5 ENCOUNTER MODEL

5.1 Background

Each navigator on a ship would like to keep an area free with respect to other ships and fixed objects. This safety area around a ship is denoted as the “ship domain”. Fujii and Tanaka analyzed the vessel movements in a number of Japanese Straits with ships travelling at service speed [2]. Later observations by Fujii et al [3] and [4] led to the following domain:

- Course direction 8.0 L
- Side direction 3.2 L

Herein is L the length of the ship.
These values were derived from Japanese waterways with:

- sufficient width to provide free navigation at service speed and without any obstruction in the channel (islands, shallow water, etc.)
- a higher traffic density than most European and US waters.

Other researchers Draper and Bennet [5] and Barratt used circles as ship domain. Goodwin [6] studied the size of ship domains in Dover Strait. She found that a domain with three sectors has the best fit with the analyzed radar observations. She searched for the area around the ship with low density of other ships. The sector on the starboard/front side (0° until 112.5°) was the largest one, a part of a circle with a radius of 0.85 nm, because this is the space used by the ship in case of a collision avoidance manoeuvre. The sector astern (112.5° until 247.5°) was the smallest with a radius of 0.45 nm, because this area is history and crossing ships through this area do not disturb the progress of the ship on her route. The portside sector (247.5° until 360°) had a radius of 0.70 nm.
Many studies in the 1970’s were carried out for assessing the effect of the introduction of traffic separation schemes (TSS), such as the TSS in Dover Strait. The result of one of these studies is described in the paper of Van der Tak and Spaans [7]. It was one of the first applications with the roots of the SAMSON-model. In that study the shape derived by Goodwin was converted to an ellipse, turned to starboard with the ship in the focal point. Originally, this ellipse shape was used in the models of SAMSON. Later this ellipse was simplified to a circle, because the calculation time was considerably less, while the results were comparable.

In the nineteen eighties, Goodwin and the Netherlands Maritime Institute (later merged in MARIN) worked together in the first European project COST301 that dealt with safety of navigation.

More recently, studies comparable to Goodwin's have been performed on basis of AIS data instead of radar data. For the North Sea area, see e.g. [8].

5.2 Description of the encounter model

The collision model for ship-ship in SAMSON is still based on the domain theory. For the other collision models, or better contact models, the domain theory is abandoned, because the domain theory is too simple for contacts with objects, and too sensitive for the rather unknown shape of the lateral distribution of a traffic flow. Especially the tail of the lateral distribution delivers the most important contribution to the contact risk.

The ship-ship collision is less sensitive for the exact location of a traffic lane and the lateral distribution. A ship crossing a traffic flow, encounters all ships of the traffic flow, only the locations of the encounters depend on the lateral distribution.

Figure 5-1 shows the encounter situation between two ships with the ellipse as ship domain. One ship is moving with speed u and course ψ_1. A second ship is moving with speed v and course ψ_2. The ship domain is an ellipse, with the ship in the focus, turned to starboard over an angle $\delta\psi_1$. The relative speed of ship 2 with respect to ship 1 is the vector ($\underline{v} - \underline{u}$), which has direction ψ_R.

Definition of an encounter:

An encounter occurs when the ship domain around a ship is entered by another ship.

All ships 2 located in the arced area of Figure 5-1 with speed $\underline{v}$ will enter the ship domain of ship 1 (thus encounter) within one hour. The arced area of Figure 5-1 has a length of $|\underline{v} - \underline{u}|$ and a width of D($\underline{u}$,$\underline{v}$). D($\underline{u}$,$\underline{v}$) is the width between the tangents of the ellipse in the direction of the relative speed ($\underline{v} - \underline{u}$) . The speed is given in nm/hour.

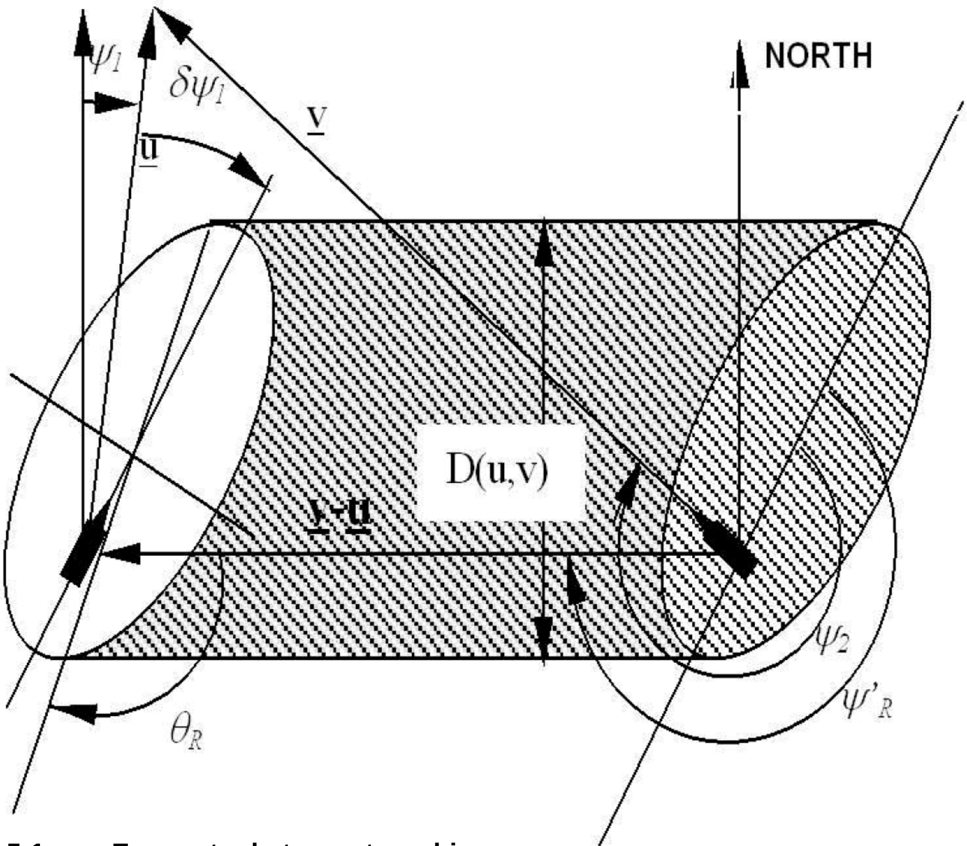

Figure 5-1 Encounter between two ships

In case of infinite wide traffic flows with a uniform lateral distribution for both ships, the number of encounters for ship 1 per hour per nm^2 is:

$$encounters = |\underline{u} - \underline{v}|\, D(\underline{u},\underline{v})\, d_2 \tag{Eq. 5-1}$$

Herein is:

d_2 the area density for ship 2.

