THEORY

RISK REPORTS

DATE: December 2023

Most of the risk results as presented in the software products are subject to additional calculations to manipulate the details produced by the risk models themselves. This document explains these additional calculations and defines the terms used in the risk reports.

No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
0	[yyyy-mm-dd]	First issue			
1	March 2016	First edition	David Worthington	Henk Witlox, Jan Stene	
2	March 2017	Add summary maximum effect zone description	David Worthington	Peter Lloyd, Allan Makura	
3	May 2020	Safeti NL version 8.3 - additions to SMEZ description	David Worthington	William Place	
4	May 2021	Apply new template	D. Vatier		
5	July 2022	Include section on Event Tree (ET) Ignition report	David Worthington	James Pickles	
6	April 2023	Clarify behaviour for long pipelines and scenarios along routes	David Worthington	Ade Oke	

Date: December 2023

Prepared by: Digital Solutions at DNV

ABSTRACT

Most of the risk results as presented in the software products are subject to additional calculations to manipulate the details produced by the risk models themselves. This document explains these additional calculations and defines the terms used in the risk reports.

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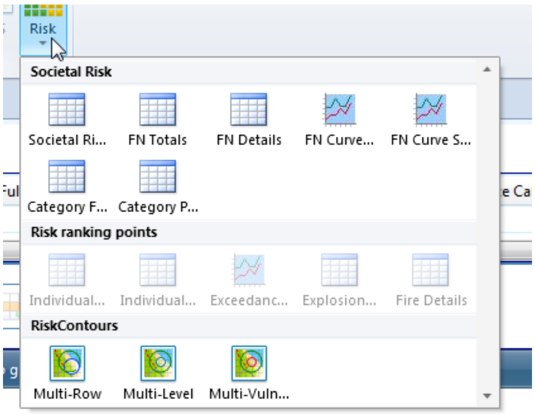
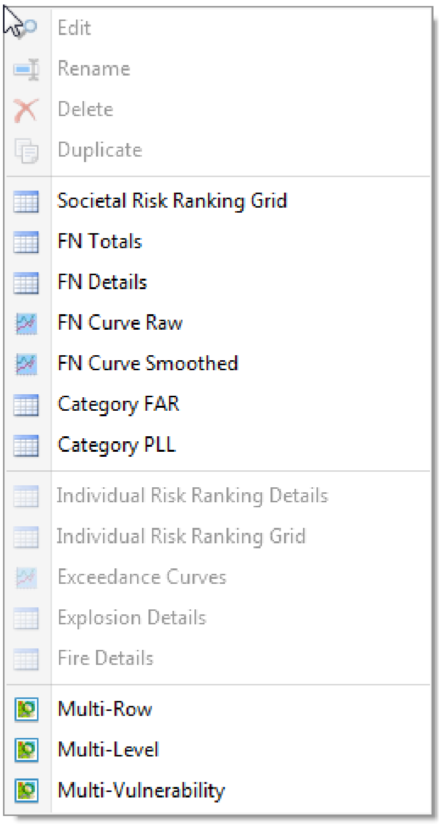
1. INTRODUCTION

The risk results are stored in a database and may be accessed via the ribbon and the 'risk gallery'.



Or they may be accessed via a right click in the results tab. Previous result filter selections are preserved for reuse and can also be adjusted to reflect updated selections.



A description of each type of result is given in this document.

CONTOURS AND TRANSECTS

1.1 The Risk Grid

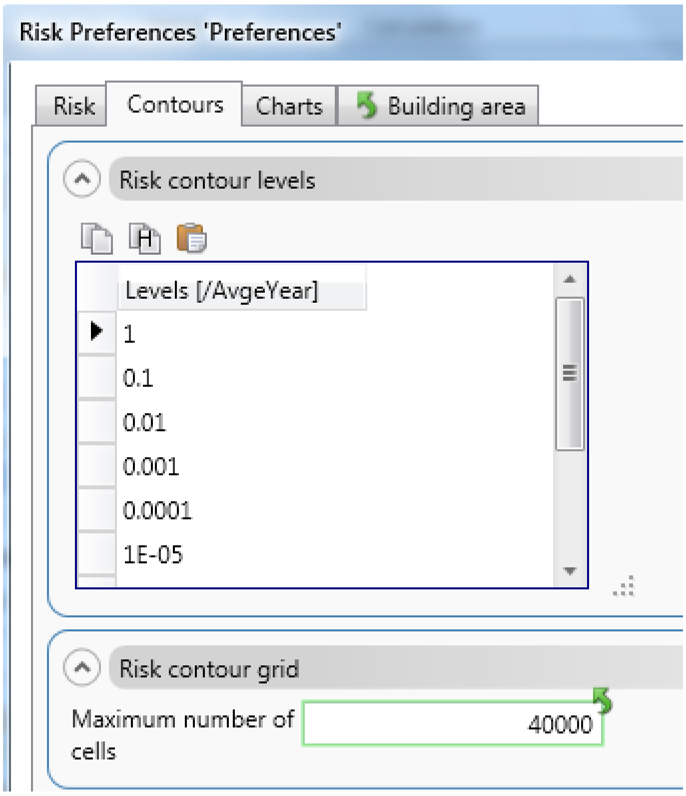
Each run row has a grid of x, y points where it accumulates risk. It accumulates risk for all building types (each assigned a vulnerability v) selected for contouring. The values at a point may be expressed;

$$IR_{x,y,v} = \sum_{All\ edfs} IR_{edf,x,y,v} \quad (1)$$

During the contouring for a single run row no combination factors are applied.

1.2 Combination of the Risk Grid

Each run row may have a different number and distribution of grid locations and spacing. To enable the contouring of combinations another grid of x,y locations is defined based on the limits of the run row grids to be combined as shown in Figure 1 and the maximum number of cells for contouring;



The contouring risk grid calculates the total risk for each building type by summing each run row contribution and applying the combination factors. So the values at a point for a given combination j may be expressed as

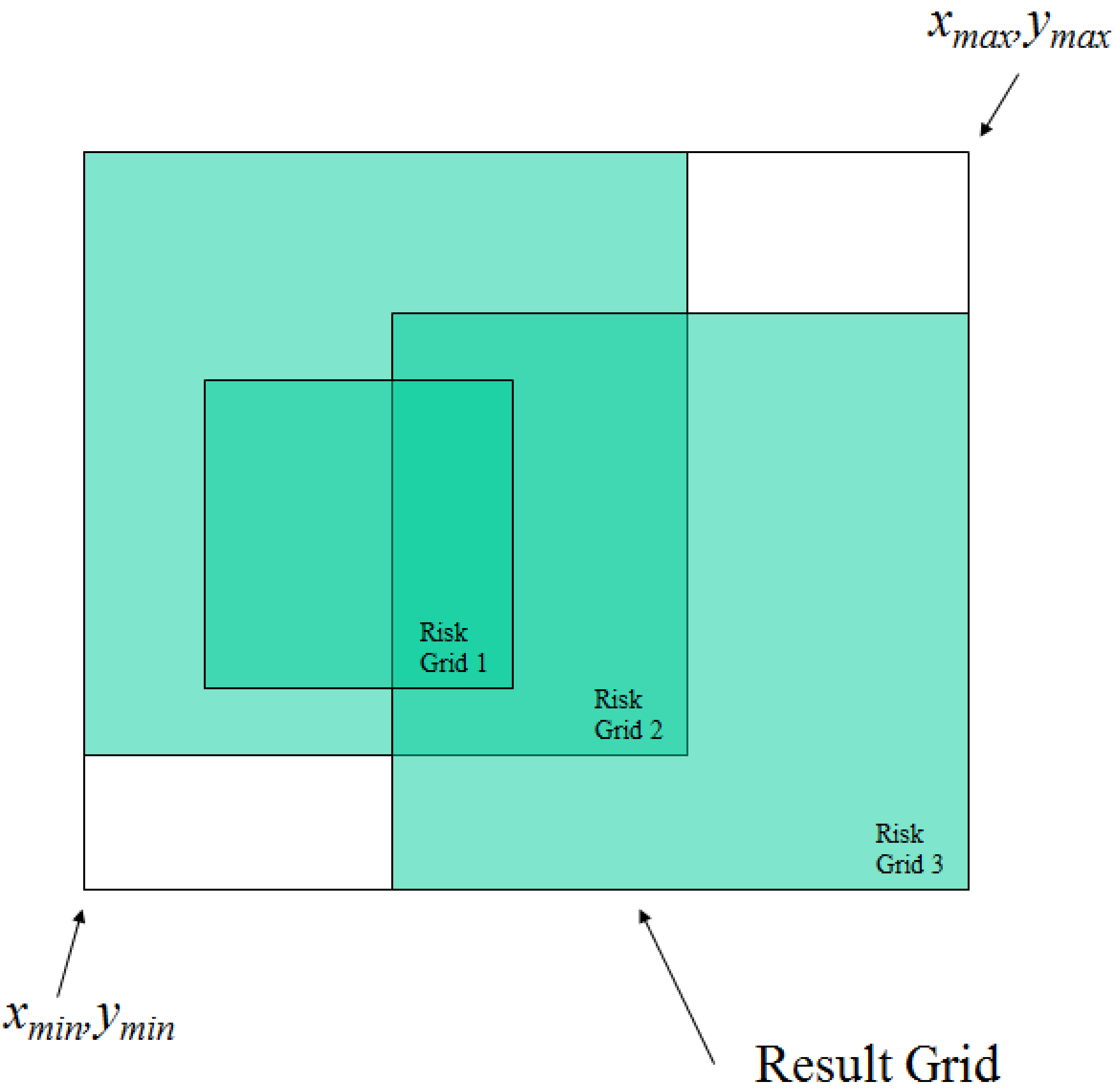


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Figure 1 – Sizing of the risk grid to be used for contouring combinations

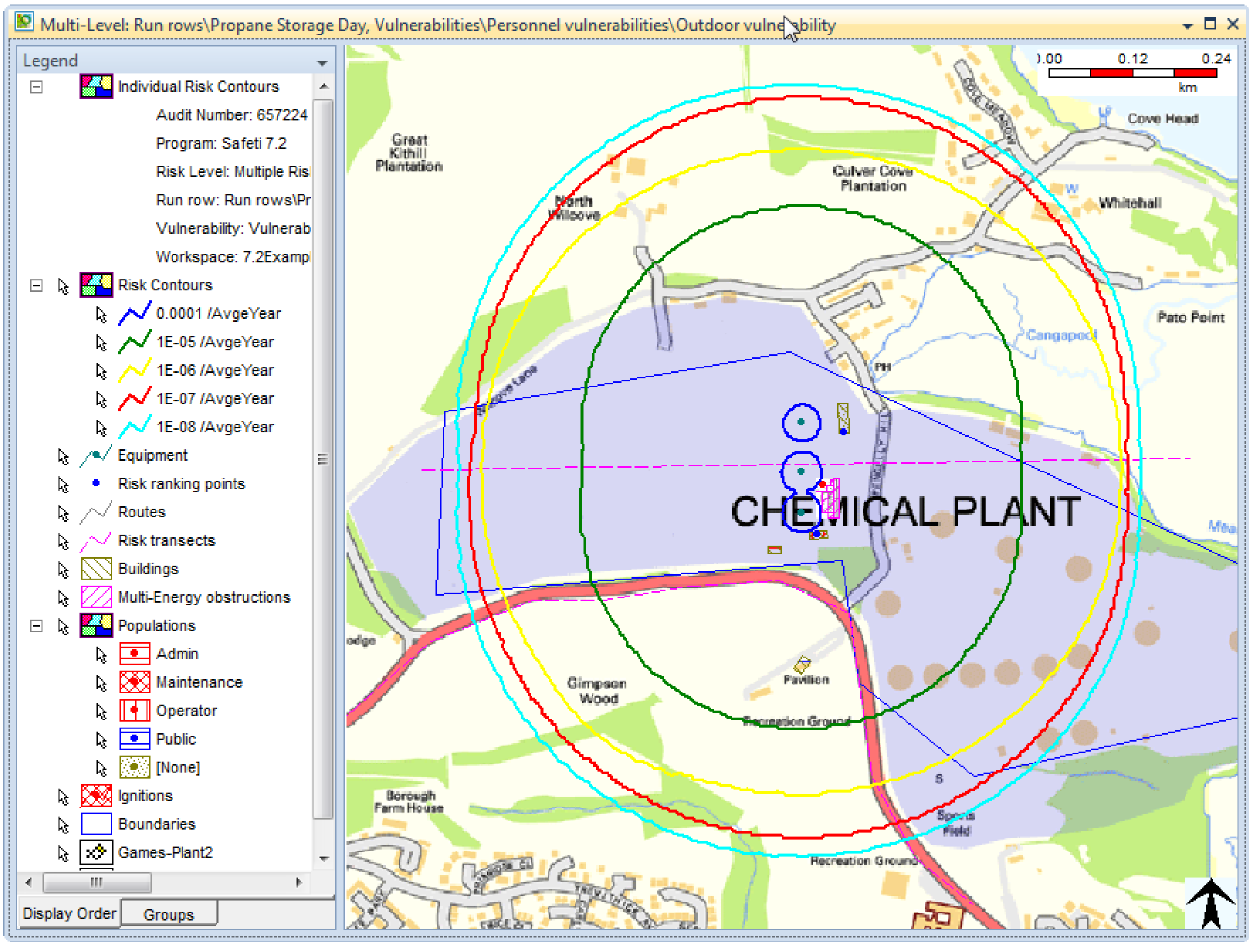
$$IR_{x,y,v,j} = \sum_{\substack{All\ run \\ rows\ i}} r_{i,j} IR_{x,y,v,i} \quad \textbf{(2)}$$

The risk values at the contouring grid locations are obtained by interpolation between the risk values at the run row grid locations.

1.3 Contours

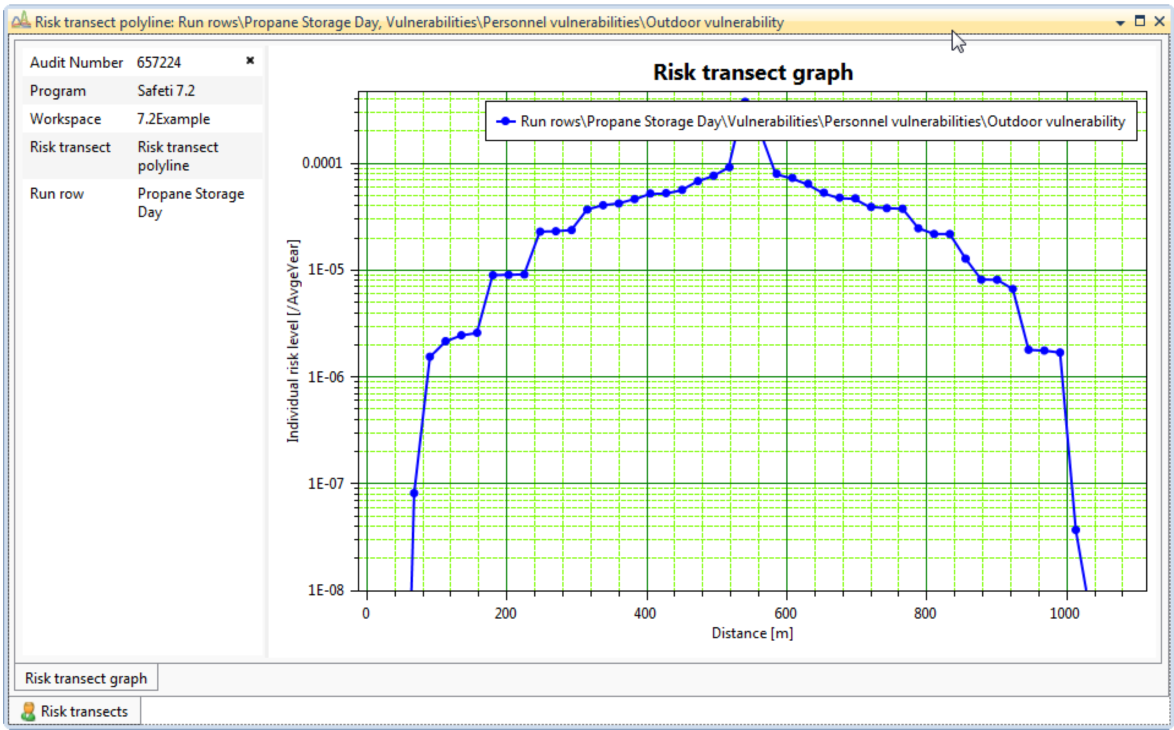
Contours representing iso-risk levels are obtained directly from the risk grids, either a single run row or a combination. A linear interpolation method is used without any smoothing algorithm. The contours are therefore an accurate representation of the risk values on the grid and can sometimes appear as steps, particularly at the furthest extent of the risk where the interpolation goes from zero risk to 'something' that can be quite large compared to the lowest contouring level of 10^{-8}/yr.

