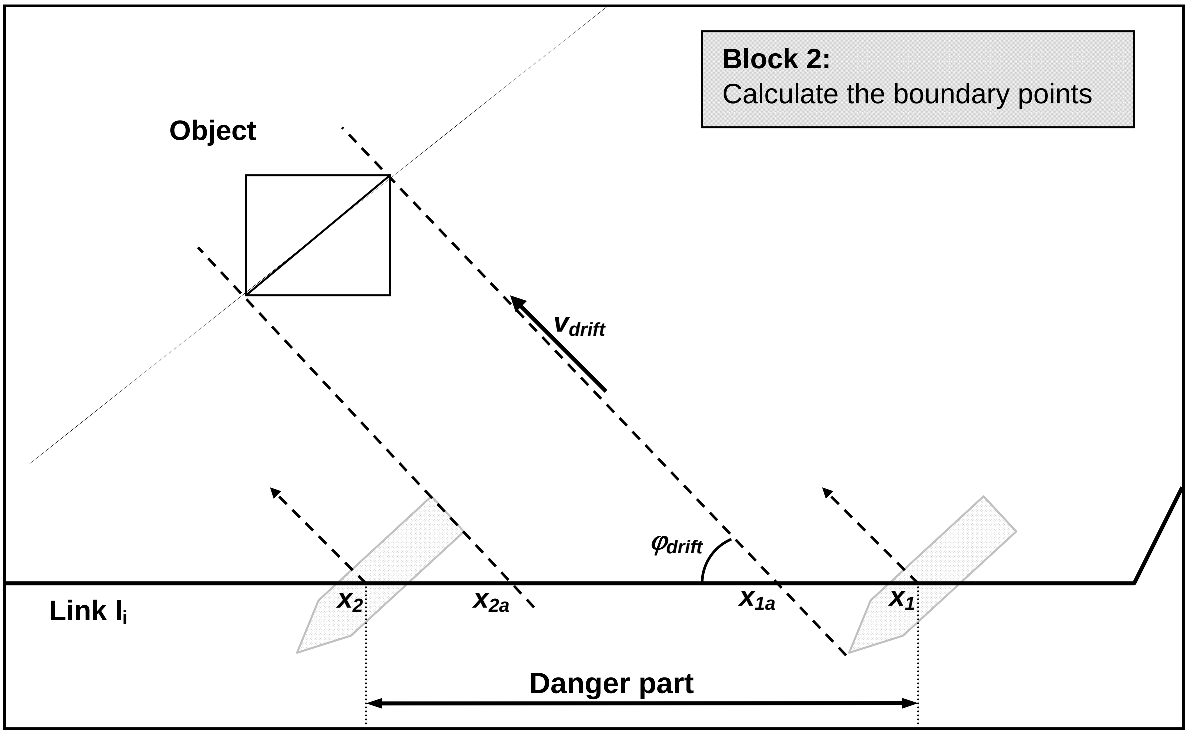


Figure 6-4 Calculation block 2 for determining the danger part of a link.

6.3 Lateral distribution over the link; sub-link

A link is defined as a connecting line between two waypoints. Because not all ships use the exact line to sail over the link, a lateral distribution over the link is defined. So, a link contains several “sub-link”-lines and the total number of ships sailing over the link is “divided” over the sub-links using a distribution function. The distance between the different sub-links, depending on the given sigma, is known for the link. So for each sub-link the minimal distance to the object can be calculated. Subsequently, therefore, the boundary points of the danger part on the sub-link, resulting from this calculated minimal distance, for a certain drift (wind) direction and ship type (length).

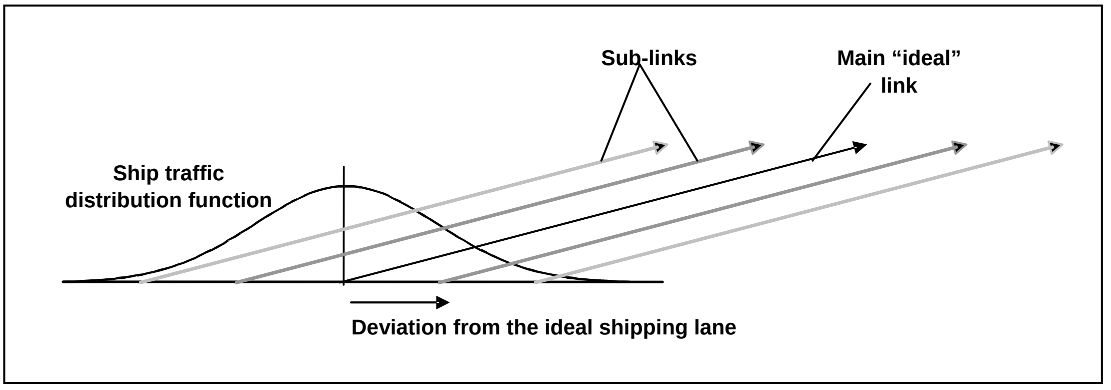


Figure 6-5 Lateral distribution of a shipping link

6.4 Minimal passing distance

Because most objects (platforms) at sea have a safety zone, the minimal passing distance is an input for the model. If the calculated minimal distance between the object and the sub-link is smaller than the given minimal passing distance, the calculated passing distance is set to the minimal distance, which means that the sub-link is moved away from the object. So, if an object is situated too close to a (sub) link, the link is being “repositioned” in a way, a (sub) link can therefore never lay inside a safety zone of an object.

6.5 Drifting distance

The danger part gives only information about which part of the link is a potential threat to the object. To determine if a ship will actually drift against the object, it is necessary to know the time needed to drift from the (sub) link to the object. To calculate this so-called drifting time, first the distance between the point on the (sub) link where the engine failure occurs and the object has to be calculated.

The object is considered as a straight line between both “hit”-point from the two boundary points of the danger part. The link (danger part) is also represented as a straight line, so the distance between a point on the link and the so-called “object-line” is a linear function depending on the point on the link, *x*.

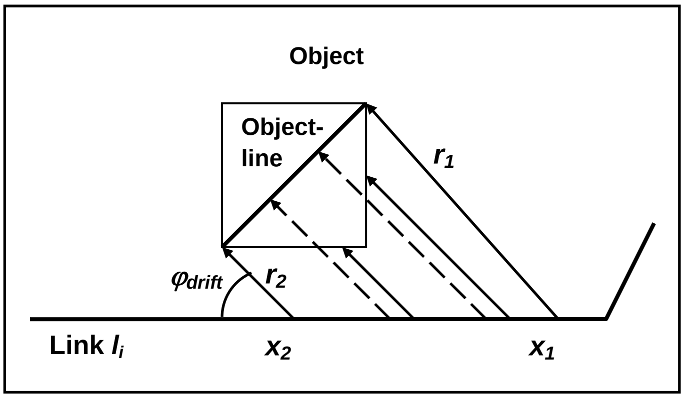


Figure 6-6 Drifting distance

Because the object is taken as a straight line, the calculated distance is not exactly correct. The actual distance will be less in most cases (a negligible amount because in reality the dimensions are quite different from what is shown in the figure), but this will not influence the total result. The same model is used for different objects, thus for platforms, piers, ships at anchor and also for stranding lines. Stranding lines have large dimensions but in this case the distance is calculated correctly.

