Term CORRA Methodology - CARR Recommended Approach

1. Overview

This document provides an overview of the Canadian Alternative Reference Rate Working Group's (CARR) recommended methodology for calculating a forward-looking Term CORRA interest rate benchmark. While the primary interest rate benchmark in Canada will be the Overnight CORRA (Canadian Overnight Repo Rate Average), CARR has developed a methodology to support the creation of a robust Term CORRA reference rate for select uses in the transition away from CDOR. The calculated rate is meant to reflect, at a point in time, the CORRA overnight index swap (OIS) rate[1] for the 1- and 3-month tenor. It builds on academic work as well as the term risk-free rates already established in other jurisdictions, including the US and UK, and has been developed by a working group of subject matter experts across the Canadian industry, including the Bank of Canada.

The case for creating a Term CORRA was first mentioned in CARR's 2021 CDOR White Paper, where it was noted that CARR would consult on a potential forward-looking rate. The resulting public consultation found that Canadian non-financial corporates, in particular, had a strong desire for a Term CORRA benchmark, as a term rate would be less operationally complex and facilitate cash flow forecasting. Based on the results of its consultation, CARR has decided that a Term CORRA benchmark would be important for the successful transition of the Canadian loan and trade finance market from CDOR to CORRA. As a result, CARR is establishing the parameters for the creation of an IOSCO-compliant benchmark with the appropriate stakeholders. While most financial instruments will reference Overnight CORRA, CARR is identifying specific use cases for the use of Term CORRA. These use cases will be embedded in the benchmark administrator's licensing arrangements (for more details see CARR's Term CORRA Use Cases).

1.1 Term CORRA tenors

Term CORRA will be a forward-looking measurement of overnight CORRA for 1- and 3-month tenors, based on market-implied expectations from CORRA derivatives markets. The rate will be calculated from 1- and 3- month CORRA futures trading on the Montréal Exchange using both transactions and executable bids and offers in the central limit order book (CLOB) over a specific calculation period.[2] Term CORRA will complement both overnight CORRA and the CORRA Compounded Index that are administered and published by the Bank of Canada.

1.2 Role of the benchmark administrator

The benchmark administrator will be responsible for all aspects of Term CORRA, including ensuring that the benchmark aligns with the IOSCO Principles for Financial Benchmarks, as well as any applicable Canadian regulation. It is expected that Term CORRA and its administrator will be subject to Canadian benchmark regulation under Multilateral Instrument 25-102 *Designated Benchmarks and Benchmark Administrators* (MI 25-102) and Ontario Securities Commission Rule 25-501 (Commodity Futures Act)

[1] OIS rates reflect market expectations for overnight CORRA settings for specific maturity tenors.

[2] As transactions are a key ingredient to the methodology, it should be expected that dealers hedging OIS exposure may impact the calculated Term CORRA rate.

Designated Benchmarks and Benchmark Administrators (OSC Rule 25-501).[3] Under MI 25-102, the benchmark administrator is responsible to assess the reliability and accuracy of CARR's recommended methodology for Term CORRA. Once the benchmark is launched, the benchmark administrator will be responsible for maintaining and updating the methodology as required under MI 25-102 to ensure it remains robust. Governance of changes to the methodology will rest with the benchmark administrator and the benchmark's independent oversight committee, which will oversee any changes to the methodology including requests to consult on significant changes to the benchmark. In line with MI 25-102, significant changes to the methodology will require a public notice be posted, benchmark users and other members of the public be provided a means to comment on the proposed change, and a summary of the comments and a response to those comments be published. It is recommended that the benchmark administrator would not apply any expert judgement in calculating the rate: it would initially be based solely on CORRA futures data from the TMX and could eventually include other transactional data. Under MI 25-102, an explanation of all of the elements of the Term CORRA methodology must be disclosed and published by the benchmark administrator.

