BANK OF FINLAND DISCUSSION PAPERS

23 • 2003

Harry Leinonen – Kimmo Soramäki
Research Department
1.10.2003

Simulating interbank payment and securities settlement mechanisms with the BoF-PSS2 simulator

Suomen Pankin keskustelualoitteita
Finlands Banks diskussionsunderlag

Suomen Pankki
Bank of Finland
P.O.Box 160
FIN-00101 HELSINKI
Finland
☎ + 358 9 1831

http://www.bof.fi

BANK OF FINLAND
DISCUSSION PAPERS

23 • 2003

Harry Leinonen* – Kimmo Soramäki**
Research Department
1.10.2003

Simulating interbank payment and securities settlement mechanisms with the BoF-PSS2 simulator

The views expressed are those of the authors and do not necessarily reflect the views of the Bank of Finland or the European Central Bank.

* Corresponding author: Research Department, Bank of Finland, e-mail: harry.leinonen@bof.fi.
** Directorate General Payment Systems, European Central Bank, e-mail: kimmo.soramaki@ecb.int.

Suomen Pankin keskustelualoitteita
Finlands Banks diskussionsunderlag

http://www.bof.fi

ISBN 952-462-082-0
ISSN 0785-3572
(print)

ISBN 952-462-083-9
ISSN 1456-6184
(online)

Suomen Pankin monistuskeskus
Helsinki 2003

Simulating interbank payment and securities settlement mechanisms with the BoF-PSS2 simulator

Bank of Finland Discussion Papers 23/2003

Harry Leinonen – Kimmo Soramäki
Research Department

Abstract

The simulation technique provides a new means for analysing complex interdependencies in payment and securities settlement processing. The Bank of Finland has developed a payment and settlement system simulator (BoF-PSS2) that can be used for constructing simulation models of payment and securities settlement systems.

This paper describes the main elements of payment and settlement systems (system structures, interdependencies, processing steps, liquidity consumption, cost and risk dimensions) and how these can be treated in simulation studies. It gives also examples on how these elements have been incorporated in the simulator, as well as an overview of the structure and the features of the BoF-PSS2 simulator.

Key words: simulations, simulator, payment systems, clearing/settlement, and liquidity

Maksujärjestelmien ja arvopaperien selvitysjärjestelmien simuloiminen BoF-PSS2-simulaattorilla

Suomen Pankin keskustelualoitteita 23/2003

Harry Leinonen – Kimmo Soramäki
Tutkimusosasto

Tiivistelmä

Simulointitekniikka tarjoaa uuden tavan tutkia maksu- ja selvitysjärjestelmien monimuotoisia riippuvuuksia. Suomen Pankki on kehittänyt maksu- ja selvitysjärjestelmäsimulaattorin (BoF-PSS2), jota voidaan käyttää rakennettaessa simulointimalleja maksu- ja selvitysjärjestelmistä.

Tässä tutkimuksessa kuvataan maksu- ja selvitysjärjestelmien pääelementtejä (rakenteet, riippuvuudet, käsittelyvaiheet, likviditeetin käyttö sekä kustannus- ja riskitekijät) sekä miten nämä voidaan sisällyttää simulointitutkimuksiin. Työssä on myös esimerkkejä siitä, miten nämä elementit on toteutettu simulaattorissa ja kuvaus simulaattorin rakenteesta ja piirteistä.

Avainsanat: simulointi, simulaattori, maksujärjestelmä, clearing/selvitys, likviditeetti

Contents

1 Introduction

Interbank payment and securities settlement mechanisms are the main facilities for transferring monetary claims and assets between financial institutions. These systems transfer many times the value transferred by cash instruments or retail payments.

The infrastructure has gradually grown into a complicated interactive network of systems that transfer claims and assets at the domestic and international level. Integration of these systems has resulted in critical interdependencies. The configurations found around the world have evolved to address local needs, customs and process organisation patterns. Technical solutions depend on when the systems were implemented. This has resulted in a wide variety of configurations; some configurations and system features are better suited to processing specific transaction flows. Suitability and efficiency can be assessed against objectives defined for financial systems, which also vary over time and region. Typical system design objectives include low counterparty risk, quick throughput, low liquidity consumption and low settlement costs.[1]

The characteristics of different payment and securities settlement systems are difficult to analyse with traditional econometric tools and econometric models are often too general to describe systems at the level of detail needed to capture differences arising from various design parameters.

Simulations, on the other hand, provide the possibility to get closer to reality and make detailed analysis. Simulations can use actual production transaction flows and exactly mimic the specific features of each system, and thereby give more precise and policy-relevant results for the specific environment of interest. They can also be used to provide empirical data on rare events (such as bank failures) or imagined system designs and structures. Simulations, of course, have limitations in optimisation analysis. Generally, only a 'what if' type of enumeration is possible, which always leaves the possibility for undiscovered better solutions.

The aim of this paper is to describe:

– general elements present in payment and securities settlement systems,
– the most interesting aspects of analysis with these systems, and
– possibilities to use simulations to study these dimensions.

This paper serves also a background document for new version of the Bank of Finland Payment and securities settlement Simulator (BoF-PSS2). In presenting

[1] For information and studies on different arrangements see Borio-Russo-Van den Bergh (1992), BIS (1990 and 1997), and ECB (2001).

the general elements found in payment and securities settlement systems, it simultaneously describes in general terms the structure and features of the simulator. An overall description of the simulator can be found in appendix 1. Detailed documentation is posted at www.bof.fi/sc/bof-pss. The simulator is freely available for central banks and research institutions.

The paper is organised as follows: Chapter 2 presents the general features and structures found in payment and settlement systems. Chapter 3 describes the interdependencies between and within systems. In chapter 4 the payment and settlement process is discussed. Chapter 5 describes the cost and liquidity aspects of settlement systems.

2 General features of payment and securities settlement systems

Payment and settlement systems can be categorised according to the transaction types they process, ie customer transfers (payment systems), interbank settlement transfers (settlement systems) or a combination of both. Payment systems process different types of transfers (credit transfers, direct debits, checks, etc) between customer accounts. Pure settlement systems are used solely for interbank settlements and no end-customer information is conveyed. Interbank claims usually originate from payment systems and securities settlement systems representing settlement for batches of individual payments. In a mixed system, customer payments and interbank settlements are processed in parallel.

Securities settlement systems process customer transfers of securities, mainly in book-entry format. While payment and securities settlement systems today are clearly separated, the technical process for transfers related to monetary currencies and book-entry securities are essentially the same. In both types of systems, accounts representing funds or securities are credited and debited.

Payment systems may also be categorised as retail or large-value payment systems. This distinction has been important because of the different risks involved and (at least in the past) differences in service speed and efficiency. Most retail payment systems are currently settled on a net basis using very simple algorithms. In these systems, the liquidity impact and settlement risks are generally low and therefore no sophisticated liquidity and risk management tools are warranted. The opposite is true for large-value payment systems, which often contain sophisticated risk and liquidity management features.

The traditional approach to processing payments was end-of-day net batch processing, whereby payments were collected by the banks in daily batches and handed over to payment systems that cleared them over the following days. Interbank settlement for such payments typically took one to three days. Today, batch systems operate with settlement cycles as short as every 30 minutes. Such systems are called deferred net settlement systems (DNS).

Thanks to real-time processing capabilities, payments can now be processed individually and immediately. Real-time processing is mainly used for large-value transfers; the bulk of retail payments are still made in deferred batches. Real-time processing should gradually expand to all kinds of payments in response to customer service requirements and the growth of e-commerce. Real-time payment systems fall into two groups: the real-time gross settlement systems (RTGS) of central banks and private continuous net settlement systems (CNS). Interbank settlement transfers in RTGS systems are directly booked on central bank accounts, ie payments and settlements are processed simultaneously. In CNS systems, payments are booked immediately, while final settlement, eg with central bank money, is typically delayed until the end of the day.

In true real-time processing, the liquidity need is fixed by the processed payment flow so it cannot be influenced. In fact, the liquidity need can be smoothed by deferring payments (eg queuing) and by netting queued payments between banks with opposing queued payment flows. This situation also gives the possibility to save interbank settlement liquidity when all payments do not require immediate processing. This has resulted in the emergence of a third group of systems, hybrid systems, which combine features from real-time and deferred net settlement systems. Most large-value payment systems currently operated by central banks are RTGS systems, but they continually acquire an increasing number of hybrid features for preserving liquidity, optimising the use of liquidity and resolution of gridlock situations.

Gross-based real-time processing is the stated goal of securities processing systems. In most cases, however, such systems actually only deliver a type of deferred real-time processing, which takes place several days after the securities trade was agreed. Thus, the transaction processing of securities settlement systems is typically T+3, although T+5 systems can even be found. Given that securities settlement systems involve so much risk, the current trend is to move from deferred net settlement to deferred real-time settlement. Internationally, the yet-to-be-achieved objective has for some years been to move to T+1 real-time settlement. Limiting risks, increasing settlement speed and removing barriers for efficient cross-border transfers have been very topical issues regarding securities settlement systems.[2] Securities settlement should eventually move to true real-time T+0 processing (ie settlement immediately when the deal is made).[3] Indeed, a true real-time system can already be found in the Czech Republic.[4] Some

[2] See BIS (1995), EU Commission (2001, 2002 and 2003) and Group of Thirty (2003).

[3] See Leinonen (2003).

[4] See ECB (2002).

systems also permit securities lending in real-time, which can be seen as the beginning of an expanded approach to real-time processing.

Systems may also be categorised as public or private systems depending on the settlement institution. The settlement institution is the institution across whose books transfers between participants take place to achieve settlement within the settlement system (BIS 2001). In most cases, the central bank is the principal settlement institution in domestic payment systems. The settlement asset in such systems is central bank money, ie claims against the central bank. For large value payments, the most common settlement asset is central bank money.[5]

The settlement institution in a payment or securities settlement system can also be a private entity such as a commercial bank or a financial institution specifically created to act as a settlement institution (eg limited purpose bank). In such systems, the settlement asset is commercial bank money, ie claims against private financial institutions. These systems generally have an added risk as the private settlement institution may go bankrupt. The bankruptcy risk of a central bank, in comparison, is almost nonexistent. Reducing the amount of risks that the settlement institution takes can reduce its probability of failure and the associated risk.

Some countries have a two-tiered settlement hierarchy, whereby a small number of large banks settle on the books of the central bank, while a large number of small and intermediary banks settle with the facilities of the larger banks. Savings and co-operative banks may also maintain an internal settlement bank as an intra-group settlement institution and as the external gateway to other banks or payment systems. A multi-tiered structure adds new risk and processing layers. Modern technology supports flat network-based structures with direct ITC contacts between all parties.[6]

In securities settlement systems, central securities depositories (CSDs), central counterparty clearing houses (CCPs), central banks and private banks can function as settlement institutions. In international securities processing, in particular, private settlement institutions currently play a major role.

The increasing flow of cross-border payments has resulted in a growing demand for multi-currency processing and settlement possibilities. Until recently, most international transfers were settled through the correspondent networks of international banks. Today, there is a clear move towards international clearing and settlement systems. There is also a distinct preference for central bank settlement of systemically critical systems.

The finality of payments and settlement has become more important with increasing cross-border payment flows over several jurisdictions. Customers and

---

[5] See BIS (2003).

[6] See Leinonen, Lumiala and Sarlin (2002).

participants need clear rules defining when a transfer is final and irrevocable. The Directive on settlement finality[7] has harmonised the EU legal rules on this issue.

The BoF-PSS2 simulator can be used to study the impact of many of the developments in payment and settlement systems described above. The simulator contains the basic features for RTGS, DNS and CNS processing. It can process large transaction volumes (several million) and the number of participants can be high (tens of thousands). A participant can further have several accounts that can be used for identifying different currencies or types of book-entry securities.

3 Interdependencies in the payment and settlement process

3.1 System hierarchy

Payment and settlement systems generally take on a hierarchical structure where different types of transactions are handled in different systems. Obligations arising from these systems are settled in interbank settlement systems. To reduce the liquidity need, interbank settlement can be concentrated into one settlement institution, typically the central bank and its RTGS system. There are several reasons for this. A central bank is neutral and provides a common settlement institution for all participants. Credit risk and reserve requirements are eliminated, standing facilities and lender-of-last resort support are available, and the central bank can enforce regulations/recommendations on systemically important payment and settlement systems.

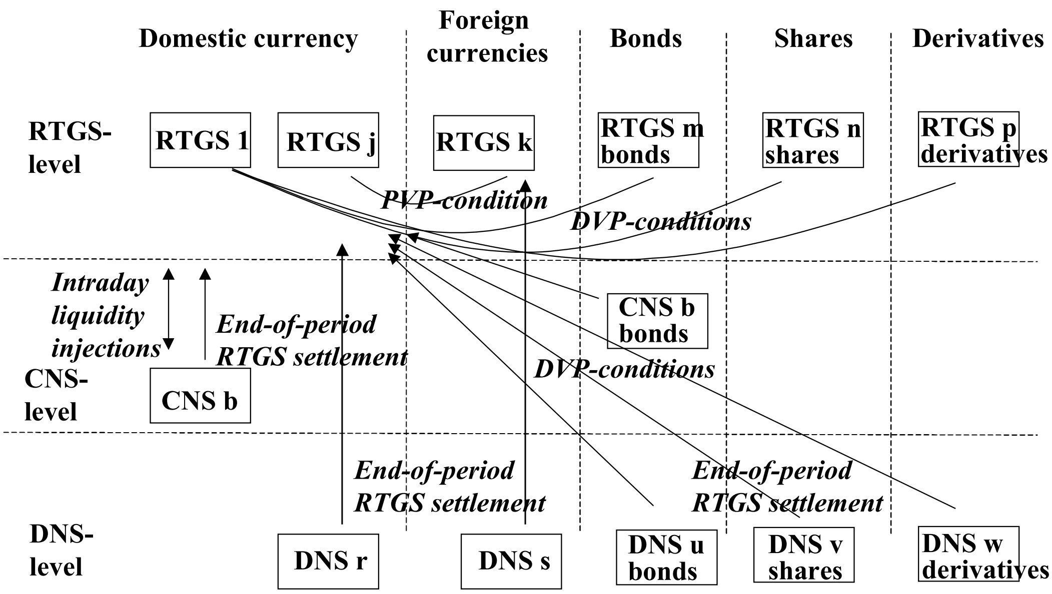
As regards retail payments, cheques are often handled separately from card payments. Credit transfers and direct debits may also be processed in separate systems. Domestic payments are normally processed apart from foreign payments. Securities settlement transactions are processed in special systems, which are often differentiated into systems for interest-bearing and equity instruments. The result varies from country to country depending on the number of factors. In some countries, the private sector has been eager to build payment system infrastructure; in others, it has been a public task. Sometimes new developments have resulted in completely new systems while in other cases old systems have been enlarged and upgraded.

The final end-of-day settlement typically occurs in public RTGS systems. This is especially the case for high-value payments, but private settlement institutions are occasionally used. The settlement positions from the other systems

[7] Directive 98/26/EC of the European Parliament and of the Council of 19 May 1998 on settlement finality in payment and securities settlement systems.

are transferred by different means from the other (ancillary) systems to the RTGS system by the end of the day. Figure 1 describes the general structural possibilities.

Figure 1. **The hierarchical structure of payment and securities settlement systems**



The RTGS level is generally the highest level as most other systems eventually settle on this level. RTGS systems can be used solely for interbank settlement or for transportation of individual payment transactions as well.

CNS systems can be considered private RTGS systems that normally settle at end of day in RTGS systems. However, these systems often use various kinds of swap or liquidity injection methods to reducing their internal risk positions (which imply interfaces with the RTGS systems). Sometimes private systems can 'autonomously' settle using central bank RTGS systems. In such cases, the private system transfers central bank liquidity into a separate account held by the central bank or the system itself on behalf of the clearing parties. All transactions are then booked on these accounts. Examples of CNS systems with RTGS interfaces are the international CLS, the French PNS and US-based CHIPS systems. In all these systems liquidity is transferred into special accounts to reach full collateralisation. Examples of partly collateralised and limit-based systems are the European Euro1 and the POPS system in Finland. Participants in these systems use intraday liquidity swaps to free credit caps and an end-of-day settlement mechanism to square the positions in the RTGS systems.

DNS systems are typically different types of Automated Clearing Houses (ACH) and thereby private ancillary systems using RTGS accounts for end-of-day settlement. The ACH routes individual payments and calculates net positions for end-of-day settlements.

There can also be a number of systems operating in parallel at the same level with intersystem transaction flows. RTGS systems and securities settlement system can have direct links with similar systems. The European TARGET system is a good example of interacting RTGS systems.

A hierarchy of interdependent systems contains different types of synchronisation problems. Transactions generated in one system have to be processed in the other system. The liquidity is shared by the systems. It should be able to flow between these systems and should be available according to the needs of the different systems. Swap and liquidity injections can be used as methods of liquidity transfer. Interdependence increases also contamination risks. Problems in one system can affect the other system, for example in a crisis scenario RTGS problems in one system can hinder processing in the international CLS system, which affect in turn other RTGS systems.

It is possible to build many types of system hierarchies with the BoF-PSS2 simulator. The transactions sent from one system can be received by any participant (account) in any other system in the same simulation. There can be a large number of systems in the same simulation. Intersystem accounts are automatically generated for maintaining the intersystem balances. Specific features and settlement algorithms can be specified separately for each system. The simulator can therefore contain eg TARGET-type structures with a large number of interconnected RTGS systems. It can also contain typical domestic structures with one RTGS system as the main system and a number of ancillary systems processing customer payments, securities, etc.

Simulations can also be used to assess different settlement modes, eg if the system moves from net settlement to gross settlement, or when additional settlement cycles are introduced. Such changes are likely to have an impact on the liquidity requirements of the participants, but also on their submission patterns of payments to the processing. Unless the submission patterns are also simulated, this will need to be controlled when the simulation results are assessed. The impact on payment queues can also be studied when systems are simulated with varying levels of liquidity available to participants.

3.2 Transaction types and interdependencies

A basic payment consists of a debit and a credit booking. A basic free-of-payment (FOP) securities book-entry transaction consists of an asset debit and an asset credit booking. In both cases, the systems are closed loops and the total amount of funds on participant accounts in a system remains the same.

Central banks and CSDs are in the position to increase the total available balance of liquidity and assets. Other settlement institutions can also increase the credit balances by extending more loans. From the system participants point of view these are external transactions, but technically these are often done over special settlement institution accounts that resemble normal participant accounts.

To ensure simultaneous and dependent deliveries, PVP, DVP, and DVD (payment-versus-payment, delivery-versus-delivery and delivery-versus-delivery) processes have been established. The PVP process in used when settling currency deals, ie the two payment transactions in different currencies are processed only if both can be made final simultaneously. The DVP process is used for settling securities deals by requiring simultaneous settlement of the payment and asset legs. The DVD process can be used for ensuring securities credits by making the delivery of borrowed securities and their collateral dependent on each other. Most countries and most securities settlement systems require DVP-based settlement to reduce risks.