To determine the distance function, the drifting distance in both boundary points of the danger part are calculated: r_1 and r_2. Using both calculated distances, the function can be determined for three situations:

1. "Object"-line is parallel to the link ($|r_1-r_2|<0.001$)

$$r(x) = r_1 \quad \text{(Eq. 6-6)}$$

2. "Object"-line does not cross the link and $|r_1-r_2|>0.001$

$$r(x) = \frac{r_2 - r_1}{x_2 - x_1}(x - x_1) + r_1 \quad \text{(Eq. 6-7)}$$

3. "Object"-line crosses the link. Occurs only in cases the "object"-line is really a stranding line, on case of an object, the link is repositioned (will be explained later)

$$x_o = x_1 - r_1 \frac{x_2 - x_1}{r_2 - r_1}$$

$$x \in [x_1, x_0] : r_I = \frac{|r_1|}{x_1 - x_0}(x - x_0) \quad \text{(Eq. 6-8)}$$

$$x \in [x_0, x_2] : r_{II} = \frac{|r_2|}{x_2 - x_0}(x - x_0)$$

6.6 Drift velocity

Knowing the distance between the (sub)link and the object (object-line) is necessary for knowing the drift velocity, to finally determine the (maximal) time for fixing the engine failure to prevent the ship to hit the object

The way the drift velocity is modelled depends mainly on the purpose of the calculations. If the drift velocity is required for operational purposes such as predicting the threat of a drifting tanker to a specific platform, one needs an extensive mathematical model to observe all hydrodynamic and aerodynamic components for the prediction of the most probable track of the drifting ship. If the drift velocity is used for determining the collision frequency for an object, it is enough to model only the main effects.

The drift velocity and direction of a ship with an engine failure is a result of the forces that are exerted by wind and waves. The current effects are simplified and are added as a vector to the drift velocity and the current will be dealt with after the wind and wave influences.

The wind direction and speed are given in a so-called compass rose and are "constant" in time. The current is given in direction and speed for high and low tide in a cycle of

12.5 hour (direction and speed given in 13 steps per cycle). Therefore the calculation of the resulting drift velocity contains two main parts. One part of the drift velocity is a result of the wind (and waves) and one part is a result of the current.

The following assumptions are made:

- wind and waves act in the same direction;
- the drifting ship moves purely in the lateral direction exerted by wind and waves (one degree of freedom);
- the wind direction and velocity are kept constant during the drifting process;
- a state of equilibrium of the forces that work on the ship, ignoring mass effects

6.6.1 Wind and waves

For calculating the drift velocity as a result of the wind and waves it is enough to model the three main effects:

- Wind force ($\boldsymbol{F_{wind}}$)
- Resistance of the ship when it is travelling through the water ($\boldsymbol{F_{res}}$).
- Second order drift force causes by the constant component of the current ($\boldsymbol{F_{wave}}$)

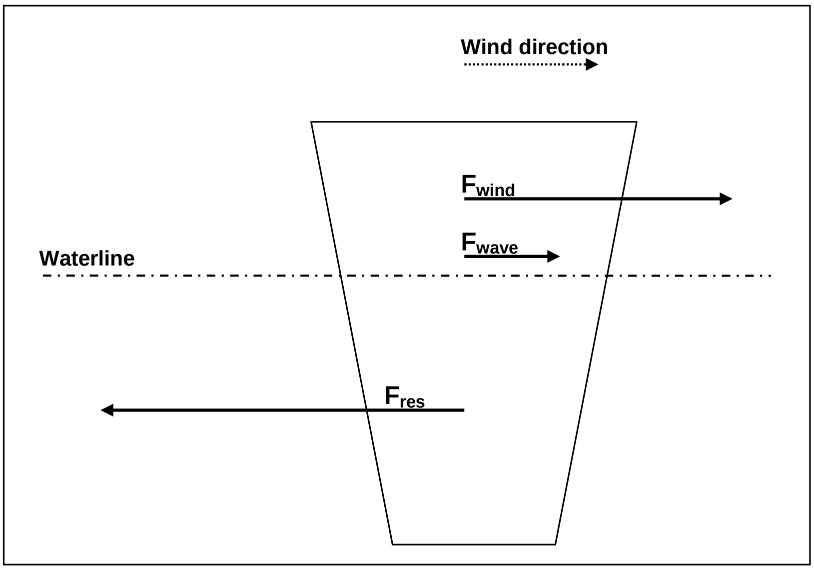


Figure 6-7 Forces acting on a drifting ship

The different forces can be calculated using the following relations (see [8] for a more detailed description):

$$F_{wind} = \frac{1}{2}\rho_{air} A_{Lin} C_{dwind} v_b^2$$

$$F_{res} = \frac{1}{2}\rho_{water} L_i T_{in} C_d v_{drw\_bin}^2 \qquad \text{(Eq. 6-9)}$$

$$F_{wave} = \frac{1}{16}\rho_{water} g \zeta_b^2 L_i R^2$$

where:

v_{drw_bin} = drifting velocity of ship i in loading condition n by wind and waves belonging to Beaufort class b as a result of the wind
v_b = wind velocity for Beaufort class b
r_{air} = density of air
r_w = density of water
A_{Lin} = the lateral wind surface of ship i in loading condition n
L_i = the length of ship i
T_{in} = the draught of ship i in loading condition n
z_b = the significant wave amplitude assumed to be generated for Beaufort class b
c_{dwind} = the lateral wind resistance coefficient of the ship
c_d = the lateral resistance coefficient of the underwater body of the ship
R = the wave drift coefficient
g = gravity constant

Assuming an equilibrium between all forces, the "constant" drift velocity of ship i in loading condition n by wind and wave belonging to Beaufort class b as a result of the wind can be estimated by:

$$v_{drift,wind}(i,n,b) = \sqrt{\frac{\rho_{air}}{\rho_w}\frac{A_{Lin}}{L_i T_{in}}\frac{c_{dwind}}{c_d} v_b^{\ 2} + \frac{1}{8}\frac{\zeta_b^{\ 2} g}{T_{in}}\frac{R^2}{c_d}} \qquad \text{(Eq. 6-10)}$$

Assumption:
c_{dwind} = 0.9 for all ship types
c_d = 0.8 for all ship types

Until January 2005, the wave drift coefficients were given coefficients only depending on the Beaufort class. Therefore, for each Beaufort class a drift wave coefficient is (was) defined. In Table 6-1 the value of the different wave drift coefficients can be found.

