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26th European Simulation and Modelling Conference 2012

Simulation and modelling of transport networks and logistic nodes

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Essen, Germany

Prof. Dr.-Ing. U. Clausen,

Fraunhofer-Institute for Material Flow and Logistics
TU Dortmund, Institute of Transport Logistics

Dipl.-Logist. D. Diekmann, Dipl.-Logist. I. Goedicke,
Dipl.-Logist. J. Kaffka, Dr. math. F. Meier, Dipl.-Geogr. C. Thaller

TU Dortmund, Institute of Transport Logistics

Overview

Challenges in transport logistics

Approaches for modelling and simulation

Conclusion & Outlook

Challenges of the future

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- Increasing scarcity of raw materials
- Limited absorbance capacity of ecosystems

Protecting the environment and preserving resources

Environmentally sound and resource-saving logistics processes

- Urbanization
- Demographic change
- Growing need for security

Securing the supply of urban systems

Robust and secure logistics solutions for conurbations

- Diversified consumption behavior
- Various leisure activities

Preserving individuality

Individual mobility and individual provision of goods and services

Logistics has to make a substantial contribution to a positive development of the present societal challenges.

Welcome to Ruhr Logistics Metropolis

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Strength of Ruhr Metropolis

- Europe‘s third-largest urban centre after Paris and London
- Turntable for the national and European traffic
  - 5,700 logistics firms along the entire value chain
  - 160,000 employed in the logistics sector and logistics-related industry
- Rapid growth of logistics sector

As one of Europe’s leading logistics locations the Ruhr Metropolis develops, implements and exports logistics solutions to meet the societal requirements.

EffizienzCluster LogistikRuhr

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- One of 15 Leading-Edge Clusters within the High-Tech Strategy 2020
- Partners
  - 120 companies
  - 11 education and research facilities
  - Several intermediate actors
- Declared strategic goal
  - To solve conflicts between efficiency and individuality
  - To create tomorrow's individuality with 75% of today's resources

The close collaboration between science and economy within the EffizienzCluster assures a transition of innovative ideas into marketable logistics solutions.

Challenges in transport networks & objectives of optimizations

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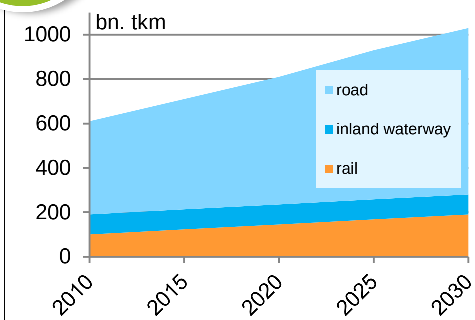

- significantly increasing transport performance, shipment volumes and GHG-emissions

- (new) restrictions for pickup and delivery tours in urban areas
- pollution by common vehicles

- increasing complexity and diversification in customer demands
- time windows, late pick ups, early deliveries

Methods to enable efficient and sustainable transport networks under the given challenges and restrictions.

Institut für Transportlogistik
Prof. Dr.-Ing. Uwe Clauser

Shell Lkw-Studie

model =

simplified, abstract copy of an existing or virtual system which represents the essential elements and interactions of the system