The simulator provides the possibility for PVP, DVP and DVD transfers within an RTGS system, between different RTGS systems and within a DNS system. PVP, DVP and DVD transactions are identified and matched based on an explicit link code that is provided by the user for each transaction. Simulations can be used to quantify the exposures that arise in unsynchronised settlement of currencies or securities. Likewise, they can be used to quantify the added liquidity requirements (or delays) when the two legs of the transactions need to be effected simultaneously.

4 The general process of interbank settlement

4.1 Steps in payment processing

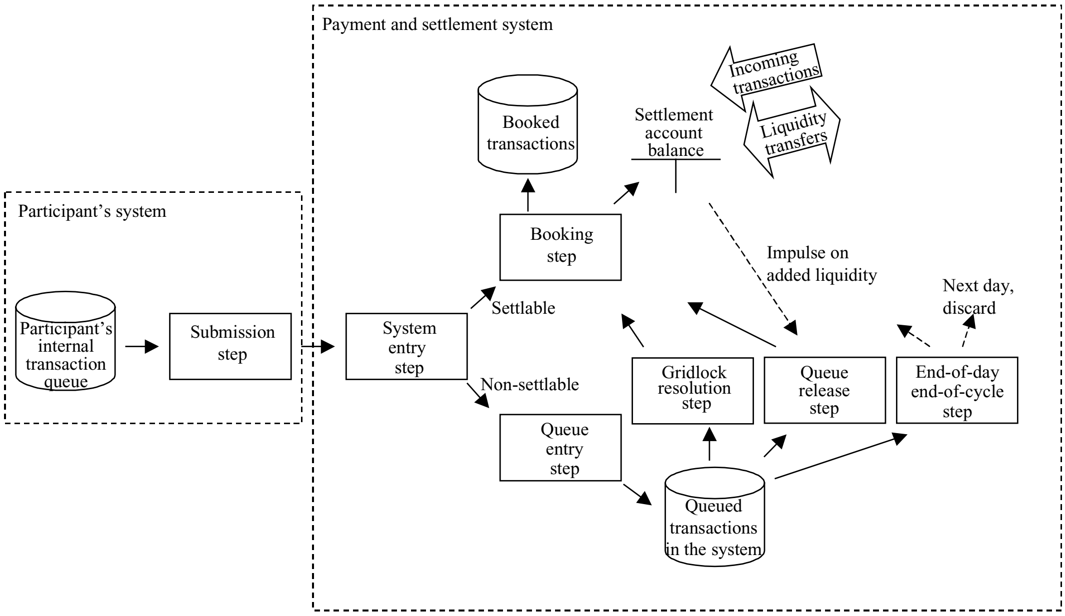
All payment and securities settlement transactions consist of a debit leg and a credit leg. Funds are moved from one interbank settlement account to another, and the customer liabilities are booked on customer accounts in the banks' systems. As a consequence of the dematerialisation of securities certificates, the transfer of securities consists merely of debits and credits to securities accounts. However, settlement of a security deal requires that both the ownership of the security and the payment are transferred.

System participants perceive the system as a flow of outgoing and incoming transactions that result in a settlement balance. The actions of one participant affects the flow of his outgoing transactions, while the actions of other participants and the system design affect the flow of his incoming transactions. Consequently, there are continuous changes in settlement balances. Rules and requirements set by the settlement institution or agreed among the participants thus impact settlement balance, credit availability, etc. The settlement features of the system are generally developed to support efficient settlement of transactions.

The process within a payment and securities settlement system can be separated into general steps or processes (also see Figure 2):

a. **Submission**, whereby the participant sends a new transaction for processing to the system, possibly from an internal transaction queue.
b. **Entry**, whereby the system determines whether the transaction in question can be directly booked either completely or partly (step c), queued for deferred settlement (step d), or rejected and resubmitted later.
c. **Booking**, whereby transactions eligible for booking are booked on settlement accounts as debits to senders and credits to receivers.
d. **Queue entry**, whereby transactions that are ineligible for booking are transferred to the waiting queue, and where the instruction may be modified (eg split the transaction into several smaller ones).
e. **Gridlock resolution**, whereby algorithms for simultaneous settlement of multiple queued transactions are applied to identify a subset of transactions from the queues that can be booked without breaching risk management or other constraints set for the system. Transactions can further be netted bilaterally or multilaterally, and for a sub-group or for all participants.
f. **Queue release**, whereby queued transactions are released as soon as they become eligible for booking (eg due to added liquidity provided by incoming transactions from other participants or liquidity injections).
g. **End-of-settlement cycle**, whereby the handling of transactions that will remain ineligible for booking until the end of the settlement cycle is determined.

Figure 2. **The processes/steps in payment sand settlement systems**



Payment and securities settlement systems display varying complexity. The basic elements of submission, entry and booking steps are available in all systems, while queuing-based functions depend on the availability of a queuing mechanism and related sub-functions.

In the case of securities or foreign exchange settlement systems, mechanisms for synchronising the transfer of the security and the payment, or two currencies may additionally be present (delivery-versus-payment or payment-versus-payment processing).

The process within the simulator follows the structure described in Figure 2. The simulator design is modular and separate algorithms are used for the different steps. The user can select among several algorithms for each step. The algorithms provided as part of the software should cover the most common settlement conventions. Users can also construct their own custom modules with special features not covered by the provided algorithms or for testing new solutions. The library of simulator algorithms should increase in the coming years.

4.2 Transaction flows

The structure of the payment flows has a considerable impact on liquidity requirements and credit positions. Most of settlement features of modern systems have the general objective of reducing liquidity requirements or risk exposures or increasing settlement speed by rearranging the settlement order of the transaction flow. Payment flows with large intraday variations generally consume more resources than synchronised flows in both directions. Participants can smooth flows by changing submission patterns.

Figure 3. **Examples of alternative transaction processing orders and liquidity impact**

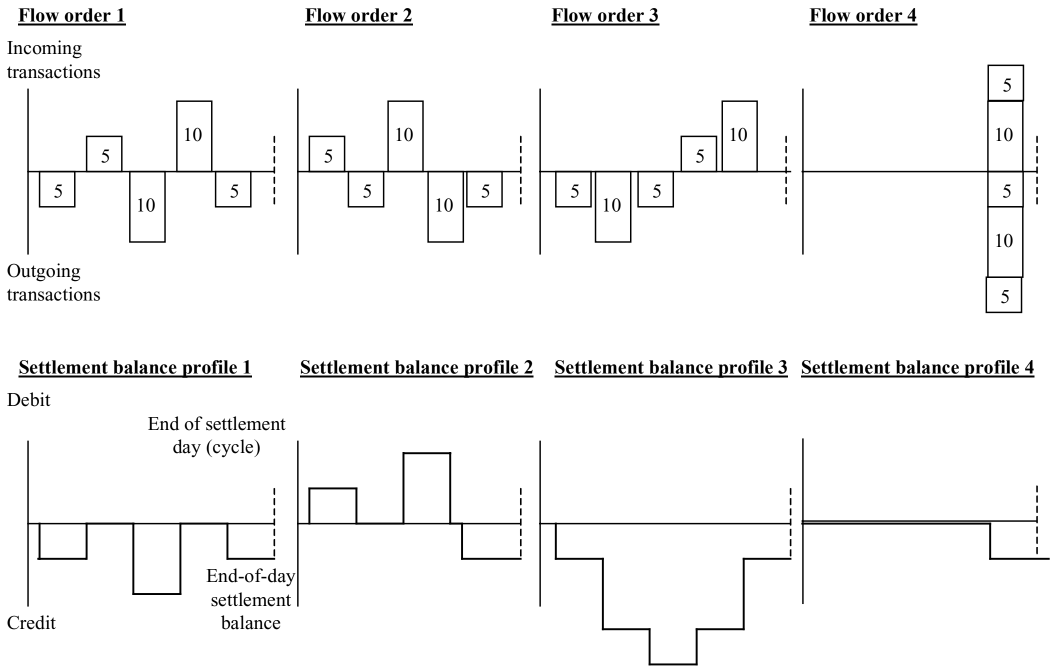


Figure 3 gives examples of the impacts of alternative flow orders on the liquidity needs of a bank. All four examples share the same transaction flow, which results in an end-of-day balance of minus 5 units. In the first example, the bank continuously runs a deficit or zero position towards other banks (or the settlement institution). In example 2, the bank can make its intraday position positive or at least zero for most of the day by rearranging the outgoing transfers, eg by queuing payments that would cause the balance of the bank to go below –5 units. Only the final transaction creates a deficit position. In example 3, incoming payments are delayed (for instance, due to a technical problems somewhere in the system), while the bank in question submits its outgoing payments early in the day. Here, the bank is subject to a large deficit throughout the day. The case 4, all transactions are delayed to the end of the day and processed simultaneously.[8]

Currently, there is a clear difference between overnight and intraday liquidity costs. Overnight delays in delivery are more costly than intraday delivery

[8] For analysis of intraday pattern of payments in Fedwire see McAndrews and Samira (2002), and in TARGET see ECB (2003).

differences, so participants are motivated to ensure that their anticipated and planned overnight positions are reached. There is greater flexibility in planning overnight positions when the bulk of transactions are processed early in the day, so the market can choose to introduce certain market practices to be followed that require early submission of transactions (especially small and mid-size transactions).

Large-value transactions and ancillary system settlements consume liquidity. To benefit from the continuous off-setting in RTGS systems, the market participants might agree that certain transactions are submitted within a certain time interval to help liquidity planning.

Simulations can be used to assess the impact of altered payment flows by simply modifying the submission times of payments in the underlying data. Such changes might be caused by policy changes in the payment system (eg differential pricing or cost of intraday credit), altered market practices or disturbances in the markets (eg delays in payment submission by the banks due to uncertainties in the market or technical failures). Simulations can be used to determine the impact on payment queues and liquidity requirements due to the altered payment flow.

Simulations can also be used to find processing timetables and patterns that would preserve liquidity. The probable effects of new market conventions can be studied via simulations by reformatting the transaction flows according to the new conventions.

4.3 Controlling transaction flows

The transaction flow has a considerable impact on liquidity positions and credit risk exposures. Settlement systems therefore often provide procedures by which the transaction flow can be monitored and controlled with greater synchronicity of funds received and sent to preserve liquidity.

The first control point lies within the sending participant's internal system, where the decision on when to submit the transaction to the central payment and securities settlement system is made. The central system may have a pre-submission storage to which participants' internal systems can send instructions in advance. The transactions can be released from the pre-submission storage based on parameters and rules employed for this purpose, eg a submission time in the instruction.

The most common processing order in payment systems is FIFO (= first in, first out). FIFO is used to release payments from queues that have built up, eg in response to a lack of liquidity. Because transactions have different urgency, instructions are often prioritised to allow more important transactions to bypass the FIFO order. Other queuing orders are also possible. For example, releasing payments in size order starting from small transactions will likely reduce the average queuing time per transaction (although this still probably delays large transactions). In some systems, participants may also reorder the transaction queues according to their preferences (eg the UK's CHAPS system).

Splitting transactions gives a possibility to use the available liquidity more efficiently. Splitting can be done using two main conventions: by defining a maximum transaction size according to which larger transactions are split or by using the available liquidity in full to create a part of the current transaction that could be settled.

Hoarding behaviour can also be found in settlement systems. Participants may delay transactions to reduce their own liquidity needs, which in turn can cause congestion at the end of the day if other participants also delay their transactions. To control fair reciprocity, multilateral or bilateral sending limits can be used. If bilateral limits are used, a participant will only release new payments to counterparties that have released the anticipated flow of transactions.

In the simulator, transaction flows must be defined separately for each system. Historical payment data are generally used for these transaction flows. When the characteristics of the system are changed (eg optimisation methods are tested) the participant behaviour will likely also change. Simulations can, however, also model participant behaviour. The submission algorithm determines the transaction flow to the system. The only submission algorithm currently available submits the payments to the settlement systems in time order. Submission algorithms that decide for each participant when and which payments should be submitted, therefore might be worth developing to bring greater dynamism to the model. Alternatively, rules for participant behaviour in existing system might be studied.

For the control of transaction flows within the system, the simulator provides queuing based on pure FIFO or FIFO with priority. The FIFO order can also be bypassed. The user can also use user-defined fields for creating custom queuing orders. To have an unambiguous queuing order the last sorting field is always the transaction ID. Splitting of transactions can be done by using a fixed maximum transaction size or by splitting transactions according to available liquidity. Parallel accounts can be used for introducing hoarding behaviour and keeping liquidity on separate accounts.

4.4 Gridlock resolution features

We use the definition for gridlock presented in Bech and Soramäki (2001 and 2002), where gridlock in a settlement systems is defined as a situation where there is insufficient liquidity to settle given transactions one by one in a specific order, but there is enough liquidity to settle these simultaneously by a netting procedure. There are several algorithms for solving gridlock situations.

Splitting transactions was described as a transaction control feature, but it can also be seen as a gridlock resolution feature. For example, if two participants have transactions with each other queuing and one of the participants has even a small amount of liquidity available, splitting according to available liquidity can process part of the original payment. This liquidity inflow to the receiver of the payment may trigger settlement of other payments.

Bilateral offsetting is a bilateral process that can solve the gridlock between two parties by netting transactions in the waiting queue. Offsetting can take place in different order, eg by FIFO, priority or size. Offsetting algorithms that work in a specific order are undemanding from the computational standpoint, while an algorithm that tries to determine the maximum transaction value to offset irrespective of transaction order may become computationally very complex in the case of many queued transactions which has a very large number of possible alternatives.

Full multilateral netting is a very simple case to solve, ie all transactions in the queue from all participants are netted and the net balance is booked on the settlement account. However, if there is a lack of liquidity to cover the negative balances of participants, the entire multilateral netting has to be discarded and possible partial multilateral netting attempted instead.

Partial multilateral netting means that some transactions or participants are removed from the netting procedure to identify a subset of transactions that can be settled in accordance with the system's risk management rules and other rules. As in bilateral offsetting, removing transactions can be done in a given queue order, which makes the computational task easier. Transactions are removed one by one from the queues of participants that lack liquidity until a solution is found that satisfies the liquidity constraints. In the case of many participants and long queues, it is a computationally non-trivial task to find an efficient algorithm to solve the problem without a queue order constraint. One possibility to improve the netting rate might be to try out a number of partial netting solutions with different queue orders in succession eg FIFO first and then size order.[9]

The need for and effects of gridlock resolution depend on the available liquidity and the urgency of settlement. There are hardly ever transactions in queues when participants have ample liquidity. Hence, there gridlock situations are rare and there is little need for gridlock resolution algorithms. Netting always requires the payments to stay in the queues for a while to let material for netting pile up. When all transactions are so urgent that they cannot be allowed to queue,

[9] See Günzter, Jungnickel and Leclerc (1998) and Ganz, Günzter and Jungnickel (1998) for a discussion on partial netting algorithms for payments and securities settlement respectively.

participants have no other option than to ensure sufficient liquidity for immediate settlement.

Figure 4. **Examples of the impact of liquidity distribution (eg gridlock and deadlock)**

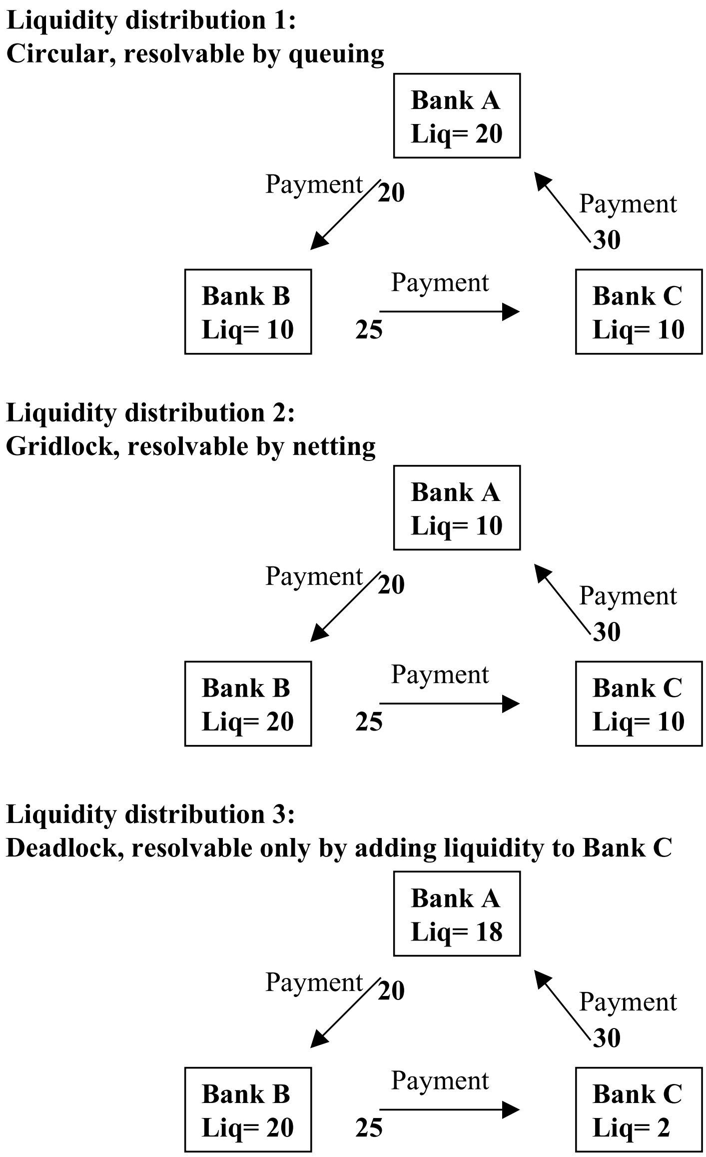


Figure 4 shows three typical situations. In the first example, the situation can be resolved by Bank A paying Bank B, which is paying Bank C, which in turn is paying Bank A. Here, Bank A has so much liquidity that it can start the circular process. In the second example, a typical gridlock situation, no bank has enough liquidity to make a payment by itself, but when incoming and outgoing payments are netted and the available liquidity is used, the payments can be settled. In the last example, a deadlock, Bank C has no way to make its payment because the liquidity from the incoming payment is still insufficient to cover the outgoing payment. This, in turn, makes it impossible for A to make its payment and B to make its payment.

The simulator contains a full multilateral netting algorithm and a partial netting algorithm as described in Bech and Soramäki (2001). For the partial netting algorithms, different types of queue orders can be defined. The output tables contain detailed statistics on every netting session.