Starting from January 2005 the wave drift coefficient is defined using a different method. This method is based on [8].
The wave drift coefficient is different for each Beaufort class, because the waves depend on the wind(force). From [8] follows the relation between the drift coefficient (R) and the dimensionless coefficient kT, composed of the wave number k and draft T. This relation is established using experimental values. The relation can be described by:

$$kT = k * T$$

$$kT > 1 \Rightarrow R = 1 \qquad \text{(Eq. 6-11)}$$

$$kT \le 1 \Rightarrow R = a*(kT)^3 + b*(kT)^2 + c*(kT)$$

with

a = -1.4736
b = 2.4765
c = -0.0315

For each Beaufort class the mean wave period (T_p) is known. Given this period, the (circular) wave frequency (ω) can be determined by:

$$\omega = \frac{2\pi}{T_p} \qquad \text{(Eq. 6-12)}$$

The relation between ω and the wave number *k* in deep water can be established from the condition that fluid particles in the surface of the fluid remain there, so:

$$\omega^2 = kg \tanh(kh) \qquad \text{(Eq. 6-13)}$$

where
ω = wave frequency
k = wave number
g = gravity constant
h = water depth

For deep water h → ∞ the relation reduces to:

$$\omega^2 = kg \Rightarrow k = \frac{(2\pi)^2}{T_p^{\ 2} g} \qquad \text{(Eq. 6-14)}$$

So, for each Beaufort class the wave number can be determined. For each ship type and ship size and loading condition the average draft T is known. Using the wave number and the average draft (for that loading condition) the drift coefficient is determined using the relation mentioned before. In Table 6-1 the wave drift coefficients are given for the different Beaufort classes and for different ship drafts in depth water. The coefficients are also plotted in Figure 6-8.

Table 6-1 Wave drift coefficients for each Beaufort class, using both methods

Bft	Wave period: T_p[s]	wave number: *k*	Wave drift coefficients *R*			
			Coefficients used till Jan 2005	Coefficients used from Jan. 2005		
				T = 5m	*T* = 10m	*T* = 15m
0	0		1	1	1	1
1	0.78	6.615	1	1	1	1
2	1.87	1.151	1	1	1	1
3	3.06	0.430	0.997	1	1	1
4	4.62	0.189	0.990	0.996	1	1
5	6.21	0.104	0.971	0.481	1	1
6	7.7	0.068	0.908	0.238	0.702	1
7	9.24	0.047	0.784	0.126	0.411	0.739
8	10.81	0.034	0.615	0.071	0.244	0.474
9	12.44	0.026	0.411	0.043	0.150	0.302
10	14.09	0.020	0.240	0.027	0.096	0.197
11	15.79	0.016	0.123	0.018	0.063	0.132

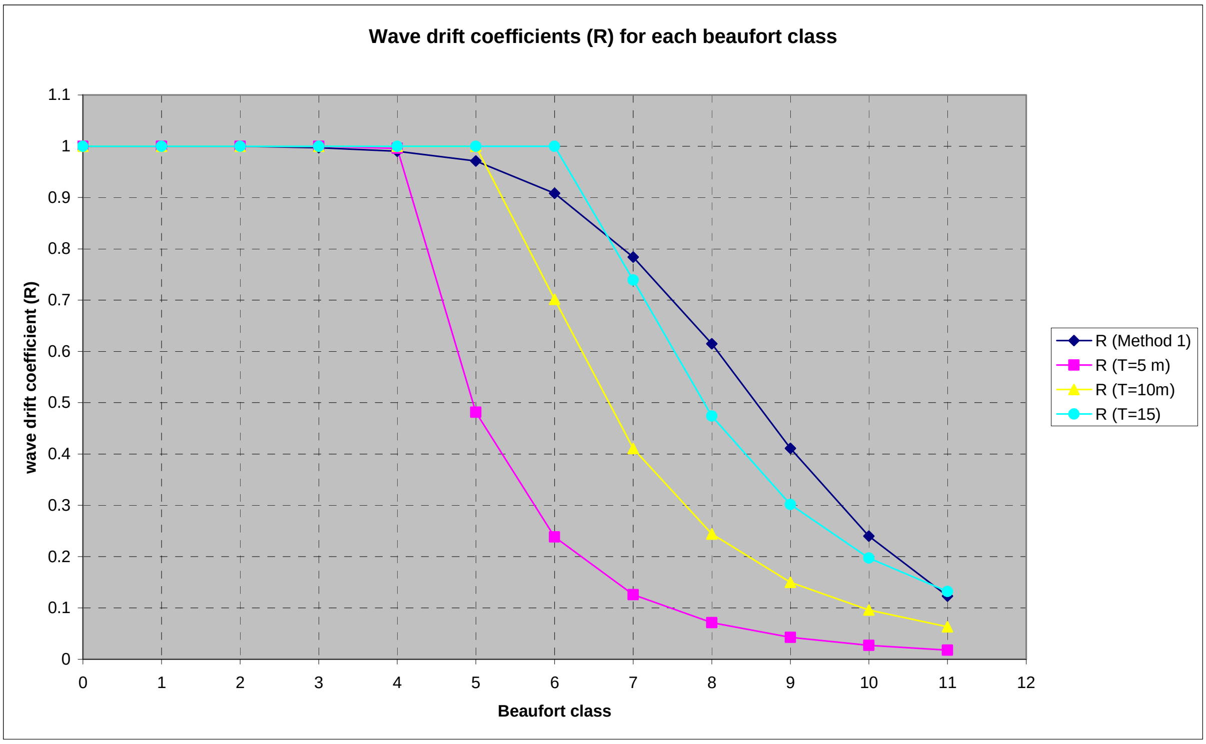


Figure 6-8 Wave drift coefficient for each Beaufort class.

6.6.2 Current

The current is given in direction and speed for high and low tide in a cycle of 12.5 hours (direction and speed given in 13 steps per cycle). Only the projected speed in the direction of the drift velocity is added to the drift velocity as a result of the wind (v_{drift}). This projected velocity is called $v_{curr}(i,j)$, with I = 1, 2,.., 13 the step of the cycle and j = 1,2 the tide. Therefore, the resulting drift velocity is different for every step in the current cycle. In reality there is also a velocity component in the perpendicular direction which means that a ship will not drift in a straight line. So, it can happen that a drift collision from a certain starting point on the link is counted in this approach while it will not occur in reality. However, such a collision should occur when the engine failure was started from another point on the traffic link, thus from a point now not leading to a drift collision, see Figure 6-9. The error by this approach in the calculated collision frequency is very small.

