EuroCCP

European Central Counterparty N.V.

Margin Model
User Manual

EUROPEAN CENTRAL COUNTERPARTY N.V.

Version 2.1

European Central Counterparty N.V.

D ISCLAIMER

This document has been prepared by European Central Counterparty N.V.(EuroCCP) with due care, however we are not liable for any errors or omissions. In particular, this document offers a description of the risk system of EuroCCP as per November 2017. The actual system can be changed without prior notice. Therefore, there can be discrepancies between this document and the actual risk system of EuroCCP.

The margin calculations and Clearing Rules of EuroCCP -and not this document or any calculation based on this document- determine the obligations of each Clearing Participant.

European Central Counterparty N.V.

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1. Introduction

Correlation Haircut (COH) is a risk system that calculates the market risk of clearing participants of European Central Counterparty N.V. (EuroCCP) on an overnight and intraday basis. It calculates the maximum theoretical loss of a clearing portfolio under a set of (stress) scenarios.

The margin model is based on a scenario grid approach. For each scenario in the grid, the risk system identifies potential profits and losses by using (theoretical) valuation models. The initial margin is determined by selecting the individual scenarios in a correlated way. This ensures a margin offset between positions in correlated products.

The purpose of this document is to describe main components of the Margin model. Furthermore, it gives a description of the risk output, which is provided to the clearing participants on a daily basis.

2. Model overview

COH computes a theoretical worst-case loss (haircut) of a client's portfolio. The general approach is to determine major risk factors for every product, build a scenario grid of profit-loss (P/L), and finally determine the haircut number by shifting risk factors in a correlated manner.

This document is structured in the following way: in this section, we will give a high-level overview of the COH model; in section 3, we will describe the detailed output. COH core risk computations and add-ons are described in section 4 and section 5. Special relationships between products are described in section 6 and finally section 7 contains a listing of parameters used in the margin system.

2.1   Risk per underlying

A margin per underlying is given by the following formula:

$$M_{UL} = P/L \text{ grid of scenarios + spread charges}.$$

The profit-loss (P/L) grid of scenarios is a two dimensional grid with 21 scenarios of the underlying (see section 4.2.2) and 5 scenarios of volatility for each underlying value in a portfolio (an underlying value is a stock, FX rate, index etc.).

2.2   Portfolio risk

The Haircut on a portfolio level can be described using the following formula:

$$H_P = COH \text{ Reference model + Portfolio charges}.$$

COH Reference model is based on Principal Component Analysis (PCA) and is used to select scenarios from the underlying grids in a correlated way. See section 4.2.3 for more details. COH Reference model is applied independently on different product groups:

- Equity
- Fixed income
- Currency

COH also applies a number of add-on on the portfolio level, for example the Liquidity add-on. These charges will be also discussed in section 5 .

3. Output description

3.1 Margin overview

The first page of a margin report gives an overview of the main risk parameters, which are the variation margin and initial margin. It also contains a breakdown of the initial margin by asset class. The output description is provided in Table 3-1 and illustrated in figure 1.

Margin report

European Central Counterparty N.V.

Account ID, account name and date

Account totals

Net. Liq.	138,927,706
Haircut	115,215,206-
Portfolio margin limit	0

Scenario information

Reporting currency	EUR

Haircut per assetclass

Equity	113,637,394-
Currency	1,577,813-

Total crash haircut	72,806,023-
21 day time decay	0

Figure 1: Sample margin overview

Table 3-1: Description of the fields in the haircut overview.

Field	Description
Net. Liq	Collateral value after haircut + Variation margin
Variation Margin	This number is a theoretical value of the portfolio when one would close all positions against valuation prices of this report.
Haircut	Also known as Initial Margin. This number is the maximum theoretical loss of the portfolio when the positions remain unchanged over the liquidation period.
Portfolio margin limit	Add-on amount to cap the difference between the sum of the margins for each product calculated on an individual basis and the margin calculated based on a combined estimation of the exposure for the combined portfolio to 80%.
Haircut per asset class	Here one can find a breakdown of the initial margin per product group in the reporting currency.
Reporting currency	The code of the currency in which the totals are reported.
Total crash haircut	This number gives the summation of the profit and loss values of the lower right scenarios in the underlying profit and loss grids.
21 day time decay	This number gives the change in value of the portfolio when one would hold the portfolio unchanged for 21 days.

The margin overview page is followed by a more detailed breakdown of the margin figures. COH reports a summary of risk figures for each product group. An example of such summary is given in Figure 1.

