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Planning and Scheduling of Semi-Urgent Surgeries

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Background

- Surgical department

- Three surgery types:
  → Elective (planned in advance)
  → Urgent (within 24 hours)
  → Semi-urgent (within 1 or 2 weeks)

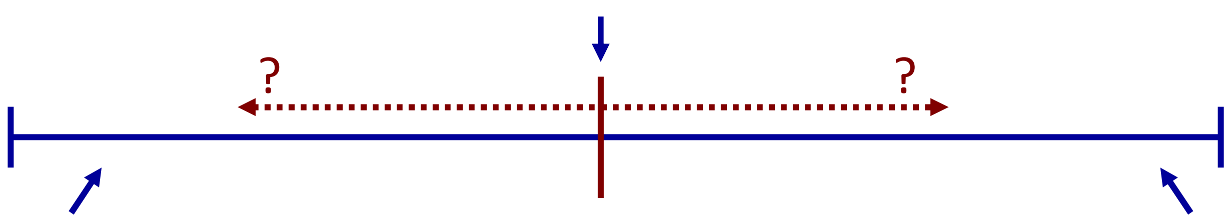
- Consider regularly scheduled hours

Motivation

- (Semi-)Urgent surgeries pose uncertain demand on resources

- Urgent surgeries usually performed in overtime or at separate OR
  → Not taken into account

- Semi-urgent surgeries may not be performed in overtime
  → Allocate part of regular OR hours to these surgeries



Contents of this Talk

- Determine optimal amount of OR time to allocate to semi-urgent surgeries
  → Queuing model

- Determine when semi-urgent surgeries should be scheduled
  → Markov decision model

Case Study - Introduction

- Case to illustrate working of models
- Actual data obtained at Leiden University Medical Center
- Neurosurgery department
- 8 OR sessions per week
- 40% of all incoming surgeries is classified semi-urgent

Queuing Model

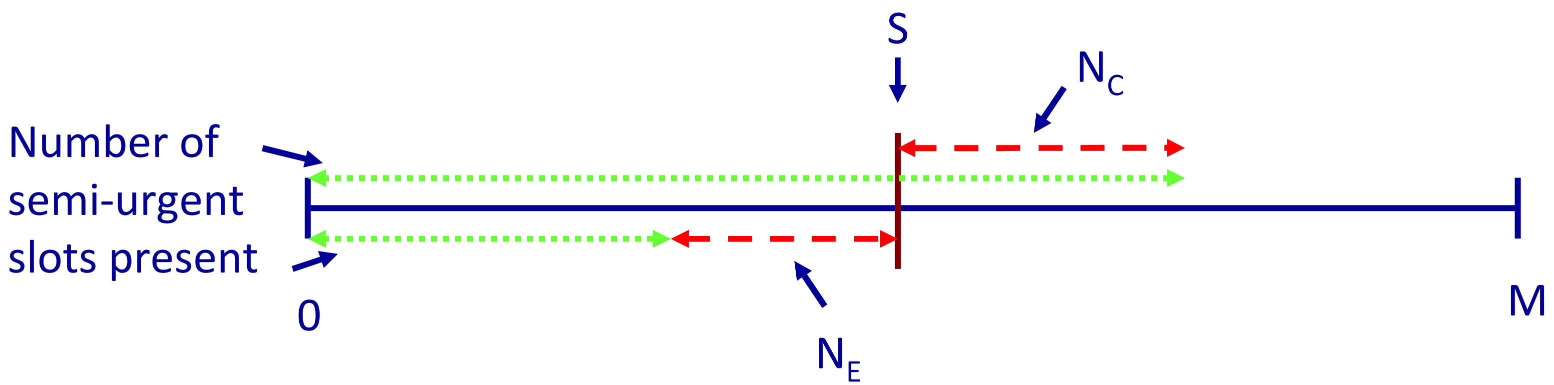
- Determine optimal amount of OR time to allocate to semi-urgent surgeries
- Each semi-urgent surgery has estimated duration 1,2,..,K slots
- Model semi-urgent slot arrivals as a compound Poisson process
- Each OR session has duration K slots
- Total number of slots available (M) = # OR sessions * K

Queuing Model

- Total number of slots available (M) = # OR sessions * K
- Allocate fraction (S) of M to semi-urgent slots
- Slotted queuing model in discrete time

Queuing Model

- Note that
  - → # of canceled elective slots (N_C) depends on S
  - → # of empty OR slots (N_E) depends on S



