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Capacity Planning and Scheduling for Semi-Urgent Surgeries at a Neurosurgery Department

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Background

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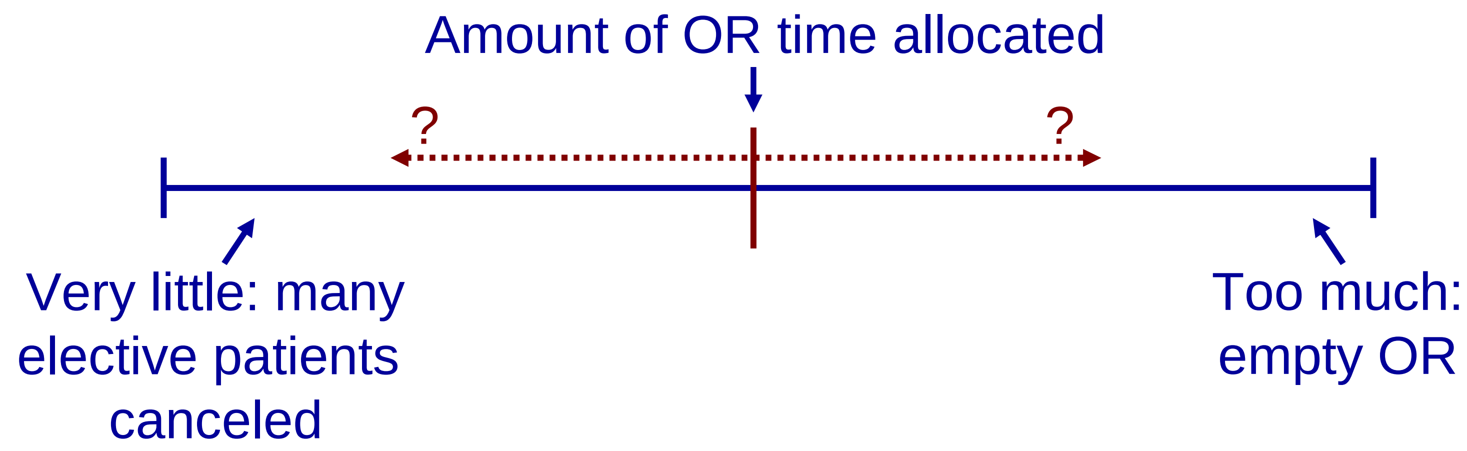
- Surgical department
- Three surgery types:
  - → Elective
  - → Urgent
  - → Semi-urgent
- Urgent: within 24 hours
- Semi-urgent: within one or two weeks
- Consider only regular opening hours of OR complex

Motivation

- (Semi-)Urgent surgeries pose an uncertain demand on resources
- Urgent surgeries usually performed in overtime or at separate OR
  → do not take into account here
- Semi-urgent surgeries may not be performed in overtime
  → allocate part of regular OR time to semi-urgent surgeries



- Focus research on capacity allocation and planning for semi-urgent surgeries

Case - Introduction

- Case to illustrate modeling approach
- Neurosurgery department
- 8 OR sessions per week
- 40% of all incoming surgeries is classified semi-urgent

- Question 1: how much OR time should the neurosurgery department allocate to semi-urgent surgeries?

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OR Capacity Planning (I)

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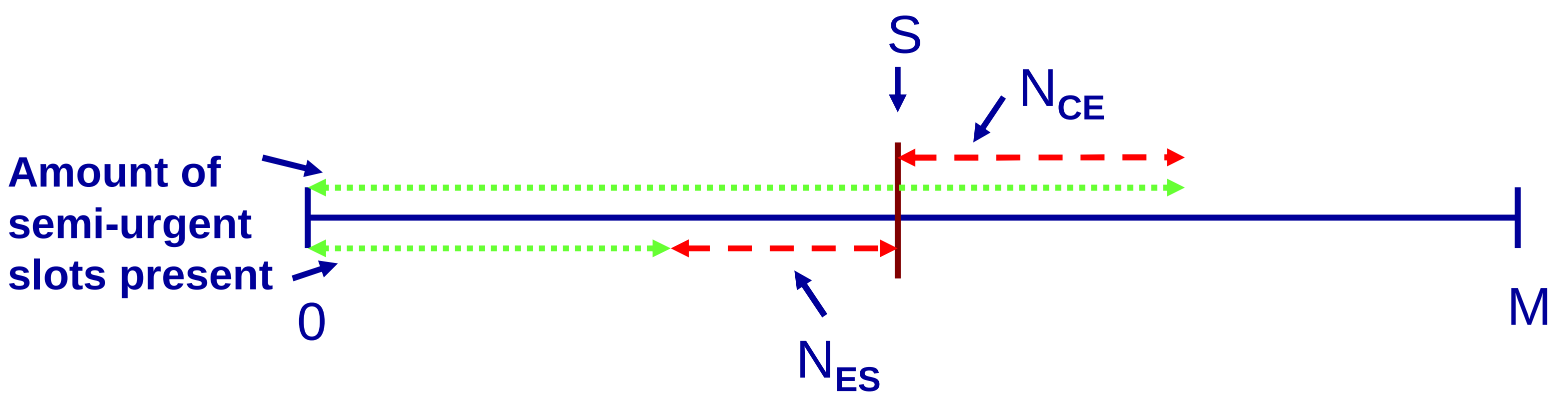
- Slotted approach
- Each OR session has a duration of 3 slots
- Expected surgery duration is either 1, 2, or 3 slots
- Total # of slots available (M) = # of OR sessions x 3
- Allocate fraction (S) of M to semi-urgent slots

