

**8th SEACEN-CPSS  
Advanced Course on  
Payment and Settlement Systems  
For Emerging Economics**



*Simulation as a tool for Payment System  
Oversight and Policy*

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## *Presentation outline*

1. Advantages of simulation studies in payment systems
2. Characteristics of payment systems
3. Examples of one simulator setups
4. Typical simulation studies
5. Development visions
6. Further reading

***Each section contains subsections***

## Section I:

### Advantages of simulation studies in payment systems

- system complexity
- network structure and interdependencies
- hidden risks and other characteristics
- what if – testing of internal/external shocks
- pretesting changes in system parameters/policies
- general applicability

***Simulation studies assist in understanding the structures and dependencies in payment systems***

## *System complexity*

- ◆ Large systems often with several thousand participants
- ◆ Large volumes ( often > 100 000 transactions/day)
- ◆ Each participant can have different behavioural patterns and processing limits towards other participants
- ◆ The system community can define market rules
- ◆ The settlement agent/bank stipulates different account rules on the settlement accounts and provide incentives for given types of processing
- ◆ The system contains processing rules for different kinds of situations
- ◆ The authorities can regulate payment and settlement processing

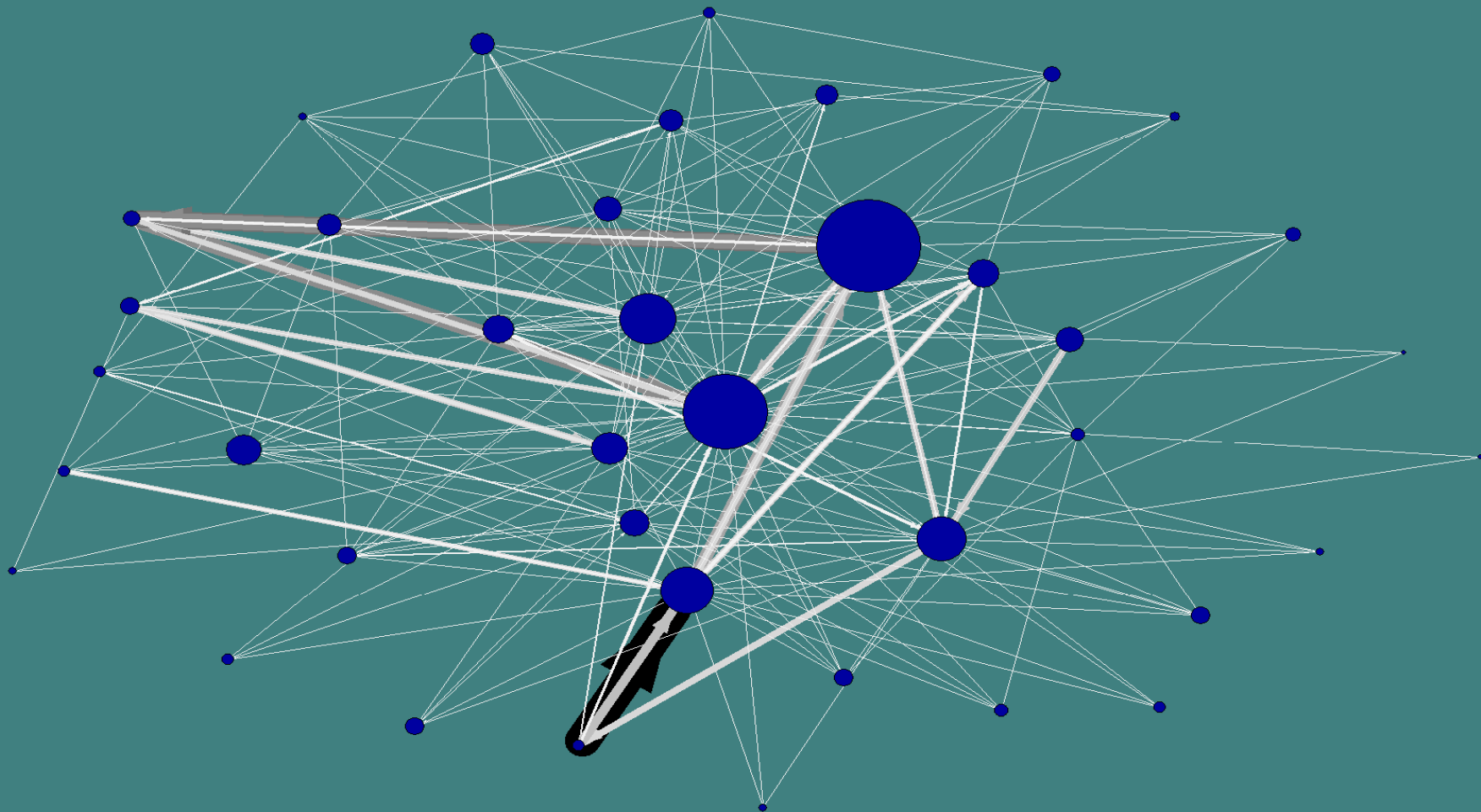
***Models based on simulation are closer to reality than models based on calculus***

## *Network structure and interdependencies*

- ◆ **Payment = debit on one and credit on another account**
- ◆ **Processed payments create an intraday transaction flow**
- ◆ **An interbank payment requires updating of interbank positions at a settlement bank (generally central bank)**
- ◆ **Interbank settlement requires liquidity (funds to transfer)**
- ◆ **Banks are dependent on the liquidity**
  - **available on the settlement account,**
  - **the incoming liquidity from other banks and**
  - **the outgoing liquidity from their transactions**
- ◆ **Banks operate in several parallel payment systems with liquidity effects on each other**
- ◆ **Transactions can have transaction level dependencies**
  - **in the form of PVP (payment-versus-payment) and**
  - **DVP (delivery-versus-payment) rules**

***Compared to other transaction flows payments must also transfer the money value between all participants***

*Payment systems and their participants are dependent on an even and predictable transaction flow*



***Some nodes (banks) and relationships (links) are more critical than others***

## *Hidden risks and other characteristics*

Generally payment systems work without problems, but ...

- ◆ Hidden single point of failures may stop the physical flow
- ◆ Liquidity drainage can stop the settlement flow
- ◆ Some systems build up credit risk exposures during the day, which can generate domino-effects in crises
- ◆ The interdependencies between systems and their participants can transmit problems throughout the system

***Simulations can be used to disclose  
the hidden characteristics of real systems***

## *Robustness towards shocks*

- ◆ Small external shocks can affect the whole system
- ◆ What if
  - a central participant experiences operational problems?
  - the largest participant fails to settle?
  - one ancillary system is delayed or stops running?
  - the liquidity market and other liquidity sources function abnormally ?

***Checking impact with simulations improve readiness for external and internal shocks***

## *Pretesting policy changes/decisions*

- ◆ Small changes in system designs and rules can have a big impact
- ◆ What if
  - liquidity supply rules changed?
  - queuing options are changed?
  - new kinds of liquidity saving mechanisms/algorithms are introduced?
  - risk mitigation features are changed?
  - opening hours are changed?
  - new participants are accepted or old excluded?