Queuing Model

- Note that
  - → # of canceled elective slots (N_C) depends on S
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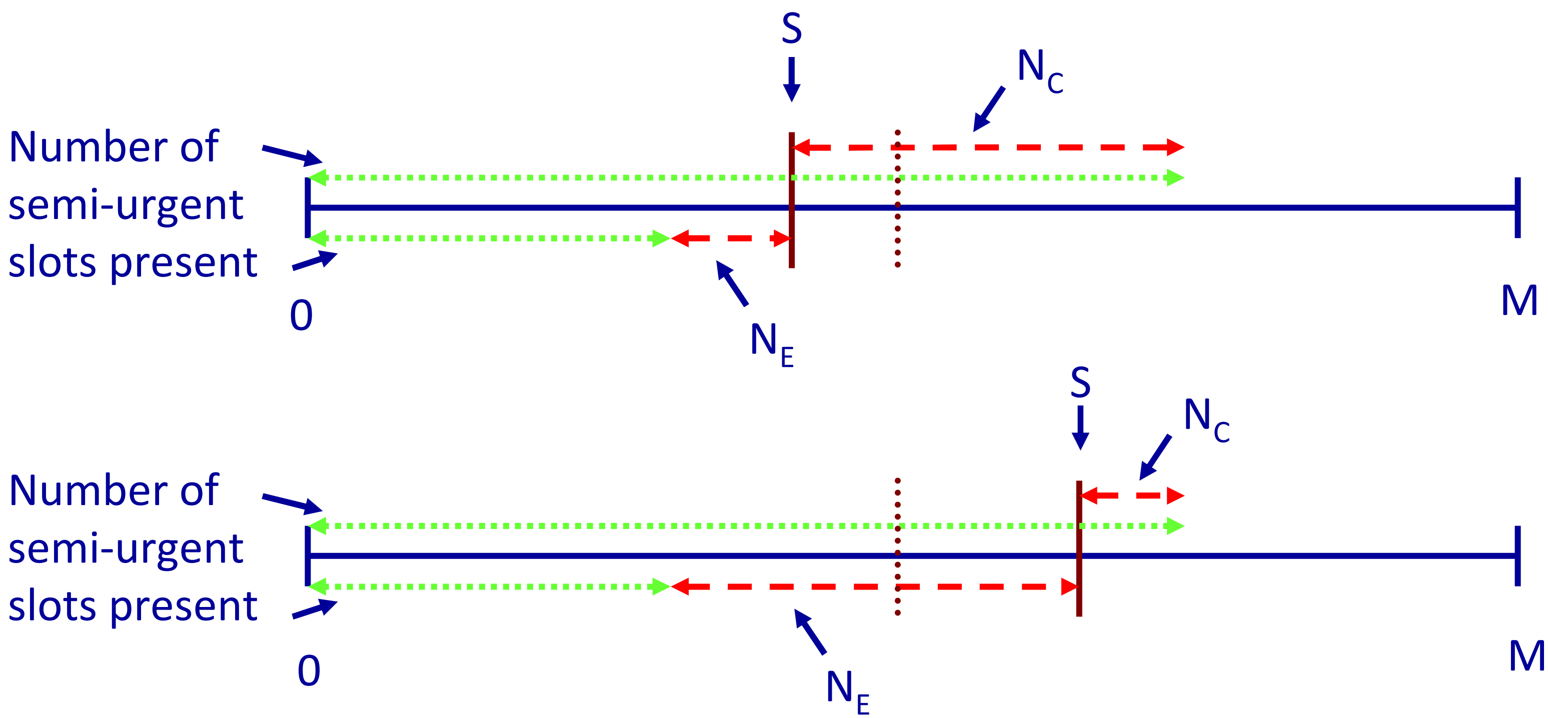


Queuing Model

- Use queuing model to determine $E[N_C]$ and $E[N_E]$ for each S
- Assign cost C_C to canceled elective slot
- Assign cost C_E to empty OR slot
- Find S* that miminizes expected total cost:

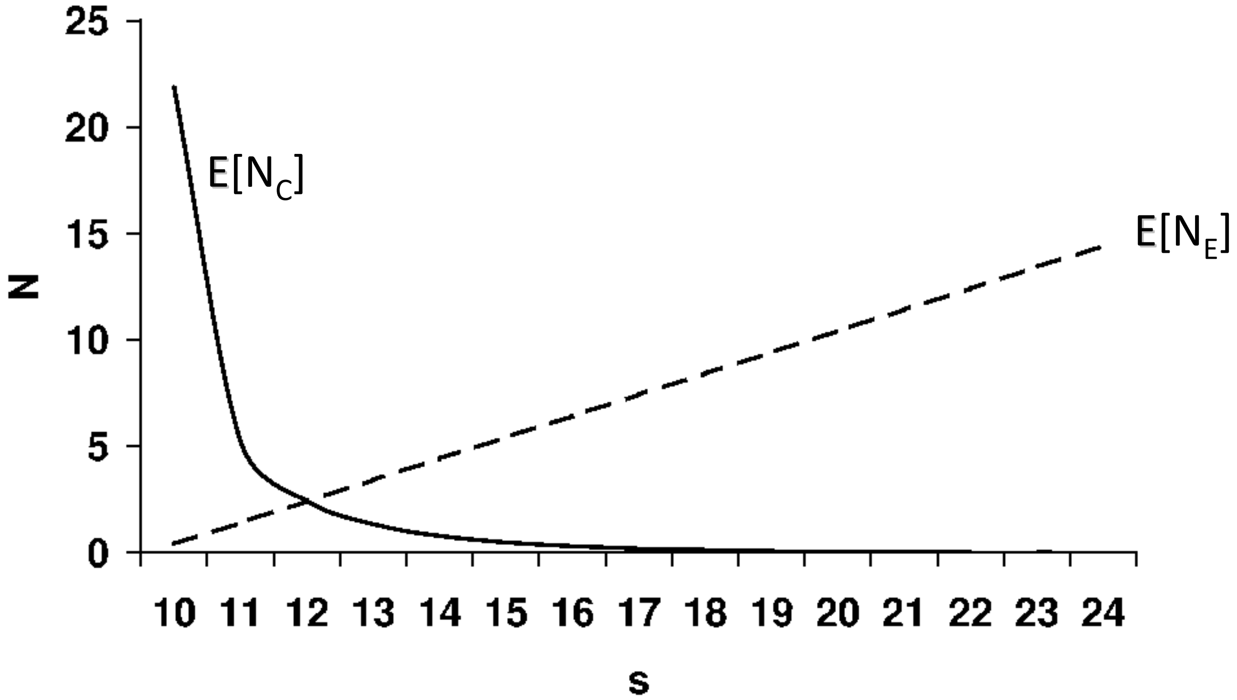
$$E[C_T] = E[N_C]*C_C + E[N_E]*C_E$$

- S* is the optimal number of slots to allocate to semi-urgent surgeries, *given C_C and C_E*

Case Study – Queuing Model

- Apply model to case study of neurosurgery department
- Total number of slots available (M) = 8*3 = 24
- On average 5.5 semi-urgent surgeries arrive per week
- P(1 slot surgery) = 0.53
- P(2 slot surgery) = 0.20
- P(3 slot surgery) = 0.27
- S_{min} = expected number of semi-urgent slot arrivals = 9.6
  → Allocate at least 10 slots to obtain a stable system

Case Study – Queuing Model



Case Study – Queuing Model

- Optimal value of S^* depends on choice of C_C and C_E
- If $(C_C , C_E) = (1, 1)$
  → $S^* = 13$ ($E[C_T] = 4.77$)
- If $(C_C , C_E) = (1, 10)$
  → $S^* = 11$ ($E[C_T] = 19.42$)
- If $(C_C , C_E) = (10, 1)$
  → $S^* = 17$ ($E[CT] = 9.45$)
- Note that $S^* > S_{min}$ in all cases!

Markov Decision Model

- Two types of semi-urgent surgeries:
  → Surgery within one week
  → Surgery within two weeks

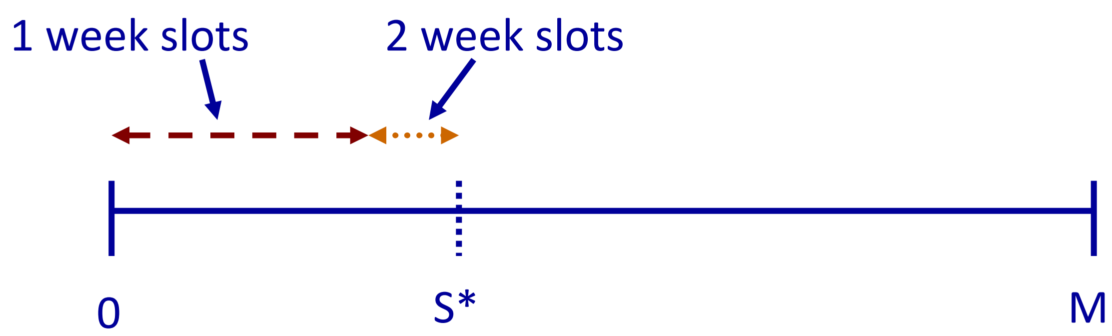
- Schedule one-week semi-urgent surgeries this week

