Simulating payment and settlement systems

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simulations as a tool for central bank policy, oversight and research

Kimmo Soramäki
European Central Bank

AGENDA

WHAT are simulations?

WHY to simulate payment systems?

WHO can benefit from simulations?

WHAT are simulations?

Examples and usage of simulations?

- <u>Examples</u>: flight simulations, role and war games, computer simulations, wind tunnels, etc...

- <u>Usage</u>: in production, logistics, finance, learning, history, psychology, etc...

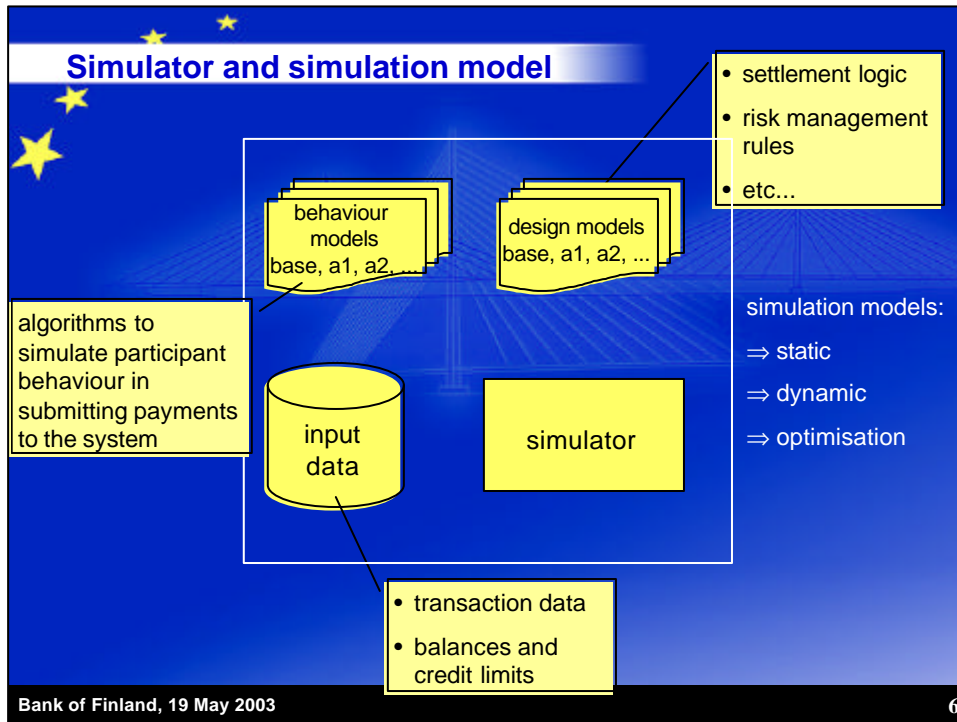- The <u>common approach</u> is to replicate real life through modelling

A brief history of simulations

- Ancient and medieval times: Chess

- 19th century: "Neues Kriegspiel" in Prussia

- 40's: First modern simulations (Monte Carlo)

- 50's: Political and social sciences (cold war, training)