It is possible to see the extent of the risk grids using a display option on the contour plot.



1.4 Transects

In a similar manner to the contours risk transects are calculated from the risk grids, either run row grids or combination grids. So on run row transects no combination factor is applied and in combinations the run row factors are used.


Risk transect polyline: Run rows\Propane Storage Day, Vulnerabilities\Personnel vulnerabilities\Outdoor vulnerability
Audit Number 657224
Program Safeti 7.2
Workspace 7.2Example
Risk transect Risk transect polyline
Run row Propane Storage Day
Risk transect graph
Run rows\Propane Storage Day\Vulnerabilities\Personnel vulnerabilities\Outdoor vulnerability
Individual risk level [/AvgeYear]
0.0001
1E-05
1E-06
1E-07
1E-08
0
200
400
600
800
1000
Distance [m]
Risk transect graph
Risk transects

2 INDIVIDUAL RISK RANKING REPORTS

This chapter describes the reports available in the risk gallery associated with the risk ranking points.

2.1 Individual Risk Ranking Details

The risk ranking details are the raw results from the risk models and they correspond to the risk outcomes. This means a particular event, weather, wind sector, branch of the event tree and location. Each outcome may record some risk at each risk ranking point and there may be several results for each point and outcome depending on the number of vulnerabilities defined in the study. The risk per point per outcome per vulnerability is recorded together with the outcome frequency. The nomenclature may be related to the contents of the table;

Run Row Name	Model Name	Model East [m]	Model North [m]	Outcome Frequency [/AvgeYear]	Risk Ranking Point	Vulnerability Name	Risk Increment [/AvgeYear]	Weather Direction deg.	Outcome Type Description
Day	Study\Toxic\Toxic leak	0	0	5.267E-06 $F_{o\gamma}$	North	Outdoor vulnerability	6.045E-07 $IR_{edf,x,y,v\|o\gamma}$		Toxic effects for a release in
Day	Study\Toxic\Toxic leak	0	0	5.267E-06	North	Indoor vulnerability	5.177E-07		Toxic effects for a release in

The Safeti software may be used to calculate the probability of harm, but if is most often used to calculate the probability of death. Therefore for the remainder in this report reference is made to ‘probability of death’ rather than ‘probability of harm’. The probability of death according to the vulnerability definition (for a given outcome *o* of effect type γ at location [*x,y*]) may be inferred as

$$P_{d,x,y,v|o\gamma} = \frac{IR_{edf,x,y,v|o\gamma}}{F_{o\gamma}} \quad (3)$$

Combination factors are not applied to the risk ranking details and results are shown for each run row.

If the wind rose is subdivided for flammable events then there may be several records in the same wind rose sector.

2.2 Individual Risk Ranking Grid

The individual risk ranking grid presents the results grouped by individual run rows and/or combinations.

2.2.1 Run Row Groups

Combination factors are not applied to the run row groups. At the lowest level the individual risk ranking details are displayed as ‘Outcome Results’. These are summed to give the total risk by outcome type at the ‘Event Outcomes’ level.

Run rows

Group Name	Group Type
Day	Run Row

Group Risk Ranking Points

Risk Ranking Point Na	RRP East [m]	RRP North [m]
North	0 x	200 y
South	0	-200
JustNorth	0	10

Risk Ranking Points Vulnerabilities

Building Type Name	Risk Total [/AvgeYear]
Outdoor vulnerability	0.0003801

$$IR_{x,y,v} = \sum_{All\ edfs} IR_{edf,x,y,v}$$

Building Type Events

Model Name	Model East [m]	Model North [m]	Model Frequency [/AvgeYear]	Total Risk [/AvgeYear]	Pct. Risk	Risk / Outcome
Study\Both\Both leak	0	0	0.0001 F_{edf}	3.52E-06 $IR_{edf,x,y,v}$	0.9262 $\Delta_{edf,x,y,v}$	0.0352 $P_{x,y,v\|edf} = \frac{IR_{edf,x,y,v}}{F_{edf}}$
Study\Flammable\Fl...	0	0	0.0001	3.44E-06	0.905	0.0344
Study\Route\Scenari...	0	5	0.005	0.0001749	46.02	0.03498
Study\Toxic\Toxic leak	0	0	0.0001	1.026E-06	0.2699	0.01026
Study\Route\Scenari...	0	-5	0.005	0.0001972	51.88	0.03944

Events Outcomes

Outcome Type Description	Total Risk [/AvgeYear]	Pct. Risk	Risk / Outcome
Continuous release with Rainout Delayed Flash Fire Only	1.679E-05 $IR_{edf,x,y,v,\gamma}$	4.511 $\Delta_{edf,x,y,v,\gamma}$	0.2927 $P_{x,y,v\|\gamma,edf}$

Outcomes Results

Run Row Name	Model East [m]	Model North [m]	Outcome Frequency [/AvgeYear]	Risk Increment [/AvgeYear]	Weather Name	Weather Direction deg	Time [s]
Day	0	-5	1.679E-05 $F_{o\gamma}$	1.679E-05 $IR_{edf,x,y,v\|o\gamma}$	Day\D 5m/s	165.0-195.0	3600

$$IR_{edf,x,y,v,\gamma} = \sum_{All\ outcomes\ of\ type\ \gamma} IR_{edf,x,y,v|o\gamma} \tag{4}$$

The sum of these is the total risk at that point.

$$IR_{edf,x,y,v} = \sum_{All\ types\ \gamma} IR_{edf,x,y,v,\gamma} \tag{5}$$

The percentage for a given effect type

$$\Delta_{edf,x,y,v,\gamma} = 100 \frac{IR_{edf,x,y,v,\gamma}}{IR_{edf,x,y,v}} \tag{6}$$

Average risk per outcome is calculated by summing the outcome frequencies of only those outcomes that cause some risk at the point as the denominator. This is the average probability of death given the type of outcome does affect the point.

$$P_{x,y,v,|\gamma,edf} = \frac{IR_{edf,x,y,v,\gamma}}{\sum_{All\ outcomes\ of\ type\ \gamma\ hitting the\ point} F_{edf,o\gamma}} \tag{7}$$

At the level ‘Building Type Events’ level results are listed for each event that can affect the point.

Building Type Events

Model Name	Location Index	Model East [m]	Model North [m]	Model Frequency [/AvgeYear]	Total Risk [/AvgeYear]	Pct. Risk	Risk / Outcome
Study\Standalones\Jet fire	1	0	0	0.001	0.0004402	99.34	0.4402
Study\Vessel/Pipe Sourc...	1	0	0	0.0001	2.945E-06	0.6647	0.02945

The total risk is

$$IR_{x,y,v} = \sum_{All\ edfs} IR_{edf,x,y,v} \tag{8}$$

The percentage risk is calculated for each event as a fraction of the total

$$\Delta_{edf,x,y,v} = 100 \frac{IR_{edf,x,y,v}}{IR_{x,y,v}} \tag{9}$$

The average risk per outcome at this level is based on the event frequency so this denominator may include outcome frequencies that do not affect the point and typically this value will be lower than at the ‘Event Outcome’ level.

$$P_{x,y,v|edf} = \frac{IR_{edf,x,y,v}}{F_{edf}} \tag{10}$$

2.2.2 Combination Groups

The combination groups apply factors per run row *i* and combination *j*, $r_{i,j}$. These factors would normally sum to 1, but not necessarily since run rows can be used for different purposes. The run row structure is intentionally flexible and a powerful feature but it is important to understand how combinations work to avoid unintentional mistakes. As an aid to following the nomenclature the following figure displays the algebraic symbols within the combination table;

Group Name	Group Type
1	Combination j

Group Risk Ranking Points

Risk Ranking Point Na	RRP East [m]	RRP North [m]
North	0 x	200 y

Risk Ranking Points Vulnerabilities

Building Type Name	Risk Total [/AvgeYear]
Outdoor vulnerability	0.0001437 $IR_{x,y,j,v}$

Building Type Events

Model Name	Model East [m]	Model North [m]	Model Frequency [/AvgeYear]	Total Risk [/AvgeYear]	Pct. Risk	Risk / Outcome
Study\Both\Both leak	0	0	0.0001 $F_{edf',j}$	1.295E-06 $IR_{edf,x,y,v,j}$	0.9011 $\Delta_{edf,x,y,v,j}$	0.01349 $P_{x,y,v,j\|edf}$
Study\Route\Scenario group\Both\Both leak	0	5	0.005	6.427E-05	44.71	0.01339
Study\Toxic\Toxic leak	0	0	0.0001	1.295E-05	9.011	0.1349

Events Outcomes

Outcome Type Description	Total Risk [/AvgeYear]	Pct. Risk	Risk / Outcome
Toxic effects for a release in which Only toxic effects were modelled	6.476E-06 $IR_{edf,x,y,v,j,\gamma}$	$\Delta_{edf,x,y,v,j,\gamma}$	0.2049 $P_{x,y,v,j\|\gamma,edf}$

Outcomes Results

Run Row Name	Model East [m]	Model North [m]	Outcome Frequency [/AvgeYear]	Risk Increment [/AvgeYear]	Weather Name	Weather Direction deg	Time [s]
Night	0	0	$F_{edf,i,j,o\gamma} = r_{i,j}F_{edf,o\gamma}$	$IR_{edf,x,y,v,i,j\|o\gamma} = r_{i,j}IR_{edf,x,y,v,i\|o\gamma}$		165.0-195.0	0
Day	0	0	2.107E-06	2.107E-06	Day\D 5m/s	165.0-195.0	0

At the detailed level ‘Outcome Results’ the run row factor is applied to the outcome frequency and the risk increment according to the run row and combination. So the event frequency and the risk increment in the table have both been multiplied by the appropriate factor;

$$F_{edf,i,j,o\gamma} = r_{i,j} F_{edf,o\gamma} \qquad \textbf{(11)}$$

And

$$IR_{edf,x,y,v,i,j|o\gamma} = r_{i,j} IR_{edf,x,y,v,i|o\gamma} \qquad \textbf{(12)}$$

The total risk for a given effect type is calculated by summing all the contributions;

$$IR_{edf,x,y,v,j,\gamma} = \sum_{\substack{All\ run\\ rows\ i}} \sum_{\substack{All\ outcomes\\ of\ type\ \gamma}} IR_{edf,x,y,v,i,j|o\gamma} \qquad \textbf{(13)}$$

And the total risk for the event by summing over all effect types;

$$IR_{edf,x,y,v,j} = \sum_{All\ types\ \gamma} IR_{edf,x,y,v,j,\gamma} \qquad \textbf{(14)}$$

The total risk is calculated by summing over all events that contribute to the combination

$$IR_{x,y,j,v} = \sum_{All\ edfs} IR_{edf,x,y,v,j} \qquad \textbf{(15)}$$

The percentage contributions and risk/outcome values are calculated at 2 levels. In the lower level ‘Event Outcomes’ section the percentage contribution is;

$$\Delta_{edf,x,y,v,j,\gamma} = 100 \frac{IR_{edf,x,y,v,j,\gamma}}{IR_{edf,x,y,v,j}} \qquad \textbf{(16)}$$

And risk/outcome;

$$P_{x,y,v,j|\gamma,edf} = \frac{IR_{edf,x,y,v,j,\gamma}}{\sum\limits_{\substack{All\ run\\ rows\ i}} \sum\limits_{\substack{All\ outcomes\ o\ of\ type\ \gamma\\ hitting\ the\ point}} F_{edf,i,j,o\gamma}} \qquad \textbf{(17)}$$

At the higher ‘Building Type Events’ level;

$$\Delta_{edf,x,y,v,j} = 100 \frac{IR_{edf,x,y,v,j}}{IR_{x,y,v,j}} \qquad \textbf{(18)}$$

And

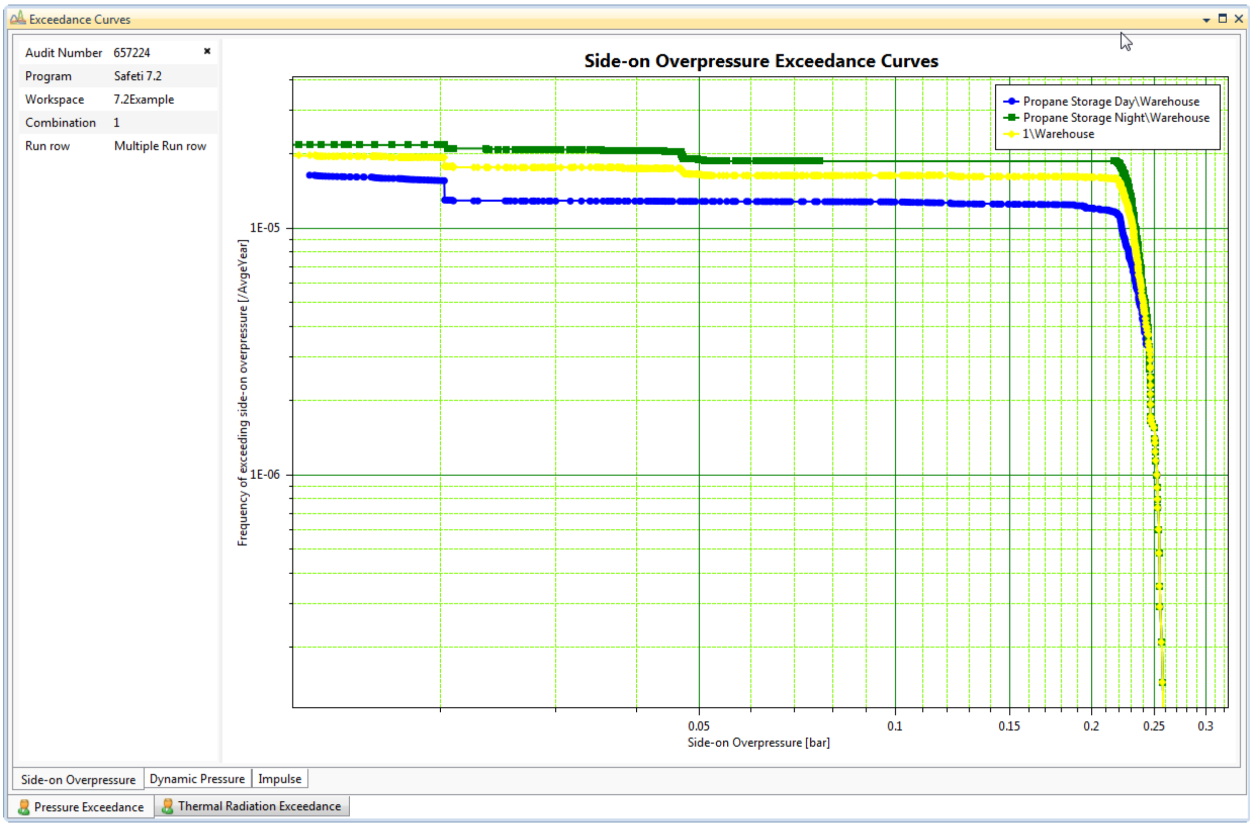
$$P_{x,y,v,j|edf} = \frac{IR_{edf,x,y,v,j}}{F_{edf,j}} \qquad \textbf{(19)}$$

The total combined frequency of the edf including all outcomes is given by

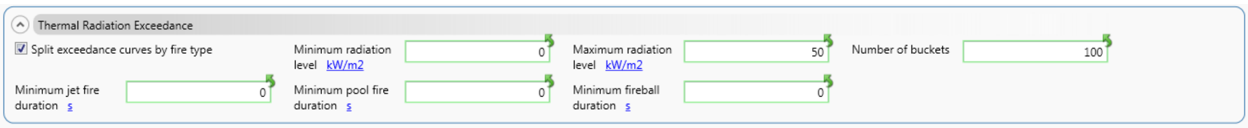
$$F_{edf,j} = \sum_{\substack{All\ run \\ rows\ i, \\ with\ edf \\ selected}} r_{i,j} F_{edf} \qquad \textbf{(20)}$$

2.3 Exceedance Curves

These are produced at risk ranking points. For each point a curve may be produced for explosion and radiation results when using the 3D obstructed region method. Explosion results are produced for side-on overpressure, dynamic overpressure and impulse. The method used to produce the curves is to sort the contributions according to the magnitude of the effect. Then the individual frequency contributions are summed starting with the highest effect level to obtain the cumulative frequency graph of frequency vs 'effect level or above'. The advantage of this method is that the results are shown at the most detailed level. The disadvantage is that the curves can be time-consuming to produce when the volume of results is large. To avoid excessive plotting delays if there are more than 1000 points to plot the number actually plotted on the graph is reduced.