NIX Equity RF									
Underlying	ISIN	Name	Haircut	Worst case	Prev Hc	Crash Hc	Market value	Theo value	Difference
ALN1V ST UL	FI0009013114	Alma Media Oyj	102-	512-	144-	512	5,731-	5,731-	0
ALO ST UL	FR0010220475	ALSTOM	689-	1,149-	592-	1,149	9,510	9,510	0
ALPHZ ST UL	CH0034389707	ALPIQ HOLDING AG	46-	232-	7-	232	2,458-	2,458-	0
ALSS ST UL	PTALT0AE0002	ALTRISGPSSA	72	358-	105-	358	3,127-	3,127-	0
ALTA ST UL	FR0000053837	ALTAMIR AMBOISE SCA	172-	287-	106-	287-	2,457	2,457	0
ALTIA ST UL	NL0011333752	ATICE NV A	63,014-	315,072-	76,827-	315,072	2,192,610-	2,192,610-	0
ALTIB ST UL	NL0011333760	ALTICE NV B	368,415-	588,872-	16,396-	588,872-	2,647,579	2,647,579	0
ALTR ST UL	FR0000034639	ALTRAN TECHNOLOGIES	0	5,664-	0	5,664	45,129-	45,129-	0
ALV ST UL	DE0008404005	ALLIANZ SE HOLD	738,506-	923,132-	933,041-	923,132-	8,510,369	8,510,369	0
ALY ST UL	GB0000533728	LAURA ASHLEY HLDGS	89-	297-	990-	297	1,855-	1,855-	0
AMAGA ST UL	AT00000AMAG3	AMAGA AUSTRIA METALL	296-	593-	455-	593-	5,930	5,930	0
AMAMC ST UL	ES0109067019	AMADEUS IT HOLDING	19,775-	21,972-	43,780	21,972-	302,445	302,445	0
AMBEA ST UL	SE0009663826	AMBEA AB	166-	333-	209-	333-	3,328	3,328	0
AMDG ST UL	DE0005093108	AMADEUS FIRE AG	610-	1,219-	193-	1,219	10,764-	10,764-	0
AMDI ST UL	FR0004125920	AMUNDI SA	3,808-	4,760-	3,804-	4,760-	50,385	50,385	0
AMEAS ST UL	FI0009000285	AMER SPORTS OYJ	27,347-	34,183-	19,521-	34,183-	303,986	303,986	0
AMEC ST UL	GB0000282623	AMEC FOSTER WHEELER	4,935-	16,449-	2,378-	16,449	139,888-	139,888-	0
AMER ST UL	GB0032087826	AMERISUR RESOURCES	995-	1,990-	57-	1,990	9,213-	9,213-	0
AMG ST UL	NL0000888691	AMG NV	0	190-	1,785-	190	1,157-	1,157-	0
AMNDI ST UL	FR0011020965	ETFS AMUNDI EM ASIA	1,422	2,370-	1,030	2,370	23,706-	23,706-	0
AMP ST UL	IT0004056880	AMPLIFON SPA ORD	1,898-	9,492-	1,819-	9,492	81,661-	81,661-	0
AMPSU ST UL	FR0012789667	AMPLITUDE SURGICAL	0	134-	0	134-	1,342	1,342	0
AMSN ST UL	AT0000A18XM4	AMS AG	38,218	127,392-	8,380	127,392	869,973-	869,973-	0
AMUN ST UL	FR0010892190	ETFS AMUNDI GVT BD	1,229-	3,072-	1,230-	3,072-	30,726	30,726	0
ANA ST UL	ES0125220311	ACCIONA SA	926	4,631-	6,641-	4,631	39,493-	39,493-	0
ANDR ST UL	AT0000730007	ANDRITZ AG	14,323	71,614-	10,382-	71,614	600,085-	600,085-	0
ANEA ST UL	GB0000365774	ANGLO EAST PLANT	310-	443-	4-	443-	3,732	3,732	0
ANHA ST UL	GB00B8HX8Z88	AL NOOR HOSPITALS	11,018-	15,740-	23,234-	15,740-	157,164	157,164	0
ANIMA ST UL	IT0004998065	ANIMA HOLDING	11,460-	14,325-	1,002-	14,325-	104,292	104,292	0
ANND ST UL	DE000A1ML7J1	VONOVIA SE	128,492-	214,153-	18,519-	214,153-	2,899,456	2,899,456	0
ANOD ST UL	DE0007788408	ALNO AG	31-	309-	34-	309-	927	927	0
ANODB ST UL	SE0000472268	ADDNODE GROUP AB	30-	74-	0	74-	745	745	0

Figure 1: Summary of risk per product group.

The following table contains description of the fields used in the summary.

Table 3-2: Description of the fields used in summary.

Field	Description
Underlying	Description of the underlying product.
ISIN	ISIN code of the underlying.
Name	Name of the underlying.
Haircut	Initial margin of the underlying product (and all products linked to it).
Worst Case	Worst case scenario in the grid for the underlying.
Prev Hc	Previous initial margin number. The initial margin observed on the previous business day.
Crash Hc	This number gives the profit and loss values of the lower right scenarios (maximum decrease in value) in the underlying profit and loss grids.
Market value	Market value of the position
Theo value	Theoretical value of the position computed with COH pricing models.
Difference	Difference between market and theoretical value. Note that this is equal to zero as the theoretical value of a cash equity is equal to the market value of a cash equity within the models of EuroCCP.

3.2 Equity

In this subsection, we will describe reporting of an equity grid. The equity grid reports a theoretical profit and loss of the underlying value for different price and volatility scenarios.

ACACIA MINING						
UL product	33A ST UL		- -	-	0	+	+ +
Base product	33A ST	2.11535	12,297-	12,297-	12,297-	12,297-	12,297-
Reference product	NIX Equity RF	2.08241	11,067-	11,067-	11,067-	11,067-	11,067-
Correlation PC1	0.21	2.04948	9,838-	9,838-	9,838-	9,838-	9,838-
Correlation PC2	0.14-	2.01654	8,608-	8,608-	8,608-	8,608-	8,608-
Movement Up	18.44%	1.98361	7,378 -	7,378-	7,378-	7,378-	7,378-
Movement Down	18.44%	1.95067	6,148-	6,148-	6,148-	6,148-	6,148-
Delta	37,337-	1.91774	4,919-	4,919-	4,919-	4,919-	4,919-
Gamma	0	1.88480	3,689-	3,689-	3,689-	3,689-	3,689-
Vega	0	1.85187	2,459-	2,459-	2,459-	2,459-	2,459-
Theta	0	1.81893	1,230-	1,230-	1,230-	1,230-	1,230-
Rho	0	1.78600	0	0	0	0	0
Epsilon	0	1.75307	1,230	1,230	1,230	1,230	1,230
UL Close	1.78600	1.72013	2,459	2,459	2,459	2,459	2,459
UL Volatility	59.47%	1.68720	3,689	3,689	3,689	3,689	3,689
UL Volatility type	EWMA	1.65426	4,919	4,919	4,919	4,919	4,919
Computation type	Relative changes	1.62133	6,148	6,148	6,148	6,148	6,148
Default Volatility	20.00%	1.58839	7,378	7,378	7,378	7,378	7,378
Bottom Volatility	49.03%	1.55546	8,608	8,608	8,608	8,608	8,608
Grid Currency	GBP	1.52252	9,838	9,838	9,838	9,838	9,838
Haircut in EUR	8,393-	1.48959	11,067	11,067	11,067	11,067	11,067
Exchange Rate	0.88	1.45665	12,297	12,297	12,297	12,297	12,297

Haircut	
Haircut	7,378-
Total	7,378-

Currency: GBP	Product: 33A										
ST Product	Position	BasketPos	Closing	Theo close	Delta	Contr sz	Extension	Vola	Hc Val	Hc Vola	Haircut
33A	37,337-		1.78600	1.78600	100	1.00	37,337-	59.47%	1.98361	59.47%	7,378-

Figure 2: Equity grid page of the COH report.