1.3 Sustainability

CARR has worked with subject matter experts from across the financial industry to create an IOSCO-compliant, forward-looking, Term CORRA benchmark. Although CARR has endeavoured to create a robust and sustainable benchmark, there are certain dependencies underpinning Term CORRA that mean its long-term sustainability is not guaranteed. In particular, Term CORRA's ongoing viability will depend on the liquidity of the underlying CORRA futures contracts used to derive Term CORRA. If the depth of liquidity in these contracts is not sufficiently robust, the Term CORRA administrator will be required to amend its methodology.[4] If changes to the methodology do not result in a sufficiently robust benchmark, the benchmark administrator will be required either to take the steps necessary to ensure that the benchmark accurately and reliably represents that part of the market or economy it is intended to represent or to cease the publication of the benchmark with appropriate notice, in line with MI 25-102. **CARR therefore expects any users of Term CORRA to have robust fallback language in place that uses in most cases overnight CORRA calculated in-arrears, and to build the operational capacity to transact in these fallbacks should Term CORRA cease to be published in the future.**

2. Methodology

This section describes the methodology that will be used to calculate Term CORRA.

[3] OSC Rule 25-501 is based on, and consistent with, MI 25-102. OSC Rule 25-501 is required in Ontario because MI 25-102 would not apply to Ontario commodity futures law.

[4] The benchmark administrator could change the calculation methodology in a number of ways including, but not limited to:

- expanding the duration of the calculation window;
- adding over-the-counter CORRA OIS transactions (which is also contemplated for Term SOFR); and/or
- changing the curve construction methodology.

Any significant changes to the methodology would require a public consultation under MI 25-102. Changing the methodology could result in the rate moving from a T+0 published rate to a T+1 published rate.

2.1 High level overview of methodology

CARR's proposed Term CORRA benchmark comprises two tenors: 1- and 3-months. The rate is calculated using a waterfall methodology comprised of two levels ("Level 1" and "Level 2"). CARR expects that the majority of time the calculation will be based on the Level 1 approach using CORRA futures transactions and executable bids and offers, with Level 2 acting as a fallback if there is not sufficient liquidity in CORRA futures on a specific day.

Term CORRA rates are calculated as follows:

Step 1) Calculate a single futures mid-price for each individual futures contract (i.e. the first three 1-month CORRA futures and the first two 3-month CORRA futures contracts) using transactions, and a random sample of executable bids and offers in the central limit order book, within an Observation Interval between 10:00 and 12:00 Eastern Time.

Step 2) If there are sufficient transactions and/or limit orders in all the necessary futures contracts to construct the curve, the Level 1 methodology will be used. This methodology constructs a yield curve from the transactions and limit orders and the 1- and 3-month Term CORRA will be calculated from that curve.

Step 3) If there are not sufficient transactions and/or limit orders to use the Level 1 methodology for a specific tenor (i.e. 1-month or 3-month Term CORRA), the Level 2 methodology will be used. This methodology is a fallback version of Term CORRA that is calculated using the previous day's published Term CORRA rate adjusted for any move in historical CORRA rates calculated over the specific tenor.

2.2 Input data

CARR's proposed Term CORRA methodology uses both executed transactions and executable bids and offers in TMX CORRA futures.[5,6]

2.2.1 Observation Interval

Data to calculate Term CORRA are taken during a two-hour interval from 10:00 and 12:00 Eastern Time (the "Observation Interval") to ensure a more accurate representation of the rate. The extended observation interval also means that the term rate is not dependent on individual transactions during a short time window. The time of the Observation Interval was chosen specifically to be after the release of the Bank of Canada's policy interest rate decisions, and the publication of most economic news releases to limit the price volatility in CORRA futures during the Observation Interval.

2.2.2 Time Slots

The Observation Interval will be further divided into twelve 10-minute data windows ("slots") to ensure that a representative rate across the whole interval can be calculated. The benchmark administrator will use as input data (i) transaction prices observed during each slot in the Observation Interval and (ii) a

[5] For more details see: https://www.m-x.ca/en/markets/interest-rate-derivatives/cra

[6] The benchmark administrator may also include in the calculation certain types of conditional level 1 (top of book) orders with the volume adjusted appropriately to mitigate double counting (e.g. BAX-to-CORRA futures spread orders).

snapshot of executable bid/offer CORRA futures prices in the CLOB taken at a random time within the same slot.