Radiation results may be for any fire or may be divided into type of fire (fireball, jet, pool) according to preferences. Radiation results may also be filtered according to the fire duration by type.



Radiation levels are plotted as a histogram according to the range of radiation levels specified for the ellipse calculations. The number of radiation ranges considered is specified by the 'Number of buckets' parameter.

For both explosion and fire run row curves the outcome frequencies are used directly. For combinations each outcome frequency is multiplied by the relevant combination factor as shown in equation (11) to give $F_{edf,i,j,o\gamma}$.

2.4 Explosion Details

This table contains the results that go to make up the exceedance curves. The run row results only are given. No combination factor is applied to the values displayed in this table. The combination factors are applied only in generating the combination curves.

Explosion Details

Audit Number: 657835

Drag a column header here to group by that column

Run Row Name	Risk Ranking Point Na	Model Name	Outcome Description	Outcome	Loc	Model East [m]	Model North [m]	Obstructed Region	Outcome Freq	Side-on Overpressure [bar]	Dynamic Pressure [bar]	Impulse [N.s/m2]	Weather Name	Weather Dire	Time Step	Time [s]
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	3	1	1280	-940	Unobstructed	5.338E-07	0.02089	0.004225	1566	D 5m/s	348.8-11.3	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	5	1	1280	-940	Unobstructed	5.294E-09	0.0209	0.004098	1563	D 5m/s	11.3-33.8	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	7	1	1280	-940	OSR1a-2 Storey M...	7.954E-07	0.2263	0.01796	629.5	D 5m/s	11.3-33.8	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	9	1	1280	-940	Unobstructed	7.059E-09	0.0209	0.004045	1561	D 5m/s	33.8-56.3	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	11	1	1280	-940	OSR1b-1 Storey M...	1.06E-06	0.1983	0.01383	511	D 5m/s	33.8-56.3	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	13	1	1280	-940	Unobstructed	5.882E-09	0.0209	0.00408	1562	D 5m/s	56.3-78.8	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	15	1	1280	-940	OSR1b-1 Storey M...	8.837E-07	0.1141	0.008323	227.1	D 5m/s	56.3-78.8	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	17	1	1280	-940	Unobstructed	4.706E-09	0.02089	0.004201	1566	D 5m/s	78.8-101.3	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	19	1	1280	-940	Unobstructed	7.07E-07	0.02026	0.008338	3143	D 5m/s	78.8-101.3	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	21	1	1280	-940	Unobstructed	3.529E-09	0.02087	0.00439	1571	D 5m/s	101.3-123.8	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	23	1	1280	-940	Unobstructed	5.302E-07	0.02026	0.008106	3221	D 5m/s	101.3-123.8	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	25	1	1280	-940	Unobstructed	2.353E-09	0.02026	0.004653	1534	D 5m/s	123.8-146.3	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	27	1	1280	-940	Unobstructed	3.535E-07	0.02026	0.008106	3340	D 5m/s	123.8-146.3	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	29	1	1280	-940	Unobstructed	1.765E-09	0.02026	0.004932	1543	D 5m/s	146.3-168.8	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	31	1	1280	-940	Unobstructed	2.651E-07	0.02026	0.008106	3510	D 5m/s	146.3-168.8	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	33	1	1280	-940	Unobstructed	1.176E-09	0.02026	0.00517	1550	D 5m/s	168.8-191.3	1	1.353
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	35	1	1280	-940	OSR4-Concrete Str...	1.767E-07	0.1077	0.008106	246.6	D 5m/s	168.8-191.3	2	7.991
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	37	1	1280	-940	Unobstructed	1.176E-09	0.02026	0.005365	1557	D 5m/s	191.3-213.8	1	1.353

The obstructed region listed is the one that is most significant in generating that side-on overpressure.

2.5 Fire Details

This table contains the results that go to make up the exceedance curves. The run row results only are given. No combination factor is applied to the values displayed in this table. The combination factors are applied only in generating the combination curves.

Fire Details

Audit Number: 657835

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Run Row Name	Risk Ranking P	Model Name	Outcome Description	Outcome	Location	Model East [m]	Model North [m]	Outcome Frequency [/AvgeYear]	Fire type	Radiation Level [kW/m2]	Duration [s]	Weather Name	Weather Direction deg	Time Step	Time [s]
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	1	1	1280	-940	7.625E-06	Fireball	37.5	16.73	D 5m/s	All directions	0	0
Propane Storage Day	Warehouse	Propane Storage\Mi...	Instantaneous releas...	54	1	1280	-940	7.625E-06	Fireball	37.5	16.73	D 1.5m/s	All directions	0	0
Propane Storage Day	Warehouse	Propane Storage\No...	Instantaneous releas...	471	1	1280	-870	7.625E-06	Fireball	37.5	16.73	D 5m/s	All directions	0	0
Propane Storage Day	Warehouse	Propane Storage\No...	Instantaneous releas...	624	1	1280	-870	7.625E-06	Fireball	37.5	16.73	D 1.5m/s	All directions	0	0
Propane Storage Day	Warehouse	Propane Storage\So...	Instantaneous releas...	1065	1	1280	-1000	7.625E-06	Fireball	37.5	16.73	D 5m/s	All directions	0	0
Propane Storage Day	Warehouse	Propane Storage\So...	Instantaneous releas...	1178	1	1280	-1000	7.625E-06	Fireball	37.5	16.73	D 1.5m/s	All directions	0	0
Propane Storage Night	Warehouse	Propane Storage\Mi...	Instantaneous releas...	1595	1	1280	-940	7.625E-06	Fireball	37.5	16.73	F 1.5m/s	All directions	0	0
Propane Storage Night	Warehouse	Propane Storage\Mi...	Instantaneous releas...	1656	1	1280	-940	7.625E-06	Fireball	37.5	16.73	D 1.5m/s	All directions	0	0
Propane Storage Night	Warehouse	Propane Storage\No...	Instantaneous releas...	2073	1	1280	-870	7.625E-06	Fireball	37.5	16.73	F 1.5m/s	All directions	0	0
Propane Storage Night	Warehouse	Propane Storage\No...	Instantaneous releas...	2178	1	1280	-870	7.625E-06	Fireball	37.5	16.73	D 1.5m/s	All directions	0	0
Propane Storage Night	Warehouse	Propane Storage\So...	Instantaneous releas...	2619	1	1280	-1000	7.625E-06	Fireball	37.5	16.73	F 1.5m/s	All directions	0	0
Propane Storage Night	Warehouse	Propane Storage\So...	Instantaneous releas...	2684	1	1280	-1000	7.625E-06	Fireball	37.5	16.73	D 1.5m/s	All directions	0	0

3 SOCIETAL RISK

This chapter explains the societal results presented in the risk gallery. They start with the basic details and then offer various levels of analysis taking into account aversion to large events (FN results), population categories (PLL by category) and working patterns (FAR results). There are also two types of FN curves. This is not an ideal feature of the program and in the future there will be a single curve but at present both curves are necessary to give a superset of available features.

3.1 FN Details

Run Row Name	Model Name	Location Index	Model East [m]	Model North [m]	Outcome Frequency [/	Fatality Probability	Area	Building	Population Category	Category N	Category PLL [/AvgeYear]	Total N	Weather Name	Weather Direction deg	Outcome Type Description
Day	Study\Both\Both leak	1	0	0	7.11E-07 $F_{edf,o\gamma}$	1	Population grid	(Indoor)	South	28.3 $\overline{N}_{v,c\|o\gamma}$	2.012E-05 $PLL_{edf,v,c,o\gamma}$	31.71 $\overline{N}_{t\|o\gamma}$	D 5m/s	345.0-15.0	Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects
Day	Study\Both\Both leak	1	0	0	7.11E-07	1	Population grid	(Outdoor)	South	3.411	2.425E-06	31.71	D 5m/s	345.0-15.0	Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects
Day	Study\Both\Both leak	1	0	0	4.74E-07	1	Population grid	(Indoor)	South	3.867	1.833E-06	4.467	D 5m/s	15.0-45.0	Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects
Day	Study\Both\Both leak	1	0	0	4.74E-07	1	Population grid	(Outdoor)	South	0.5995	2.842E-07	4.467	D 5m/s	15.0-45.0	Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects

These are the lowest level details and can include several rows of results for each outcome. These include the average number of people killed in each population category *c* and how many people are killed indoors vs outdoors and in specific buildings.

$$PLL_{edf,v,c,o\gamma} = F_{edf,o\gamma}\,\overline{N}_{edf,v,c|o\gamma} \quad \textbf{(21)}$$

Total N is obtained for a given outcome by summing all the categories of people killed by a specific outcome.

$$\overline{N}_{t|o\gamma} = \sum_{c} \sum_{\substack{Indoors \\ Outdoors \\ All\,buildings}} \overline{N}_{v,c|o\gamma} \quad \textbf{(22)}$$

Results at this detailed level are not factored at all by the run row combination factors. If a combination is chosen then the report contains all run rows included in the combination without application of the combination factors.

3.2 FN Totals

Run Row Name	Model Name	Model East [m]	Model North [m]	Outcome Frequency [/	Total N	PLL [/AvgeYear]	Risk Integral [/AvgeYear]	Weather Name	Weather Direction deg	Outcome Type Description
Day	Study\Both\Both leak	0	0	1.843E-07 $F_{edf,o\gamma}$	44.27 $\overline{N}_{t\|o\gamma}$	8.161 $PLL_{edf,o\gamma}$	8.161E-06 $RI_{edf,o\gamma}$	D 5m/s	345.0-15.0	Continuous release with Rainout Immediate Horizontal Jet fire
Day	Study\Both\Both leak	0	0	1.58E-07	38.73	6.12E-[illegible]	6.12E-06	D 5m/s	15.0-45.0	Continuous release with Rainout Immediate Horizontal Jet fire
Day	Study\Both\Both leak	0	0	1.317E-07	31.71	4.175E-06	4.175E-06	D 5m/s	45.0-75.0	Continuous release with Rainout Immediate Horizontal Jet fire
Day	Study\Both\Both leak	0	0	1.229E-07	23.12	2.842E-06	2.842E-06	D 5m/s	75.0-105.0	Continuous release with Rainout Immediate Horizontal Jet fire

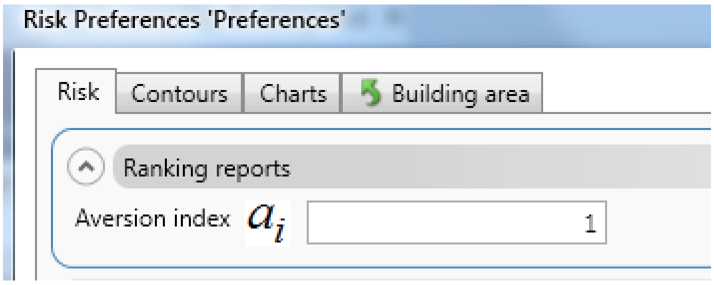
This table lists the total results for each outcome, one record per outcome. It includes the total N value from the FN Details table, the total PLL for the outcome and also the Risk Integral measure based on the aversion index.

$$PLL_{edf,o\gamma} = \sum_{c} \sum_{\substack{Indoors \\ Outdoors \\ All\,buildings}} PLL_{edf,v,c,o\gamma} \quad \textbf{(23)}$$

The risk integral includes the use of the aversion index a_i and is identical to the PLL when the index is 1.

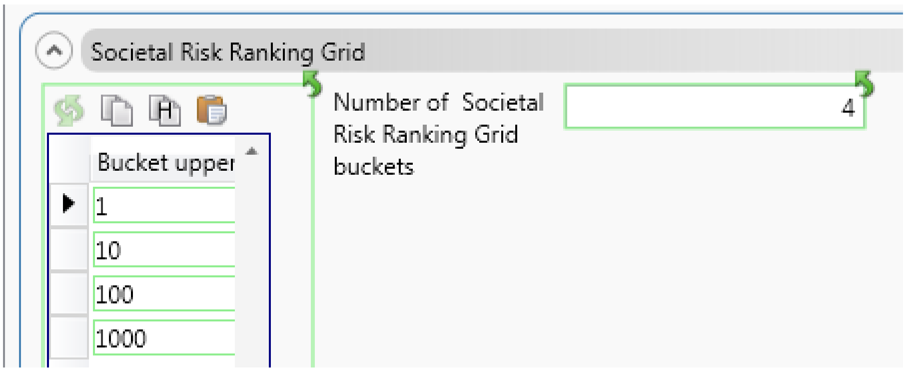
$$RI_{edf,o\gamma} = F_{edf,o\gamma}\left(\overline{N}_{t|o\gamma}\right)^{a_i} \quad \textbf{(24)}$$

Results at the FN Totals level are not factored at all by the run row combination factors. If a combination is chosen then the report contains all run rows included in the combination without application of the combination factors. The aversion index may be edited in the preferences.



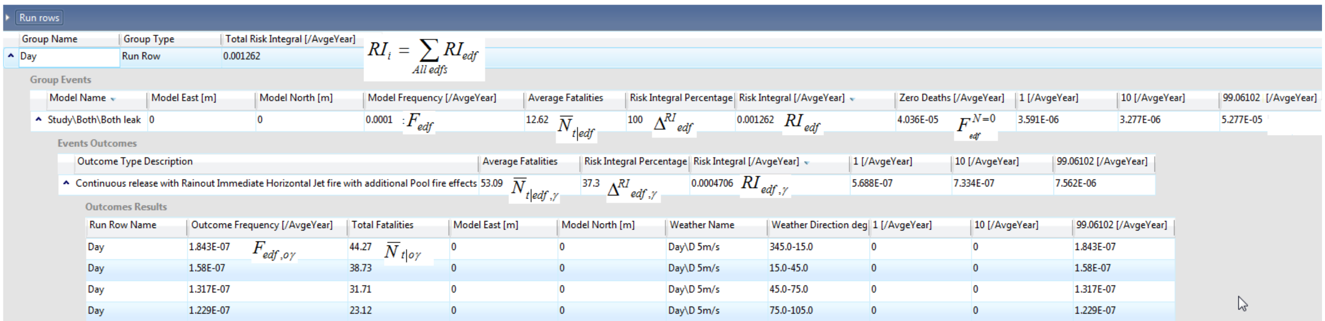
3.3 Societal Risk Ranking Grid

The societal risk ranking report groups the results in range of N values. These ranges default to 1,10,100 and 1000. These values may be adjusted through the preferences. It also sums the risk integrals and gives average N values at different levels.



The results may be viewed for individual run rows (see Section 3.3.1) and/or combinations (see Section 3.3.2).