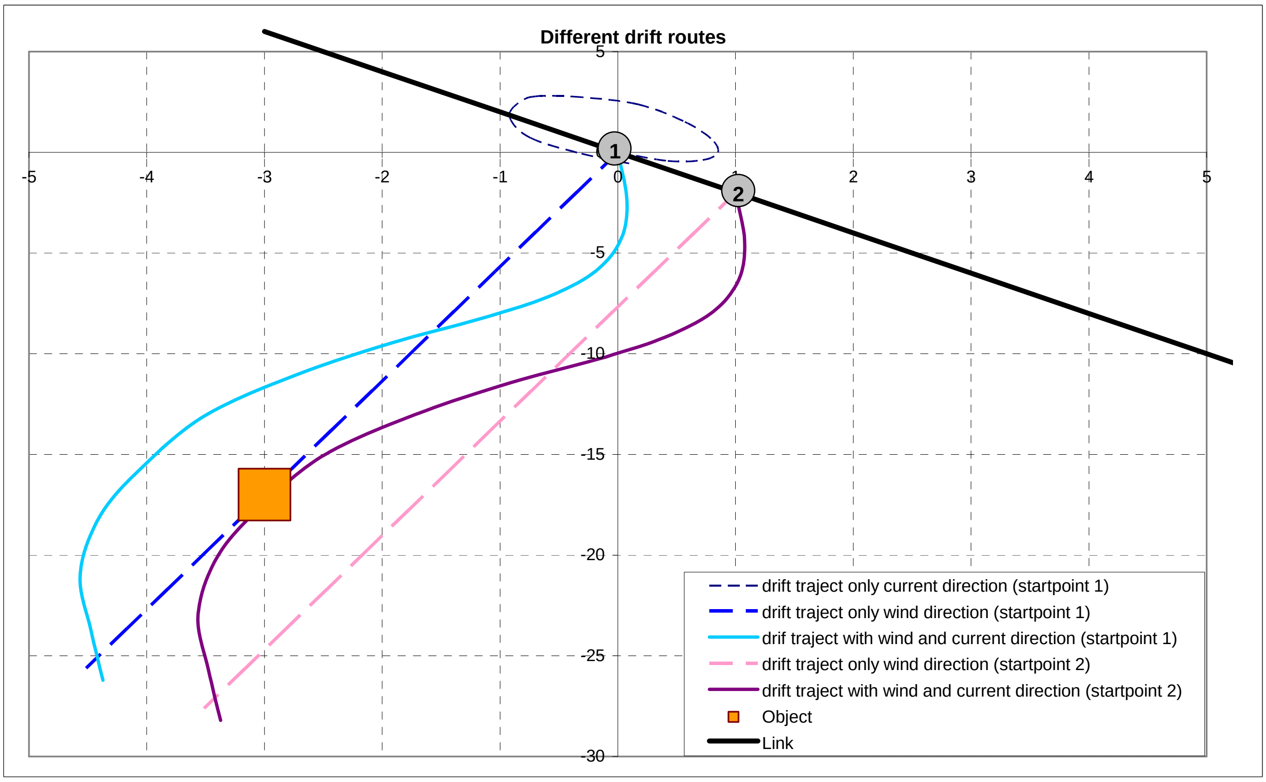


Figure 6-9 Drift routes starting from two different points on the link.

6.6.3 Total average drift velocity

The final drift velocity is determined using the average distance between the object and the (sub)link:

$$r_0 = \frac{r_1 + r_2}{2} \qquad \text{(Eq. 6-15)}$$

The drifting time is determined using the combined drift velocity, starting at a certain tide (t) and step in the tide cycle (c). Using this (average) drifting time and the (average) distance to the object, the (average) drift velocity is calculated.

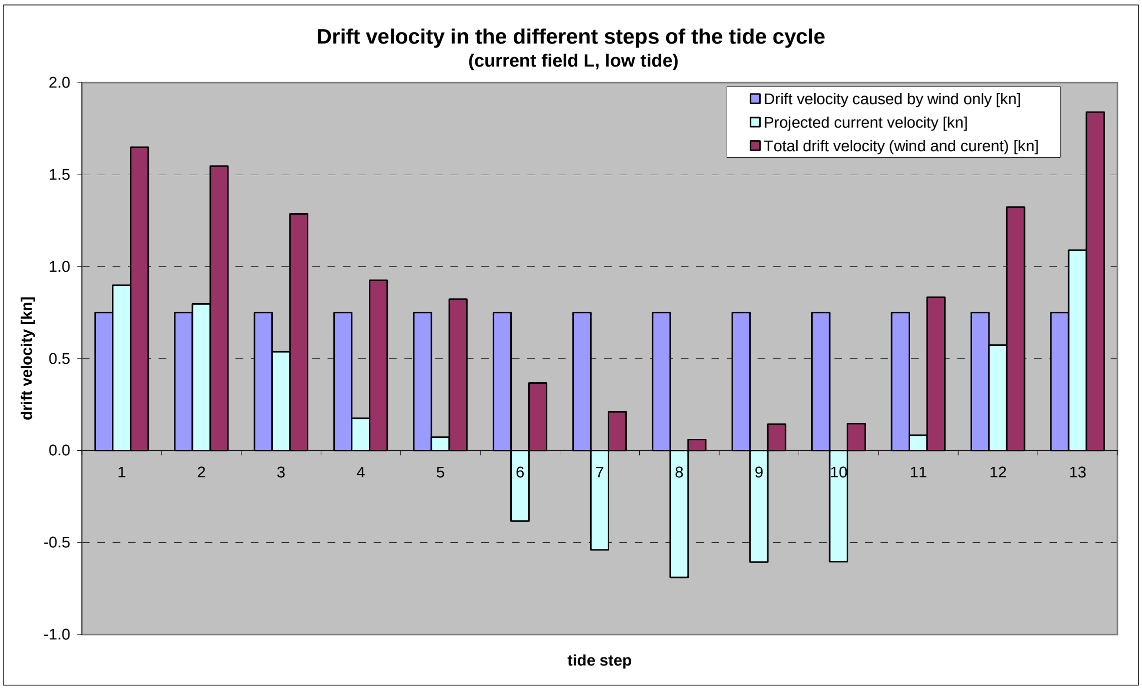


Figure 6-10 Drift velocity in the different steps in the tide cycle.

Figure 6-10 shows an example for the velocity components and total drift velocity in the different steps of the tide cycle. The drift velocity initiated by the wind is constant, but the projected current speed is different for each step. So the total drift velocity is also different for each step in the tide cycle. In Figure 6-11 the travelled (drifted) distance is plotted starting from different steps of the tide cycle. From the figure it is clear that the average drift velocity will be different for each step of the tide curve.
The time available to repair or to be rescued by a salvage tug is very dependent on which cycle of the tidal stream the failure occurred in. After one complete tide cycle (spring + neap) the three curves go through the same point, meaning that the total distance drifted is the same on that time independent of the starting time.

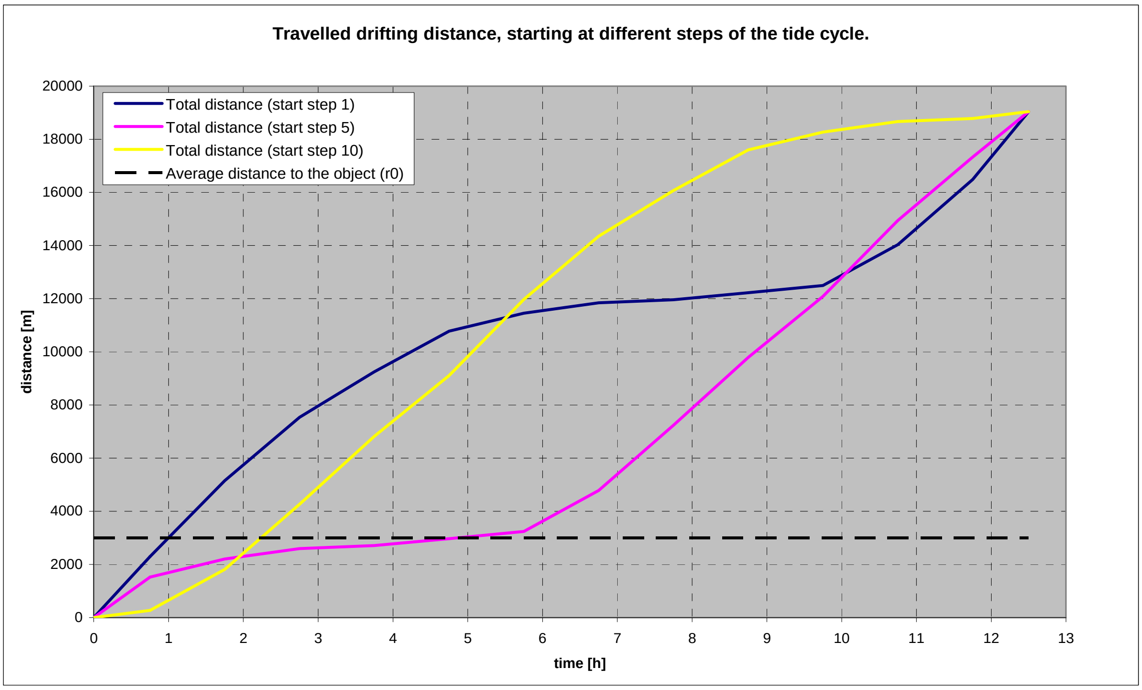


Figure 6-11 Travelled drifting distance, starting at different steps of the tide cycle.