D(u,v) can be calculated with:

$$\tan\psi_R = \frac{v\sin\psi_2 - u\sin\psi_1}{v\cos\psi_2 - u\cos\psi_1} \tag{Eq. 5-2}$$

$$\psi_R^{'} = \psi_R - \psi_1 - \delta\psi_1 \tag{Eq. 5-3}$$

$$\tan\theta_R = -\frac{b}{a\tan\psi_R^{'}} \tag{Eq. 5-4}$$

$$D(u,v) = 2\left| a\sin\psi_R^{'}\cos\theta_R - b\cos\psi_R^{'}\sin\theta_R \right| \tag{Eq. 5-5}$$

Herein, *a* is the length of the long axis and *b* the length of the short axis of the ellipse.

In reality, the ships are not distributed uniformly. Two groups of ships are distinguished based on their sailing behaviour, namely:

- Route bound traffic: This group contains the merchant ships that sail from port to port. They follow the shortest route taking into account the traffic separation schemes, the operational draft and other rules, for example the restricted use of coastal zones. This traffic is described with traffic flows of ships using a route segment between two waypoints. All ships in the lane have nearly the same course. The behaviour within the traffic flow is further described by a speed distribution for each ship type and ship size class. The lateral distribution describes the use of the route.

- Non-route bound traffic: This group contains the traffic with a mission at sea. The largest share is delivered by fishing vessels. These vessels do not use routes but sail more or less with random courses. For this reason this group cannot be described by traffic flows, but by densities. The density gives the average number of ships in the area. The speed distribution for each ship type and size gives the expected speed. The lateral distribution is not opportune anymore, because it is assumed that the ships are distributed uniformly over the sea area. The densities are given on the Genogrid, a grid structure with areas of 8 by 8 km. At the start of SAMSON, the Directorate North Sea used this genogrid (gehele Noordzee grid) for presenting results.

Based on the modelling, three different elaborations of the encounter are described, namely for:

- encounters among route bound traffic, thus between two traffic flows;
- encounters between route bound traffic and non-route bound traffic;
- encounters among non-route bound traffic.

5.2.1 Encounters among route bound traffic

A ship follows a route and does not deviate too much from this route. A traffic flow is characterized by:

- the number of ships passing a cross section;
- the lateral distribution;
- the speed distribution for each ship type and ship size.

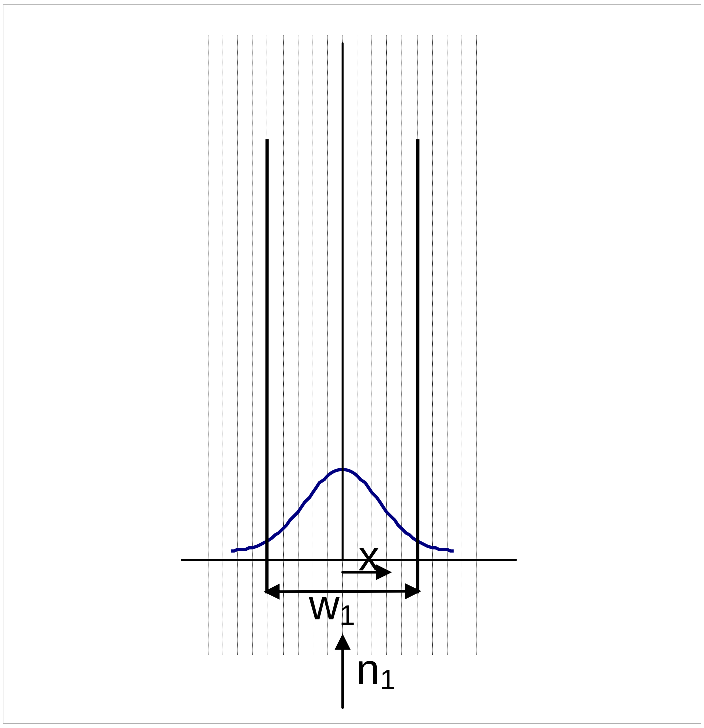

Figure 5-2 Traffic flow, width w_1, n_1 ship movements per year, lateral distribution

In case of a uniform lateral distribution the density per nm^2 is:

$$d_1 = \frac{n_1}{24*365\ w_1} \frac{1}{u} \qquad \text{(Eq. 5-6)}$$

Herein is:

n_1	number of movements over the traffic flow per year
w_1	the width of the traffic lane, containing nearly all traffic
u	speed in knots

The first part of the right hand side is the average number of ships passing a crossing line per hour over a length of 1 nm. The last term 1/u is the time in hours that a ship will stay in a block of 1 nm length.

For a non-uniform lateral distribution, the density of ships at a distance *x* of the centre line can be written as:

$$d_1(x) = g(x)\int \frac{1}{u} f(u)\,du \qquad \text{(Eq. 5-7)}$$

Herein is:

f(u) the probability function for the speed
g(x) the lateral distribution function of ships in a cross section

The density of ships at a distance y of the centre line for the second traffic flow can be written as:

$$d_2(y) = g(y)\int \frac{1}{v} f(v)\,dv \qquad \text{(Eq. 5-8)}$$

Herein is:

f(v) the probability function for the speed
g(y) the lateral distribution function of ships in a cross section

Assumption:
It is assumed that the distributions for passing a cross section, the lateral distribution and all the speed distributions are independent. This is not completely true, because large ships will keep more to the centreline of the traffic lane than small ships. For the most serious crossing risk this small dependency has no effect, because crossing ships will always meet each other. Only the meeting place varies with the lateral distribution, but not the frequency.

The crossing times of ships follow a Poisson distributed, which means the times between two crossing are independent. At sea, this is a good assumption. Only in the neighbourhood of ports, especially in the area of entering and leaving the port this is not always true. In a port approach area there will occur peak hours, related with the working hours in the port. In some studies, corrector factors have been applied to determine the correct number of encounters. This approach has been applied in the safety studies for LNG carriers to Rotterdam. These LNG ships have only permission to enter Rotterdam during a time window at night with lower densities.
The same phenomenon occurs in case of tidal windows for calling a port.

The encounters between two traffic lanes occur only in the meeting area between the two traffic flows, shown in Figure 5-3.