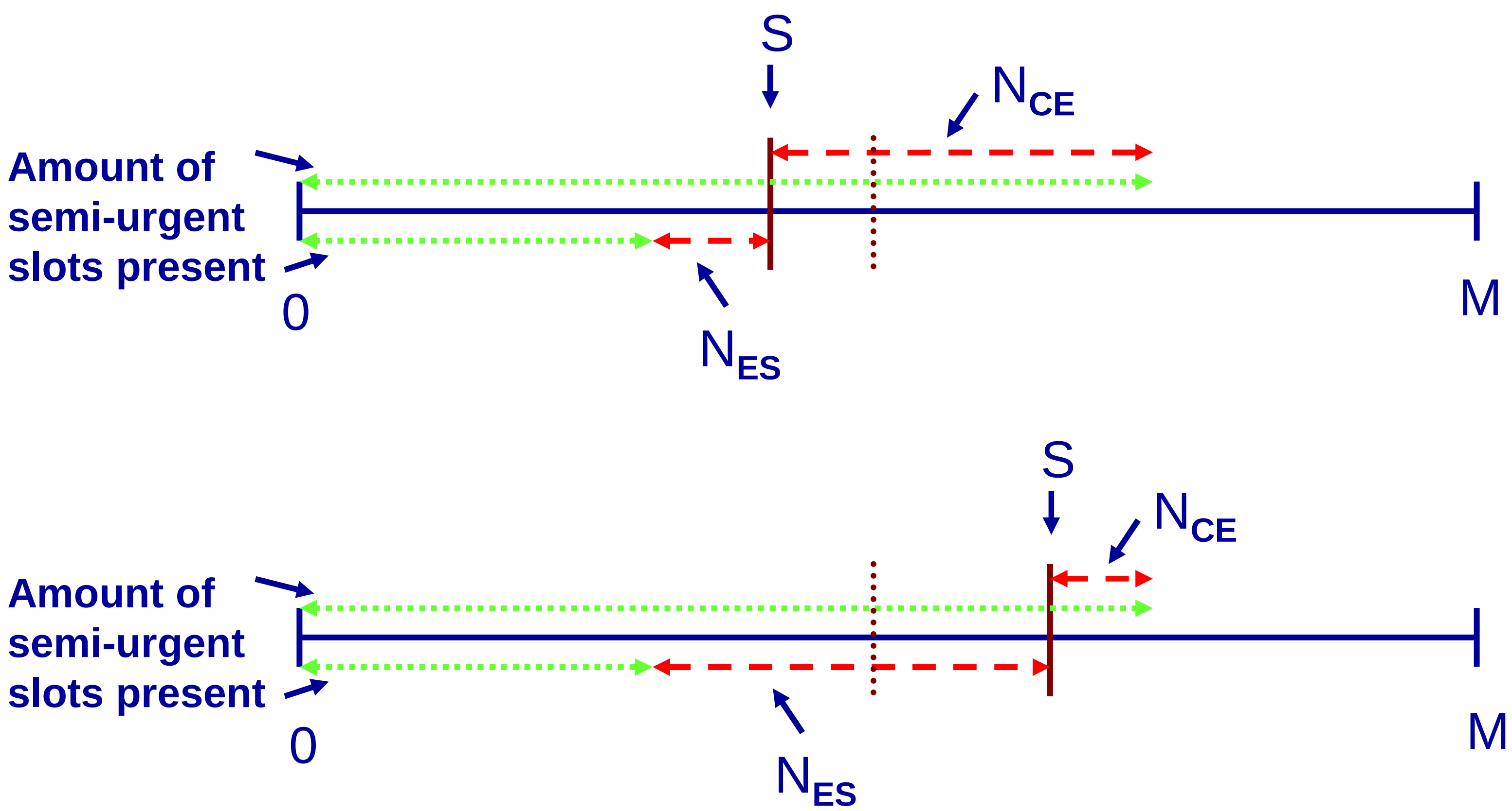
OR Capacity Planning (II)

- Note that
  - → # of canceled elective slots (N_{CE}) depends on S
  - → # of empty OR slots (N_{ES}) depends on S

