7 CONTACT RAM-MODEL

A ramming collision with an object is the result of a navigational or human error. The navigator might have left the bridge and upon his/her return he/she notices that the vessel is on a collision course with an object. He/she will do whatever he/she deems necessary to avoid the object by initiating an emergency turn off by giving “Full Astern”.
In addition, heart attack, drunkenness and sleep deprivation are contributory factors to the navigation error. Other infrequent factors are criminal negligence of duty and suicidal behaviour.

7.1 General model (old situation)

Most models described in the literature are based on counting the number of ships heading for the object multiplied with a causation factor. The causation factor is the result of a fault tree analysis in which all failure models are modelled.
This method was used in SAMSON too, but since there are a few disadvantages to the method another model was developed. In order to give a total overview of the models used within SAMSON the old method will be described here all the same.

In the SAMSON-model, route bound ships sail from one waypoint to another over a link. Because not all ships will sail exactly over this defined link, a lateral distribution over the link is defined. A link contains several “sub-links” and the total number of ships sailing over the link is divided over these sub-links using the distribution function.

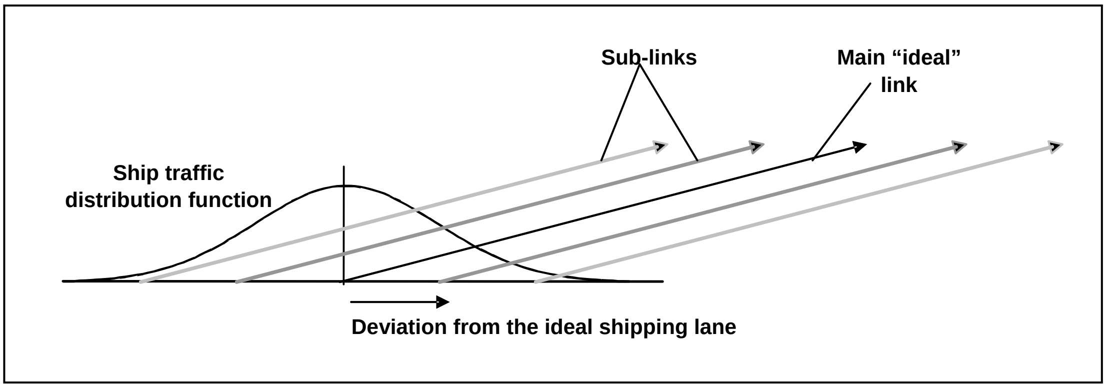

Figure 7-1 Lateral distribution of a shipping link.

The distance between the sub-links is determined by the number or sub-links used and the total width of the link; sigma. The possible number of ships that will hit the object (given no action is taken) is defined by the number of ships on the sub-link(s) that “sail”: across the object (see Figure 7-2). Finally this number of ship is multiplied with a causation factor, a probability that no action will be taken by the ship to avoid a collision.

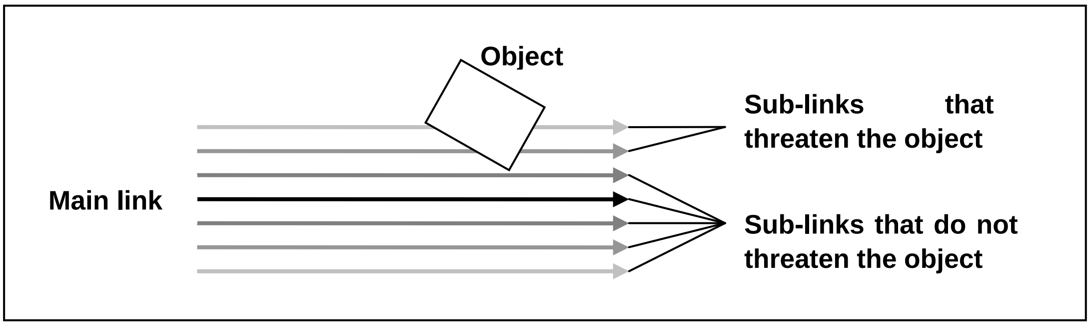

Figure 7-2 Sub-links that threaten an object

Disadvantages

This method to determine the number of ships that will hit (ram) an object due to a navigational error has several disadvantages.