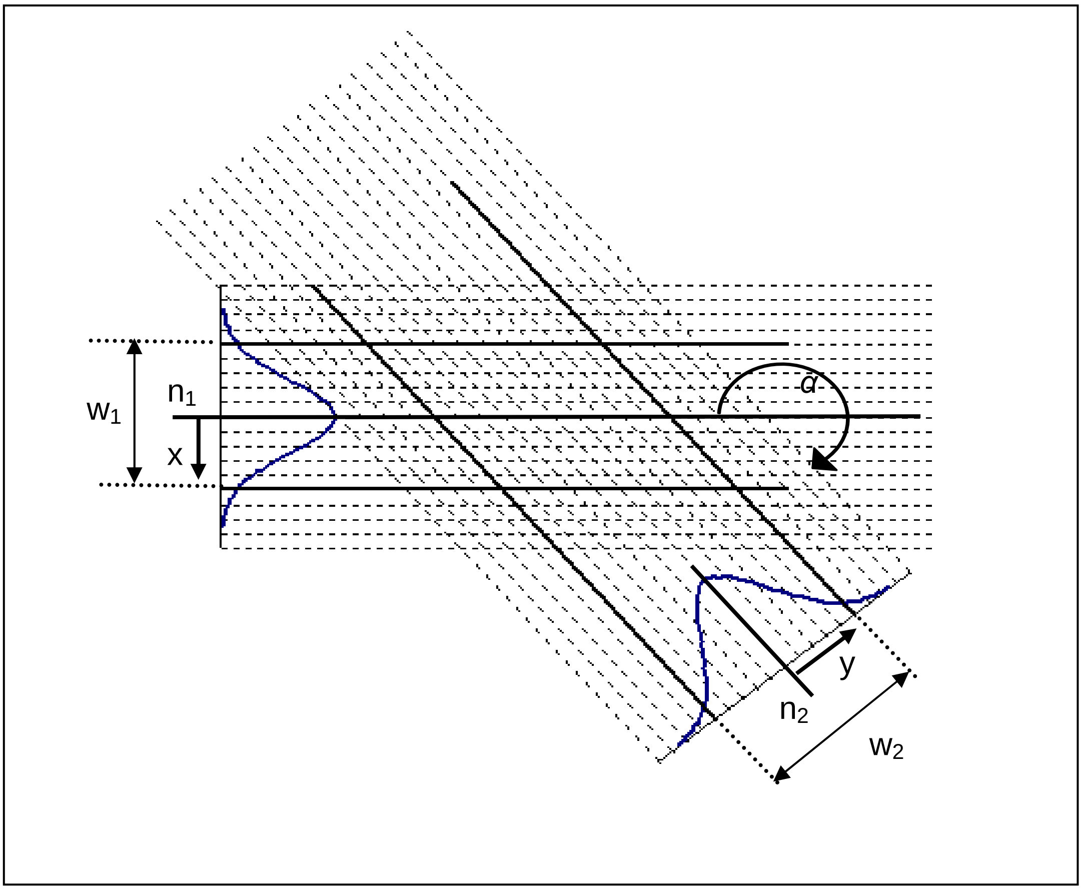

Figure 5-3 Encounter area between two crossing traffic flows

The meeting area is the parallelogram between the two traffic flows. To determine the number of encounters for ship 1, the traffic flow of ship 1 is divided into small lanes *dx* and the other traffic flow in small lanes *dy*. The average densities in such lanes are given by the probability density functions. The meeting area where ships 2 will enter the domain of ships 1 is a parallelogram of size *dxdy*/sin(α). The number of encounters in meeting area in time *dt* amounts:

$$enc = \iint g(x)\frac{1}{u} f(u)\, g(y)\frac{1}{v} f(v)\,|\underline{v}-\underline{u}|\,D(\underline{u},\underline{v})\,dvdu\,\frac{dxdy}{\sin\alpha}dt \qquad \text{(Eq. 5-9)}$$

The number of encounters per year for the two traffic flows follows from above formulation after integrating over *x*, *y* and *t* and is:

$$enc = \int_{-w_1/2}^{w_1/2}\int_{-w_2/2}^{w_2/2}\iint g(x)\frac{1}{u} f(u)\, g(y)\frac{1}{v} f(v)\,|\underline{v}-\underline{u}|\,D(\underline{u},\underline{v})\,dvdu\,\frac{dxdy}{\sin\alpha}dt \qquad \text{(Eq. 5-10)}$$

Given the above assumption of independency between the lateral distribution and the speed distribution and of course between the distribution of different traffic flows, the formulae for the number of encounters per year can be simplified to:

$$enc_{12} = \frac{1}{\sin\alpha} \int_{-w_1/2}^{w_1/2} g(x)dx \int_{-w_2/2}^{w_2/2} g(y)dy \iint \frac{1}{u} f(u) \frac{1}{v} f(v) \,|\, \underline{v} - \underline{u} \,|\, D(\underline{u},\underline{v}) dvdu \int_0^{24*365} dt$$

(Eq. 5-11)

Herein is:

$$\int_{-w_1/2}^{w_1/2} g(x)dx = \frac{n_1}{24*365} \qquad \text{(Eq. 5-12)}$$

$$\int_{-w_2/2}^{w_2/2} g(y)dy = \frac{n_2}{24*365} \qquad \text{(Eq. 5-13)}$$

Finally the number of encounters per year for a ship of traffic flow 1 by a ship of traffic flow 2 is:

$$enc_{12} = \frac{1}{24*365} \frac{n_1 n_2}{\sin\alpha} \iint \frac{1}{u} f(u) \frac{1}{v} f(v) \,|\, \underline{v} - \underline{u} \,|\, D(\underline{u},\underline{v}) dvdu \qquad \text{(Eq. 5-14)}$$

The number of encounters increases when the crossing angle α approaches 0° or 180°. In case of 0°, the course of the two traffic flows is equal and the encounters are real overtaking encounters. In case of 180°, it are real head-on encounters.
For small values of sin α, the traffic flows are parallel or nearly parallel. These cases are dealt with separately because the meeting area is very large, which requires a different approach. Two cases are distinguished, namely:

- exactly the same or opposite direction;
- nearly the same or opposite direction.

Two traffic flows with exactly the same or opposite direction
In case of two coinciding (for example overtakings within the own traffic flow) or nearly coinciding traffic flows, the meeting area between the two traffic flows is no longer a parallelogram of size $w_1 w_2/\sin(\alpha)$, but the encounters will take place in the whole link. The total number of encounters per year for a link with a common length of *L* nm (see Figure 5-4) is:

$$enc_{12} = 24*365\ L \int_{-w_1/2}^{w_1/2} \int_{-c-x-D/2}^{-c-x+D/2} \iint g(x)g(y)dydx \frac{1}{u} f(u) \frac{1}{v} f(v) \,|\, \underline{v} - \underline{u} \,|\, D(\underline{u},\underline{v}) dvdu$$

(Eq. 5-15)