3.3.1 Run Row Groups



Run rows

Group Name	Group Type	Total Risk Integral [/AvgeYear]
Day	Run Row	0.001262 $RI_i = \sum_{All\ edfs} RI_{edf}$

Group Events

Model Name	Model East [m]	Model North [m]	Model Frequency [/AvgeYear]	Average Fatalities	Risk Integral Percentage	Risk Integral [/AvgeYear]	Zero Deaths [/AvgeYear]	1 [/AvgeYear]	10 [/AvgeYear]	99.06102 [/AvgeYear]
Study\Both\Both leak	0	0	0.0001 :F_{edf}	12.62 $\overline{N}_{t\vert edf}$	100 Δ^{RI}_{edf}	0.001262 RI_{edf}	4.036E-05 $F^{N=0}_{edf}$	3.591E-06	3.277E-06	5.277E-05

Events Outcomes

Outcome Type Description	Average Fatalities	Risk Integral Percentage	Risk Integral [/AvgeYear]	1 [/AvgeYear]	10 [/AvgeYear]	99.06102 [/AvgeYear]
Continuous release with Rainout Immediate Horizontal Jet fire with additional Pool fire effects	53.09 $\overline{N}_{t\vert edf,\gamma}$	37.3 $\Delta^{RI}_{edf,\gamma}$	0.0004706 $RI_{edf,\gamma}$	5.688E-07	7.334E-07	7.562E-06

Outcomes Results

Run Row Name	Outcome Frequency [/AvgeYear]	Total Fatalities	Model East [m]	Model North [m]	Weather Name	Weather Direction deg	1 [/AvgeYear]	10 [/AvgeYear]	99.06102 [/AvgeYear]
Day	1.843E-07 $F_{edf,o\gamma}$	44.27 $\overline{N}_{t\vert o\gamma}$	0	0	Day\D 5m/s	345.0-15.0	0	0	1.843E-07
Day	1.58E-07	38.73	0	0	Day\D 5m/s	15.0-45.0	0	0	1.58E-07
Day	1.317E-07	31.71	0	0	Day\D 5m/s	45.0-75.0	0	0	1.317E-07
Day	1.229E-07	23.12	0	0	Day\D 5m/s	75.0-105.0	0	0	1.229E-07

For the societal risk ranking grid report for an individual run row no combination factors are applied. At the highest level the total risk integral is shown. This is the sum of all risk integral contributions for the run row. The report is presented with three levels 'Group Events', 'Events Outcomes' and 'Outcomes Results'. At all levels the frequencies are presented in columns according to the N values associated with each outcome. At the outcome level this frequency is the contribution due to a single outcome. At the higher levels the frequencies are summed.

The maximum N value is used as the label of the largest N value range. The column headings represent the highest N value in that range. So the frequencies in the "1" column represent the frequency of killing between N=0 and N=1 persons. The frequencies in the "10" column represent N values in the range 1 to 10. There is no special treatment of fractional N values so for instance all the frequency of an N value less than 1 will go in the 1 column even though the frequency could be adjusted to sometimes kill 1 person and other times 0.

At the 'Events Outcomes' level

$$RI_{edf,\gamma} = \sum_{\substack{All\ outcomes \\ of\ type\ \gamma}} RI_{edf,o\gamma} \tag{25}$$

The average fatality for the outcome type is calculated from the PLL rather than Risk Integral (these are identical when the aversion index is 1). The PLL values are calculated internally but not displayed in the report.

$$\overline{N}_{t|edf,\gamma} = \frac{PLL_{edf,\gamma}}{\sum_{\substack{All\ outcomes \\ of\ type\ \gamma}} F_{edf,o\gamma|N>0}} \tag{26}$$

At the ‘Group Events’ level the total risk integral for each edf is calculated as;

$$RI_{edf} = \sum_{\substack{All\ effect \\ types\ \gamma}} RI_{edf,\gamma} \tag{27}$$

The total for the run row *i* is;

$$RI_i = \sum_{All\ edfs} RI_{edf} \tag{28}$$

The average number of fatalities is calculated using the edf frequency so takes into account the frequency of outcomes that don’t kill anyone;

$$\overline{N}_{t|edf} = \frac{PLL_{edf}}{F_{edf}} \tag{29}$$

The frequency of zero deaths is calculated as

$$F_{edf}^{N=0} = F_{edf} - \sum_{All\ outcomes} F_{edf,o\gamma|N>0} \tag{30}$$

The risk integral percentage at the ‘Group Events’ level shows the relative importance of the edf to the run row risk integral and is calculated as

$$\Delta^{RI}{}_{edf} = 100\frac{RI_{edf}}{RI_i} \tag{31}$$

The risk integral percentage at the ‘Events Outcomes’ level shows the relative importance of the outcome type to the risk integral total for the edf and is calculated as

$$\Delta^{RI}{}_{edf,\gamma} = 100\frac{RI_{edf,\gamma}}{RI_{edf}} \tag{32}$$

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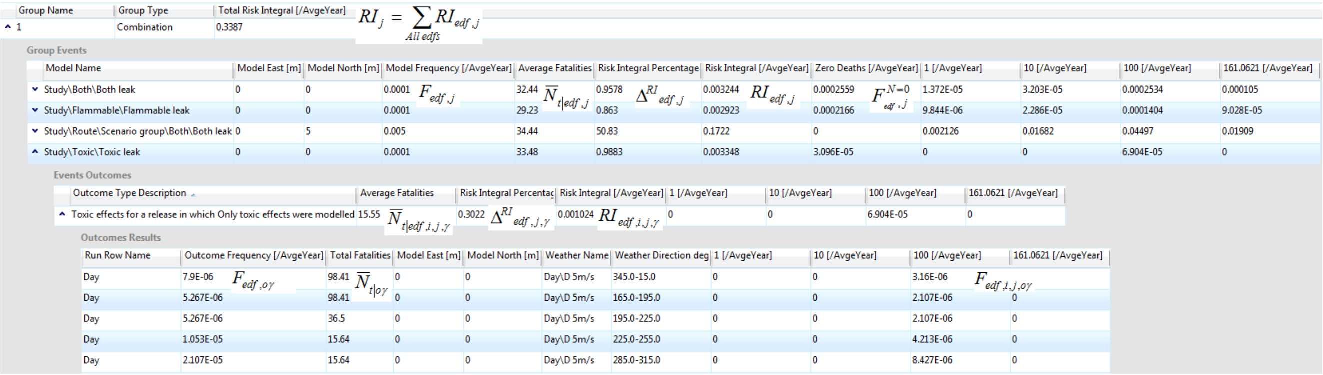
3.3.2 Combination Groups



Group Name	Group Type	Total Risk Integral [/AvgeYear]
1	Combination	0.3387 $RI_j = \sum_{All\ edfs} RI_{edf,j}$

Group Events

Model Name	Model East [m]	Model North [m]	Model Frequency [/AvgeYear]	Average Fatalities	Risk Integral Percentage	Risk Integral [/AvgeYear]	Zero Deaths [/AvgeYear]	1 [/AvgeYear]	10 [/AvgeYear]	100 [/AvgeYear]	161.0621 [/AvgeYear]
Study\Both\Both leak	0	0	0.0001 $F_{edf,j}$	32.44 $\overline{N}_{t\|edf,j}$	0.9578 $\Delta^{RI}_{edf,j}$	0.003244 $RI_{edf,j}$	0.0002559 $F^{N=0}_{edf,j}$	1.372E-05	3.203E-05	0.0002534	0.000105
Study\Flammable\Flammable leak	0	0	0.0001	29.23	0.863	0.002923	0.0002166	9.844E-06	2.286E-05	0.0001404	9.028E-05
Study\Route\Scenario group\Both\Both leak	0	5	0.005	34.44	50.83	0.1722	0	0.002126	0.01682	0.04497	0.01909
Study\Toxic\Toxic leak	0	0	0.0001	33.48	0.9883	0.003348	3.096E-05	0	0	6.904E-05	0

Events Outcomes

Outcome Type Description	Average Fatalities	Risk Integral Percentag	Risk Integral [/AvgeYear]	1 [/AvgeYear]	10 [/AvgeYear]	100 [/AvgeYear]	161.0621 [/AvgeYear]
Toxic effects for a release in which Only toxic effects were modelled	15.55 $\overline{N}_{t\|edf,i,j,\gamma}$	0.3022 $\Delta^{RI}_{edf,j,\gamma}$	0.001024 $RI_{edf,i,j,\gamma}$	0	0	6.904E-05	0

Outcomes Results

Run Row Name	Outcome Frequency [/AvgeYear]	Total Fatalities	Model East [m]	Model North [m]	Weather Name	Weather Direction deg	1 [/AvgeYear]	10 [/AvgeYear]	100 [/AvgeYear]	161.0621 [/AvgeYear]
Day	7.9E-06 $F_{edf,o\gamma}$	98.41 $\overline{N}_{t\|o\gamma}$	0	0	Day\D 5m/s	345.0-15.0	0	0	3.16E-06 $F_{edf,i,j,o\gamma}$	
Day	5.267E-06	98.41	0	0	Day\D 5m/s	165.0-195.0	0	0	2.107E-06	0
Day	5.267E-06	36.5	0	0	Day\D 5m/s	195.0-225.0	0	0	2.107E-06	0
Day	1.053E-05	15.64	0	0	Day\D 5m/s	225.0-255.0	0	0	4.213E-06	0
Day	2.107E-05	15.64	0	0	Day\D 5m/s	285.0-315.0	0	0	8.427E-06	0

The combination groups apply factors per run row *i* and combination *j*, $r_{i,j}$. The outcome frequencies are modified accordingly;

$$F_{edf,i,j,o\gamma} = r_{i,j} F_{edf,o\gamma} \quad (33)$$

These modified frequencies are the values used to accumulate frequency in each range of N values. Note that the table also includes the factored Outcome frequency. The contribution of each outcome to the Risk Integral may be calculated as;

$$RI_{edf,i,j,o\gamma} = F_{edf,i,j,o\gamma} \overline{N}^{a_i}{}_{t,i|o\gamma} \quad (34)$$

At the 'Events Outcomes' level the sum for each run row is calculated

$$RI_{edf,i,j,\gamma} = \sum_{\substack{All\ outcomes \\ of\ type\ \gamma}} RI_{edf,i,j,o\gamma} \quad (35)$$

The average fatality for the outcome type is calculated from the PLL (ie Risk Integral with aversion index of 1) as;

$$\overline{N}_{t|edf,i,j,\gamma} = \frac{PLL_{edf,i,j,\gamma}}{\sum_{\substack{All\ outcomes \\ of\ type\ \gamma}} F_{edf,i,j,o\gamma|N>0}} \quad (36)$$

At the 'Group Events' level the total risk integral for each edf is calculated as;

$$RI_{edf,j} = \sum_{\substack{All\ run \\ rows\ i}} \sum_{\substack{All\ effect \\ types\ \gamma}} RI_{edf,i,j,\gamma} \quad (37)$$

The total for the combination *j* is;

$$RI_j = \sum_{All\ edfs} RI_{edf,j} \quad (38)$$

The average number of fatalities at the 'Group Events' level is calculated using the edf frequency so take into account the frequency of outcomes that don't kill anyone;

$$\overline{N}_{t|edf,j} = \frac{PLL_{edf,j}}{F_{edf,j}} \tag{39}$$

The total combined frequency of the edf including all outcomes is given by

$$F_{edf,j} = \sum_{\substack{All\ run \\ rows\ i}} r_{i,j} F_{edf} \tag{40}$$

The frequency of zero deaths is calculated as

$$F^{N=0}_{edf,j} = F_{edf,j} - \sum_{\substack{All\ run \\ rows\ i}} \sum_{All\ outcomes} F_{edf,i,j,o\gamma|N>0} \tag{41}$$

The risk integral percentage at the ‘Group Events’ level shows the relative importance of the edf to the run row risk integral and is calculated as

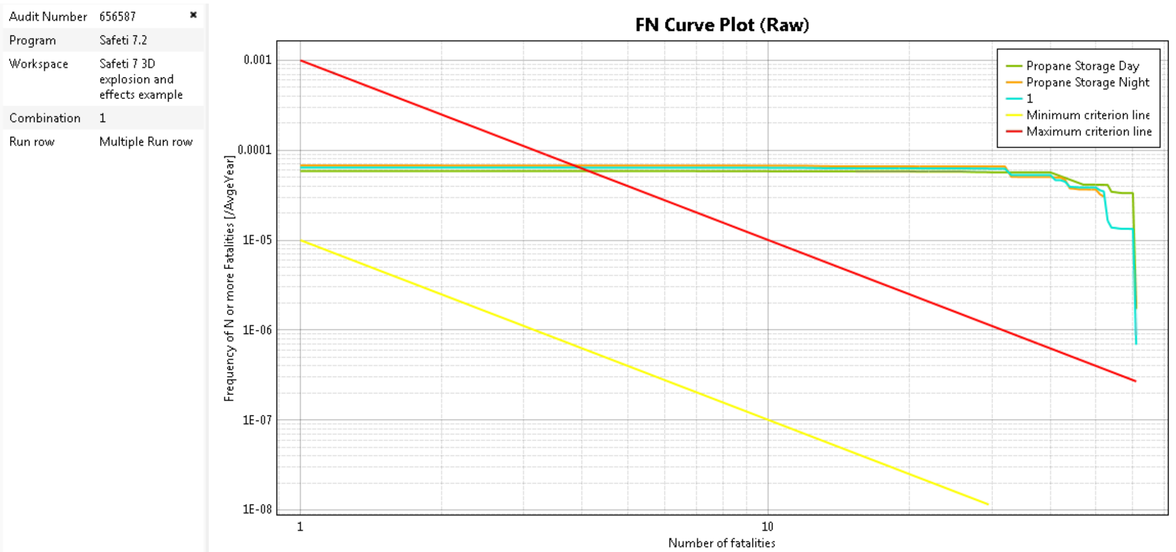
$$\Delta^{RI}{}_{edf,j} = 100 \frac{RI_{edf,j}}{RI_{j}} \tag{42}$$

The risk integral percentage at the ‘Events Outcomes’ level shows the relative importance of the outcome type to the risk integral total for the edf and is calculated as

$$\Delta^{RI}{}_{edf,j,\gamma} = 100 \frac{RI_{edf,j,\gamma}}{RI_{edf,j}} \tag{43}$$

3.4 FN Curve Raw

The FN curve in general is a cumulative frequency graph of killing N or more people, $F_{N=>N_k,i}$. In accumulating the frequency it recognises that a fraction of a person cannot be killed.



The $\overline{N}_{t|o\gamma}$ values for each representative outcome calculated by MPACT are normally non-integer and represent the average number of fatalities expected for that outcome type. In the FN curve calculation this non-realistic average outcome is replaced by two realistic outcomes where $\overline{N}_{t|o\gamma}$ is rounded down to the nearest integer, $N_{l,o\gamma}$ and up to the nearest integer, $N_{h,o\gamma}$. To preserve the average rate of death the frequency between of each outcome must be calculated as;

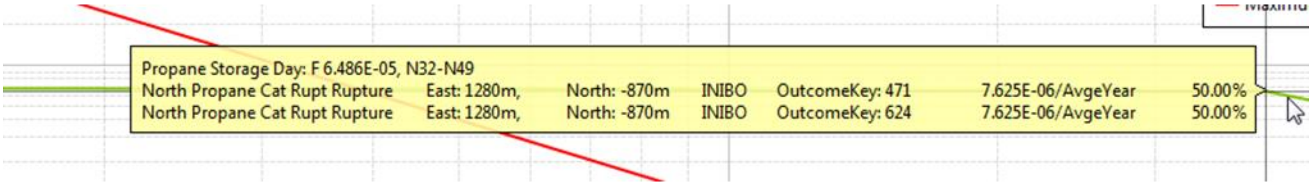
$$F_{edf,h,o\gamma} = \left(\overline{N}_{t|o\gamma} - N_{l,o\gamma}\right) F_{edf,o\gamma} \tag{44}$$

$$F_{edf,l,o\gamma} = \left(N_{h,o\gamma} - \overline{N}_{t|o\gamma}\right) F_{edf,o\gamma} \tag{45}$$

These two 'realistic' outcomes are used to apportion frequency between adjacent bins on the FN curve. This curve is built dynamically from the raw FN results at the outcome level. These may be seen in the FN Total tables as described in section 3.2 and represent average N values for the given outcome. This neglects the potential probabilistic spread of results represented by this average. Crucially this means this curve may appear different to the smoothed version. The advantage of this particular view is that it allows for a 'drilldown' capability.

