SLF Fieldtrip, Leipzig, 27 March 2018

Holland.

Spare Parts Inventory Control under System Availability Constraints

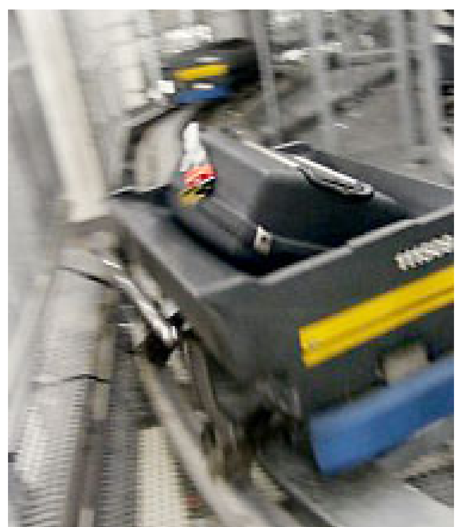
Geert-Jan van Houtum
Professor of Maintenance and Reliability

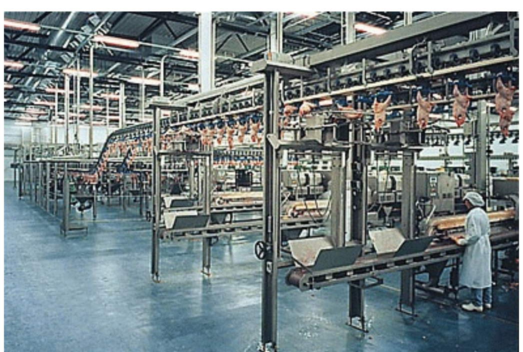
SERVICE LOGISTICS FORUM

TU/e Technische Universiteit Eindhoven University of Technology

Where innovation starts

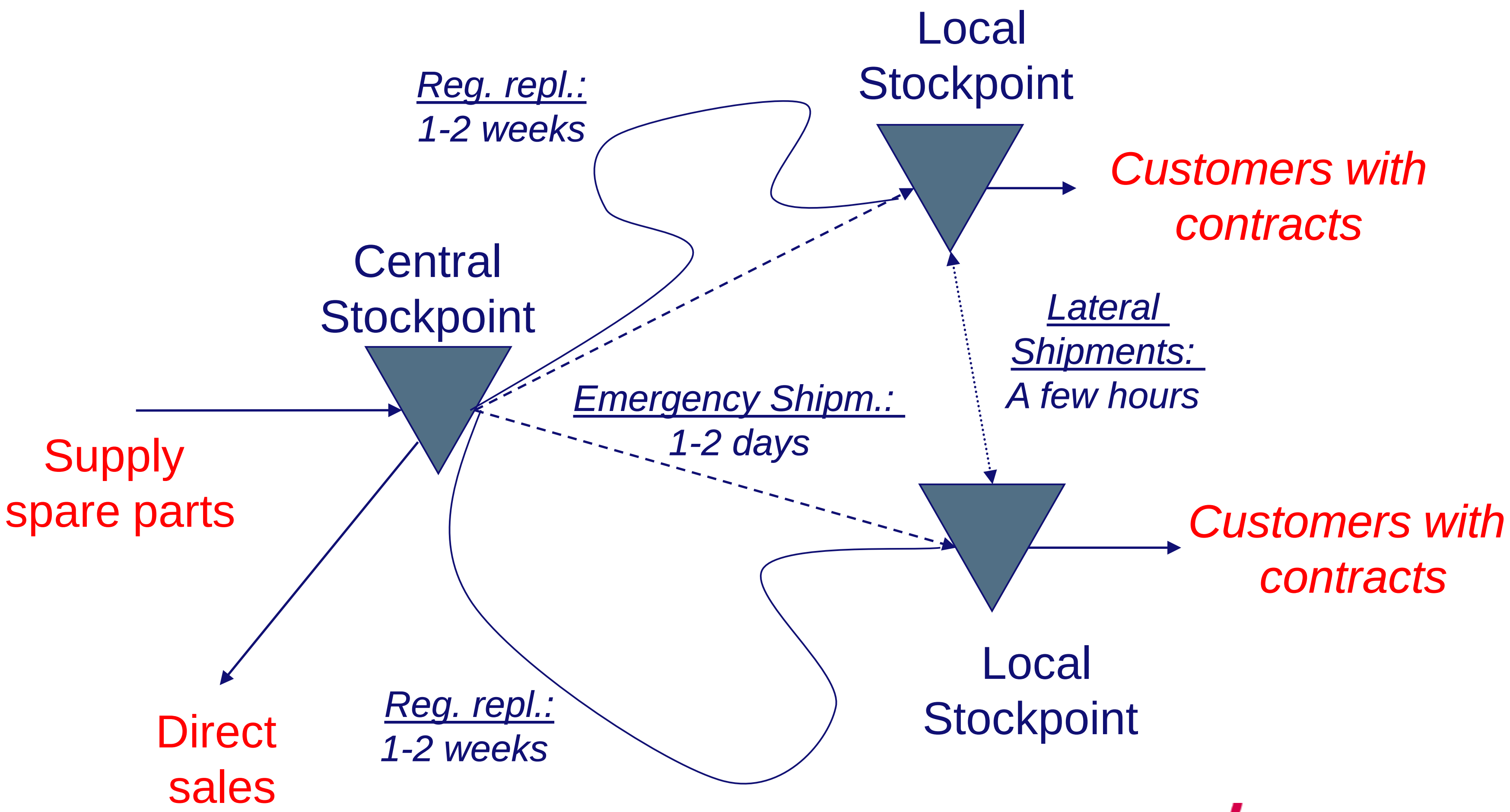

XF
DAF



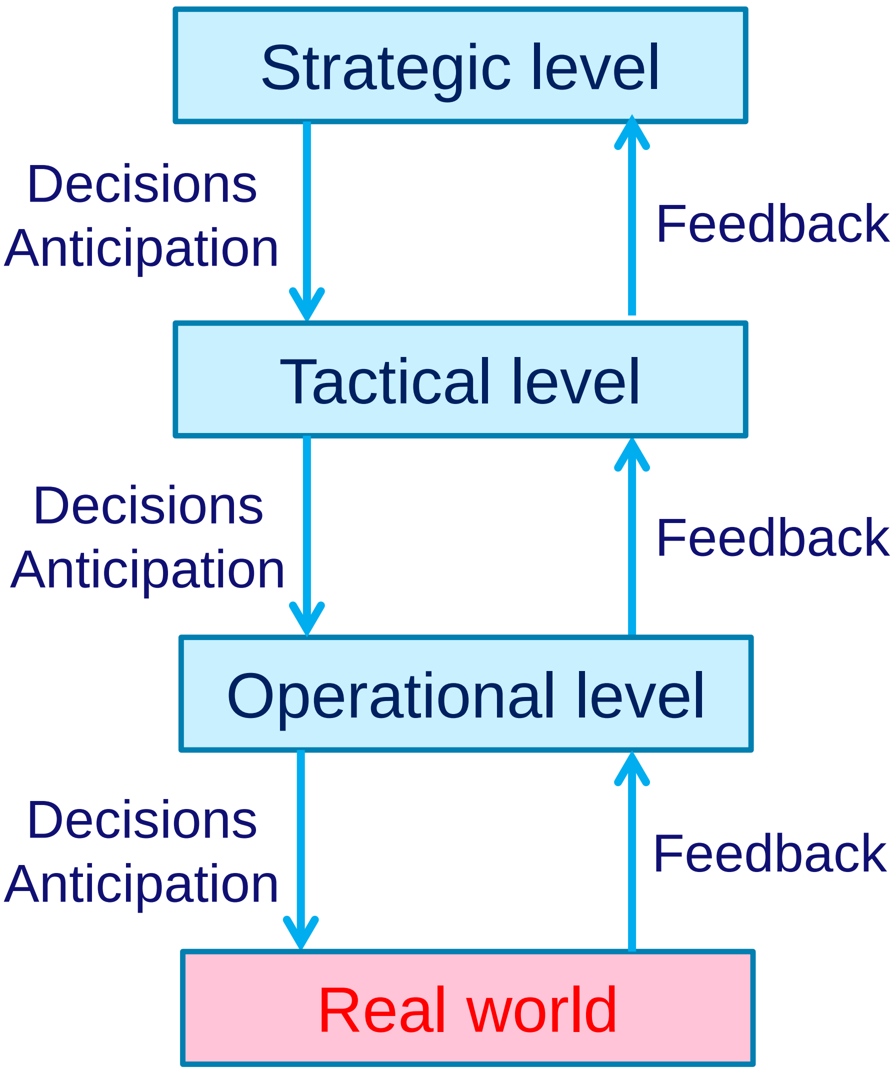



ASML

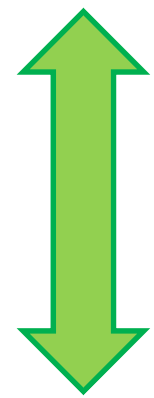
Service supply chain: Example



Planning levels



Aggregate information
Long horizon
Low frequency



Detailed information
Short horizon
High frequency

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Challenge

Given the SLA's in service contracts, requirements For other demand streams, and the design of the network:

- *How much to keep on stock of each SKU?*
- *In which locations?*
- *When to apply lateral and emergency shipments?*
- *How to deal with different customer classes?*
- *…*

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4. Status of system-oriented models
5. New challenges