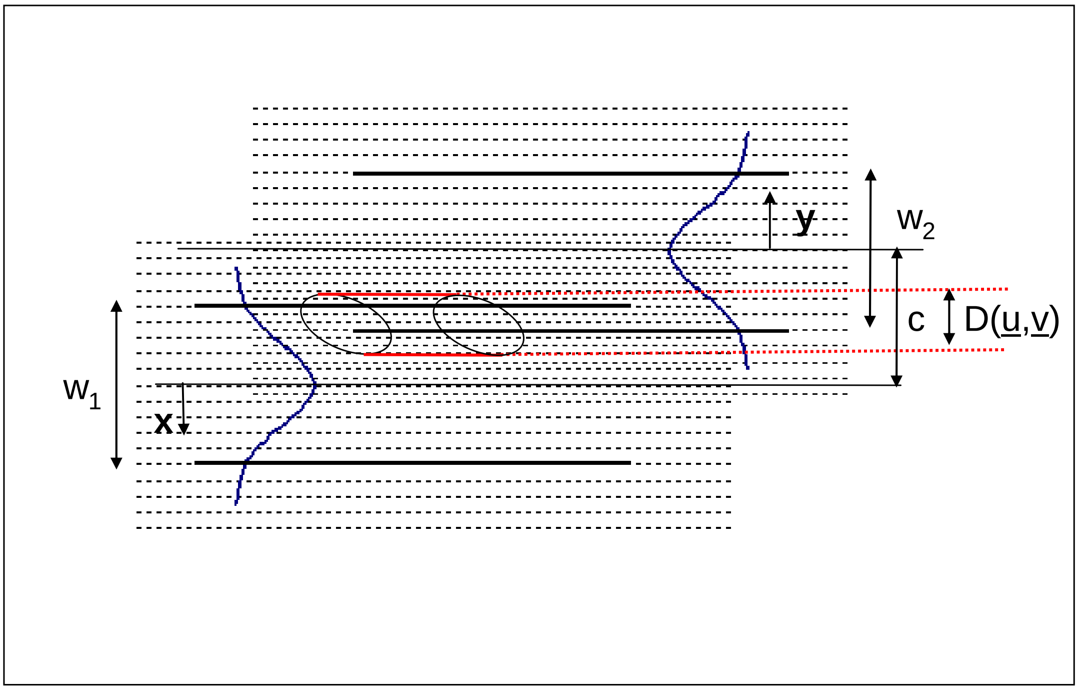

Figure 5-4 Two parallel traffic lanes

In case the two traffic flows have an opposite direction, as illustrated in Figure 5-4, the number of head-on manoeuvres per year in a traffic flow with length *L* can be written as:

$$enc_{12} = 24*365\ L \int_{-w_1/2}^{w_1/2} \int_{-c-x-D/2}^{-c-x+D/2} \iint g(x)g(y)(\frac{1}{u}+\frac{1}{v})\, f(u)\, f(v)\, D(\underline{u},\underline{v})dvdudydx$$

(Eq. 5-16)

For two traffic flows in the same direction, thus Figure 5-4 in which the sailing direction of the second traffic flow is reversed, the number of overtakings follows from:

$$enc_{12} = 24*365\ L \int_{-w_1/2}^{w_1/2} \int_{c+x-D/2}^{c+x+D/2} \iint g(x)g(y)|\frac{1}{u}-\frac{1}{v}|\, f(u)\, f(v)\, D(\underline{u},\underline{v})dvdudydx$$

(Eq. 5-17)

In the above formulas is *c* the distance between the centre lines of the two traffic flows. In case *c*=0 the two traffic flows coincide. This is for example the case when calculating the overtaking encounters within the traffic flow, or the head-on encounters on a route with two directional traffic.

Two traffic flows with nearly the same or opposite direction

In case of two traffic flows with nearly the same or opposite direction, an approach is applied in which the second traffic flow is divided into a number of traffic flows that run completely parallel with the first traffic flow. In fact, this means that the distance between the traffic flows increases or decreases slowly in steps. The formulas of exactly parallel running traffic flows are applied.

5.2.2 Encounters between route bound traffic and non-route bound traffic

For a route bound ship in a traffic lane, the number of encounters per hour by non-route bound traffic is:

$$enc = \iint f(v)\,|\underline{v}-\underline{u}\,|D(\underline{u},\underline{v})d_2 dvdt \qquad \text{(Eq. 5-18)}$$

where d_2 is the density of non-route bound traffic.

The number of encounters per year in the area for all ships 1 in a traffic link with a length *L* amounts to:

$$enc = Ld_2 \int g(x) \iint \frac{1}{u} f(u)\, f(v)\,|\underline{v}-\underline{u}\,|D(\underline{u},\underline{v})dvdudx \int_0^{24*365} dt \qquad \text{(Eq. 5-19)}$$

Using the independency of the different distributions, this can be simplified to:

$$enc = Ln_1 d_2 \iint \frac{1}{u} f(u)\, f(v)\,|\underline{v}-\underline{u}\,|D(\underline{u},\underline{v})dvdu \qquad \text{(Eq. 5-20)}$$

5.2.3 Encounters among non-route bound traffic

The number of encounters per hour for a ship 1 by non-route bound traffic, represented by an area density d_2 is:

$$enc = \iint f(v)\,|\underline{v}-\underline{u}\,|D(\underline{u},\underline{v})d_2 dvdt \qquad \text{(Eq. 5-21)}$$

The number of encounters per nm^2 per year for all ships 1 per nm^2 is per year is:

$$enc = 24*365\ d_1 d_2 \iint f(u)\, f(v)\,|\underline{v}-\underline{u}\,|D(\underline{u},\underline{v})dvdu \qquad \text{(Eq. 5-22)}$$

5.3 Circular ship domain and grid

The encounter calculation is rather complex, because of the large number of different situations that can occur. Another aspect that makes it even more complex is that the results of the calculations have to be assigned to a geographical area. The factor between encounters and collisions can be influenced by measures, such as VTS. Also, the consequences of the collision can be different for different locations. For this reason the number of encounters are calculated in advance for each cell (8 x 8 km) of the genogrid. This intermediate result is used in additional calculations for a case, in which area, measures, ship selections, and dangerous goods can be varied.

In case of an ellipse as ship domain, the ship domain varies with the situation. In case of a circular ship domain with radius *R*, the encounter width D(u,v) depends not longer on u, v and α but is always 2*R*. This simplifies a number of formulas derived in 5.2. Further, it is not expected that the use of a circular model has large consequences on the results of calculations, because the relation between encounters and collisions is taken to be different for head-on, crossing and overtaking, more or less the base sectors of Goodwin [6] on which the ellipse as domain is based. Thus, the difference between a circular and an elliptical domain is implicitly compensated by the determination of the CASRAT.

5.3.1 Encounters among route bound traffic

The number of encounters per year between two crossing flows is:

$$enc_{12} = \frac{2R}{24*365} \frac{n_1 n_2}{\sin\alpha} \iint \frac{1}{u} f(u) \frac{1}{v} f(v) \sqrt{(u^2 + v^2 - 2uv\cos\alpha)}\, dv\, du$$

(Eq. 5-23)

In case the two traffic flows have an opposite direction, as illustrated in Figure 5-4, the number of head-on manoeuvres per year in a traffic flow with a length *L* can be written as:

$$enc_{12} = 24*365\ L\, 2R\left(\frac{1}{u} + \frac{1}{v}\right) \int_{-w_1/2}^{w_1/2} \int_{-c-x-D/2}^{-c-x+D/2} g(x) g(y)\, dy\, dx \qquad \text{(Eq. 5-24)}$$

For two traffic flows in the same direction the number of overtakings follows from:

$$enc_{12} = 24*365\ L\ 2R \int_{-w_1/2}^{w_1/2} \int_{c+x+D/2}^{c+x+D/2} g(x) g(y)\, dy\, dx \iint \left|\frac{1}{u} - \frac{1}{v}\right| f(u) f(v)\, dv\, du$$

(Eq. 5-25)

5.3.2 Encounters between route bound traffic and non-route bound traffic

The number of encounters per year for all ships 1 in a traffic link with length *L* in the area amounts:

$$enc = Ld_2 \int g(x) \iint \frac{1}{u} f(u)\, f(v)\, |\underline{v} - \underline{u}|\, D(\underline{u}, \underline{v})\, dv\, du\, dx \int_0^{24*365} dt \qquad \text{(Eq. 5-26)}$$