Simulations can be used to test and compare the various optimisation methods. They can be helpful in selecting the best gridlock resolution, splitting, or bilateral offsetting algorithm for the system and in assessing its effects in terms of reduced liquidity requirements and delays in payments. Such simulations can not only be performed to see the impact at a day-to-day level, but also to assess how such features can remedy abnormal situations such as delays caused by market uncertainty or the effects of participant being unable to fulfil their obligations in the system.

Simulations can be used to quantify the need for any overnight funding or the value and number of transactions that remain unsettled (eg in the event of a participant failure) if funding is not available. It can also be used to test the effectiveness of various gridlock resolution algorithms in their ability to clear queues at the end of the day.

4.5 The need for liquidity

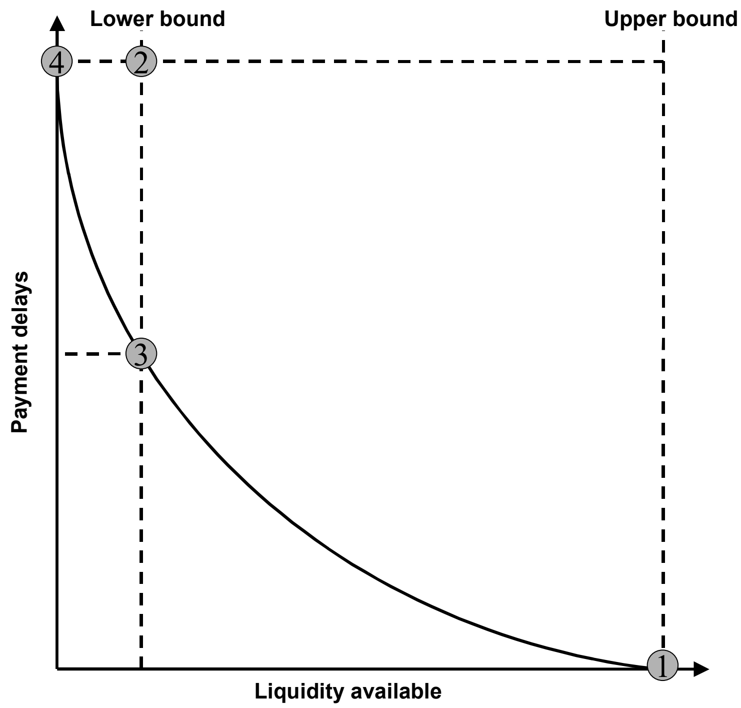
Payment processing requires liquidity, ie assets to pay for interbank claims arising from payment transfers. One form of liquidity is the possibility to have negative positions ie credit limits, whereby the settlement institution grants the necessary credit. This, of course, creates credit risks. Much attention has been put on reducing credit risks in payment and settlement systems. Most systems have currently strict limits on intraday credits. Participants can only have negative positions on the settlement account (towards the system or towards the settlement institution) up to a given limit, which is decided based on credit risk evaluations. When the central bank is the settlement institution, banks are often allowed to use the reserve deposits at the central bank as settlement assets.

Participants requesting for intraday credit often have to put up collateral to secure their limits. These limits can be fully or partly collateralised. Some private systems demand full collateralisation in central bank money and a squaring of accounts when the end-of-day settlement is performed. Some systems such as the US Fedwire charge for intraday overdrafts instead of requiring collateralisation of the positions.

If processing stops when limits are reached, some systems employ liquidity injections or swaps to free the limits. Liquidity can be transferred from another system or another account to the account with insufficient liquidity. Sometimes injections are automated, eg between TBF, the French RTGS system and RGV (Euroclear France), the securities settlement system.[10]

To preserve liquidity and/or limit counterparty risk, bilateral limits or filters can be used to reduce the outflow of liquidity. Such a system prioritises payments towards participants depending on the flow in the opposite direction. Maintaining bilateral limits in a system with a large number of participants creates some overhead (the general dimension of the table would be N*(N–1) individual limits).

Figure 5. **Lower and upper bound of liquidity**



There must be sufficient liquidity in the system to process payments. If every participant has enough funds to settle all transactions when submitted, the liquidity available is at or above upper bound (point 1). The upper bound is defined as the liquidity amount above which any additional liquidity will remain unused. When some or all participants have less liquidity than the upper bound, payments cannot be settled immediately and must be delayed. Where this is done by an automatic queuing facility, the trade-off in terms of liquidity and delay is a

[10] See ECB (2001).

convex curve as shown in the figure above[11]. The more liquidity is reduced, the longer the delays. This is explained by the increase of gridlocks and deadlocks in the system when liquidity is reduced[12].

The minimum amount of liquidity required to settle all payments submitted during a day is called the lower bound of liquidity. The lower bound of liquidity equals the net amount of incoming and outgoing payments for a bank, or zero if the inflow of funds is higher than the outflow. If all participants in the system have this amount of liquidity available, the system is at point 2 in the figure for end-of day net settlement systems or at point 3 for RTGS systems with an automatic queuing facility. In an end-of-day settlement system, the liquidity usage is minimised and the delay is maximised. In an RTGS system with an automatic queuing facility, the relationship between liquidity needs and delays can be improved, and thus the payment delays for point 3 are significantly lower than for point 2. The RTGS system is, however, very likely to be gridlocked at the end of the day with some payments remaining unsettled if gridlock resolution is not applied.

In case one or more participants have less than the lower bound of liquidity, some payments will necessarily remain unsettled. When liquidity is reduced to zero (point 4), all payments are delayed until the end of the day and remain unsettled unless participants have offsetting positions that can be settled by a partial net settlement algorithm.

The upper bound of liquidity for a system can be determined in the simulator by making a RTGS simulation in which all participants have been granted unrestricted intraday credit. The resulting minimum balances will be the upper bound of liquidity required for immediate processing without queuing. The end-of-day balances in this simulation will be the lower bound of liquidity provided that a netting procedure is applied in the end of the day.

4.6 System configuration elements

The features and decision parameters of a particular system configuration can be categorised as follows:

1. Processing and settlement mode (eg real-time or deferred, bilateral or multilateral and gross, hybrid and net settlement).
2. Connections or relationships to other systems (eg ancillary system interfaces).
3. Limits on accounts and net positions.

---

[11] For a more detailed discussion on the trade-off curve, see Koponen and Soramäki (1998) and Leinonen and Soramäki (1999).

[12] See Bech and Soramäki (2001).

4. Transaction control features (eg prioritising, queuing, reordering and splitting).
5. Gridlock resolution (eg bilateral off-setting, partial netting and multilateral netting).
6. DVD or PVP support.
7. End-of-day procedures (eg processing of non-settled transactions).
8. Tariff and pricing parameters (eg transaction pricing, fixed tariffs, intraday interest rate and delay costs).

In addition to features described in earlier chapters, end-of-day procedures are important to system participants. At the end of the day or the end of a settlement cycle, some transactions may remain in the waiting queues that cannot be settled with the available liquidity. In such cases, there are three options available: discard them, transfer them to the next day or grant/inject additional liquidity to make processing possible. In some cases, the open hours of the system may be extended to give participants or service providers more time to solve the situation by getting more liquidity, submit missing transactions, etc.

In a net settlement system, the lack of liquidity or a credit limit restriction may lead to postponement of the entire net settlement session or implementation of some sort of partial netting algorithm, which can imply unwinding of some of the transaction flow. This, in turn, has implications on the finality of transfers.

In order to cover costs, the services of payment systems generally priced according to a mix of transaction-based, fixed and start-up tariffs. The settlement service provider can affect the behaviour of participants and choice of system. For example, if transaction tariffs are high, bunching and the use of alternative routes become issues. High fixed tariffs can motivate smaller banks to pool their resources and cooperate to share fixed costs. These cost elements affect the settlement system structure and market shares over the long run.

Service providers can also price the usage of credit. If credit is needed and it is costly then participants have an interest to delay payments to avoid negative balances for as long as possible. This, however, results in end-of-day congestion when there are no processing rules or customer agreements stipulating faster transfers. To avoid congestion at certain moments or time intervals, the service provider may apply a time-dependent tariff policy.

The simulation technique gives a good possibility to test the effects of changes to the system parameters and see what impact they might have on liquidity needs of participants, cost components, processing speed, etc.

5 The costs of settlement

Existing payment and securities settlement systems involve varying transaction costs depending on the efficiency of the software and hardware systems, and available economies of scale. Modern technologies are usually more efficient than old solutions (eg current server hardware outperforms old mainframes). Reduction of manual routines and increased automation also play an important role in reducing operational costs. Operational costs, however, tend to be a minor part of the total costs of payment and securities settlement system structures. Moreover, operational costs tend to be very similar for different system structures as long as the systems employ efficient technology and are efficiently organised. The interesting cost elements, therefore, are those dependent on the configuration of the payment and securities settlement system, ie

a. the cost of liquidity,
b. the cost of financial risks, and
c. the costs of delayed transactions.

These cost parameters determine which kind of system design will minimise overall costs and have an impact on how the participants will submit transactions and at what speed they will be processed in the system. All three types of costs are interrelated and can be traded off against each other by choosing different system designs.

A main determinant of the above costs is the settlement asset or media used in the system. This can take the following form in a funds transfer system:

(i) deposits with the settlement institution,
(ii) credit from the settlement institution, or
(iii) credits/deposits with other participants.

In the first case, transactions in the system can only be made if enough deposits are available to fund the transaction. In the second alternative, transactions in the system can only be made if the credit lines agreed with the settlement institution facilitate the transfer. In the third option, transactions can be made as long as the credit lines agreed bilaterally with other members of the system are not exceeded. Naturally, a system can use a combination of these options or operate without restrictions on the credits/deposits allowed.

The cost of the settlement media depends on its alternative investment possibilities. For instance, the cost of liquidity is close to zero in the case of mandatory reserve requirements without alternative investment possibilities. For intraday credits requiring first-class collateral, the costs could be seen as the losses made on keeping low-risk and low-return assets compared to investments with higher yields. In case of overdrafts with credit risk, there is a need to calculate the costs of taking these credit risks.

In the following sections, we discuss the costs of liquidity, financial risks and delayed transactions associated with the three options for the settlement asset.

5.1 Cost of liquidity

Liquidity, in conjunction with payment and securities settlement systems, can be understood as the ability to fulfil ones obligations at a reasonable cost. Liquid assets are assets or claims on other assets that are generally accepted as payment (or assets that can easily be converted into such). Sight deposits, either at the central bank or at commercial banks, are normally the most liquid asset form.

A division is generally made between intraday and overnight liquidity. The division stems from the fact that interest is calculated on the basis of value dates rather than continuously. The cost of both intraday liquidity and overnight liquidity is determined by the central bank. EU central banks currently provide intraday liquidity free of charge, while eg the Federal Reserve charges approximately 0.36% for it[13]. Both intraday and overnight credit must be collateralised, which carries an additional cost.

If the system operates on deposits, the cost of intraday liquidity is the opportunity cost of income that would be received by investing the funds held on settlement accounts in assets of equal risk. Such liquidity costs can be close to zero when eg ample central bank required reserves that otherwise would be idle can be used for settlement purposes. To increase deposits at the settlement institution, participants can borrow funds from each other. While an intraday market could give a market price for intraday funds, no intraday market has yet evolved (probably because intraday liquidity is provided free of interest or at a very low cost by central banks).[14]

If the system operates on credit from the settlement institution, the liquidity costs depend on the remuneration and collateralisation required by the settlement institution. While the remuneration cost is direct, collateralisation requirements also pose opportunity costs for the assets pledged as collateral. The laws of supply and demand govern the opportunity costs of collateral. The costs are increased if the list of collateral accepted is short (short supply), and if there are plenty of opportunities to use the collateral to make generate profits (eg securities lending)

---

[13] Federal Reserve Policy Statement on Payments System Risk, January 4, 1999.

[14] For a discussion on the link between intraday and overnight credit, see Rossi (1995) and Dale and Rossi (1996). For analysis on intraday credit policies by the central bank see Humphrey (1990 and 1996), Furfine and Stehm (1997) and Kahn and Roberds (1998b).

or if they are needed elsewhere (increased demand). Further costs of collateralisation may arise if banks may be forced to hold inferior portfolios compared to those that would result from free choice. Moreover, if the list of securities eligible as collateral is short, those on the list may generate lower returns due to their increased liquidity.

If the system operates exclusively on uncollateralised debt relations between the participants, the liquidity costs are zero.

The availability of liquidity can vary, which means the cost of liquidity can also vary. Liquidity costs may also vary by seasonally and as the result of general market conditions. Liquidity may become scarce at the end of the day, in the end of the reserve maintenance period or due to special circumstances, when everybody starts to hoard liquidity.

5.2 Cost of financial risks

The two main financial risks in payment and securities settlement systems are credit risk and liquidity risk. Credit risk is the risk that a counterparty will never settle an obligation for full value. The party expecting to receive the funds makes up the loss to the principal amount of the transaction.

Liquidity risk can be understood two ways. First, it can be understood from the receiving institution's perspective as the risk that its counterparty fails to settle its obligation for full value when due, but does settle eventually. Second, it can be understood from the paying institution's perspective as the risk associated with difficulties in finding the required liquidity at economic terms.

5.2.1 Credit risk

In case the system operates on deposits at the settlement institution, a participant of the system faces the risk that the settlement institution fails while it has a claim on it.

If the system operates on credit lines from the settlement institution, the situation is reversed, ie the settlement institution faces the risk that the participant fails while it is in a credit position vis-à-vis the settlement institution. Central banks and other settlement institutions can be exposed to considerable credit risks depending on their credit and collateral policies. The costs of interbank credit risks perceived by banks also depend on official policies towards banks in crises. Currently, most payment and securities settlement systems have internal features limiting maximum credit risks as recommended by the Lamfalussy standards and subsequently the Core Principles for Systemically Important Payment Systems and Recommendations for Securities Settlement Systems[15].

In theory, a system based on credit from the settlement institution could run continuously without periodic settlement of the resulting positions with other claims. Generally, however, systems based on credit from the settlement institution contain a final end-of-day/end-of-settlement-cycle settlement of the credit positions in some safer claim such as central bank money. Many systems have settlement and clearing institutions that can partly take up credit exposures or control collateral or settlement asset accounting.

If, on the other hand, the system is based on interbank debt relations, the receiving bank has to accept increased liabilities for each transfer received. The liability depends on the transaction finality point towards the customer and towards the other bank.

The interbank liabilities can be distributed among the participants through a loss-sharing agreement. Overall limits can be used to keep the overall credit risks within acceptable magnitudes. The credit risks can still vary greatly during the system open hours for individual participants. A loss-sharing agreement can be used for evening out random peaks closer to average positions. A loss-sharing agreement can be seen as a joint insurance scheme, where everybody takes part in covering the losses using predefined distribution keys.

The payment and securities settlement systems can also be based on a combination of liquidity transfers and credit caps. For instance, a liquidity transfer may be required when the upper limit of the credit cap is reached. An example of such a system is the Finnish POPS system for large-value cheques and express transfers.[16]

5.2.2 Liquidity risk

In systems that operate on the basis of deposits with (or credit from) the settlement institution, liquidity risks can arise if the participant runs out of funds and is unable to settle transactions as planned. Liquidity risk is therefore closely related to the costs of payment delays and the cost of liquidity. In such a situation, the bank faces the choice of delaying payment until it receives sufficient funds to settle or it can acquire the funds from the settlement institution or the market.

There is a further dimension creating liquidity risk that stems from the incentives of system participants to free-ride on the liquidity of other participants. The treasurer of a bank would wish to receive payments early and send them late in order to save liquidity. However, a delay in settlement reduces the sender's

[15] See BIS (2001) and BIS/IOSCO (2001a, 2001b and 2002) respectively.

[16] See ECB (2001).

liquidity costs but increases both its delay costs and the receiver's liquidity costs as it needs to finance its outgoing payments using other means. This creates a dead-weight loss at system level. In an extreme situation the system might end up in a situation where the number of payments submitted is strongly reduced as the participants each await liquidity from others.[17]

5.2.3 Settlement risk

Settlement risk is a type of credit risk independent of the settlement asset used. Settlement risk in securities and foreign exchange settlement is generally defined as the risk that one party to a transaction will provide the asset it sold but not receive the asset it bought. Settlement risk has both a credit risk and a liquidity risk dimension.

Settlement risk can arise in payment systems if the receiving bank credits the funds on the customer accounts in anticipation of receiving the funds from the sending bank. If the sending bank goes bankrupt, the credit risk is borne by the receiving bank. Such settlement risks can arise in systems with any of the three settlement assets.

In securities and foreign exchange trading, the party that has first made the payment for one leg of the transaction faces the possibility that its counterparty may not deliver the other asset when due. If the happens, it must finance the shortfall until the counterparty honours its obligation (liquidity risk). The party paying first also faces a risk that the counterparty may fail to complete the second leg of the transaction. Thus, it is exposed to liability for the full amount of the transaction (credit risk).

Settlement risk can also arise from legal uncertainty (eg a situation where it is unclear if the rules of netting will be accepted by the courts).

5.2.4 Systemic risk

In the context of payment and securities settlement systems, systemic risk refers to the risk that the failure of one participant in a system to meet its required obligations causes other participants to be unable to meet their obligations when

[17] On bank incentives in payment systems see Kahn and Roberds (1998a). A game theoretical model on bank behaviour under different credit policies of the central bank has been developed in Bech and Garrat (2003). On a discussion on the deadweight losses and other externalities in payment systems see Schoenmaker (1993) and Angelini (1998). For a model on total costs (liquidity and risk) in net and gross systems, see Schoenmaker (1995).

due. Notably, similar systemic risks can be caused by the failure of the settlement institution itself.[18]

The cost of a systemic disturbance can be high. The chain reaction may expand into an overall systemic crisis and can jeopardise the operation of the entire financial system and ultimately the real economy. Central banks have been concerned of limiting systemic risk, eg by issuing the Core Principles for Systemically Important Payment Systems[19].

Because of efforts to reduce risks in interbank payment system, the likelihood of a chain reaction caused by exposures in these systems seems currently to be relatively low. This at least is the outcome of studies for Finnish, Danish and Canadian interbank payment systems[20]. Blåvarg and Nimander (2002) find similar results for payment system exposures in Sweden, but point out that the systemic risk comes mainly from foreign exchange exposures. The introduction of CLS reduced globally systemic risks stemming from foreign exchange settlement substantially.