***Checking impact with simulations improve policy decisions and readiness for change***

## *General applicability*

- ◆ Central banks can use payment simulations in
  - The payment and settlement system oversight work
  - Preparing payment and settlement system policies
  - Managing operational services
- ◆ Clearing centres and other service providers the tools for
  - Developing system rules and practices
  - Improving the efficiency of the system
  - Assessing the risks in the provided services
- ◆ Academics have increased their interest in
  - Payment system research on efficiency & risks
  - Modelling systems and participant behavior

***The application area of simulations  
seem to grow rapidly***

## *Summary of advantages*

- ◆ A possibility to model complex systems close to reality
- ◆ Describe and study the payment network processes and dependencies
- ◆ Find out hidden characteristics and assess robustness towards external and internal shocks
- ◆ Pretesting change alternatives without affecting production environment

## Section II:

### Characteristics of payment systems

- DNS, CNS and RTGS systems
- Delay, credit risk and liquidity costs
- Gridlock resolution, liquidity saving mechanisms and other processing algorithms
- Risk mitigation and liquidity drainage limits
- Inter-system connections and liquidity bridges
- Back-up facilities

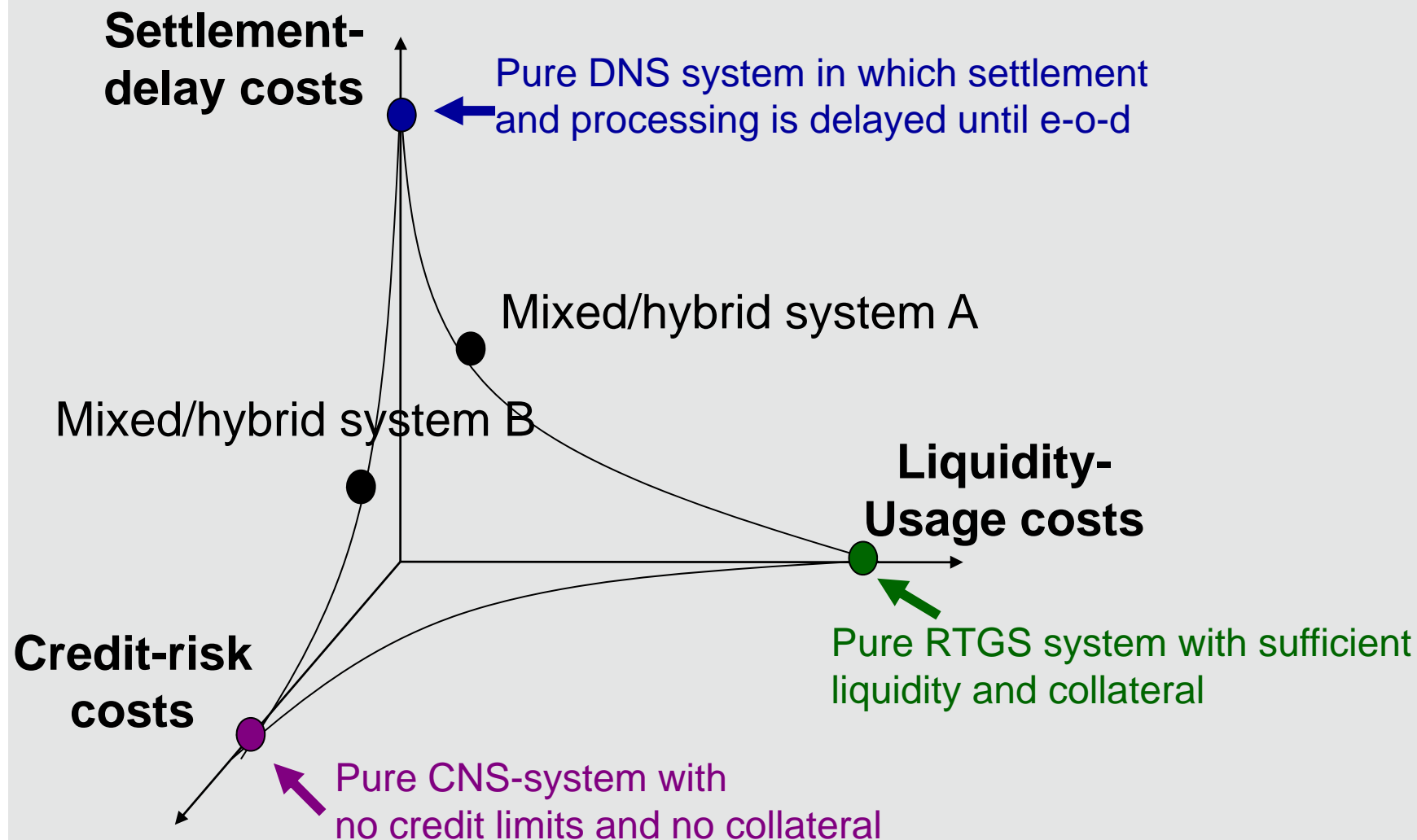
***The system characteristics are  
one of the major simulation research topics***

## *Three pure types of payment systems*

- ◆ Deferred net settlement systems (=DNS) collect all transactions to a given, mostly, end-of-day settlement
  - Only net liquidity needed, all payments are delayed, no credit risked when payments are stopped due to insufficient liquidity
- ◆ Continuous net settlement systems (=CNS) process continuously payments and updates settlement positions which will be settled only later (mostly at end-of-day)
  - Payments are credited to customers before interbank settlement, which results in credit risks supporting rapid delivery
- ◆ Real-time gross settlement systems (=RTGS) process payments continuously by also making final settlements
  - Payments can be credited directly to customers as these are settled directly, but this will require more intraday liquidity

***Most of the real systems are some kind of hybrid systems containing a mix of features***

# System type and cost structures



Source: Harry Leinonen (ed) Liquidity, risks and speed in payment and settlement systems  
- A simulation approach, Bank of Finland Studies E:31. 2005 / Leinonen & Soramäki Introduction p47