The first and main disadvantage is that the number of ships ramming the object is largely dependent on the position of the shipping link and the sigma of the distribution function. This dependence is illustrated in Figure 7-4 and Figure 7-5. In both figures three different ship distribution functions are plotted. The total number of ships that could ram an object is given by the surface under the ship traffic distribution function.
In Figure 7-4 the distribution functions are shown for three different positions of the main link. It is clear that for the object the surface under the graph for function 3 is much larger than for function 1.
In Figure 7-5 the distribution function for three different sigma's (maximal width of the shipping links) are plotted. Again, for the object the surface under the graph of function 3 is much larger than for function 1. Besides the width and the position of the main link, the shape of the distribution function also determines how many ships could ram the object.

Thus, in order to use this method to determine the number of ramming ships of an object one needs to know the "exact" position and width of a shipping link.
In reality it is not possible to assess the location of the centre line of a traffic link and the shape of the lateral distribution with sufficient accuracy to make an accurate estimation.
Even in the case of a traffic separation scheme where the location of the centreline is clear, it is difficult to assess the shape of the distribution function just outside the traffic separation scheme.
Even when using the data from the VONOVI flights it was not possible to assess the exact shape of the lateral distribution in each traffic separation scheme. For links outside the separation scheme, where ships are free to sail, it is really impossible to determine the exact location of the centre line and the lateral distribution parameters with sufficient accuracy.

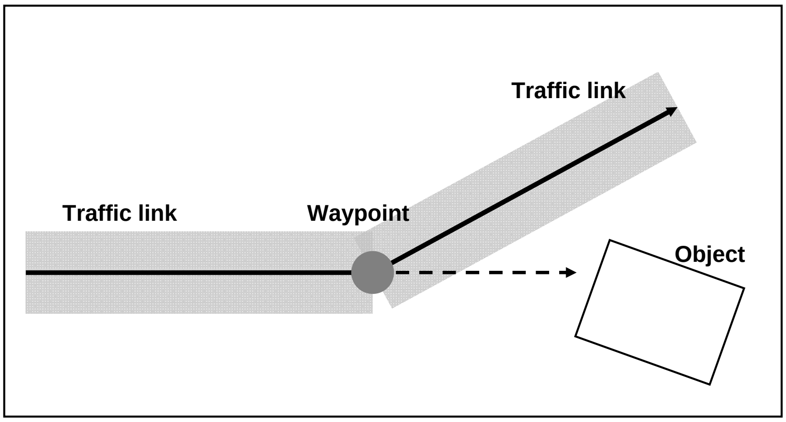

Figure 7-3 Ship on a traffic link that does not "cross" an object can still be a threat.

Beside the uncertainties in the layout of the traffic database there is another disadvantage. Sometimes ships are on ramming course with an object even if they are sailing over a defined link, but this link bends before it reaches the object, see Figure 7-3. The ships sailing on the link are not considered a threat to the object with this method. However, it can happen that a ship does not change course on time and stays on ramming course with the object. These ships should also be taken into account because it is a realistic scenario.