6.7 Anchoring

An anchor can be used to keep the ship from drifting when an engine failure occurs. When a ship uses its anchor in a drifting situation the ship will not drift anymore and therefore will not be a threat to an object on sea. Not all anchoring are successful, for instance in bad weather or when a ship is drifting to fast an anchor cannot be used without the risk of failure. This is implemented in the SAMSON-model: anchor failure function.

The assumptions regarding the anchor failure function are adjusted in January 2005. Both functions are described, one used before January 2005 and one used after January 2005.

6.7.1 Anchor failure function used before January 2005

The assumptions (until January 2005) of the SAMSON-model with respect to the use of the anchor are very conservative. The use of the anchor was based on nearly 100% successful anchoring without losing the anchor(s) based on the design criteria for anchors. However, in case of an emergency when the ship impends to drift against an object, one should be prepared to take the risk of losing the anchor(s) in an attempt to avoid the collision. In those cases of using the anchor above the design criteria, the risk of losing anchors increases with the drift velocity.
The success of an anchor manoeuvre is only dependent on the drift velocity of the ship. If a ship of a certain size class has a drift velocity below a defined value, the anchor is assumed to be used successful and the drift velocity is zero. This means that the drifting ship is no longer a threat to the object.
In Figure 6-12 the anchor failure functions are shown for the eight different size classes.

Table 6-2 Overview of the (assumed) maximal drift speed for which anchoring will not fail per size class

Ship's size class [GT]	Maximal drift speed for which anchoring will not fail [kn]
100-0500	1.944
500-1000	1.652
1000-1600	1.361
1600-10000	1.069
10000-30000	0.778
30000-60000	0.680
60000-100000	0.583
>100000	0.486

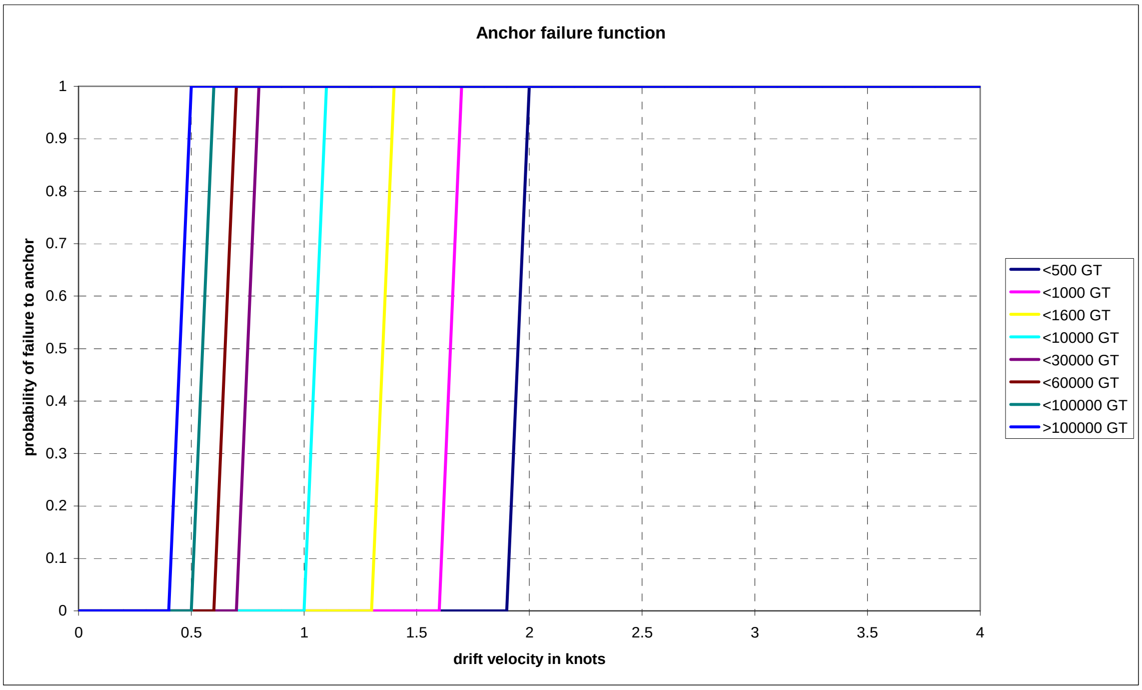


Figure 6-12 Anchor failure function used before January 2005

6.7.2 Anchor failure function used after January 2005

The anchor failure function used after January 2005 is dependent on the Beaufort class instead of the drift velocity. Based on the data provided by the Netherlands Coastguard the anchor functions shown in Figure 6-13 are proposed within the SAFESHIP project. In Table 6-3 the probabilities for an anchor failure for each Beaufort class are given for both options. Consequently, it is assumed that the probability of an anchor failure at Beaufort 5 is 10% for option 1 and 7% for option 2.
While writing this version of the documentation it is not clear which version will be used in future.

Therefore, the final probability for drifting against a certain object at a certain Beaufort class will be multiplied with a factor for anchoring:

$P_{ANCHOR}(BF)$ = probability on an anchor failure.

For the SAFESHIP project it is agreed that the second option will be used, so it is assumed that for Beaufort class 11 a successful anchoring will take place in 30% of all cases.

Table 6-3 Probability of an anchor failure for each Beaufort class

Beaufort class	$P_{ANCHOR}(BF)$	
	Proposal 1	Proposal 2
0	0.01	0.01
1	0.01	0.01
2	0.01	0.01
3	0.01	0.01
4	0.05	0.35
5	0.1	0.07
6	0.18	0.126
7	0.3	0.21
8	0.5	0.35
9	0.7	0.49
10	0.9	0.63
11	1	0.70