*All dimensions carry direct or indirect costs*

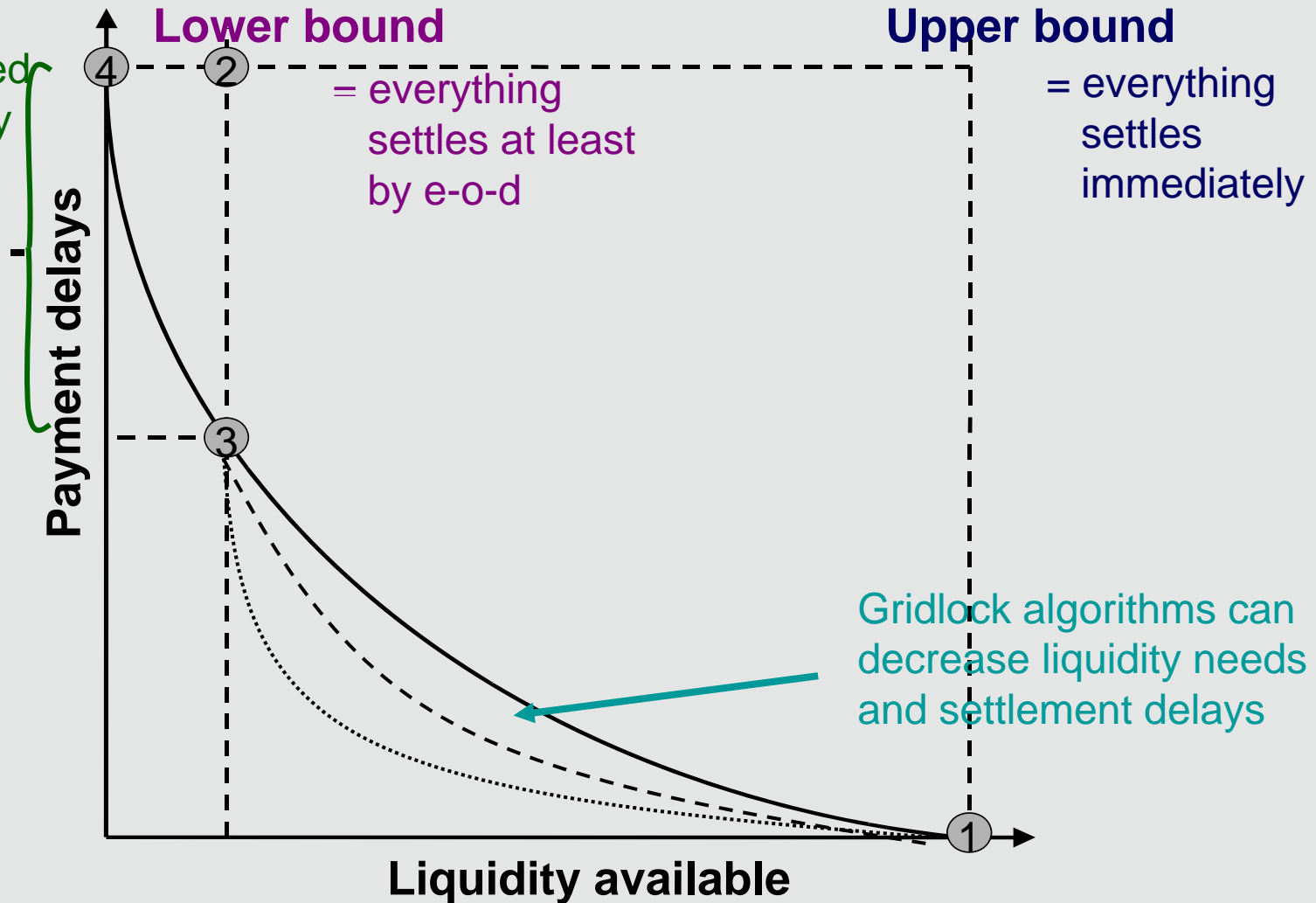
- ◆ Intraday liquidity used in payment systems carry costs in the form of an interest rate or a collateral (alternative) cost
- ◆ Extended credits carry always a risk and thereby a cost, which can partly be reduced by collateral, but collateral carries also costs for its provider
- ◆ Delays can have costs in the form of penalties or other delay charges, but also in the form of "bad will" or reduced trust
- ◆ An inefficiently functioning system will have higher costs than necessary

***Minimising system costs requires thorough analysis of the cost factors***

# Mixed/hybrid systems balance cost factors

## RTGS can speed up processing

RTGS benefit over DNS when same liquidity is used during the day



Source: Harry Leinonen (ed) Liquidity, risks and speed in payment and settlement systems

- A simulation approach, Bank of Finland Studies E:31. 2005 / Leinonen & Soramäki Introduction p37

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*Participants' decisions affect the others,  
some participants may be free-riders in RTGS*

- ◆ Participants select generally their liquidity levels
- ◆ Reducing liquidity towards lower bound, will delay outgoing payments
- ◆ Reduced outgoing payments, will decrease incoming payments, which could trigger new outgoing payments
- ◆ Some "free-riding" participants may reduce their liquidity anticipating that others will send off payments as before, providing them (=free-riders) with incoming liquidity

***Simulation studies can be used to discover  
efficient liquidity level and possible free-riders***

## *Gridlock resolution algorithms*

- ◆ Gridlock resolution can be applied on queued payments
- ◆ The queue-order and/or gridlock-solution order affect netting possibilities
- ◆ For example strict FIFO (=first in, first out) order is rigid compared to different kinds of by-pass FIFO solutions
- ◆ Several algorithms can be applied in different search order and with different "parcelling" convention
  - Bilateral offsetting nets bilaterally corresponding queues
  - Full multilateral netting nets all queued transactions
  - Partial multilateral netting nets suitable parts of queued transactions among some participants

***The efficiency of gridlock-resolution algorithms depends on the queue size and structure plus the "search" efficiency of the algorithm***

## *Risk mitigation and liquidity drainage limits*

- ◆ In CNS systems participants use multilateral or bilateral debit caps to reduce credit risks
- ◆ In RTGS systems this corresponds to bilateral or multilateral net sending limits which reduces "liquidity drainage" risks
- ◆ Liquidity drainage can occur eg when central participant experiences operational problems hindering its outgoing payment flow = it becomes a "liquidity sink"
- ◆ Debit caps and net sending limits can both be used too little, fairly and too protectively