Using the independency of the different distributions this can be simplified to:

$$enc = Ln_1 d_2\, 2R \int_0^{2\pi} \iint \frac{1}{u} f(u)\, f(v) \sqrt{(u^2 + v^2 - 2uv\cos\alpha)}\, dv\, du\, d\alpha \qquad \text{(Eq. 5-27)}$$

5.3.3 Encounters among non-route bound traffic

The number of encounters per year for all ships 1 per nm^2 is per year is:

$$enc = 24*365\, d_1 d_2\, 2R \int_0^{2\pi} \frac{1}{2\pi} \iint f(u)\, f(v) \sqrt{(u^2 + v^2 - 2uv\cos\alpha)}\, dv\, du\, d\alpha$$

(Eq. 5-28)

5.4 Encounters on a grid

The encounters can be calculated in an area or on a grid. Within SAMSON the results of the encounter calculations are stored per grid cell. The definition of the grid for which the encounter calculation has to be executed is defined in the input file \SHIPPING\PROGRAM\COORDINA.INI. Table 5-1 contains the contents of this file for the definition of the GENOGRID. Only the first values of the first 8 lines are read with Free Format. The remaining part of the line is used for the description of what the value represents.

Each defined grid in COORDINA.INI is an equidistant (x,y) grid. This grid is pinpointed on the earth with one point, the reference point. This point is defined in the first two lines with an angle in radians, corresponding with the latitude and the longitude of the reference point, which is (55°N, 4°E) for the genogrid. This reference point in genogrid coordinates is point (64,80), which is the left under point of grid cell (64,80). Line 5 contains a parameter for the flattening of the earth and line 6 the radius of earth in meters. With these parameters the conversion between geographical coordinates and genodgrid coordinates and vice versa are performed. The size of the genogrid cell in x and y direction is given in meters in line 7 and 8 of COORDINA.INI. The remaining lines are comment.

Table 5-1 File COORDINA.INI for the GENOGRID

```
.959931088      parpo   (55*pi/180, is latitude of reference point in radians)
.06981317       parlo   (4*pi/180, is longitude of reference point in radians)
   64.          parmo  (the x-value of the reference point)
   80.          parno   (the y-value of the reference point)
    0.          parao (parameter for the flattening of the earth)
 6371515.       parro  (radius of earth in reference point)
   8000.        dxgeno
   8000.        dygeno

open(1,file='coordina.ini')
c      data  parpo /.959931088/, parlo /.06981317/,
c     1      parmo / 64./, parno / 80./, parao /0./, parro / 6371515./,
c     1      dxgeno /8000./, dygeno / 8000./
RefNBx100 = 5500
RefOLx100 = 400
RefGridX = 64
RefGridY = 80
ParR0 = 6371515
GridSizeX = 8000
GridSizeY = 8000
MaxGridX = 134
MaxGridY = 142
```

The COORDINA.INI file may not be changed within the same application, because the encounter calculations are performed only once for a certain traffic database.

One can use another grid by changing the file COORDINA.INI. However, in case one changes COORDINA.INI during an application the encounter result files GENOVER.RAN and GENOENC.RAN located in \SHIPPING\SCENARIO\SHIP\[year]\ have to be removed or deleted. In this case a new encounter calculation will be started when the collision risk has to be calculated. SAMSON does not check whether or not COORDINA.INI is changed.

The purpose of the encounter calculation is to find a sound base for estimating the number of collisions that can be expected. The encounter calculation uses the encounter angle; but this can only be used in a limited way. The main reason is that encounters for different angles cannot be related with real historical data from collision databases, because the collision angle is never (as far as known) taken as field in the historical databases. Only Capt. Cockcroft has collected this data for a large number of collisions in the nineteen seventies and nineteen eighties. He was involved in the COST301 for the European Commission. The research within this project has delivered the distribution of the collisions over the types head-on, crossing and overtaking collisions. This distribution is still used for splitting up the number of collisions over these types before the CASRAT (relation between encounters and collisions) is determined. His definition was based on the course difference of the traffic flows of the two routes that were sailed by the colliding ships.

Because more traffic separation schemes have been introduced since the research of Cockcroft, it can be expected that the share of head-on collisions has decreased. This impact can only be determined with a new large and time consuming project, in which collisions are classified within the three types. However, when the same collision sensitivity is still valid for the three encounter types, SAMSON calculates the correct level for the collision risk, because the number of encounters is the base for the collision risk and not the historical data. In case of more traffic separation schemes, SAMSON will calculate fewer head-on encounters thus fewer head-on collisions.

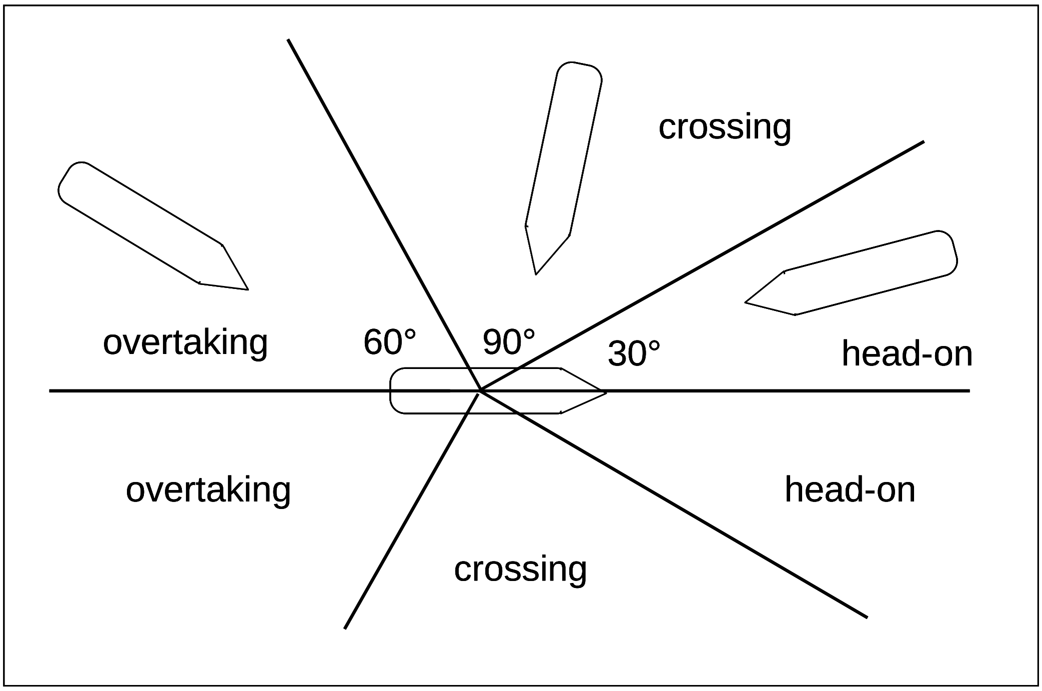

Figure 5-5 Definition of the three encounter types

Given the risk calculations based on SAMSON, the number of encounters in each of the three segments is required. Thus, the number of encounters within each type can be summarized. The ship type and size remain important because the CASRAT is sensitive for these two characteristics. The ship type is more or less related to the manoeuvrability. Well manoeuvrable ships will have relatively fewer collisions because last minute collision avoidance manoeuvres have more effect. The ship size is important, because this does not only affect the manoeuvrability, but also because a larger ship has a larger body that can collide or can be collided with.