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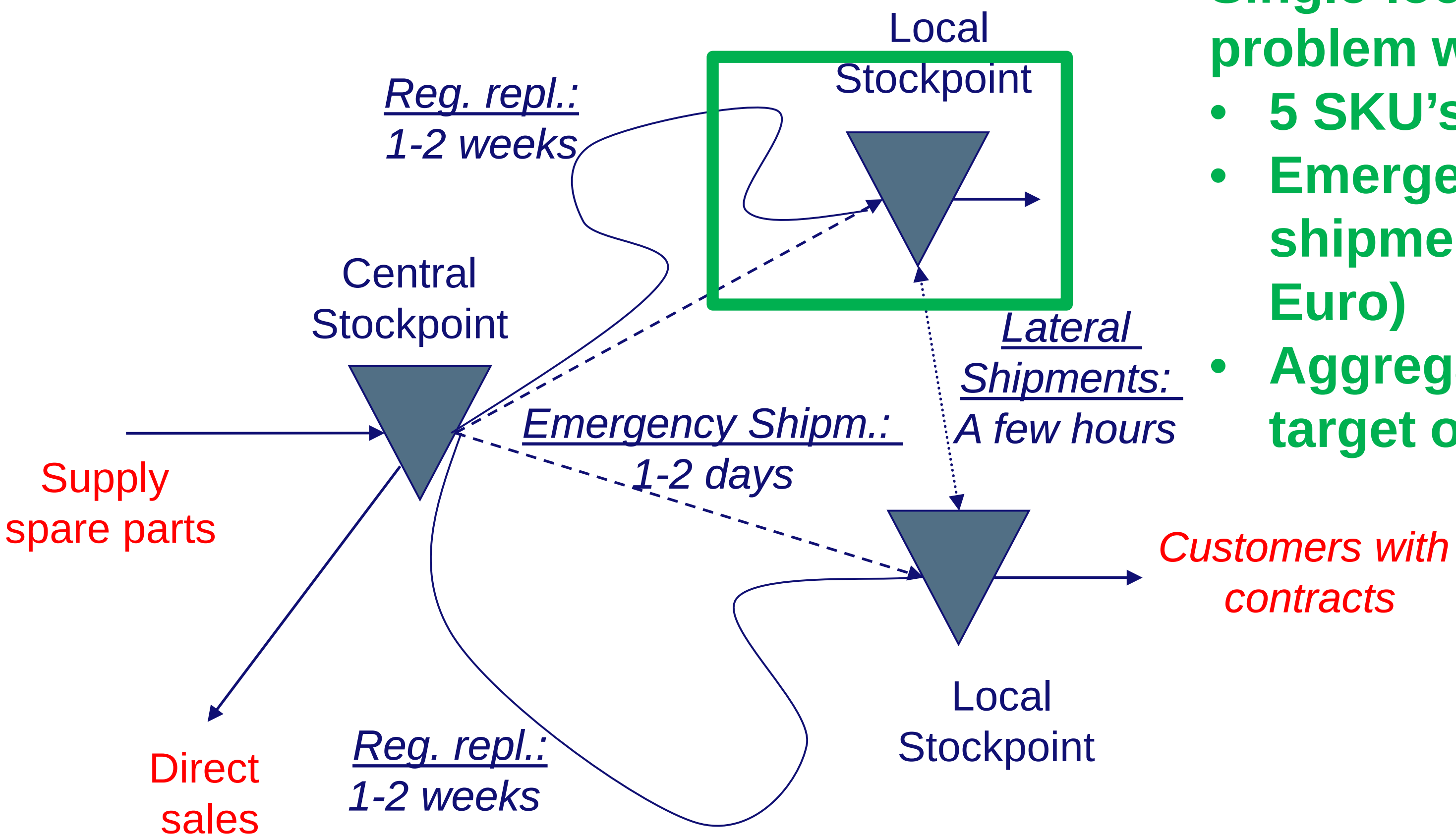
2. System vs. item approach

EXAMPLE



Single-location problem with:

- **5 SKU's**
- **Emergency shipments (250 Euro)**
- **Aggregate fill rate target of 95%**

EXAMPLE (cont.)

SKU	Demand (per yr)	Price (Eur)	Leadtime (wks)
1	2,5	1000	1
2	1,3	4000	1
3	0,7	14000	1
4	0,3	20500	1
5	0,1	34000	1

Inv. Holding cost rate: 0.4% per wk

EXAMPLE (cont.)

Item approach

SKU	Demand (per yr)	Price (Eur)	Leadtime (wks)	Base stock
1	2,5	1000	1	5
2	1,3	4000	1	4
3	0,7	14000	1	3
4	0,3	20500	1	2
5	0,1	34000	1	1

Aggr. fill rate: 94.8%

Inv. Holding cost rate: 0.4% per wk

Costs: 616 Eur/wk

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EXAMPLE (cont.)

System approach

SKU	Demand (per yr)	Price (Eur)	Leadtime (wks)	Base stock
1	2,5	1000	1	?
2	1,3	4000	1	?
3	0,7	14000	1	?
4	0,3	20500	1	?
5	0,1	34000	1	?