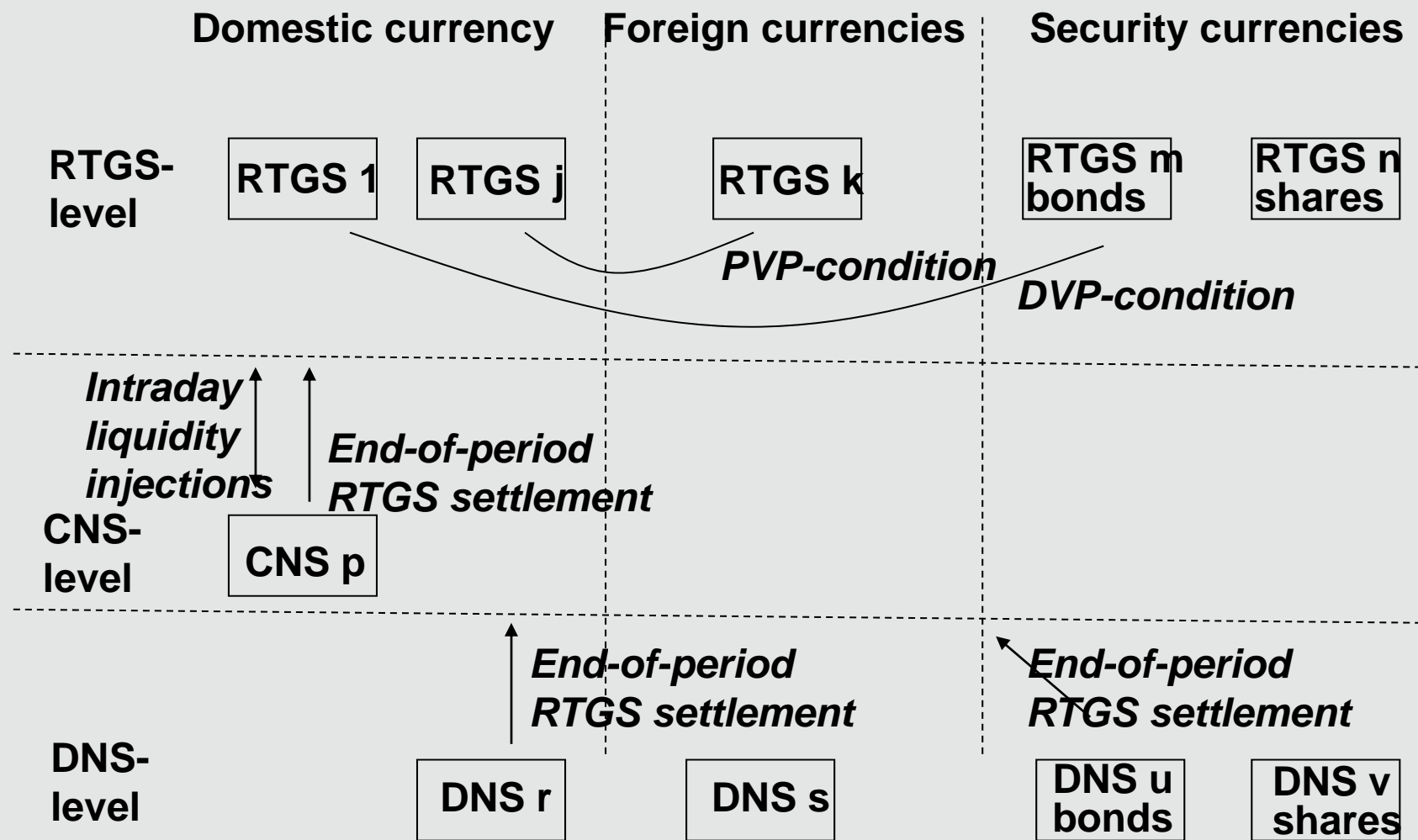
***The market, system owner or authorities may prescribe suitable or minimum limits to be used***

## *System linkages and liquidity bridges*

- ◆ Most payment systems are integrated and interlinked due to ICT-developments
- ◆ Typically ancillary systems such as retail DNS systems and real-time securities settlement systems use the central bank accounts in RTGS systems for settlement
- ◆ There are several types of system linkages
  - End-of-day or settlement cycle net settlement transfers
  - Liquidity bridges for transferring liquidity between systems
  - DVP- or PVP-based transfers with the different legs (money or security) in two interconnected systems
- ◆ Systems linkages make systems dependent on each other

***The linked systems create large networks by themselves in the global financial markets***

# Possible multisystem structures



**Growing financial and ICT integration  
increase the number of system linkages**

Source: Harry Leinonen (ed) Liquidity, risks and speed in payment and settlement systems

- A simulation approach, Bank of Finland Studies E:31. 2005 / Leinonen & Soramäki Introduction p25

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## *Back-up facilities*

- ◆ Payment and settlement systems form the backbone of modern economies
- ◆ Without these economic activities would be difficult to settle
- ◆ High reliability is required from all kind of systems
- ◆ Payment and settlement systems therefore need to have well-designed back-up systems
- ◆ When payments are of different urgencies, the top back-up facilities can be designed for highly urgent payments only

***Simulation models can be used to check the functioning and capacity of back-up solutions***

## *Summary of system characteristics*

- ◆ Payment and settlement systems contain a larger number of characteristics and parameters such as system design, liquidity provision, credit risks, counterparty risk and net-sending limits, gridlock resolution algorithms etc
- ◆ Small changes in these parameters can have major impact on the payment flows especially when the effects are interrelated
- ◆ Simulation have proved to be a good option for studying these relationships and their effects

## **Section III:** **Examples of simulator setups**

- **How true to the production environment?**
- **Input data considerations**
- **General processing structure**
- **Caution with results**

## *How true to nature?*

- ◆ Real payment systems contain a multitude of detailed processing rules and conventions
- ◆ Behavioural patterns can be stable but also random with unanticipated changes
- ◆ Participant numbers and transaction volumes can be huge in large systems
- ◆ Simulation technology gives the possibility to design models that are true to nature

***The complexity of the simulation models should be designed according to research needs***

## *Input data starting points*

- ◆ Payment flows ie transactions
- ◆ Rules governing payment processing
- ◆ Liquidity provision and risk limitations
- ◆ Participants and their behavioral patterns

***The input data will vary depending on  
the focus of the simulations***

*Input data close to production data  
would include ...*

- ◆ System level data describing the processing conventions of the system
- ◆ Transaction data with or without DVP/PVP-linkages
- ◆ Basic participant data
- ◆ Beginning of day liquidity (settlement account) balances
- ◆ Intraday credit provisions
- ◆ Bilateral or multilateral debit caps and/or sending limits
- ◆ Behavioural patterns of participants

***The “real and hard” data is generally available,  
however the “soft behavioural” data is seldom  
available and it is difficult to describe***

## *Simulated transaction flows can constitute of ...*

- ◆ Historic data for testing "what if" something different would have happened in the past
- ◆ Modified historic data for example based on behavioral assumptions
- ◆ Artificial data based on assumed participant and network structures
- ◆ Flows generated by agent-based behavioral models

