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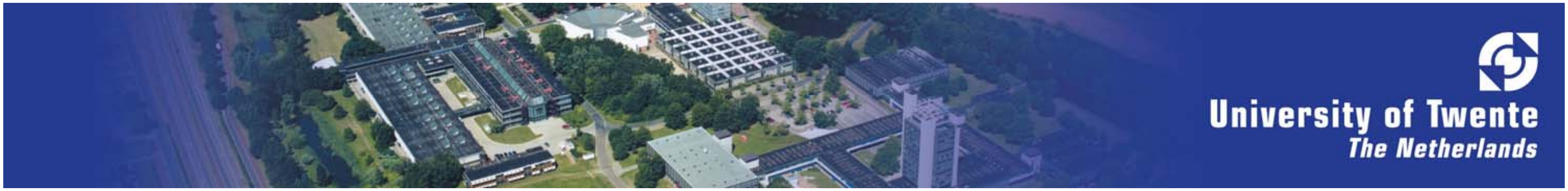
Operating room planning & scheduling

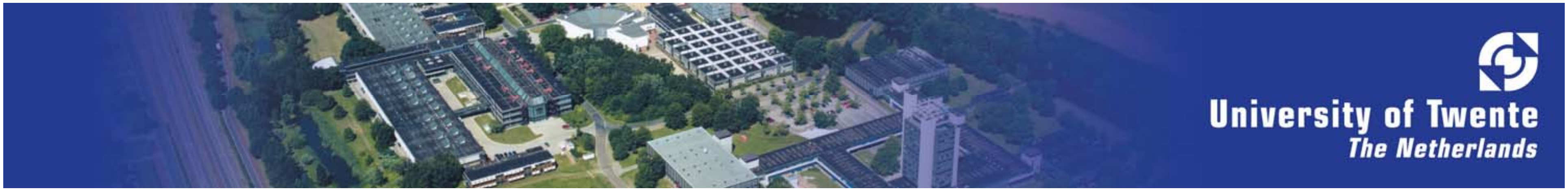
Erwin Hans

Center for Healthcare Operations Improvement & Research (CHOIR)



Overzicht presentatie

- Achtergrond
- Introductie OK planning & scheduling
- Robuuste planning van electieve operaties
- Master Surgical Scheduling (MSS)
- Spoed-OKs of niet?
- OK management game & software demo

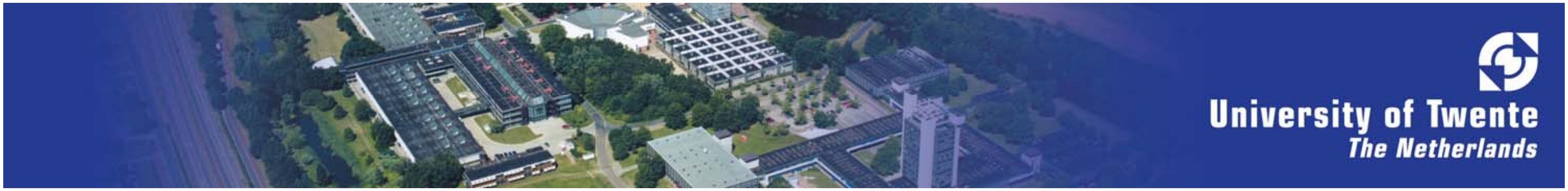


Achtergrond

- (1997) MSc Toegepaste Wiskunde (OR & Math. Progr.), UT
- (2001) PhD Tactical capacity planning in discrete manufacturing (promotoren Henk Zijm, Steef van de Velde)
- (2001-) UD “Operational Methods for Production & Logistics
- (2003-) Onderzoek “Process optimization in healthcare”
- (2007-) Voorzitter UT center of expertise:

Center for Healthcare Operations Improvement & Research

(http://www.choir.utwente.nl)



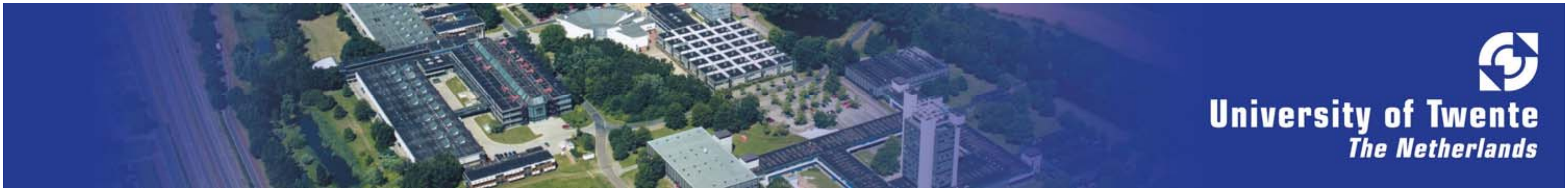
UT-kenniscentrum
CHOIR

Center for Healthcare Operations Improvement & Research

- 17 stafleden, 9 promovendi
- > 70 publicaties sinds 2000

Disciplines:

- Operations Management, Logistiek, Inkoopmgmt.
- Stochastische OR, Discrete Wiskunde & Math. Prog.
- Quality & Safety Mgmt., Informatie & Techn. Mgmt.



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Samenwerking met (zorg)instellingen:

- NKI/AVL, AMC, Erasmus MC, LUMC, UvM, UMCG, NFU
- Regionale zh: MST, ZGT, DZ, Isala klinieken, SKB, RdGG, Groene Hart ZH, etc.
- Overig: ORTEC, Bouwcollege (CBZ)

UT-kenniscentrum
CHOIR

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Onderwijs:

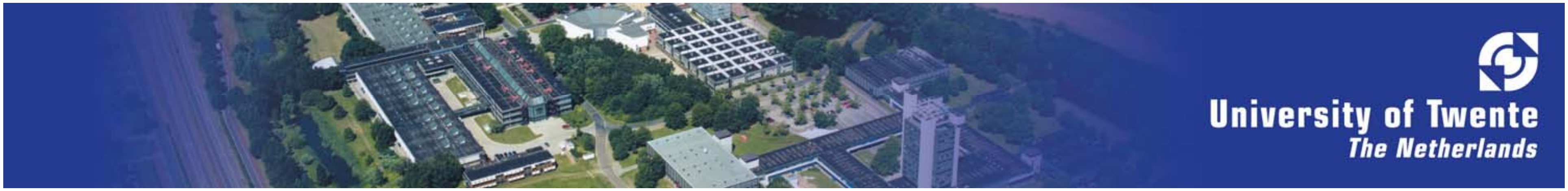
- Industrial Engineering & Management master tracks:
  - Healthcare Technology & Management
  - Production & Logistics Management
- Health Sciences (Gezondheidswetenschappen)
  - Healthcare management master

OK planning & scheduling (inleiding)

Erasmus MC, Rotterdam

Erasmus MC
Universitair Medisch Centrum Rotterdam

- Grootste UMC in Nederland
- Onderzoekssamenwerking met Universiteit Twente, m.b.t. toepassing OR-technieken voor procesoptimalisatie
- Onderzoeksaanpak middels samenwerking medici, managers & wiskundigen
- > 15 papers & book chapters

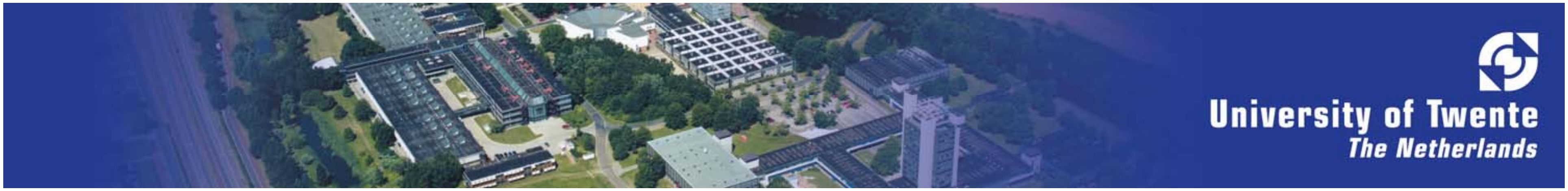


Positioneringsraamwerk voor ziekenhuis planning & besturing

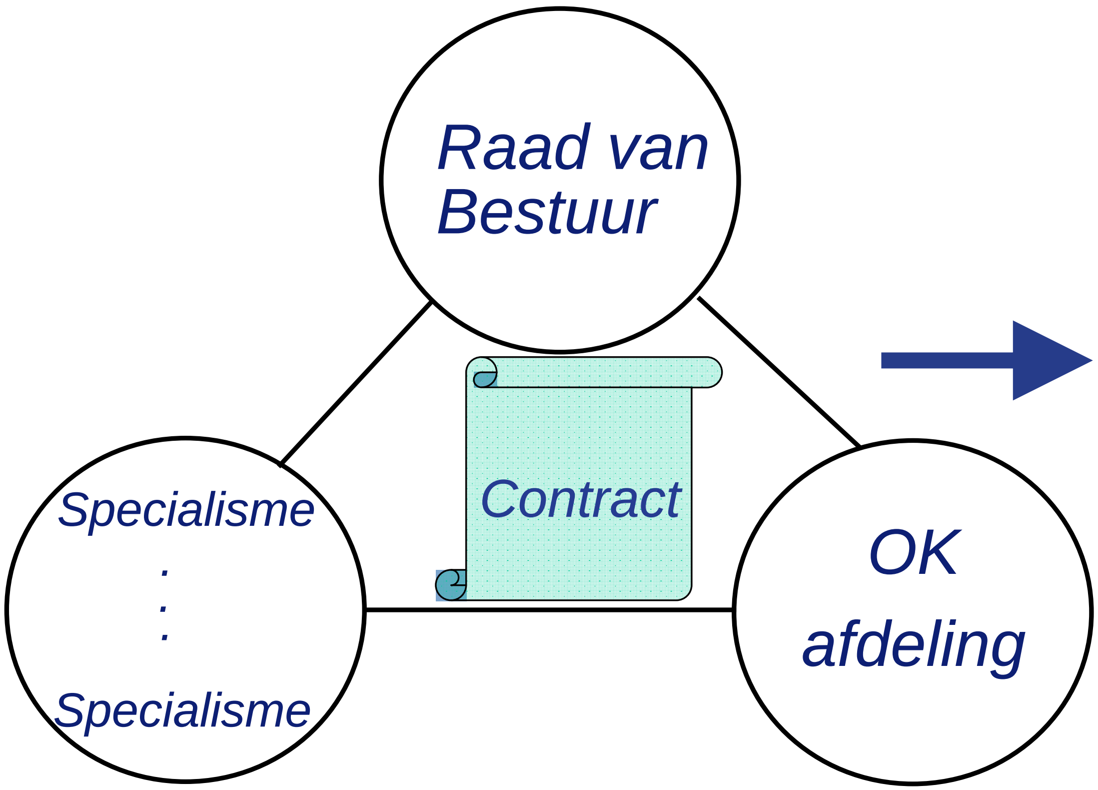
	Medical planning	***Resource capacity planning***	***Material coordination***	***Financial planning***
Strategic	Research planning, introduction of new treatment methods	Case mix planning, layout planning, capacity dimensioning	Supply chain and warehouse design	Agreements with insurance companies, capital investments
Tactical	Definition of medical protocols	Allocation of time and resources to specialties, rostering	Supplier selection, tendering, forming purchasing consortia	Budget and cost allocation
Operational offline	Diagnosis and planning of an individual treatment	Patient scheduling workforce planning	Purchasing, determining order sizes	DRG billing, cash flow analysis
Operational online	Triage, diagnosing complications	Monitoring, emergency coordination	Rush ordering, inventory replenishing	Expenditure monitoring, handling billing complications