The grid contains 21 scenarios of the underlying and 5 scenarios of the volatility shifts which lead to 105 joint scenarios. The selected haircut scenario is marked red. An example of the equity grid report is given in Figure 2. In the following table we explain the fields that can be seen in the top left part of the equity grid page.

Table 3-3: Descriptions of fields of the equity grid page.

Field	Description
UL product	Underlying equity product.
Base product	Short description of the underlying equity product.
Reference product	This field identifies to which group the product is linked to. For example, equity or fixed income reference.
Correlation PC1	This number gives the correlation between the underlying and the first reference.
Correlation PC2	This number gives the correlation between the underlying and the second reference.
Movement up	This is the maximum price movement up applied in the grid.
Movement down	This is the maximum price movement down applied in the grid.
Delta	This number gives the sensitivity of the portfolio value when the underlying price changes by 1 point. Note that this figure is equal to the unsettled position for cash equity products.
Gamma	This number gives the sensitivity of the delta when the underlying price changes by 1 point. Not filled for EuroCCPs portfolio's.
Vega	This number gives the sensitivity of the portfolio value when the volatility increases by 1%. E.g. from 20% to 21%. Not filled for EuroCCPs portfolio's.
Theta	This number gives the sensitivity of the portfolio when one holds the

Field	Description
	portfolio for 1 day, while keeping other risk parameters unchanged. Not filled for EuroCCPs portfolio's.
Rho	This number gives the sensitivity of the portfolio when all interest rates change by +100 basis points. Not filled for EuroCCPs portfolio's.
Epsilon	This number gives the sensitivity of the portfolio when dividends increase by 1%. Not filled for EuroCCPs portfolio's.
UL Close	Closing market price of the underlying security.
UL Volatility	This number gives the volatility of the underlying that is used to calculate the price range.
UL Volatility type	This value indicates whether the UL volatility is an EWMA (exponentially weighted moving average), default volatility or bottom volatility.
Default volatility	In case no EWMA volatility is available, this value will be used to calculate the price range.
Bottom volatility	In case the underlying volatility is lower than this value, the risk system will use the bottom volatility to determine the price range.
Grid Currency	Currency of the Profit/Loss numbers in the scenario grid.
Haircut margin in…	Initial margin number in the Base (Reporting) currency of the Client.

The initial margin overview table is situated below the 'underlying' description. It contains fields specified in Table 3-4. Note that all the spread charges are reported in three numbers. The first one is the result of a relevant spread charge algorithm, next one is the scaling constant, and the third one is the haircut charge (a result of multiplication of the first two).

Table 3-4: Description of the initial margin table of the equity grid page.

Field	Description
Haircut	Initial margin scenario of the grid.
Equal spread	See the equal spread charge section for details.
Liquidity add-on	See the liquidity add-on section for details.
Total	Final initial margin number after all add-ons applied.

3.2.1 Equal Spread matrices

For equity products the position equal spread matrix and price equal spread matrix can be reported. See for example Figure 4. These matrices will be displayed if the equal-relation is set up between products. Rows of the position equal spread matrix are different codes of the products with the equal-relation. Columns are currencies in which the product is traded.

The price equal spread matrix contains information about the market close price of the products linked in the equal-relation. Rows of this matrix contain the product codes and columns for different countries (currencies).

COH uses net equal spread position and exchange price in its computations. For a detailed description of the equal-relation see section 6.1.

Figure 4: Example of the spread matrices.

3.2.2 Equity position overview

The equity grid is followed by positions overview, see Figure 5. A description of the fields of such overview is given in
Table **3-**5.

Figure 5: Example of the positions overview

Table 3-5: Description of fields of position overview.

Field	Description
Product	Product symbol.
Position	Position in the corresponding product.
Closing	Closing price of the product.
Theo Close	Theoretical close price based on the COH pricing model.
Delta	Sensitivity of the product with respect to the underlying equity.
Contr sz	Contract size.
Extension	Extension is a position size times delta times contract size.
Vola	The underlying volatility.
Hc Val	Value of the product in the margin scenario.
Hc Vola	Underlying volatility used in the margin scenario.
Haircut	Margin value for the position.

3.3 Fixed income

Reporting of the fixed income is similar to the equity grid reporting, but it has some specific features. In this section, we will focus on the differences.

3.3.1 Capital market

For the capital market products changes of the yield are the major risk driving factor. Similar to the equity grid 105 scenarios are computed. 21 rows represent scenarios of yield and 5 columns are scenarios of volatility or spread depending on the product.

3.3.1.1 Bonds

An example of the report for a bond is given in Figure 6. The P/L grid consists of 105 scenarios. Every row has 2 headers with the first number being the scenario of the yield and the second number (the one in brackets) corresponding price of the bond. Five columns represent credit spread scenarios with the spread shift in basis points.

Figure 6: Example of the bond reporting.

Fields of the bond report are very similar to the fields of the equity report. In the following table, we will state only additional and different fields.

Table 3-6: Fields and corresponding description of the bond reporting which are different from the equity reporting.