***The input data choice depends on  
the objective of the study***

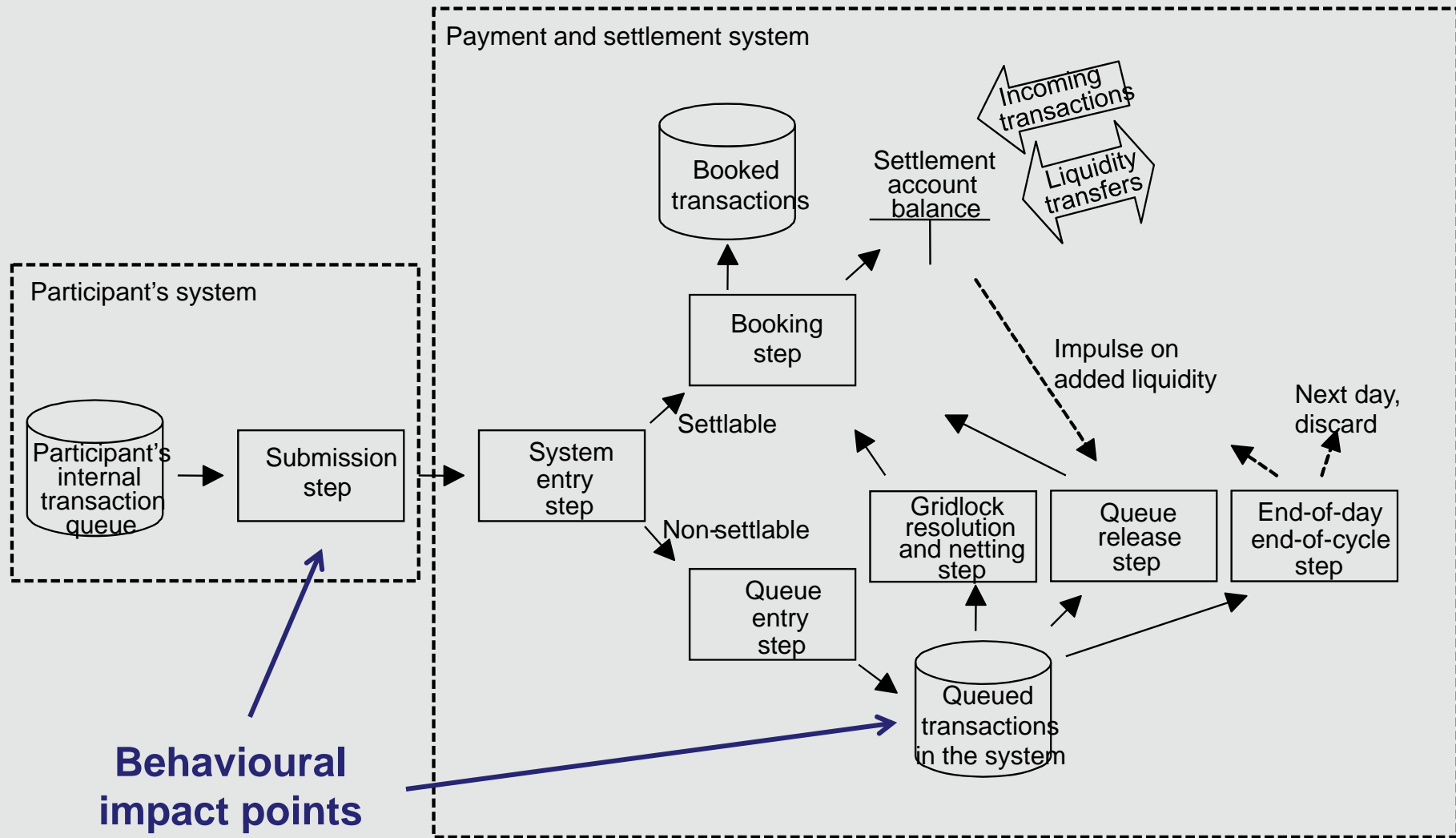
## *Agent-based payment behavioural modeling*

- ◆ Participants (agents) submit payments dependent on
  - Internal queuing/submission rules and patterns
  - Reactions to general system situations (eg liquidity availability)
  - Reactions to behaviour of other participants (eg delays)
- ◆ Participants select and modify liquidity levels and counterparty limits are dependent on
  - Internal rules and patterns
  - Reactions to general liquidity market, cost and risk situations
  - Reactions to behaviour of other participants (eg symmetric limits)
- ◆ Participants reorder queued payments dependent on
  - Overall system and queuing situation
  - Cost/benefit considerations
  - Behavioru of other participants

***Participants (agents) can make choices for given factors while the system process follows otherwise strict processing rules***

# Transaction driven simulations

Basically same events occur in the same sequence in simulations as in real-systems.



Source: Harry Leinonen (ed) Liquidity, risks and speed in payment and settlement systems  
 - A simulation approach, Bank of Finland Studies E:31. 2005 / Leinonen & Soramäki Introduction p29

## *A typical simulation project structure*

- ◆ Define and obtain input data
  - Participants/accounts, transactions, system data
  - Historic data can be difficult to obtain
  - Behavioural parameters for agent-based models are difficult to define
- ◆ Build the simulator for simulations
  - Ready made or using programming or modelling tools
- ◆ Execute simulations
  - Different background data, different parameters
  - Good preplanning helps in massive simulations
- ◆ Analyse results
  - Find suitable comparison points
  - Possibilities for international comparisons are growing
- ◆ Reiterate
  - Simulations are often learn-by-doing processes

***Large simulations are time-consuming***

## *Simulations are only simulations*

- ◆ Historic data is history, not the future
- ◆ In historic data abnormal situations are rare
- ◆ Treasurers' payment behaviour and preferences are mainly unknown and especially in new circumstances
- ◆ Behaviour in stress situations can be surprisingly different
- ◆ The results take mostly the form of probability outcomes

***Despite its weaknesses simulations provide important insights to the complex payment processes***

## *Summary of simulation setups*

- ◆ Realistic simulations require detailed copying of production processes
- ◆ Especially submission of payments are behaviour driven, but behavioral background factors are little known
- ◆ Obtaining input data can be difficult
- ◆ Building a “realistic” simulator needs thorough programming
- ◆ Simulations have limitations

## **Section IV:** **Typical simulation studies**

- **network**
- **liquidity**
- **credit risks**
- **efficiency/delay/operations**

## Available payment and settlement simulation studies

	Network analysis *	Liquidity analysis	Credit risk analysis	Delay/queuing analysis
Oversight	2 USA, UK	23 FIN, UK, SWE, CAN, AUT, JPN, SUI, HOL, HUN, DEN, POL, NOR, ROM, BIS	16 ISL, UK, CAN, FIN, AUT, JAP, SUI, HOL, DEN, POL, BIS	14 DEN, FIN, UK, SWE, CAN, AUT, JAP, HOL, HUN, POL
Operational development issues		7 USA, KOR, FIN, CAN, UK	4 ISL, CAN, UK, FIN	5 USA, DEN, CAN, UK, FIN
Policy concerns	2 USA, UK	16 FIN, KOR, DEN, SWE, CAN, USA, UK, POL, NOR, AUS	11 FIN, ISL, DEN, CAN, USA, UK, POL	13 FIN, DEN, SWE, CAN, USA, UK, POL
Basic research	1 FIN	6 USA, FIN, JAP, ITA, BIS	4 USA, FIN, JAP, BIS	5 USA, DEN, FIN, UK

Source: Bank of Finland Payment and Settlement Simulation seminars 2003-2009  
see [www.bof.fi/sc/bof-pss](http://www.bof.fi/sc/bof-pss)

## *Typical oversight studies*

### ◆ **Network analysis**

- Which are the most important participants and connections?
- Do connections vary during the day and from day to day?
- What are the end-of-day and overnight patterns?
- How would the network change during outages?

### ◆ **Liquidity analysis**

- What are the current liquidity levels and effects of general drainage?
- What is the impact of large participants' liquidity problems or stoppage?
- Are some participants working with too low liquidity levels?
- How large shocks can the current liquidity supply sustain?

### ◆ **Credit risk analysis**

- How large are the current credit risk levels and systemic risk probabilities?
- By how much will credit risks grow in crisis situations?
- To what extent can participants sustain current credit limits?
- What impact will more stringent credit risk requirement have?

### ◆ **Delay/queuing analysis**

- What effect will large participants' and system stop have on delays
- Do some participants delay payments more than others?