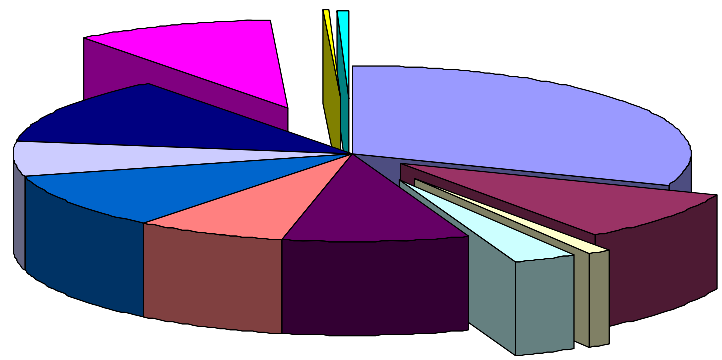
↑ hierarchical decomposition ↓

← managerial areas →



Introductie OK planning: strategisch niveau



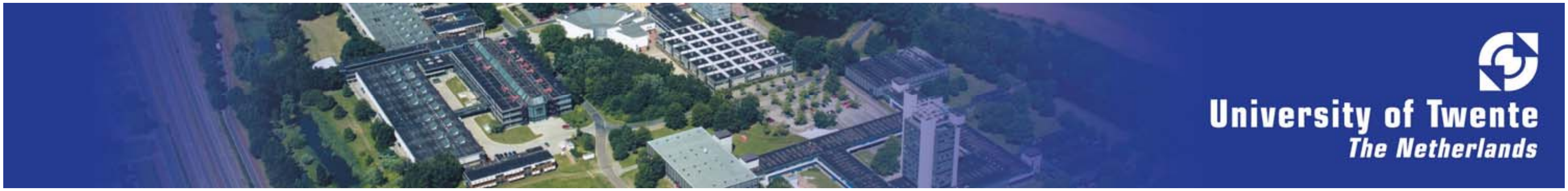


"capaciteitscake"
+
case mix

Introductie OK planning: strategisch niveau

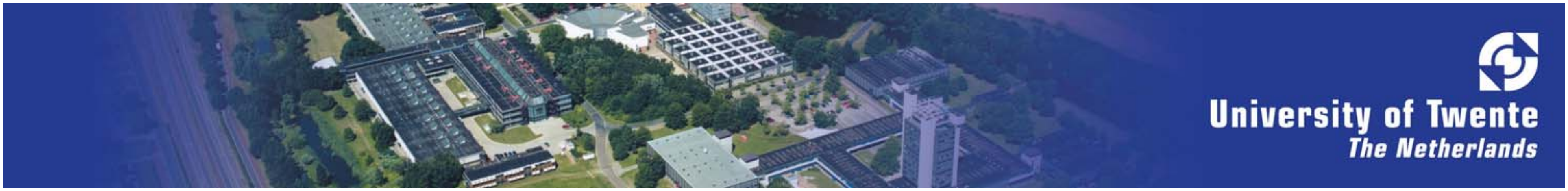
Capaciteitsdimensionering betreft:

- #OKs (klinisch, poliklinisch, spoed-OK)
- Anesthesisten
- Anesthesieassistenten, OK-assistenten
  - # teams beschikbaar gedurende de nacht
- (verplaatsbare) Instrumenten (bijv. X-rays)
- Instrumenten (netten)
- Materialen



Introductie OK planning: tactisch niveau

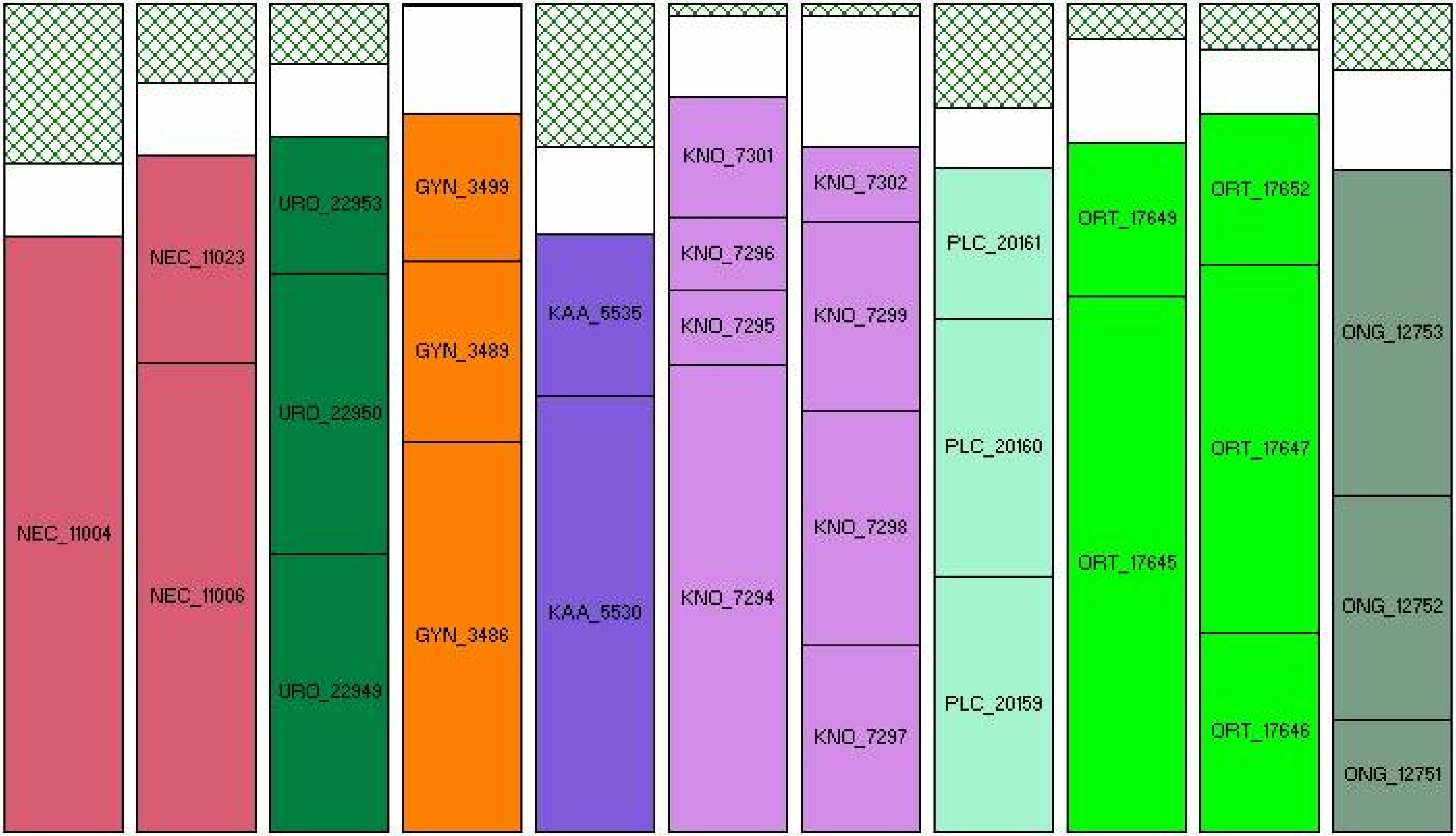
- Blok planning (specialismen ←→ blokken)
  - OK personeel, chirurgen
  - Beddenplanning (vpl, ICU)
- Toewijzing *electieve* operaties aan blokken
  - Per specialisme, bijv. 1 of 2 weken van tevoren
  - Operatieduur gebaseerd op historische data
  - Naast “verwachte duur” voldoende slack plannen, gebaseerd op historische variabiliteit in operatieduur

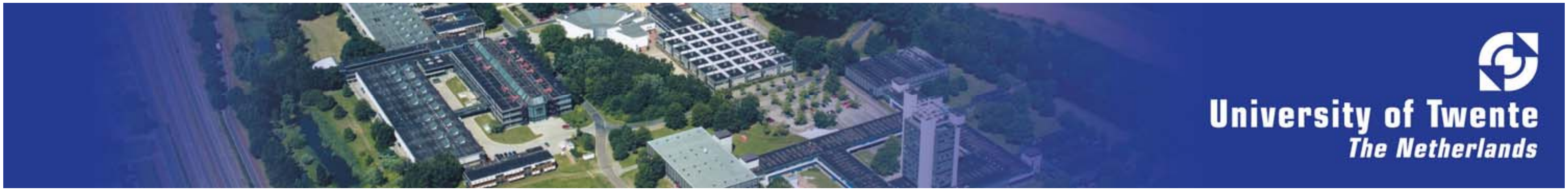


Introductie OK planning: offline operationele niveau

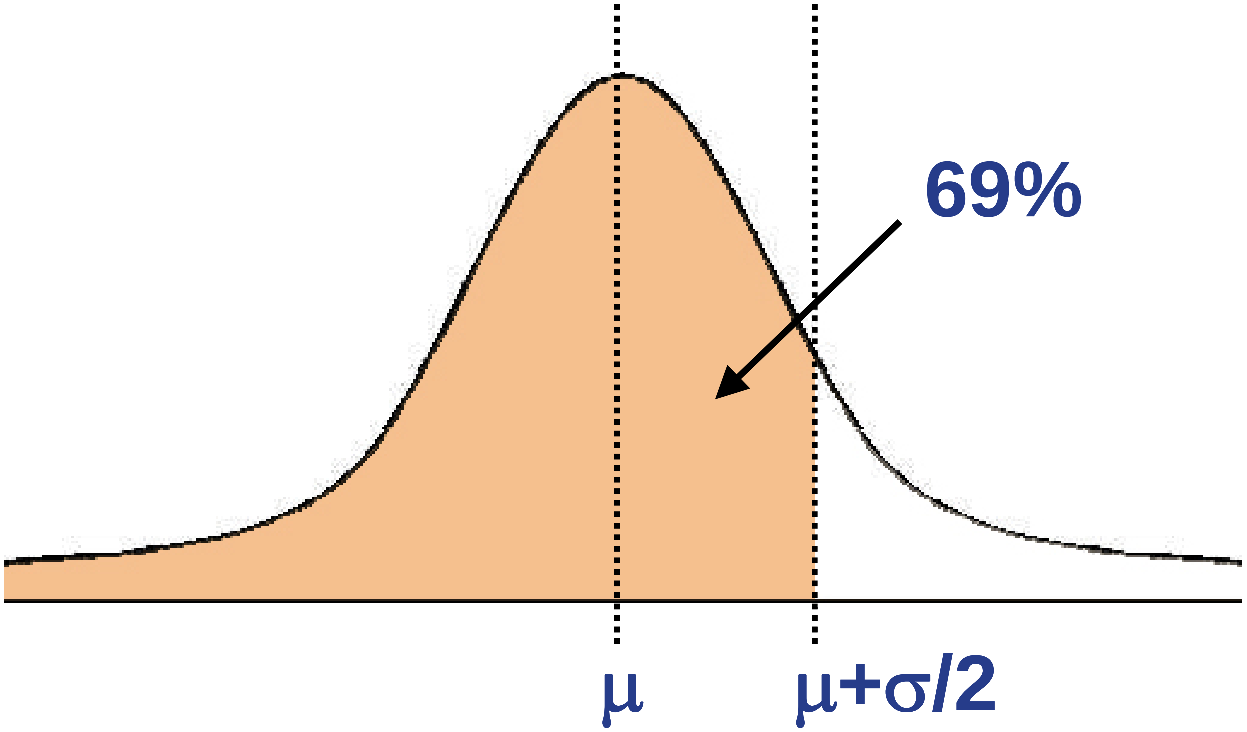
- "Add-on scheduling" van semi-urgente operaties
- Sequencen van de electieve operaties
  - Bijv. om problemen te voorkomen met een beperkt aantal X-rays
- Personeelsroostering

Voorbeeld (11 OKs)