2.2.3 Standard Market Size

If an individual slot meets or exceeds a standard market size then that slot is considered 'valid'. The defined standard market size is $1 billion for 1-month and $750 million for 3-month. These sizes reflect (a) the aggregate of transactions effected over the duration of the slot and (b) acceptable bids and offers in the CLOB taken at a random interval at some point in the slot. 'Acceptable' bids and offers are those at or inside 2.5bps from a calculated mid-price, representing a total bid-offer of 5bps or less.

2.2.4 Calculated Slot Price

The benchmark administrator calculates a mid-price for each slot from the sampled best bid and offer. Then a volume-weighted average bid price for the slot is calculated for a standard market sized transaction. The same is done for the offered side of the market. This is done by using the transactions in the slot together with the executable bids/offers that are within +/-2.5bps of the mid-price until the standard market size is reached.[7] The volume-weighted averages are calculated using a weighting system that provides more value to transactions and those bid/offer prices close to the mid-price.[8] This results in a weighted average bid and offer and the mid-price between them is the slot's determined mid-price. If there is insufficient transaction, bid, and offer volume in a slot, then no determined mid-price is available and the slot is invalid for the purposes of calculating a slot price. If the value of the transactions equals or exceeds the standard market size in any time slot, then all transactions in the slot will be used in calculating the volume weighted average price and no sampled order data will be used.

2.2.5 Calculated Specific Futures Price

Where there are between 4 to 12 valid slots in an observation interval the specific futures price can be used in using the Level 1 methodology. The specific futures price is calculated as the median of all the valid slot mid-prices (median will be defined as the middle slot, or if the range is even then the average between the two central slots will be used). If four slots cannot be filled, this futures price will not be available for use in the curve construction.

2.2.6 Curve Construction

To be considered valid, curves must also use a certain minimum number of futures contracts, as follows:

- For the 1-month tenor, valid fixings must be built using at least the first two 1-month futures prices. If this is not the case, Level 2 Methodology will be employed.
- For the 3-month tenor, valid fixings must be built using at least the first two 3-month futures prices and the first three 1-month futures prices. If this is not the case, Level 2 methodology will apply.

Level 1 and Level 2 methodologies can apply separately for 1- and 3-month Term CORRA fixings.[9]

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[7] The standard market sizes are consistent with the methodology for Term SONIA.

[8] Trades are given a weight of 3; bids/offers within 1bp of mid are given a weight of 2; remaining bids/offers have a weight of 1.

[9] Given the requirements for the two tenors, however, either (i) the Level 1 Methodology would apply for both fixings; (ii) the Level 2 methodology would apply for both tenors; or (iii) the Level 1 Methodology would apply for the 1-month tenor and the Level 2 Methodology would apply for the 3-month tenor.

2.3 Level 1 methodology

Under Level 1, Term CORRA will be constructed using the Heitfield and Park methodology developed by the New York Federal Reserve.[10] A path for overnight CORRA rates is determined under the assumption that these rates follow a piecewise constant step function and only move up or down the day after a Bank of Canada Fixed Announcement Date. The benchmark administrator will use TMX CORRA futures, which provide an estimated level of overnight CORRA over a given period (1- or 3-months), to estimate an optimal path for overnight rates so as to calculate 1- and 3-month Term CORRA values.

2.3.1 Calculation Methodology

Let t_0 represent the date for the Term CORRA benchmark and let t represents a day after t_0 that is a Business Day (in accordance with the International Money Market (IMM) calendar), the following notations are used for the calculation of projected overnight CORRA rates:

- M_k: the date of the k-th Bank of Canada Fixed Announcement Date that occurs on or after t_0;
- θ_0: the initial overnight CORRA rate as of date t_0;
- θ_k: the jump size in overnight CORRA rate occurs on the day after the k-th Bank of Canada Fixed Announcement Date.
    - A positive θ_k means the overnight CORRA rate jumps up after the k-th Bank of Canada Fixed Announcement Date M_k
    - a negative means the overnight CORRA rate jumps down after the k-th Bank of Canada Fixed Announcement Date M_k
- $f_{t;\vartheta}$: the overnight CORRA rate as of date t, where $\Theta = (\theta_0, \ldots, \theta_k)$ and K is the index of the last relevant Bank of Canada Fixed Announcement Date
- 1{}: binary function returning 1 if the statement in the parenthesis is true and 0 otherwise.