- Two-week semi-urgent surgeries can be postponed one week

- When to schedule two-week semi-urgent surgeries?

Markov Decision Model

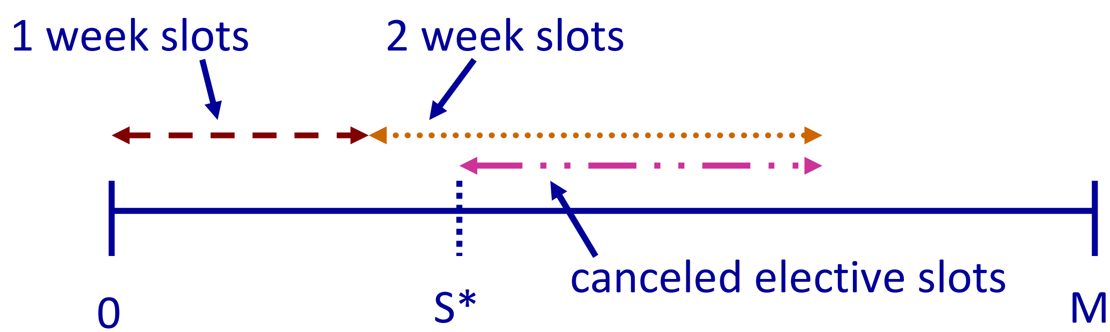
- Continue with slotted approach
- Schedule up to S*?



Markov Decision Model

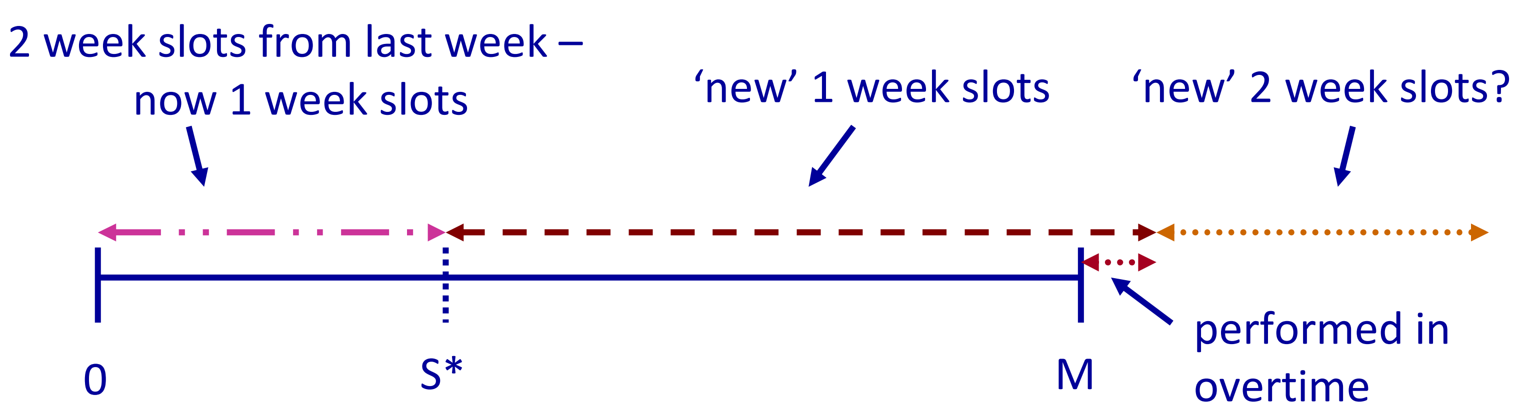
- Or more?