Introductie OK planning: offline operationele niveau



Historische data

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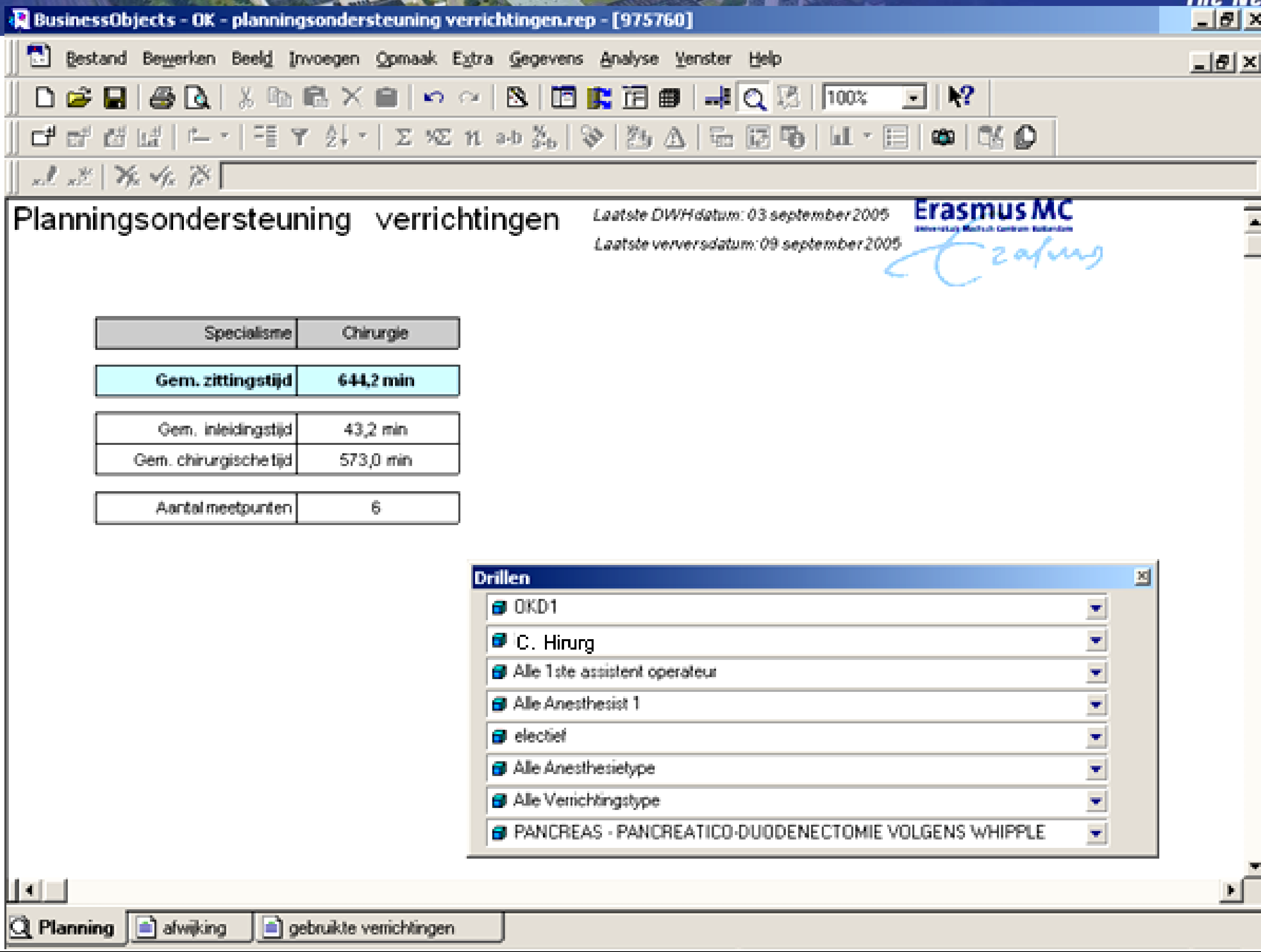
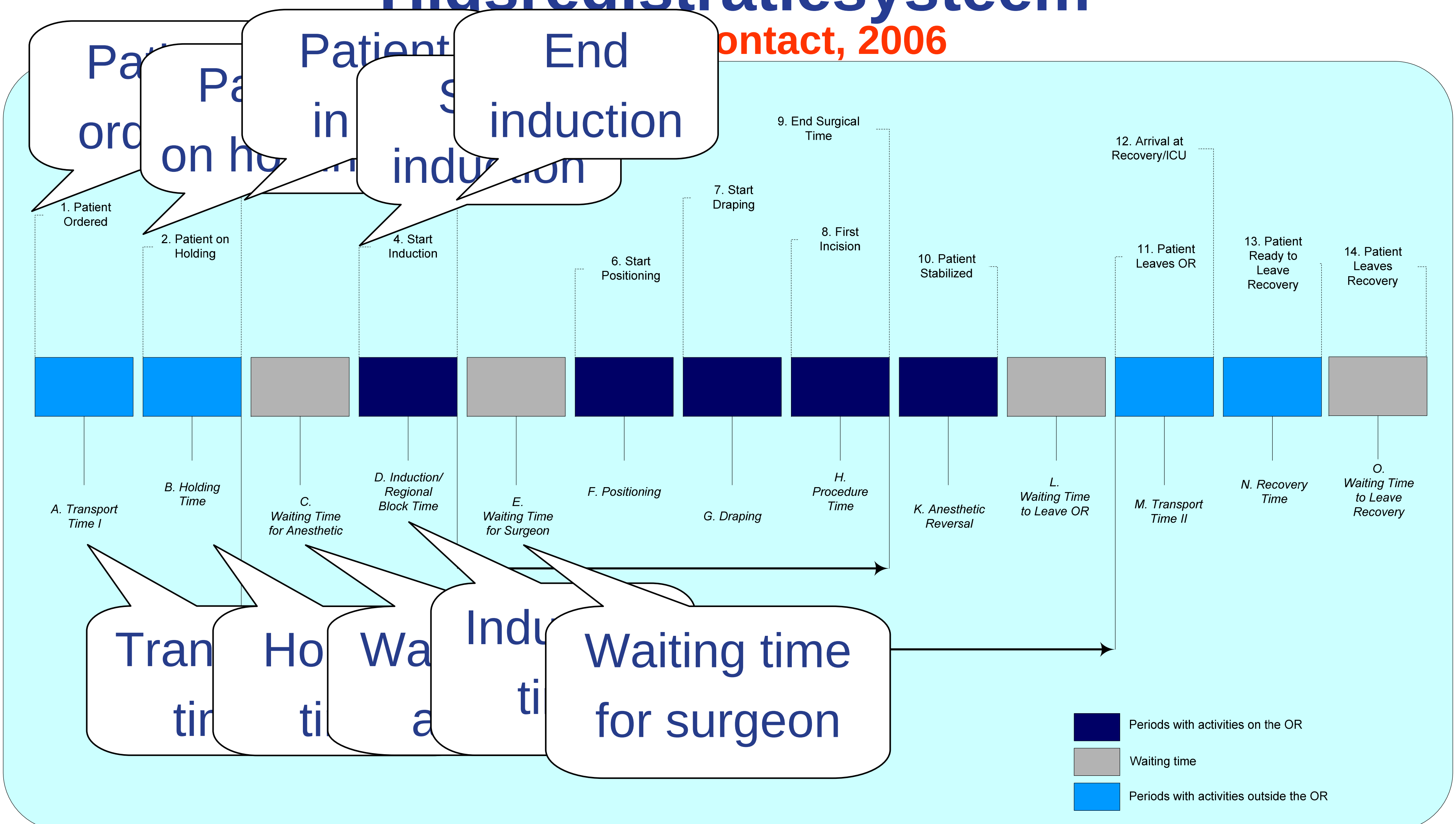


Tiidsregistratiesysteem

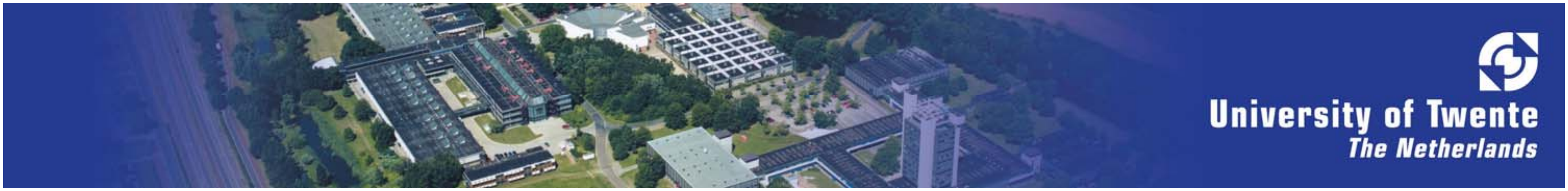
ontact, 2006



Introductie OK planning: online operationele niveau

Spoed-operatiescheduling (gedurende de dag):

- Spoed-OKs
  - Spoedoperaties in (daarvoor gereserveerde) OKs
- Geen spoed-OKs
  - Spoedoperaties in electieve programma



Master surgical scheduling

a cyclic, integral planning of ORs and ICU department

(tactical planning level)

OR Spectrum, 2007 (co-work Van Oostrum *et al.*)

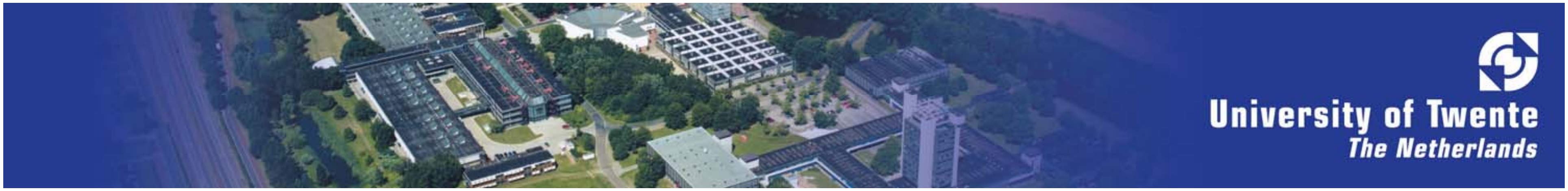
Preliminary study

Question:

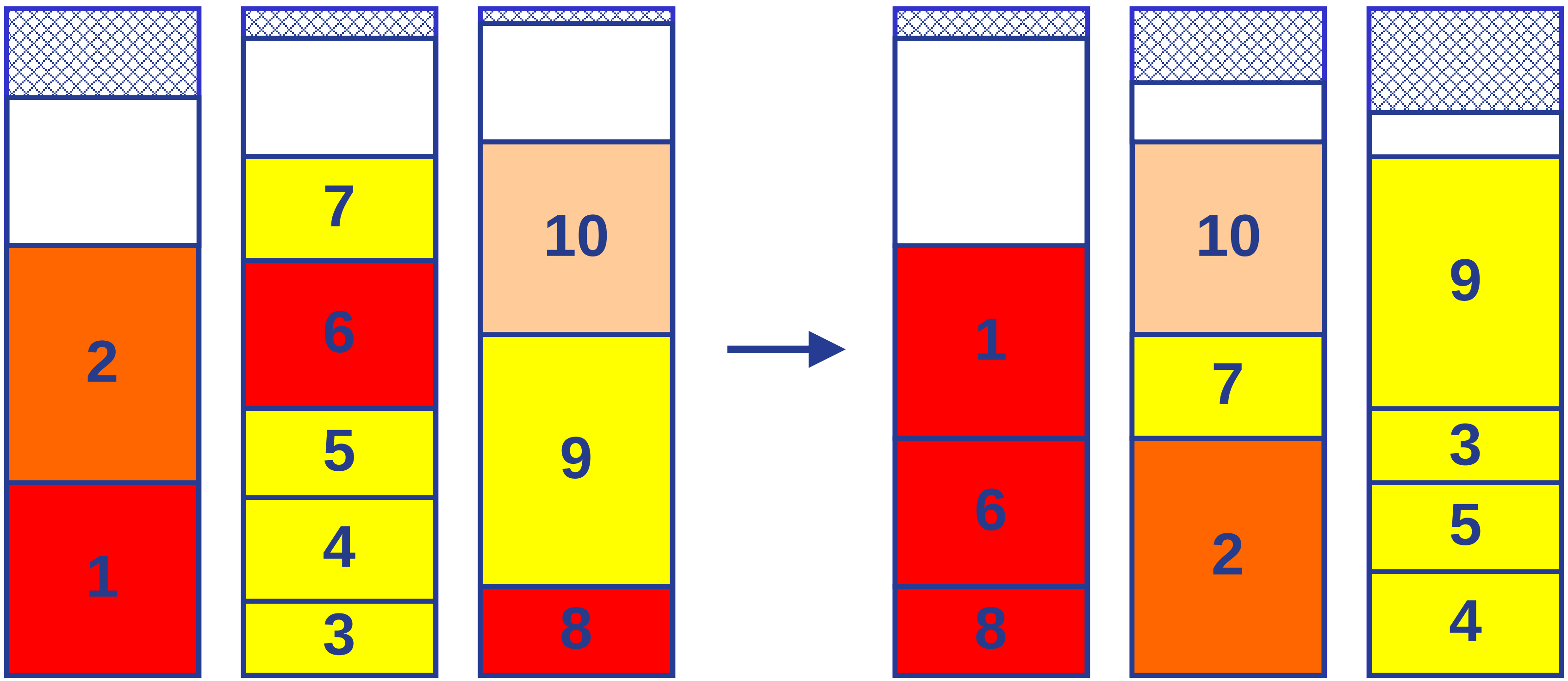
- how much can OR-utilisation be increased by optimising the elective surgery schedule?

Approach (see our paper in EJOR 185):

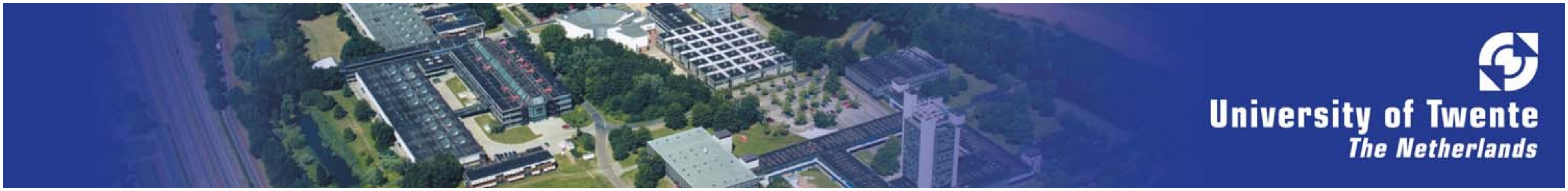
- Optimisation of elective scheduling by exploiting the portfolio effect



Preliminary study
Portfolio-effect



Capacity gain 2.3%, increase in unused capacity: 40%

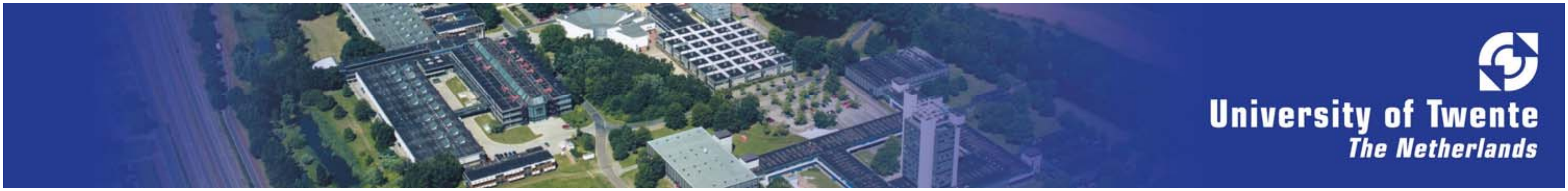


Motivation of research

- Low OR utilisation, many cancellations
- OR-scheduling is time-consuming, and repetitive

  However: many elective surgery types are recurring!

- Weekly optimisation using mathematical techniques
  - Leads to “nervous schedules”
  - May interfere with autonomy of medical specialists
  - Hard to implement



Elective surgery scheduling

Challenges:

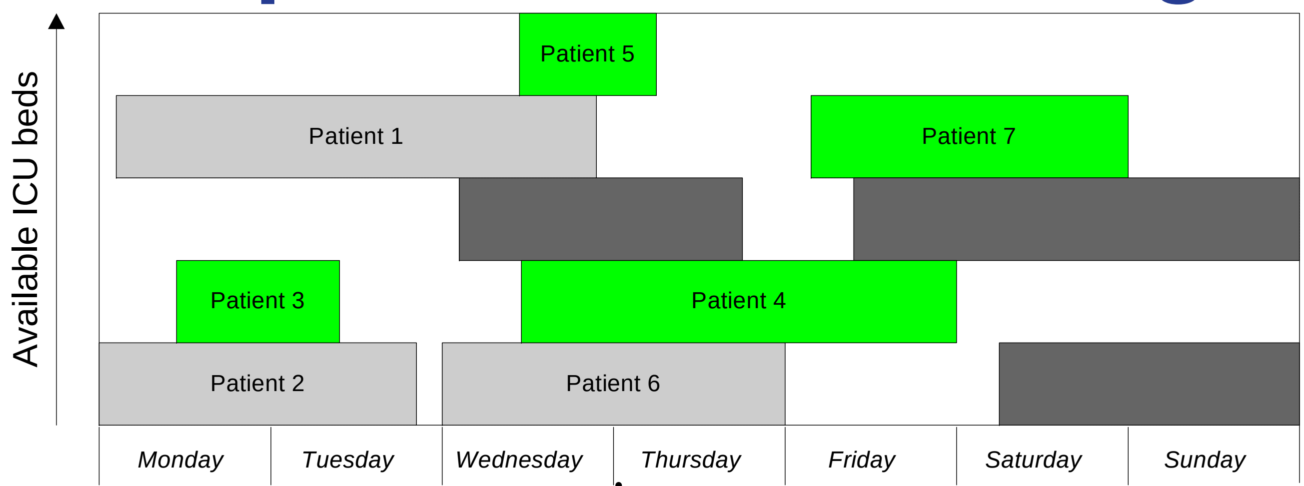
- Optimise utilisation surgeons and ORs
- Optimise robustness (e.g. minimise overtime)
- Optimise other resources (ward/ICU bed, X-ray)
- Care chain optimisation, early personnel coord. etc.
- Easy implementation

…while <u>maintaining the autonomy of the surgeons</u> as much as possible

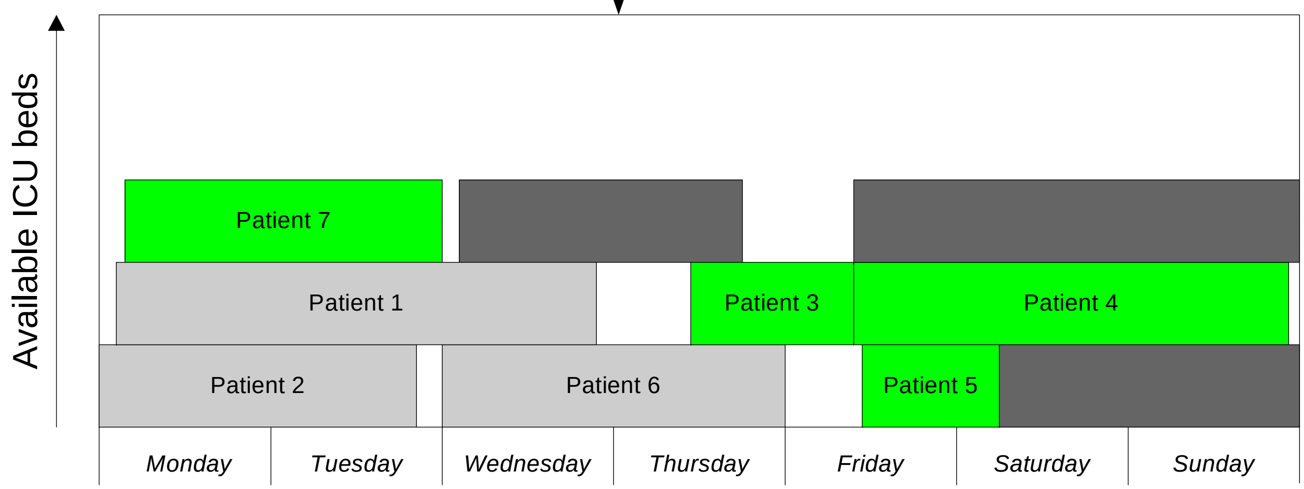
→ Promising approach: Master Surgical Scheduling

ICU bed requirements after surgery

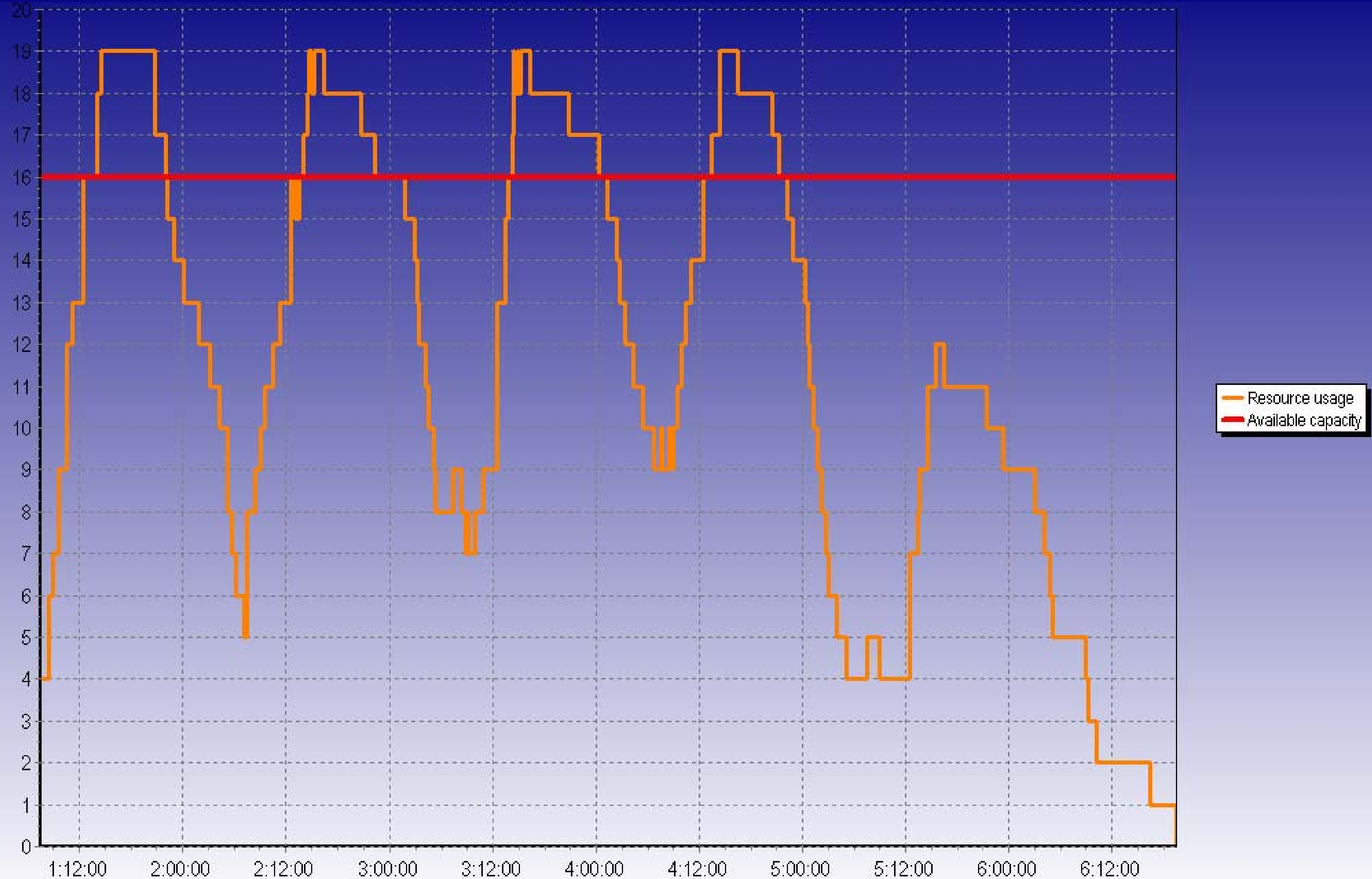
Expected ICU utilization of elective patients without coordination