Example: an average N value of 1.4 with a frequency of 0.001 will result in a frequency contribution to the N>=1 range of (2-1.4)x0.001 and a contribution of (1.4-1)x0.001 to the N>=2 range.

The tooltip gives the top contributing outcomes in the range near the mouse. For instance in this example the top contributors in the range N=32 and N<49 are given. The value F, is the frequency of N=32 or more.



3.5 FN Curve Smoothed

In this graph the cumulative frequency of killing N or more people is calculated in ranges of N from 1 and up. There is one set of values for each run row. The user may choose to plot run rows or combinations. If the run row only is displayed then the results from the risk modelling is plotted directly without any additional scaling factors. The results include the probabilistic variation of N values around the mean for each outcome as explained in the Mpact Theory Manual. This is the main difference between this plot and the raw version of the FN curve. In addition there are functional differences in that the curve cannot be constructed dynamically from the list of events and there is no drill down capability.

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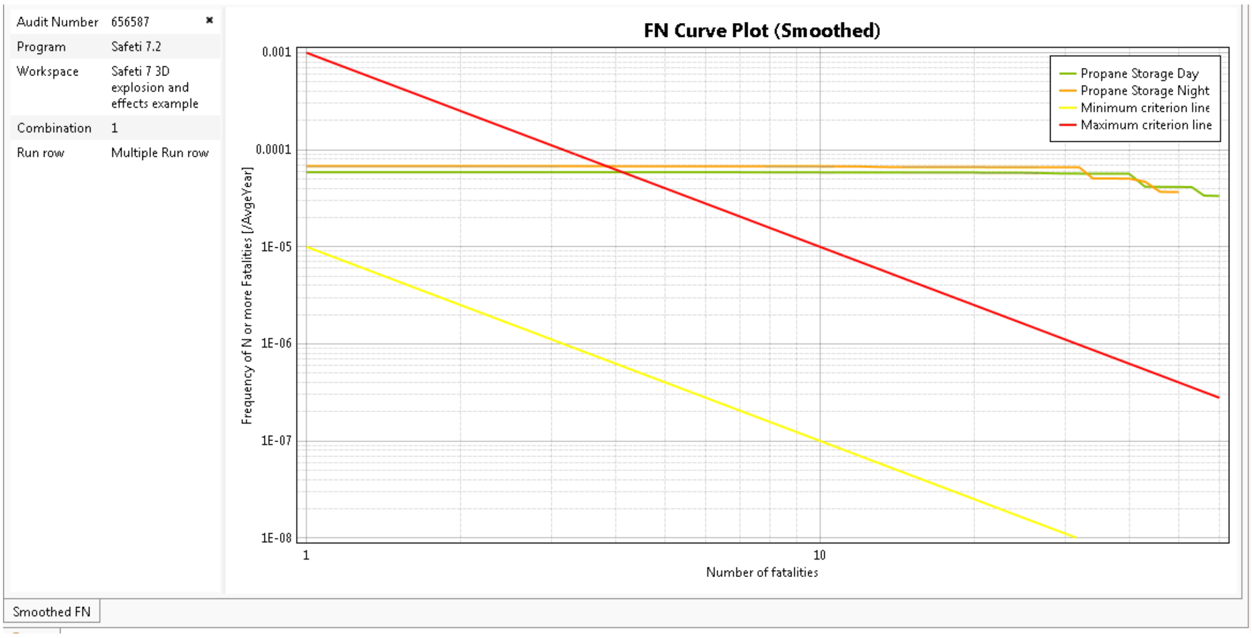


Combined curves use the run row combination factors applied to the frequency values of each run row to obtain a composite curve where $F_{N=>N_k,i}$ is the cumulative frequency of killing N_k or more people on run row *i*.

$$F_{N=>N_k,j} = \sum_{\substack{All\ run \\ rows\ i}} r_{i,j} F_{N=>N_k,i} \qquad \textbf{(46)}$$

In the 7.2 version the N_k values are fixed. They are every integer value up to 23. After that there are a selection of integer values that repeat in multiples of 10. The first 2 multiple are illustrated;

Small N range	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23
1st multiple of 10	25,27,30,32,34,36,38,40,43,46,50,53,56,60,63,66,69,73,77,80,87,90,97,100,105,110, 115,120,125,130,135,140,145,150,160,170,180,190,200,210,220,230,
2nd multiple of 10	250,270…. As above x10

3.6 Category PLL

This report is available for run rows and/or combinations. The run row reports apply no combination factors

3.6.1 Run Row Category PLL

The report displays the top level, total PLL value and this breaks down to 5 levels;

Run row Areas

Area Buildings

Building Models

Model outcome codes

Outcome code results

The run row Areas level will show the PLL summed for each area present in the run row. If there are grid populations then these are labelled as 'Population Grid'. The summation is made in total and grouped by population category for each building and for populations on the risk grid. At the lowest Outcome code results level the outcome frequency and average N values are listed for every population where there is some probability of death for that outcome. The PLL contribution from each record is not shown but can be expressed;

$$PLL_{edf,b,c,o\gamma} = F_{edf,o\gamma}\,\overline{N}_{edf,b,c|o\gamma} \tag{47}$$

At the Model outcomes level these are summed by category for each outcome type and a total of all categories is also given;

$$PLL_{edf,b,c,\gamma} = \sum_{\substack{\text{All outcomes } o \\ \text{of type } \gamma}} PLL_{edf,b,c,o\gamma} \tag{48}$$

and total of all categories;

$$PLL_{edf,b,\gamma} = \sum_{\text{All categories}} PLL_{edf,b,c,\gamma} \tag{49}$$

At the Building models level all the outcome type results are summed;

$$PLL_{edf,b,c} = \sum_{\substack{\text{All outcome} \\ \text{types } \gamma}} PLL_{edf,b,c,\gamma} \tag{50}$$

and total of all categories;

$$PLL_{edf,b} = \sum_{\text{All categories}} PLL_{edf,b,c} \tag{51}$$

At the Area buildings level the total PLL is given for each category;

$$PLL_{b,c} = \sum_{\text{All edfs}} PLL_{edf,b,c} \tag{52}$$

and total of all categories;

$$PLL_{b} = \sum_{\text{All edfs}} PLL_{edf,b} \tag{53}$$

At the Run row Areas level the total PLL is given for all buildings in the area;

$$PLL_{A,c} = \sum_{\substack{All\,buildings \\ in\,the\,area}} PLL_{b,c} \tag{54}$$

and total of all categories;

$$PLL_A = \sum_{All\ categories} PLL_{A,c} \tag{55}$$

At the Run row level the overall total PLL is given – not by category;

$$PLL_i = \sum_{\substack{All \\ areas}} PLL_A \tag{56}$$

Run rows

Group Name	Group Type	Total [/AvgeYear]
Propane Storage Day	Run Row	0.003911 PLL_i

Run row Areas

Area Name	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeYe	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
Onsite	0.001303	0.0009012	0.0006515 $PLL_{A,c}$		0.0006342	0.00349 PLL_A

Area Buildings

Building Name	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeYe	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
Control Room	0.001303	0	0.0006515 $PLL_{b,c}$		0	0.001954 PLL_b

Building Models

Model Name	Location	Model East [m]	Model North [m]	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeYe	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
Propane Storage\Middle Propane Cat Rupt\Middle Propane Cat Rupt Rupture	1	1280	-940.6	0.0004894 $PLL_{edf,b,c}$		0.0002447	0	0	0.0007341 $PLL_{edf,b}$
Propane Storage\North Propane Cat Rupt\North Propane Cat Rupt Rupture	1	1280	-870.6	0.0003101	0	0.0001551	0	0	0.0004652
Propane Storage\South Propane Cat Rupt\South Propane Cat Rupt Rupture	1	1280	-1001	0.0005035	0	0.0002517	0	0	0.0007552

Model outcome codes

Outcome Type Description	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeYe	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
Instantaneous release No rainout Immediate fireBall Only	0.000305	0	0.0001525 $PLL_{edf,b,c,\gamma}$		0	0.0004575 $PLL_{edf,b,\gamma}$
Instantaneous release No rainout delayed Flash fire with eXplosion	0.0001844	0	9.218E-05	0	0	0.0002765

Outcome code results

Run Row Name	Outcome Key	Location	Model East [m]	Model North [m]	Outcome Frequency [/AvgeYear]	Fatality Probability	Category N	Population Category	Total N	Weather Name	Time Step	Time [s]
Propane Storage Day	54	1	1280	-940	7.625E-06	1	10	Maintenance	68.47	Day Weathers\D 1.5...	0	0
Propane Storage Day	54	1	1280	-940	7.625E-06	1	20	Operator	68.47	Day Weathers\D 1.5...	0	0
Propane Storage Day	1	1	1280	-940	7.625E-06	1	10	Maintenance	68.47	Day Weathers\D 5m/s	0	0
Propane Storage Day	1	1	1280	-940	7.625E-06	1	20	Operator	68.47	Day Weathers\D 5m/s	0	0

3.6.2 Combination Category PLL

The report displays the top level, total combined PLL value and this breaks down to the same 5 levels;

The run row Areas level will show the PLL summed for each area present in the combination. If there are grid populations then these are labelled as 'Population Grid'. The summation is made in total and grouped by population category for each building and for populations on the risk grid. At the lowest Outcome code results level the outcome frequency and average N values are listed for every population where there is some probability of death for that outcome. These values are before any factoring is applied. They are the same values that appear in the Run Row Category PLL and include all run rows that give fatalities for the given outcome. The PLL contribution from each record is not shown but can be expressed;

$$PLL_{edf,i,j,b,c,o\gamma} = r_{i,j} F_{edf,o\gamma} \overline{N}_{edf,b,c|o\gamma} \tag{57}$$

At the Model outcomes level these are summed by category for each outcome type and a total of all categories is also given;

$$PLL_{edf,j,b,c,\gamma} = \sum_{\substack{All\ outcomes\ o \\ of\ type\ \gamma}} PLL_{edf,i,j,b,c,o\gamma} \quad (58)$$

and total of all categories;

$$PLL_{edf,j,b,\gamma} = \sum_{All\ categories} PLL_{edf,j,b,c,\gamma} \quad (59)$$

At the Building models level all the outcome type results are summed;

$$PLL_{edf,j,b,c} = \sum_{\substack{All\ outcome \\ types}} PLL_{edf,j,b,c,\gamma} \quad (60)$$

and total of all categories;

$$PLL_{edf,j,b} = \sum_{All\ categories} PLL_{edf,j,b,c} \quad (61)$$

At the Area buildings level the total PLL is given for each category;

$$PLL_{j,b,c} = \sum_{All\ edfs} PLL_{edf,j,b,c} \quad (62)$$

and total of all categories;

$$PLL_{j,b} = \sum_{All\ categories} PLL_{j,b,c} \quad (63)$$

At the Run row Areas level the total PLL is given for all buildings in the area;

$$PLL_{j,A,c} = \sum_{\substack{All\ buildings \\ in\ the\ area}} PLL_{j,b,c} \quad (64)$$

and total of all categories;

$$PLL_{j,A} = \sum_{All\ categories} PLL_{j,A,c} \quad (65)$$

At the Combination level the overall total PLL is given – not by category;

$$PLL_j = \sum_{\substack{All \\ areas}} PLL_{j,A} \quad (66)$$

^ 1	Combination	0.00361 PLL_j

Run row Areas

Area Name	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeY	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
^ Onsite	0.001499	0.001001	0.0002606 $PLL_{j,A,c}$		0.0006735	0.003434 $PLL_{j,A}$

Area Buildings

Building Name	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeY	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
^ Control Room	0.001415	0	0.0002606 $PLL_{j,b,c}$		0	0.001676 $PLL_{j,b}$

Building Models

Model Name	Location	Model East [m]	Model North [m]	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeY	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
^ Propane Storage\Middle Propane Cat Rupt\Middle Propane Cat Rupt Rupture	1	1280	-940.6	0.0005412	$PLL_{edf,j,b,c}$	9.787E-05	0	0	0.0006391 $PLL_{edf,j,b}$

Model outcome codes

Outcome Type Description	Operator [/AvgeYear]	Admin [/AvgeYear]	Maintenance [/AvgeY	Public [/AvgeYear]	None [/AvgeYear]	PLL [/AvgeYear]
^ Instantaneous release No rainout Immediate fireBall Only	0.000305	0	6.1E-05 $PLL_{edf,j,b,c,\gamma}$		0	0.000366 $PLL_{edf,j,b,\gamma}$

Outcome code results

Run Row Name	Outcome Key	Location	Model East [m]	Model North [m]	Outcome Frequency [/AvgeYear]	Fatality Probability	Category N	Population Category	Total N	Weather Name	Time Step	Time [s]
Propane Storage Day	54	1	1280	-940	7.625E-06	1	10	Maintenance	68.47	Day Weathers\D 1.5...	0	0
Propane Storage Day	54	1	1280	-940	7.625E-06	1	20	Operator	68.47	Day Weathers\D 1.5...	0	0
Propane Storage Day	1	1	1280	-940	7.625E-06	1	10	Maintenance	68.47	Day Weathers\D 5m/s	0	0
Propane Storage Day	1	1	1280	-940	7.625E-06	1	20	Operator	68.47	Day Weathers\D 5m/s	0	0
Propane Storage Night	1656	1	1280	-940	7.625E-06	1	20	Operator	52	Night Weathers\D 1....	0	0
Propane Storage Night	1595	1	1280	-940	7.625E-06	1	20	Operator	52	Night Weathers\F 1.5...	0	0

3.7 Category FAR

The Fatal Accident Rate (FAR) report is available for run rows and/or combinations. The concept is that it represents the number of fatalities per group of 1000 people over a period representing their entire working lifetimes (10^8 hours). The focus is on workers so only people inside the plant boundary are considered (the FAR report is not available if there is no plant boundary). So for instance if the FAR is 5 it means that out of 1000 people doing that job for a combined 10^8 hours 5 will be killed and 995 will survive. Normally the actual exposure of workers is less so an individual is exposed to the risks for a reduced period. So for instance if the FAR is 5 (a typical value for drilling operations) and the worker is exposed for 280 days per year on an 8 hour shift the worker is exposed to an Individual Risk Per Annum (IRPA) of $5 \times 8 \times 280/10^8 = 1.12 \times 10^{-5}$.

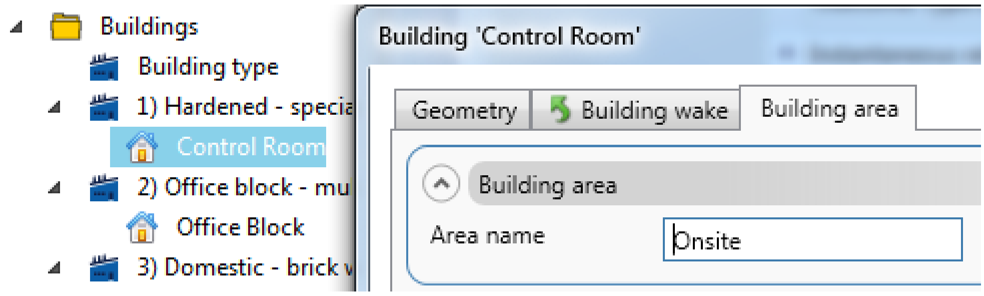
$$FAR = \frac{Number\ of\ fatalities\ in\ period \times 10^8\ hours}{Total\ hours\ worked\ by\ all\ employees\ during\ period} \quad \textbf{(67)}$$

The 10^8 hours is obtained as follows:

$$Total\ number\ of\ hours = \left(\frac{40\,hr}{wk}\right)\left(\frac{50\,wk}{yr}\right)\left(\frac{50\,yr}{career}\right)\cdot 1000\ careers = 10^8\ hr \quad \textbf{(68)}$$

The run row reports apply no combination factors or FAR factor. The FAR calculations make use of workspace Risk Preferences for Personnel hours per year and Total exposure time.