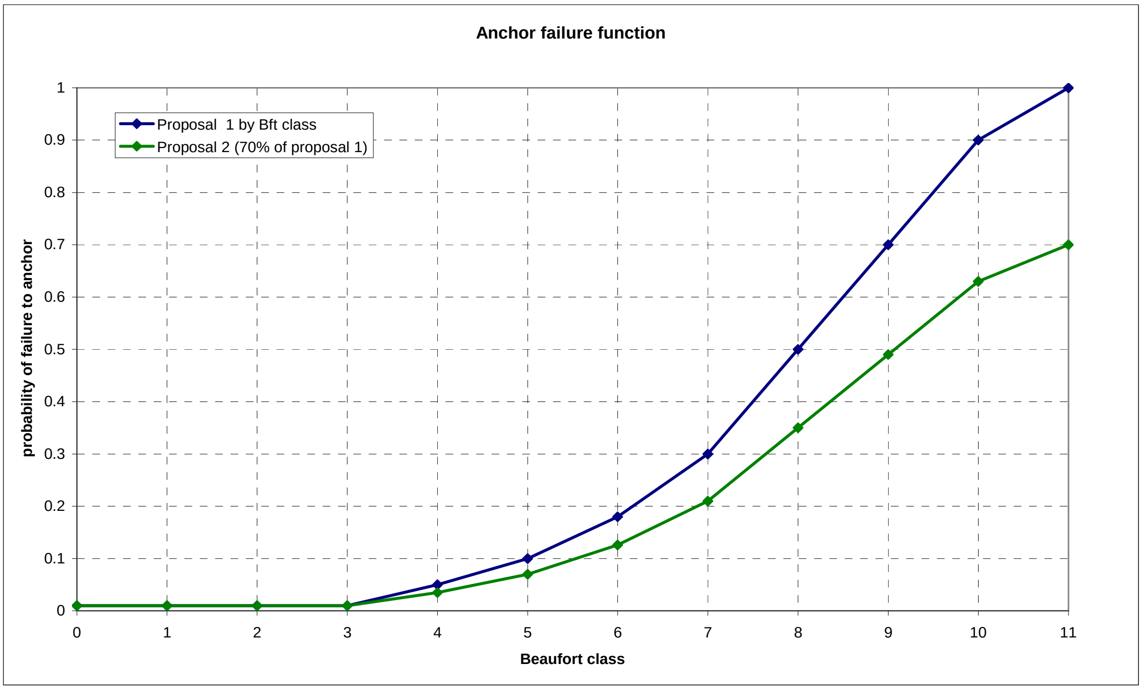


Figure 6-13 Anchor failure function used after January 2005.

Comparing both models
Based on the average wind velocity an estimate is determined for the average drift velocity for each Beaufort class. Using these drift velocities both anchor failure functions are shown in Figure 6-14.
From the figure it is clear that the probability of an anchor failure is less in the new situation, therefore the final frequencies (the number of ships drifting against the object) will decrease because of this change in the model. This is due to the fact that more ships will successfully anchor and, because of that, will not drift against the object.

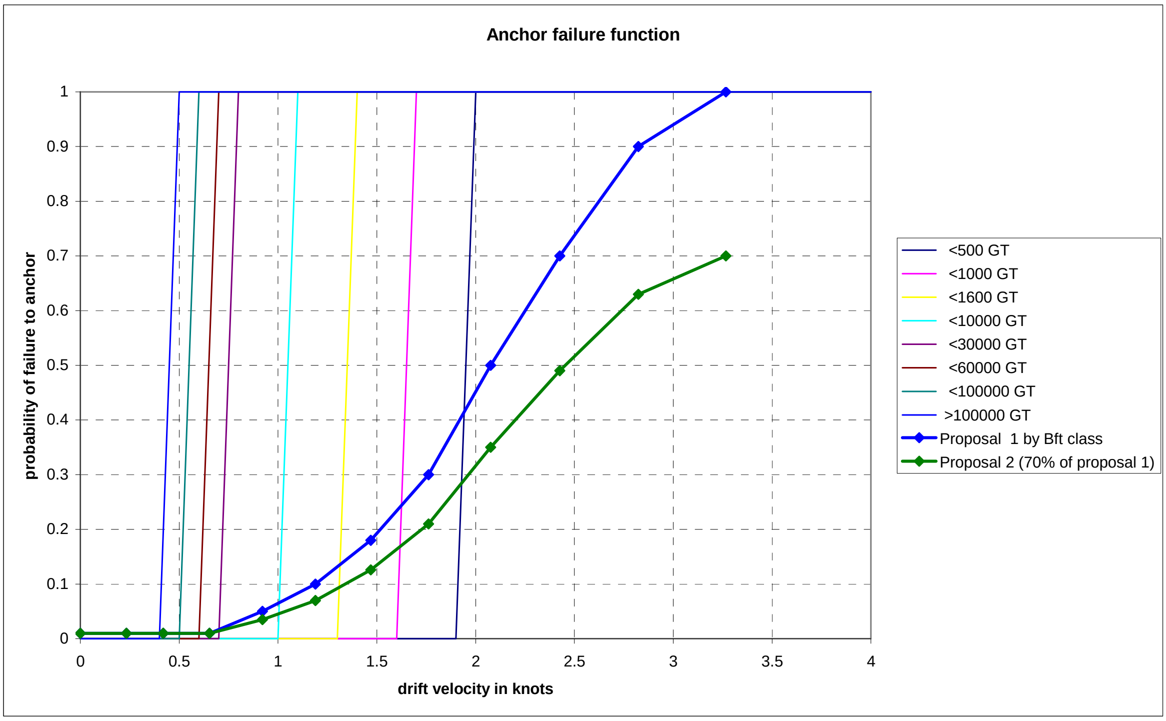


Figure 6-14 Both anchor failure functions

6.8 Repair function

A drifting ship will only hit an object if it takes more time to repair the engine failure than it takes to drift from a link to the object. Therefore, a repair function is defined. The repair function is a probability function for the duration of an engine failure.

Until January 2005 this repair function was based on information from the Lloyds casualty database. In 2002 and 2003 the Netherlands Coastguard collected all data on drifting ships in the Dutch part of the North Sea. Using this new data a new repair function has been derived. This function will be implemented in and used from January 2005. Both repair functions are described in this document.

6.8.1 Repair function used till January 2005

The probability of an engine failure with a given duration is determined based on the following information (estimates by experts):

- a failure of more than 6 hours has a frequency of R
- a failure between 2 and 6 hours has a frequency of 3R
- a failure between 0 and 2 hours has a frequency of 60R

The value of R is determined using the casualty database by the assumption that all vessels with an engine failure of more than six hours are assisted by a tug. This number is known from the casualty database. The corresponding value of R varies from 0.3 to 3 times 10^{-6} per nautical mile per year depending on ship type and ship size.

The engine failure rate can be described by the following probability function:

$$p(t) = ae^{-t/T} \qquad \text{(Eq. 6-16)}$$

with:
p(t) : probability for an engine failure of *t* hour

The parameters a and T are calculated using the number of failures with a duration of more than 6 hours and the number of failures between 2 and 6 hours.

$$\left.\begin{aligned} \int_2^6 ae^{-t/T}dt &= 3R \\ \int_6^\infty ae^{-t/T}dt &= R \end{aligned}\right\} \Rightarrow \begin{aligned} a &= 2.774R \\ T &= 2.885 \end{aligned} \qquad \text{(Eq. 6-17)}$$

Now the probability of an engine failure that takes more than the drifting time ts to the platform, object or grounding line can be written as follows:

$$P_{EF}(t > t_S) = \int_{t_S}^{\infty} 2.774\,\mathrm{R}e^{-t/2.885}dt = 8\,\mathrm{R}e^{-t_s/2.885} \qquad \text{(Eq. 6-18)}$$

In Figure 6-15 the number and duration of a drifting after an engine failure is plotted. The light blue and dark blue lines are based on data received from the Dutch Coastguard concerning all ships that were reported drifting in 2002 and 2003 and the duration of the drift. The green line is based on the model as described before. R is taken as the average frequencies over all ship types and ship sizes.

