EUROPEAN CENTRAL BANK

EUROSYSTEM

T2S CHANGE REQUEST FORM			
General Information (Origin of Request) ☐ User Requirements (URD) or GUI Business Functionality Document (BFD) ☒ Other User Functional or Technical Documentation (SYS)			
Request raised by: 4CB	**Institute:** 4CB		**Date raised:** 11/05/2021
Request title: T2S Multi-Criteria Settlement Optimisation			**Request No.:** T2S 0763 SYS
Request type: Common	**Classification:** Maintenance		**Urgency:** Normal
1. Legal/business importance parameter[1]: Medium		**2. Market implementation efforts parameter[2]:** Low	
3. Operational/Technical risk parameter[3]: Medium		**4. Financial impact parameter[4]:** Medium-Low	
Requestor Category: 4CB		**Status:** Implemented	

Reason for change and expected benefits/business motivation:

The general objective of T2S settlement optimisation procedures is to maximise the volume and value of settlement with the available securities and cash resources.
During the T2S project phase the market expressed some additional requirements regarding the settlement of transactions during the optimisation process.
These requirements can be summarized as follows:

1. T2S settlement optimisation engine shall favour the settlement of transactions with a higher level of priority
2. In case of the same level of priority competing for settlement, it shall favour the settlement of transactions with the oldest intended settlement date (ISD)
3. In case of the same level of priority and same intended settlement date, it shall favour the settlement of transactions in a way that maximises the volume and value of settlement (in an optimum balance)
4. It shall use resources for oldest transactions first in order to reduce the time during which a transaction remains unsettled beyond the intended settlement date

The requirements regarding priority and age could have been achieved using a hierarchical optimisation process. However, up to 2019 there was no optimisation solver at the state of the art allowing the design of T2S to achieve this hierarchical optimisation in an efficient manner. It has therefore been agreed during the design phase to handle these requirements in the Mathematical Optimisation Module using weights on pairs of priorities and ages and favour high priorities and/or ages by giving more weight to higher (priority, age).

Unfortunately, this weighting approach showed some weakness in the two last years as some issues were raised by the market regarding some priority and age not respected by the NTS settlement process.
These incidents have been closed vs the solution retained for the T2S design or handled with alternative solutions (e.g., CR-741).

In the meantime, IBM Cplex the solver used in the Mathematical Optimisation Module has released a new feature in 2019 called “Multi-Objective” or “Multi-Criteria” allowing us to apply another solution approach and thus avoid the observed side-effects induced by the weighting approach. An evaluation of this new feature has shown that on tested cases where the weighting approach does not work the usage of this feature results to expected solution.

The aim of this change request is to apply this Multi-Criteria optimisation feature in the Mathematical Optimisation Module algorithms in order to improve the solution found by the optimisation process regarding priority and age requirement.

[1] Legal/business importance parameter was set to Medium because the background of this CR are production incidents, for which alternative solutions have been found in the meantime
[2] Market implementation effort parameter was set to Low because the change does not require a long implementation time and any significant resources on the side of Participating CSDs, CBs and their communities
[3] Operational/technical risk parameter was set to Medium because the CR will modify algorithms which are the core of the T2S settlement functionality.
[4] Low < 100kEUR < Low-Medium < 200 kEUR < Medium < 400kEUR < High < 700kEUR < Very high

Description of requested change:

Reminder: current weighted objective

T2S Night Time Settlement process

During the night-time settlement period, the T2S settlement is split into cycles and sequences defining the settlement process perimeter and scheduling.

- Sequence 0 : Liquidity transfers and cash settlement restrictions;
- Sequence 1 : Settlement instructions related to corporate actions;
- Sequence 2 : Free of Payment (FOP) Settlement instructions for rebalancing purpose;
- Sequence 3 : Settlement instructions related to Central Bank Operations (CBO);
- Sequence 4: All type of settlement instructions, settlement restrictions and liquidity transfers;
- Sequence X: Sequence 4 with partial settlement available;
- Sequence Y: Liquidity transfers related to reimbursement of the "multiple liquidity providers";
- Sequence Z: All liquidity transfers.

Current scheduling of night-time is:

- Cycle 1: Sequence 0, Sequence 1, Sequence 2, Sequence 3 and Sequence 4;
- Last cycle: Sequence 4, Sequence X, Sequence Y and Sequence Z.

The Mathematical Optimisation Module

The Mathematical Optimisation Module[5] runs in sequences 1 to X with a series of settlement optimisation algorithms associated to the current cycle-sequence. Each algorithm tries to find the "best" (i.e. with the highest value of its objective function) set of transactions based on its own optimisation strategy and is executed in sequence to improve the previous settlement ratio of the previous cycle-sequence in a predefined time constraint.