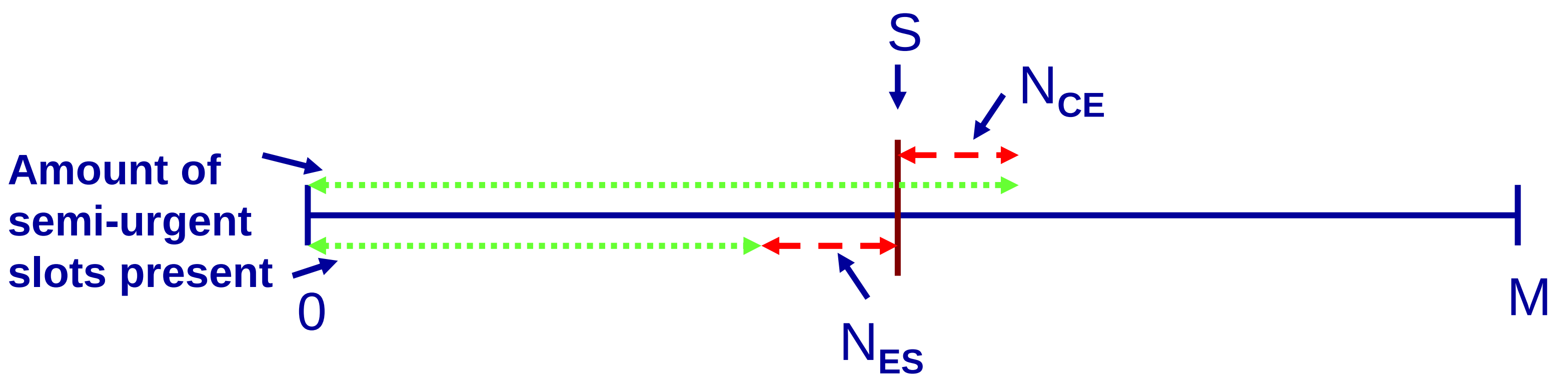


OR Capacity Planning (III)

- Note that
  → # of canceled elective slots (N_{CE}) depends on S
  → # of empty OR slots (N_{ES}) depends on S



OR Capacity Planning (IV)



- Use slotted queuing model to determine $E[N_{CE}]$ and $E[N_{ES}]$ for each S
- Assign cost C_{CE} to 1 canceled elective slot
- Assign cost C_{ES} to 1 empty OR slot

OR Capacity Planning (V)

- Find S* that minimizes Expected Total Cost:
  $E[C_T] = E[N_{CE}]*C_{CE} + E[N_{ES}]*C_{ES}$

- S* is the optimal number of slots to allocate to semi-urgent surgeries, *given* C_{CE} *and* C_{ES}

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Case – Capacity Planning (I)

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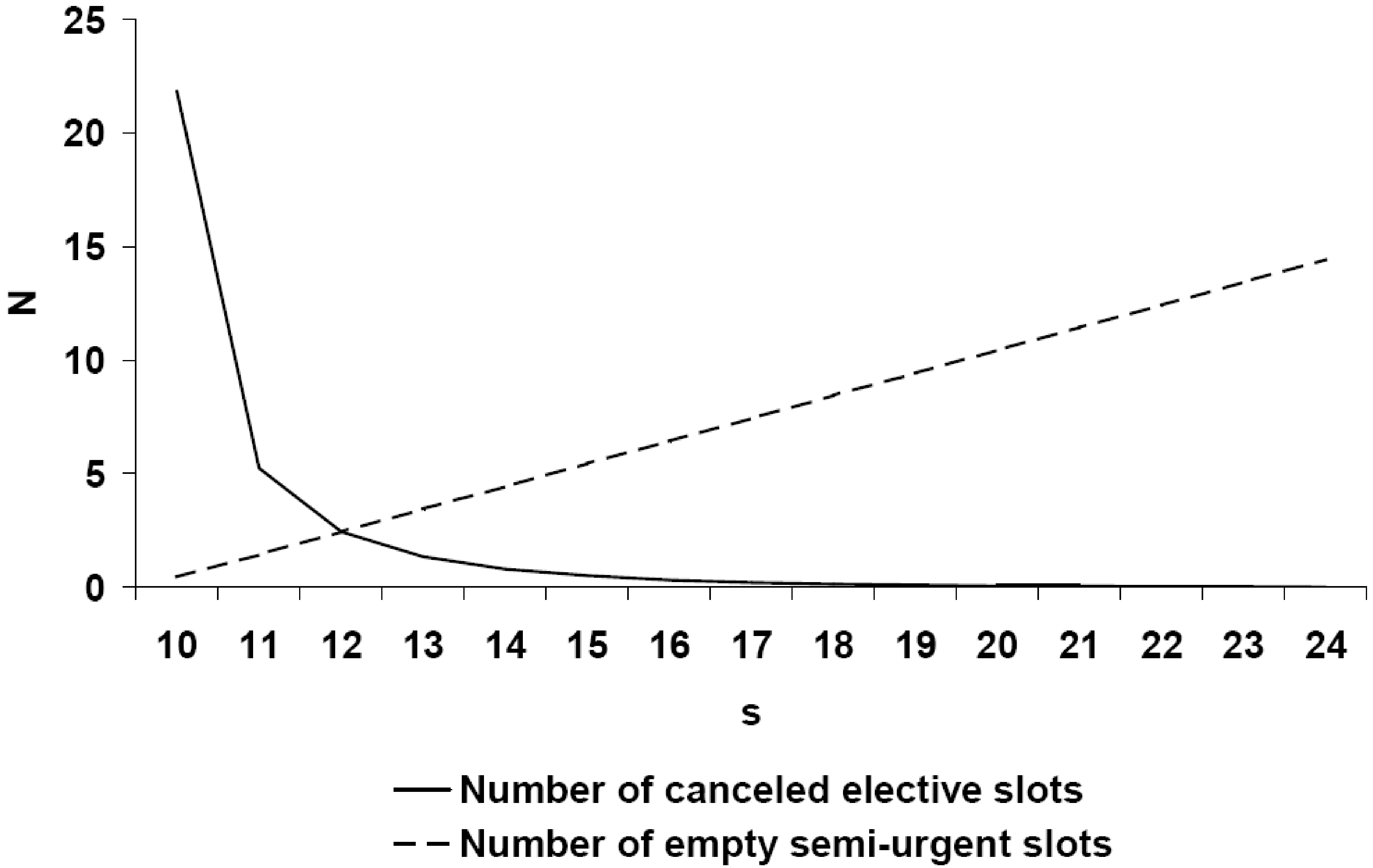
- Total # of slots available (M) = 8 x 3 = 24
- On average 5.5 semi-urgent surgeries arrive each week