model classifications

purpose

- forecasting
- simulation
- decision, optimization

type of information

- quantitative
- qualitative

type of abstraction

- deterministic – stochastic
- static – dynamic
- total – partial

Comparison of methods

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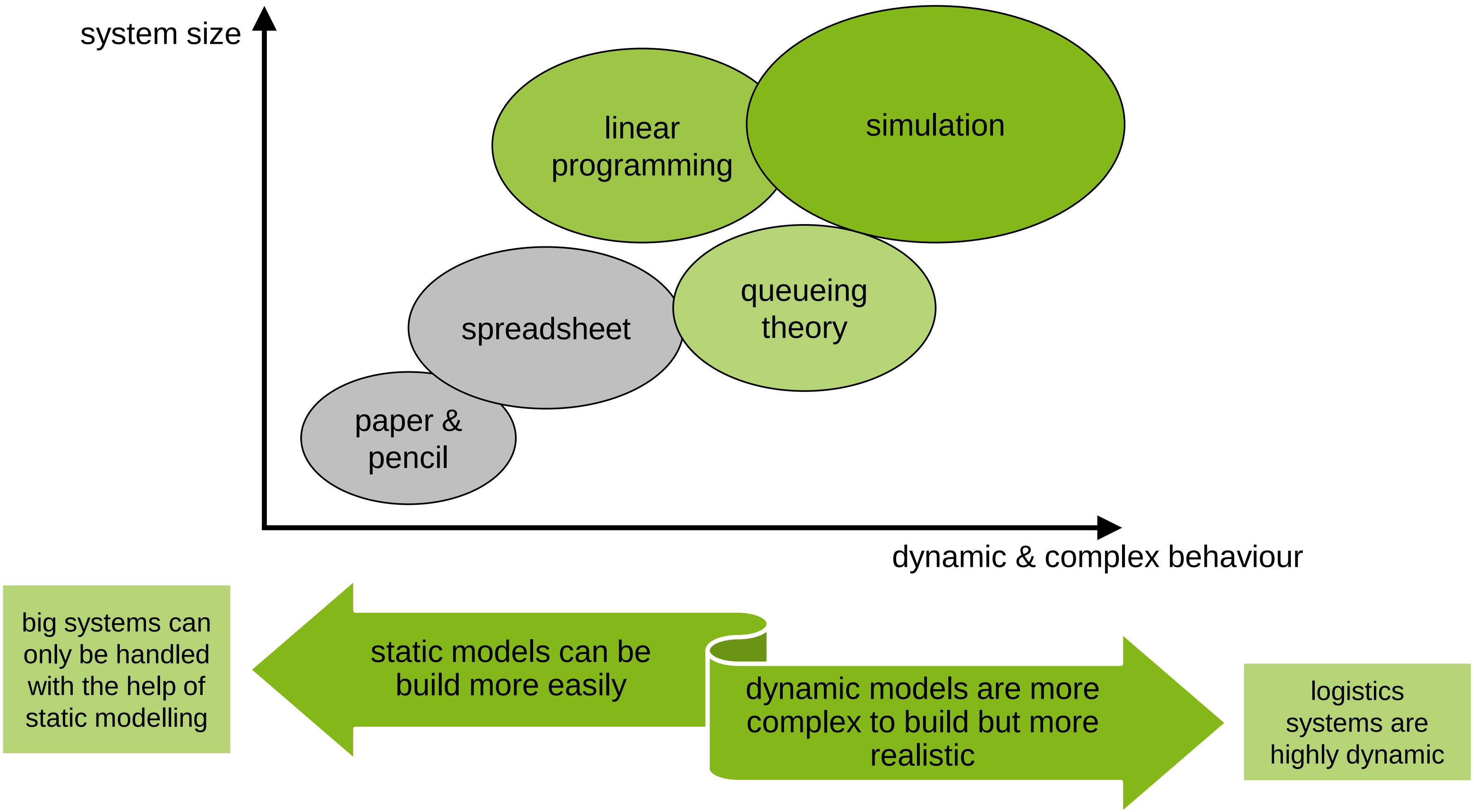

Figure: Incontrol Simulation Solutions

Overview

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Insights into tranport logistics modelling and research – overview

Economic Modelling

Operations Research

Simulation

Static modelling of commercial traffic

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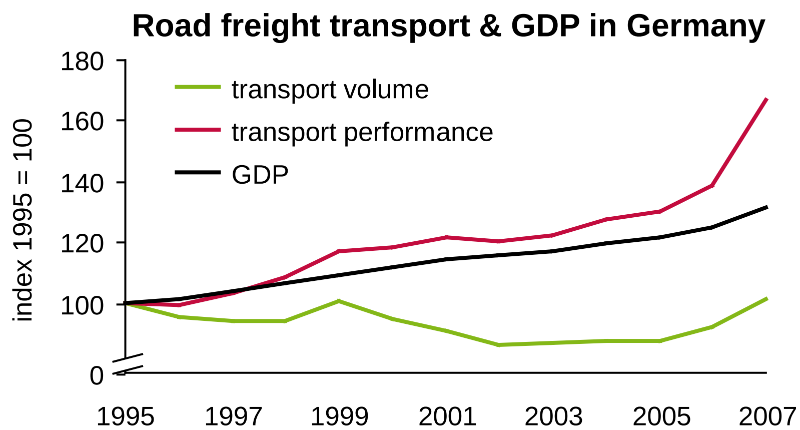
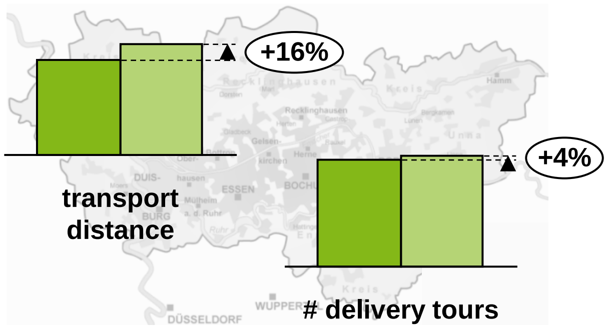


- GDP and other aggregate data are an insufficient basis for deriving freight transport
- Logistics structures and strategies have to be considered

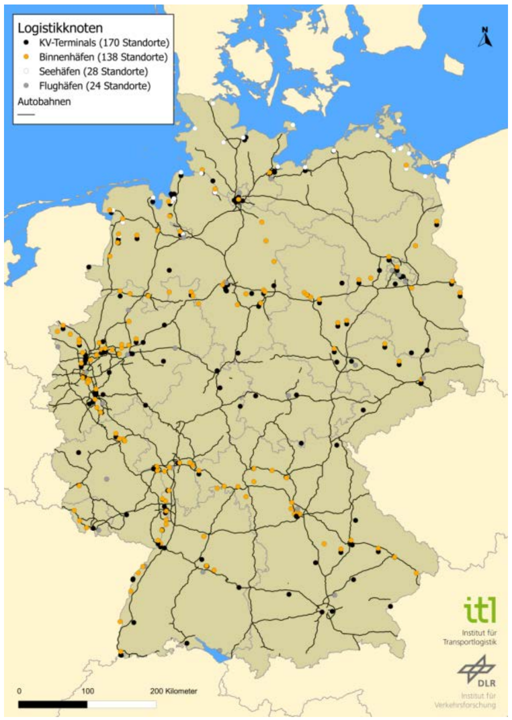
- Integration of delivery time windows in urban areas
  - structures, activities and behaviour of forwarders
- Results for the integration of delivery time windows in the Ruhr Area
  - e.g. increasing amount of time windows:



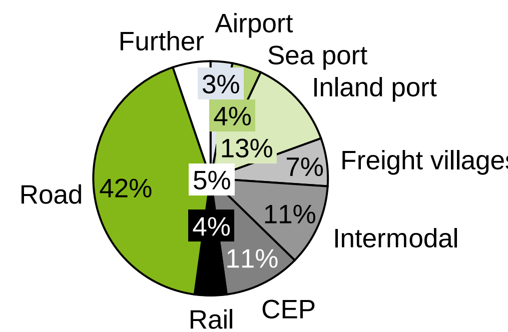
It is essential to integrate logistic parameters and effects to determine actually induced freight flows and stress for infrastructure.

Destatis 2007, Iddink 2009, Seredenko 2008/2011

Commercial Traffic Modelling – Integration of logistics nodes



- Integrate characteristics and specific throughput volume of logistics nodes in the demand modelling of freight transport
  - Typology of logistics nodes
  - Empirical analysis of different hub types



  - Objective: new demand theory for the integration of transport nodes in transport models

Which models can help to predict the operations of transport logistics?

Source: DLR, ITL 2012

Problem: Transport small shipping volumes between a lot of dispatchers and receivers.
Ad hoc solution: A direct transport network.

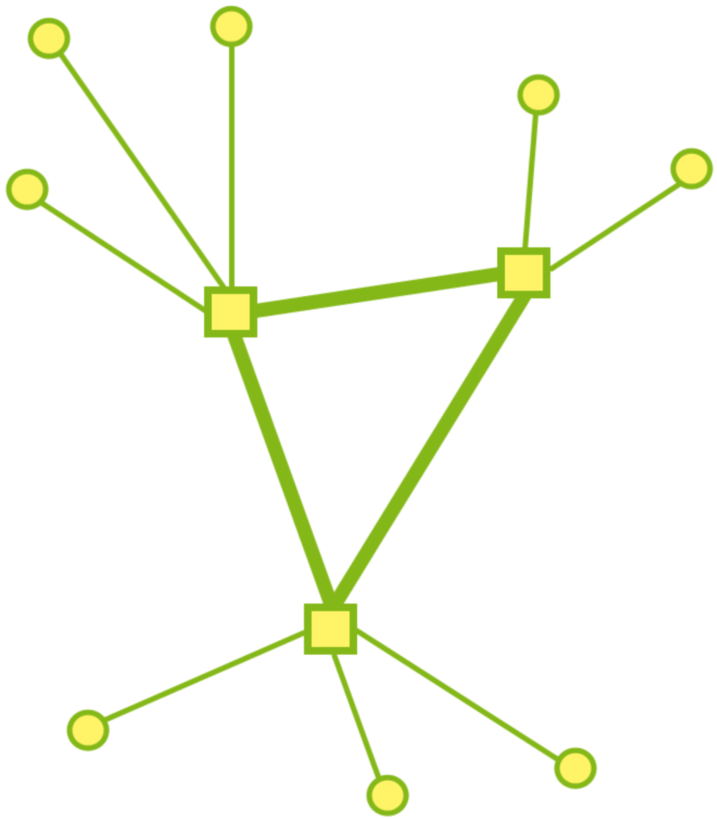
Disadvantages:

- Low capacity utilization
- Large number of connections to maintain.

Better solution: Consolidate and deconsolidate goods at hubs:

Use economies of scale.

Hub location problem: Where should we build hubs to minimize costs while fulfilling all real world conditions?

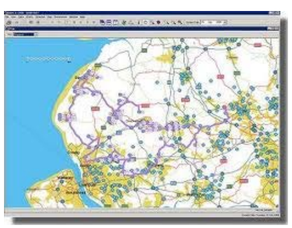


Hub Location Problems – Building a model

1. **Model the important restrictions/conditions**

Maximal capacity of hubs and/or connections

Maximal total time for each point-to-point connection or for complete routes



Allow any route from A to B or make restrictions (e.g. every dispatcher of country X delivers to hub H)

2. **Model the costs**

Fixed and variable transport costs (depend on the chosen routes and the capacity utilization)

Costs for building and maintaining the hubs and undertaking transshipments technische universität dortmund

Routing

Real world conditions	Example	Computability?
Few routes allowed	Postal services require sending letters for sorting to nearest hub	Computable, but little improvement to ad hoc solution
A lot of feasible routes	In LTL you might allow to route every shipping volume individually.	Huge solution space which (usually) contains very good solutions. *Problem:* You often overlook them.

Transport costs

Real world conditions	Example	Computability?
Costs depend on kg/m³ on each route	(rare case)	Computable linear model
Costs depend mostly on the number and type of vehicles on each route	LTL, air (cargo and passengers)	A lot of integer variables. Difficult.