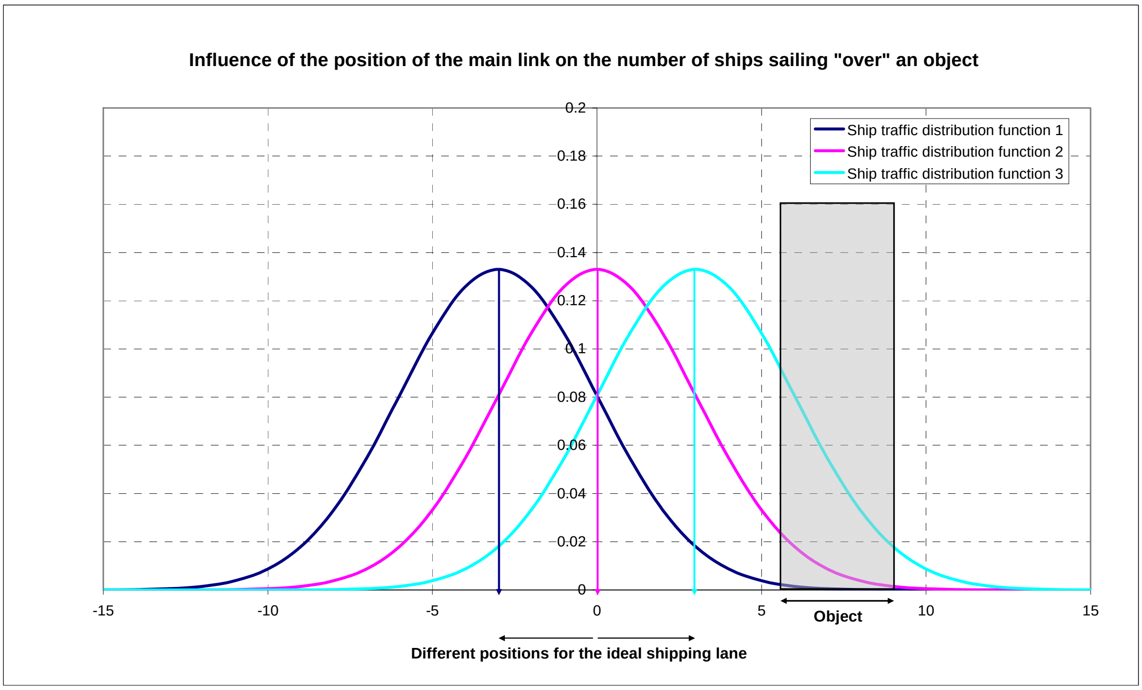

Figure 7-4 Influence of the position of the centre line on the number of ships sailing "over" an object.

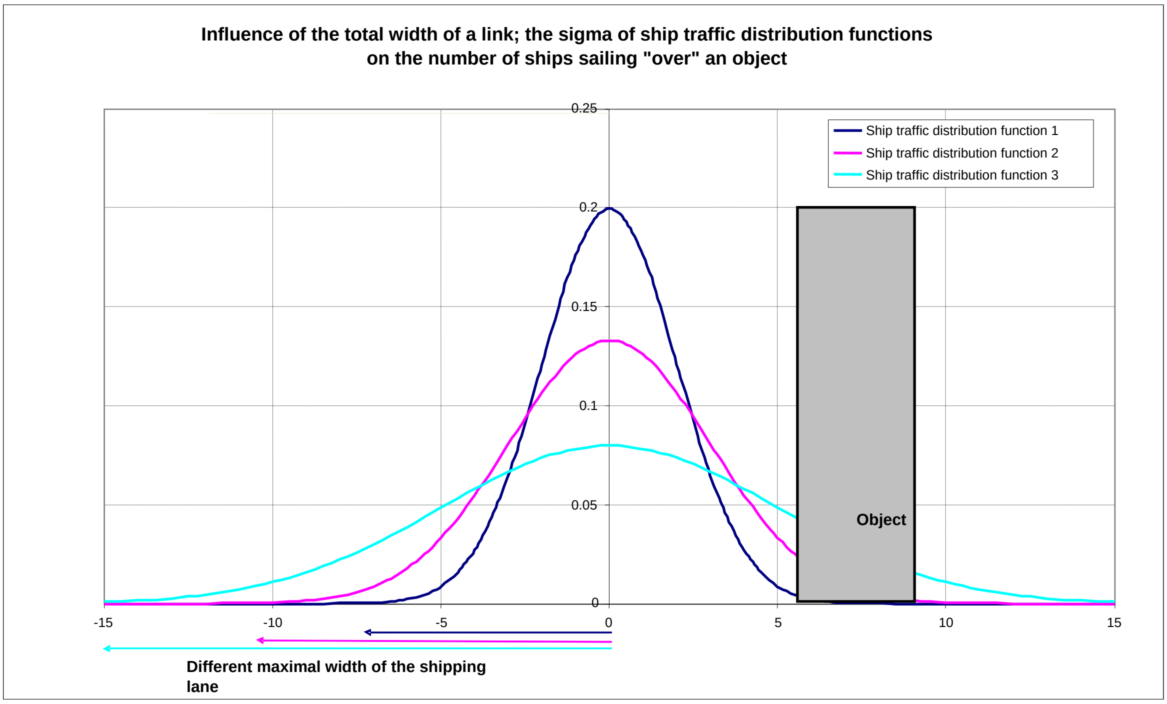

Figure 7-5 Influence of the total width of a link; the sigma of the ship distribution function on the number of ships sailing "over" an object.