6.8.2 Repair function used from January 2005

In 2002 and 2003 the Netherlands Coastguard collected data about drifting ships on the Dutch part of the North Sea. This data is analysed in [9]. From the data two curves were extracted, one with the drifting time and one with the drifting time plus the time at anchor. The second curve is more representative for the duration of the engine failure. Both curves can be found in Figure 6-15. Also the repair function used before January 2005 is plotted in the figure. Based on the new information a new repair function is defined as:

$$P_{EF}(t > t_s) = 1 \qquad \text{for t<0.25} \qquad \text{(Eq. 6-19)}$$

$$P_{EF}(t > t_s) = \frac{1}{1.5(t_s - 0.25) + 1} \qquad \text{for t>0.25}$$

This “new” repair function is also added to Figure 6-15.

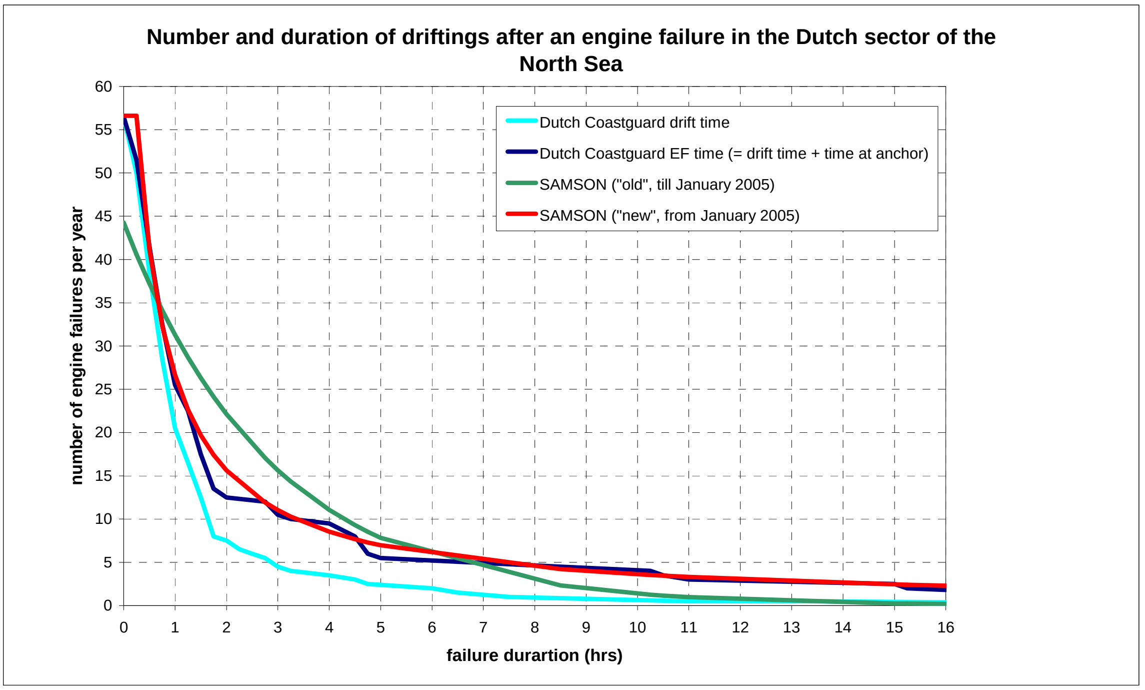


Figure 6-15 Number and duration of driftings after an engine failure in the Dutch sector of the North Sea

6.9 Using an emergency towing vessel (ETV)

Sometimes a drifting ship has some minor problems and thinks that she will continue her voyage within short time. But in case of serious or unknown troubles it is mandatory to report that to the closest Coastguard. The Netherlands Coastguard can judge the location and will send out an ETV to the drifting ship. The Netherlands Coastguard has contracted the salvage tug “De Waker” for this purpose. De Waker also fulfills other tasks. In bad weather conditions, the probability of a failure is larger and the potential threat of a drifter to others (e.g. offshore platforms) is larger. Therefore the ETV is at anchor near the TSS-Texel, thus close to the most offshore platforms, in case of wind force of 5 Beaufort or higher. She is ready to sail out, directly to the drifter when she is required.

The effect of one or more ETVs can be determined with SAMSON. For this purpose a list of ETVs can be composed in which all possible ETVs are described. Because the weather conditions affects the location of the ETV, the speed to reach the drifter and the time it takes to get the drifter under control these items are required for each wind force class. Each record of the input file ETV_DATA.INP for SAMSON contains

- Beaufort class
- Number of ETV
- Start position, longitude in degrees
- Start position, latitude in degrees
- Speed under this condition
- Total extra time for saving the ship

The total extra time is the sum of the average time for:

- The time between the failure and the warning of the ETV;

- The time required to sail out from the given position;
- The time required to bring the line and get the drifter under control;
- The maximum size class of route bound ships that can be saved;
- The maximum size class of non-route bound ships that can be saved;

In SAMSON it is assumed that the ship can be reached via a straight line from the given start position to the drifter. This is not the case for an ETV in a port. For this case it is better to give a position at sea just outside the port and add the time to reach that point from the quay to the total extra time.

In the contact model for drifting, the probability to hit an object is determined given the drift speed and drift direction. With the calculated distance to the object, the time for reaching the object is determined. It is assumed that the ETV sails directly to the potential contact point of the object. In case the sailing time plus the extra time is less than the drifting time, the ship will not hit the object. In all other cases the contact is counted because it could not be prevented by the ETV.

In the study for the capacity of salvage tugs along the Dutch coast the ETV is not applied in the model. First of all the number of drifting contacts were determined for a number of drifting times. The results in type and size classes were stored. Next, the time for being saved was determined for a certain defined fleet of salvage tugs for each type and ship size for each point. Combining these databases delivered the ships that could be saved.

6.10 Final: Probability of drifting against the object

Now the probability of hitting an object from a certain point *x* can be given, using the repair function given in section 6.8. If a ship is at point *x* on the link, the distance to the object is given by *r(x)* (see section 6.5). So given the (average) drift speed v_{drift} (section 6.6) it will take the ship *t(x)* hours to reach the object and hit it, with *t(x)* given by:

$$t(x) = \frac{r(x)}{v_{drift}} \qquad \text{(Eq. 6-20)}$$

When the duration of the engine failure is longer than *t(x)* the ship will hit the object. So the probability of hitting the object from point *x* on the link is given by the probability of an engine failure that will take longer than *t(x)*:

$$P_{DRIFT}(x) = P_{EF}(t > t(x)) \qquad \text{(Eq. 6-21)}$$

A ship can only drift against an object when it is in the danger part of the link, so only if *x* is between x_1 and x_2. So integrating the probability of one point over the total danger part results in the total probability of drifting against an object by a ship sailing on a certain link l_i:

$$P_{DRIFT}(l_i) = \int_{x_1}^{x_2} P_{DRIFT}(x)dx \qquad \text{(Eq. 6-22)}$$

with

x_1 and x_2: boundary points of the danger part of (sub)link l_i, the position of these points is dependent on the wind direction (j_{wind}) and the length of the ship (combination of ship type and ship size) , so $x_i(j_{wind}, type, size)$)

r(x): distance from point *x* on link l_i to the object.