Field	Description
Delta	In case of a bond, delta is the notional value.
UL Volatility type	Volatility type used to create the scenario grid. For the fixed income products COH uses EWMA volatility.
Implied credit rating	If the credit rating is not available COH computes an implied credit rating based on the market prices.
Bond Category	Bond category.

Product list contains the same information as equity. The only difference is that notional is reported in the position field.

3.4   Extra information

On the last pages of the report, COH prints extra information, which gives additional insight into the total haircut number. An example of such additional information is given in Figure 7. Fields description is given in Table 3-7.

Figure 7: Example of additional information printed in the end of the COH report.

COH also reports the Beta list for each product. Those can be interpreted as a linear sensitivity of returns of the particular underlying product to the changes of references. The Beta list consists of the product identifier, Beta of first and second references and volatility of residuals. An example of beta list is given in Figure 8.

Table 3-7: Fields of additional information

Field	Description
Interest Rates	Zero yield interest rate curves per currencies that are used in COH calculations. Currently not in use by EuroCCP.
Foreign Currency rates	Exchange rates with respect to the base currency.


```
NIX Equity RF PCA Beta list
Product              Beta 1  Beta 2  Vol res
2GBD                 0.024   0.003   0.954
3I                   0.045   0.040-  0.754
47814                0.046   0.068   0.587
5AB                  0.002-  0.020   0.986
A3ME                 0.024   0.069   0.766
AAL                  0.033   0.012   0.903
AALB                 0.052   0.013-  0.742
ABBN                 0.044   0.029-  0.798
ABEN                 0.026   0.001-  0.945
ABFL                 0.040   0.008   0.860
AC                   0.035   0.015   0.888
ACA                  0.026   0.028-  0.916
ACE                  0.033   0.052   0.802
ACOTE                0.037   0.017   0.870
ACSA                 0.045   0.038   0.757
ACX                  0.035   0.007-  0.894
ADAG                 0.006   0.009   0.994
ADEN                 0.042   0.005-  0.847
ADM1                 0.025   0.042-  0.881
ADN1                 0.044   0.040-  0.762
ADPP                 0.028   0.008-  0.931
ADSD                 0.013   0.082-  0.716
ADXN                 0.002   0.013   0.994
AEDR                 0.001-  0.001-  1.000
AEM                  0.020   0.041   0.905
AERL                 0.023-  0.010-  0.951
AF                   0.035   0.028   0.862
AGKPW                0.004-  0.009-  0.996
AGL                  0.026   0.008   0.943
AGN                  0.031   0.003-  0.917
AH                   0.048   0.007-  0.793
AHT                  0.040   0.047-  0.767
AI                   0.036   0.008-  0.890
AIX                  0.034   0.022-  0.881
AJAD                 0.005   0.002   0.998
AKEF                 0.039   0.005-  0.871
AKVER                0.032   0.019-  0.899
AKZ                  0.037   0.006-  0.878
```

Figure 8: Example of the Beta list

Finally, COH reports scenarios of references and corresponding P/L. An example of the reference grid is given in Figure 9. The reference P/L grid is a table with 105 scenarios: 21 rows represent scenarios of the first reference and 5 columns of the second reference. Figure 9 also contains values of yearly volatility of the first and second reference.

NIX Equity RF PCA Vols

Vol type 1	75.853293
Vol type 2	44.036238

NIX Equity RF Haircut

	-13.66	-6.83	0.00	6.83	13.66
23.52	361,751-	348,766-	295,171-	278,456-	236,405-
21.17	355,006-	347,835-	320,776-	274,426-	264,569-
18.82	385,470-	360,542-	347,782-	295,613-	280,217-
16.46	372,305-	357,807-	340,766-	292,028-	284,980-
14.11	392,759-	407,221-	348,837-	327,311-	302,785-
11.76	389,366-	400,457-	360,218-	340,336-	302,277-
9.41	401,189-	418,447-	366,778-	349,329-	298,468-
7.06	428,950-	415,760-	401,860-	364,959-	347,863-
4.70	442,130-	431,483-	413,551-	362,247-	346,543-
2.35	441,384-	425,427-	435,993-	381,976-	373,064-
0.00	456,668-	467,972-	430,514-	408,124-	361,690-
2.35-	456,108-	468,112-	456,369-	429,201-	390,985-
4.70-	466,819-	484,940-	460,938-	432,945-	383,220-
7.06-	501,314-	488,068-	500,939-	444,789-	428,871-
9.41-	509,892-	497,255-	505,737-	445,618-	429,805-
11.76-	519,721-	497,539-	512,333-	468,676-	448,859-
14.11-	527,844-	537,206-	525,830-	506,242-	446,689-
16.46-	528,260-	541,534-	523,766-	513,574-	472,819-
18.82-	561,519-	555,207-	535,281-	527,055-	475,535-
21.17-	570,963-	551,043-	564,186-	538,693-	506,433-
23.52-	558,907-	564,429-	**572,930 -**	541,731-	524,913-

Figure 9: Example of the reference scenarios for equity

4. Core Risk Computations

The margin requirement needs to cover two parts: the current exposure (or variation margin) and the potential future exposure (or initial margin). Variation margin is defined as the (unrealised) profit or loss in the portfolio. Initial margin is defined as the potential future exposure of the portfolio i.e. the potential maximum loss in the portfolio over the time till close out of the portfolio under 'normal' circumstances.

The total margin called by EuroCCP is equal to Max[0;(initial margin – variation margin)]

4.1   Variation margin

The variation margin is influenced by the following variables:
- Position
- (Average) Transaction price
- Current or closing price

The positions and (average) transaction prices are information that is provided to EuroCCP as part of the novation process and are therefore available at all times. The current price / closing price of a product is available through our data vendor.