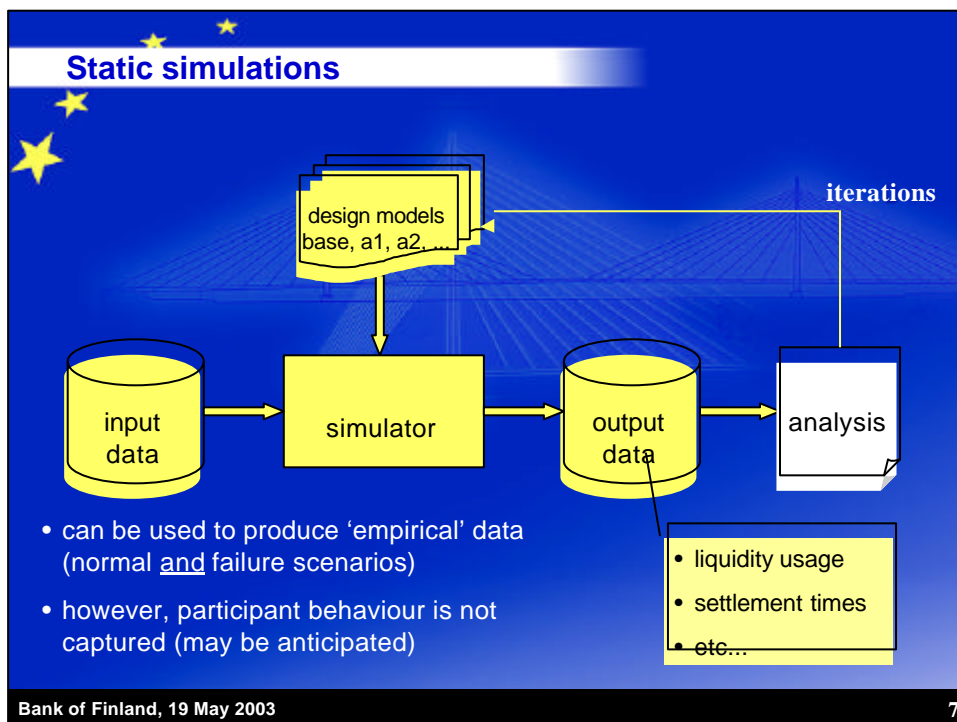- 60's to 80's: Many other fields

- 90's: Payment systems

The common goals are to learn, to analyse and to optimise

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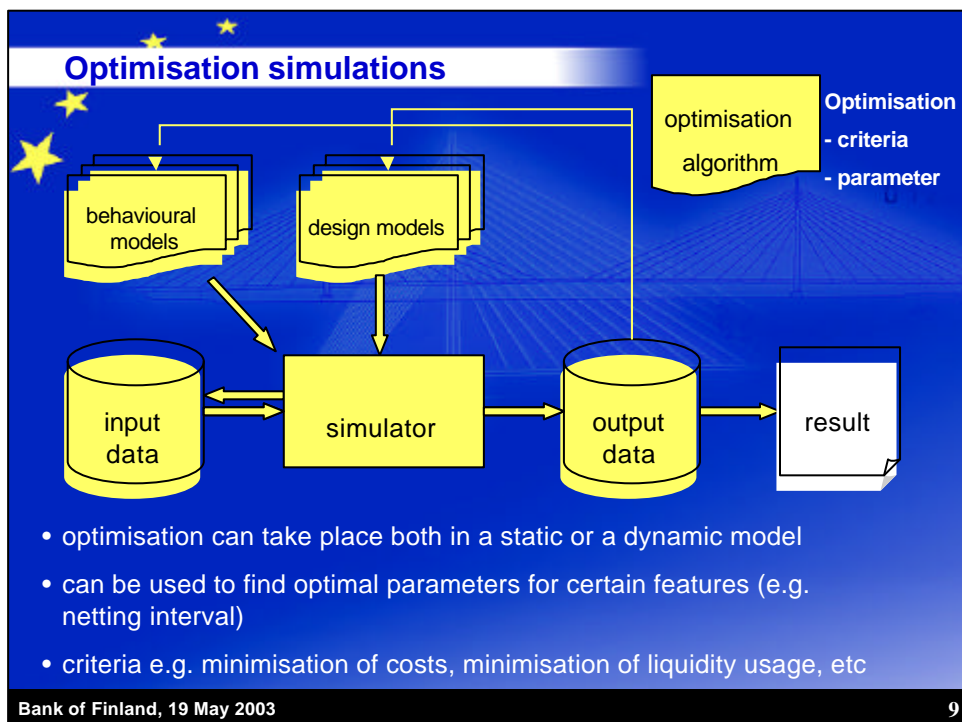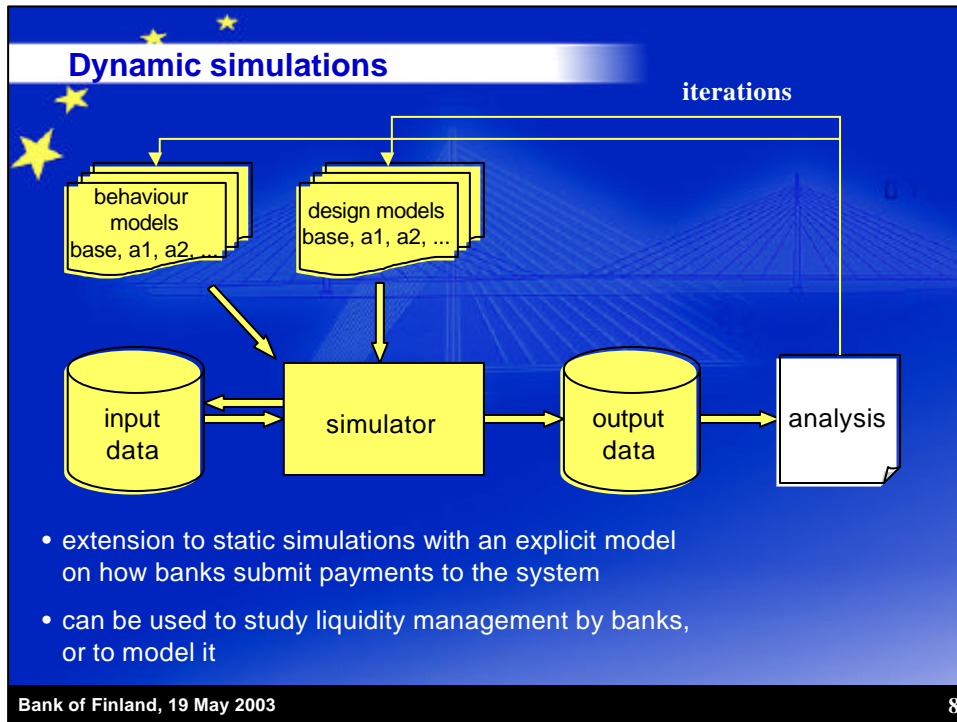