V_{drift}: the drift speed, which is dependent on the wind speed (Bf), ship type, ship size, loading condition (*load*), tide (*t*) and step in the tide cycle (*c*), so $v_{drift}(type, size, Bf, load, t, c)$

So the probability of drifting against a certain object from a ship sailing on a certain (sub)link l_i, is calculated for one wind direction, one ship type, one ship size, one wind speed, one loading condition, one tide and one starting step in the tide cycle:

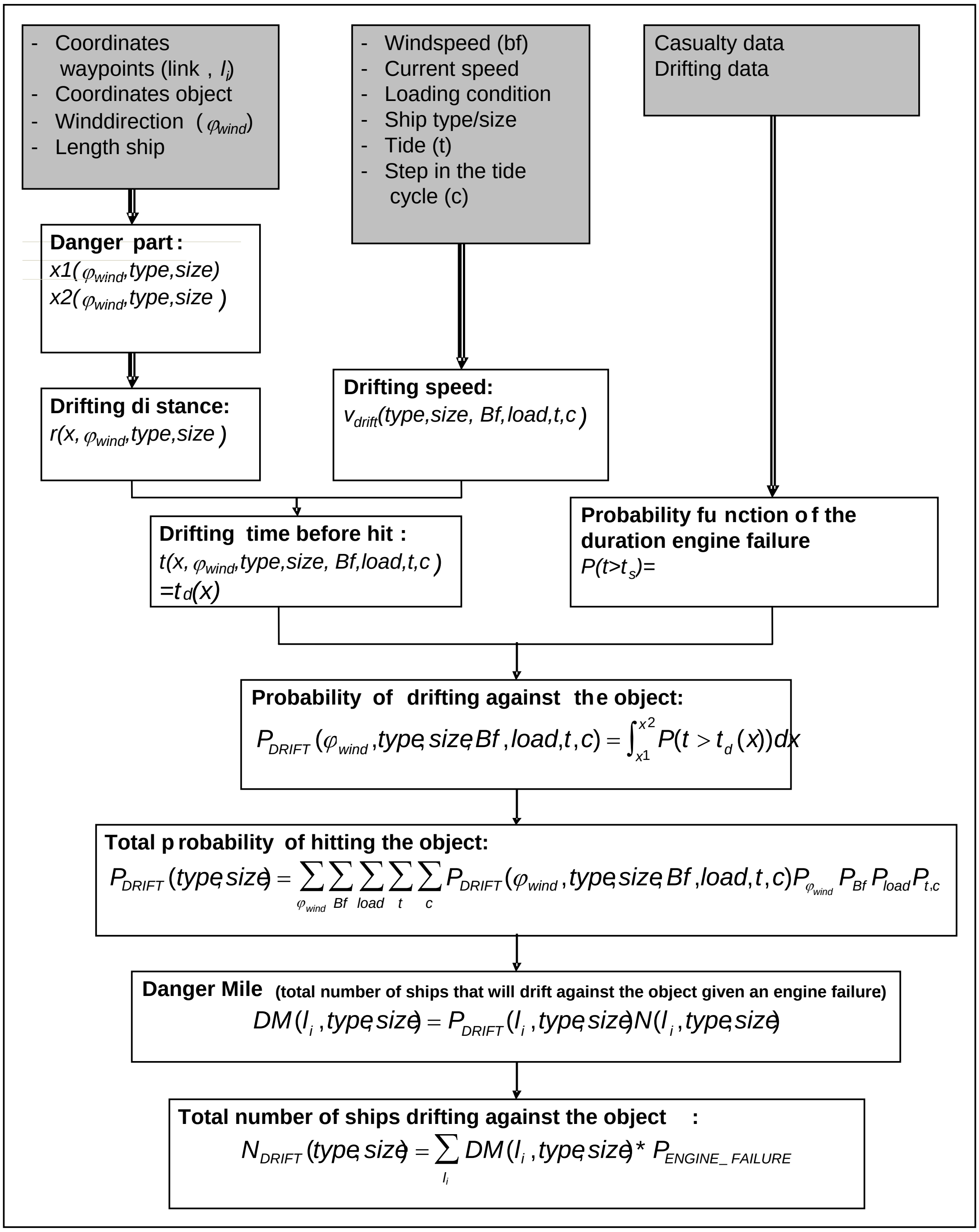
$$P_{DRIFT}(l_i, type, size, \varphi_{wind}, load, Bf, t, c) \qquad \text{(Eq. 6-23)}$$

The total probability per (sub)link, ship type and ship size is given by:

$$P_{DRIFT}(l_i, type, size, Bf) = \sum_{\varphi_{wind}} \sum_{load} \sum_{c} \sum_{t} P_{DRIFT}(l_i, type, size, \varphi_{wind}, load, Bf, t, c) P(\varphi_{wind}) P(load) P(c,t)$$

(Eq. 6-24)

Calculation plan



6.11 Assumptions

- The direction in which the ship will drift after an engine failure occurs(ed), is only determined by the wind direction.

- The drift velocity of a ship is determined by the wind, wave and current speed. The current speed is projected to the wind direction. This is done for practical reasons, which does not affect the calculated number of hits. In reality, the danger part of the link moves with the start of the drifting time within the current cycle.

- The maximal drifting time is an input to the model. In most cases the maximal drifting time is set to six hours. Therefore, it is assumed that after six hours the engine failure is fixed, or within these six hours there are tugs available to prevent the ship from drifting any further. During sensitive analyses of the assumptions until January 2005, it was found that the hit frequencies did not increase significantly in calculations with longer drifting times.

- It is not possible that an object (object-line) and a (sub)link cross. The minimal passing distance of an object is an input for the model, usually 0.5 nm. When the (calculated) minimal distance between an object and a link is less than the (given) minimal passing distance, the distance between the object and the link is set to this given minimal passing distance. So the link is being “repositioned” away from the object. Therefore, it is not possible that a link is positioned inside a safety zone around an object, e.g. a platform.

- Dropping an anchor can prevent a ship from drifting against an object; whether or not anchoring is successful is largely dependent on the drifting speed and the weather condition (Beaufort class).

- A standby ETV (Emergencies Towing Vessel) can be near the ship in time to prevent the ship to drift against the object. Whether or not the towing vessel can prevent a collision will an object is largely dependent on the position of the vessel and the drifting ship. It also depends on the weather conditions.

Summary of adjustments of the contact drift model after January 2005

Sub-section	subject	Situation before January 2005	Situation after January 2005
2.6.1	**Wave drift coefficient**	Given (fixed) value for each Beaufort class	The calculated value is dependent on the draft of the ship and the wave number, which is dependent on the wave period which is given for each Beaufort class
2.7	**Anchor failure function**	Probability of an anchor failure is dependent on the drift velocity and size of the ship and has a value of 0 or 1.	Probability of an anchor failure is dependent on the Beaufort class, it has a value between 0 and 1 and is the same for every ship size.
2.8	**Repair function**	$P_{EF}(t > t_S) =$ $\int_{t_S}^{\infty} 2.774\,\mathrm{Re}^{-t/2.885}dt = 8\,\mathrm{Re}^{-t_s/2.885}$	$P_{EF}(t > t_s) = 1$ for t<0.25 $P_{EF}(t > t_s) = \frac{1}{1.5(t_s - 0.25) + 1}$ for t>0.25