4.2   Initial margin

To calculate the initial margin of the portfolio, we first estimate the potential movement of each product until the end of the liquidation period. This calculation is based on the closing prices of the past k days. For this period for each product in position the volatility is calculated. Based on the volatility, the potential movement for a product is estimated. See section 4.2.1 for more detail on the volatility calculation.

Having estimated the potential movements for all products individually, we can turn to the estimation of the potential movement of the portfolio as a whole. This estimation is performed by using the Principal Component Analysis (PCA). Through the use of PCA, we can map the potential movement of each position in the portfolio towards the potential movement of the portfolio as a whole. This mapping is not performed with the classical VaR approach but rather it is assumed that the correlation between the individual product and the portfolio as a whole is described by an interval and not a single number. See section 4.2.2 for further detail. The EuroCCP approach safeguards against too much reliance on the correlation number and therefore takes into account that we do not know the correlation for certain but on the other hand if it has been stable for a period, we may assume that it hoovers in a certain interval. As such the EuroCCP approach to the estimation of the potential loss in the portfolio is conservative as it does not set a priori fixed correlations between the products but rather it sets a potential interval in which the correlation moves. This interval is larger when the correlation is smaller.

Once all potential movements for the portfolio are determined, the theoretical P&L for each scenario is calculated. Finally the worst case scenario is chosen as the initial margin for the portfolio.

4.2.1   Volatility estimations

The volatility is calculated and serves as input to estimate the scanning range. Since it is required to have a volatility defined, the following order is applied to ensure that at least a volatility is calculated:

1) EWMA volatility

2) If no EWMA volatility can be calculated, the default volatility is used.

3) If the selected volatility is less than the bottom volatility, the bottom volatility is used.

To limit procyclicality, as required by Commission Delegated Regulation (EU) No 153/2013 article 28, the bottom volatility is set at the 10 year historical volatility as observed in the

market. If only a shorter period of historical price data is available the bottom volatility will be estimated using this shorter lookback period.

The bottom volatility is calculated outside the system and set as parameter in the system once per month.

The Exponentially Weighted Moving Average (EWMA) estimation of volatility is generally used and the volatility and expected return is given by:

$$\sigma = \sqrt{(1-\lambda)\sum_{t=1}^{k-1}\lambda^{t-1}(r_t - \bar{r})^2} \; ,$$

$$\bar{r} = (1-\lambda)\sum_{t=1}^{k-1}\lambda^{t-1}r_t \; ,$$

where,

$\lambda = 0.94$ Parameter of the model.

$k = 250$ Number of historical observations used by COH.

$r_t = \ln(S_t/S_{t-1})$ Log-return on a day t.

S_t Closing price of the underlying (e.g., stock, index, yield proxy) on the day t.

4.2.2 Scanning range

For every risk factor (e.g., stock price, bond yield, etc.) COH computes a number of scenarios. A combination of the maximum and minimum scenarios is called a scanning range. The scanning range $[Max, Min]$ is determined in the following way:

$$M_{up} = n_{up} \times \sigma \; , \; M_{dowm} = n_{down} \times \sigma \; ,$$

$$Max = s_0(1 + M_{up}) \; , \; Min = s_0(1 + M_{down}) \; ,$$

where,

σ Daily volatility of the underlying.

n_{up} / n_{down} Number of standard deviations up/ down. These values are parameters of COH depending on the underlying product group.

M_{up} / M_{down} Movement up/down in percent.

s_0 Closing price of the underlying.

Once boundaries of the scanning range are determined COH divides it into 21 scenarios. Let's consider an example of the computation of the scanning range.

Example

For example, a current stock price is 1.216 and volatility is 47.75%. COH parameters for the equity products are $n_{up} = 5$ and $n_{down} = -5$. First we will compute a daily volatility $\sigma = 0.4775/\sqrt{260} = 0.029613293$. Then we will determine movements up and down (numbers are rounded for this example):

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$$M_{up} = n_{up} \times \sigma = 14.81\%$$

$$M_{dowm} = n_{down} \times \sigma = -14.81\%$$

Finally, the scanning range is determined by:

$$Max = s_0(1 + M_{up}) = 1.216 \times 1.1481 = 1.39607$$

$$Min = s_0(1 + M_{down}) = 1.216 \times 0.8519 = 1.03593$$

An example of the scanning range from COH report is given in Figure 30.

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		- -	-	0	+	+ +
UL product	CETHE ST UL	1.39607	3,141-	3,141-	3,141-	3,141-	3,141-
Base product	CETHE ST	1.37806	2,827-	2,827-	2,827-	2,827-	2,827-
Reference product	NIX Equity RF	1.36005	2,513-	2,513-	2,513-	2,513-	2,513-
Correlation PC1	0.12	1.34205	2,199-	2,199-	2,199-	2,199-	2,199-
Correlation PC2	0.16	1.32404	1,885-	1,885-	1,885-	1,885-	1,885-
Movement Up	14.81%	1.30603	1,571-	1,571-	1,571-	1,571-	1,571-
Movement Down	14.81%	1.28803	**1,256** -	1,256-	1,256-	1,256-	1,256-
Delta	17,444-	1.27002	942-	942-	942-	942-	942-
Gamma	0	1.25201	628-	628-	628-	628-	628-
Vega	0	1.23401	314-	314-	314-	314-	314-
Theta	0	1.21600	0	0	0	0	0
Rho	0	1.19799	314	314	314	314	314
Epsilon	0	1.17999	628	628	628	628	628
UL Close	1.21600	1.16198	942	942	942	942	942
UL Volatility	47.75%	1.14397	1,256	1,256	1,256	1,256	1,256
UL Volatility type	EWMA	1.12597	1,571	1,571	1,571	1,571	1,571
Default Volatility	20.00%	1.10796	1,885	1,885	1,885	1,885	1,885
Bottom Volatility	32.24%	1.08995	2,199	2,199	2,199	2,199	2,199
Grid Currency	EUR	1.07195	2,513	2,513	2,513	2,513	2,513
Initial margin in EUR	1,256-	1.05394	2,827	2,827	2,827	2,827	2,827
		1.03593	3,141	3,141	3,141	3,141	3,141

Figure 30: Example of the scanning range in the COH report.