7.2 Global description of the model (present situation)

A navigational error can happen on every position of the link, but as a result of the error the ship will not suddenly sail backwards. So, within the model it is defined that a navigational error can result in seven different course changes from -30° till 30° with steps of 10°.
Therefore, an object can not be reached from all positions on the link after a navigational error.
Analogous to the contact drift model, first the danger part of a link has to be determined given a certain course change (φ_{cc}), see Figure 7-6.

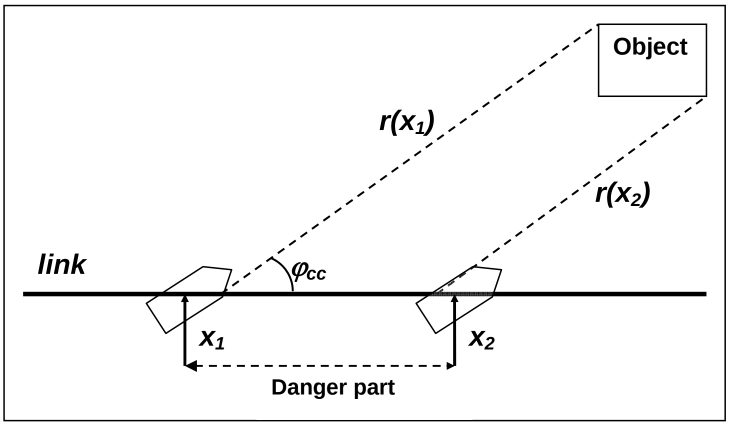

Figure 7-6 Danger part of a link for the ram contact model

If an error is detected in time a collision can be avoided, but when the error is detected too late, when a ship is already too close to an object, the probability of a collision will be larger. So again, analogous to the drift model, the distance between the object and the link is determined by the so-called ramming distance (*r(x)*), given a certain course change.

The time necessary to avoid a collision, depends mostly on the length (L), and therefore the type and size of the ship. The probability whether or not a ship will ram the object given a certain course change is therefore given by a function of the length of the ship and the distance to the object:

$$P_{HIT}(r, L) \qquad \text{(Eq. 7-1)}$$

The distance to the object depends on the position x on the link, the type and size of the ship and the course change angle φ_{cc}: $r(x, type, size, \varphi_{cc})$.
So, the probability for a ship to ram an object from a certain point of the danger part given a navigational error is given by:

$$P_{RAM}(x, type, size, \varphi_{cc}) = P_{HIT}(r(x, type, size, \varphi_{cc}), L(type, size)) \qquad \text{(Eq. 7-2)}$$

where:

$P_{HIT}(r,L)$	:	Probability that a ship of length *L* will ram an object at distance r of the link
$r(x,type,size,\varphi_{cc})$	:	Distance between point *x* on the link and the object
L(type,size)	:	Length of a ship of a certain type and size.

Integrating this function over all points of the danger part gives the total possible threat by ramming of the link to the object given a navigational error and for a certain course change angle, type and size of the ship.

$$P_{RAM}(type, size, \varphi_{cc}) = \int_{x_1}^{x_2} P_{RAM}(x, type, size, \varphi_{cc})dx \qquad \text{(Eq. 7-3)}$$

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

The total probability for a ship on link l_i ramming the object (given a navigational error) can be determined by multiplying the probability for a certain course change angle with the probability for that specific course change angle. Finally, all contributions for all angles are added up:

$$P_{RAM}(type, size) = \sum_{\varphi_{cc}} P_{RAM}(type, size, \varphi_{cc})P(\varphi_{cc}) \qquad \text{(Eq. 7-4)}$$