LTL Problem

- Measure transport costs by vehicle and allow a lot of routes (more realistic)
- How do we solve this? (CPLEX and GUROBI fail for 50 dispatchers or more)

Approach

Combine the following three elements:

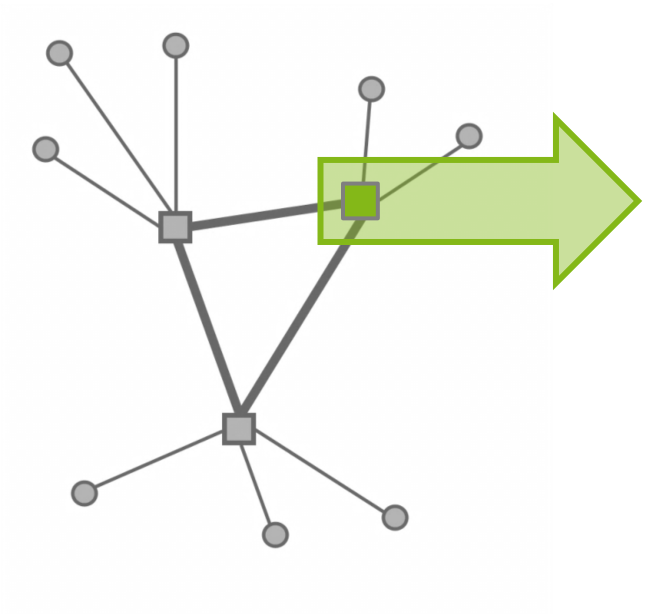
- Standard branch-and-cut techniques (in combination with commercial solvers)
- Problem-specific heuristics: They create good feasible solutions and measure the "quality" of the possible hubs.
- Quadratic techniques: Additional restrictions can be derived mathematically from the quadratic nature of the cost function. This allows to reduce the search space.

Preliminary results are promising

- Good (though not optimal) solutions can be computed for 60 dispatchers in 12 hours.

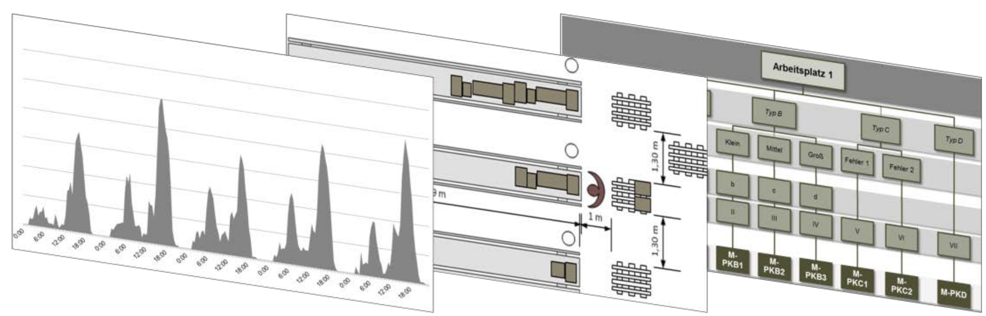
Robustness of the solution under stochastic influences, especially concerning the network nodes cannot be evaluated with the approach.

Modelling of nodes in logistics networks



Challenges for terminal operators

- Significant peak hours in system loads
- Combination of manual and automated handling processes
- Heterogenous goods



High level of system dynamics

High level of complexity

Using simulation to control system dynamics and complexity

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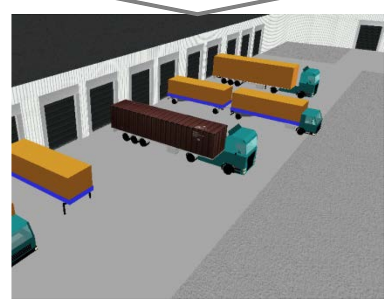
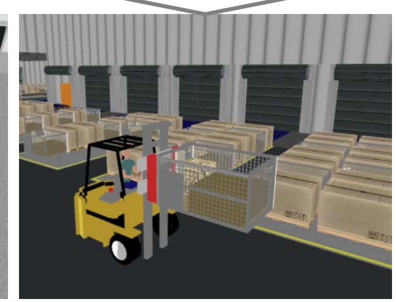
	Yard management	**Door as interface**	**Terminal building**
Layout planning	Size and utilization of external areas	Loading & unloading locations; assigning destinations to doors	Size and utilization of internal areas
Operating strategies	Management of traffic flow & shunting; crane control	Allocation rules	Personnel management; loading concepts





Modelling of logistics nodes

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The used software …

ENTERPRISE DYNAMICS PLATFORM | ENTERPRISE DYNAMICS LOGISTICS | ENTERPRISE DYNAMICS TRANSPORT

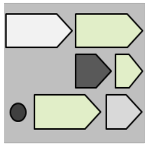
- provides typical modules of logistics nodes for microscopic modelling
- allows implementation of specific characteristics by individual programming

System components

- Static: doors, buffer areas, gate-keeper, roads …
- Dynamic: forklifts, vehicles, trains, containers…

Settings

- Driving speed (depending on vehicle type)
- Process times, capacities
- …



Realistic process chains

- Process steps of different vehicles & sending types
- Controlling strate-gies of resources (forklifts, cranes …)

Realistic scale modeling of complex systems
→ results of the simulation experiments can be transferred to the real system