4.2.3   Reference model

The COH reference model is based on the Principal Component Analysis (PCA). PCA is a statistical technique that is used for dimensionality reduction applications. In COH PCA is used to select correlated scenarios across different underlings. The COH reference model is given by the following linear relationship:

$$r_i' = \beta_{1i}R_1 + \beta_{2i}R_2 + \varepsilon_i,$$

$$r_i = \sigma_i(r_i' + \bar{r}_i),$$

where,

r_i' Standardized log - return of $i-th$ underlying.

R_1 Scenario of the first reference.

R_2 Scenario of the second reference.

ε_i Residual term.

β_{ji} Sensitivity of $i-th$ underlying to $j-th$ Reference.

σ_i Volatility of $i-th$ underlying.

$\bar{r}_i$ Expected return of $i-th$ underlying.

r_i Log return of $i-th$ underlying.

Every combination of scenarios of first and second reference determines a certain scenario of the underlying. By defining different scenarios for the references, one can fully explain the P/L of the portfolio. COH also computes volatilities of the residuals ε_i for every underlying in the portfolio. These volatilities of the residuals are used for computing a potential interval. Let us consider an example of COH PCA computations.

Example

For example, we have 3 stocks in the portfolio namely A, B and C. Each of the stocks is characterised with the following closing prices 50, 70 and 100 respectively. Yearly volatilities are $\sigma_A = 30\%$, $\sigma_B = 20\%$ and $\sigma_C = 10\%$. For simplicity, let us assume that expected returns are zero. Moreover, let us consider the following representation of the COH reference model (beta values):

$$r'_A = -0.54R_1 + 0.82R_2 + \varepsilon_A,$$

$$r'_B = -0.61R_1 - 0.23R_2 + \varepsilon_B,$$

$$r'_C = -0.58R_1 - 0.53R_2 + \varepsilon_C.$$

For this example, volatilities of the residuals are 0.05, 0.22 and 0.18 respectively. For COH parameter $n_{up} = -n_{down} = 6$, scanning ranges and corresponding P/L are given in the table below:

Scenario	A	P/L A		B	P/L B		C	P/L C
1	55.58	5.58		75.21	5.21		103.72	3.72
2	55.02	5.02		74.69	4.69		103.35	3.35
3	54.47	4.47		74.17	4.17		102.98	2.98
4	53.91	3.91		73.65	3.65		102.60	2.60
5	53.35	3.35		73.13	3.13		102.23	2.23
6	52.79	2.79		72.60	2.60		101.86	1.86
7	52.23	2.23		72.08	2.08		101.49	1.49
8	51.67	1.67		71.56	1.56		101.12	1.12
9	51.12	1.12		71.04	1.04		100.74	0.74
10	50.56	0.56		70.52	0.52		100.37	0.37
11	50	0.00		70	0.00		100	0.00
12	49.44	-0.56		69.48	-0.52		99.63	-0.37
13	48.88	-1.12		68.96	-1.04		99.26	-0.74
14	48.33	-1.67		68.44	-1.56		98.88	-1.12
15	47.77	-2.23		67.92	-2.08		98.51	-1.49
16	47.21	-2.79		67.40	-2.60		98.14	-1.86
17	46.65	-3.35		66.87	-3.13		97.77	-2.23
18	46.09	-3.91		66.35	-3.65		97.40	-2.60
19	45.53	-4.47		65.83	-4.17		97.02	-2.98
20	44.98	-5.02		65.31	-4.69		96.65	-3.35
21	44.42	-5.58		64.79	-5.21		96.28	-3.72

For further risk calculations let us assume COH is using 2 standard deviations in the residual interval for stocks A, B and C. We will show selected haircut for the scenario of references $R_1 = 8$ and $R_2 = 3$:

$$r_A' = -0.54R_1 + 0.82R_2 \pm 2 \times 0.05 = -1.86 \pm 2 \times 0.05 = -1.86 \pm 0.10$$

,

$$r_B' = -0.61R_1 - 0.23R_2 \pm 2 \times 0.22 = -5.57 \pm 2 \times 0.22 = -5.57 \pm 0.44$$

,

$$r_C' = -0.58R_1 - 0.53R_2 \pm 2 \times 0.18 = -6.23 \pm 2 \times 0.18 = -6.23 \pm 0.36$$

.

After multiplying by the volatility of the corresponding underlying, we will obtain the following log-returns:

$$r_A = -0.035 \pm 0.002 \,,$$

$$r_B = -0.069 \pm 0.005 \,,$$

$$r_C = -0.039 \pm 0.002 \,.$$

The interval of scenarios to select is:

$$A \in [48.21; 48.39],$$

$$B \in [64.97; 65.68],$$

$$C \in [96.00; 96.43].$$

On the next step we will select corresponding (the closest) scenarios of the potential interval from the grid. The final step is to determine the haircut value, which is the worst case in each of the potential intervals. An example of the scenario grid with selected potential intervals is given in the next table, where red scenario indicates selected haircut and grey range is potential (i.e., residual).