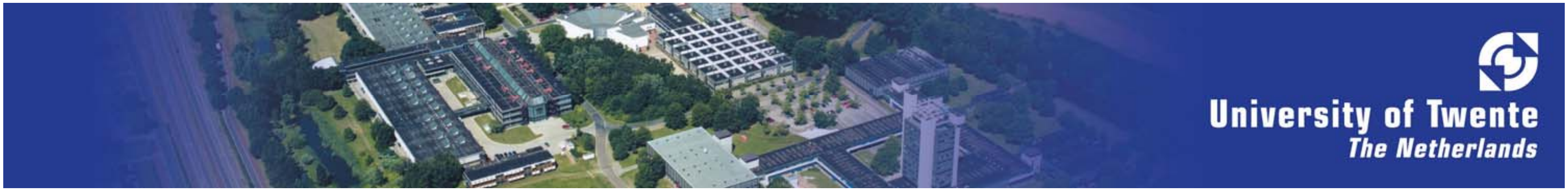


Expected ICU utilization of elective patients with coordination



Capacity usage for shortstay ward



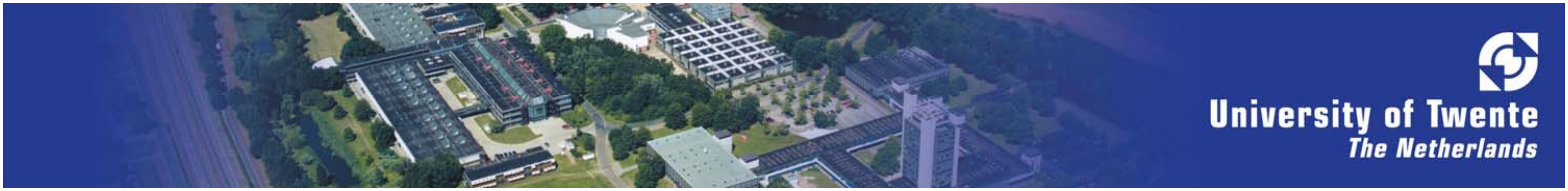


Master surgical scheduling: idea

Idea: design a cyclic schedule of surgery types that:

- covers all frequent elective surgery types
- levels the workload of the specialties
- levels the workload of subsequent departments (ICU, wards)
- is robust against uncertainty
- improves OR-utilisation
- maintains autonomy of clinicians

Assign patients to the “slots” in the schedule



MSS: problem description

Goal:

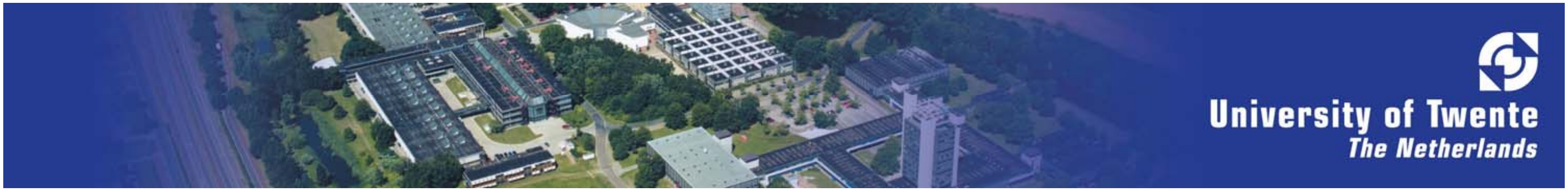
- Maximise the OR-utilisation
- Level capacity usage of subsequent resources (ICU)

Constraints:

- OR-capacity constraints (probabilistic)
- All surgery types must be planned i.c.w. their frequency

To determine:

- Length of the planning cycle
- A list of surgery types for every OR-day (“OR-day schedule”)



Mathematical program (base model)

maximises the OR utilisation

levels the hospital bed usage

$$\min \theta_1 \cdot \sum_{t=1}^{T}\sum_{j=1}^{J} o_{jt} \cdot W_{jt} + \theta_2 \cdot \sum_{b=1}^{B} \left[\frac{c_b}{\left[\sum_{i=1}^{I} l_{ib} \cdot s_i\right] / T} \cdot \max_{\tau \in T} \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{t=1}^{T} \psi_{t\tau ib} \cdot V_{ijt} \right]$$

Subject to

$$V_{ijt} \leq s_i \cdot W_{jt}, \qquad i = 1,\ldots,I, j = 1,\ldots,J, t = 1,\ldots,T$$

$$\sum_{t=1}^{T}\sum_{j=1}^{J} V_{ijt} = s_i, \qquad i = 1,\ldots,I$$

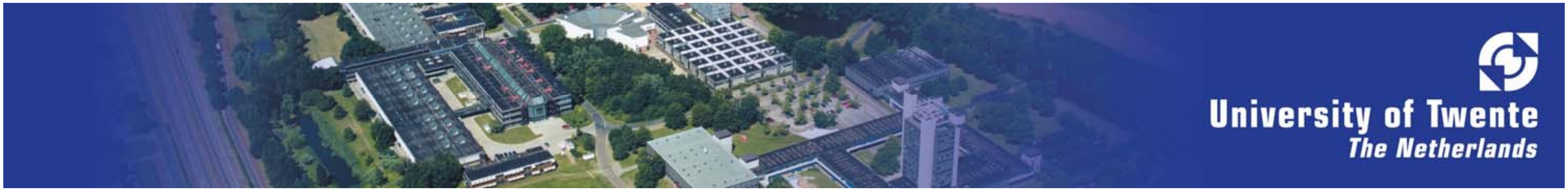
← All surgeries assigned

$$\Pr[f_{jt}(V) \leq o_{jt}] \geq \alpha, \qquad j = 1,\ldots,J, t = 1,\ldots,T$$

$$V_{ijt} \in \mathbb{N}, \qquad i = 1,\ldots,I, j = 1,\ldots,J, t = 1,\ldots,T$$

$$W_{jt} \in \{0,1\}, \qquad i = 1,\ldots,I, t = 1,\ldots,T$$

Probabilistic constraints



Master surgical scheduling: approach

PHASE 1:
Generation of
"OR-day schedules"

Goal: capacity utilisation

→ ILP, solved by column generation and then rounding

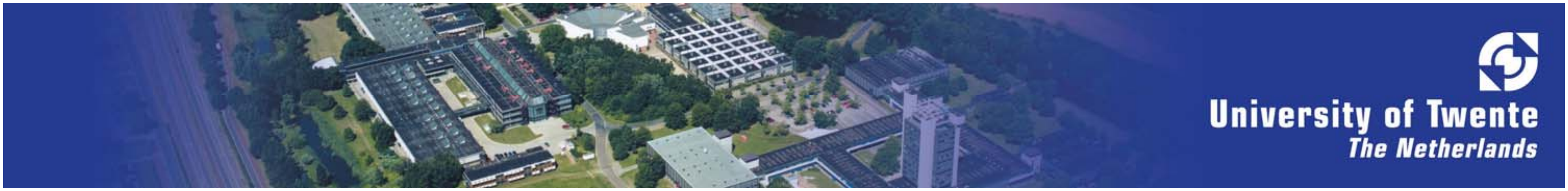
Constraints:

- All surgeries must be planned
- OR-capacity (probabilistic)

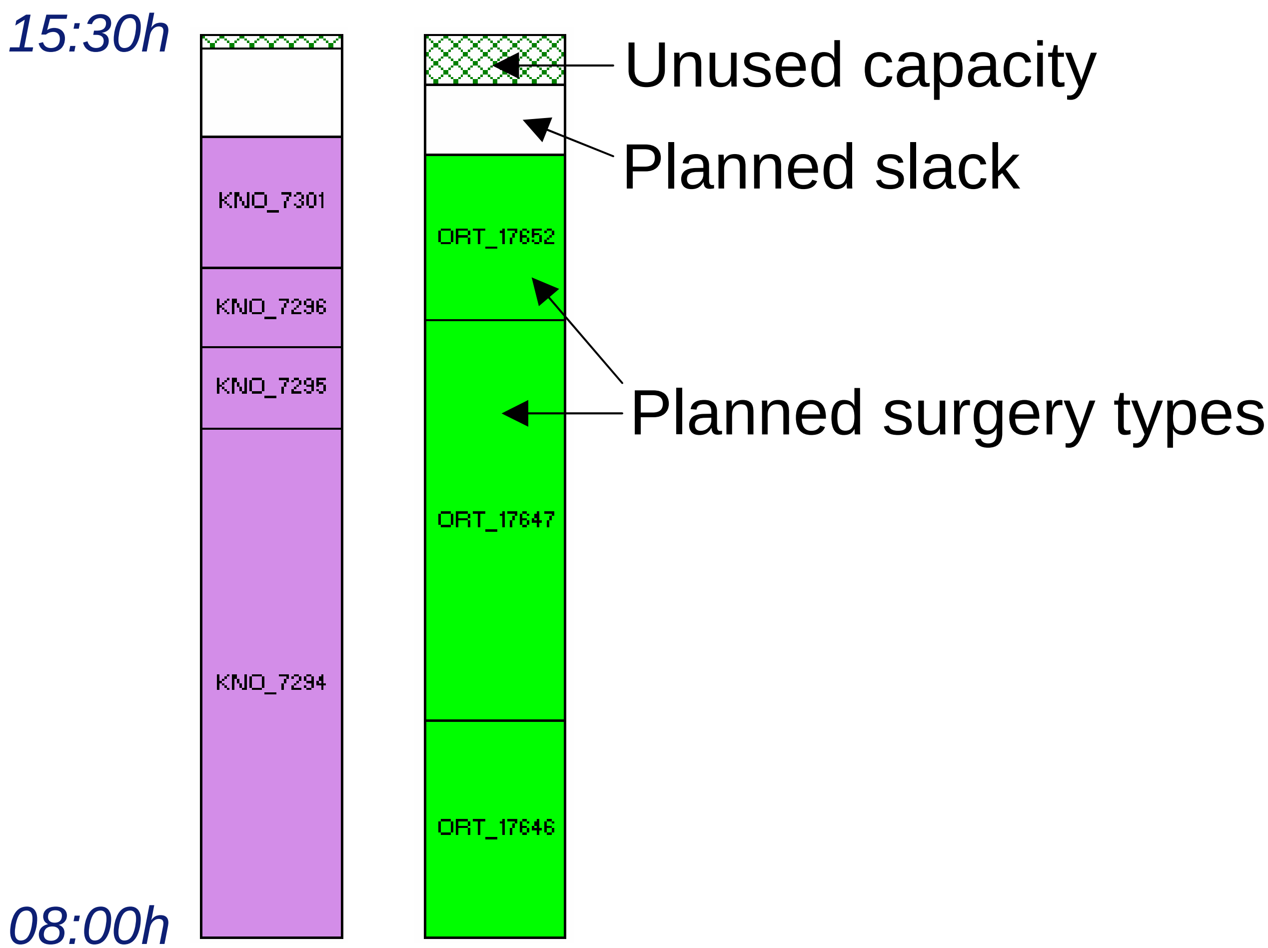
PHASE 2:
Assignment of
"OR-day schedules"