- P(1 slot surgery) = 53%
- P(2 slot surgery) = 20%
- P(3 slot surgery) = 27%

- S_{min} = expected # of semi-urgent slot arrivals = 9.6 slots
  → at least 10 slots required for stability

Case – Capacity Planning (II)



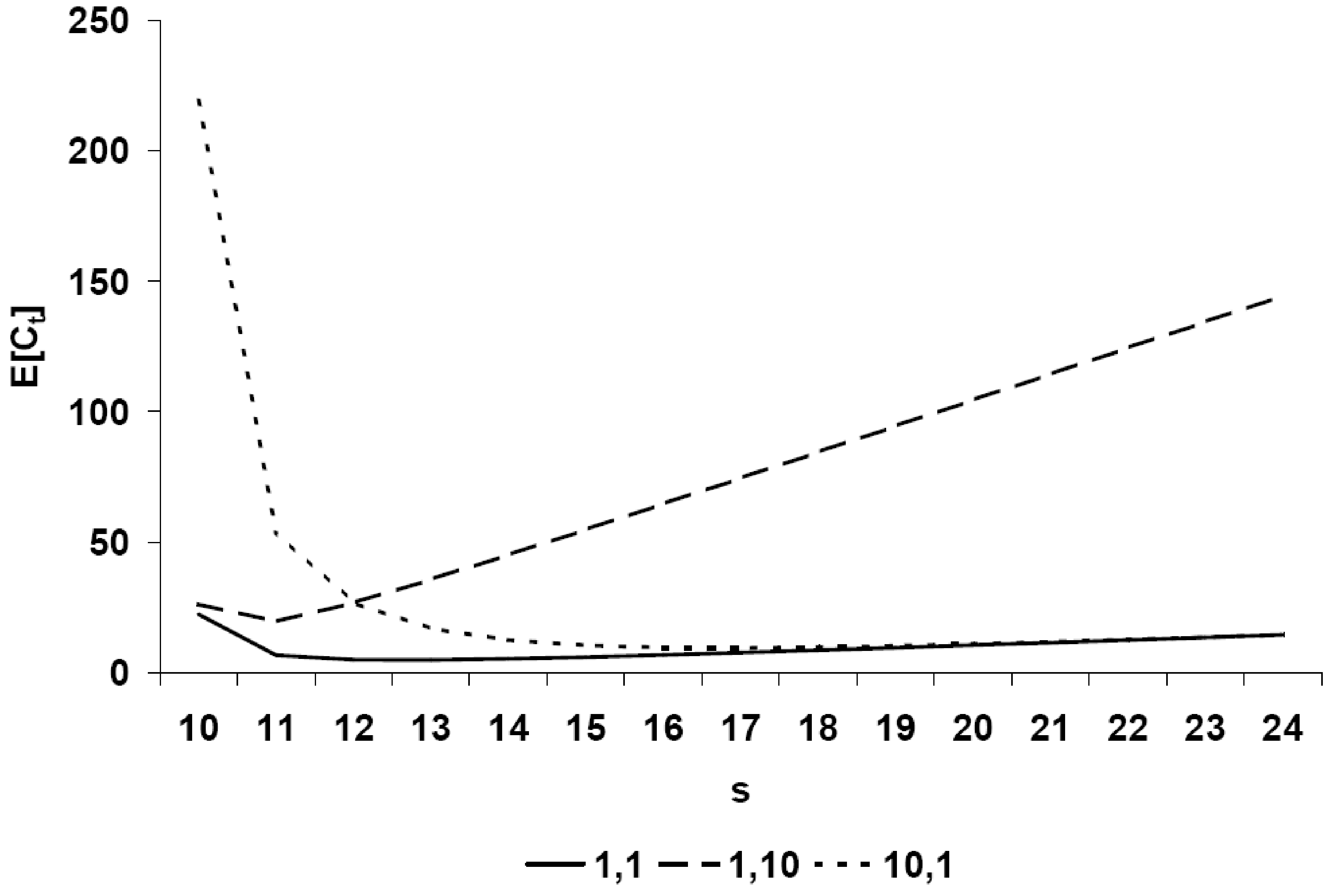
Case – Capacity Planning (III)