Scenario	A	P/L A		B	P/L B		C	P/L C
1	55.58	5.58		75.21	5.21		103.72	3.72
2	55.02	5.02		74.69	4.69		103.35	3.35
3	54.47	4.47		74.17	4.17		102.98	2.98
4	53.91	3.91		73.65	3.65		102.60	2.60
5	53.35	3.35		73.13	3.13		102.23	2.23
6	52.79	2.79		72.60	2.60		101.86	1.86
7	52.23	2.23		72.08	2.08		101.49	1.49
8	51.67	1.67		71.56	1.56		101.12	1.12
9	51.12	1.12		71.04	1.04		100.74	0.74
10	50.56	0.56		70.52	0.52		100.37	0.37
11	50	0.00		70	0.00		100	0.00
12	49.44	-0.56		69.48	-0.52		99.63	-0.37
13	48.88	-1.12		68.96	-1.04		99.26	-0.74
14	48.33	-1.67		68.44	-1.56		98.88	-1.12
15	47.77	-2.23		67.92	-2.08		98.51	-1.49
16	47.21	-2.79		67.40	-2.60		98.14	-1.86
17	46.65	-3.35		66.87	-3.13		97.77	-2.23
18	46.09	-3.91		66.35	-3.65		97.40	-2.60

Scenario	A	P/L A		B	P/L B		C	P/L C
19	45.53	-4.47		65.83	-4.17		97.02	-2.98
20	44.98	-5.02		65.31	-4.69		96.65	-3.35
21	44.42	-5.58		64.79	-5.21		96.28	-3.72

The haircut value, which correspond to the scenario of references $R_1 = 8$ and $R_2 = 3$ is equal to -10.60.

Schematic representation of a P/L selection in the reference model is provided in Figure 41.
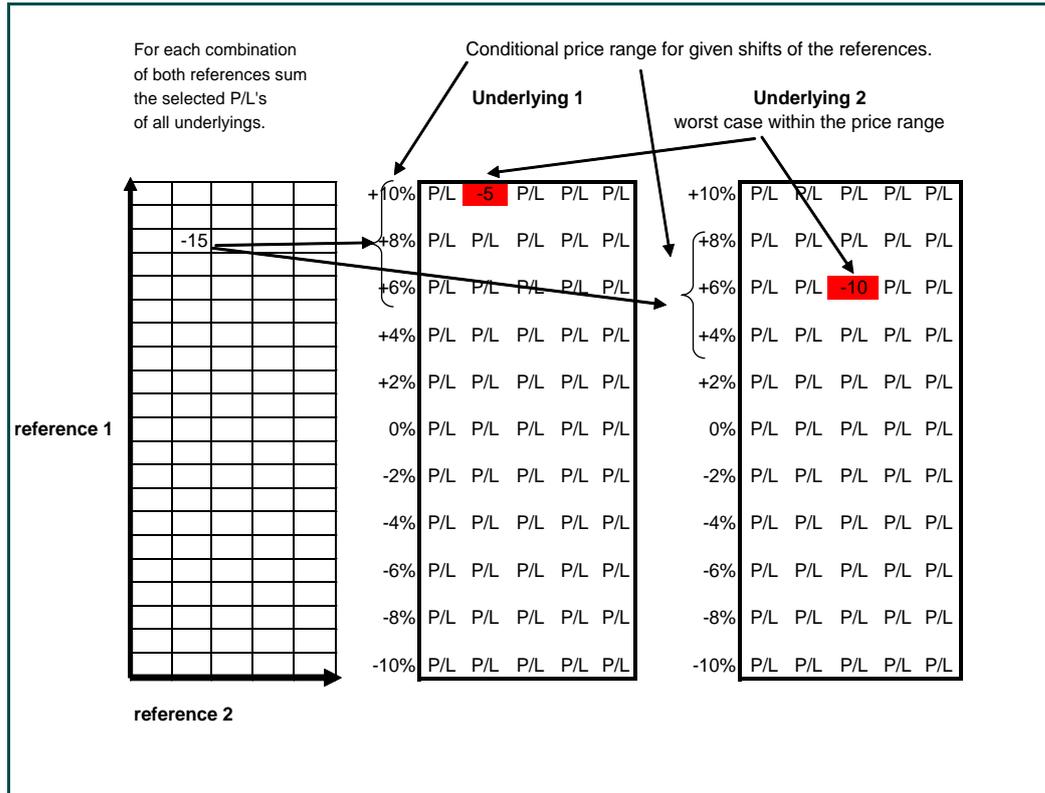
Figure 41: Price interval calculations and P/L selection in the reference model.

4.3   Currency risk

Shifts in FX rates can change the value of a portfolio. The margin system captures this risk by analyzing the potential impact on the portfolio under different FX rate scenarios.

4.3.1   FX Haircut

For each currency that differs from the reporting (base) currency, a market value is calculated which is the summation of the cash amounts plus the mark to market value of the positions. The profit and loss scenarios values are calculated over the amount by changing the FX rate between the foreign currency and the reporting currency, taking into account correlations with other currency exposures that may be part of the portfolio. The correlations between the FX rates are captured by a COH reference model (PCA).

4.4   Fixed Income products haircut

The haircut for fixed income products (e.g. bonds) is computed in accordance with the Regulation Collateral and not repeated here.

5. Add-ons to the margin calculation

5.1 Liquidity add-on

Within the default settings of COH it is assumed that all positions can be liquidated within three trading days at no more cost than represented by the margin requirement of EuroCCP. In other words: the margin model assumes that the liquidity of the stock position is no constraint on the liquidation of the position in that stock. It is possible that there will be occasions where this assumption will not hold especially in cases where the position of a client is large compared to the traded volume in the market.

5.1.1 Definition of liquidity risk

In this context liquidity risk is defined as the risk of being unable to liquidate a position in a timely manner at a reasonable price. The risk is that transaction prices will be substantially different than those quoted prior to transaction and/or prior used as calculation basis for the margin calculation.

5.1.2 Liquidity Risk add-on

As already mentioned in the above, liquidity risk is dependent on the position in an instrument versus the volume in the instrument. We therefore first calculate for a position in security i the time it would take to close out the position under the assumptions made above:

$$LiqPer\,(i) = \frac{Position\,(i)}{VolumePct\,(i)\,*\,MedVol\_20d\,(i)}$$

Where Position(i) is the position in security I,
MedVol_20d(i) is median trading volume[1] (number of shares) during the last 20 working days for a particular security I and
VolumePct(i) is the percentage of daily volume that can be traded without significant impact on the market price of that security i.