5.3 Costs of delayed payments

The speed of transaction settlement and processing is a critical element in settlement system costs. If payments could be postponed without costs, nobody would have an interest in settlement or in providing liquidity. The delay costs are generally determined based on a given time limit. Exceeding the time limit implies such high costs that, in most cases, parties have incentive to avoid exceeding the time limit. These costs may be explicit fines for delays, but it is often intangible values that make up delay costs (eg expected service quality). Because there is generally no special gain in paying/settling too early, transactions are often transmitted close to the time limit. This is especially the case in systems where settlement funds are costly. In systems with idle and low-cost settlement assets, continuous transaction flows are often preferred to avoid operational congestion. Interbank payment and securities settlement systems in the past have generally showed day-based timetables in the form of T+1, T+2 or even T+5 settlement. The speed is currently improving with more true real-time based systems and batch systems processing with many settlement cycles during the same day. The priority/importance of the transaction also affects the desired

[18] For general studies on systemic risk stemming from netting systems see BIS (1989), McAndrews and Wasilyew (1995), Angelini, Maresca and Russo (1996), Borio and Van den Bergh (1993). For a comparison on gross and net settlement systems see Freixas and Parigi (1998). For a survey on different concepts of systemic risk see de Bandt and Hartmann (2000).

[19] See BIS (2001).

[20] See Kuussaari (1996), Bech, Madsen and Natorp (2002) and Northcott (2002) respectively.

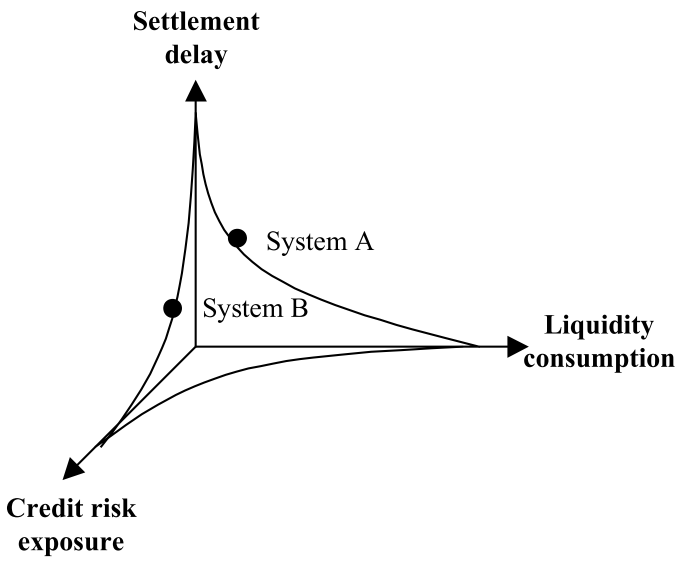
processing speed. Additional liquidity costs are acceptable for urgent payments, while the processing of less urgent transactions can be postponed to later. The trend towards enhanced speed increases also the share of immediately settled and processed transactions.

5.4 Combined costs

Liquidity requirements, financial risks and payment delays both mirror the transaction flow, but from opposite angles.

By choosing payment and securities settlement system structures and processing features, system participants/providers can attempt to identify the optimal point as a balance between the three main objective variables as depicted in Figure 6.

Figure 6.1 **The variables in the objective function**



Generally, the system structure is more efficient when it is closer to origin. Different participants may have different utility functions and different views on the relative weights of the variables. In general, increasing liquidity consumption, credit risk exposure, or both, can increase settlement speed. Different methods for smoothing and ordering payment flows, gridlock resolution and netting algorithms can be used for reducing liquidity consumption and/or credit risk exposure with a moderate amount of increased settlement delay. Liquidity consumption and credit risks exposures can be fixed if the transaction flows have to be settled at once when transactions are submitted without a possibility to affect the flow and depart from the FIFO processing order. When transactions can be rearranged and a certain amount of delay is allowed, the transaction flow can be smoothed and thereby reduce liquidity or credit risk variations. The objective of netting, splitting, reordering by prioritising features is to smooth transaction flows.

Payment and settlement systems contain varying degrees of risk. Simulations can be used to ascertain risk information unavailable in current system statistics. For example, intraday exposures by individual participants and/or the entire system can be studied. The systemic impacts of failures of large participants in the system can be evaluated and the consequences of large breakdowns examined. In complex environments, it is particularly difficult to foresee all the consequences without simulating possible situations.

References

Angelini, P. – Maresca, G. – Russo, D. (1996) **Systemic Risk in the Netting System.** Journal of Banking and Finance 20, 853–868.

Angelini, P. (1998) **An Analysis of Competitive Externalities in Gross Settlement Systems.** Journal of Banking and Finance 22, 1–18.

Bech, M. – Garrat, R. (2003) **The Intraday Liquidity management Game.** Journal of Economic Theory, (forthcoming).

Bech, M. – Madsen, B. – Natorp, L. (2002) **Systemic Risk in the Danish Interbank Netting System.** Working Paper 8/2002, Danmarks Nationalbank.

Bech, M. – Soramäki, K. (2001) **Gridlock Resolution in Payment Systems.** Monetary Review 4/2001, Danmarks Nationalbank.

Bech, M. – Soramäki, K. (2002) **Liquidity, Gridlocks and Bank Failures in Large Value Payment Systems.** E-Money and Payment Systems Review, Central Banking Publications, 111-126.BIS (1989), Report on Netting Schemes (Angell Report), Group of Experts on Payment Systems of the Central Banks of the Group of Ten Countries, Bank for International Settlements, Basle.

BIS (1990) **Large-value Funds Transfer Systems in the Group of Ten Countries.** Group of Experts on Payment Systems of the Central Banks of the Group of Ten Countries, Bank for International Settlements, Basle.

BIS (1995) **Cross-border Securities Settlement.** Committee of Payments and Settlement Systems of the Central Banks of the Group of Ten Countries, Bank for International Settlements, Basle.

BIS (1997) **Real-time Gross Settlement Systems.** Prepared by the Committee on Payment and Settlement Systems of the Central Banks of the Group of Ten Countries, Bank for International Settlements, Basle.

BIS (2001) **Core Principles for Systemically Important Payment Systems.** Committee on Payment and Settlement Systems of the Central Banks of the Group of Ten Countries, Bank for International Settlements, Basle.

BIS/IOSCO (2001) **Securities lending transactions: market development and implications.** Committee on Payment and Settlement Systems, Technical Committee of the International Organization of Securities Commissions, Basle.

BIS /IOSCO (2001) **Recommendations for securities settlement systems.** Committee on Payment and Settlement Systems, Technical Committee of the International Organization of Securities Commissions, Basle.

BIS/IOSCO (2002) **Assessment methodology for 'Recommendations for Securities Settlement Systems'.** Committee of Payments and Settlement Systems, Technical Committee of the International Organization of Securities Commissions, Basle.

BIS (2003) **The role of central bank money in payment systems.** Committee on Payment and Settlement Systems, Technical Committee of the International Organization of Securities Commissions, Basle.

Blåvarg, M. – Nimander, P. (2002) **Interbank exposures and systemic risk.** Penning och valutapolitik, no. 2/2002, Sveriges Riksbank.

Borio, C. – Russo, D. – Van den Bergh, P. (1992) **Payment System Arrangements and Related Policy Issues: A Cross Country Comparison.** SUERF Papers on Monetary Policy and Financial Systems 13, Société Universitaire Européenne de Recherches Financiéres, Tilburg.

Borio, C. – Van den Bergh, P. (1993) **The nature and management of payment system risks: an international perspective.** Economic Papers 36, Bank for International Settlements.

Bowman, M. (1995) **Simulation Modelling of Large Value Transfer Systems.** Paper prepared for Eurobanking 1995, Association for Payment Clearing Services.

Dale, S. – Rossi, M. (1996) **A Market for Intra-day Funds: Does it have Implications for Monetary Policy?** Bank of England.

De Bandt, O. – Hartmann, P. (2000) **Systemic risk – a Survey.** Discussion Paper No. 2634, Centre for Economic Policy Research.

ECB (2001) **Payment and securities settlement systems in the European Union.** (the Blue Book), European Central Bank, Frankfurt.

ECB (2002) **Payment and securities settlement systems in accession countries.** European Central Bank, Frankfurt.

ECB (2003) **TARGET Annual Report 2002.** European Central Bank, Frankfurt.

EU Commission (2001) **The Giovanni Group report Cross-Border Clearing and Settlement Arrangements in the European Union. November 2001.** Brussels.

EU Commission (2002) communication, **Clearing and settlement in the European Union – Main policy issues and future challenges.** May 28, 2002 Brussels.

EU Commission (2003) **The Giovanni Group Second Report on EU Clearing and Settlement Arrangements.** April 2003, Brussels.

Freixas, X. – Parigi, B. (1998) **Contagion and Efficiency in Gross and Net Interbank Payment Systems.** Journal of Financial Intermediation 7, 3–31.

Furfine, C. – Stehm, J. (1997) **Analyzing Alternative Intraday Credit Policies in Real-Time Gross Settlement Systems.** Finance and Economics Discussion Series 1997-40, Board of Governors of the Federal Reserve System (US).

Ganz, M. – Günzter, M.M. – Jungnickel, D. – Noltsch, G. (1998) **Effizientes Real-Time Gross Settlement in der Wertpapierabwicklung.** Die Bank 2, 94–97.

Group of Thirty (2003) **Global Clearing and Settlement – a Plan of Action.** Washington D.C.Güntzer, M.M., Jungnickel, D. and Leclerc, M. (1998), “Efficient Algorithms for the Clearing of Interbank Payments,” European Journal of Operational Research 106, 212–219.

Horowitz, E. – Sartaj, S. (1978) **Fundamentals of Computer Algorithms.** Computer Science Press, Inc.

Humphrey, D. (1986) **Payments Finality and the Risk of Settlement Failure.** In Saunders, A. and White, L. C. (eds). Technology and the Regulation of Financial Markets, Lexington Books, D.C. Heath and Company, 97–120.

Humphrey, D. (1990) **Pricing Intraday Overdrafts.** In Haraf, E.S. and Cagan, P. (eds). Monetary Policy for a Changing Financial Environment, AIE Press, Lanham, 108–131.

Humphrey, D. (1996) **Comment on Intraday Bank Reserve Management: The Effects of Caps and Fees on Daylight Overdrafts.** Journal of Money, Credit, and Banking 28, 909–913.

Kahn, C. – Roberds, W. (1998a) **Payment System Settlement and Bank Incentives.** Review of Financial Studies, vol. 1, no. 4, 845–870.

Kahn, C. – Roberds, W. (1998b) **Real-Time Gross Settlement and the Cost of Immediacy.** Working Paper 98-21, Federal Reserve Bank of Atlanta.

Koponen, R. – Soramäki, K. (1998) **Intraday Liquidity Needs in a Modern Interbank Payment System – A Simulation Approach.** Studies in Economics and Finance E:14, Bank of Finland, Helsinki.

Kuussaari, H. (1996) **Systemic Risk in the Finnish Payment System: An Empirical Investigation.** Discussion Paper 3/1996, Bank of Finland, Helsinki.

Leinonen, H. (1998) **Interbank Funds Transfer Systems: Liquidity Needs, Counterparty Risks and Collateral.** Discussion Paper 16/98, Bank of Finland, Helsinki.

Leinonen, H. – Soramäki, K. (1999) **Optimizing Liquidity Usage and Settlement Speed in Payment Systems.** Bank of Finland Discussion Paper 16/1999.

Leinonen, H. – Lumiala, V.-M. – Sarlin, R. (2002) **Settlement in modern network-based payment infrastructures – description and prototype of the E-settlement model.** Discussion Paper 23/2002, Bank of Finland.

Leinonen, H. (2003) **Restructuring securities systems processing – a blue print proposal for real-time/t+0 processing.** Bank of Finland Discussion Paper 7/2003.

McAndrews, J.J. – Samira, R. (2002) **Timing and Funding of Fedwire Funds Transfers.** FRBNY Economic Policy Review, July 2000.

McAndrews, J.J. – Wasilyew, G. (1995) **Simulations of Failure in a Payment System.** Economic Research Division Working Paper 95-19, Federal Reserve Bank of Philadelphia.

Northcott, C.A. (2002) **Systemic Risk, Designation, and the ACSS.** Financial System Review, December 2002, Bank of Canada.

Rossi, M. (1995) **Pricing Intraday Credit in Real-Time Gross Settlement Systems.** Discussion Paper 211, London School of Economics Financial Markets Group.

Schoenmaker, D. (1993) **Externalities in Payment Systems: Issues for Europe.** Financial Markets Group, London School of Economics.

Schoenmaker, D. (1995) **A Comparison of Alternative Interbank Settlement Systems.** LSE Financial Markets Group Discussion Paper 204, ESRC Research Centre, London.

Appendix 1

An overview of the BoF-PSS2 payment and settlement system simulator

Background

In the mid-1990s, a payment system simulator was developed within Bank of Finland. It was found to be a valuable tool for studying the probable effects of the introduction of EMU on Finnish payment systems. Some other countries also used this first BoF simulator for other types of analysis such as queuing and algorithm studies, and clarification of risk and liquidity issues. Due to its popularity, a more efficient user-friendly and comprehensive version was built in 2003. BoF-PSS2 is now available for research purposes at no charge and with complete documentation.

Basic features of the simulator

BoF-PSS2 is intended for independent use by payment and settlement systems designers, administrators, analysts at central banks and financial institutions, research institutions and academics. The simulation software is downloaded to the user's computing environment (typically a PC) for local processing. The download includes user documentation. The Bank of Finland will arrange, from time to time, simulation seminars and will provide limited start-up support. User support, if needed, is available from a software company. This support is priced according to this company's normal pricing policy.

The BoF-PSS2 simulator is a tool for making a variety of payment system analyses. The basic principle is that given payment flows are processed in a given model of an existing or contemplated payment and settlement system structure. The simulator thus models settlement processes for a specified payment system environment. The simulation results are account bookings and account balances made according to the rules defined for the payment system environment. The transaction processing output can then be analysed with an included analyser tool or exported into other programs such as Excel. Typical areas of interest include intersystem credit risk, liquidity consumption and risks, settlement speed, gridlock resolution and settlement efficiency.

The simulation process starts with the creation of the payment or transaction flow(s) to be processed and defining of the payment/settlement system environment and rules (eg systems, participants, limits and settlement rules). Next the simulation is run. The results are then compared against other simulation runs or real-life observations. Using the simulation tool is essentially an iterative learning process, ie earlier simulation runs become the basis for improving and refining subsequent simulation runs. Thus, the simulator is not a deterministic econometric optimisation model, but rather a heuristic tool for analysing systems that are too complex for deterministic models. The BoF-PSS2 can process in one simulation several million transactions to be booked on several thousand accounts in several interlinked systems. In other words, optimisation analysis is mainly done via a 'trial-and-error' or enumeration process. The simulation runs are repeated for different values on the decision-making parameters and the resulting objective values are compared for the different combinations. For instance, a central bank might want to determine the bank-specific minimum liquidity required for guaranteeing that in 99.5% of all cases continuous settlement during the day is maintained so that transactions are not queued for longer than ten minutes. To find the answer, the bank would model various levels of liquidity to see which levels fulfil the objective. The model is thus a workbench for testing alternatives.

The simulator's basic features are:

1. **Input data import and export tool.** All input data must be presented in comma-separated values (CSV) format. The importer supports free ordering of the data fields and ensures that the imported data are formatted correctly. Basic data validations are done and key fields are matched against each other. For example, participant keys in transaction data must match those for participant (account) data.

2. **Transaction submission algorithms** determine which transactions are submitted to the system and when they are submitted. The submission algorithm can be used to introduce rule-based user behaviour into a model (eg early submission of large volumes of low-priority payments only allowed for participants from which reciprocal payments have been received).

3. **Transaction processing algorithms** for simulating real-time gross settlement systems (RTGS) with gridlock resolution and other optimisation features, deferred net settlement systems (DNS) and continuous net settlement systems (CNS).

4. **Linking of different systems,** ie payments debited from one system can be credited to an account in another system, or settlement totals as calculated in an ancillary system can be settled in another system. The first option gives the possibility to simulate a network of interlinked systems (eg TARGET links together 16 different RTGS systems). The second option gives the user the

possibility to model payment structures consisting of main and ancillary systems.

5. **Handling of multiple accounts per participant and multiple currencies in each system** can be simulated, as well as simulation of multi-currency and securities settlement systems. In the simulator settlement of each transaction results in book entries on accounts. There is no difference in the basic process with respect to currency or securities type. The meaningfulness of transactions must thus be ensured in the payment data (eg so that a debit is not made to an EUR account when the corresponding credit goes to a GBP account).

6. **Settling two-leg transactions** where settlement of one leg is conditional upon the settlement of the other leg. This enables simulations of payment-versus-payment (PVP) in foreign exchange settlement and delivery-versus-payment (DVP) systems in securities settlement.

7. **Output exporter and analyser** for a given set of basic statistical parameters and an output exporter for transferring the results to external analysis programs (eg Excel) for detailed analysis.

   BoF-PSS2 contains basic submission and transaction processing algorithms adequate for most common simulation needs. The model also allows for user customisation via external algorithm interfaces. Users or third parties can program additional algorithms to incorporate in the simulator. Custom algorithms may be submitted to the BoF-PSS2 general library, from where they can be retrieved by other users.

The main difference between the simulator and an actual payment system is that the time function is event-driven and not real time. Processing is performed transaction by transaction. The simulator operates generally faster than the real world, but processing speed depends on the volumes, processing complexity and available processing capacity. In RTGS test cases, the simulator has processed and booked about two million transactions in one hour. In any case, the end result is the same as if the simulator had run in real time.

Simulations can be carried out for separate days or for sequences of days. In the later case, closing balances and unsettled transactions can be carried over to the next day or next settlement occasion/period. The simulator uses the standard calendar and assumes all days (even weekends) are banking days. However, if there are no transactions for a given day the account balances will remain stable until payment flows are detected on a subsequent banking day.

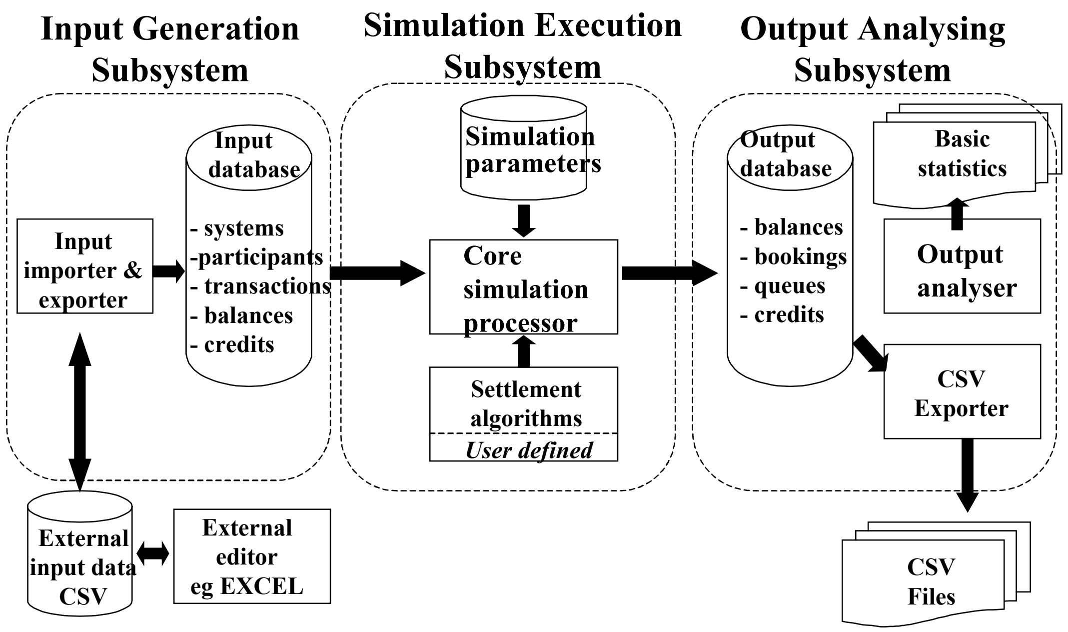
For the sake of manageability, each feature has been implemented in a standardised way (in real systems, features can be implemented in many ways). Thus, the user must transform the input data according to the convention used in the simulator (eg DVP and PVP transactions are matched based on a given individual code field and a code has to be given by the user for such transactions if the matching is performed using other conventions). BoF-PSS2 is limited purely to payment and transaction processing and the pledge type of collateral aspects of payment systems are not explicitly included. However, repo-type of collateral processing could be included through DVP repo transactions, especially if the simulation in question contains a securities settlement system. Both repo- and pool-based collateral requirements and processes might also be introduced into the simulator by defining special collateral systems, which would store the collateral balances and would have DVP links with the RTGS system(s).