The results of the encounter calculation for one cell are stored for the calculation of the collision risk. The data required for the additional collision risk calculations is:

- Head-on, overtaking and crossing encounters for each ship type and ship size;
- Average ships for each ship type and size.

In 5.3 the formulas are given for the number of encounters for different situations. The introduction of the grid makes it even more difficult. This is illustrated in Figure 5-6, in which the red lines are the borders of the grid cells.

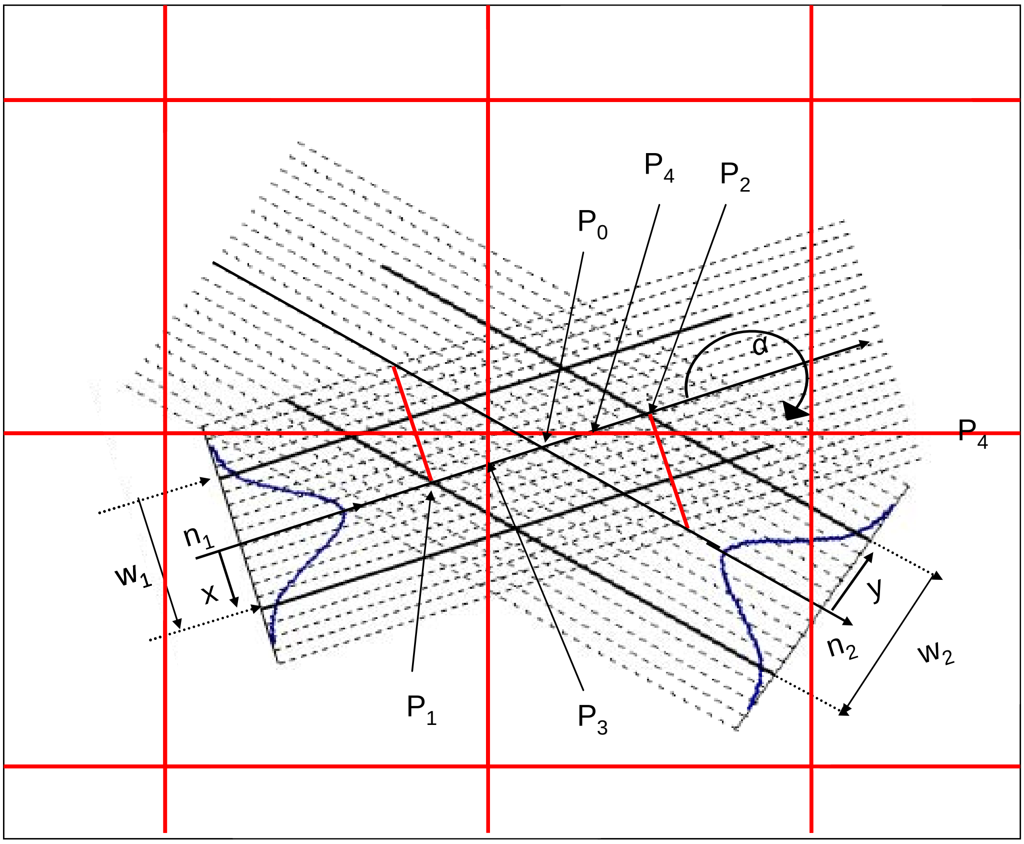

Figure 5-6 Two traffic flows with the a grid

The encounters between the two traffic flows occur in different grid cells. The assignment to different cells is complicated because sometimes, the encounters occur in a number of grid cells. Taking into account the ship domain, than ships that encounter in one grid cell in the next time unit, can come from another grid cell.
A simple robust approach is followed for assigning the calculated encounters to grid cells. It is assumed that all calculated encounters are uniformly spread over the line P_1P_2. The positions of P_1 and P_2 are defined as the crossing points of the borders of the second traffic link with the centre line of the first traffic flow for which the encounters are calculated. The point P_0 is the crossing point between the centre lines of the two traffic flows. In case P_1P_2 is located completely in one grid cell, all encounters are assigned to that grid cell. In case the link runs through more than one grid cell, the encounters are assigned to the different grid cells, in ratio with the length of the line P_1P_2 in each cell. For the example of Figure 5-6 one cell gets length(P_1P_3)/length(P_1P_2) of all encounters, the second cell gets length(P_3P_4)/ length(P_1P_2) of all encounters, and the third cell gets length(P_4P_2)/ length(P_1P_2) of all encounters. Points P_3 and P_4 are the crossing points of the line P_1P_2 with the borders of the grid cells. For a different composition of the grid the same number of encounters will be determined, only the division over the cells will be different.

For larger angles the meeting area between the traffic flows is rather limited. Therefore all crossing encounters are assigned to the grid cell that contains P_0.

5.4.1 Genogrid and non-route bound ships

The calculation of the encounters of a route bound ship by a non-route bound ship is as follows. First, the length *L* of the traffic flow within the grid cell is calculated, see Figure 5-7.

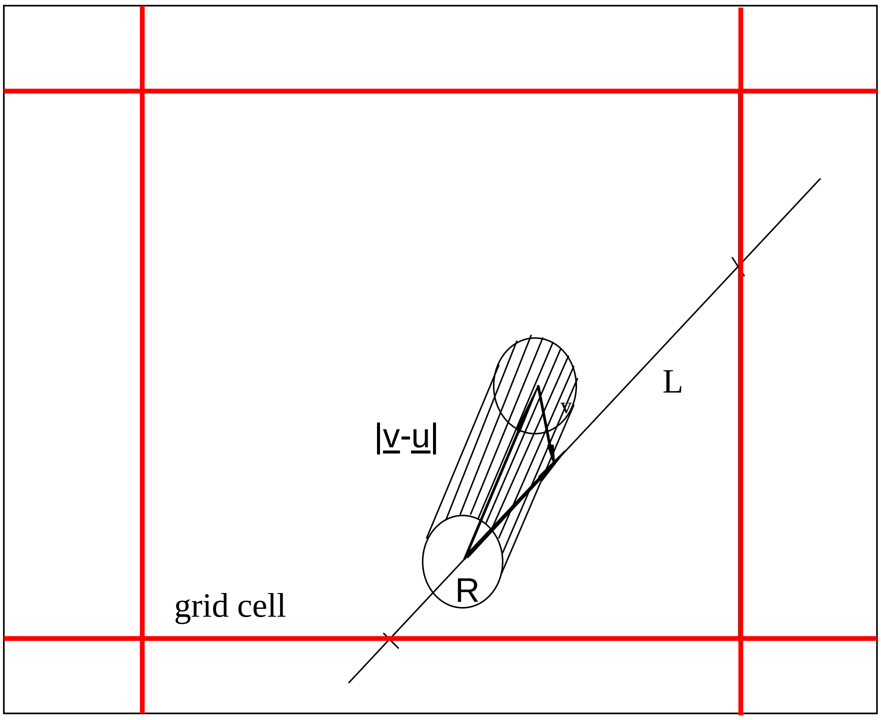

Figure 5-7 Encounters between a ship on a traffic flow and a non-route bound ship

The number of encounters per year for ships of the traffic flow is:

$$enc = Ln_1 d_2 2R \int_0^{2\pi} \iint \frac{1}{u} f(u)\, f(v) \sqrt{(u^2 + v^2 - 2uv\cos\alpha)}\, dv du d\alpha \qquad \text{(Eq. 5-29)}$$

It is assumed that the density d_2 of non-route bound ships is the density of the grid cell and not the density of adjacent grid cells when the domain exceeds the border of the grid cell.