Series of settlement optimisation algorithms are basically composed by three steps:

1. A building step: mathematical optimisation algorithms using IBM Cplex helps to select rapidly a subset of Settlement Transactions which may be part of a good solution;
2. An improvement step: algorithms based on local search theory aim to enhance the previous solution;
3. A reparation step: ad hoc algorithm applies all T2S Business Rules to transform previous "temporary" solution to a final solution (i.e. a settlable collection of Settlement Transactions). Some of those reparation algorithms are using IBM Cplex.

Each step of the optimisation algorithms is guided by its own implementation of the optimisation objective function to find the best reachable solution.

The optimisation function calculate a Balanced Ratio Indicator (BRI). The BRI is today expressed as a linear objective function with different weights for the different level of priority p and age a with ages capped to 3.

$$BRI_\lambda = \frac{1}{\sum_{p,a} Weight(p,a)} \sum_{p,a} Weight(p,a) \times BRI_\lambda(p,a)$$

Where the BRI(p,a) is the balance between volume and value ratio respectively Rvol and Rval

$$BRI_\lambda(p,a) = \lambda R_{Vol}(p,a) + (1-\lambda) R_{Val}(p,a)$$

[5] The Night-Time Settlement (NTS) functional design is described in 'UDFS- T2S NTS Algorithms Objectives'.
More information about the Mathematical Optimisation Module can be found in the scientific paper "Securities and cash settlement framework" in International Conference on Mathematical Optimization Theory and Operations Research (E. Alekseeva et al. ,2020).

In T2S, since the go-live, the lambda value is set to 0.5.

The weights are obtained with the following formula

$$Weight(p,a) = \frac{1}{10^{2(4p-a-1)}}$$

This formula should have ensured a sufficient gap between weights for higher and lower (priority, age). Unfortunately, this does not work in all situations and may end up with transaction with lower priority settled instead of higher priority.

Proposed change: multi-criteria objective

4CB proposes to replace the weighted objective function in the algorithms implemented with IBM Cplex by a hierarchical multiple objectives, these modifications affect three main algorithms: two building algorithms and one reparation/improvement algorithm.

Below a simplified representation of the proposed changes:

Current implementation

Maximize

$$BRI_\lambda = \frac{1}{\sum_{p,a} Weight(p,a)} \sum_{p,a} Weight(p,a) \times BRI_\lambda(p,a)$$

Where

$$BRI_\lambda(p,a) = \lambda R_{Vol}(p,a) + (1-\lambda) R_{Val}(p,a)$$

(p,a) in				
	(Reserved,3)	(Top,3)	(High,3)	(Normal,3)
	(Reserved,2)	(Top,2)	(High,2)	(Normal,2)
	(Reserved,1)	(Top,1)	(High,1)	(Normal,1)
	(Reserved,0)	(Top,0)	(High,0)	(Normal,0)

New implementation

Maximize **multi-objectives**

(Reserved, 3) : BRI_λ (Reserved, 3)

(Reserved,2) : BRI_λ (Reserved, 2)

….

(Top,3) : BRI_λ (Top, 3)

….

(Normal, 0) : BRI_λ (Normal, 0)

Where

$$BRI_\lambda(p,a) = \lambda R_{Vol}(p,a) + (1-\lambda) R_{Val}(p,a)$$

Under the new implementation, for any (priority, age) level an optimisation attempt is executed taking into account all transactions from higher, current and lower (priority, age) levels and the solution obtained from the previous optimisation attempt illustrated as follows:

- The first optimization attempt involves all transactions but maximize only BRI_lambda(reserved,3)
  The solution found after this attempt is the optimal solution for (reserved,3) with BRI_lambda (reserved, 3) = Opt_R3.

- The objective of the second optimization is to maximize BRI_lambda (reserved,2)
  It involves all transactions with a constraint on
  - BRI lambda (reserved,3) >= Opt_R3

  The optimal solution found has BRI_lambda (reserved,2) = Opt_R2 and the solution for transactions R3 remains optimal.

- The objective of the third optimization is to maximize BRI_lambda (reserved,1)
  It involves all transaction with a constraint on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2

  The optimal solution found has BRI_lambda (reserved,1) = Opt_R1 and the solution for transactions R2 and higher remains optimal

- The objective of the fourth optimization is to maximize BRI_lambda (reserved,0)
  It involves all transactions with a constraints on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2
  - BRI_lambda(reserved,1) >= Opt_R1

- The optimal solution found has BRI_lambda (reserved,0) = Opt_R0 and the solution for transactions R1 and higher remains optimal.