System structure

The BoF-PSS2 system structure consists of three main subsystems:

a) Input Generation Subsystem,
b) Simulation Execution Subsystem, and
c) Output Processing Subsystem.

Figure A1. **BoF-PSS2 system structure**



The Input Generation Subsystem contains tools for importing and validating transaction data, participant data, as well as data on daily account balances and credit limits All data are stored in database files. The importer checks that the input data are formally valid and transfers them into system database structures. The correctness of the input data is vital. Account numbers in the transaction file must correspond with those in the participant (account) data. While all data must be presented in CSV format, it can be entered in any user-defined order. The user defines templates to describe the CSV files and match the input files with the database structure. Data in the database can also be edited by exporting them as CSV files into eg Excel and then importing them after the changes are made. The simulator does not include a proprietary editor for this purpose.

The Simulation Execution Subsystem includes tools for configuring and running simulations. It also contains the actual simulation and settlement logic. This subsystem keeps a log of all events and bookings and makes reports and statistics on the simulation runs. A configurator/executor tool facilitates configuring and execution of simulation runs.

The Output Processing Subsystem includes the functionality for reporting basic statistics on the most common result parameters. The output database contains the raw data of the booking order of the transactions and the balances on the settlement accounts. The input database contains the transaction flow, while the output database contains the settlement flow (the settlement order and timing of the submitted transactions). The analyser tool is used for generating additional reports and transferring selected statistics to CSV files for later use. Users typically perform many simulations and then compare the results. The analyser tool provides some basic reports and comparison possibilities, but advanced analyses need to be made by exporting CSV files into eg Excel for further analysis. Before running a simulation, it is advisable to create a structure for the simulation runs and determine how the results will be stored in databases for further analysis. Databases can be overwhelmed when transaction volumes are very high and all transaction level events are retained in the databases.

Input data

System data defines the systems in the simulation. A large number of systems, each with individual properties, can be included. For example, many RTGS, CNS and DNS systems can run in parallel in the same simulation. There are no specific limitations for the number of systems. The system data contains the information on the features implemented in these systems (eg queuing method, end-of-day conventions, netting algorithms used, open hours and net settlement timing). System-level input data are defined, due to their complexity, through a separate input screen and not through the CSV format as used for the other input data tables.

Participant (account) data contains information about the participants (accounts) in each simulated system.

Balance data contains the daily initial account balances for each account in the systems. Another way to introduce initial balances is through payments from central bank accounts to the participants' accounts. When simulations for a sequence of days are performed, end-of-day balances for the previous day can be carried forward to the next day or defined separately for each day.

Intraday credit limit data contains information about the intraday credit limit of the accounts and changes to them during the day. In simulations with a sequence of days, credit limit changes remain in force until the next change.

Transaction data includes all information about individual transactions. Such transactions can be payments or transfers of securities, and their properties include the value of the transaction, sender and sending account, and receiver and receiving account. Five user-defined fields in transaction data can be used to carry information that can be used in user-defined submission and transaction processing algorithms (eg priority codes).

Output data

Simulation results are written to an output database organised by levels (simulation, system, participant and event levels).

The simulation level contains the general data of the simulation, eg date and time, input database and a description given by the user.

The system level contains the overall statistics for each system and transaction and account totals.

The participant level gives totals and averages for each participant (account). These can be used to check the impact of simulated 'what if' scenarios on individual participants or participant groups.

The event level data make up the main bulk of the output database. It is a transaction level log of everything the simulator processed. Submission, booking and queuing events are reported separately. Gridlock resolution events or violation events (eg overdraw limits) are reported separately. User-defined modules can also write comment events for later analysis. To limit the output data, the user can select data to be retained or reported for each simulation run.

There are ready-made basic statistics reports on system and participant (account) level. There is also a basic reporting tool for comparing simulations. Because the output data are so vast and users have such diverse needs, a general output exporter has been created. The user can select interesting output data and export them as CSV files for additional analysis in Excel and other applications that support CSV files. **The user defines templates to describe the output CSV files and selection criteria to select the data content.**

Overview of settlement capabilities

The simulator identifies three general types of systems: RTGS (real-time gross settlement), CNS (continuous net settlement), and DNS (deferred net settlement systems). Table 1 provides an overview of the current features available for various systems. The palette will likely expand as users and Bank of Finland create new modules.

Table 1. **Current available settlement palette**

	RTGS	**CNS**	**DNS**
Queuing	Based on available liquidity	Based on available liquidity	Based on credit limits
Gross settlement	FIFO or Bypass-FIFO and priority	FIFO or Bypass-FIFO and priority	
Bilateral offsetting of reciprocal payment	As long as FIFO rule is applied	As long as FIFO rule is applied	
Net settlement	Bilateral, partial or multilateral	Bilateral, partial or multilateral	Bilateral, partial or multilateral
Splitting	Maximum value or available liquidity	Maximum value or available liquidity	
Forced EOD settlement	At specified settlement occasions	At specified settlement occasions	At specified settlement occasions
Transfers to next day	Queued payments and balances	Queued payments	Queued payments
Liquidity injections	Given amount or as % of limit	Given amount or as % of limit	
DvP and PvP	Within and between systems	Within and between systems	Within systems

The user has the possibility to introduce user-defined modules that contain eg settlement conventions that are not currently supplied as ready-made algorithms.

Hardware and system requirements

The simulator software is distributed online and contains an automated installation package.

The minimum hardware requirements are a PC with an Intel Pentium 4 class processor and at least 256 MB of RAM (main memory). For large simulations, at least 512 MB of RAM is recommended.

The system can be installed and run on Windows NT/2000 or Windows XP. Although untested, it should work with modifications on Linux operating systems with a compliant installation of Sun Microsystem’s Java Runtime Environment (JRE) version 1.3.

The simulator requires installation of the MySQL database. It is also recommended that Microsoft Excel is available.

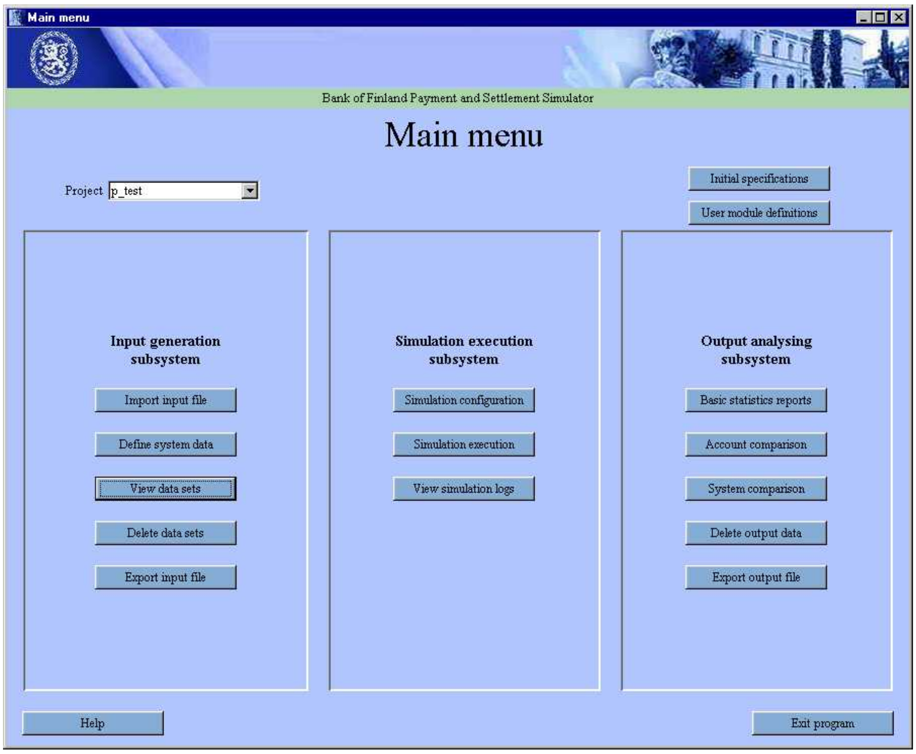
Availability, ordering and further information

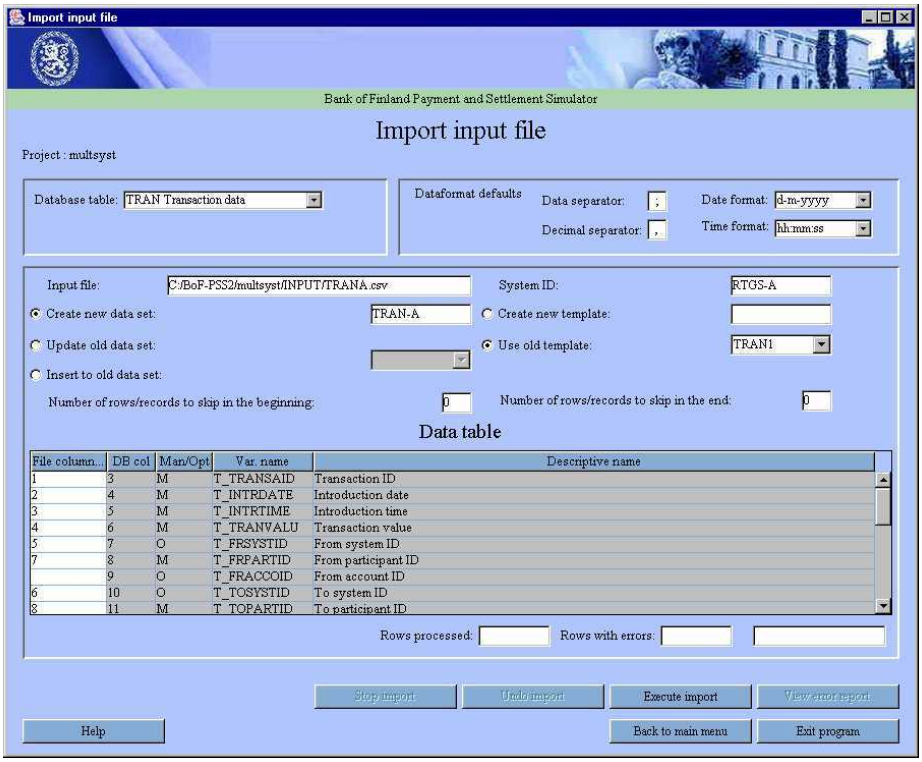
Further information (PowerPoint presentations, user manual, installation guide, database descriptions, etc.) on the simulator can be found at www.bof.fi/sc/bof-pss.

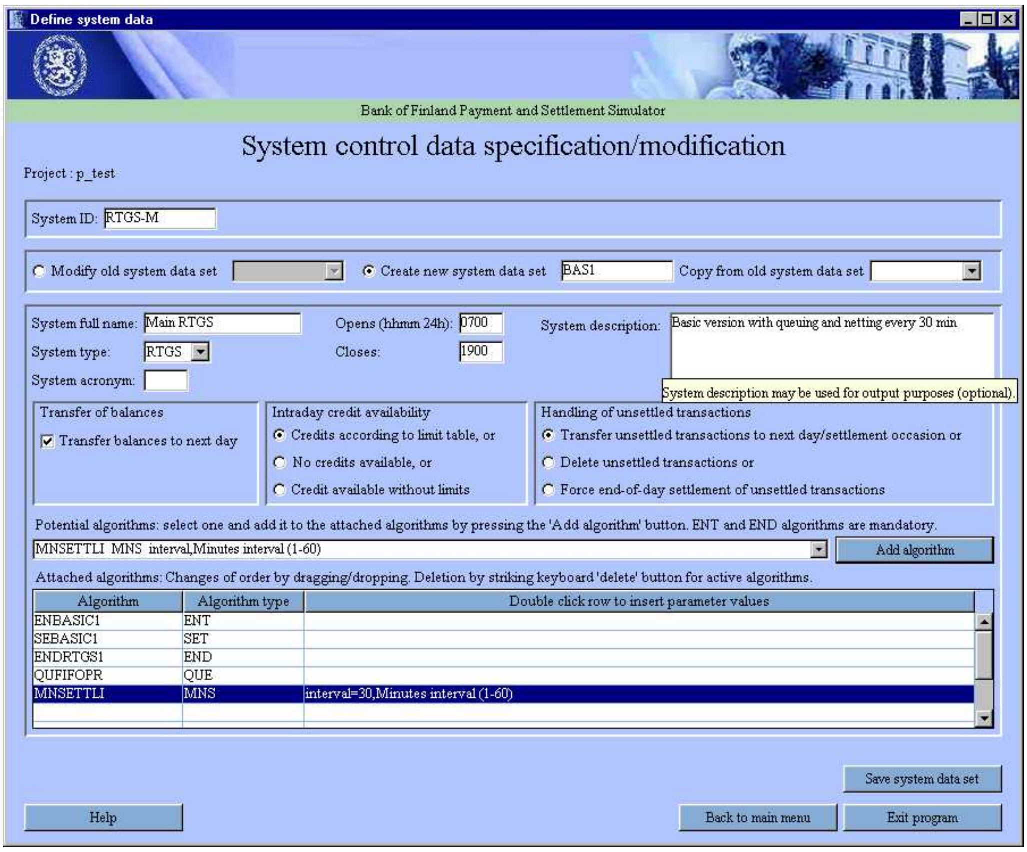
A beta version is currently available. The first generally available version will be released in early 2004. The simulator can be ordered by sending a fax to the Bank of Finland as described on the web page.