Aggr. fill rate: …

Inv. Holding cost rate: 0.4% per wk

Costs: … Eur/wk

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EXAMPLE (cont.)

System approach

SKU	Demand (per yr)	Price (Eur)	Leadtime (wks)	Base stock
1	2,5	1000	1	9
2	1,3	4000	1	5
3	0,7	14000	1	3
4	0,3	20500	1	1
5	0,1	34000	1	0

Aggr. fill rate: 95.9%

Inv. Holding cost rate: 0,4% per wk

Costs: 417 Eur/wk

3. How to create pooling effects?

How to create pooling effects?

Use of:

- *Lateral and/or emergency shipments*
- *Joint inventories in case of customer differentiation,*
- *Commonality*

Case: Lateral shipments

Problem

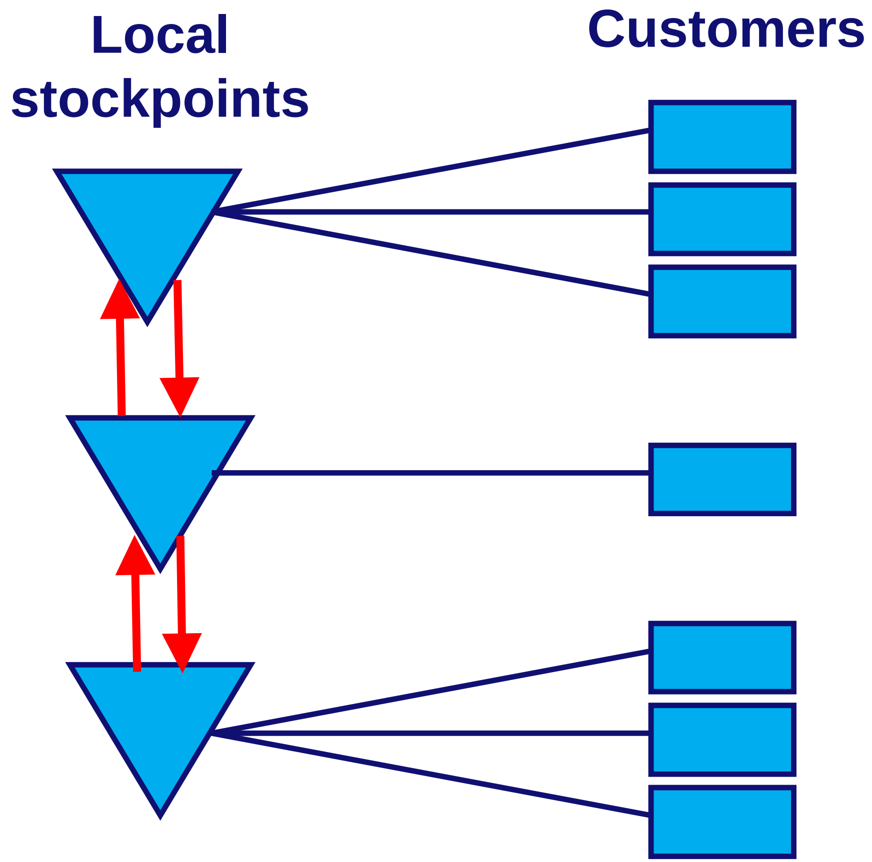
- **Given:**
  - OEM of high-tech systems
  - 19 local stockpoints
  - 1451 SKU’s (expensive till cheap)
  - Use of lateral shipments at the operational level
  - Costs: Inventory holding and transportation costs
- **Question:**

How much to stock?

(tactical decision problem)

Developed: Inventory model with lateral shipments

- Model with **multiple** local stockpoints
- **Integral** inventory control
- **Multi-item** setting!



Comparison

- Scenario 1 (cf. what was done until 2005):
  - No lateral shipments are taken into account at tactical planning level
  - But, lateral shipments are used at operational level
- Scenario 2:
  - Same, but lateral shipments are taken into account at tactical planning level

Comparison (2)

- Scenario 1 (cf. what was done until 2005):
  - No lateral shipments are taken into account at tactical planning level
  - But, lateral transshipments are used at operational level
- Scenario 2:
  - Same, but lateral transshipments are taken into account at tactical planning level