Reference project – Dispatching rules for forklifts

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component	process		functional unit
external (yard)	arrival	departure	gatekeeper / barrier system
	waiting time	waiting time	waiting area / parking
	shunting	shunting	shunting vehicle
Interface yard↔building	unloading	loading	door
in-house (building)	sorting and buffering		manual or automated sorting

Research objective

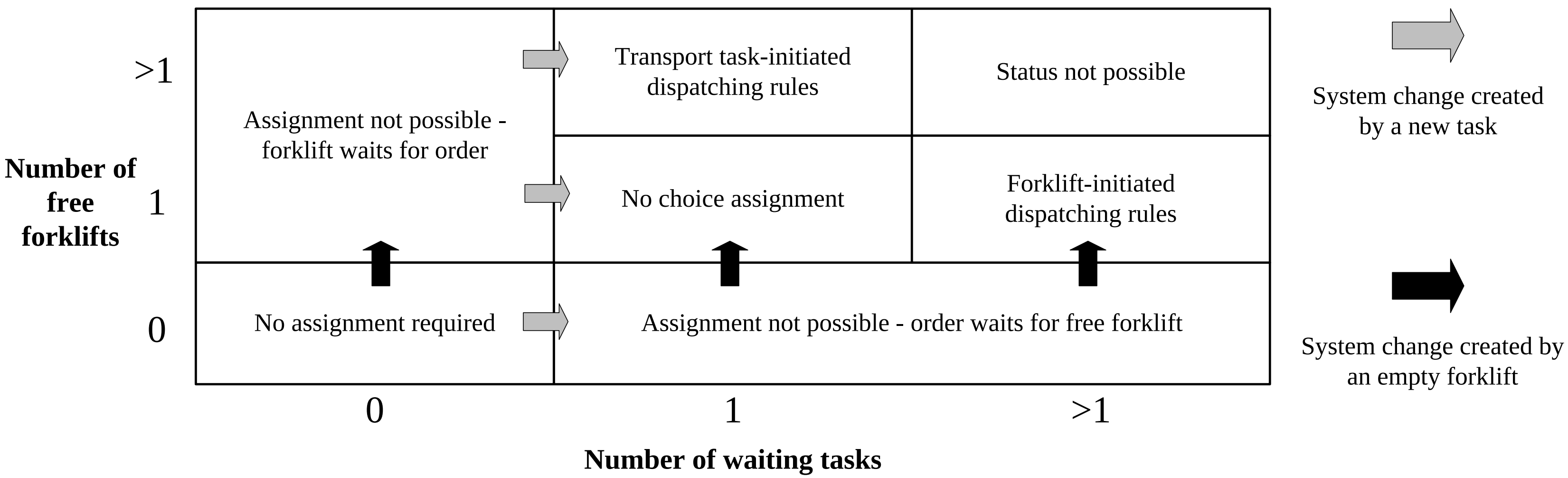
- Develop dispatching rules and evaluate their impact on terminal activities with the help of simulation

Procedure

- Mapping system load data, processes, operating strategies in forwarding agencies
- Development and implementation of different dispatching rules (single and multiple attribute rules)
- Creation of the model in the simulation environment and simulation study

Picture: Jungheinrich

Reference project – Dispatching rules for forklifts



Forklift initiated rules

- Longest Waiting Time (LWT)
- Shortest Travel Distance Pickup Point (STDPP)
- Maximum Queue Size (MaxQS)

Task-initiated rules

- First Transporter First (FTF)
- Nearest Vehicle (NV)
- Least Utilized Vehicle (LUV)

Combination “First Transporter First-Longest Waiting Time” is considered as basic scenario. The dispatching rules LWT, STDPP, FTF and NV are tested with all possible combinations.