- Note that value of optimal S* depends on choice for C_{CE} and C_{ES}

- For CC_1: $C_{CE} = 1$, $C_{ES} = 1$
  → S* = 13
- For CC_2: $C_{CE} = 1$, $C_{ES} = 10$
  → S* = 11
- For CC_3: $C_{CE} = 10$, $C_{ES} = 1$
  → S* = 17

- Note that $S^* > S_{min}$ in all cases!

Case – Capacity Planning (IV)



OR Scheduling (I)

- We now have determined the amount of OR time to dedicate to semi-urgent surgeries (S*)
- Two types of semi-urgent surgeries:
  → within one week
  → within two weeks
- Schedule one week semi-urgent surgeries this week
- Two week semi-urgent surgeries can be postponed for one week
- Question 2: Now that we know S*, when should we schedule two week semi-urgent surgeries?

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OR Scheduling (II)

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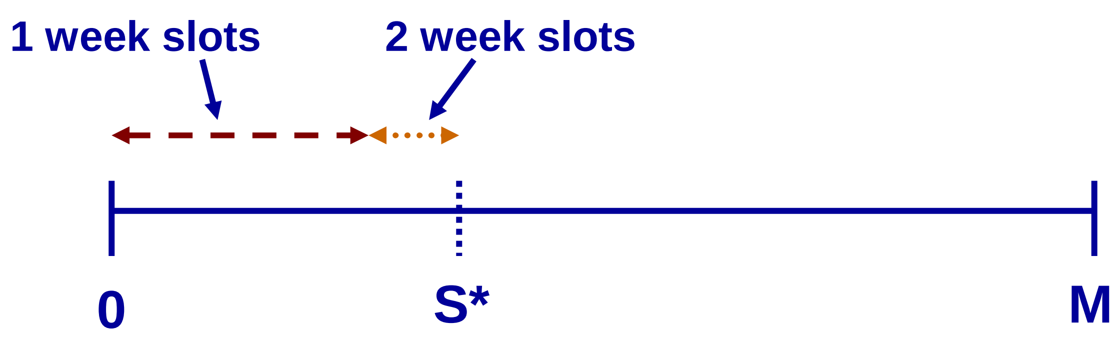
- Question 2: Now that we know S*, when should we schedule two week semi-urgent surgeries?

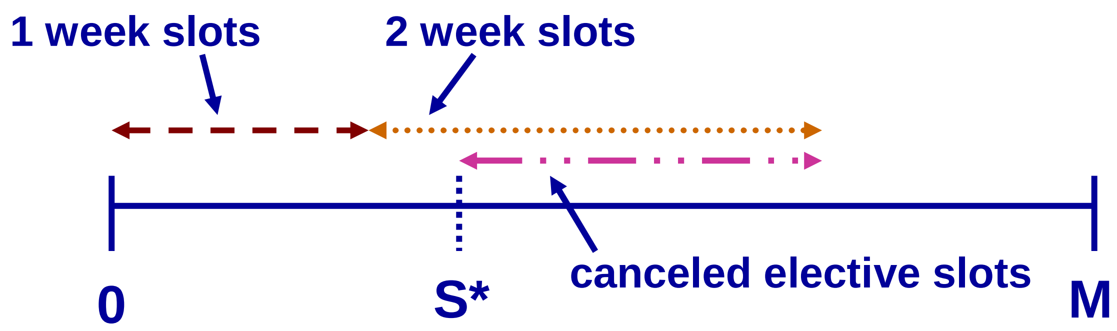
- Only up to S*?



OR Scheduling (III)

- Question 2: Now that we know S*, when should we schedule two week semi-urgent surgeries?