The overnight CORRA rate for date t can be computed as:

$$f(t;\Theta) = \theta_0 + \sum_k \theta_k * 1\{t > M_k\}$$

The benchmark administrator will solve for the unknown parameter set $\Theta = (\theta_0, \ldots, \theta_k)$ such that the projected path of overnight CORRA rates results in the smallest mismatches for 1- and 3-month CORRA futures prices as determined from the sections below.

2.3.2 Optimization

As is also the case for Term SOFR, in order to determine the optimal path for the overnight CORRA, the benchmark administrator will implement the Broyden-Fletcher-Goldfarb-Shanno algorithm to solve for the parameter set $\Theta = (\theta_0, \ldots, \theta_k)$. Four 1-month and two 3-month CORRA futures contracts will normally be used to cover the Term CORRA computation period up to 3-month tenor, but see the Input data Section 2.2 for circumstances when a smaller number of futures are accepted.

The optimization function is designed to solve the following minimization problem:

[10] Heitfield, Erik, and Yang-Ho Park (2019). "Inferring Term Rates from SOFR Futures Prices," Finance and Economics Discussion Series 2019-014. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/FEDS.2019.014.

$$min_{\Theta}\left\{\left[\sum_{m=0}^{4} w_m^1 * \left(P_m^1 - \hat{P}_m^1(\Theta)\right)^2 + \sum_{q=0}^{2} w_q^3 * \left(P_q^3 - \hat{P}_q^3(\Theta)\right)^2\right]^{\frac{1}{2}} + \lambda * \left[\sum_{k=1} {\theta_k}^2\right]^{\frac{1}{2}}\right\}$$

Where:

- P_m^1 and P_q^3: the observed blended prices of 1- and 3- month CORRA futures contracts with reference month m and reference quarter q, respectively
- $\hat{P}_m^1(\Theta)$ and $\hat{P}_q^3(\Theta)$: the implied value of 1- and 3- month CORRA futures contracts with reference month m and reference quarter q, respectively
- w_m^1 and w_q^3: weighting parameters for pricing errors of 1- and 3- month CORRA futures contracts with reference month m and reference quarter q, respectively
    - $w_m^1$and w_q^3 will be determined as (the number of unset overnight rates for a given contract) / (the total number of overnight resets for that contract). This will typically be 1 except for the partially fixed front contracts, which will have lower weights.
- λ: weighting parameter for penalty function $\lambda = \frac{0.3}{\sqrt{K}}$; where K is the number of scheduled Bank of Canada meetings in the period.

The optimization process produces a yield curve which minimizes the differences between (i) the observed blended prices of 1- and 3-month CORRA futures contracts and (ii) the implied value of 1- and 3-month CORRA futures contracts taken from the curve. Multiple possible "jumps" (i.e. rate changes on meeting dates) may be implied by the same contract prices. To make this jump pattern unique, the penalty function chooses the jump pattern that equalizes the size of jumps. The 1- and 3-month Term CORRA are then implied from the resulting yield curve.

For 1-month CORRA contracts, whose reference month is not the current month (m > 0), the implied value only depends on projected overnight CORRA rates:

$$\hat{P}_m^1(\Theta) = 100 * \left[1 - \frac{365}{N_m^1}\left(\prod_{t \in T_m^1}\left(1 + \frac{f(t;\Theta) * d_t}{365}\right) - 1\right)\right]$$

Where:

- T_m^1: set of Business Days for the m-th month
- N_m^1: total number of calendar days in m-th month
- d_t: the number of calendar days from date t to its next Business Day following the IMM Holiday Schedule, if the next Business Day is no later than the end date of the m-th month; otherwise, d_t equals to the number of days from date t to the end date of the m-th month.