- The objective of the fifth optimization is maximize BRI_lambda (top, 3)
  It involves all transactions with a constraint on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2
  - BRI_lambda(reserved,1) >= Opt_R1
  - BRI_lambda(reserved,0) >= Opt_R0

  The optimal solution found has BRI_lambda (top, 3) = Opt_T3 and the solution for transactions R0 and higher remains optimal.

- The objective of the sixth optimization is to maximize BRI_lambda (top, 2)
  It involves all transactions with a constraint on
  - BRI_lambda(reserved,3) >= Opt_R3
  - BRI_lambda(reserved,2) >= Opt_R2
  - BRI_lambda(reserved,1) >= Opt_R1
  - BRI_lambda(reserved,0) >= Opt_R0
  - BRI_lambda(top, 3) >= Opt_T3

  The optimal solution found has BRI_lambda (top, 2) = Opt_T2 and the solution for transactions T3 and higher remains optimal.

  Etc…
-

.

This new implementation:

- will be introduced at least in cycle-sequences 4 and X whereas the preceding cycle-sequences are less subject to the described weakness of the weighting approach because the optimisation problem to solve is easier (less transactions competing for the same resources).

- will require performance tests in a wide range of production data benchmarks in order to assess the impact on the whole framework execution time and efficiency. According to the tests results it may be necessary to find a trade-off between the hierarchical multiple objectives and the weighted objectives and/or to keep, for example, the reparation algorithm unchanged while preserving the improvement achieved by this new implementation with the other algorithms.

Submitted annexes / related documents:

Outcome/Decisions:

*CRG on 25 May 2021 : the CRG agreed to launch the preliminary assessment of CR-763.

*CRG on 09 November 2021: the CRG agreed to recommend CR-763 for authorisation by the T2S Steering Level

*PMG on 19 November 2021: the PMG agreed to launch the detailed assessment of CR-763 with a view of scoping in Release 7.0

*CSG on 17 November 2021: the CSG agreed to authorise CR-763

*NECSG on 18 November 2021: the NECSG agreed to authorise CR-763

*AMI-SeCo on 19 November 2021 : the AMI-SeCo agreed with the CRG recommendation of CR-763 for T2S Steering Level Authorisation

*MIB on 24 November 2021: the MIB agreed to authorise CR-763

* CRG on 28 February 2022: the CRG agreed to recommend to the PMG the inclusion of CR-763 in the scope of R7.0

*PMG on 09 March 2022: the PMG agreed to recommend the inclusion of CR-763 in the scope of R7.0

*OMG on 18 March 2022: the OMG identified an operational impact from the inclusion of CR-763 in R7.0

*MIB on 29 March 2022: the MIB approved the inclusion of CR-763 in the scope of R7.0, subject to CSG and NECSG resolution.

*CSG on 30 March 2022: the CSG approved the inclusion of CR-763 in the scope of R7.0.

*NECSG on 30 March 2022: the NECSG approved the inclusion of CR-763 in the scope of R7.0.

Documentation to be updated:

Preliminary assessment:

- **Financial Impact:** Medium-Low
- **Impacted modules:** SETT
- **Impact on other Eurosystem Services or Projects**: No impact
- **Risk Analysis:** No risks has been identified during the preliminary assessment
- **Findings:**

The impacts of the requested modifications on the optimisation process have been widely presented in the description of the requested changes of the CR.

The modifications of the objective function affect three main algorithms: two building algorithms and one reparation/improvement algorithm.
A preliminary assessment of these changes show different degree of complexity on the modification and tuning needed for these three algorithms:

- First building algorithm : used in sequence C1S4 **– with a medium complexity foreseen**
- Second building algorithm : used in sequences C1S1, C1S2, C1S3, C2S4 and C2SX (with partial settlement allowed in this later) **– with a high complexity foreseen**
- Reparation/improvement algorithm : used in sequences C1S4, C2S4 and C2SX (with partial settlement allowed in this later) **– with a high complexity foreseen**

In addition, 4CB foresees that it might not be necessary to have this new implementation in both buildings and reparation/improvement algorithms. This will be assessed through performance tests on production data involving only the Mathematical Optimisation Module.

4CB propose to proceed by steps:

- First step with a focus on C1S4 sequence and thus on the First building and Reparation/improvement algorithms.
- Second step with a focus on C2SX sequence and thus the second building and Reparation/improvement algorithms with partial settlement allowed.
- Third step with a focus on the remaining sequence and thus on the second building and Reparation/improvement algorithms with no partial settlement allowed.
- For each step considered above - to develop a POC (Proof of concept) to provide some performance analytics and ensure that no specific risks are posed by the objective function new implementation.

Only a prototype and volumetric tests on a relevant sample (at least 20 business dates of production data) would allow evaluating concretely the impact of these changes and the possibility to go to production with the new implementation for each step.