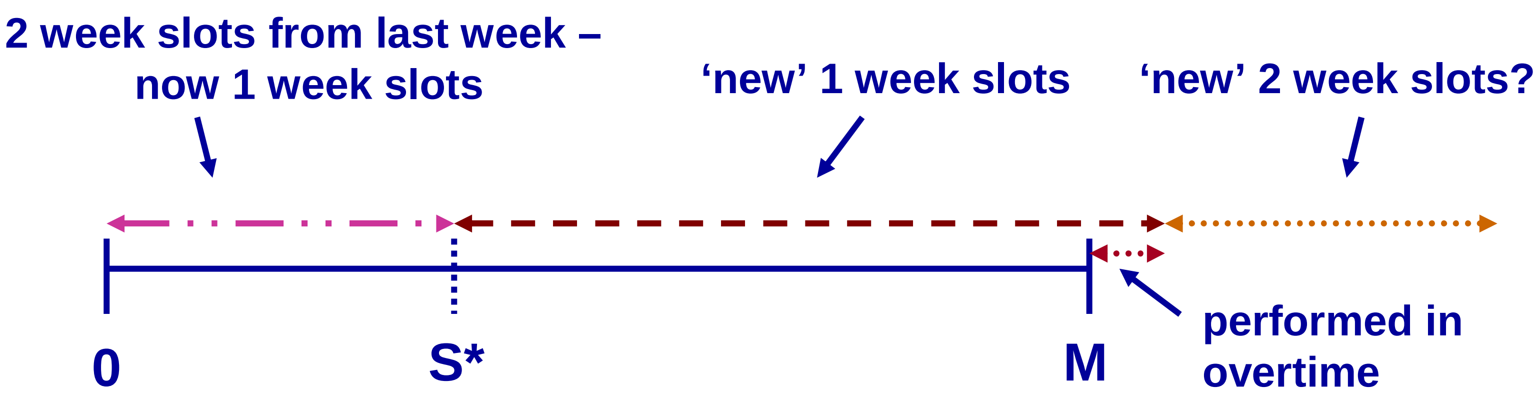
- Or more?
- Drawback: canceling of elective slots



OR Scheduling (IV)

- Question 2: Now that we know S*, when should we schedule two week semi-urgent surgeries?

- Risk of postponement: 1 week surgeries in overtime



OR Scheduling (V)

- Develop Markov decision model
- Determine for each state (possible combination of one and two week slots present) an action (how many two week slots to plan this week)
- Use S* calculated with queuing model
- Introduce additional costs for overflow of semi-urgent slots
- Minimize expected total discounted costs

Case – OR Scheduling (I)

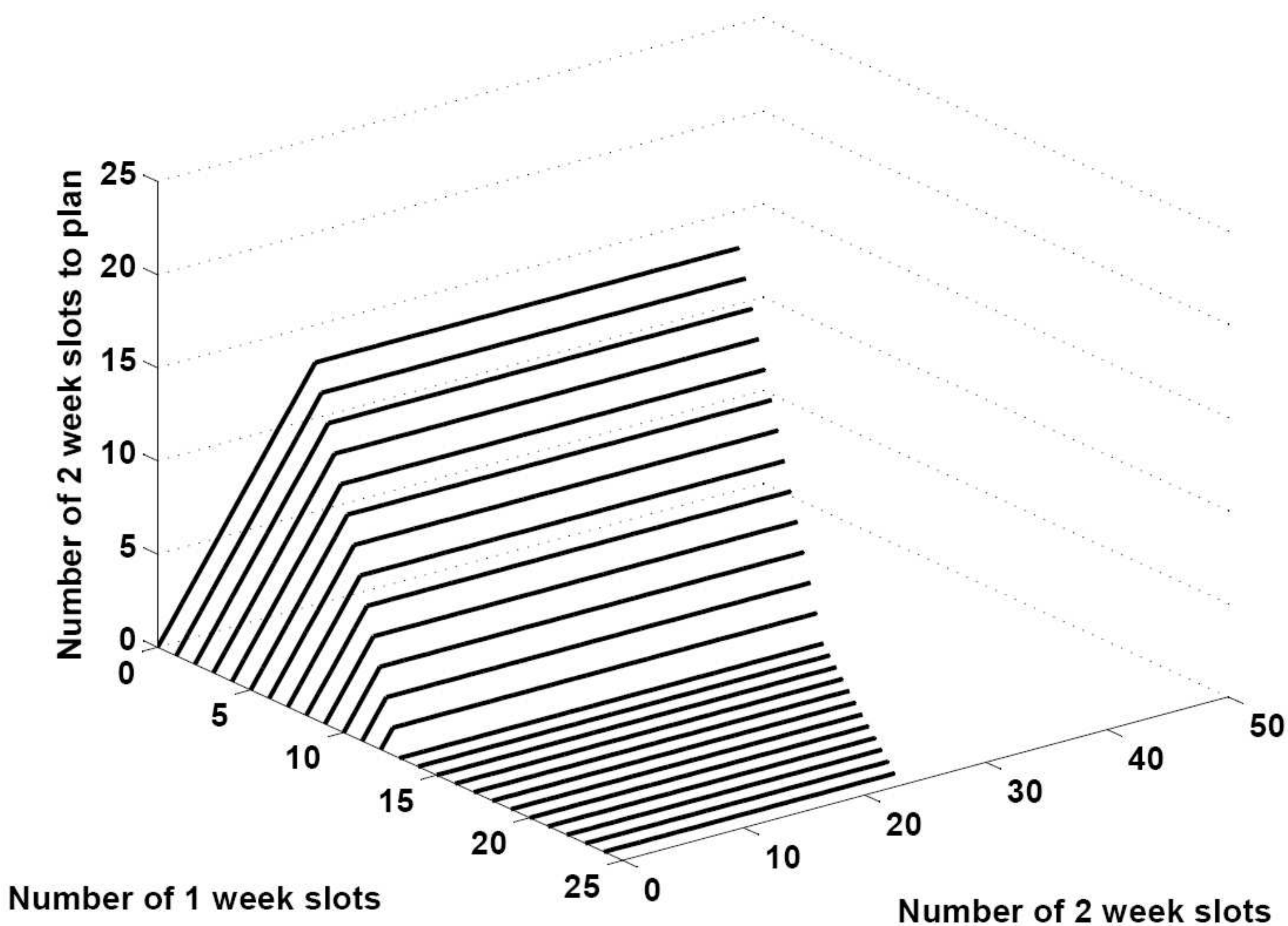
- Trivial problem?
- More than 1000 states for our case!
- Simplifies scheduling job