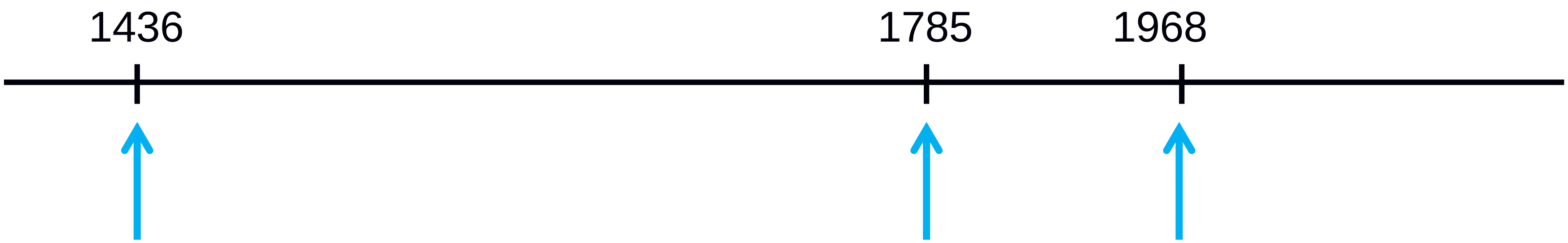
=> Scenario 2 is 32% cheaper than scenario 1

Additional remarks

- Algorithm has been implemented, and is in use since 2005.
- Results:
  - slight decrease in inventory investment
  - strongly improved service levels
  - under increased size of installed base

4. Status of system-oriented methods

History



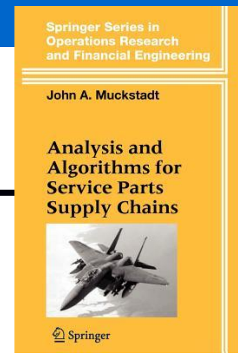
<u>Arsenal of Venice:</u>
Use of **standard parts** for warships

<u>Honoré Blanc:</u>
- French gunsmith
- Musket assembled from **interchangeable components**
- Adopted by US Government (Jefferson)

<u>Craig Sherbooke:</u>
- **METRIC model**
- Paper in *Operations Research*
- Worked at The Rand Corporation

Spare parts books

1992 — 2005 — 2015



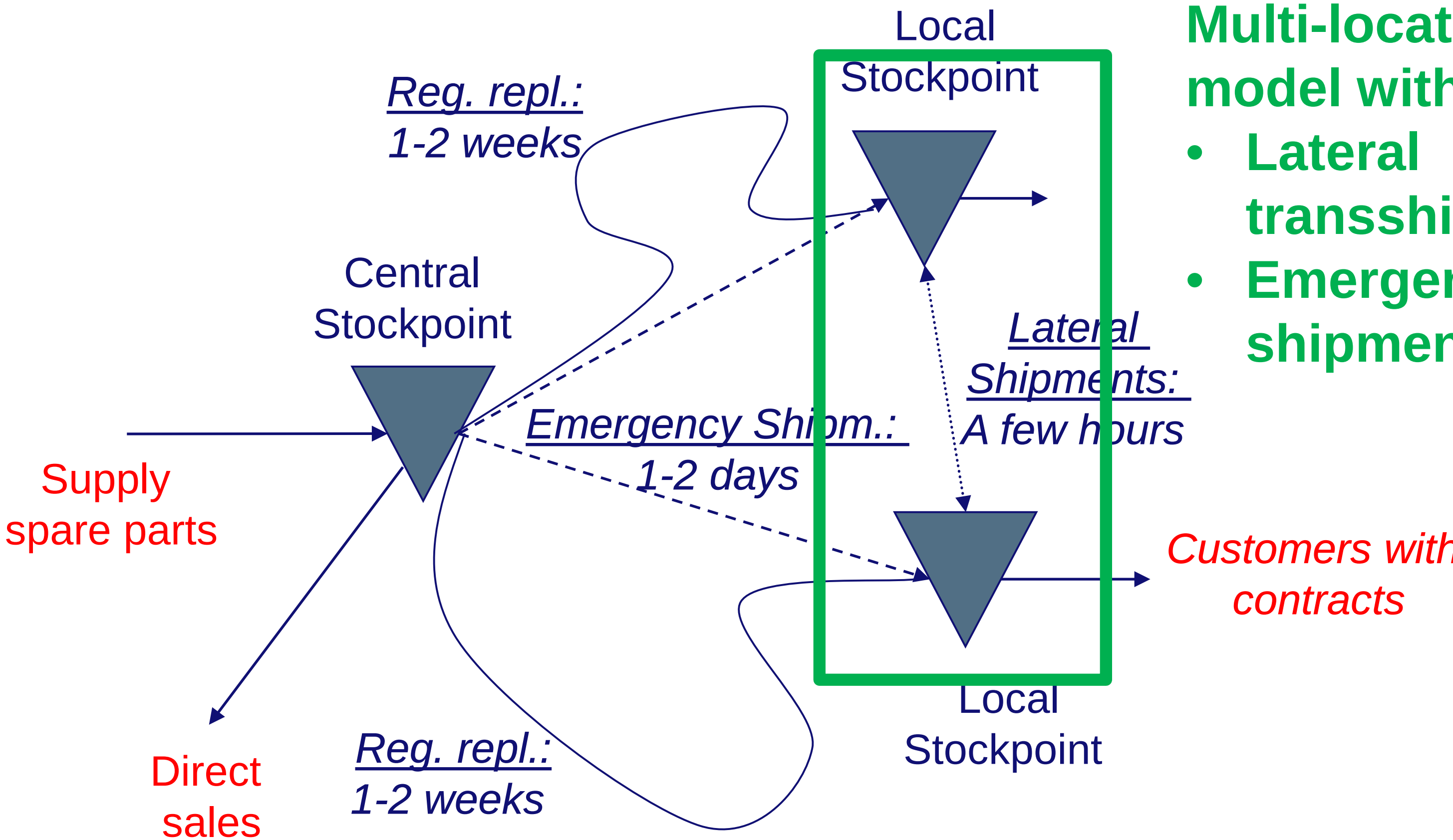
Book Sherbrooke:
- Motivation: Military world
- Tactical planning
- System approach
- METRIC Model
- Multi-indenture