Dispatching rules for forklifts – Simulation model

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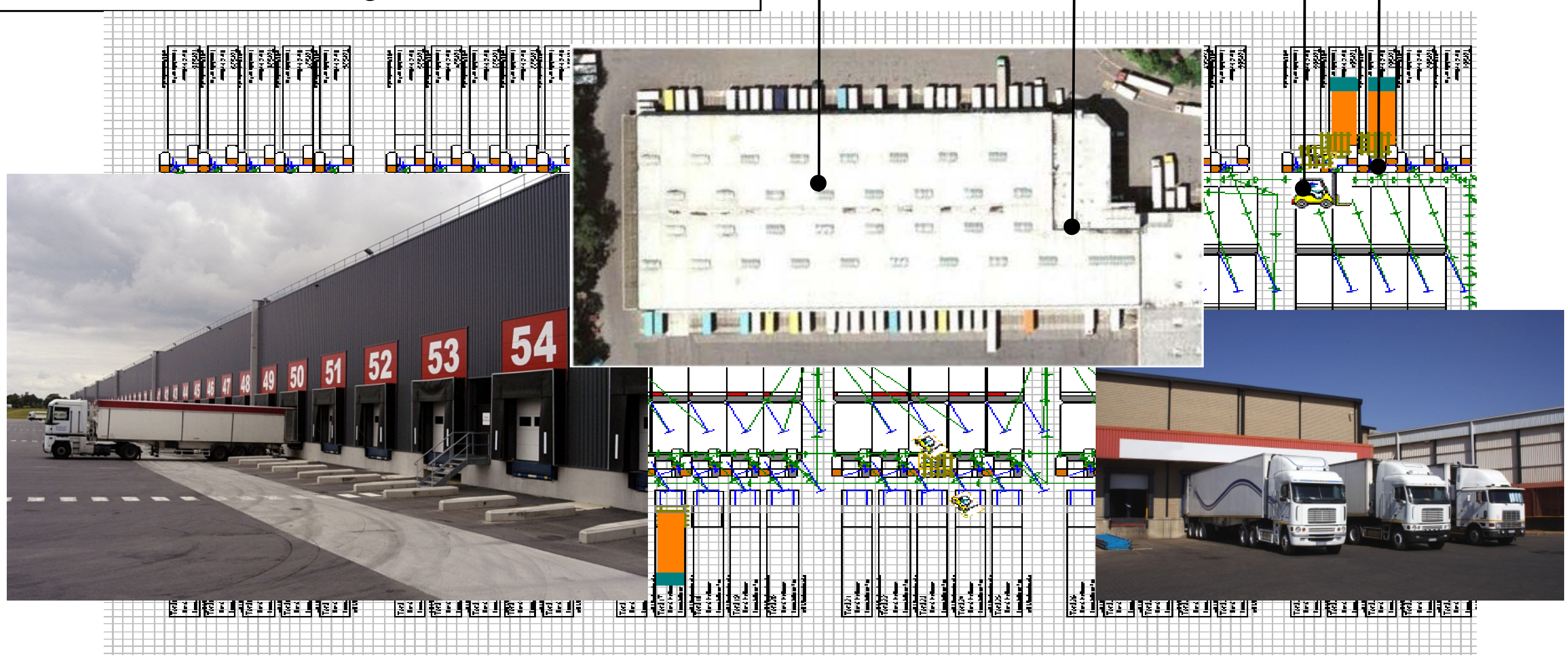
Key figures

- Ground space of 6.300m²
- 24 unloading / 36 loading doors
- 4.300 handling units per day
- 23 national and 33 regional destinations



Dispatching rules for forklifts – Simulation model

Key figures
▪ Ground space of 6.300m²
▪ 24 unloading / 36 loading doors
▪ 4.300 handling units per day
▪ 23 national and 33 regional destinations

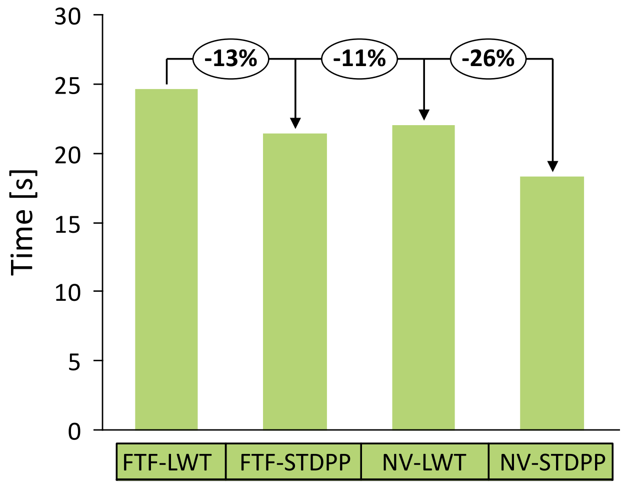
Dispatching rules for forklifts – Results

Average full travel time:

- Constant in the different scenarios

Average empty travel time :

- 13% faster by changing forklift initiated rule “Longest Waiting Time” to “Shortest Travel Distance Pickup Point”
- 11% faster by changing task initiated rule from “First Transporter First” to “Nearest Vehicle”
- 26% faster by changing both rules (FTF-LWT to NV-STDPP)



Simulation gives a unique opportunity to test different strategies and evaluate the potential to increase system efficiency.

Dispatching rules for forklifts – Conclusion and Outlook

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- Conclusion
  - Travel path optimized forklift fleet control reduces the empty travel time of the forklifts but requires process changes and additional investments
  - Scanning of shipments after unloading and tracking positions of forklift trucks is necessary

- Outlook
  - Extension of the single to multi attribute strategies for the fleet control
  - Apply strategies for more complex terminal shapes

Terminal operations involve a lot of decisions (e.g., door assignment, vehicle priorization, resource allocation) – what is the best strategy mix?

Research project –
Statistics and Simulation

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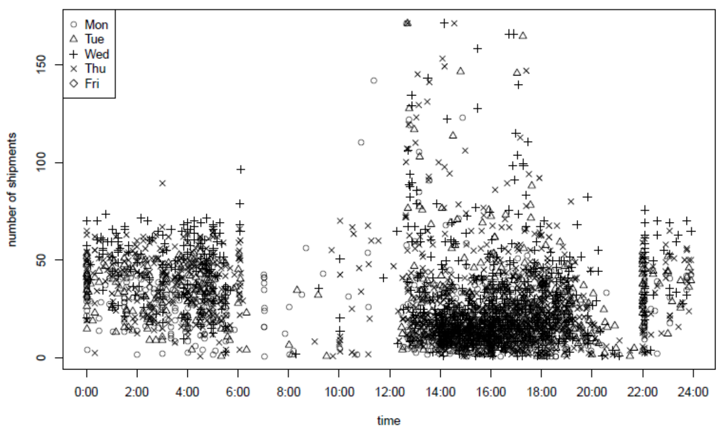