For the 1-month CORRA futures contracts, whose reference month is the current month (m = 0), the implied value can be calculated using published CORRA fixings and projected overnight CORRA rates:

$$\hat{P}_m^1(\Theta) = 100 * \left[1 - \frac{365}{N_0^1}\left(\prod_{t \in T_m^{1-}}\left(1 + \frac{r_t * d_t}{365}\right) * \prod_{t \in T_m^{1+}}\left(1 + \frac{f(t;\Theta) * d_t}{365}\right) - 1\right)\right]$$

Where:

- $T_m^{1+} = \{t \in T_m^1 \mid t \geq t_0\}$
- $T_m^{1-} = \{t \in T_m^1 \mid t < t_0\}$
- r_t: published CORRA fixing for date t

For 3-month CORRA futures contracts, whose reference quarter is not the current quarter ($q > 0$), the implied value only depends on projected overnight CORRA rates:

$$\hat{P}_q^3(\Theta) = 100 * \left[1 - \frac{365}{N_q^3}\left(\prod_{t \in T_q^3}\left(1 + \frac{f(t;\Theta) * d_t}{365}\right) - 1\right)\right]$$

Where:

- T_q^3: set of Business Days for the q-th quarter;
- N_q^3: total number of calendar days in q-th quarter;
- d_t: the number of calendar days from date t to its next Business Day following the IMM Holiday Schedule, if the next Business Day is no later than the end date of the q-th quarter; otherwise, d_t equals to the number of days from date t to the end date of the q-th quarter.

For the 3-month CORRA futures contract, whose reference quarter is the current quarter ($q = 0$), the implied value can be calculated using published CORRA fixings and projected overnight CORRA rates:

$$\hat{P}_0^3(\Theta) = 100 * \left[1 - \frac{365}{N_0^3}\left(\prod_{t \in T_q^{3-}}\left(1 + \frac{r_t * d_t}{365}\right) * \prod_{t \in T_q^{3+}}\left(1 + \frac{f(t;\Theta) * d_t}{365}\right) - 1\right)\right]$$

Where:

- $T_q^{3+} = \{t \in T_q^3 \mid t \geq t_0\}$
- $T_q^{3-} = \{t \in T_q^3 \mid t < t_0\}$
- r_t: published CORRA fixing for date t

Heitfield and Park note that, depending on how the calculation periods for available futures contracts line up, some elements of Θ may not be well identified. To address this, they impose two constraints on the estimation of Θ:

- *Policy Gradualism*. multiple jump patterns for forward rates may lead to the same implied contract prices. For example, a three-month contract price indicating that forward rates will rise during a quarter containing two Bank of Canada announcement dates is consistent: (a) a large increase at the first meeting and no increase at the second (or vice-versa); or (b) equal sized increases at both meeting. To address this, a small positive number will be assigned to λ,[11] in other words assuming option (b) of similar-sized jumps, and hence it will not materially affect the parameter estimates.

[11] $\lambda = \frac{0.3}{\sqrt{K}}$

- *Nine Month Jump Window*. In order to eliminate the need to make assumptions about the timing of as-yet unscheduled Bank of Canada announcement dates, it is assumed that no jumps will occur more than nine months after the as of date.

2.3.3 Computing Term Rates from Projected Overnight Rates

Term Rates are derived by compounding the overnight CORRA rates over 1 and 3 months. The compounding follows conventions listed as below:

$$h(T) = \frac{365}{T} * \left[\prod_{t \in \tilde{T}(T)} \left(1 + \frac{f(t;\Theta) * d_t}{365} \right) - 1 \right]$$

- $\tilde{T}(T)$: the set of Business Days from the term start date to date T days in the future. Each term tenor will start on (and include) two Business Days following the publication day, based on Following convention. The term rate will span the corresponding tenor (e.g. 1-month or 3-month which is represented by T days in the formula) in accordance with Modified Following conventions.
- t: a Business Day in set $\tilde{T}(T)$
- d_t: the number of calendar days from date t to its next Business Day following the IMM Holiday Schedule, if the next Business Day is no later than the end date of Term CORRA rate; otherwise, dt is equal to the number of days from date t to the end date of Term CORRA rate.
- $f(t, \Theta)$: the overnight CORRA rate as of date t

If there are insufficient futures prices to compute a 1-month or 3-month Term CORRA, the Term CORRA calculation for that tenor moves to Level 2.