Goal: bed usage leveling

→ ILP, solved using CPLEX in AIMMS modeling language



OR-day schedule example



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Master surgical scheduling: approach

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→ ILP, solved by column generation and then rounding

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- All surgeries must be planned
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PHASE 2:
Assignment of
"OR-day schedules"

Goal: bed usage leveling

→ ILP, solved using CPLEX in AIMMS modeling language

MSS test approach

1. Statistical analysis of surgery frequencies
2. Select a cycle length (1, 2, or 4 weeks)
3. Construct an MSS (2-phase approach)

   Tools: AIMMS modeling language with integrated CPLEX solver

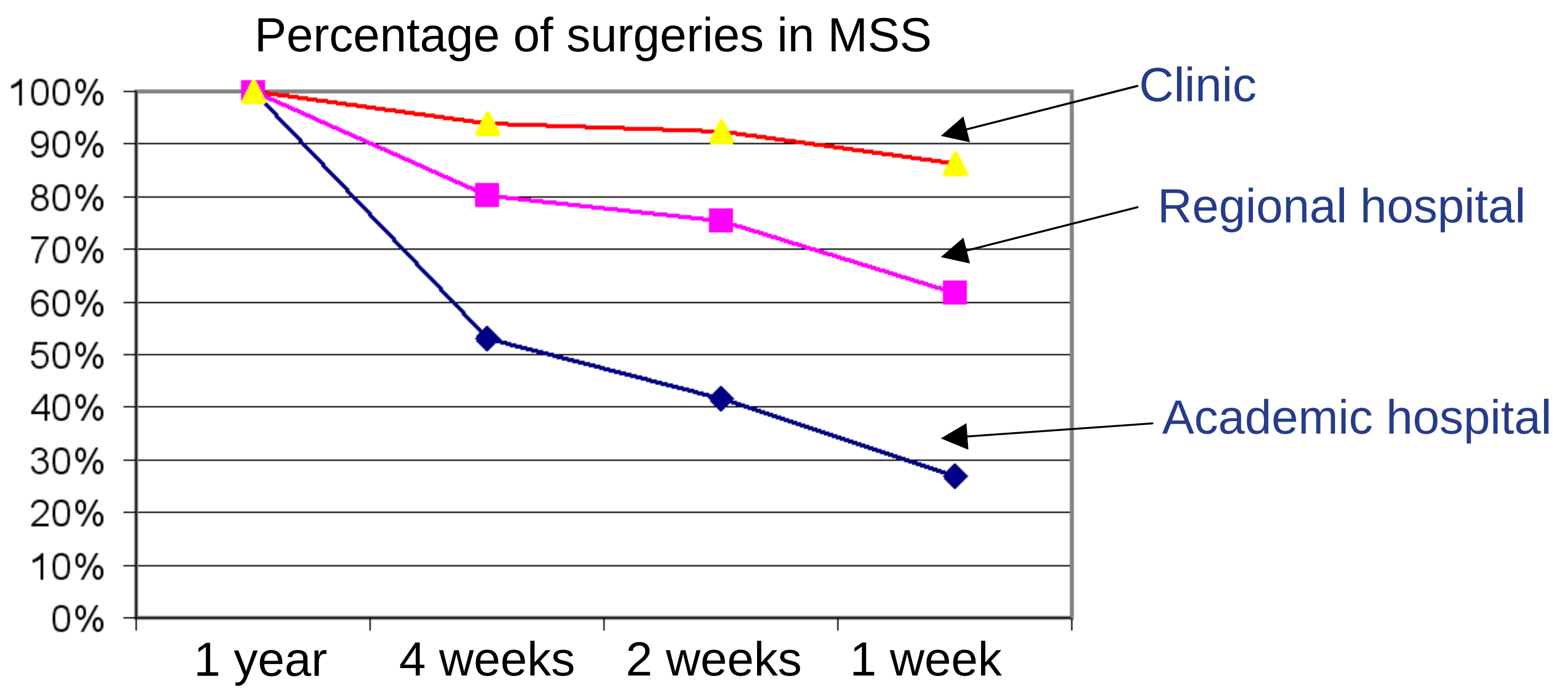
4. Discrete event simulation

   Schedule rare elective procedures in reserved capacity

   Admission of emergency surgeries (add-on and online planning)

Master surgical scheduling: results

Results differ for different types of hospitals:

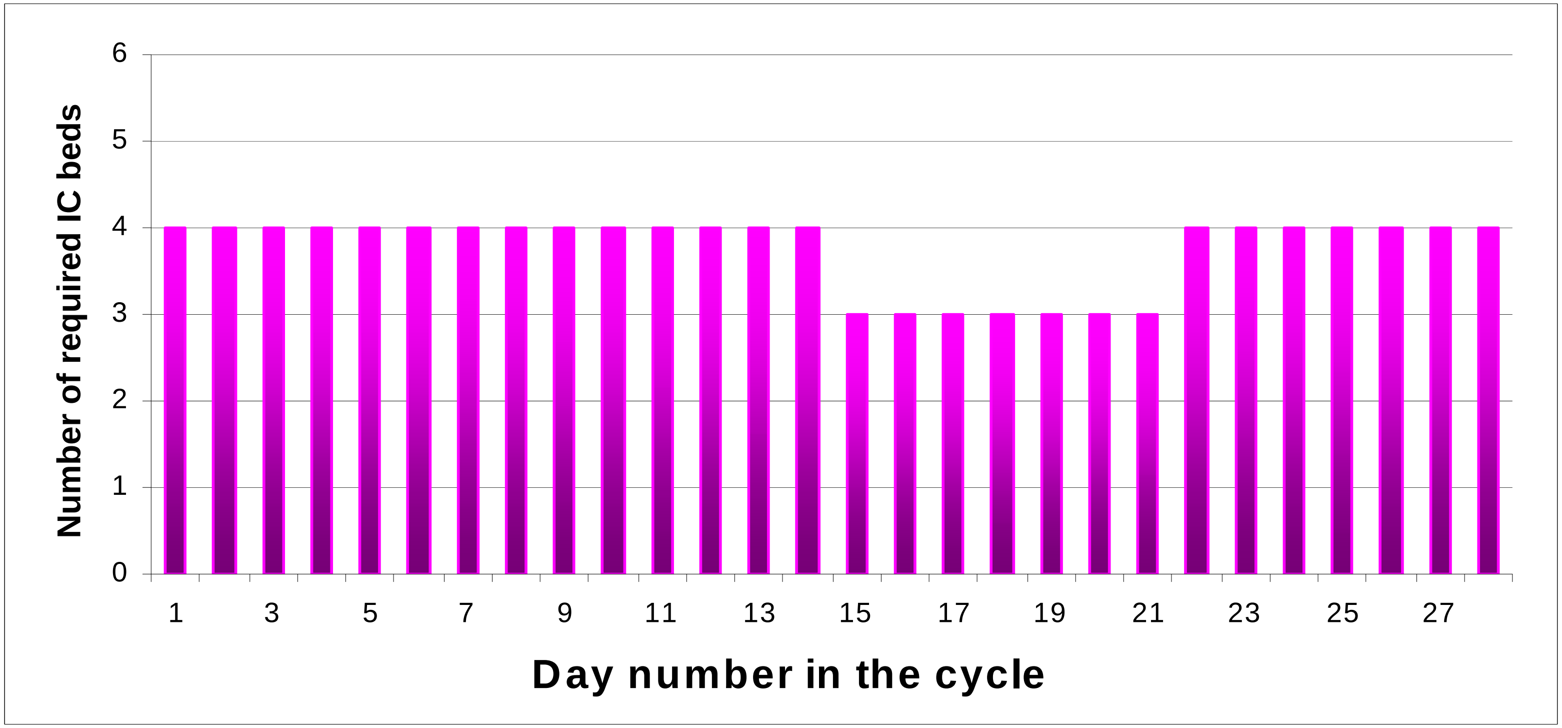


Reason: different volume and case mix range

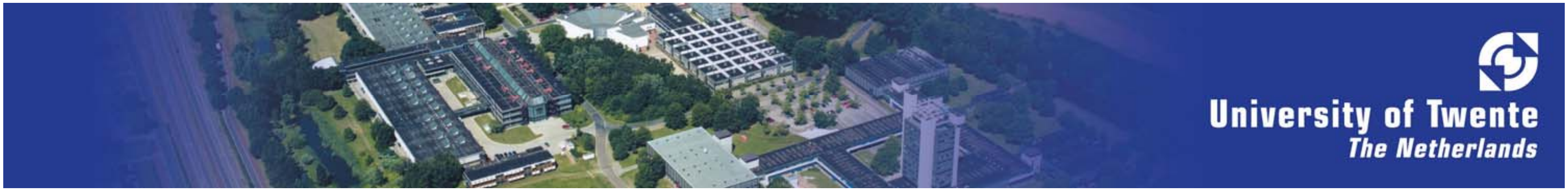
Master surgical scheduling: results

Req. number of ICU-beds <u>without MSS</u>: between 0 and 12 p.day

Req. number of ICU-beds <u>with MSS</u> (4 week cycle):



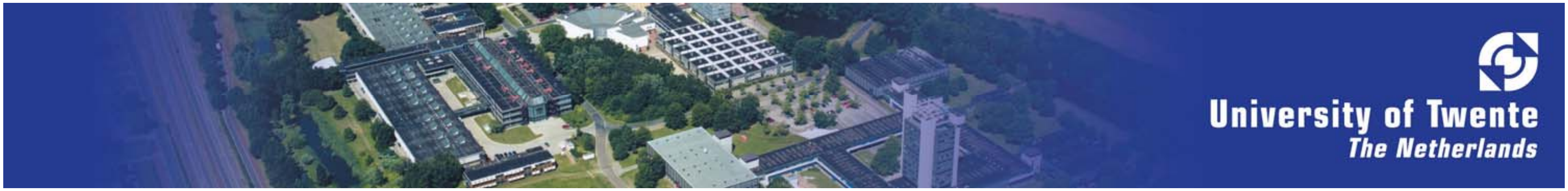
74.3% of the total ICU bed requirement is planned in an MSS of four weeks.