Safeti also calculates the overall Potential Loss of Life (PLL) for the installation and can break this down into population categories by area and building.

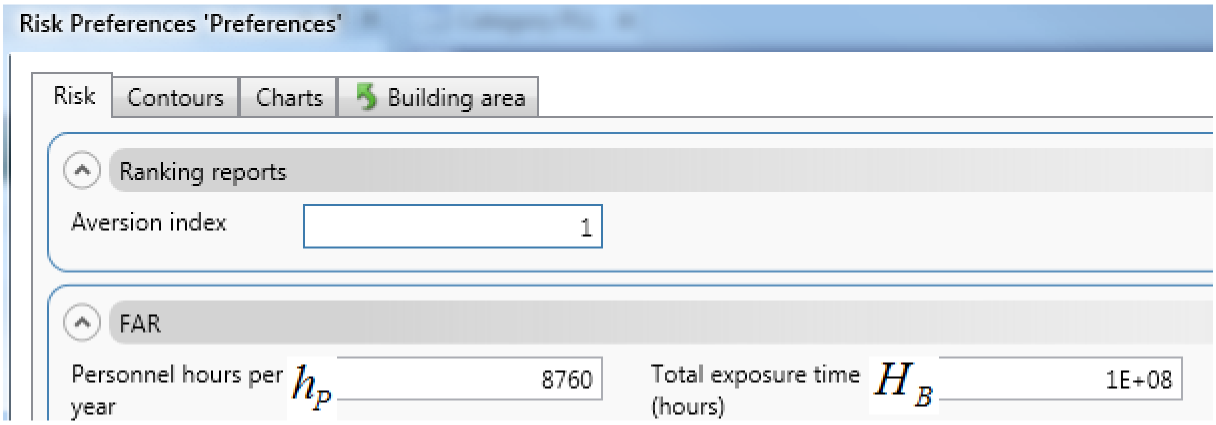


The PLL for a particular worker category may be quite low but this could be deceptive since the number of exposed hours during an operational year may also be quite low. The risk levels per hour on the job may still be high.

The FAR and PLL are closely related according to;

$$FAR = PLL \frac{H_B}{N_e h_p} \quad \textbf{(69)}$$

Where H_B is a constant number of hours and h_p is exposure time per person and they can be set in the risk preferences. N_e is the number of people of that category exposed to the hazards.



3.7.1 Run Row Category FAR

In the run row category FAR the report displays the top level, total FAR value and this breaks down to 5 levels, similar to the PLL report;

Run row Areas

  Area Buildings

    Building Models

      Model outcome codes

        Outcome code results

The run row Areas level will show the FAR summed for each area present in the run row. If there are grid populations then these are labelled as 'Population Grid'. The summation is made in total and grouped by population category for each building and for populations on the risk grid. At the lowest Outcome code results level the outcome frequency and average N values are listed for every population where there is some probability of death for that outcome. The FAR contribution from each record is not shown but can be expressed;

$$FAR_{edf,b,c,o\gamma} = \frac{H_B \times PLL_{edf,b,c,o\gamma}}{N_{b,c} h_P} \quad \textbf{(70)}$$

At the Model outcomes level they are again calculated from the relevant PLL;

$$FAR_{edf,b,c,\gamma} = \frac{H_B \times PLL_{edf,b,c,\gamma}}{N_{b,c} h_P} \quad \textbf{(71)}$$

For the total of all categories it must take into account the total number of people present;

$$FAR_{edf,b,\gamma} = \frac{H_B \times PLL_{edf,b,\gamma}}{h_P \sum_{\substack{All \\ categories}} N_{b,c}} \quad \textbf{(72)}$$

At the Building Models level all the outcome type results are included;

$$FAR_{edf,b,c} = \frac{H_B \times PLL_{edf,b,c}}{N_{b,c} h_P} \quad \textbf{(73)}$$

For the total of all categories it must take into account the total number of people present;

$$FAR_{edf,b} = \frac{H_B \times PLL_{edf,b}}{h_P \sum_{\substack{All \\ categories}} N_{b,c}} \quad (74)$$

At the Area Buildings level all the edfs are included;

$$FAR_{b,c} = \frac{H_B \times PLL_{b,c}}{N_{b,c} h_P} \quad (75)$$

For the total of all categories it must take into account the total number of people present;

$$FAR_b = \frac{H_B \times PLL_b}{h_P \sum_{\substack{All \\ categories}} N_{b,c}} \quad (76)$$

At the Run row Areas level all the buildings in the area are included and the number of people exposed must be calculated;

$$N_{A,c} = \sum_{\substack{All\ buildings \\ in\ the\ area}} N_{b,c} \quad (77)$$

And the FAR is;

$$FAR_{A,c} = \frac{H_B \times PLL_{A,c}}{N_{A,c} h_P} \quad (78)$$

Summing all categories;

$$N_A = \sum_{\substack{All \\ categories}} N_{A,c} \quad (79)$$

And the FAR is;

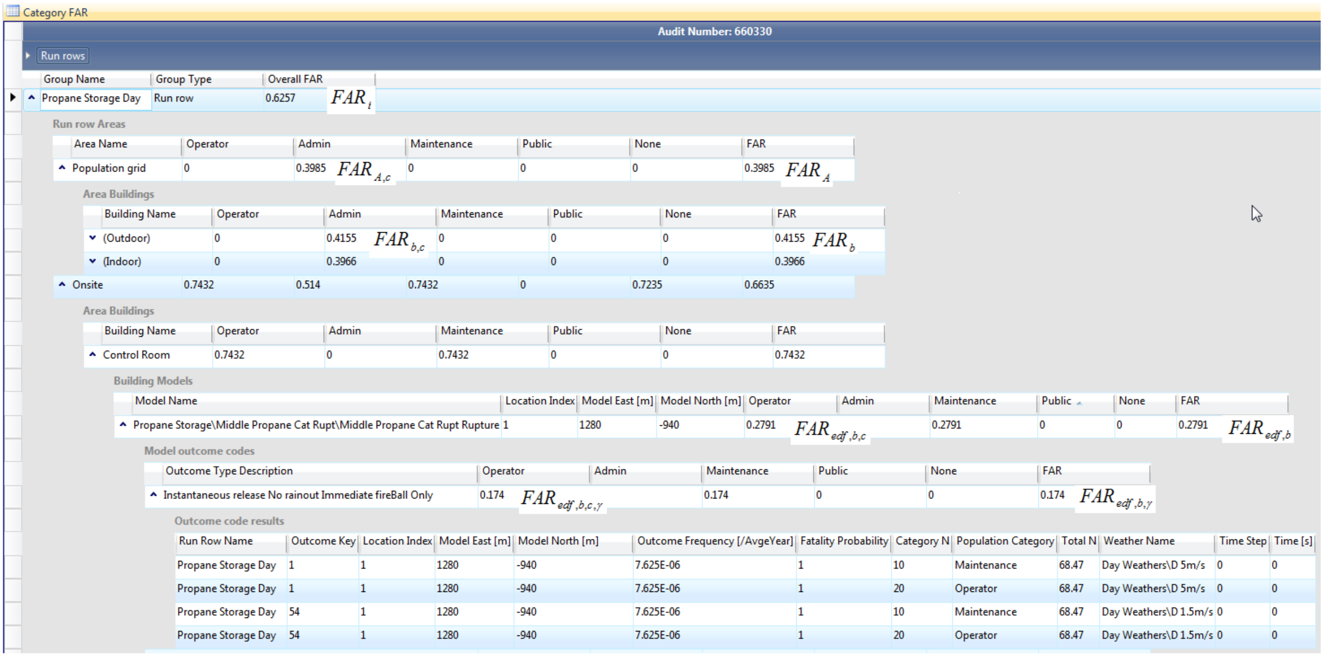
$$FAR_A = \frac{H_B \times PLL_A}{N_A h_P} \quad (80)$$

At run row level and overall FAR may be defined using the total number of people present;

$$N_i = \sum_{\substack{All \\ areas}} N_A \quad (81)$$

And the total FAR;

$$FAR_i = \frac{H_B \times PLL_i}{N_i h_P} \quad (82)$$



3.7.2 Combination Category FAR

In the combination category FAR the report displays the top level, total FAR value and this breaks down to 5 levels, similar to the PLL report;

Run row Areas

Area Buildings

Building Models

Model outcome codes

Outcome code results

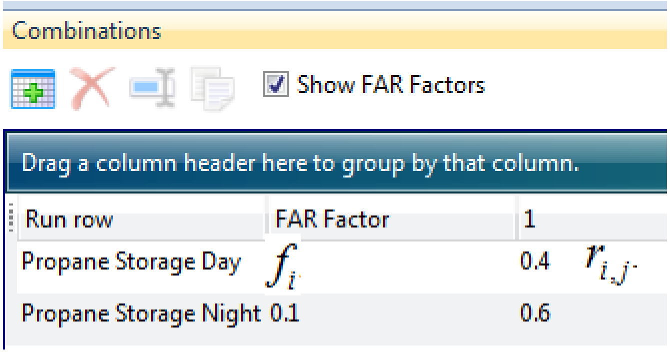
The run row Areas level will show the FAR summed for each area present in the run row. If there are grid populations then these are labelled as ‘Population Grid’. The summation is made in total and grouped by population category for each building and for populations on the risk grid.

For combinations the number of people exposed per run row can vary and this affects the number of exposed hours that are represented by the PLL values. If the run row factors represent time and sum to 1 then they can be used to calculate a weighted average of the number of people exposed;

$$N_{b,c,j} = \sum_{\substack{All\ run \\ rows\ i}} r_{i,j} N_{b,c,i} \qquad \textbf{(83)}$$

In this case the combination can be considered to represent a single year and the exposure time is consistent with the FAR definition. However, run row factors may add up to more than 1 because the study has been broken down into several run rows – for instance to split toxic and flammable events or to separate contributions from different process area. If so the average number of people present will not be correct using the combination factors alone. To compensate for this an additional ‘FAR factor’ may be specified per run row (default 1).

$$N_{b,c,j} = \sum_{\substack{All\ run \\ rows\ i}} f_i r_{i,j} N_{b,c,i} \qquad (84)$$



This factor provides the means to obtain the correct FAR combinations. However, please do take care with this because along with the flexibility provided by the run row feature this is flexible enough to obtain incorrect and misleading results particularly if the idea is to compare the calculated values with published data. Some examples are given later to illustrate the point.

At the lowest Outcome code results level the outcome frequency and average N values are listed for every population where there is some probability of death for that outcome. At this level the combination factors are not applied and the un-factored outcome details are given for each run row with relevant results. The FAR contribution from each record is not shown but can be expressed;

$$FAR_{edf,i,j,b,c,o\gamma} = \frac{H_B \times PLL_{edf,i,j,b,c,o\gamma}}{N_{b,c,i} h_P} \qquad (85)$$

At the Model outcomes level they are again calculated from the relevant PLL;

$$FAR_{edf,j,b,c,\gamma} = \frac{H_B \times PLL_{edf,j,b,c,\gamma}}{N_{b,c,j} h_P} \qquad (86)$$

For the total of all categories it must take into account the total number of people present;

$$FAR_{edf,j,b,\gamma} = \frac{H_B \times PLL_{edf,j,b,\gamma}}{h_P \sum_{\substack{All \\ categories}} N_{b,c,j}} \qquad (87)$$

At the Building Models level all the outcome type results are included;

$$FAR_{edf,j,b,c} = \frac{H_B \times PLL_{edf,j,b,c}}{N_{b,c,j} h_P} \qquad (88)$$

For the total of all categories it must take into account the total number of people present;

$$FAR_{edf,j,b} = \frac{H_B \times PLL_{edf,j,b}}{\sum_{\substack{All \\ categories}} N_{b,c,j} h_P} \qquad (89)$$

At the Area Buildings level all the edfs are included;

$$FAR_{j,b,c} = \frac{H_B \times PLL_{j,b,c}}{N_{b,c,j} h_P} \quad (90)$$

For the total of all categories it must take into account the total number of people present;

$$FAR_{j,b} = \frac{H_B \times PLL_{j,b}}{h_P \sum_{\substack{All \\ categories}} N_{b,c,j}} \quad (91)$$

At the Run row Areas level all the buildings in the area are included and the number of people exposed must be calculated;

$$N_{A,c,j} = \sum_{\substack{All\,buildings \\ in\,the\,area}} N_{b,c,j} \quad (92)$$

And the FAR is;

$$FAR_{j,A,c} = \frac{H_B \times PLL_{j,A,c}}{N_{A,c,j} h_P} \quad (93)$$

Summing all categories;

$$N_{A,j} = \sum_{\substack{All \\ categories}} N_{A,c,j} \quad (94)$$

And the FAR is;

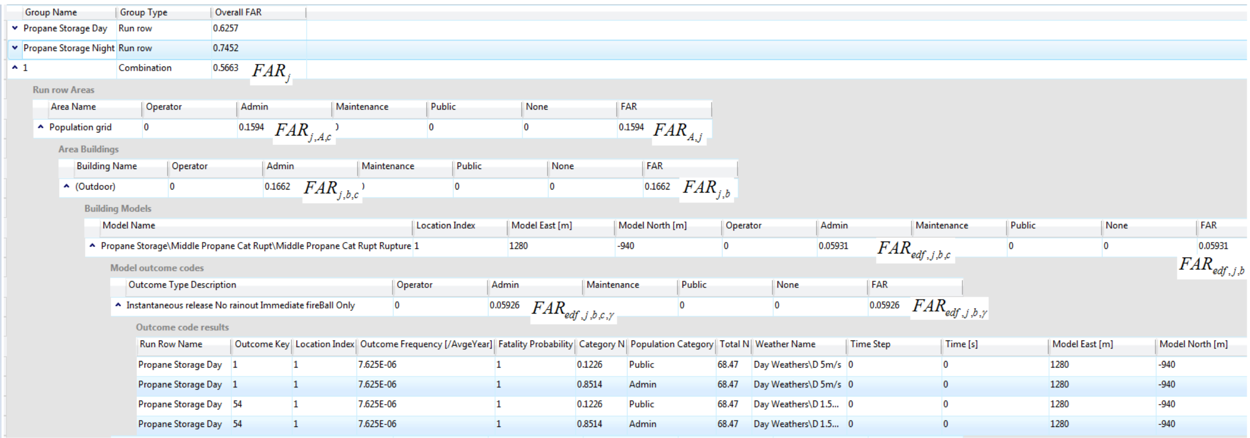
$$FAR_{A,j} = \frac{H_B \times PLL_{j,A}}{N_{A,j} h_P} \quad (95)$$

At the very highest level the total number of people over all areas must be calculated;

$$N_j = \sum_{\substack{All \\ areas}} N_{A,j} \quad (96)$$

And the FAR is;

$$FAR_j = \frac{H_B \times PLL_j}{N_j h_P} \quad (97)$$



3.7.2.1 Combination Examples

Consider a plant with a day/night working pattern with 2 types of workers, administration and technical. Consider that the administration staff are present only during the day and the same number of technical people are present at all times. The day factor is 0.4 and night 0.6. There are 20 administrators and 100 technical. The daytime run row PLL is 0.01 for technical staff and 0.001 for administrators. At night it is the same for technical staff, 0.01.

Run row	Combination factor	FAR factor	Technical	Admin	Overall
Day	0.4	1	FAR = 0.01x10^8/ (100x8760)= 1.14	FAR = 0.001x10^8/ (20x8760)= 0.57	FAR = 0.011x10^8/ (120x8760)= 1.05
Night	0.6	1	FAR = 0.01x10^8/ (100x8760)= 1.14	N/A	FAR = 0.01x10^8/ (100x8760)= 1.14
Combination			FAR = (0.4x0.01+0.6x0.01)x10^8/ ((0.4x100+0.6x100)x8760)= 1.14	FAR = (0.4x0.01+0.6x0.0)x10^8/ ((0.4x100+0.6x0)x8760)= 0.57	FAR = (0.4x0.011+0.6x0.01)x10^8/ ((0.4x120+0.6x100)x8760)= 1.1

Arranged as a spreadsheet and with PLL and N values;

Run row	$r_{i,j}$	f_i	Technical			Administration			Overall		
			PLL	N	FAR	PLL	N	FAR	PLL	N	FAR
Day	0.4	1	0.0100	100	1.14	0.0010	20	0.57	0.0110	120	1.05
Night	0.6	1	0.0100	100	1.14	0.0000	0	N/A	0.0100	100	1.14
Combined			0.0100	100	1.14	0.0004	8	0.57	0.0104	108	1.10

Now consider that the study has 4 run rows to split the QRA into toxic and flammable risks. The PLL for technical workers is 0.005 toxics and 0.005 flammable. For administrators the split is 0.0007 and 0.0003. Clearly the overall FAR should be the same as in the previous example.