The same approach is followed for the encounters among non-route bound ships. In this case it is assumed that the densities of d_1 and d_2 are the densities of the grid cell dealt with. The number of encounters per year for all ships 1 per nm^2 is:

$$enc = 24*365\, d_1 d_2\, 2R \int_0^{2\pi} \frac{1}{2\pi} \iint f(u) f(v) \sqrt{(u^2 + v^2 - 2uv\cos\alpha)}\, dv du d\alpha$$

(Eq. 5-30)

5.5 Storage of the encounters

The result of the encounter calculation is an intermediate result that is used to determine the number of collisions in a next step. The result of the encounter calculation is stored in two files in the directory \SHIPPING\SCENARIO\SHIP\[year]\ that also contains the traffic database. The files are

- GENOVER.RAN;
- GENOENC.RAN.

Both files are random access files that cannot be read with a text editor. The random access approach is necessary to write and read quickly the results for a certain grid cell.

The GENOVER.RAN has records with the total result for each grid cell. The first record defines the dimension of the total grid and the number of records used in GENOENC.RAN for storing the detailed results of the encounter calculation. It contains:

- the total number of records (stored cells) (I94) in use in file GENOENC.RAN (with file number 94 in SAMSON)
- the maximum number of grid cells in x-direction (KGRIDX);
- the maximum number of cells in y-direction (KGRIDY).

The address (record number) where information can be found of cell (igeno, jgeno) is (igeno-1)*kgridy+jgeno+1. This record contains five values, describing the status of the genogrid cell (igeno, jgeno), namely:

- the address (record number) of file GENOENC.RAN where the full matrix results of the encounter calculation can be found (-1 when not calculated, 0 when no encounters take place in the grid cell);
- the average number of ships in the grid cell;
- the number of head-on encounters per year in the grid cell;
- the number of overtaking encounters per year in the grid cell;
- the number of crossing encounters per year in the grid cell;

These two random access files are built up during the encounter calculations. As soon as the results of a grid cell are calculated, a new storage position is used to store the results. The new location is i94+1. The results are written to this record of GENOENC.RAN and i94 is increased with one and this new number of occupied records is written to record 1 of GENOVER.RAN.
The five main items (records in use (=i94), average number of ships, head-on, overtaking and crossing encounters) are written to record number (igeno-1)*kgridy+jgeno+1 of genover.ran.

The following data is written unformatted to one record of GENOENC.RAN:

- CHAREA contains a string of 22 characters, containing the name of the area. In case of the genogrid or other defined grid it contains the grid cell, for example "/ 12 12 5 5 /" for indicating grid cell (i,j). In case of a step size of more cells the four values are igeno, igeno+istep-1, jgeno, jgeno+jstep-1;
- XAG(2,10) with the points of the grid cell. In case of the genogrid five points (four points plus the fifth point (= first point) to close the area). The sixth point has latitude xag(2,6) of 0 what means that it belongs not to the area;
- XAGEX(4) with the outmost coordinates (minimum latitude, minimum longitude, maximum latitude, maximum longitude);
- SIGMIN is the lower bound of sigma. The links with a sigma < SIGMIN are not included in the calculation;

- SKIP is the lower border for the estimated number of encounters that are taken into account. If the first estimate $n_1 n_2/(\sin\alpha)$ is lower than SKIP the link is skipped. Nowadays the skip value is always 0, which means that all links are considered.
- For each ship type and ship size the number of head-ons, overtakings and crossings per year and the average number of ships.

After the encounter calculation all cells are calculated, and GENOVER.RAN and GENOENC.RAN are completely filled for the defined grid.

5.6 Calculation of encounters

The encounter calculation will be carried out only one time for each new traffic database. The risk for different areas or for different scenarios, wind farms, off shore platforms or measures can be determined without new encounter calculations. The results are retrieved from GENOVER.RAN and GENOENC.RAN as described in the previous chapter.
Before the calculation, these random access files are prepared for a new traffic database with the program CRGENO.EXE (create genogrid) in which the main parameters of the grid are written to the files.
Thereafter the encounter calculation can be started with ENCOUNST.EXE. Figure 5-8 gives the steps of the encounter calculation.