Implemented in commercial software packages

Book Muckstadt:
- Motivation: Military world
- Tactical planning
- System approach
- METRIC Model
- Multi-indenture
- Lateral transsh. cf. Axsäter [1990] (full pooling, no emerg. sh.)
- One chapter on operational planning

Book Van Houtum and Kranenburg:
- Motivation: High-tech industry
- Tactical planning
- System approach
- METRIC Model
- Multi-indenture
- Emergency shipments
- Customer differentiation
- Lateral transshipments

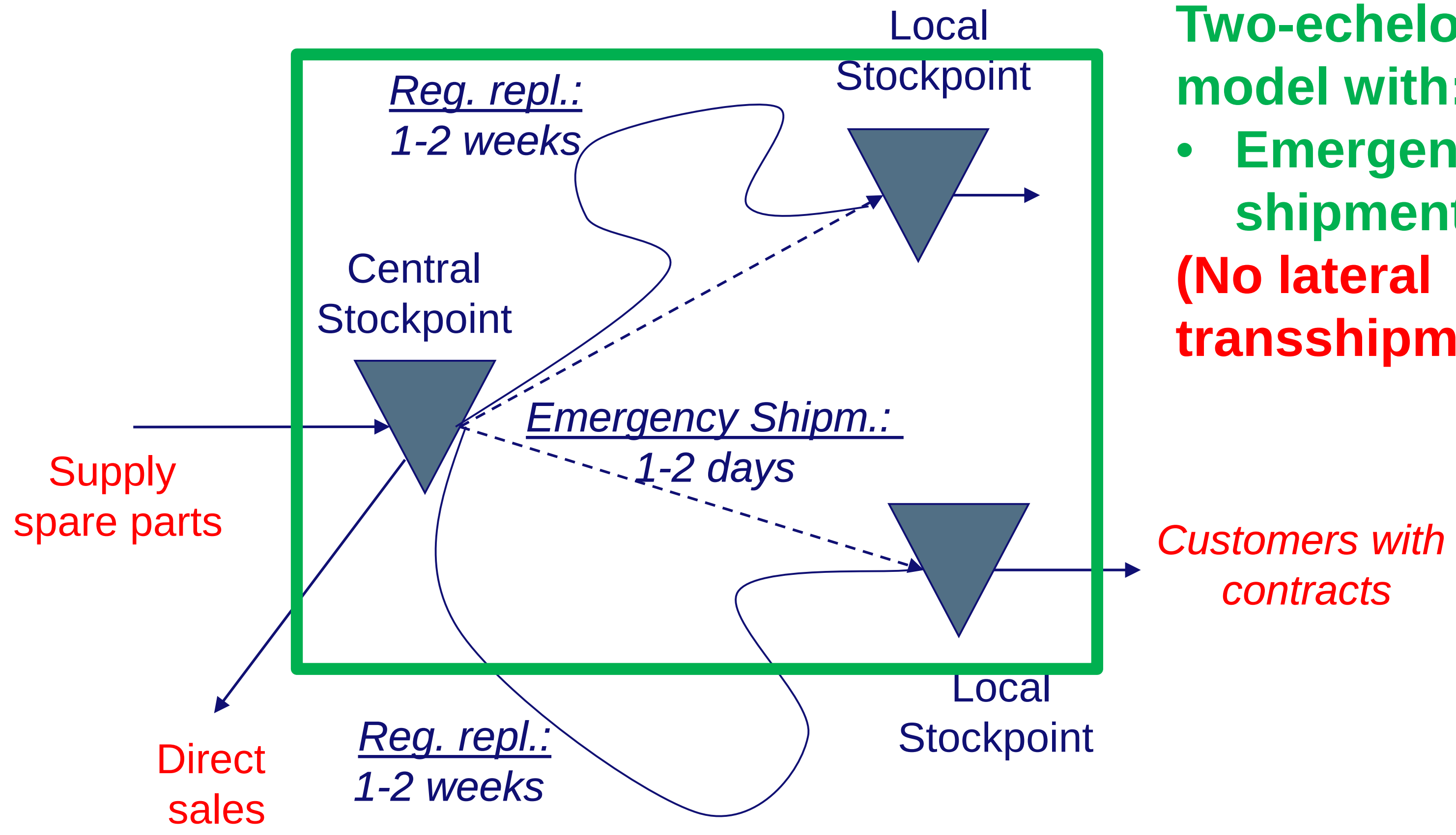
Example: Available building block



Multi-location model with:

- **Lateral transshipments**
- **Emergency shipments**

Example: Available building block

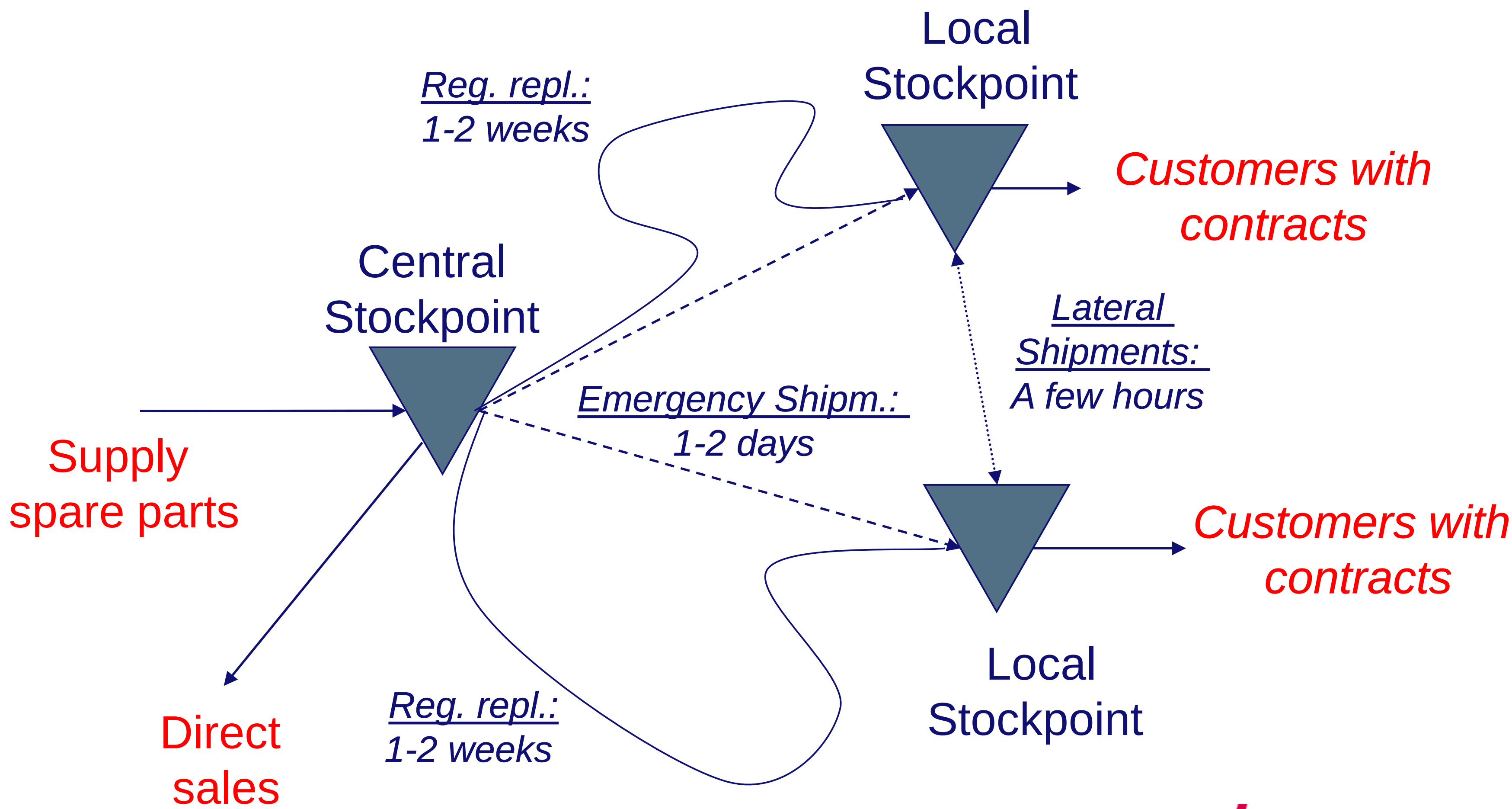


Two-echelon model with:

- **Emergency shipments**

(No lateral transshipments)

How to solve the full problem?