## *Example 1: Liquidity effects of a participant-level operational disruption in the Swiss Interbank Clearing*

- ◆ Simulations with May 2004 data: 13 million payments worth SFR 3 bn
- ◆ 1 or 2 major participants' payment submissions are disrupted at "worst" point
- ◆ Results:

<i>May 2004</i>	<b>Number of transactions</b>		<b>Value of transactions in million CHF</b>	
	<b>Daily average</b>	<b>% (minimum to maximum)</b>	<b>Daily averages</b>	<b>% (minimum to maximum)</b>
<b>Settled transactions</b>	661'000	92 (85 to 98)	89'100	54 (33 to 93)
<b>Unsettled transactions - direct effect</b>	32'000	4 (1 to 7)	40'400	24 (4 to 44)
<b>Unsettled transactions - systemic effect</b>	26'000	4 (0 to 9)	36'200	22 (1 to 37)
<b>Total</b>	<b>719'000</b>	<b>100</b>	<b>165'700</b>	<b>100</b>

Source: M. Glaser – P. Haene in Bank of Finland publication E:42

## *Typical policy studies*

### ◆ **Network analysis**

- What would be the impact of new participant access criteria?
- What is the current level of tiering and the impact of possible changes?
- What is the network characteristic of prioritised transactions?

### ◆ **Liquidity analysis**

- What is the impact of new liquidity regimes
- What would be the effects of new liquidity pricing schemes?
- What would be the impact of different prioritising regimes?
- What would be the most efficient liquidity/delay levels?

### ◆ **Credit risk analysis**

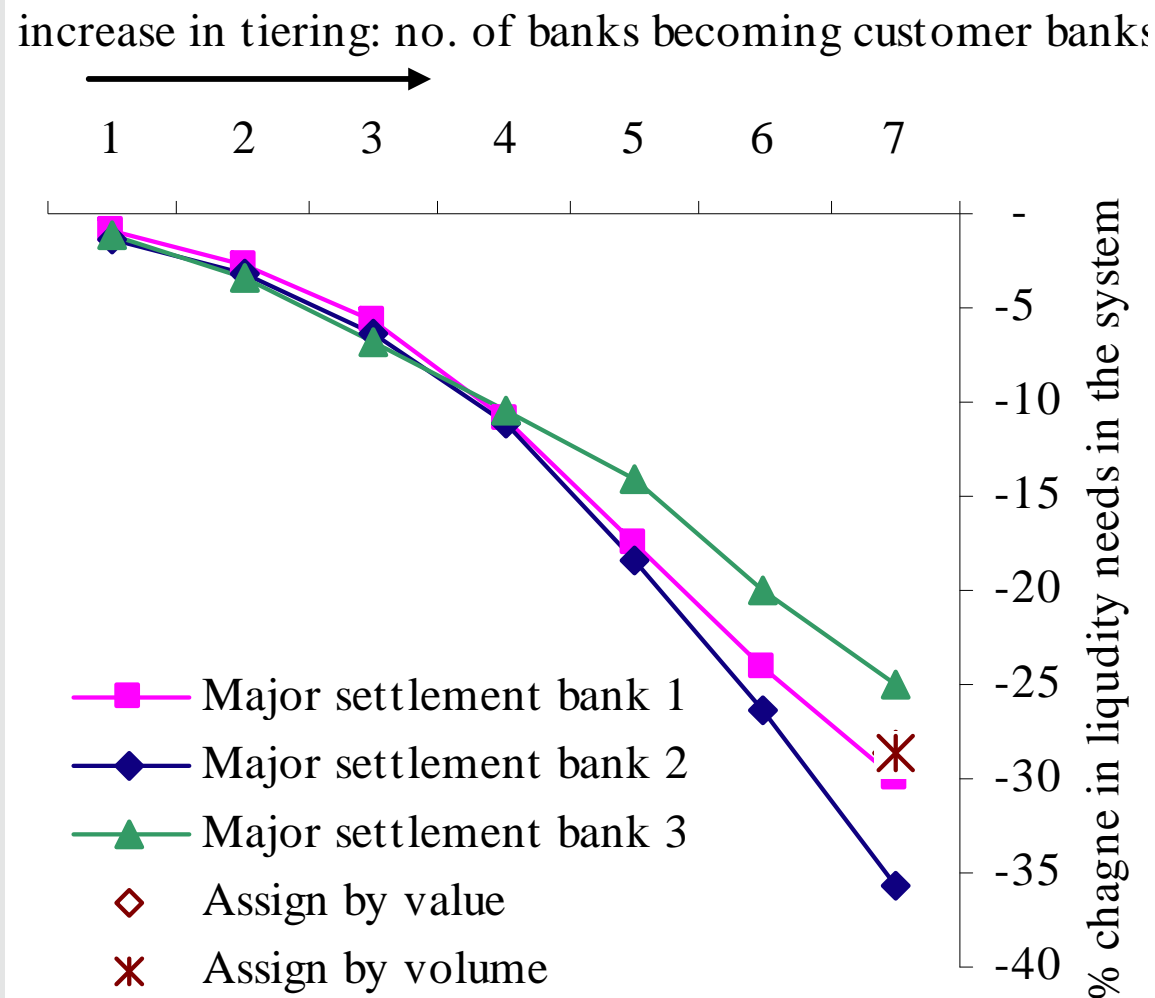
- What would be the impact of new credit risk rules?
- What would be the most efficient credit risk/delay levels?

### ◆ **Delay/queuing analysis**

- What could be the effects of new rush-hour pricing policies?
- Which gridlock resolution algorithms would be most efficient for given payment flows?
- What are the effects of bypassing FIFO or other processing order rules?
- What are the effects of new opening hour rules?

## Example 2: Risks and efficiency gains of the tiered structure in CHAPS (UK)

- ◆ Simulations with June 2005 data: 2.5 million payments worth GBP 4.2 trillion
- ◆ Increasing tiering by reducing number of direct participants ie moving small banks to become indirect participants of major banks
- ◆ Results: Substantial liquidity savings, but increased node and credit risks



Source: A. Lasaosa – M. Tudela in Bank of Finland publication E:39

## *Typical operational studies*

### ◆ **Network analysis**

- What are the current capacity profiles and bottlenecks?
- How would different shocks change the capacity profiles?
- How much capacity do different prioritising schemes for different system outage scenarios require

### ◆ **Liquidity analysis**

- What effects would different kinds of marked-based synchronisation and timing rules have?
- What impact would shifting volumes between different systems have?
- What are the effects of different types of liquidity bridges?
- How fast should liquidity expansion operations be?