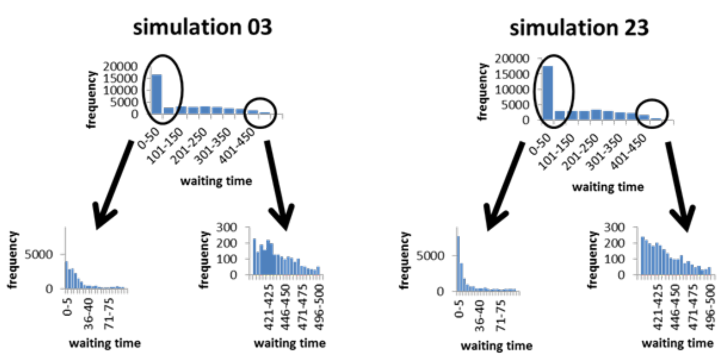

Research objective

- Develop a method to identify the best possible mix of operating strategies in forwarding agencies
- Statistic based experimental planning

Procedure

- Mapping system load data, processes, operating strategies in forwarding agencies
- Generate input data on a kernel density based approach
- Develop evaluation models and logistical hypothesis
- Identify the best mix of operating strategies with loops of experimental planning, simulation studies and recursive partitioning

Deutsche Forschungsgemeinschaft

Institut für Mathematische Statistik und industrielle Anwendungen

Institut für Transportlogistik
Prof. Dr.-Ing. Uwe Clausen

Modelling external systems – Container terminals

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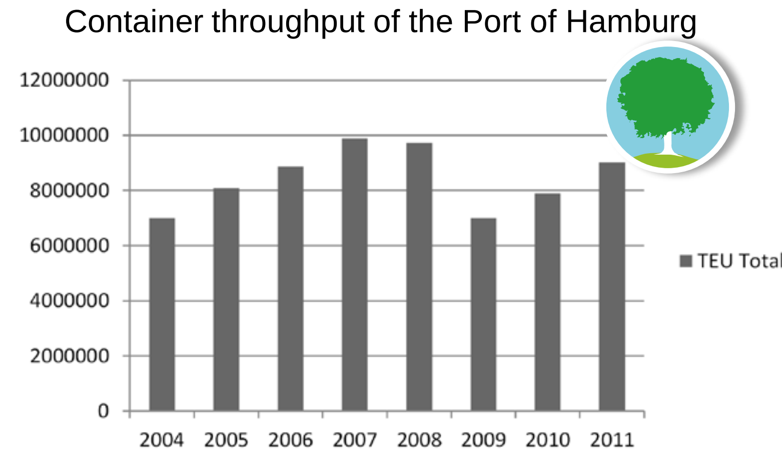


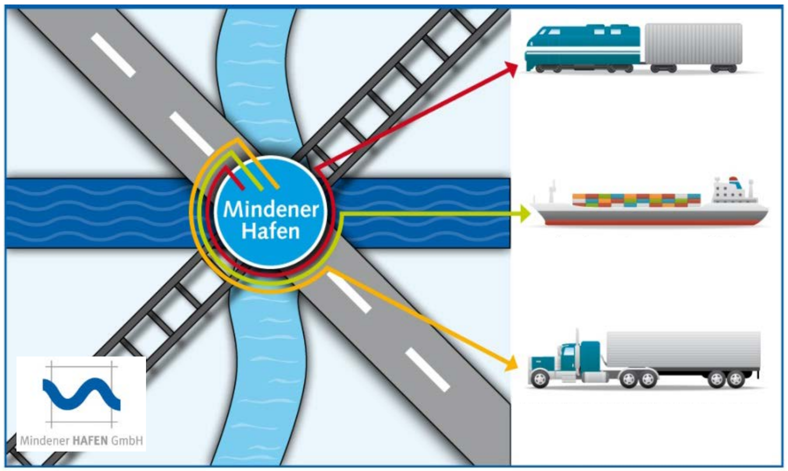
- 95% of goods worldwide are transported with ships
- Key factor in maritime transport is the container
- Shipping volume of containers grew by the factor 5 in the past 20 years

- Increase of throughput in terminals but space to handle the container is limited
- Container terminals are complex material flow systems with many subsystems

Large impact of stochastic influences, interdependencies of subsystems and complex decisions indicate advantages of simulation methods.

Böse 2004, Port of Hamburg 2012

Research project – Managing a Trimodal Hinterland Hub



Research objective

- Merging of mathematical optimization and simulation in one tool
- Support in planning and operating new intermodal terminals
- Meet challenges of inland port terminals

Methodologies

- Automated layout creation for modelling, intelligent operating strategies
- Preterm optimization of resource allocations
- Crane control and sequencing of container movements using mathematical optimization

Strategies for optimal terminal operations

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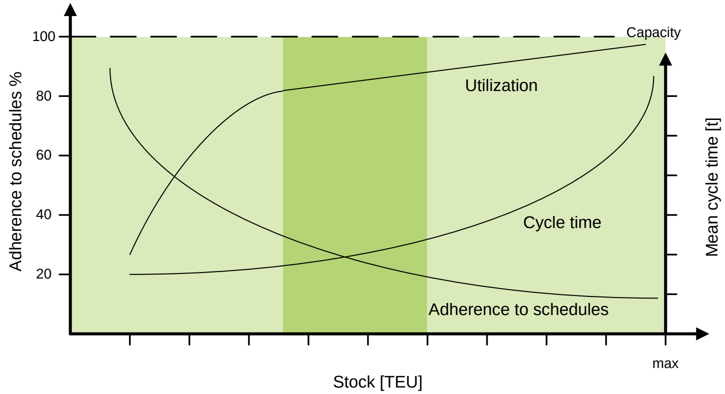