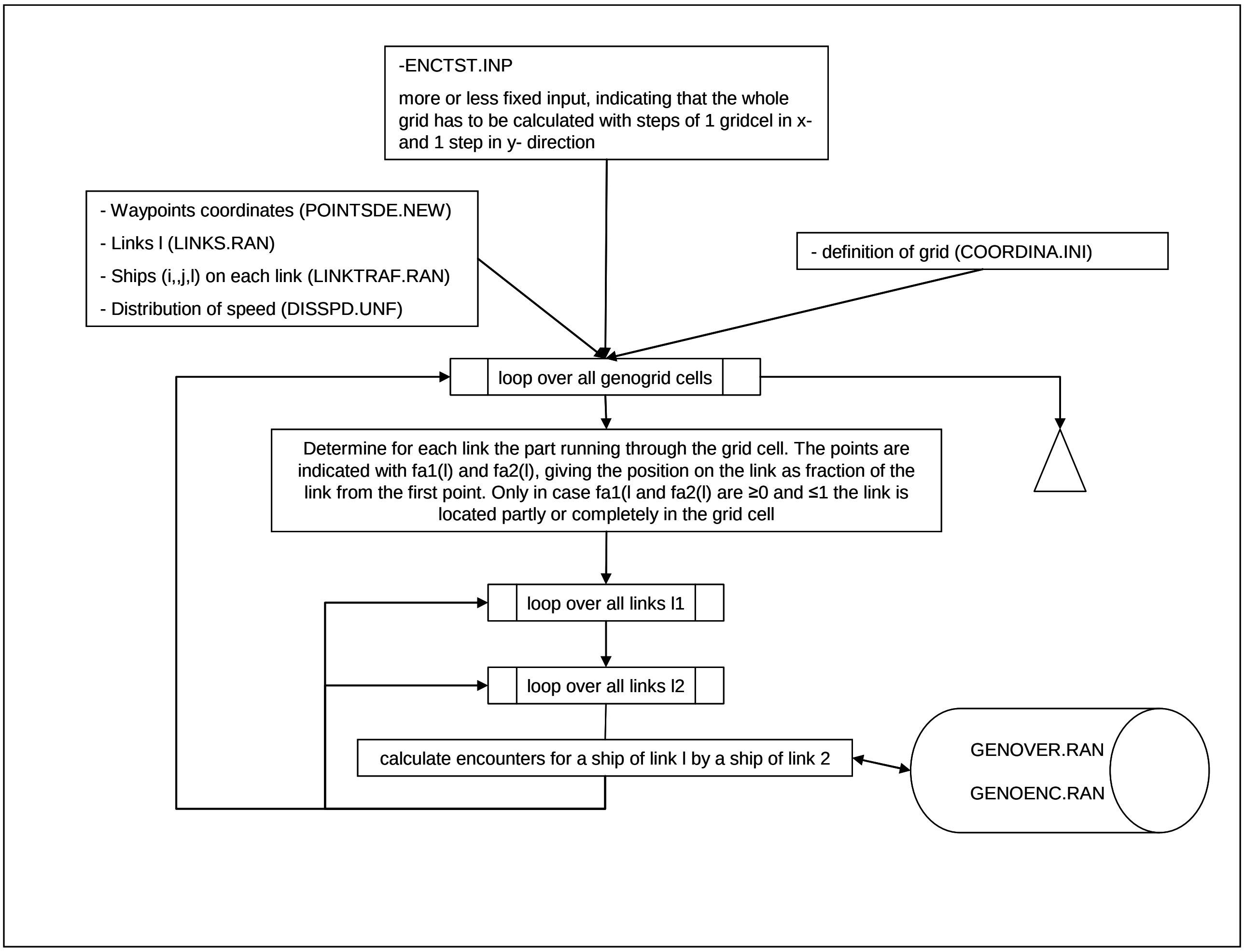

Figure 5-8 Short calculation plan: encounter model

The process is that the encounters are calculated for each genogrid cell. It is rather complex to determine which encounters will exactly occur in one grid cell, because it is a composition of two traffic flows with a lateral distribution and the dimension of a grid cell. How this is solved is illustrated in Figure 5-9 in which the centreline of two links are plotted.

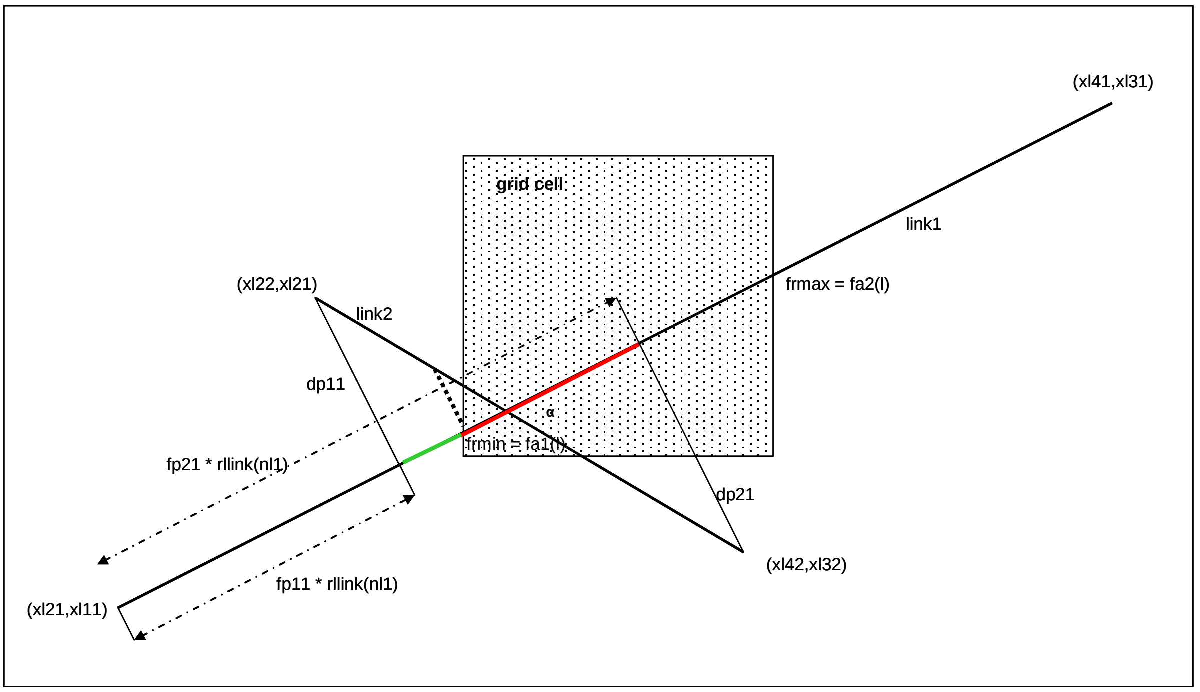

Figure 5-9 Two links with a grid cell

Traffic flow 1 (link1) runs through the grid cell from fa1(l) to fa2(l) of traffic flow 1. The encounters for a ship on traffic flow 1 by a ship of traffic flow 2 are counted on the part between fp11 and fp21 of link 1. The points fp1 and fp2 are the crossing points of the perpendiculars from the end points of link2 with the centre line of link 1. All encounters of a ship 1 of link2 with a ship on link 1 are assigned to the part fp1 to fp2 of link 1. The encounters for the common red part of link1 are assigned to the plotted grid cell. The common part stretches from max (fa1(l), fp11) to min(fa2(l),fp21). The description of the encounter situation is further completed with the distances dp11 and dp21. The encounters for ship 1 in the grid cell are calculated for this description.

The encounters on the green part are assigned to other grid cells, and calculated when the other grid cells are dealt with.

The calculation of encounters is reduced to elementary steps in which the number of encounters are determined for two traffic links.

5.7 Assumptions

The following assumptions have been used in the derivation of the formulas for the encounter calculation:

- The lateral distribution and the speed distribution are independent;
- The speed distributions are different for each type and size class. These distributions are independent;
- The event of passing a cross section of a traffic lane follows a Poisson process, which means that the ships move completely independent of each other.

5.8 Future work

The encounter multiplied with the casualty rate delivers the probability of a collision given an encounter. This is a well known approach, just like the distinction in head-on, overtaking and crossing. However, it has one disadvantage, namely that the difference between the different encounters are sharp transits. This means that an encounter at an encounter angle of 151° is classified as a head-on encounter and an encounter at an angle of 149° is classified as a crossing encounter. Because the casualty rate for a crossing encounter is much higher than for a head-on encounter, the collision risk for two traffic flows with a course difference of 149° is much higher than the collision risk between traffic flows with a course difference of 2° more. For a large area it is not a large problem because the many situations will compensate each other. However, in case of a measure to move a traffic link over a short distance, the border between two types of encounters can be passed, which give a larger change in collision risk than in reality can be expected. It is better to implement for the collision rate a more continuously function of the collision angle.

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