2.4 Level 2 Methodology

Under Level 2, a fallback version of Term CORRA is calculated using the previous day's published rate. Specifically, the day's setting will equal the calculated backwards-looking compounded rate for the specific tenor (i.e. 1- or 3-month) for today, plus the difference between 1) the previous day's Term CORRA and 2) a backwards-looking rate computed as of the previous business day for the same tenor.

Specifically:

$$R_t = C_t + [R_{t-1} - C_{t-1}]$$

Where:

- R_t: today's Term CORRA rate setting
- R_{t-1}: the previous business day's Term CORRA rate setting
- C_t: backwards-looking compounded rate (of the same tenor) from today
- C_{t-1}: backwards-looking compounded rate (of the same tenor) from the previous business day.

C_t and C_{t-1} are determined as follows:

$$C_t = \left[\prod_{i=t_1}^{t-1}\left(1 + \frac{CORRA_i * n_{i,i+1}}{365}\right) - 1\right] * \frac{365}{n_{(t_1,t)}}$$

$$C_{t-1} = \left[\prod_{i=t_0}^{t-2}\left(1 + \frac{CORRA_i * n_{i,i+1}}{365}\right) - 1\right] * \frac{365}{n_{(t_0,t-1)}}$$

Where:

- $CORRA_i$: CORRA value on day *i*
- $n_{i,j}$: the number of calendar days from *i* to *j*
- t_0: 30 (or 90) calendar days before *t-2*. If t_0 does not fall on a business day, it is moved back to the first preceding business day.
- t_1: 30 (or 90) calendar days before *t-1*. If t_1 does not fall on a business day, it is moved back to the first preceding business day.

This fallback methodology can be used for up to ten business days in a row, after which time the benchmark administrator is expected to assess the underlying liquidity in CORRA futures and any potential changes to the calculation methodology to ensure its robustness. The use of this fallback rate means that the liquidity in the underlying futures market is not sufficiently robust to calculate a transaction or committed quote based rate and therefore potentially raises the question about the longer-term viability of the rate. Therefore, after Level 2 calculations are made for ten consecutive business days, the benchmark administrator's Oversight Committee, together with the benchmark administrator, will meet to determine whether it is possible to amend the calculation methodology so as to ensure that an IOSCO-compliant and MI 25-102-compliant rate can be published, or whether the rate should be potentially wound down in an orderly fashion. Any significant amendments to the methodology would require a public consultation under MI 25-102.

Annex: CORRA Futures Contract Specifications

TMX currently offers a 3-month CORRA future (CRA) and intends to launch 1-month contract in January 2023.

The 3-month CORRA Futures (CRA) contract is a quarterly contract that follows International Money Market (IMM) dates.

- For a given contract, interval from (and including) the 3rd Wednesday of the Contract Reference Month, to (and not including) the 3rd Wednesday of the Delivery Month. The Contract Reference Month is different from the Delivery Month.
- Contract Reference Month: For each contract, the Contract Reference Month is the month in which the Reference Quarter begins.
- Delivery Month: For each contract, the Delivery Month is the month in which the Reference Quarter ends. Example for a June contract: The Reference Quarter starts on IMM Wednesday of June, the Contract Reference Month, and ends with Termination of Trading on the first business day before IMM Wednesday of September, the contract Delivery Month.

The final settlement price is 100 minus the compounded daily CORRA rate over the reference quarter:

$$R = \left[\prod_{i=1}^{d_0}\left(1 + \frac{CORRA_i * n_i}{365}\right) - 1\right] * \frac{365}{d} * 100$$

Where:

- d_0: the number of business days in the reference quarter
- $CORRA_i$: CORRA value on the i-th day of the reference quarter
- n_i: the number of calendar days in the relevant reference quarter on which the rate is $CORRA_i$
- d: the number of calendar days in the relevant reference quarter

$$Final\ settlement\ price = 100 - R$$

Simple interest is accrued to all non-Business Days in the reference quarter (weekends and holidays) based on the CORRA benchmark from the preceding good Business Day. Then all Business Days' interest is compounded.

1-month CORRA-futures are expected to follow a similar methodology.