- Global controlling strategies
  - Layout decisions
  - Vehicle loading point allocation
  - Human resource planning

$$P_j = \sum_{i=1}^{n} p_i \cdot g_i \quad j \in \text{Container}; \; p_i \in [0,1]$$

- Operational strategies
  - For handling equipment (e.g. crane control)
  - Priority parameter for every company and market requirement
  - Importance can be adjusted by the weighting per parameter

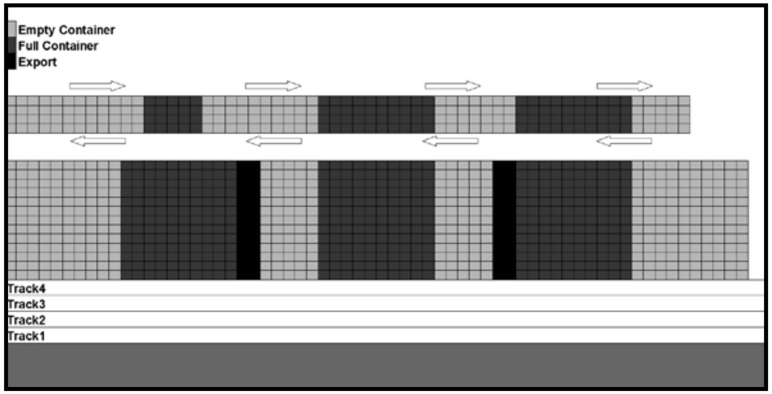
Different scenarios can be analysed with the help of the developed simulation suite

Online Optimization: every change of state of the system induces recalculation

Nyhuis and Wiendahl 2002

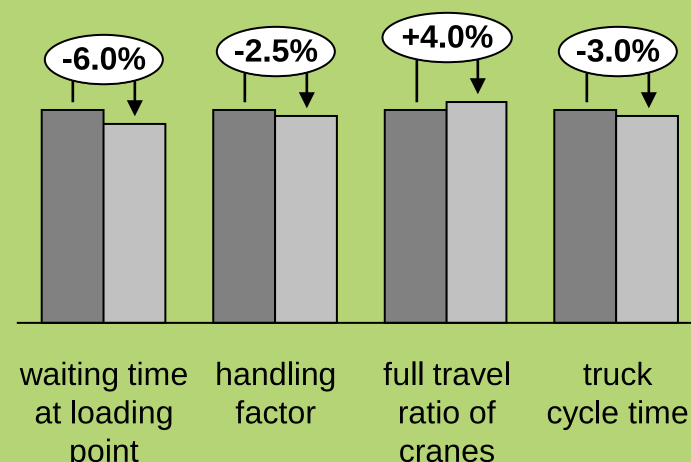
Strategies for optimal terminal operations – case study

Current layout of the observed container terminal



- Inland port container terminal
- 3 handling cranes
- 1.000 Ground slots
- 4 loading tracks for trains
- 400 meter quay for 2 barges
- 20 loading points for trucks

Increased terminal performance by optimized layout and control strategy (priority number)



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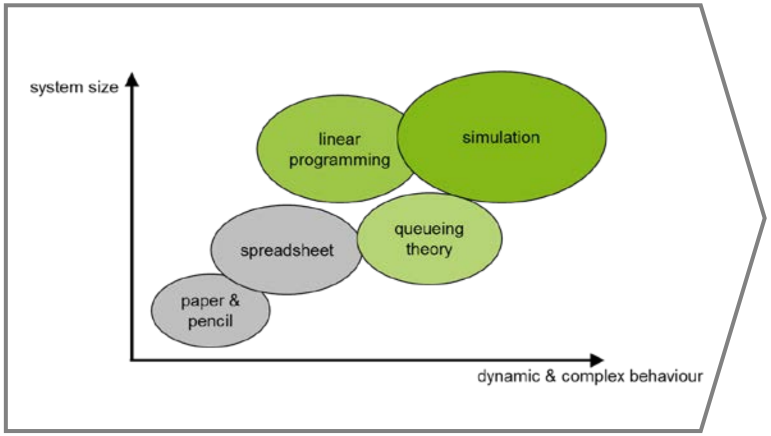

- Modelling characteristics are determined by
  - System specifications
    - system load, complexity of system interactions, system dynamics …
  - Scope of analysis
    - robustness, search for optimum, comparing operating scenarios …
- Combining the advantages of different methods is a main objective but very difficult to achieve

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Thank you for your attention

Prof. Dr.-Ing Uwe Clausen
TU Dortmund, Faculty Mechanical Engineering
Institute of Transport Logistics
Leonhard-Euler-Str. 2, 44227 Dortmund, Germany
Tel.: +49 231 755-6335
E-Mail: clausen@itl.tu-dortmund.de