- Consider S* = 13, S* = 11, S* = 17
  (optimal S for CC_1, CC_2 and CC_3)

- Graphic representation of strategies

Case – OR Scheduling (II)

- S* = 13



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Case – OR Scheduling (III)

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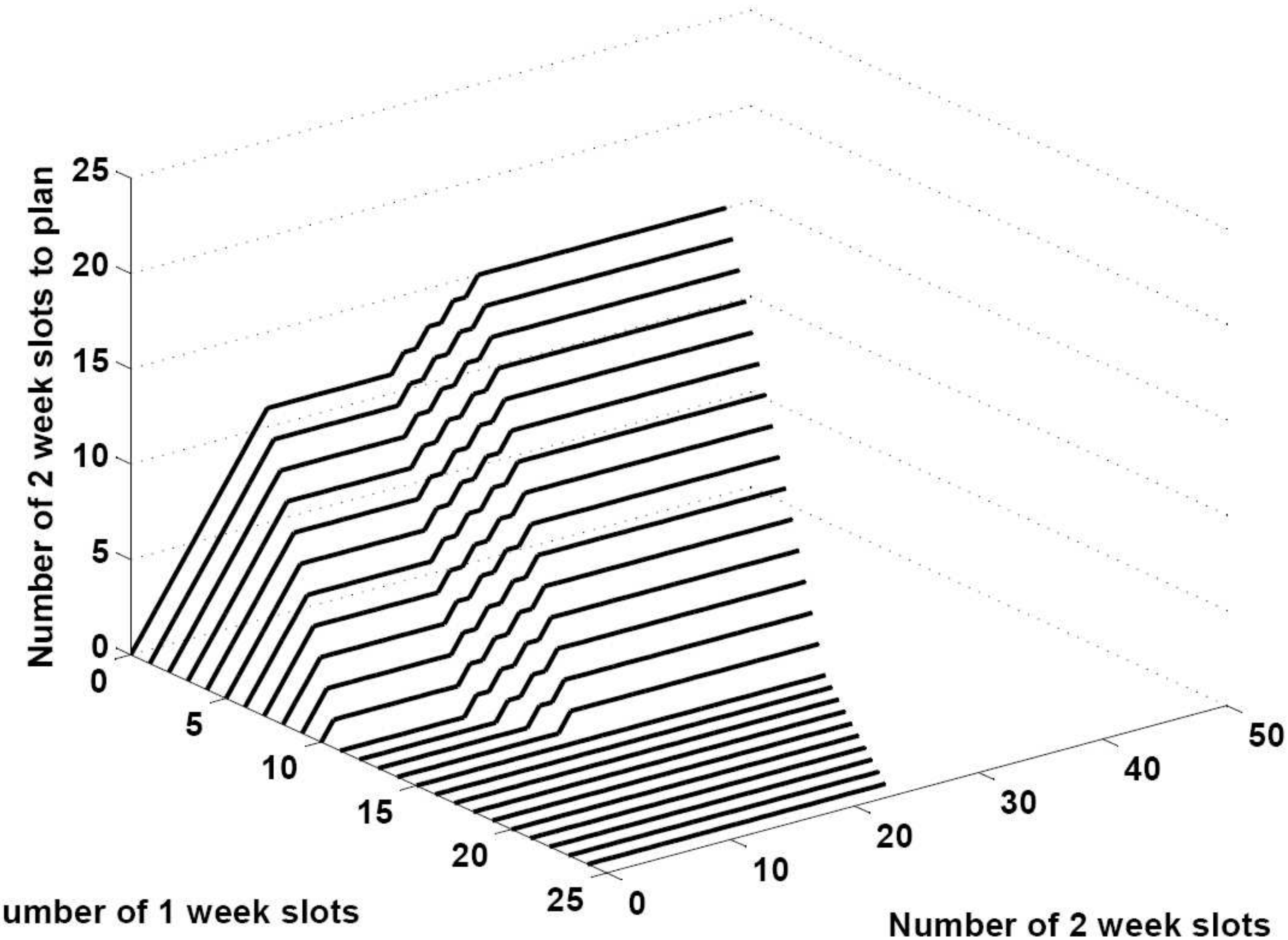
- S* = 11