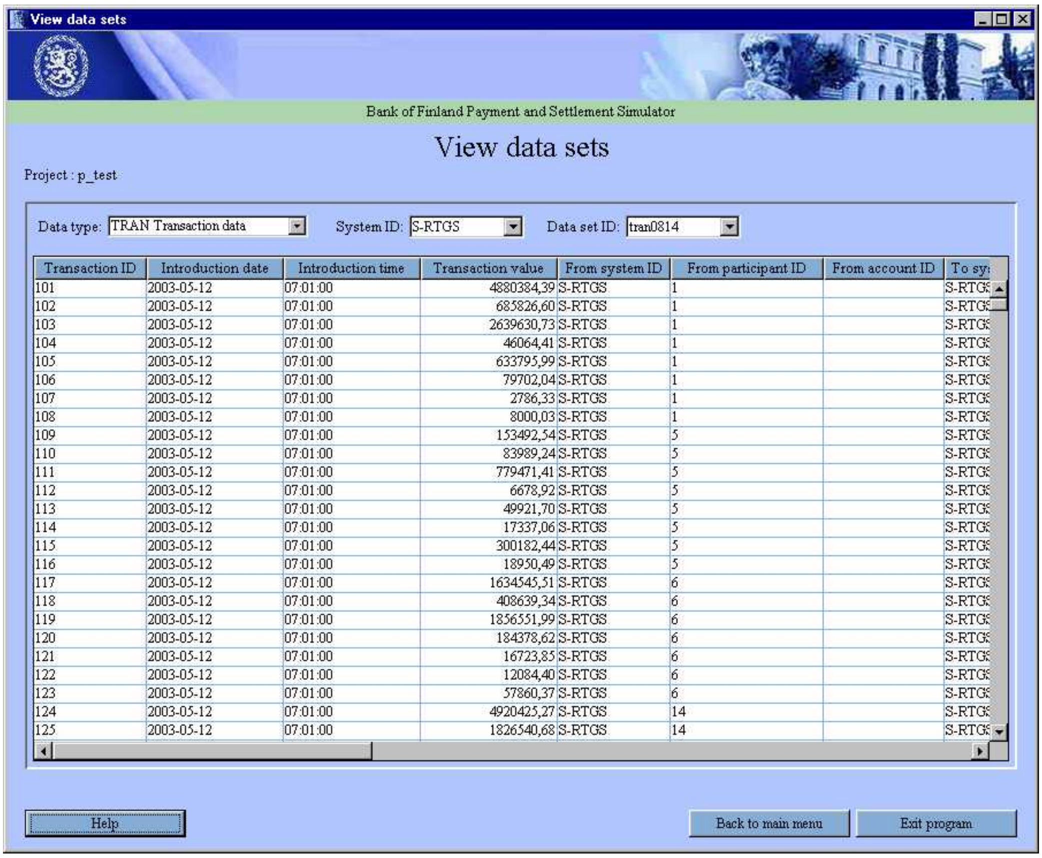
Appendix 2

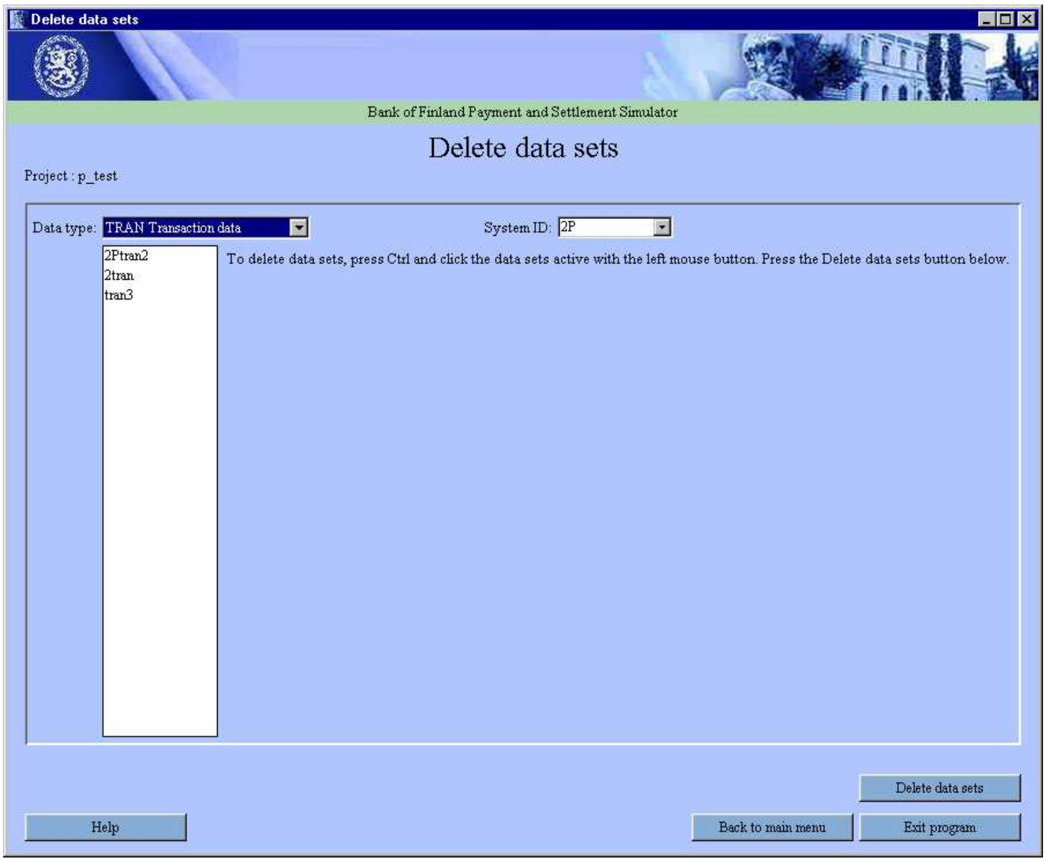
BoF-PSS2 screen shots

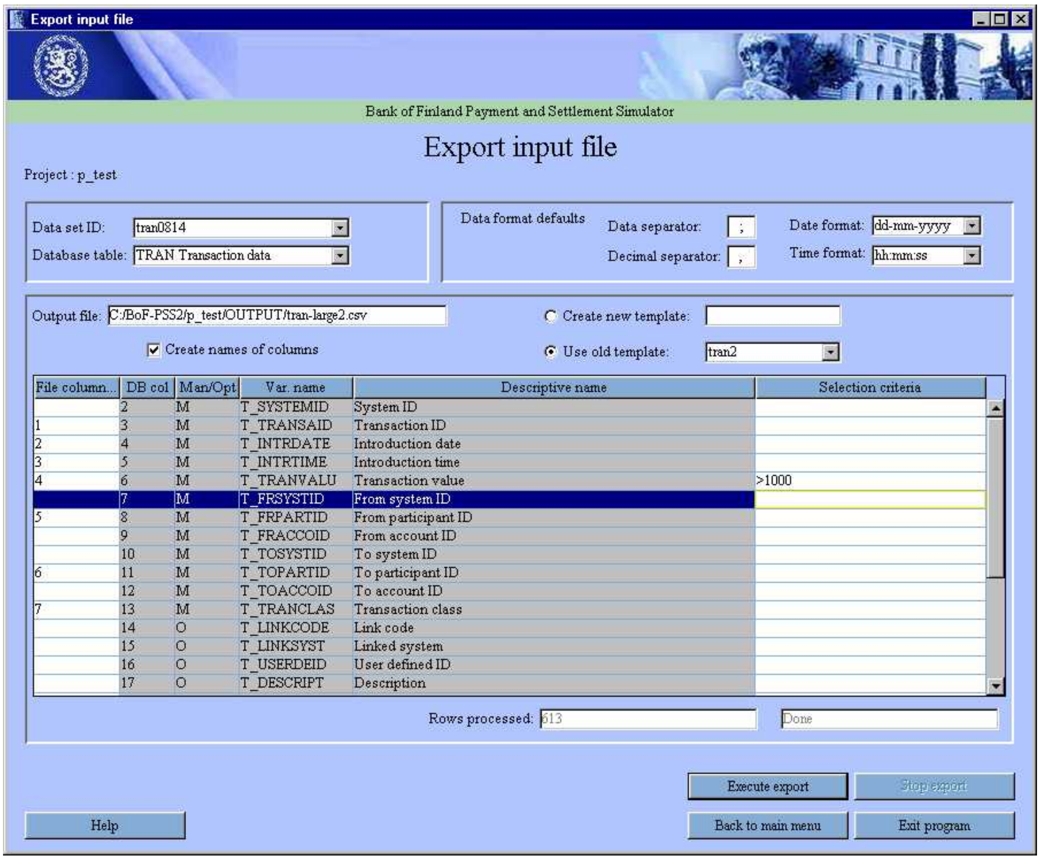


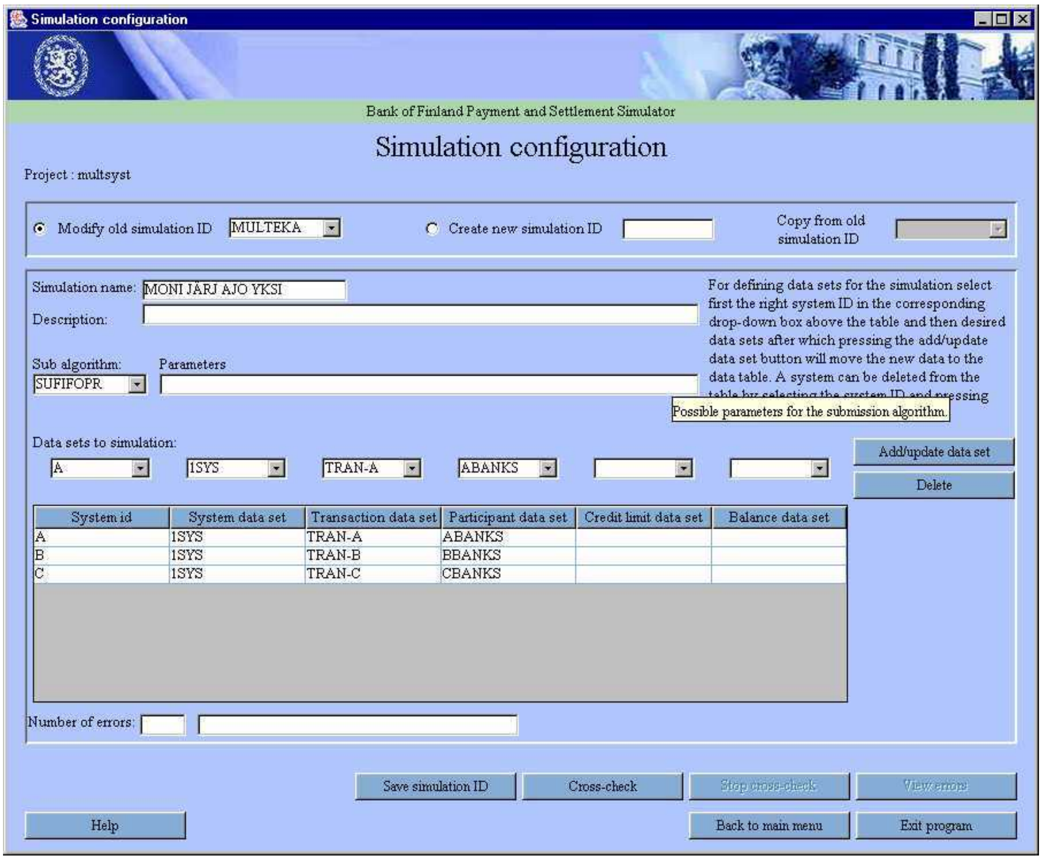


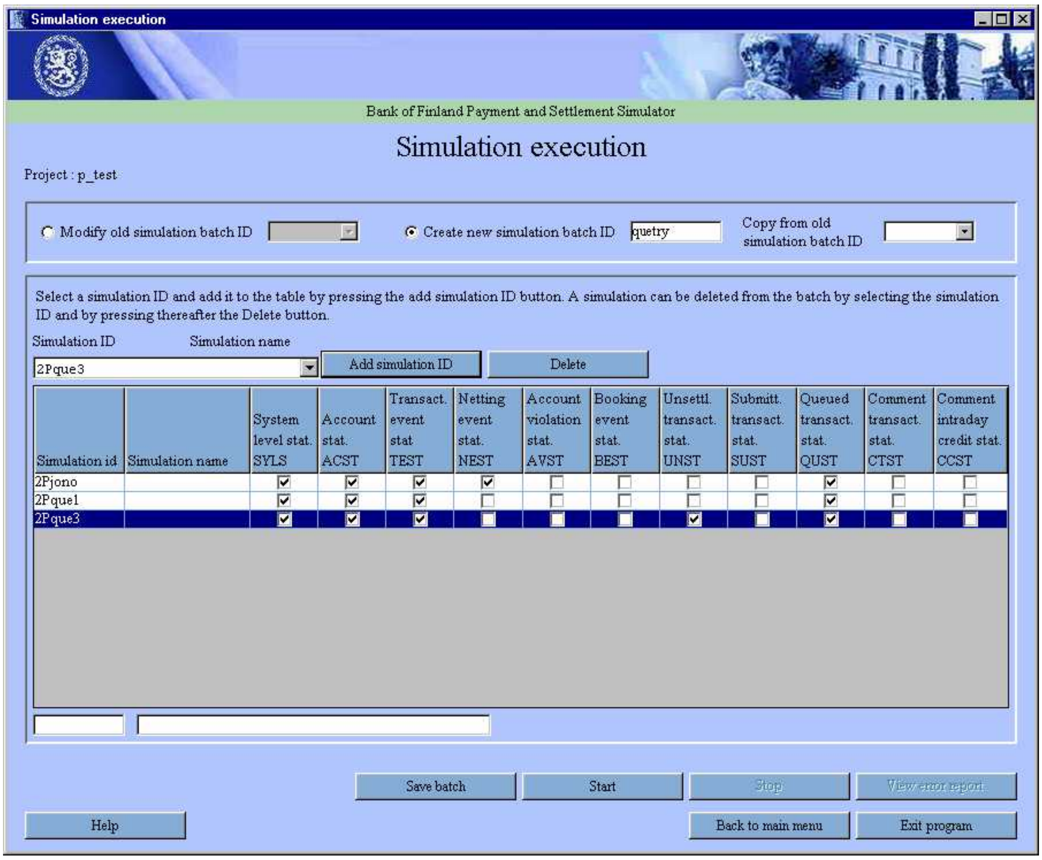

Define system data
Bank of Finland Payment and Settlement Simulator
System control data specification/modification
Project : p_test
System ID: RTGS-M
Modify old system data set
Create new system data set BAS1
Copy from old system data set
System full name: Main RTGS
Opens (hhmm 24h): 0700
System description: Basic version with queuing and netting every 30 min
System type: RTGS
Closes: 1900
System acronym:
System description may be used for output purposes (optional).
Transfer of balances
Transfer balances to next day
Intraday credit availability
Credits according to limit table, or
No credits available, or
Credit available without limits
Handling of unsettled transactions
Transfer unsettled transactions to next day/settlement occasion or
Delete unsettled transactions or
Force end-of-day settlement of unsettled transactions
Potential algorithms: select one and add it to the attached algorithms by pressing the 'Add algorithm' button. ENT and END algorithms are mandatory.
MNSETTLI MNS interval,Minutes interval (1-60)
Add algorithm
Attached algorithms: Changes of order by dragging/dropping. Deletion by striking keyboard 'delete' button for active algorithms.
Algorithm | Algorithm type | Double click row to insert parameter values
ENBASIC1 | ENT
SEBASIC1 | SET
ENDRTGS1 | END
QUFIFOPR | QUE
MNSETTLI | MNS | interval=30,Minutes interval (1-60)
Save system data set
Help
Back to main menu
Exit program

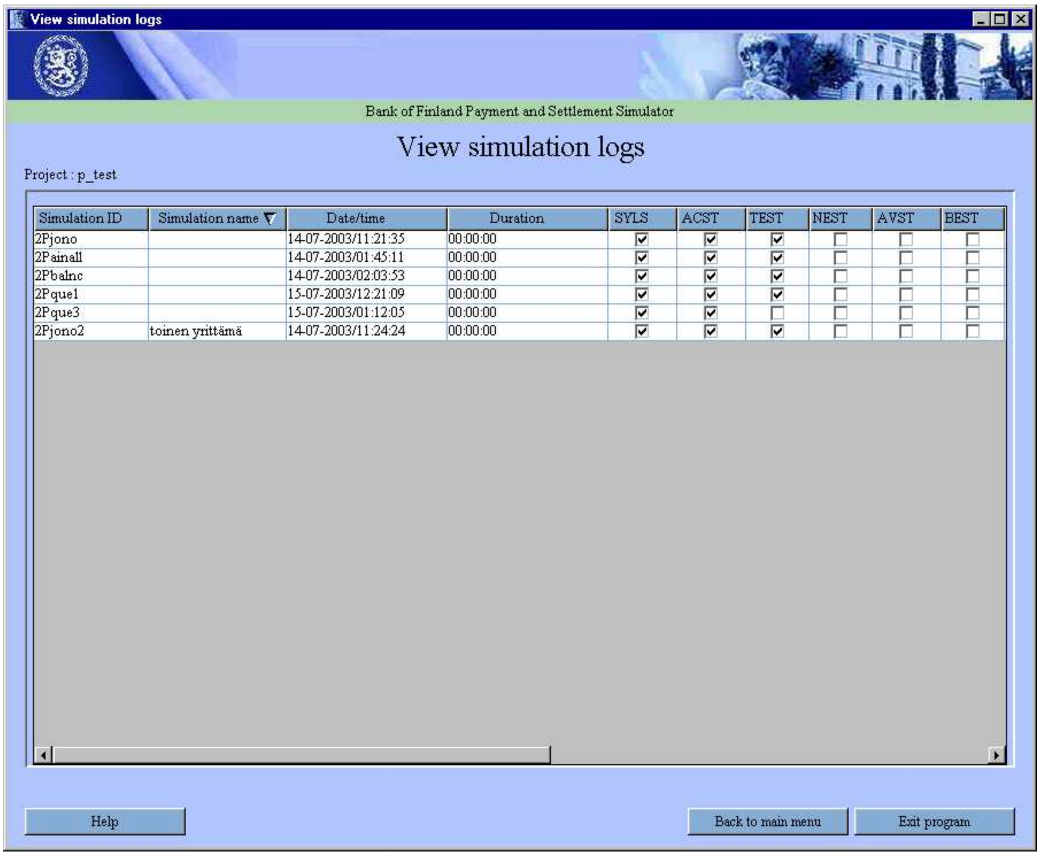

View data sets
Bank of Finland Payment and Settlement Simulator
View data sets
Project : p_test
Data type: TRAN Transaction data
System ID: S-RTGS
Data set ID: tran0814
Transaction ID | Introduction date | Introduction time | Transaction value | From system ID | From participant ID | From account ID | To sy
101 | 2003-05-12 | 07:01:00 | 4880384,39 | S-RTGS | 1 | | S-RTG
102 | 2003-05-12 | 07:01:00 | 685826,60 | S-RTGS | 1 | | S-RTG
103 | 2003-05-12 | 07:01:00 | 2639630,73 | S-RTGS | 1 | | S-RTG
104 | 2003-05-12 | 07:01:00 | 46064,41 | S-RTGS | 1 | | S-RTG
105 | 2003-05-12 | 07:01:00 | 633795,99 | S-RTGS | 1 | | S-RTG
106 | 2003-05-12 | 07:01:00 | 79702,04 | S-RTGS | 1 | | S-RTG
107 | 2003-05-12 | 07:01:00 | 2786,33 | S-RTGS | 1 | | S-RTG
108 | 2003-05-12 | 07:01:00 | 8000,03 | S-RTGS | 1 | | S-RTG
109 | 2003-05-12 | 07:01:00 | 153492,54 | S-RTGS | 5 | | S-RTG
110 | 2003-05-12 | 07:01:00 | 83989,24 | S-RTGS | 5 | | S-RTG
111 | 2003-05-12 | 07:01:00 | 779471,41 | S-RTGS | 5 | | S-RTG
112 | 2003-05-12 | 07:01:00 | 6678,92 | S-RTGS | 5 | | S-RTG
113 | 2003-05-12 | 07:01:00 | 49921,70 | S-RTGS | 5 | | S-RTG
114 | 2003-05-12 | 07:01:00 | 17337,06 | S-RTGS | 5 | | S-RTG
115 | 2003-05-12 | 07:01:00 | 300182,44 | S-RTGS | 5 | | S-RTG
116 | 2003-05-12 | 07:01:00 | 18950,49 | S-RTGS | 5 | | S-RTG
117 | 2003-05-12 | 07:01:00 | 1634545,51 | S-RTGS | 6 | | S-RTG
118 | 2003-05-12 | 07:01:00 | 408639,34 | S-RTGS | 6 | | S-RTG
119 | 2003-05-12 | 07:01:00 | 1856551,99 | S-RTGS | 6 | | S-RTG
120 | 2003-05-12 | 07:01:00 | 184378,62 | S-RTGS | 6 | | S-RTG
121 | 2003-05-12 | 07:01:00 | 16723,85 | S-RTGS | 6 | | S-RTG
122 | 2003-05-12 | 07:01:00 | 12084,40 | S-RTGS | 6 | | S-RTG
123 | 2003-05-12 | 07:01:00 | 57860,37 | S-RTGS | 6 | | S-RTG
124 | 2003-05-12 | 07:01:00 | 4920425,27 | S-RTGS | 14 | | S-RTG
125 | 2003-05-12 | 07:01:00 | 1826540,68 | S-RTGS | 14 | | S-RTG
Help
Back to main menu
Exit program