### ◆ **Credit risk analysis**

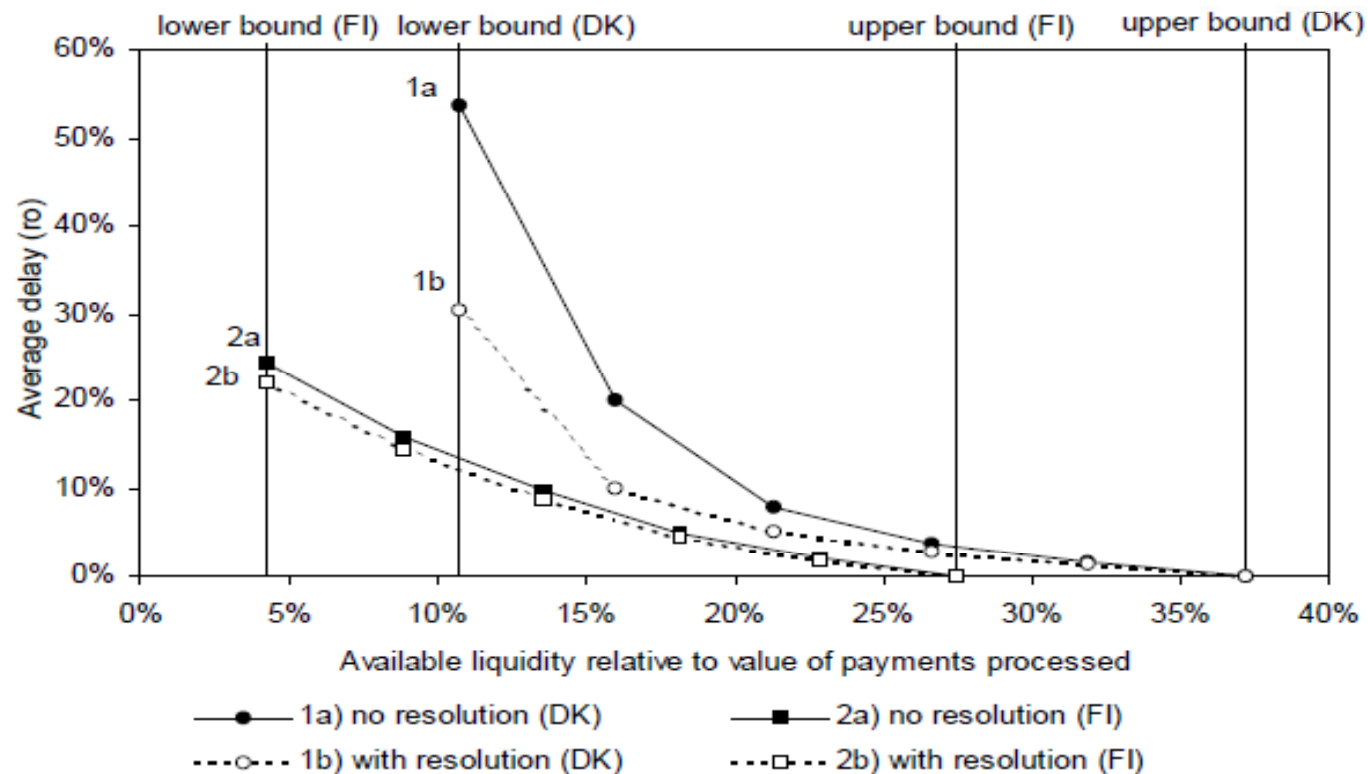
- How fast do credit limit change procedures need to be?

### ◆ **Delay/queuing analysis**

- What would be the effects of introducing prioritising, queuing and gridlock resolution features?
- How efficiently are current prioritising, queuing and gridlock resolution features used?
- How would algorithms' parameter changes affect overall queuing?

## Example 3: Effects of gridlock resolution mechanisms in Danish and Finnish RTGS systems

- ◆ Simulations for last 64 days/1999 in Denmark (daily average EUR 9.4 bn and 925 transactions) and last 100 days/2000 in Finland (daily average EUR 15 bn and 1428 transactions)
- ◆ A partial net-settlement gridlock solution algorithm is tested
- ◆ Results: **Trade-off between liquidity and delay**



Source: M. Bech - K. Soramäki in Bank of Finland Discussion Paper 9/2001

# *Typical basic research studies*

## ◆ **Network analysis**

- What are current network structures in different systems?
- Are there typical trends in network structure changes?
- Are there differences in market-driven and society-optimal network structures?

## ◆ **Liquidity analysis**

- Do liquidity levels vary across systems and countries?
- Are there typical trends in liquidity provision regime changes?
- What are the differences between public and private liquidity regimes?

## ◆ **Credit risk analysis**

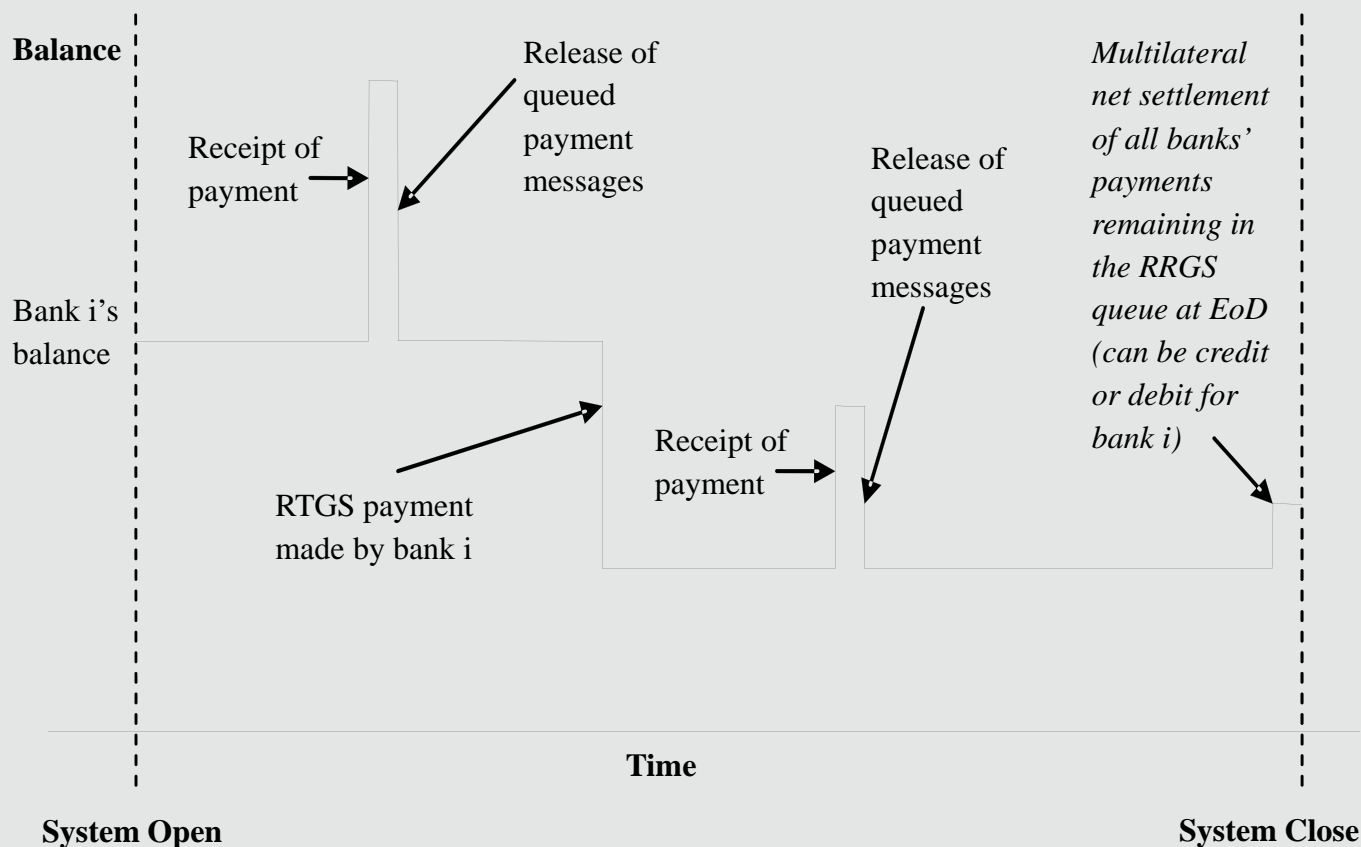
- Are there general warning signals for increased systemic risk?
- How could systemic risk probabilities be best measured?
- What are the historic correlations between systemic risks and participants credit risks?
- What are the efficiency and risk concerns of private vs public credit risks?