The factor f_i is necessary to factor the number of hours exposed to avoid double-counting the day and night periods. Essentially the hours of exposure to the risk are split between the two day run rows.

Run row	$r_{i,j}$	f_i	Technical			Administration			Overall		
			PLL	N	FAR	PLL	N	FAR	PLL	N	FAR
Day toxic	0.4	0.5	0.0050	100	0.57	0.0007	20	0.40	0.0057	120	0.54
Night toxic	0.6	0.5	0.0050	100	0.57	0.0000	0	N/A	0.0050	100	0.57
Day flam	0.4	0.5	0.0050	100	0.57	0.0003	20	0.17	0.0053	120	0.50
Night flam	0.6	0.5	0.0050	100	0.57	0.0000	0	N/A	0.0050	100	0.57
Combined			0.0100	100	1.14	0.0004	8	0.57	0.0104	108	1.10

In the explanation above the FAR values have been expressed in terms of the relevant PLL values. It is also possible to combine FAR values directly but care needs to be taken if the number of people exposed is changing. For the technical group in the example above the N value is the same day and night so it is legitimate to combine using the day and night factors – ie FAR combined = 0.4*FAR(day)+0.6*FAR(night). However, this is not the case in general as the number of people exposed can vary across the different groups and time periods. FAR values can be combined if care is taken to use a weighted average of the number of people exposed;

$$FAR_{edf,j,b,\gamma} = \frac{\sum_{\substack{All \\ categories}} \left(N_{b,c,j} FAR_{edf,j,b,c,\gamma} \right)}{\sum_{\substack{All \\ categories}} N_{b,c,j}} \qquad \textbf{(98)}$$

Run row	Combination factor	FAR factor	Technical	Admin	Overall
Day	0.4	1	FAR = 0.01x10^8/ (100x8760)= 1.14	FAR = 0.001x10^8/ (20x8760)= 0.57	FAR = 0.011x10^8/ (120x8760)= 1.05
Night	0.6	1	FAR = 0.01x10^8/ (100x8760)= 1.14	N/A	FAR = 0.01x10^8/ (100x8760)= 1.14
Combination N			N=100*0.4*1+100*0.6*1=100	N=20*0.4*1+0*0.6*1=8	N=8+100 = 108
Combination FAR			FAR = (0.4*100*1.14+0.6*1.14*100)/100 =1.14	FAR = 0.4*0.57*20/8 = 0.57	FAR = (100*1.14+8*0.57)/108 = 1.10

3.7.2.2 Comparison with 6.7

In 6.7 the weighted average of the number of people exposed was obtained by averaging the populations sets present;

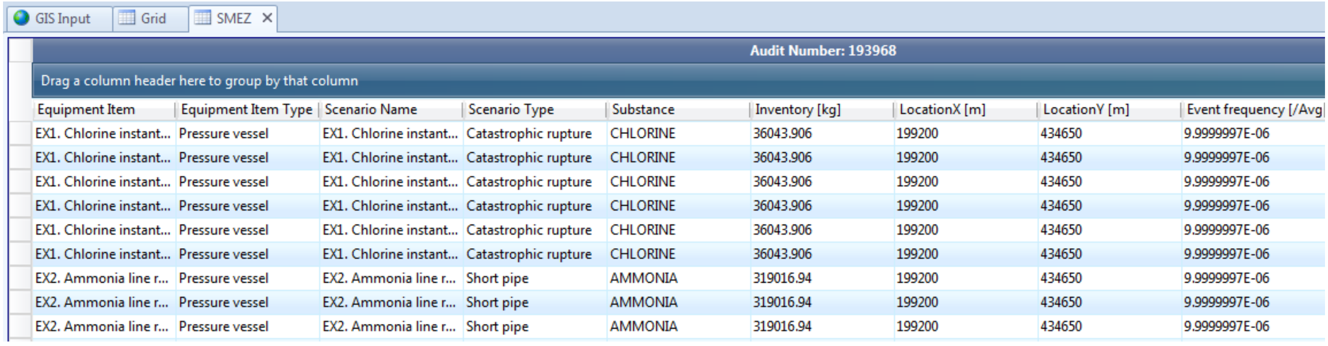
$$N_{b,c,j} = \sum_{\substack{All\ population \\ sets\ included\ in\ j}} f_s N_{b,c,s} \qquad \textbf{(99)}$$

In 6.7 the population selection was restricted to population sets and so this was a quite straightforward mechanism to obtain the correct number of people exposed. In 7.2 the population selection is more open and for instance the same population may exist in separate selections. This is why the approach taken in 7.2 is somewhat different.

4 SUMMARY MAXIMUM EFFECT ZONES (SMEZ)

4.1 Introduction

This report is currently available in the NL version only. It provides a table of events reporting certain items of input, consequence and risk information considered useful at this summary level. By accessing this report there is no need to look at detailed information for each event if these summary items of information are sufficient for the current purpose. Overall, this report can save a lot of time for the user. To illustrate the concept the image below is provided and shows the left-most columns from this report.



Equipment Item	Equipment Item Type	Scenario Name	Scenario Type	Substance	Inventory [kg]	LocationX [m]	LocationY [m]	Event frequency [/Avg]
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	36043.906	199200	434650	9.9999997E-06
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	36043.906	199200	434650	9.9999997E-06
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	36043.906	199200	434650	9.9999997E-06
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	36043.906	199200	434650	9.9999997E-06
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	36043.906	199200	434650	9.9999997E-06
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	36043.906	199200	434650	9.9999997E-06
EX2. Ammonia line r...	Pressure vessel	EX2. Ammonia line r...	Short pipe	AMMONIA	319016.94	199200	434650	9.9999997E-06
EX2. Ammonia line r...	Pressure vessel	EX2. Ammonia line r...	Short pipe	AMMONIA	319016.94	199200	434650	9.9999997E-06
EX2. Ammonia line r...	Pressure vessel	EX2. Ammonia line r...	Short pipe	AMMONIA	319016.94	199200	434650	9.9999997E-06

Each row in the above report includes data associated with a given equipment scenario and associated weather. Some of the data is input, some of the data is consequence data not used by the risk calculations directly and some of the data records values calculated during the risk calculations. The data correspond to assumptions based on outdoor individual risk calculations.

In version 8.3 of Safeti NL effect contours and ranking reports are optionally available. These additional calculations are not all aligned directly with the SMEZ report;

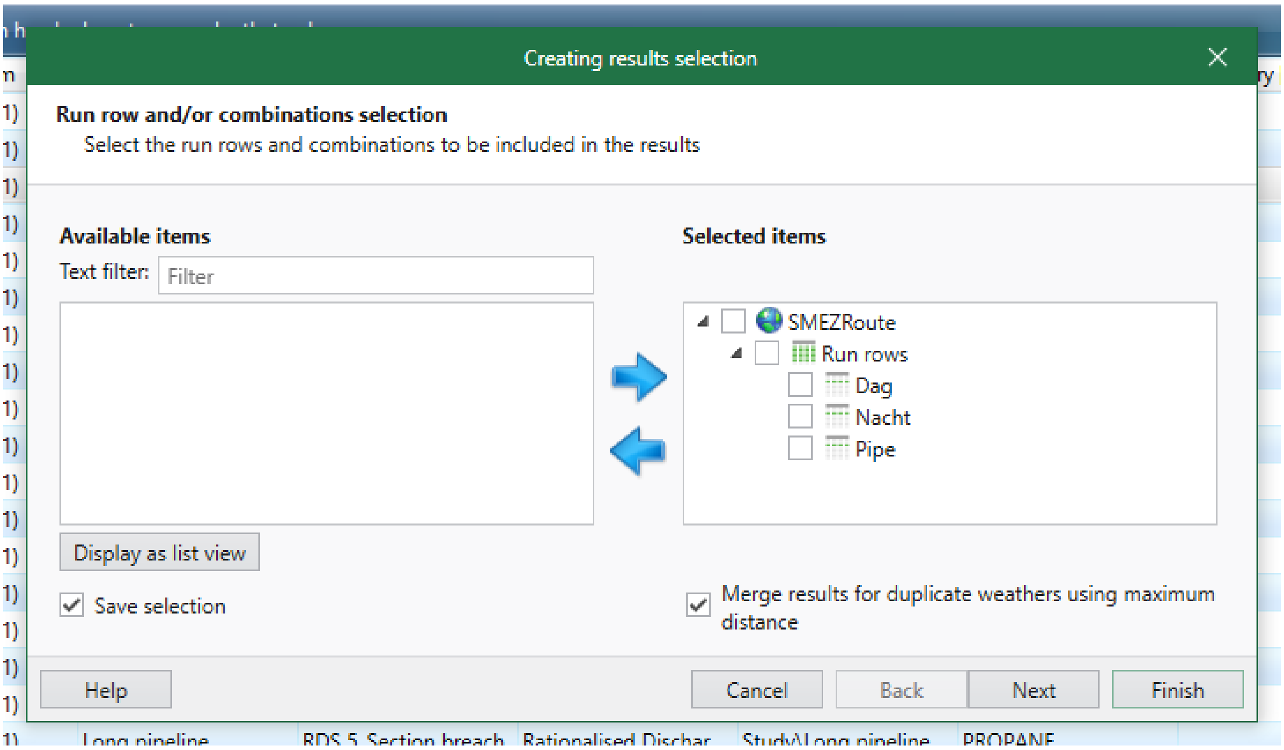
- The NLIV distances used for the effect contours are based on the toxic averaging time of 10mins whereas the distances in the SMEZ report are based on 1hour averaging and require this averaging time to be selected on each scenario.
- For the effect contours there is a plant boundary explosion rather than a free field explosion and this is likely to give quite different explosion distances.

For the radiation zones there is alignment and the distances shown in the SMEZ report correspond to the ellipse shapes that are used in the effect calculations. The radiation distances though are not used directly in the outdoor risk calculations and instead the lethality ellipses derived from the radiation probits are used for the risk.

All event types are considered and so not all data items are relevant on every row in the table. In such cases the irrelevant data items are left empty; for instance there is no release rate for a catastrophic rupture.

4.2 Setting Options for the Report

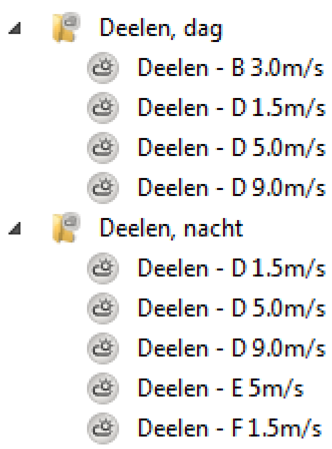
As the report is requested the run rows to be included can be selected. All Events that are selected on the requested run rows are included in the report.



There is also the option to check **'Merge results for duplicate weathers using maximum distance** ' and this relates to the treatment of results for different weathers.

If **checked** then if the Summary Report covers several Run Rows (e.g. a Day Row and a Night Row), then a weather with a given combination of stability class and wind speed may be present for more than one Run Row. If you select the option to Report maximum results in case of multiple occurrences of the same weather, then the Summary Report will contain a single entry for each Scenario or Model for each combination of stability class and wind speed, and this entry will report the maximum distance for each relevant effect-type, over all weather categories with that combination of stability class and wind speed.

Considering the standard weather distributions used in Safeti NL we can see that the superset of dag and nacht conditions gives a list of 6 unique combinations of wind speed and stability.



As an example the event below has 6 results corresponding to the superset of wind speed and stability classes modelled over the nacht and dag run rows.

Equipment Item	Equipment Item Type	Scenario Name	Scenario Type	Substance	Weather
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	B 3
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	D 1.5
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	D 5
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	D 9
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	E 5
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	F 1.5

If **unchecked**, then the Summary Report will contain an entry for each Scenario or Model for every weather category modelled, even if some categories have the same combination of stability class and wind speed.

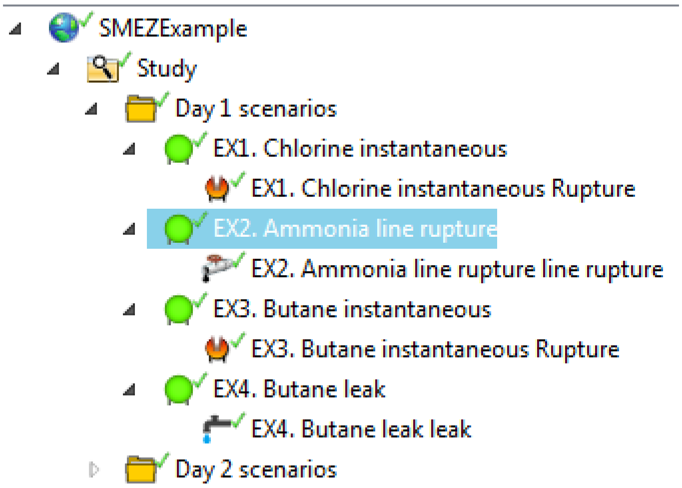
So in the example we can see that there are 2 results for D 1.5, D 5 and D9 corresponding to nacht and dag conditions. Normally these results will be similar but not exactly the same because of different parameter settings.

Equipment Item	Equipment Item Type	Scenario Name	Scenario Type	Substance	Weather
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - D 1.5m/s (nacht)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - D 5.0m/s (nacht)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - D 9.0m/s (nacht)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - E 5m/s (nacht)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - F 1.5m/s (nacht)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - B 3.0m/s (dag)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - D 1.5m/s (dag)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - D 5.0m/s (dag)
EX1. Chlorine instant...	Pressure vessel	EX1. Chlorine instant...	Catastrophic rupture	CHLORINE	Deelen - D 9.0m/s (dag)

4.3 Input Data Items

The first four items list information that is shown as a tree structure in the Model tab.

Equipment Item, Equipment Item Type, Scenario Name, Scenario Type. The full path is then given in column **Path to Root**



The next item is '**Substance'** and this names the released material. In the case of a warehouse fire this field is blank because it uses the 'Warehouse reference' and the composition of this changes case-to-case.

Inventory is the next item. This is reported for Vessel/Pipe Sources Models and for user-defined cases. For other cases this is left blank.

The **LocationX** and **LocationY** fields give the east and north location of the Scenario in absolute coordinates. If the scenario is on a route then the first location along the route used in the risk calculations is reported irrespective of where the maximum effect is located along the route. Likewise, long pipelines using rationalised discharge scenarios that are spread along the pipeline report the first location used in the risk calculations.

The **Event Frequency** gives the annual frequency for the hazardous event. If the scenario is on a route, then the highest frequency for an individual location along the route used in the risk calculations is reported[1]. Likewise, long pipelines using rationalised discharge scenarios that are spread along the pipeline report the highest frequency for an individual location used in the risk calculations. Should the frequency be zero (as entered by the user or as a result of rationalising scenarios along a long pipeline) then the scenario will not be used in the risk and will not be included in the table.

The **Hole Size / Pipe diameter** gives the size of a hole for a leak event. This is reported for Leak scenarios for Vessel/Pipe Sources Models only.

The **Weather** identifies each weather or weather category reported for the Scenario. If the option to 'Merge results for duplicate weathers using maximum distance' in case of multiple occurrences of the same weather was selected in the Options, each weather will be identified by the stability class and wind speed, whereas if the option to Report results for separate weather categories was selected, each weather will be identified by the name that is assigned to it in the Study Folder file.

4.4 Discharge Data Items

The **Discharge Mass** column gives the total mass released for a Catastrophic failure or Fireball.