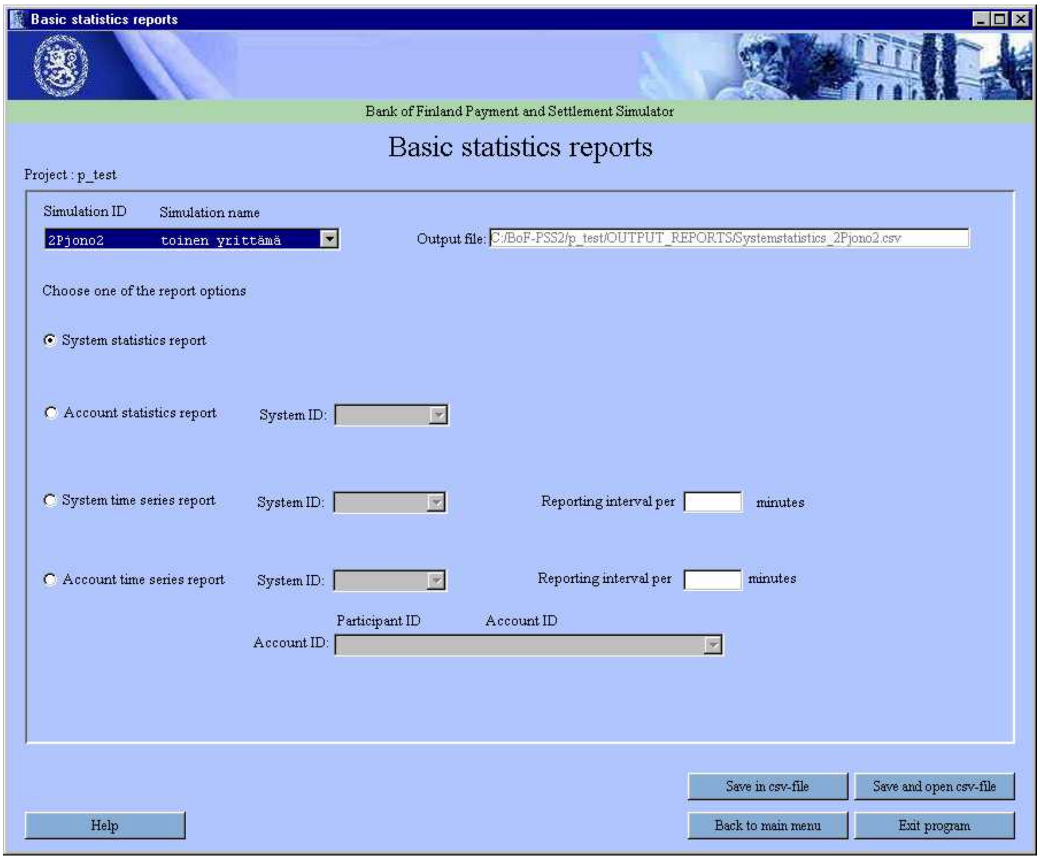

Delete data sets
Bank of Finland Payment and Settlement Simulator
Delete data sets
Project : p_test
Data type: TRAN Transaction data
System ID: 2P
2Ptran2
2tran
tran3
To delete data sets, press Ctrl and click the data sets active with the left mouse button. Press the Delete data sets button below.
Delete data sets
Help
Back to main menu
Exit program

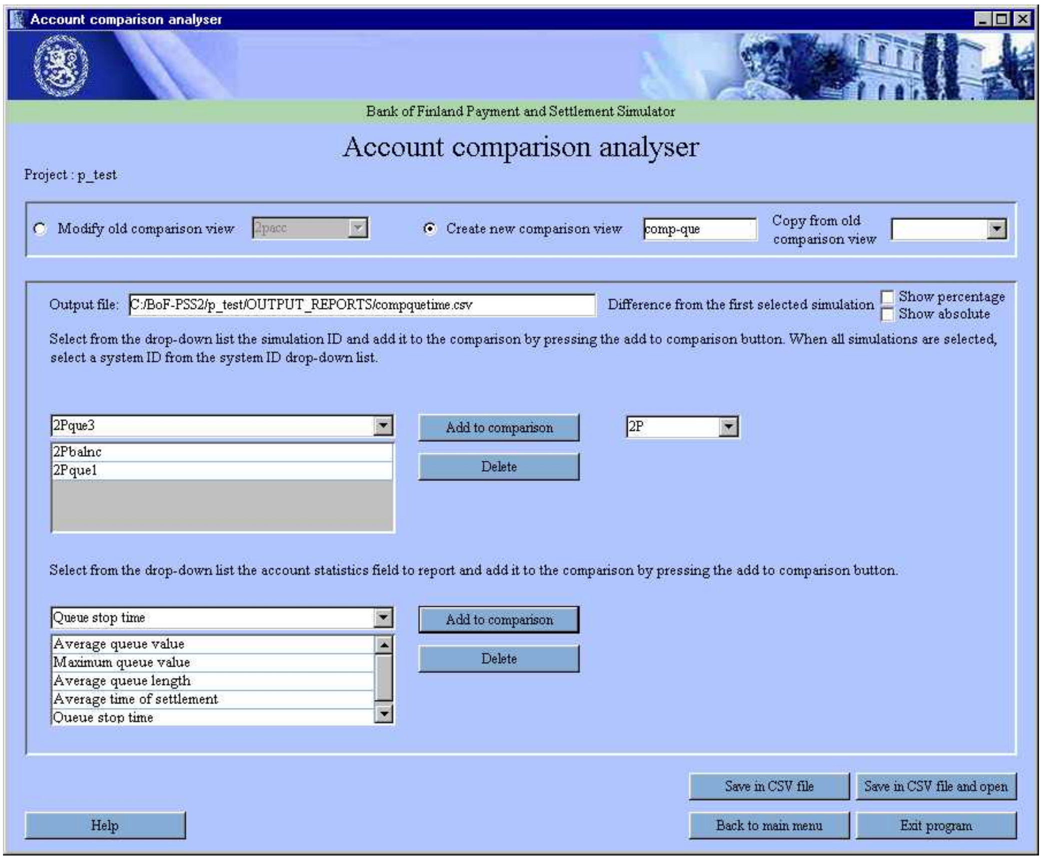

Export input file
Bank of Finland Payment and Settlement Simulator
Export input file
Project : p_test
Data set ID: tran0814
Database table: TRAN Transaction data
Data format defaults
Data separator: ;
Decimal separator: ,
Date format: dd-mm-yyyy
Time format: hh:mm:ss
Output file: C:/BoF-PSS2/p_test/OUTPUT/tran-large2.csv
Create new template:
Use old template: tran2
Create names of columns
File column... DB col Man/Opt Var. name Descriptive name Selection criteria
2 M T_SYSTEMID System ID
1 3 M T_TRANSAID Transaction ID
2 4 M T_INTRDATE Introduction date
3 5 M T_INTRTIME Introduction time
4 6 M T_TRANVALU Transaction value >1000
7 M T_FRSYSTID From system ID
5 8 M T_FRPARTID From participant ID
9 M T_FRACCOID From account ID
10 M T_TOSYSTID To system ID
6 11 M T_TOPARTID To participant ID
12 M T_TOACCOID To account ID
7 13 M T_TRANCLAS Transaction class
14 O T_LINKCODE Link code
15 O T_LINKSYST Linked system
16 O T_USERDEID User defined ID
17 O T_DESCRIPT Description
Rows processed: 613
Done
Execute export
Stop export
Help
Back to main menu
Exit program

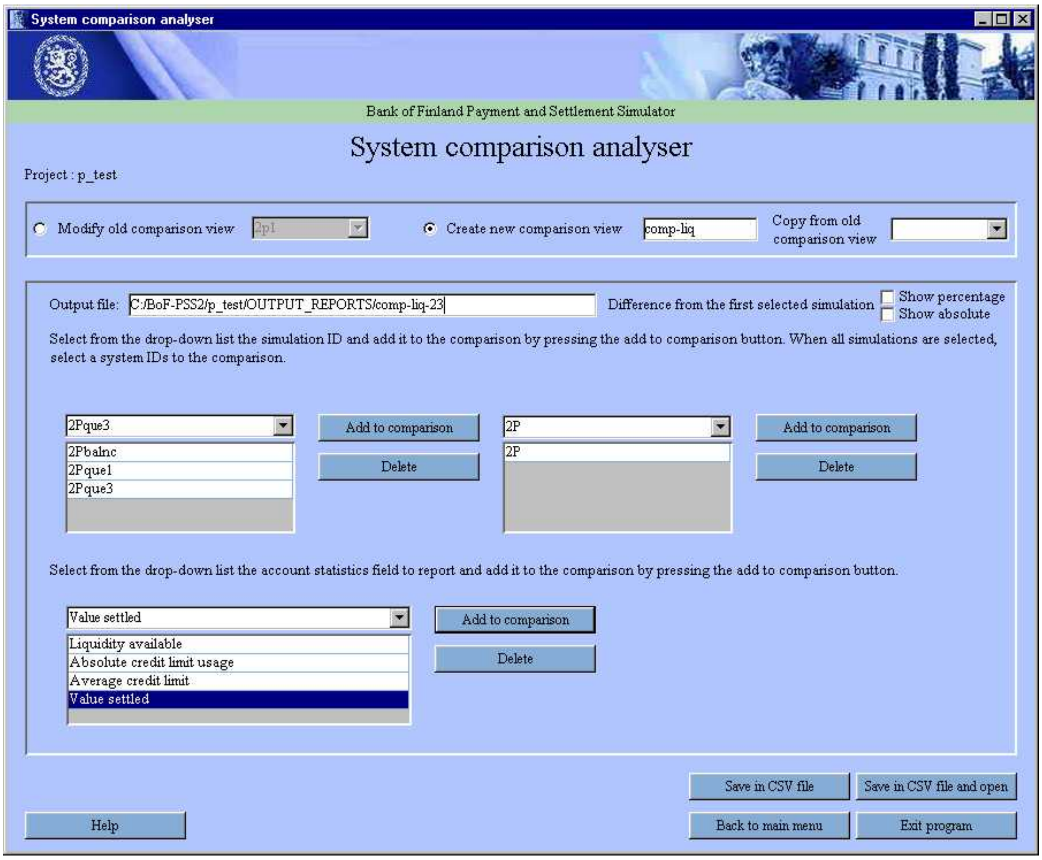

Simulation configuration
Bank of Finland Payment and Settlement Simulator
Simulation configuration
Project : multsyst
Modify old simulation ID
MULTEKA
Create new simulation ID
Copy from old simulation ID
Simulation name:
MONI JÄRJ AJO YKSI
Description:
Sub algorithm:
Parameters
SUFIFOPR
For defining data sets for the simulation select first the right system ID in the corresponding drop-down box above the table and then desired data sets after which pressing the add/update data set button will move the new data to the data table. A system can be deleted from the
Possible parameters for the submission algorithm.
Data sets to simulation:
A
1SYS
TRAN-A
ABANKS
Add/update data set
Delete
System id
System data set
Transaction data set
Participant data set
Credit limit data set
Balance data set
A 1SYS TRAN-A ABANKS
B 1SYS TRAN-B BBANKS
C 1SYS TRAN-C CBANKS
Number of errors:
Save simulation ID
Cross-check
Stop cross-check
View errors
Help
Back to main menu
Exit program

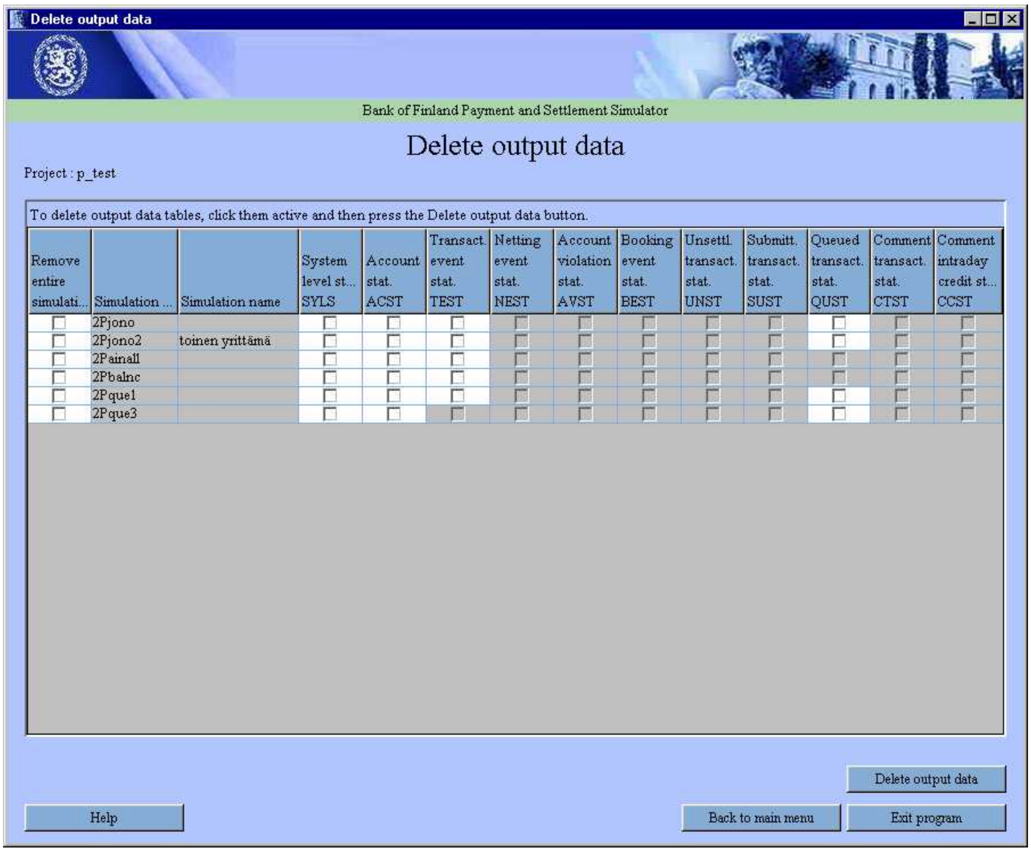

Simulation execution
Bank of Finland Payment and Settlement Simulator
Simulation execution
Project : p_test
Modify old simulation batch ID
Create new simulation batch ID
quetry
Copy from old simulation batch ID
Select a simulation ID and add it to the table by pressing the add simulation ID button. A simulation can be deleted from the batch by selecting the simulation ID and by pressing thereafter the Delete button.
Simulation ID
Simulation name
2Pque3
Add simulation ID
Delete
Simulation id
Simulation name
System level stat. SYLS
Account stat. ACST
Transact. event stat TEST
Netting event stat. NEST
Account violation stat. AVST
Booking event stat. BEST
Unsettl. transact. stat. UNST
Submitt. transact. stat. SUST
Queued transact. stat. QUST
Comment transact. stat. CTST
Comment intraday credit stat. CCST
2Pjono
2Pque1
2Pque3
Save batch
Start
Stop
View error report
Help
Back to main menu
Exit program

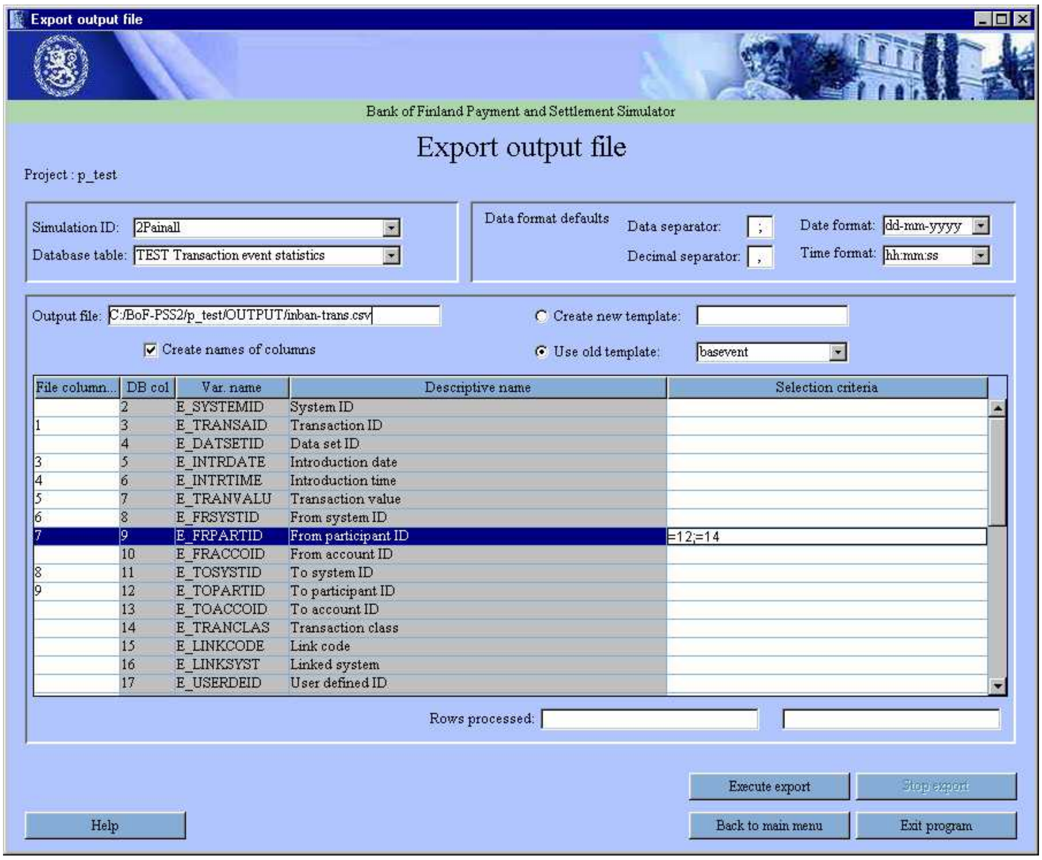

View simulation logs
Bank of Finland Payment and Settlement Simulator
View simulation logs
Project : p_test
Simulation ID
Simulation name
Date/time
Duration
SYLS
ACST
TEST
NEST
AVST
BEST
2Pjono 14-07-2003/11:21:35 00:00:00
2Painall 14-07-2003/01:45:11 00:00:00
2Pbalnc 14-07-2003/02:03:53 00:00:00
2Pque1 15-07-2003/12:21:09 00:00:00
2Pque3 15-07-2003/01:12:05 00:00:00
2Pjono2 toinen yrittämä 14-07-2003/11:24:24 00:00:00
Help
Back to main menu
Exit program