For <u>each considered step</u> above the assessment impact is:

- **Low for the functional impact**
- **Low medium for the development impact.**

Detailed assessment:

EUROSYSTEM ANALYSIS – GENERAL INFORMATION

T2S Specific Components		Common Components
LCMM		
	Instructions validation	
	Status management	
	Instruction matching	
	Instructions maintenance	
	Penalty Mechanism	
Settlement		
	Standardisation and preparation to settlement	

X	Night-time Settlement	
	Daytime Recycling and optimisation	
	Daytime Validation, provisioning & booking	
	Auto-collateralisation	
Liquidity Management		
	Outbound Information Management	
	NCB Business Procedures	
	Liquidity Operations	
T2S Interface *(as of June 2022 without Static Data Management, Communication for SDMG, Scheduler, Billing)*		**Eurosystem Single Market Infrastructure Gateway** (from R6.0 June 2022)
	Communication	Communication
	Outbound Processing	Outbound Processing
	Inbound Processing	Inbound Processing
Static Data Management *(until June 2022)*		**Common Reference Data Management** *(from R6.0 June 2022)*
	Party data management	Party data management
	Securities data management	Securities data management
	Cash account data management	Cash account data management
	Securities account data management	Securities account data management
	Rules and parameters data management	Rules and parameters data management
Statistics and archive		**Statistics and archive**
	Statistical information (until June 2022)	Short term statistical information
	Legal archiving (until June 2022)	Legal archiving (from R6.0)
		Data Warehouse (from R6.0)
Information *(until June 2022 containing reference data)*		**CRDM business interface** *(from R6.0 June 2022)*
	Report management	Report management
	Query management	Query management
		Communication
		Outbound Processing
		Inbound Processing
Operational Services		
	Data Migration (T2S DMT)	Data Migration (CRDM DMT, from R6.0)
	Scheduling (until June 2022)	Business Day Management (from R6.0)
		Business Day Management business interface (from R6.0)
	Billing (until June 2022)	Billing (from R6.0)
		Billing business interface (from R6.0)
	Operational Monitoring	Operational and Business Monitoring
	MOP Contingency Templates	

Impact on major documentation		
Document	**Chapter**	**Change**
Impacted GFS chapter		
Impacted UDFS chapter		
Additional		

deliveries for Message Specification (UDFS, MyStandards, MOP contingency templates)		
UHB		
Impacted GDPR message/ screen fields		No impact
External training materials		

Links with other requests				
Links	Reference		Title	

OVERVIEW OF THE IMPACT OF THE REQUEST ON THE T2S SYSTEM AND ON THE PROJECT

Summary of functional, development, infrastructure and migration impacts

Following the preliminary assessment review, the breakdown in steps have been removed, and the feature will be delivered as a single version. Nevertheless, the efficiency and/or feasibility assessment will still be performed on an algorithm basis.

The modifications of the objective function affect three main algorithms: two building algorithms and one reparation/improvement algorithm.

The preliminary assessment of these changes showed a different degree of complexity on the modification and tuning needed for these three algorithms, detailed assessments showed:

- First building algorithm: used in sequence C1S4. This algorithms is already “multi-objective-friendly” as it processes small transactions batches, limiting the overall performance loss caused by the multi-objective optimisation;
- Second building algorithm: used in sequences C1S1, C1S2, C1S3, C2S4 and C2SX (with partial settlement allowed in this later). Though this algorithm also processes small transactions batches, its internal behaviour has several mechanism that needs a deep reworking to accommodate multi-objective;
- Reparation/improvement algorithm: used in sequences C1S4, C2S4 and C2SX (with partial settlement allowed in this later). This algorithm is tied to the “blended” optimisation objective. A number of deep changes must be performed in this algorithm.

As 4CB foresees that it might not be necessary to have this new implementation in both buildings and reparation/improvement algorithms, a series of performance testing will be performed as soon as the three Proof of Concepts have been developed. The results of those tests will allow assessing the exact content of this CR’s implementation.

Main Cost drivers

- Update of the NTS Optimisation documentation
- Implementation of the multi-objective version of the objective function in the three mentioned algorithms

Impact on other TARGET Services and projects

No impact has been identified.

Summary of project risk

No risk identified.

Security analysis

No adverse effect has been identified during security assessment

15 February 2022

Cost assessment on Change Requests

T2S-763-SYS – T2S Multi-Criteria Settlement Optimisation			
One-off	Assessment costs* - Preliminary - Detailed	 2,000.00 10,000.00	 Euro Euro
One-off	Development costs	282,321.19	Euro
Annual	Operational costs - Maintenance costs - Running costs	 24,757.22 0.00	 Euro Euro

*The relevant assessment costs will be charged regardless of whether the CR is implemented (Cf. T2S Framework Agreement, Schedule 7, par. 5.2.3).