Master surgical scheduling: results

Reduction OR-capacity:

Cycle length	1 week	2 weeks	4 weeks
Academic hospital	1.1 %	2.7 %	4.2 %
Regional hospital	2.8 %	5.7 %	6.3 %
Clinic	4.9 %	7.3 %	8.6 %



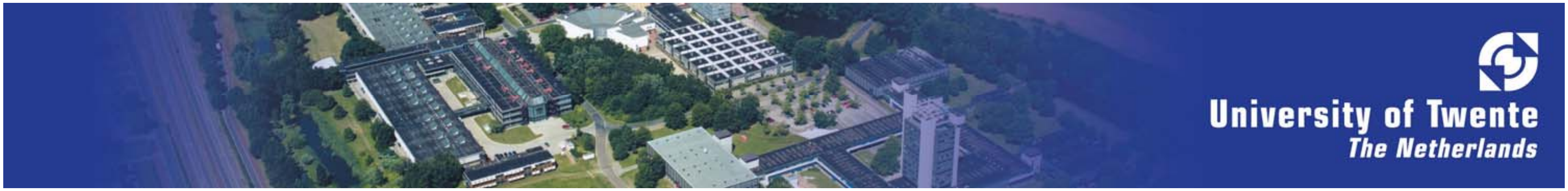
Master surgical scheduling conclusions

Advantages:

- Easy to implement
- Allows personnel coordination in early stage
- Less overtime, higher utilisation (up to 8.6%)
- Less surgery cancellations → shorter lead-times
- Improved coordination between departments

Disadvantage:

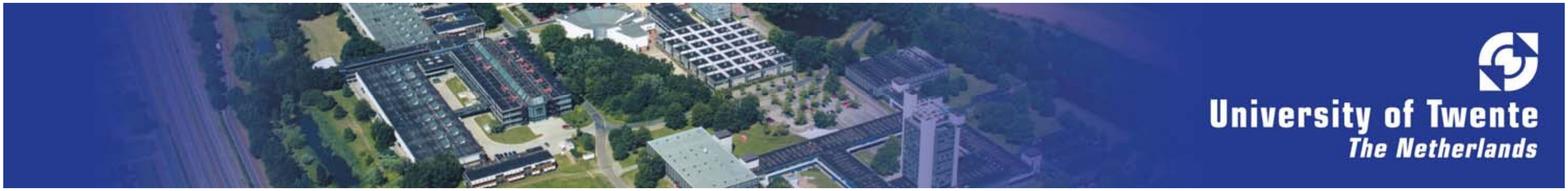
- Does not cover all surgeries



Emergency OR or NOT?

Robust optimisation of the OR schedule to deal with emergency surgery

(offline operational level)



Research motivation

The arrival of emergency surgeries is the most important source of disturbances in the OR

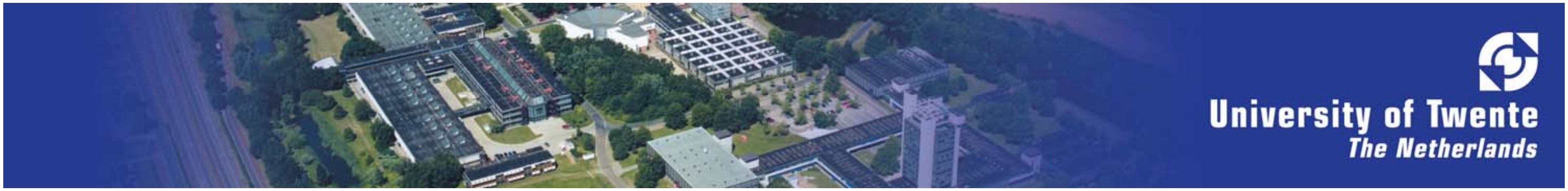
→ leads to: overtime, surgery cancellations, waiting time, reduced OR utilisation

Options to deal with emergency surgery:

Dedicated emergency ORs

vs.

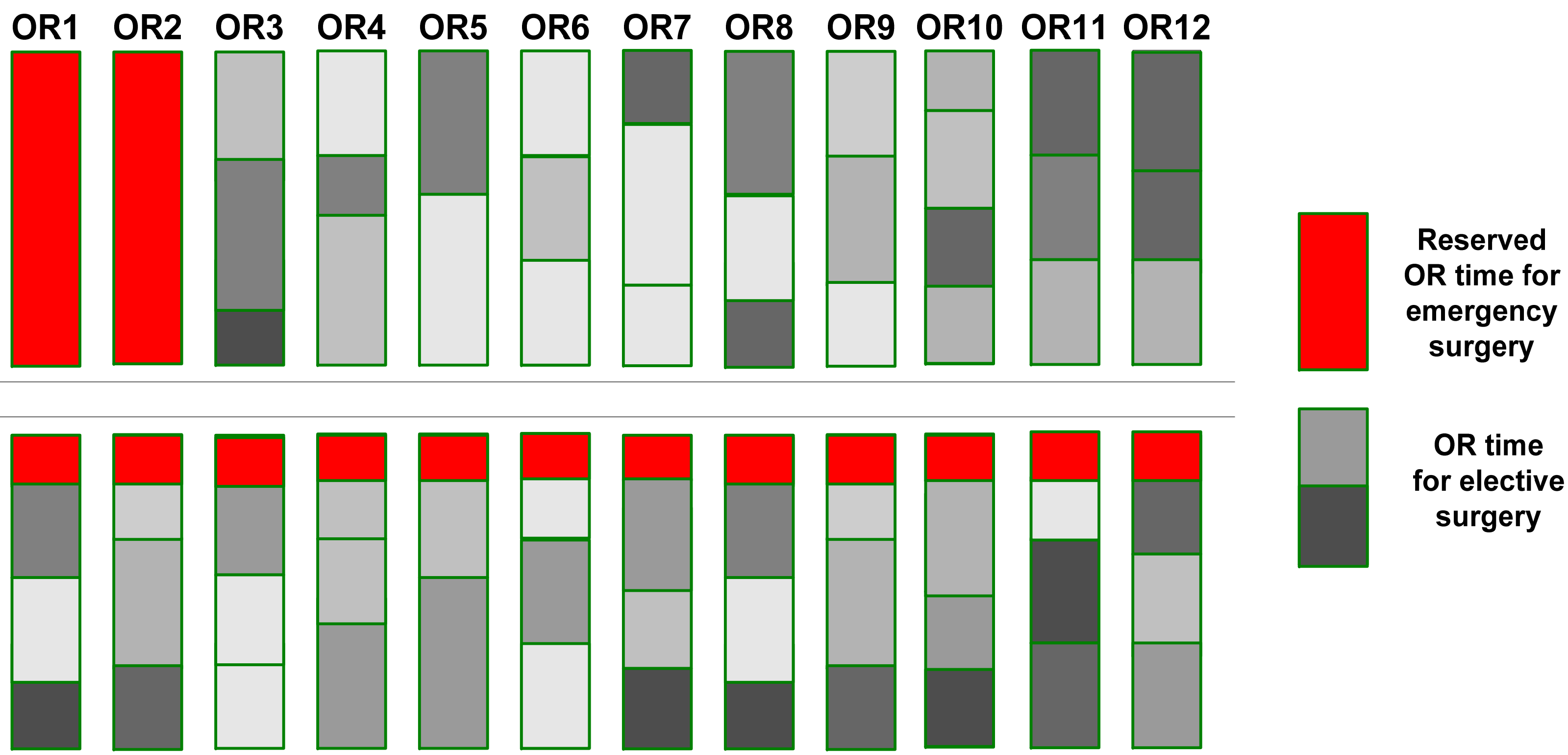
Schedule emergency surgery in elective ORs

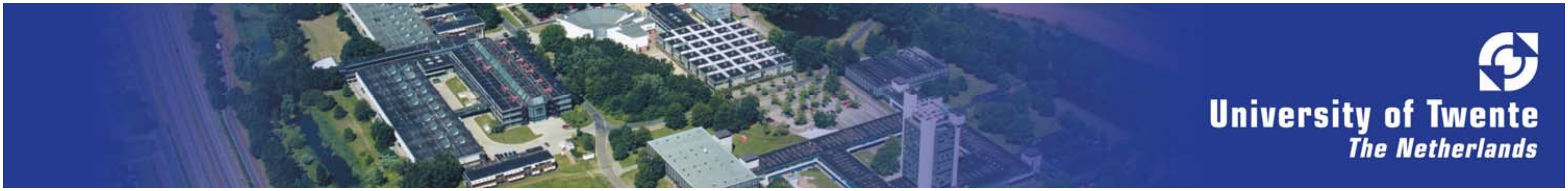


Emergency OR, or not?

Concept: "emergency ORs"

Concept: "No emergency ORs"

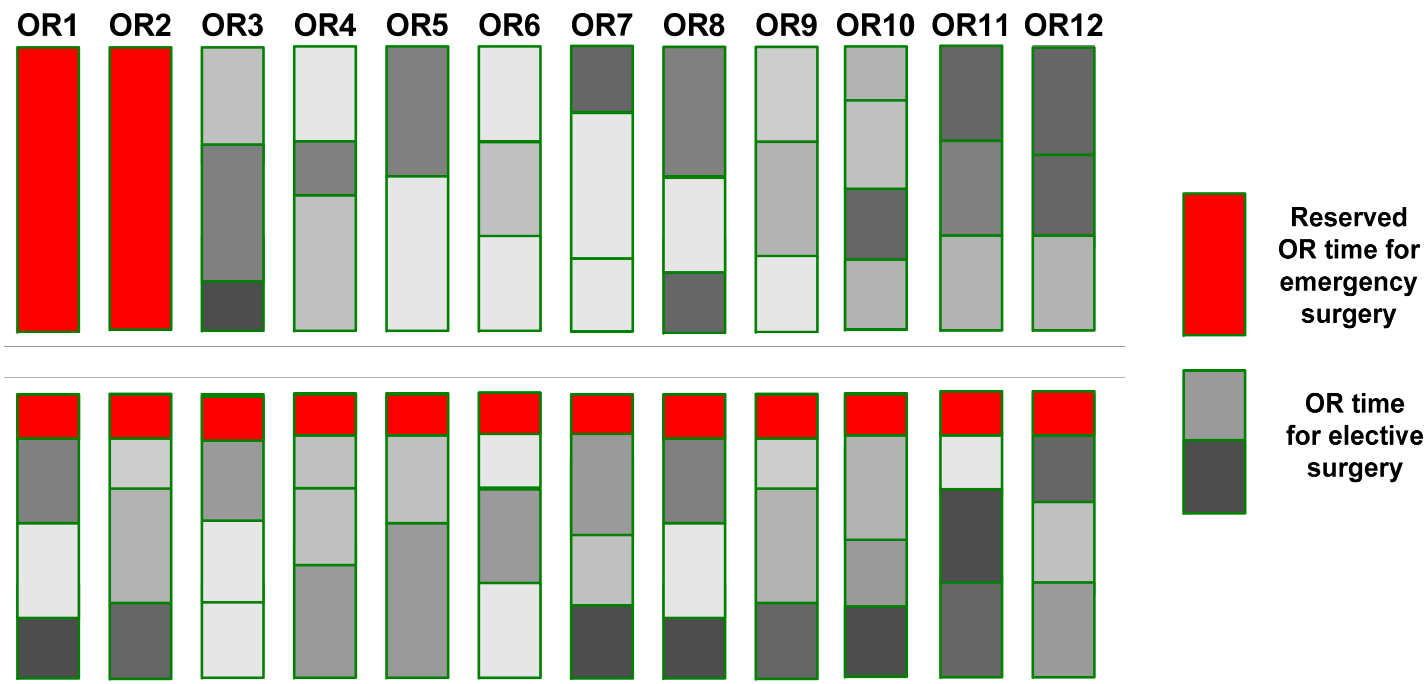




Emergency OR, or not?