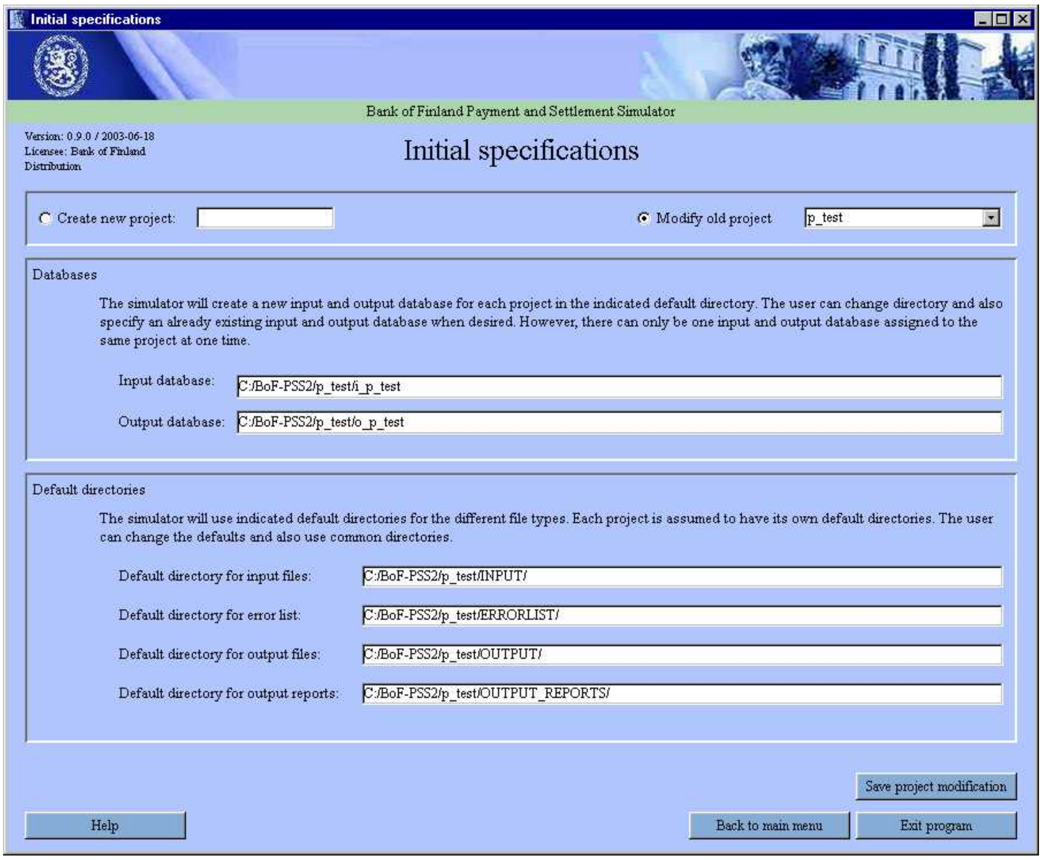

Basic statistics reports
Bank of Finland Payment and Settlement Simulator
Basic statistics reports
Project : p_test
Simulation ID
Simulation name
2Pjono2 toinen yrittämä
Output file: C:/BoF-PSS2/p_test/OUTPUT_REPORTS/Systemstatistics_2Pjono2.csv
Choose one of the report options
System statistics report
Account statistics report
System ID:
System time series report
System ID:
Reporting interval per
minutes
Account time series report
System ID:
Reporting interval per
minutes
Participant ID
Account ID
Account ID:
Save in csv-file
Save and open csv-file
Help
Back to main menu
Exit program

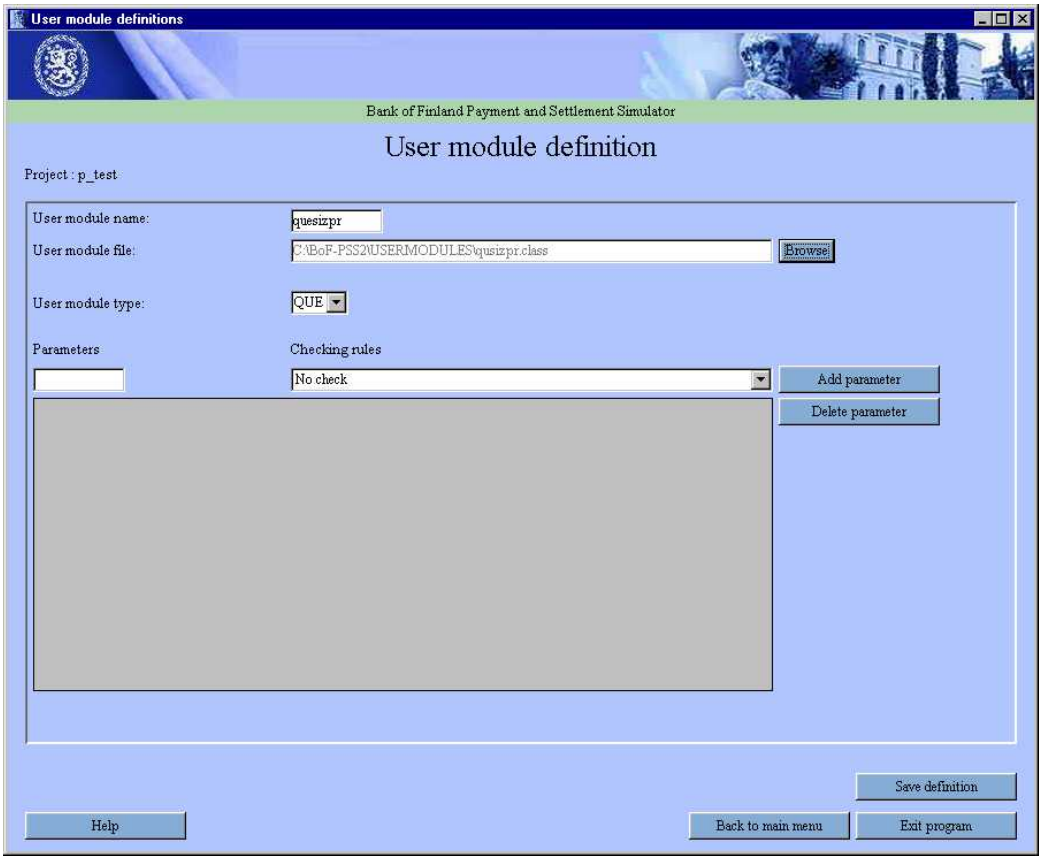

Account comparison analyser
Bank of Finland Payment and Settlement Simulator
Account comparison analyser
Project : p_test
Modify old comparison view
Create new comparison view
comp-que
Copy from old comparison view
Output file:
C:/BoF-PSS2/p_test/OUTPUT_REPORTS/compquetime.csv
Difference from the first selected simulation
Show percentage
Show absolute
Select from the drop-down list the simulation ID and add it to the comparison by pressing the add to comparison button. When all simulations are selected, select a system ID from the system ID drop-down list.
2Pque3
Add to comparison
2P
2Pbalnc
2Pque1
Delete
Select from the drop-down list the account statistics field to report and add it to the comparison by pressing the add to comparison button.
Queue stop time
Add to comparison
Average queue value
Maximum queue value
Average queue length
Average time of settlement
Queue stop time
Delete
Save in CSV file
Save in CSV file and open
Help
Back to main menu
Exit program

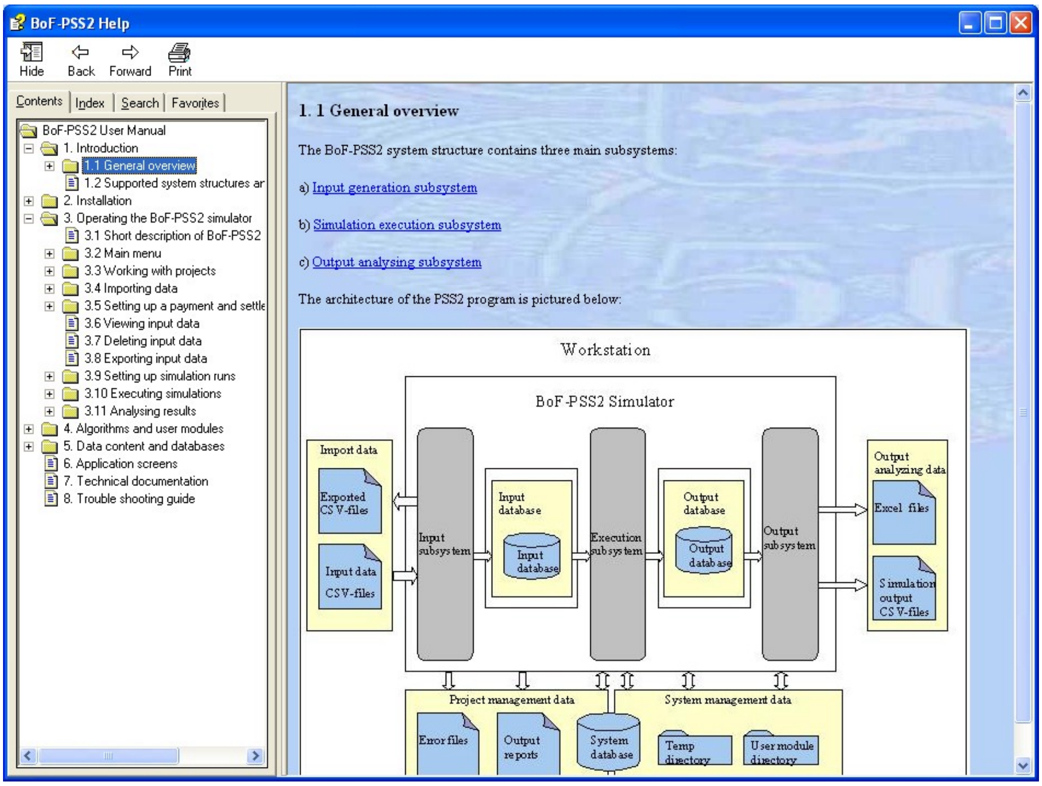

System comparison analyser
Bank of Finland Payment and Settlement Simulator
System comparison analyser
Project : p_test
Modify old comparison view
Create new comparison view
comp-liq
Copy from old comparison view
Output file:
C:/BoF-PSS2/p_test/OUTPUT_REPORTS/comp-liq-23
Difference from the first selected simulation
Show percentage
Show absolute
Select from the drop-down list the simulation ID and add it to the comparison by pressing the add to comparison button. When all simulations are selected, select a system IDs to the comparison.
2Pque3
Add to comparison
2P
Add to comparison
2Pbalnc
2Pque1
2Pque3
Delete
2P
Delete
Select from the drop-down list the account statistics field to report and add it to the comparison by pressing the add to comparison button.
Value settled
Add to comparison
Liquidity available
Absolute credit limit usage
Average credit limit
Value settled
Delete
Save in CSV file
Save in CSV file and open
Help
Back to main menu
Exit program


Delete output data
Bank of Finland Payment and Settlement Simulator
Delete output data
Project : p_test
To delete output data tables, click them active and then press the Delete output data button.
Remove entire simulati...
Simulation ...
Simulation name
System level st... SYLS
Account stat. ACST
Transact. event stat. TEST
Netting event stat. NEST
Account violation stat. AVST
Booking event stat. BEST
Unsettl. transact. stat. UNST
Submitt. transact. stat. SUST
Queued transact. stat. QUST
Comment transact. stat. CTST
Comment intraday credit st... CCST
2Pjono
2Pjono2
toinen yrittämä
2Painall
2Pbalnc
2Pque1
2Pque3
Delete output data
Help
Back to main menu
Exit program


Export output file
Bank of Finland Payment and Settlement Simulator
Export output file
Project : p_test
Simulation ID: 2Painall
Database table: TEST Transaction event statistics
Data format defaults
Data separator: ;
Decimal separator: ,
Date format: dd-mm-yyyy
Time format: hh:mm:ss
Output file: C:/BoF-PSS2/p_test/OUTPUT/inban-trans.csv
Create names of columns
Create new template:
Use old template: basevent
File column... | DB col | Var. name | Descriptive name | Selection criteria
2 E_SYSTEMID System ID
1 3 E_TRANSAID Transaction ID
4 E_DATSETID Data set ID
3 5 E_INTRDATE Introduction date
4 6 E_INTRTIME Introduction time
5 7 E_TRANVALU Transaction value
6 8 E_FRSYSTID From system ID
7 9 E_FRPARTID From participant ID =12;=14
10 E_FRACCOID From account ID
8 11 E_TOSYSTID To system ID
9 12 E_TOPARTID To participant ID
13 E_TOACCOID To account ID
14 E_TRANCLAS Transaction class
15 E_LINKCODE Link code
16 E_LINKSYST Linked system
17 E_USERDEID User defined ID
Rows processed:
Execute export
Stop export
Help
Back to main menu
Exit program


Initial specifications
Bank of Finland Payment and Settlement Simulator
Version: 0.9.0 / 2003-06-18
Licensee: Bank of Finland
Distribution
Initial specifications
Create new project:
Modify old project
p_test
Databases
The simulator will create a new input and output database for each project in the indicated default directory. The user can change directory and also specify an already existing input and output database when desired. However, there can only be one input and output database assigned to the same project at one time.
Input database:
C:/BoF-PSS2/p_test/i_p_test
Output database:
C:/BoF-PSS2/p_test/o_p_test
Default directories
The simulator will use indicated default directories for the different file types. Each project is assumed to have its own default directories. The user can change the defaults and also use common directories.
Default directory for input files:
C:/BoF-PSS2/p_test/INPUT/
Default directory for error list:
C:/BoF-PSS2/p_test/ERRORLIST/
Default directory for output files:
C:/BoF-PSS2/p_test/OUTPUT/
Default directory for output reports:
C:/BoF-PSS2/p_test/OUTPUT_REPORTS/
Save project modification
Help
Back to main menu
Exit program


User module definitions
Bank of Finland Payment and Settlement Simulator
User module definition
Project : p_test
User module name:
quesizpr
User module file:
C:\BoF-PSS2\USERMODULES\qusizpr.class
Browse
User module type:
QUE
Parameters
Checking rules
No check
Add parameter
Delete parameter
Save definition
Help
Back to main menu
Exit program


BoF-PSS2 Help
Hide
Back
Forward
Print
Contents
Index
Search
Favorites
BoF-PSS2 User Manual
1. Introduction
1.1 General overview
1.2 Supported system structures ar
2. Installation
3. Operating the BoF-PSS2 simulator
3.1 Short description of BoF-PSS2
3.2 Main menu
3.3 Working with projects
3.4 Importing data
3.5 Setting up a payment and settle
3.6 Viewing input data
3.7 Deleting input data
3.8 Exporting input data
3.9 Setting up simulation runs
3.10 Executing simulations
3.11 Analysing results
4. Algorithms and user modules
5. Data content and databases
6. Application screens
7. Technical documentation
8. Trouble shooting guide
1. 1 General overview
The BoF-PSS2 system structure contains three main subsystems:
a) Input generation subsystem
b) Simulation execution subsystem
c) Output analysing subsystem
The architecture of the PSS2 program is pictured below:
Workstation
BoF-PSS2 Simulator
Import data
Exported CSV-files
Input data CSV-files
Input subsystem
Input database
Input database
Execution subsystem
Output database
Output database
Output subsystem
Output analyzing data
Excel files
Simulation output CSV-files
Project management data
System management data
Error files
Output reports
System database
Temp directory
User module directory

BANK OF FINLAND DISCUSSION PAPERS

ISSN 0785-3572, print; ISSN 1456-6184, online

1/2003 Tanai Khiaonarong **Payment systems efficiency, policy approaches, and the role of the central bank.** 2003. 69 p. ISBN 952-462-025-1, print; ISBN 952-462-026-X, online. (TU)

2/2003 Iftekhar Hasan – Heiko Schmiedel **Do networks in the stock exchange industry pay off? European evidence.** 2003. 44 p. ISBN 952-462-027-8, print; ISBN 952-462-028-6, online. (TU)

3/2003 Johanna Lukkarila **Comparison between Asian, Russian and Turkish financial crises**. (In finnish). 2003. 57 p. ISBN 952-462-029-4, print; ISBN 952-462-030-8, online. (KT)

4/2003 Samu Peura – Esa Jokivuolle **Simulation-based stress testing of banks' regulatory capital adequacy.** 2003. 41 p. ISBN 952-462-035-9, print; ISBN 952-462-036-7, online. (RM)

5/2003 Peik Granlund **Economic evaluation of bank exit regimes in US, EU and Japanese financial centres.** 2003. 60 p. ISBN 952-462-037-5, print; ISBN 952-462-038-3, online. (TU)

6/2003 Tuomas Takalo – Otto Toivanen **Equilibrium in financial markets with adverse selection.** 2003. 45 p. ISBN 952-462-039-1, print; ISBN 952-462-040-5, online (TU)

7/2003 Harry Leinonen **Restructuring securities systems processing – a blue print proposal for real-time/t+0 processing.** 2003. 90 p. ISBN 952-462-041-3, print; ISBN 952-462-042-1, online (TU)

8/2003 Hanna Jyrkönen – Heli Paunonen **Card, Internet and mobile payments in Finland.** 2003. 45 p. ISBN 952-462-043-X, print; ISBN 952-462-044-8, online (RM)

9/2003 Lauri Kajanoja **Money as an indicator variable for monetary policy when money demand is forward looking.** 2003. 35 p. ISBN 952-462-047-2, print; ISBN 952-462-048-0, online (TU)

10/2003 George W. Evans – Seppo Honkapohja **Friedman's money supply rule vs optimal interest rate policy.** 2003. 22 p. ISBN 952-462-049-9, print; ISBN 952-462-050-2, online (TU)

11/2003 Anssi Rantala **Labour market flexibility and policy coordination in a monetary union.** 2003. 48 p. ISBN 952-462-055-3, print; ISBN 952-462-056-1, online. (TU)

12/2003 Alfred V. Guender **Optimal discretionary monetary policy in the open economy: Choosing between CPI and domestic inflation as target variables.** 2003. 54 p. ISBN 952-462-057-X, print; ISBN 952-462-058-8, online. (TU)

13/2003 Jukka Vauhkonen **Banks' equity stakes in borrowing firms: A corporate finance approach.** 2003. 34 p. ISBN 952-462-059-6, print; ISBN 952-462-060-X, online. (TU)

14/2003 Jukka Vauhkonen **Financial contracts and contingent control rights.** 2003. 33 p. ISBN 952-462-061-8, print; ISBN 952-462-062-6, online. (TU)

15/2003 Hanna Putkuri **Cross-country asymmetries in euro area monetary transmission: the role of national financial systems.** 114 p. ISBN 952-462-063-4, print; ISBN 952-462-064-2, online. (RM)

16/2003 Kari Kemppainen **Competition and regulation in European retail payment systems.** 69 p. ISBN 952-462-065-0, print; ISBN 952-462-066-9, online. (TU)

17/2003 Ari Hyytinen – Tuomas Takalo **Investor protection and business creation.** 32 p. ISBN 952-462-069-3, print; ISBN 952-462-070-7, online. (TU)

18/2003 Juha Kilponen **A positive theory of monetary policy and robust control.** 26 p. ISBN 952-462-071-5, print; ISBN 952-462-072-3, online. (TU)

19/2003 Erkki Koskela – Rune Stenbacka **Equilibrium unemployment under negotiated profit sharing.** 28 p. ISBN 952-462-073-1, print; ISBN 952-462-074-X, online. (TU)

20/2003 Eric Schaling **Learning, inflation expectations and optimal monetary policy.** 49 p. ISBN 952-462-075-8, print; ISBN 952-462-076-6, online. (TU)

21/2003 David T. Llewellyn – David G. Mayes **The role of market discipline in handling problem banks.** 34 p. ISBN 952-462-077-4, print; ISBN 952-462-078-2, online. (TU)

22/2003 George W. Evans – Seppo Honkapohja **Policy interaction, expectations and the liquidity trap.** 32 p. ISBN 952-462-079-0, print; ISBN 952-462-080-4, online. (TU)

23/2003 Harry Leinonen – Kimmo Soramäki **Simulating interbank payment and securities settlement mechanisms with the BoF-PSS2 simulator.** 55 p. ISBN 952-462-082-0, print; ISBN 952-462-083-9, online. (TU)