- Drawback: canceling of elective slots



Markov Decision Model

- Then just up to S*?
- Risk of postponement: one-week semi-urgent surgeries performed in overtime



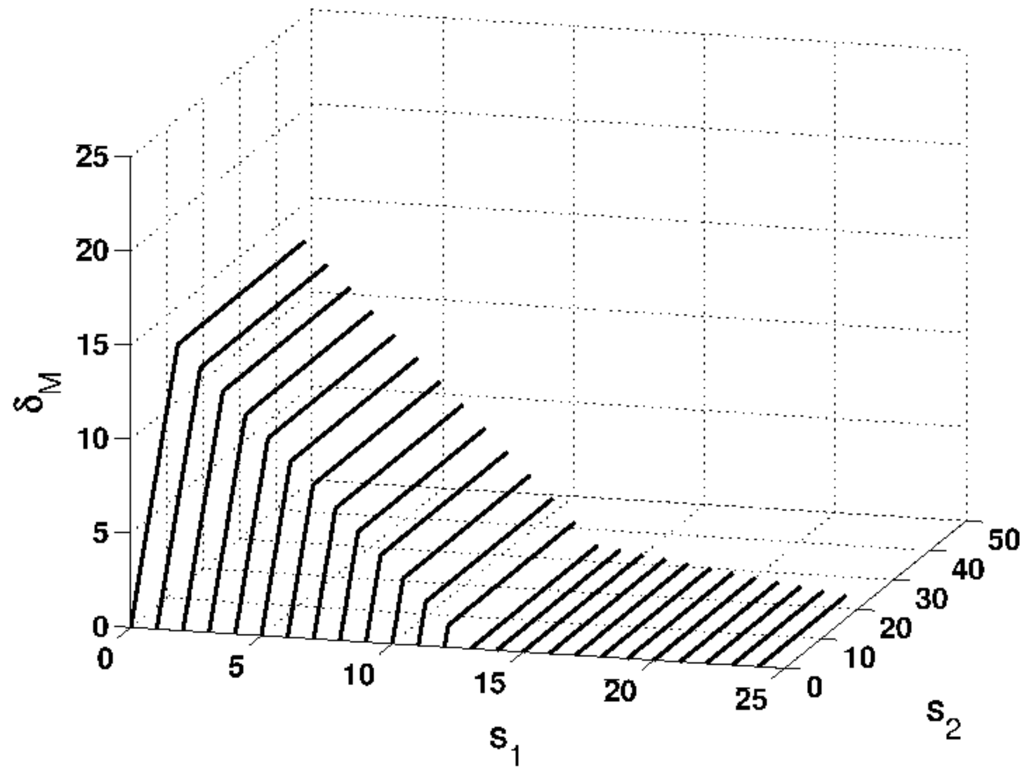
Markov Decision Model

- Develop Markov Decision Model
- Determine for each state (combination of number of one- and two-week semi-urgent slots waiting) an action (how many two-week slots to plan this week)
- Use costs and related S* calculated in queuing model
- Introduce additional costs for overflow of semi-urgent slots
- Minimize expected total discounted costs

Case Study - Markov Decision Model

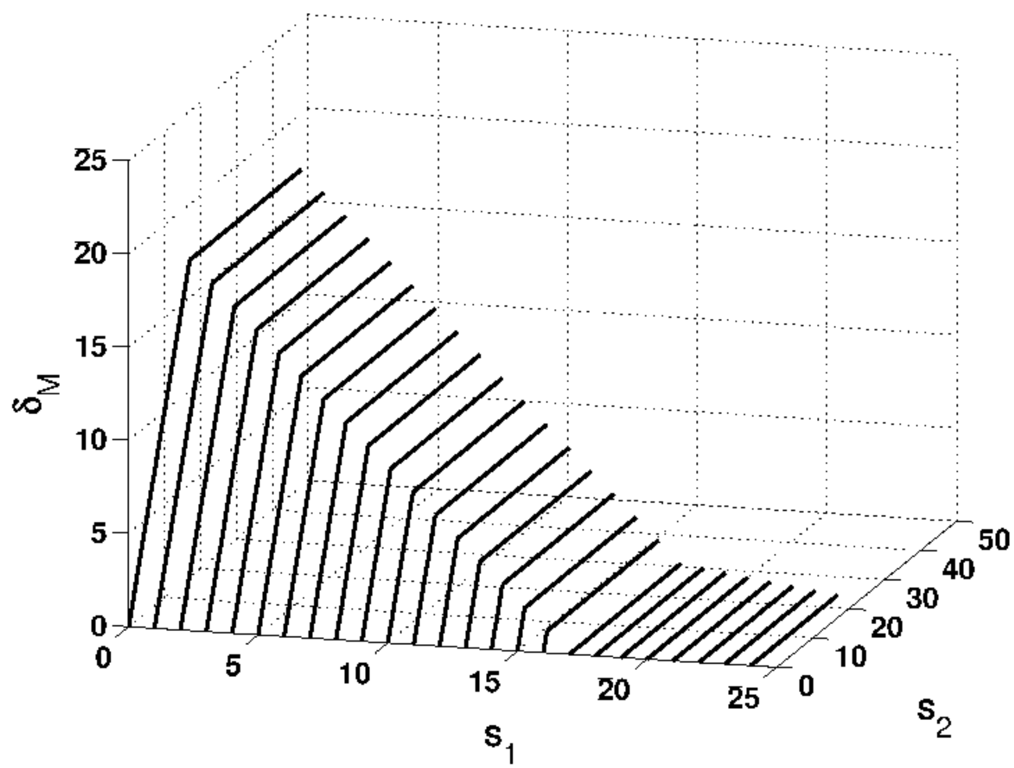
- Trivial problem?
- More than 1000 states for neurosurgery case study!
- Consider $(C_C , C_E) = (1, 1); (1, 10); (10, 1)$
- Graphic representation of strategies