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Case – OR Scheduling (IV)

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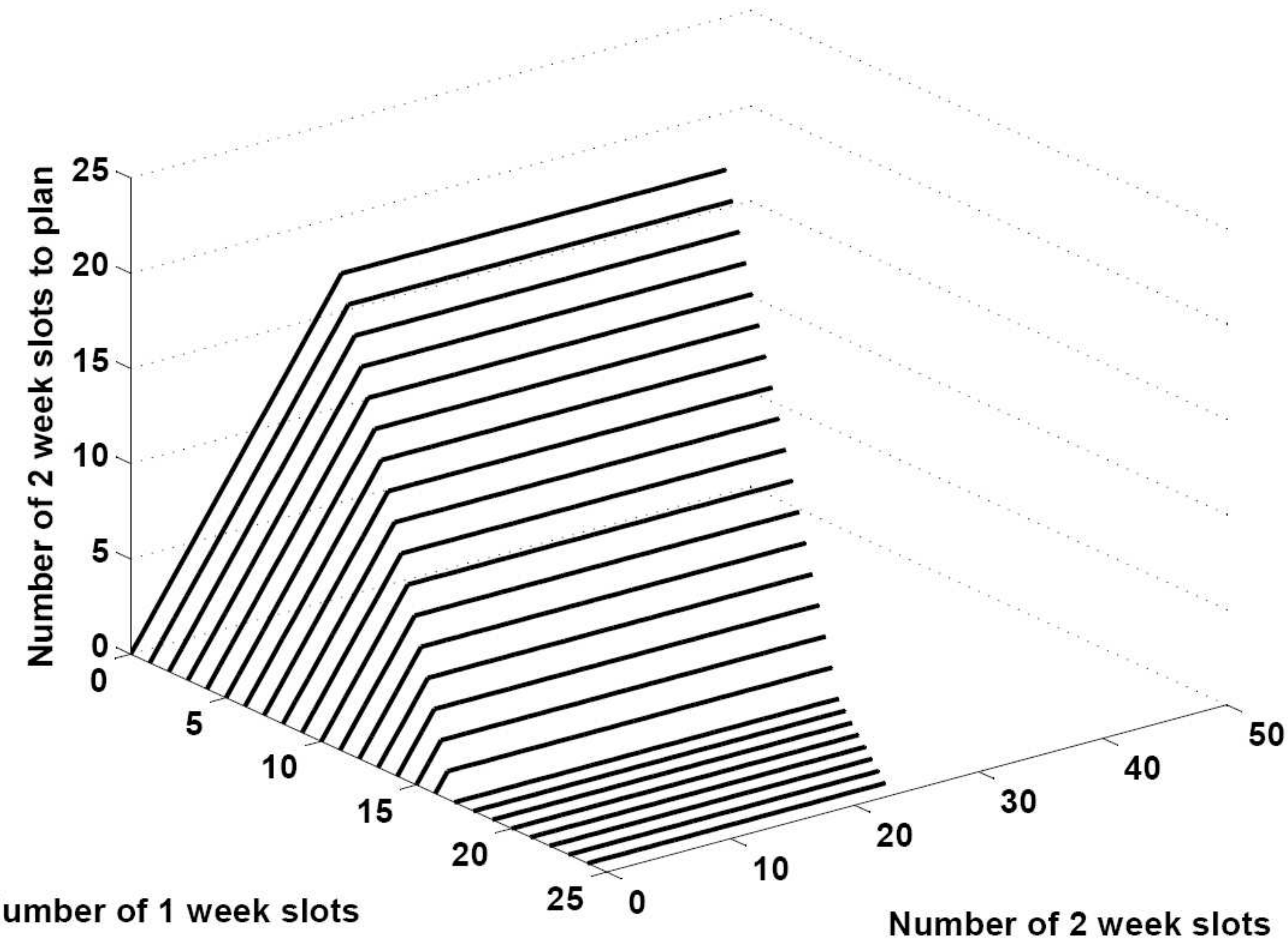
- S* = 17



Conclusion

- Use queuing model to determine amount of OR time to allocate to semi-urgent surgeries
  → dangerous to focus only on average behavior
- Use Markov decision model to decide upon actual scheduling
  → simplifies scheduling job
- Mathematical modeling approach allows for numerical comparison of alternative solutions

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Questions?