What are payment system simulations?

- Replicate a payment system by modelling:
  - different system designs, and/or
  - participant behaviour, and/or
  - rare events

- By doing so we can:
  - learn how they work
  - analyse different scenarios
  - optimise their operation

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Simulator and simulation model

- settlement logic
- risk management rules
- etc...

behaviour models
base, a1, a2, ...

design models
base, a1, a2, ...

algorithms to simulate participant behaviour in submitting payments to the system

input data

simulator

simulation models:
⇒ static
⇒ dynamic
⇒ optimisation

- transaction data
- balances and credit limits

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Static simulations

iterations

design models
base, a1, a2, ...

input data → simulator → output data → analysis

- can be used to produce 'empirical' data (normal <u>and</u> failure scenarios)
- however, participant behaviour is not captured (may be anticipated)

- liquidity usage
- settlement times
- etc...

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Dynamic simulations

iterations

behaviour models
base, a1, a2, ...

design models
base, a1, a2, ...

input data → simulator → output data → analysis

- extension to static simulations with an explicit model on how banks submit payments to the system
- can be used to study liquidity management by banks, or to model it

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Optimisation simulations

optimisation algorithm

Optimisation
- criteria
- parameter

behavioural models

design models

input data → simulator → output data → result

- optimisation can take place both in a static or a dynamic model
- can be used to find optimal parameters for certain features (e.g. netting interval)
- criteria e.g. minimisation of costs, minimisation of liquidity usage, etc

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Why to simulate payment systems?

Why to simulate payment systems?