Having calculated the time it takes to liquidate a position, we can formulate the liquidity risk add-on as follows:

$$LiqRisk\_add\_on(i) = position\_overdraft\,(i)\,*\,\sqrt{Max((LiqPer\,(i) - liquidatio\ nhorizon\,);0)}\,*$$

$$daily\_scanning\_range\,(i)\,*\,price\,(i)$$

Where Position_overdraft(i) is the position in security i that cannot be liquidated within the liquidation horizon or stated differently: it is the maximum of both zero and (position i minus liquidation horizon times VolumePct of the median volume in i),
Liquidation horizon is the number of days needed to close out a position as assumed in CoH. This number is 3 days currently and
Daily scanning range(i) is the scanning range of the original calculation for security i divided by the square root of the liquidation horizon to scale it to a one-day horizon.
The outcome of the Liquidity Risk add-on calculation will be added on top of the normal correlation haircut figure.

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1 The trading volumes are normally retrieved from the primary market and there is no aggregation of volumes across markets applied.

5.2 Large position margin add-on

To balance the size of the overall financial resources and the margin requirements, EuroCCP has introduced the so-called "Large position margin add-on".

The LP margin add-on formula is the following:

LP Margin add-on = CP stress outcome -/- (CP Collateral + 45% EuroCCP Financial resources)

Applying this formula means that large and extreme stress outcomes are charged a higher margin amount. This approach is a 'polluter-pays' approach and will discourage CPs to take large extreme exposures. An additional benefit is that this formula allows us to apply a dynamic and flexible approach with regards to determining the financial resources.

5.3 Portfolio margin limit add-on

Following Regulation (EU) No 153/2013 Article 27 regarding portfolio margining the amount of margin reduction shall be capped to 80 % of the difference between the sum of the margins for each product calculated on an individual basis and the margin calculated based on a combined estimation of the exposure for the combined portfolio. This limited margin reduction is taken into account by the "Portfolio Margin Limit" add-on.

The Portfolio Margin Limit add-on is calculated as follows:

PML= HCu – 80% * (HCu - HCd) – HCx

Where,
PML: Portfolio Margin Limit
HCd: Initial margin with range of residual of 0 standard deviations
HCx: Initial margin with range of residual of 2 standard deviations
HCu: Worst case scenario

The outcome of the Portfolio Margin Limit add-on will be included in the total initial margin figure. If the Portfolio Margin Limit is below zero, zero is taken as outcome.

5.4 Wrong way risk

Broader than the EMIR definition of wrong way risk, the more general definition of wrong way risk is given as the risk that occurs when exposure to a counterparty is adversely correlated with the credit quality of that counterparty. In short it arises when default risk and credit exposure increase together. We could encounter this wrong way risk for those clearing participants clearing their own issued securities and mitigate this risk by setting a minimum margin requirement. The minimum margin percentage for shares issued by the clearing participant is set at the same stress percentage used for all shares in the sector "Financial Services". Currently this means the scanning range for such securities is set to 30% by applying a bottom volatility of 96.75% for clearing participants clearing their own issued securities.

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6. Product relations and spread charges

Some products are interconnected with one another. This connection (beyond statistical correlation) can be captured by setting relations between products.

For the long/short position in underlying and/or its derivatives COH applies additional charge called a spread charge. The spread charges are reported in a separate table left from the P/L scenario grid.

6.1 Equal-relation

The equal-relation is meant for products where one product is identical to the other but is listed on a different exchange. Both products obtain the same relative movement interval and the products can offset each other completely. An example of an equal-relation is a stock that settles in two different CSDs. In such case, the primary settlement location will be selected; and the closing prices corresponding to that CSD will be used in COH computations. Products that are included into equal-relation are reported under the equity P/L grid.

6.1.1 Equal spread charge

Equal spread risk is applied for long/short positions in products with equal relation. The general approach is to compute size of "overlapping" position, then to multiply it by closing price and certain risk parameter. The result is the equal spread charge. For example, client holds 10 long stocks A from the First exchange and 15 short A from the Second exchange. The overlapping position, which will be used in computations, is 10 stocks.

6.2 Absolute relation

The absolute relation is meant for two products which by definition get the same absolute price movement to be applied for the scanning ranges.

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7. Parameters

A number of parameters are to be set for the COH system. At this moment the following parameters are in place:

Range of the Underlying grid

The parameters below determine the range of the underlying grid.

Product group	# standard deviations up	# standard deviations down
Equity	5	5
Fixed income	5	5
Currency	5	5

Range of the residual

The parameters below determine the range of the residual.

Product group	# standard deviations
Equity	2
Fixed income	2
Currency	2

Range of the PC 1 interval (reference)

The parameters below determine the range of the PC's per product group.

Product group	# standard deviations up	# standard deviations down
Equity	5	5
Fixed income	5	5
Currency	5	5

Range of the PC 2 interval (reference)

The parameters below determine the range of the PC's per product group.

Product group	# standard deviations up	# standard deviations down
Equity	5	5
Fixed income	5	5
Currency	5	5

Minimum range for the underlying grid

Product group	Up	down
Equity	10 %	10 %
Fixed income	3 %	3 %
Currency	3 %	3 %

Furthermore the following parameters are set system-wide:

Product group	Up	down
Equity	10 %	10 %
Fixed income	3 %	3 %
Currency	3 %	3 %

Volatility

Product group	Default volatility	Bottom Volatility
Equity	20 %	10 year historical volatility per ISIN
Fixed income	8 %	Set at the combined stress levels in the maturity buckets and credit rating buckets as defined in the "Acceptable Collateral" document which can be found on www.euroccp.com
Currency	5 %	9.67 %