Finally, the Ramming Opportunities (RO) for a certain link l_i is given by the total number of ships (per type and size) that will ram the object given a navigational error:

$$RO(l_i, type, size) = P_{RAM}(type, size)N(type, size, l_i) \qquad \text{(Eq. 7-5)}$$

with
$N(l_i, type, size)$: the number of ships of certain type and size on link l_i

The final step in determining the total number of ships that will ram the object is multiplying the Ramming Opportunity with the probability of a navigational error for that certain ship type and ship size. Then, adding all contributions of all links will give the total possible ships that will ram a given object:

$$N_{RAM} = \sum_{l_i}\sum_{type}\sum_{size} RO(l_i, type, size)P_{NAVIGATIONAL\_ERROR}(type, size) \qquad \text{(Eq. 7-6)}$$

7.3 Danger part

The traffic database of the SAMSON-model consists of different waypoints connected by different links. In the database, the number of ships which sail on each link per ship type and ship size is known.
For the ramming model the danger part of a link is that part of a link from which a (specific) ship will ram an object given a navigational error and a certain course change angle and given that the navigational error remain unnoticed.

The calculation of the danger part (for ramming) of a link is the same as the calculation for the danger part for drifting.

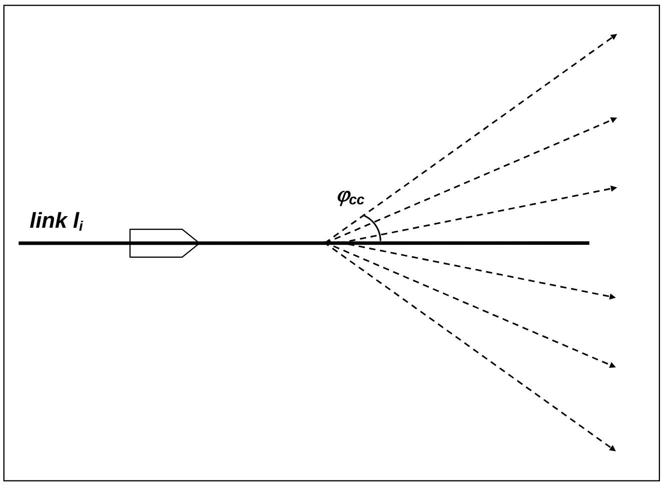

Figure 7-7 Different "ram"-directions

The calculation of the danger part (for ramming) of a link is the same as the calculation for the danger part for drifting.
The only difference is the direction in which the ship will travel. In case of a drifting ship, it is assumed that the ship will move in the direction of the wind, because the ship is not under control. For ramming it is assumed that a navigational error can result in seven different course change angles according to the direction of the link (see Figure 7-7)
The probability of the different course change angles is given in Table 7-1.

Course change angle φ_{cc}	Probability P_{cc}
-30	0.05
-20	0.10
-10	0.20
0	0.30
10	0.20
20	0.10
30	0.05

Table 7-1 Probability for the different course change angles

7.4 Ramming distance

The danger part gives only information on which part of the link a ship is a possible threat to the object given a navigational error (that remains unnoticed) and a given course change angle.
Whether or not a ship will actually hit an object given a navigational error depends on the distance between the point of the link the error occurs and the object. This distance is called the ramming distance. The calculation of this ramming distance is the same as calculating the drifting distance in the contact drift model (see 2.5).
Also the remarks made in 6.3 and 6.4 about the lateral distribution and the minimal passing distance apply here.

7.5 Avoidance function

Not all navigational errors remain unnoticed; in most cases a navigational error is detected and acted upon. However, even when an error is detected in time it is still possible that a collision cannot be avoided.
Therefore, a so-called avoidance function is defined (parallel to the repair function in the contact drift model). Whether or not a ship can avoid an object depends on the length (size) of the ship and the ramming distance. Large ships need more time to change their course than smaller vessels, so the probability of not being able to avoid a collision is a combination of the ramming distance and the size of the ship:

$$P_{HIT}(r, L) = e^{-a\frac{r}{L}} \qquad \text{(Eq. 7-7)}$$

where:
P_{HIT} : Probability of hitting the object given a ramming distance and ship length
r : Ramming distance
L : Length of a certain ship
a : (dimensionless) danger measure (default value 0.1)