"Simulations start where mathematics fail"

- If the system is complex
  - e.g. many systems, complex processing rules
  - simulations can use real data and exactly replicate a real payment system
- If the system is interactive
  - e.g. queuing, participant behaviour, many 'if - then' rules
  - any interaction can be programmed in the simulator
- If the time aspect is important
  - e.g. changes in system state, order of events
  - simulations force to set the time sequence of events

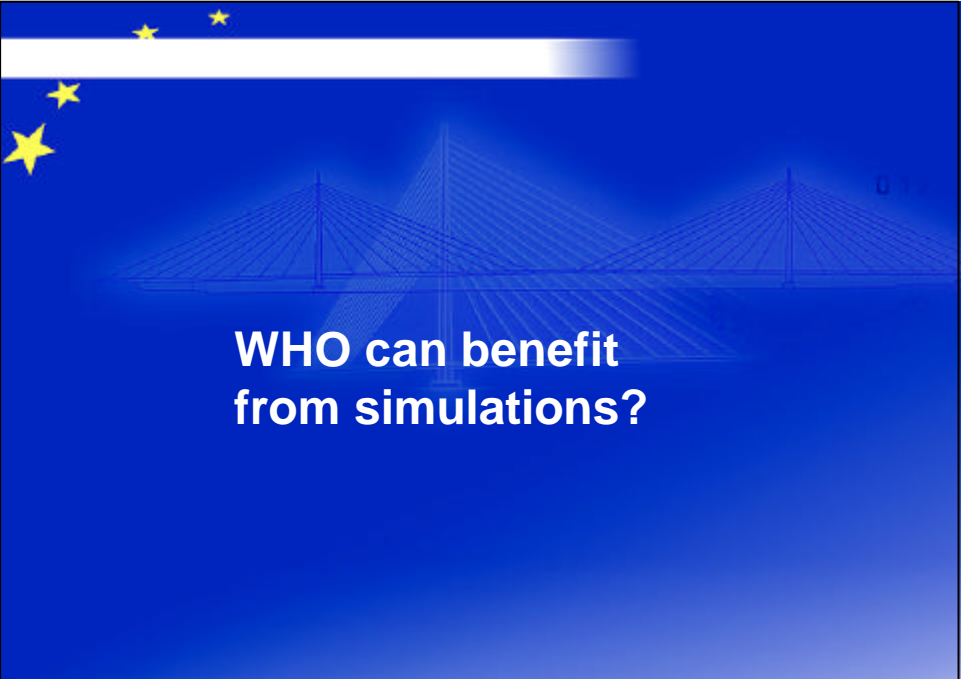Mathematical models may need to be too simple to be of practical use
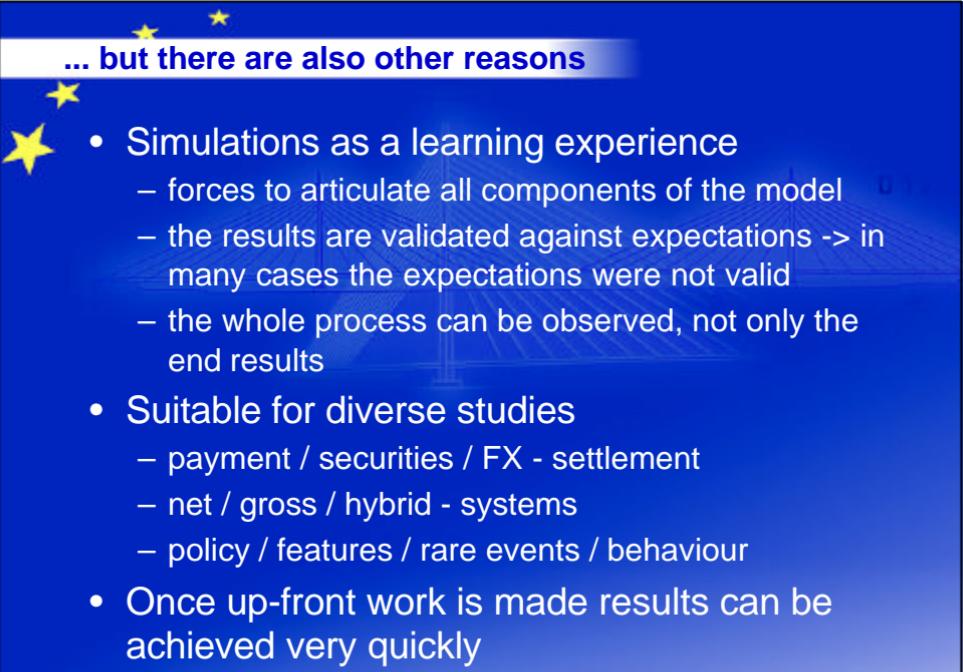
... but there are also other reasons