The **Discharge rate** is given for continuous releases. If the release has multiple release rates the first rate is given.

The **Release duration** column gives the duration of the release for a Leak, User defined source or Warehouse Scenario. For a Catastrophic Rupture, the field is blank. If the release has multiple release rates the duration of the first rate is given.

Note: for modelled cases these are results from the discharge models. For user-defined cases these are inputs.

4.5 Toxic Items

The **Largest Distance to 1% lethality** is the largest distance at which the toxic effects produce a lethality level of 1%. If the event did not produce a lethality level of 1%, this will be blank.

The values for **Largest Distance to VRW, AGW and LBW** are the largest distances to the various Dutch intervention concentrations set for the material involved in the hazardous event. These are only calculated if the NLIV 1 hour averaging time for reports is selected on the Models/Dispersion tab.

Note: the results are for the effects on people outdoors. The distances are downwind distances from the release point. The distances to the intervention values are not used directly in the risk calculations so are not included in the possible causes of 1% lethality.

4.6 General Flammable Items

[1] In 8.5 and 8.8 of SAFETI-NL the SMEZ report will include rows for scenarios along a route that have the event probability set to 0. This would be an odd situation and these scenarios do not contribute to the risk (ADO 447192)

The **Probability of Direct Ignition** is given for flammable materials (or materials which are both flammable and toxic) Source Models, and is the probability that the release ignites immediately, before a flammable cloud has started to disperse.

The **Largest Distance to LFL** is the largest distance modelled in the risk calculations for a flash fire for a flammable material. The effect distance for a flash fire is defined by the distance to the lower flammable limit. If a flash fire was not modelled in the risk calculations (i.e. because no onsite ignition sources were present and LFL envelope does not exceed plant boundary), then this will be blank.

The **Largest Distance 1% Lethality** is the largest distance to a lethality level of 1% that was modelled in the risk calculations for any flammable effect, e.g. for flash fires, for explosions, or for radiation from jet fires, pool fire or fireballs. The effect level assumed to produce an outdoor lethality level of 1% is as follows:

Type of Effect	Effect Level
Flash fire only outcomes	Distance to LFL in event of a flash fire with immediate ignition, or of ignition by an onsite source, or of free field ignition
Flash fire with Pool fire outcomes	Greater of distance to LFL in event of a flash fire with immediate ignition, or of ignition by an onsite source, or of free field ignition and distance to downwind edge of pool fire lethality ellipses
Flash fire with Explosion outcomes	The greater of the distance to overpressure level of 0.3 bar and the distance to LFL
Flash fire with Explosion and Pool Fire outcomes	The greater of the distance to overpressure level of 0.3 bar, the distance to LFL and distance to downwind edge of pool fire lethality ellipses
Jet Fire Fireball Pool Fire	Distance to lethality level of 1%, as reported in Hazard Zones Report. The lethality level for radiation is a function of the location, shape and intensity of the flame, and of the duration

For flash fires and explosions, the worst-case outcome is considered for all ignition times used in the risk (accounting for specified onsite ignition sources and free-field scenario). For pool fires, both early/immediate and late pool fires are considered.

The **Corresponding event (1% Lethality)** identifies the type of flammable effect that produced the largest distance to 1% lethality. The effect is identified by an Outcome Code. In the case that different outcomes give the same distance it will report the outcome code associated with the outcome with the higher outcome frequency. In the unlikely event that the outcome frequencies are equal, then both outcome codes will be reported, for instance 'CRdFFP-CRdFXP.

Note: the results are for the effects on people outdoors and assumptions based on individual risk. The distances are downwind distances from the release point. The full list of possibly outcome codes is provided in the application help system.

4.7 Flammable Results for Radiation

This section gives the **Largest Distance to radiation levels of 35 kW/m2, 10 kW/m2 and 3 kW/m2**, considering all radiation results that are present for the current Scenario and Weather. This includes fireballs, vertical and horizontal jet fires, early, immediate and late pool fires.

Note: The distances are downwind distances from the release point. These values are not used directly in the core personnel risk calculations so are not included in the possible causes of 1% lethality. They may be included in the outcomes used to calculate the radiation effect contours but this will depend on the ignition modelling used for risk. For instance, the largest distance might be due to the late pool fire and this will only be used for the effect contours if there are delayed ignition outcomes; jet fire and fireball outcomes are only included if there is immediate ignition. It is important to understand this point when comparing the values reported in the SMEZ report with the various effect contours.

4.8 Flammable Results for Explosion

This section gives **Largest Distance to 0.3 bar** and **Largest Distance to 0.1 bar**.

Note: the results are for the effects on people outdoors. These results are for explosions modelled during the risk calculations. The **Largest Distance to 0.1 bar** does not cause fatalities outdoors so is not included in the **Largest Distance 1% Lethality** calculation. Furthermore, the 0.1 bar distance corresponds to the same explosion that generates the largest distance to 0.3 bar and therefore 1% lethality. Some explosions may give a larger 0.1bar distance but these are not considered because of the zero outdoor lethality.

The plant boundary explosions that are used for the distances to 0.3 and 0.1 bar effect contours that are introduced in Safeti NL 8.3 are not considered for the SMEZ report and instead the free field explosions are used. These are most likely to give further distances than the contours.

5 EVENT TREE (ET) REPORTS – IGNITION

This report gives information relevant to the flammable event trees.

Run Row Name	Model Name	Location Index	Model East [m]	Model North [m]	Event frequency [/AvgeYear]
Run Row	Base Case LNG Train 1 Obstructions\Acid Gas Removal\Feed Gas to Absorber\100mm	1	1109.03	322.794	0.00285
Run Row	Base Case LNG Train 1 Obstructions\End Flash Gas/LNG Rundown\LNG Flash Drum\100mm	1	803.676	322.794	0.00285
Run Row	Base Case LNG Train 1 Obstructions\End Flash Gas/LNG Rundown\Flash Exchange HX\100mm	1	746.534	338.866	0.00285
Run Row	Base Case LNG Train 1 Obstructions\Gas Dehydration\Feed Gas Dehydrator\100mm	1	1098.32	403.151	0.00285
Run Row	Base Case LNG Train 1 Obstructions\LNG Liquefaction\Feed Gas from Propane\100mm	1	916.176	310.294	0.00285
Run Row	Base Case LNG Train 1 Obstructions\LNG Liquefaction\LNG from Expander\100mm	1	789.391	396.008	0.00285
Run Row	Base Case LNG Train 1 Obstructions\LNG Liquefaction\Feed to MR Compressor\100mm	1	823.319	392.437	0.00285
Run Row	Base Case LNG Train 1 Obstructions\LPG Fractionation\Deprop Overheads\100mm	1	885.819	321.008	0.00285
Run Row	Base Case LNG Train 1 Obstructions\NGL Recovery\Expander Recompressor\100mm	1	1023.32	308.508	0.00285
Run Row	Base Case LNG Train 1 Obstructions\Process Fuel Gas\Fuel Gas 1\100mm	1	1109.03	322.794	0.00285

There is a row per event; that is a given scenario and release location such that scenarios along a route will have multiple rows. Each location is given an index and the release x and y coordinates are given along with the Event frequency. The left-most columns are shown in the image above. Towards the right of the report there are further columns with results related to the event tree modelling.

Immediate Ignition Pr	Delayed Ignition Prob	Explosion Probability	Flash Fire Only Probab	Immediate Ignition Fr	Delayed Ignition Frequ	Explosion Frequency
0.3	0.105541	0.0949873	0.0105541	0.000855	0.000300793	0.000270714
0.3	0.138273	0.124445	0.0138273	0.000855	0.000394077	0.000354669
0.3	0.105326	0.094793	0.0105326	0.000855	0.000300178	0.00027016
0.3	0.105488	0.0949392	0.0105488	0.000855	0.000300641	0.000270577
0.3	0.10569	0.0951214	0.010569	0.000855	0.000301218	0.000271096
0.3	0.115164	0.103648	0.0115164	0.000855	0.000328218	0.000295396
0.3	0.105438	0.0948941	0.0105438	0.000855	0.000300498	0.000270448
0.3	0.105602	0.0950419	0.0105602	0.000855	0.000300966	0.000270869
0.3	0.105704	0.0951335	0.0105704	0.000855	0.000301256	0.00027113
0.3	0.105437	0.0948929	0.0105437	0.000855	0.000300494	0.000270445

To explain and understand this report it is helpful to read from right to left because the calculations start with frequencies. The risk results are analysed and there might be 1000's of outcomes for a given event. Frequencies are summed according to groupings corresponding to the column headings. All outcomes identified as immediate ignition[2] are summed together and those not included in this column are summed as 'Delayed Ignition'. Note that as a result, the residual pool fire and free-field outcomes are included in this sum.

A subset of the immediate and delayed ignition outcomes are identified as explosions[3] and these frequencies are summed as the 'Explosion Frequency'. This sum includes delayed explosion outcomes as generated by the default parameter settings. It will also include any immediate ignition outcome explosions present (for instance for short duration releases) and also detonations if these are active due to non-default parameter settings tailored for a given study.

The probability column values are derived from the frequency results.

Immediate Ignition Probability

This is calculated by dividing the immediate ignition frequency by the event frequency. It may give a lower value than expected when comparing with the input specification. This is because only outcomes that have an impact are included. If for instance a jet fire does not have any significant radiation ellipses then it won't be included in the risk calculations.

Delayed Ignition Probability

This is calculated by dividing the delayed ignition probability by the event frequency. It will give an idea of the overall strength of ignition sources found by this particular event. Do note that is does include the residual pool fire and free field outcomes so it may seem quite high even without ignition sources present.

Explosion Probability

This is calculated by dividing the explosion frequency by the event frequency and will include detonations and immediate explosion outcome frequencies if these are present.

Flash Fire Only Probability

This is calculated by dividing the difference between the delayed ignition probability and explosion probability by the event frequency. Again, do note that is does include the residual pool fire outcomes and these will be included even though the title mentions only the flash fire.

[2] Readers familiar with the risk diagnostic files will be familiar with the 'outcome codes'. These are a compact series of letters that identify the characteristics of the outcome. Immediate ignition is indicated by having 'i' or 'I' as the 3rd letter.

[3] Again referring to the outcome codes the logic excludes codes including XX since these related only to plant boundary explosions since these are not used in the core risk calcuations.

NOMENCLATURE

$\Delta_{edf,x,y,v}$	Percentage contribution of the given *edf* to the total risk at the point
$\Delta_{edf,x,y,v,\gamma}$	Percentage contribution of a given effect type γ to the results
$\Delta_{edf,x,y,v,j}$	Percentage contribution of a given *edf* to the results for a given combination *j*
$\Delta_{edf,x,y,v,j,\gamma}$	Percentage contribution of a given effect type γ to the results for a given combination *j*
$\Delta^{RI}{}_{edf}$	Percentage contribution of an edf to the total Risk Integral for a run row
$\Delta^{RI}{}_{edf,\gamma}$	Percentage contribution of an outcome type to the total Risk Integral for an edf
$\Delta^{RI}{}_{edf,j}$	Percentage contribution of an edf to the total Risk Integral for the combination
$\Delta^{RI}{}_{edf,j,\gamma}$	Percentage contribution of an outcome type to the total Risk Integral for an edf and combination
FAR	Fatal accident rate: number of fatalities per group of 1000 people over their career
$F_{edf,o\gamma}$	Frequency of a given outcome *o* and particular effect type γ
F_{edf}	Event (equivalent discrete failure) frequency
$F_{edf,i,j,o\gamma}$	Frequency for a given event of a given outcome *o* and effect type γ modified by the factor for run row i and combination j
$F^{N=0}_{edf}$	Frequency of the edf that kills no one
$F_{edf,o\gamma\|N>0}$	Outcome frequency of an outcome where the average N value is >0
$F_{edf,i,j,o\gamma}$	Outcome frequency modified by the combination factor for the run row and combination
$F_{edf,j}$	Total event frequency for the edf and combination
$F^{N=0}_{edf,j}$	Frequency of the edf that kills no one for this combination
$F_{edf,i,j,o\gamma\|N>0}$	Outcome combination frequency of an outcome where the average N value is >0
$F_{N=>N_k,i}$	Cumulative frequency of killing N_k or more people on run row *i*
H_B	Constant number of hours representing combined careers of 1000 workers. Default value 10^8 hours. Can be changed in Risk Preferences.
h_p	Annual exposure time per person per year. Default value continuous exposure, i.e. 8760 hours. Can be changed in Risk Preferences.
$IR_{x,y,v}$	Summation of all risk increments at the point *(x,y)* for given vulnerability type v
$IR_{edf,x,y,v}$	Summation of all risk increments for a given event (*edf* = Equivalent Discrete Failure)
$IR_{edf,x,y,v,\gamma}$	Summation of risk increments for given event (edf) and a given effect type γ
$IR_{edf,x,y,v\|o\gamma}$	Risk increment for given event and a given outcome *o* and effect type γ (lowest level)
$IR_{x,y,j,v}$	Summation of risk increments for all events (edfs) in the combination *j*
$IR_{edf,x,y,v,j}$	Summation of risk increments for all effect types for a given *edf* and combination *j*
$IR_{edf,x,y,v,j,\gamma}$	Summation of risk increments for a given *edf*, effect type γ and combination *j*
$IR_{edf,x,y,v,i,j\|o\gamma}$	Risk increment for given run row *i* and combination *j* (including run row factor r_{ij}) for a given outcome o and effect γ
N_e	The number of people exposed to hazards
$\overline{N}_{v,c\|o\gamma}$	Average number of people of a population category by a particular outcome $o\gamma$
$\overline{N}_{t\|o\gamma}$	Total number of people killed by a particular outcome $o\gamma$

$\overline{N}_{t\|edf,\gamma}$	Average number of people killed by an event by outcomes of type γ
$\overline{N}_{t\|edf}$	Average number of people killed by a given edf
$\overline{N}_{t\|edf,i,j,\gamma}$	Average number of people killed by outcomes of this edf of type γ
$\overline{N}_{t\|edf,j}$	Average number of people killed by this edf and combination
$P_{d,x,y,v\|o\gamma}$	Probability of death, given the location is hit by a particular outcome *o* of type γ
$P_{x,y,v\|edf}$	Risk/outcome or probability of death given that the *edf* happens
$P_{x,y,v\|\gamma,edf}$	Risk/outcome or probability of death given that *edf* happens and the point is affected by the given effect γ
$P_{x,y,v,j\|edf}$	Risk/outcome or probability of death for the combination *j* given that the *edf* happens
$P_{x,y,v,j,\|\gamma,edf}$	Risk/outcome or probability of death given that *edf* happens and the combination is hit by the given type of outcome γ
$PLL_{edf,v,c,o\gamma}$	Potential Loss of Life for a given edf, vulnerability, population category, outcome and type
$PLL_{edf,o\gamma}$	Potential Loss of Life of all populations for a given edf, outcome and type
$r_{i,j}$	Run row Factor for row *i* and combination *j*
$RI_{edf,o\gamma}$	Risk integral for a given outcome
$RI_{edf,\gamma}$	Risk integral total of a given outcome type for an edf
RI_{edf}	Risk integral total for the edf
RI_{i}	Risk integral total for run row *i*
$RI_{edf,i,j,o\gamma}$	Risk integral for an edf, run row, combination and outcome of a particular type
$RI_{edf,i,j,\gamma}$	Risk integral total contribution for outcomes of type γ to the edf total
$RI_{edf,j}$	Total risk integral for the edf and combination
RI_{j}	Total risk integral for the combination

Subscripts

ai	Aversion index
b	Population in a particular building or the outdoor or indoor grid population
c	Population of a particular category
edf	Equivalent discrete failure
i	Run row *i*
j	Run-row combination (column j; summation of individual run rows accounting for run row factors
o	Specific outcome (event, location, weather, direction, position in event tree)
x	East-west location of risk ranking point
y	North-south location of risk ranking point
γ	Effect type (position in event tree; toxic, fire-radiation or explosion-overpressure or combined effects)
v	Vulnerability type (indoor versus outdoor, individual versus societal risk)
A	Area grouping for PLL and FAR reports
f_i	FAR factor for run row *i*

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