## ◆ **Delay/queuing analysis**

- Can general optimality among gridlock algorithms be established?
- Are there differences among service providers' and customers' preferences?

## Example 4: Simulating the impact of a hybrid receipt reactive processing convention in CHAPS

- ◆ Simulations using artificial and CHAPS (UK) data
- ◆ Testing the impact of introducing a receipt reactive processing convention



- ◆ **Results: RRGs (receipt reactive) processing can achieve a level of welfare that weakly dominates that achievable under RTGS**

Source: K. Ercevik – J. Jackson in Bank of Finland publication E:42

## *Summary of typical simulation studies*

- ◆ Simulation studies are used for all kind of central bank tasks: oversight, policy, operations and research
- ◆ Studies are made concerning network, liquidity, credit risk, efficiency etc payment issues
- ◆ Simulation studies are a growing research area
- ◆ Private institutions' interest in simulation studies is also growing

## **Section V:** **Development visions**

- **better understanding of payment processes**
- **deeper knowledge of critical risks**
- **expanded models**
- **improved behavioural modeling**

## *Understanding payment processes better*

- ◆ Payment systems have often been seen as "black boxes"
- ◆ Only critical situations have generated more focus on these important parts of the economies
- ◆ Payment research has been growing since early 1990s
- ◆ Deeper understanding have resulted in core principles (BIS/CPSS), recommendations and standards for efficient payment and settlement systems
- ◆ System requirements seem to become harmonised globally
- ◆ International cooperation regarding multinational and multicurrency systems will become necessary

***Understanding the "hard facts" of payment systems have increased and it seems now be the time to focus on the "soft parts" of payment processing***

## *Improved behavioural modelling*

- ◆ Which factors steer banks payment submission behaviour?
- ◆ Which factors steer banks counterparty reactions in different situations?
- ◆ What affect banks behaviour in crisis situations?
- ◆ How can the payment behaviour of large institutional investors and large companies etc be modelled?

***We will need more basic research  
on the underlying behavioural factors***

## *Deeper knowledge of critical risks*

- ◆ Financial turmoil has brought back focus on financial risks and the need to secure sufficient liquidity
- ◆ Payment systems have often embedded risk factors and authorities have need to penetrate deeper into critical risk factors
- ◆ Global real-time payment processing will require fast response times in problem situations both by participants and authorities

***The development speed seems to accelerate and all concerned parties need to update their information on critical risk issues***

## *Expanded simulation models*

- ◆ From payment systems to general market stability simulations
- ◆ From interbank system simulations to customer-level models
- ◆ From very simple behavioural models to more complex models

***Today, computer capacity is no limitation for building even comprehensive “economy-level” simulation models, but we lack sufficiently reliable behavioural information***

## *Summary of development visions*

- ◆ The research on payment and settlement systems has steadily grown since the 1990s
- ◆ Systems have become more standardised and harmonised
- ◆ The topic of payment behaviour will need more research
- ◆ ICT developments will provide improved high-capacity tools

***Simulation models of payments systems  
will still improve and become more versatile  
(from second generation to third generation models)***

## *Section VI: Further reading*

Bank of Finland series **E:14** Risto Koponen – Kimmo Soramäki **Intraday Liquidity Needs in a Modern Interbank Payment System. A Simulation Approach. 1998.** 135 p. ISBN 951-686-601-8.

Bank of Finland series **E:31** Harry Leinonen (ed.) **Liquidity, risks and speed in payment and settlement systems – a simulation approach.** 2005. Compilation. 350 p. ISBN 952-462-194-0, print; ISBN 952-462-195-9, online.

Bank of Finland series **E:39** Harry Leinonen (ed.) **Simulation studies of liquidity needs, risks and efficiency in payment networks.** 2007. Proceedings from the Bank of Finland Payment and Settlement System Seminars 2005–2006. 320 p. ISBN 978-952-462-360-5, print; ISBN 978-952-462-361-2, online.

Bank of Finland series **E:42** Harry Leinonen (ed.) **Simulation analyses and stress testing of payment networks. 2009.** Proceedings from the Bank of Finland Payment and Settlement System Seminars 2007–2008. 340 p. ISBN 978-952-462-512-8, print; ISBN 978-952-462-513-5, online.

***You can find more information on the web-site***

***[www.bof.fi/sc/bof-pss](http://www.bof.fi/sc/bof-pss)***

***and in the list of published studies after the last slide***

*Thank you for your interest.*

*Q & A*

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## *Oversight studies with publically available results I*

**Finnish BoF-RTGS** - assess liquidity effects of introduction of TARGET and the shift to a greater use of RTGS settlement – results published 1997 in BoF E:14

**Iceland's Sedlabanki** - netting vs. real-time gross settlement - setting credit limits for the system, 1999

**Bech and Soramäki (2002)** '*Liquidity, Gridlocks and Bank Failures in Large Value Payment systems*', E-Money and Payment systems Review (Bech-Soramäki)

**Paul Bedford - Stephen Millard - Jing Yang, BoE:** Analysing the impact of operational incidents in large-value payment systems: A simulation approach, 2005

**Johan Pettersson, Sveriges Riksbank:** Liquidity levels and delays in RIX, 2005

**Darcey McVanel, Bank of Canada:** The impacts of unanticipated failures in Canada's Large Value Transfer System, 2007

**Matti Hellqvist, Bank of Finland:** Stress testing securities settlement systems using simulations, 2007

**Claus Pühr, Stefan W. Schmitz / Oesterreichische Nationalbank:** Risk Concentration and Operational Risk in Payment Systems – A Simulation Approach, 2007

**Kei Imakubo, Yutaka Soejima / Bank of Japan:** Intraday Settlement Activities in the BOJ-NET RTGS, 2007

## *Oversight studies with publically available results II*

**Ana Lasaosa, Merxe Tudela / Bank of England:** Risks and efficiency gains of a tiered structure in large-value payments: a simulation approach, 2007

**Matti Hellqvist / Bank of Finland:** Stress testing liquidity needs in Finnish retail securities settlement system, 2007

**Martina Glaser, Philipp Haene / Swiss National Bank:** Simulation of participant-level operational disruption in Swiss Interbank Clearing, 2009

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