- Simulations as a learning experience
  - forces to articulate all components of the model
  - the results are validated against expectations -> in many cases the expectations were not valid
  - the whole process can be observed, not only the end results
- Suitable for diverse studies
  - payment / securities / FX - settlement
  - net / gross / hybrid - systems
  - policy / features / rare events / behaviour
- Once up-front work is made results can be achieved very quickly

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WHO can benefit from simulations?

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in policies regarding own systems

- In the design phase of a new system or a new feature
  – what to build?
  – e.g. to test the effectiveness of alternative features before implementation
- To prepare for the introduction of a new system or changes to existing systems
  – what is the impact?
  – e.g. to provide analysis for participants to understand the risks
- To test the effects of changes in policies (e.g. on intraday credit)

Most major new system have been simulated before live operations (RTGS+, Kronos, newCHAPS, ...)

by overseers

- To test the systemic risk implications of system changes or new systems
- Prepare for worst case scenarios
  – to test systems' risk management
  – to analyse the spillover effects and systemic implications
  – test the liquidity impact of ancillary systems
- Analyse actions taken in a crisis situation
  – "what if" - scenarios

Simulations as an oversight tool is in its early stages (e.g. required for regulatory approval of CLS)

by researchers

- Analyse effects of liquidity optimisation methods
- Compare different settlement arrangements
- Study gridlocks and their resolution
- Study externalities
- Study banks' liquidity management and effects of alternative behaviour
- ...

Studies from Bank of Finland, FRBNY, Danmarks Nationalbank, Banca d'Italia, Banque de France, ...

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Simulation studies with BoF-PSS1 (1)

1997: 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

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

2000 -> : FRB New York
- alternative queuing/liquidity concepts
- a 'Receipt Reactive Gross Settlement' queue
- results are to be published this year

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Simulation studies with BoF-PSS1 (2)

2000: Danmarks Nationalbank
- main focus on gridlock resolution
- results published in BoF discussion paper series 9/2001 and DNB Monetary Review 4/2001

2002 -> : Bank of Korea
- alternative liquidity provision, optimisation methods

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Summary

WHAT : to replicate a payment system by modelling different system designs, participant behaviour, and rare events

WHY : To learn, analyse and to optimise

WHO : Policy, oversight and research

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Thank you, questions?

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Annex: Research with the simulator

Koponen and Soramäki (1998) '*Intraday Liquidity Needs in a Modern Interbank Payment System - a Simulation Approach***', Bank of Finland Studies in Economics and Finance E:14**

Leinonen and Soramäki (1999) '*Optimizing Liquidity and Settlement Speed in Payment Systems***', Discussion Paper, Bank of Finland**

Soramäki (2000) '*Alternative Liquidity Management Features in an RTGS Environment***', Financial Markets Department Working Paper**

Bech and Soramäki (2001) '*Gridlock Resolution in Interbank Payment Systems***', Discussion Paper, Bank of Finland**

Bech and Soramäki (2001) '*Resolving Gridlocks in Payment Systems / Opløsning af gridlock i betalingssystemer***', Monetary Review, Danmarks Nationalbank**

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

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