Case Study – Markov Decision Model



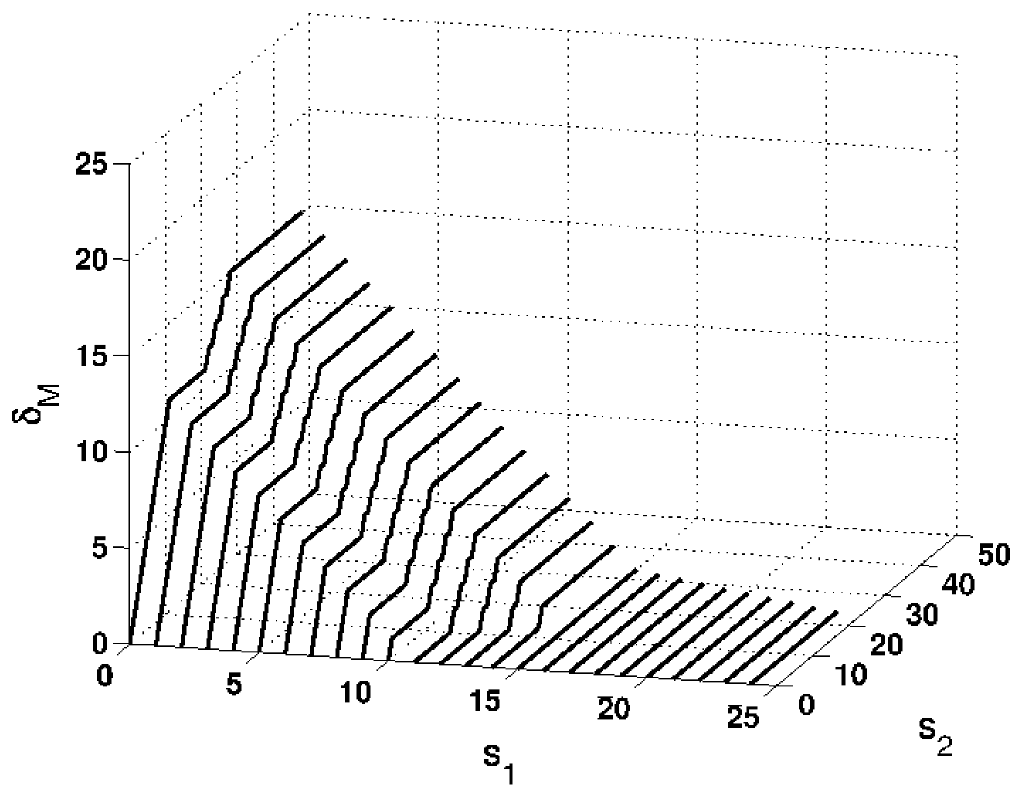
S* = 13

Case Study – Markov Decision Model



S* = 17

Case Study – Markov Decision Model



S* = 11

Conclusion

- Determine with queuing model how much OR time should be allocated to semi-urgent surgeries
  - → Optimal solution depends highly on costs
  - → Dangerous to focus only on average behavior

- Use Markov decision model to decide upon actual scheduling
  - → Simplifies scheduling job

Questions?

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ORchestra Bibliography

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