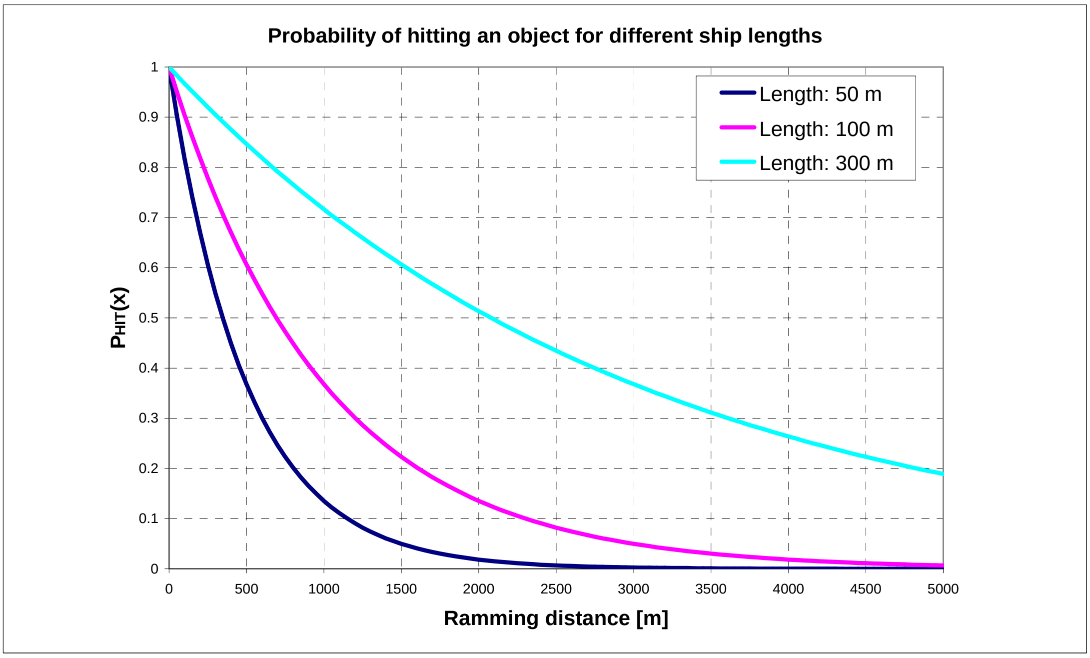

Figure 7-8 Avoidance function for different ship lengths.

7.6 Anchoring and use of ETV

Because of the (higher) speed of the ship on ramming course, dropping an anchor to prevent a ramming contact will have no effect and will not be done in practice. Therefore, it is assumed that no anchor is used to prevent a ramming contact.

Also, because of the speed of the vessel it is assumed that an ETV will not be in time to prevent the ship on ramming course from actually ramming the object.

7.7 Calculation plan

- Coordinates waypoints (link , l_i)
- Coordinates object
- Course change angle (φ_{cc})
- Breadth ship

↓

Danger part:

$x_1(\varphi_{cc}, type, size)$

$x_2(\varphi_{cc}, type, size)$

↓

Ramming distance:

$r(x, \varphi_{cc}, type, size)$

Avoidance function:

$$P_{HIT}(r, L) = e^{-a\frac{r}{L}}$$

↓

Probability on ramming the object:

$$P_{RAM}(\varphi_{cc}, type, size) = \int_{x1}^{x2} P_{HIT}(r(x, \varphi_{cc}, type, size), L)dx$$

$$= \int_{x1}^{x2} e^{-a\frac{r(x, \varphi_{cc}, type, size)}{L}} dx$$

↓

Total probability on ramming the object:

$$P_{RAM}(type, size) = \sum_{\varphi_{cc}} P_{RAM}(\varphi_{cc}, type, size) P_{\varphi_{cc}}$$

↓

Ramming Opportunity

$$RO(l_i, type, size) = P_{RAM}(l_i, type, size) N(l_i, type, size)$$

↓

Total number of ships ramming the object:

$$N_{RAM}(type, size) = \sum_{l_i} RO(l_i, type, size) * P_{NAVIGATIONAL\_ERROR}$$