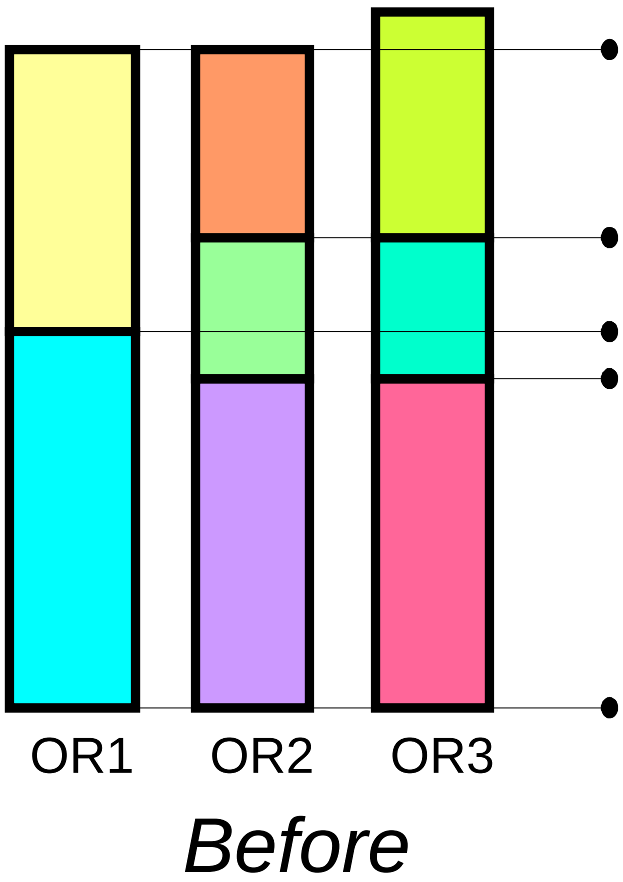
Concept: “emergency ORs”

Concept: “No emergency ORs”

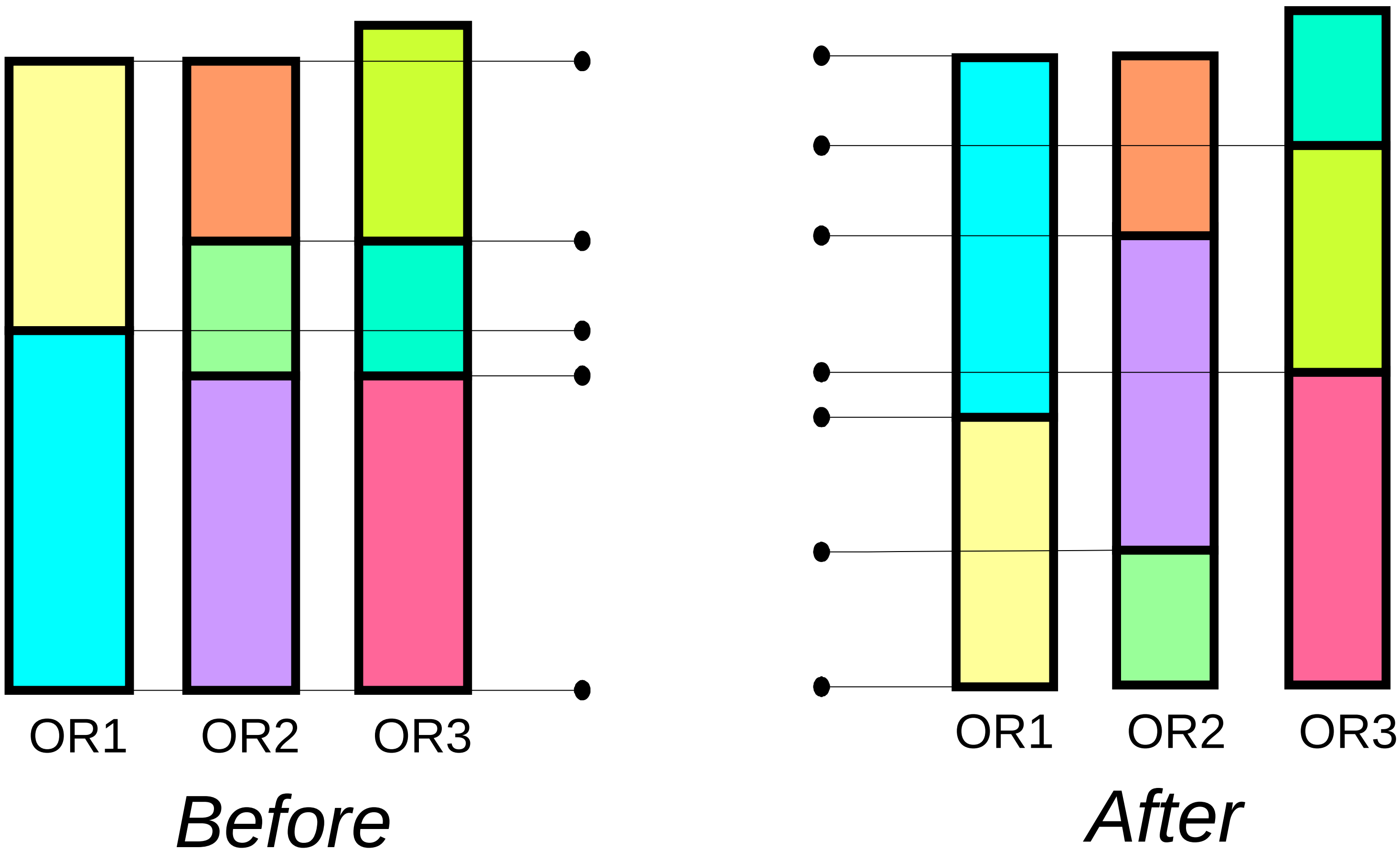


Result of simulation: emergency OR has **worse** performance w.r.t.: emergency surgery waiting time, overtime, OR utilisation

Problem description



Problem description



Solution approach

Goal: spread "Break-In-Moments" between elective surgeries as evenly as possible

Problem is NP-hard in the strong sense (proof by reduction from 3-partition)

Input: an elective surgery schedule for a given week

Optimisation: constructive + local search heuristics

Constructive heuristic

First calculate λ: a lower bound to "min max BII"

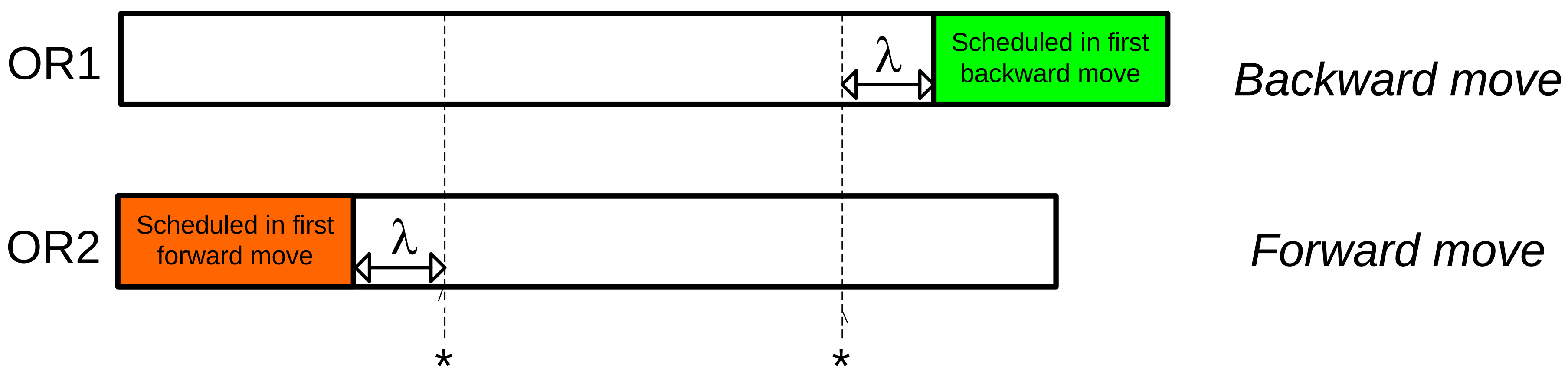
$$\lambda = \frac{E - S}{1 + \sum_{j \in J} (M_j - 1)}$$

E: *earliest OR end time*

S: *latest OR start time*

M_j: *number of surgeries in OR j*

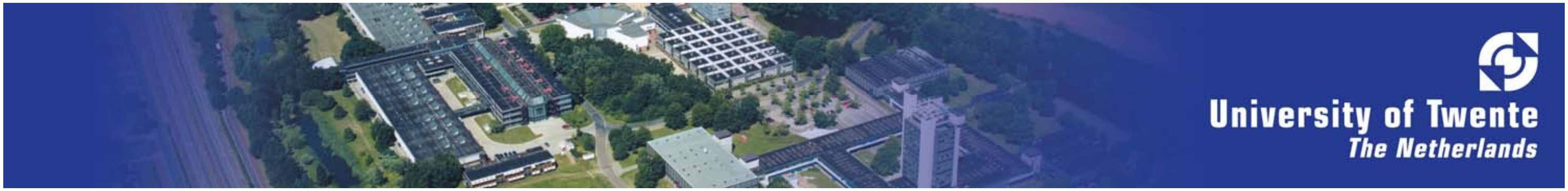
Then iteratively schedule a surgery forward or backward closest to ∗



Simulation results operational problem

Waiting time less than:	First emergency procedure		Second emergency procedure		Third emergency procedure	
	No BII opt.	BII opt.	No BII opt.	BII opt.	No BII opt.	BII opt.
10 minutes	28.8%	48.6%	34.9%	44.9%	40.4%	46.2%
20 minutes	53.0%	75.8%	56.9%	73.6%	63.0%	69.8%
30 minutes	70.5%	90.9%	71.8%	87.2%	76.3%	86.7%

Case mix Academic Hospital



Results after simulation

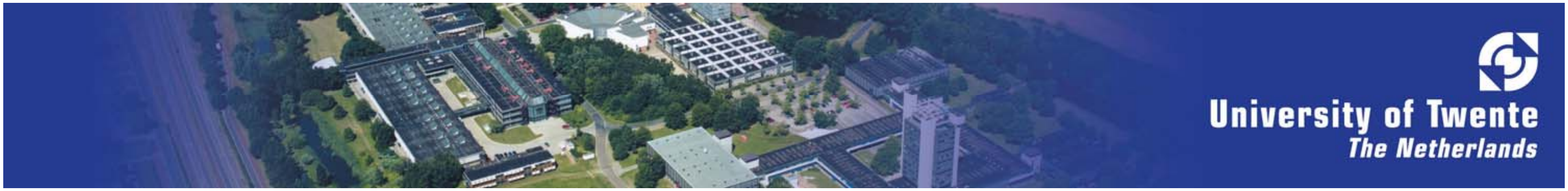
"Emergency surgery in elective program" instead of "emergency ORs" yields:

- Improved OR utilisation (3.1%)
- Less overtime (21%)

Break-in-moment optimisation yields:

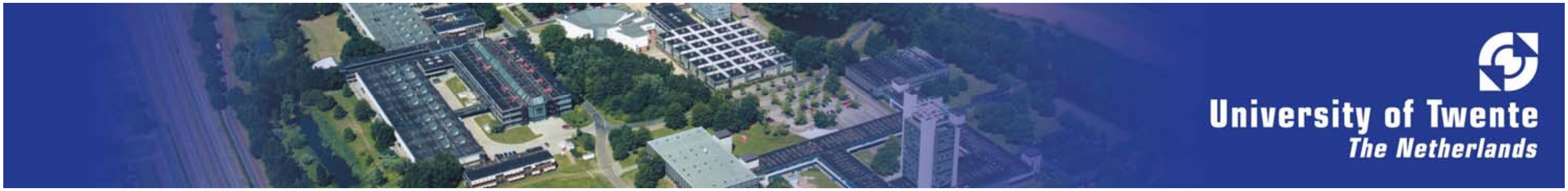
- Reduced waiting time for emergency surgery, especially for the first arrival

  (patients helped within 10 minutes: from 28.8% → 48.6%)



OK Management Game

- T.b.v. Master Industrial Engineering & Management
- Studenten zijn “virtuele OK managers”
- Management game in 4 ronden:
  - Strategisch management
  - Tactisch management
  - Operationeel management
  - Benchmarking
- Paper in special issue van INFORMS Transactions On Education



Voorbeelden van recente/nieuwe projecten

- Capaciteitsmanagement van radiologiemodaliteiten (AMC, NKI/AVL)
- Capaciteitsplanning van polikliniek van nieuwe Deventer Ziekenhuis
- Follow-up afspraken na mamma care (MST Enschede)
- OK Benchmarking Project (NFU)
- Procesoptimalisatie SEH (AMC, Isala klinieken)
- Optimalisatie instrumentennetten OK (Isala kl., AMC)
- STW LogiDOC: Optimalisatie van zorgpaden, patiëntstromen

Vragen…?

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