Answer

Combine and couple existing building blocks

See work of Martijn van Aspert for ASML

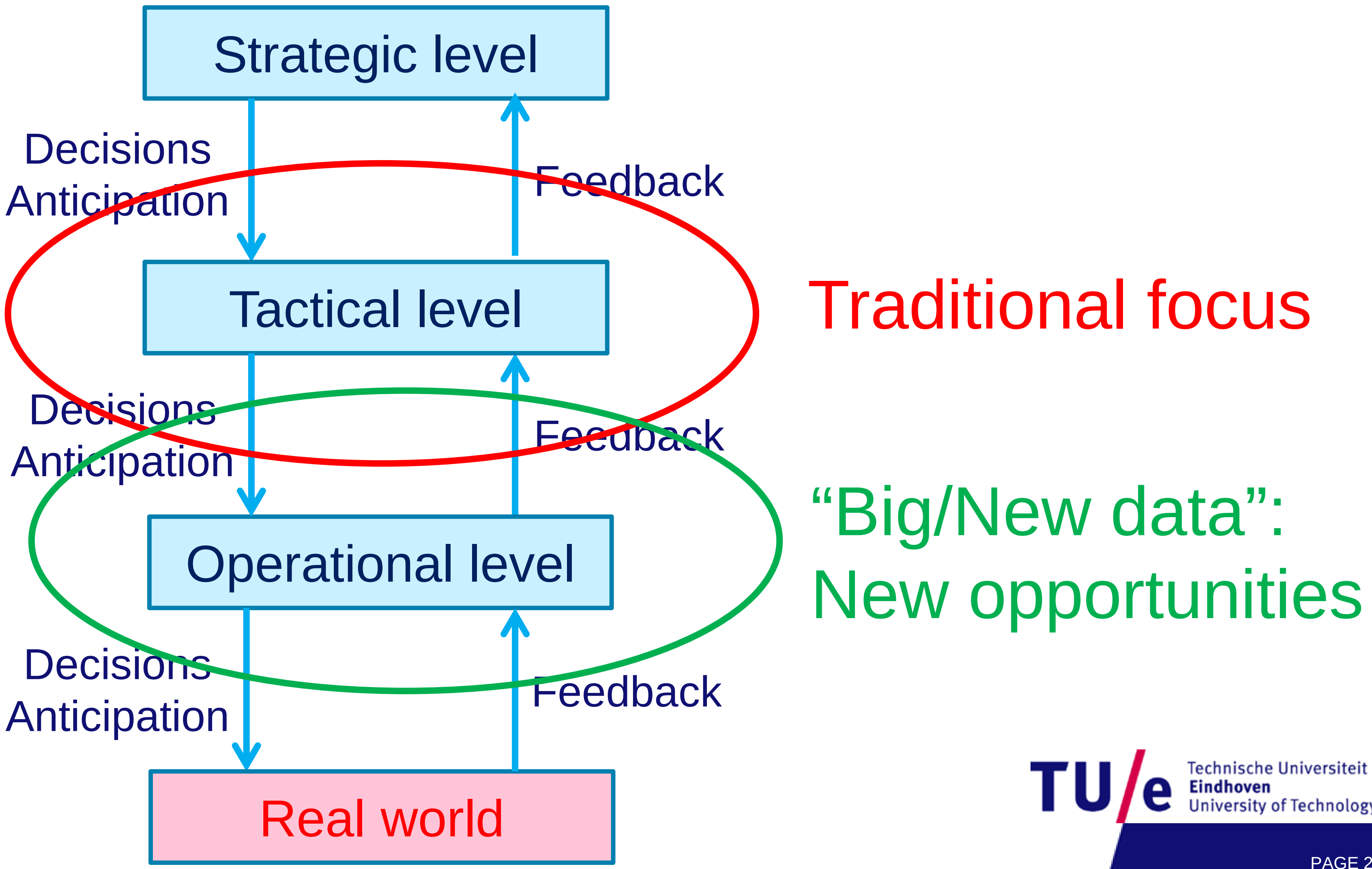
(part of NWO-TOP project)

Users of system-oriented methods

- ASML: For local warehouses
- Océ: For field stock (cars and QRS's)
- IBM: Via Neighborhood
- Thales: Uses Inventri
- Users of Xelus and MCA Solutions (without lateral transshipments)
- US Coast Guard
- …

5. New challenges

Planning levels



Studied topics

- Predictive spare parts supply
  - Even unreliable predictions can lead to significant savings (study by Topan et al., 2018)
- Predictive maintenance (see e.g. PhD work of Zhu)
  - Many different models for components
  - Required reaction times may differ per component
  - Interaction with production schemes of customers
- Dynamic control to meet SLA's during finite-term contracts (PhD work of Lamghari)
- Uncertainty in failure rates (projects by Javanmardi and Van Wingerden)

Overall approach in practice

Control tower !!!

- Needs all relevant information
- Real-time decision making
  - Fast, simple algorithms
  - Based on most relevant data
- Type of research:
  - Heuristics
  - Comparison via simulation

Discussion

- Who of you uses a system-oriented approach?
- Who of you already exploits “new data”?