A Markov model for measuring service levels in non-stationary *G(t)/G(t)/s(t)+G(t)* queues

Stefan Creemers (IESEG)

Mieke Defraeye (KU Leuven)

Inneke Van Nieuwenhuyse (KU Leuven)

IÉSEG SCHOOL OF MANAGEMENT

KATHOLIEKE UNIVERSITEIT LEUVEN

Creemers S., Defraeye M. & Van Nieuwenhuyse I. (2013). The optimal allocation of server time slots over different classes of patients. KU Leuven working paper KBI 1306.

Creemers S., Defraeye M. & Van Nieuwenhuyse I. (conditional accept). The optimal allocation of server time slots over different classes of patients. KU Leuven Performance Evaluation.

Creem & Van Nieuwenhuyse I. (2013). ation of server time slots over differen ts. KU Leuven working paper KBI 1

Creemers S. & Van Nieuwenhuyse accept). T llocation of server time different c patients. KU Leuven Per Evaluation.

The optimal allocation of server time slots over different classes of patients

Stefan Creemers (IESEG)

Jeroen Beliën (HUB)

Marc Lambrecht (KU Leuven)

IÉSEG SCHOOL OF MANAGEMENT

HUB

KATHOLIEKE UNIVERSITEIT LEUVEN

HOSPITAL

HOSPITAL

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

HOSPITAL

ORTHOPEDIC SURGERY

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

HOSPITAL

ORTHOPEDIC SURGERY

DENTAL SURGERY

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

HOSPITAL

ORTHOPEDIC SURGERY

DENTAL SURGERY

NEUROLOGICAL SURGERY

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

HOSPITAL

ORTHOPEDIC SURGERY

DENTAL SURGERY

NEUROLOGICAL SURGERY

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

HOSPITAL

ORTHOPEDIC SURGERY

DENTAL SURGERY

NEUROLOGICAL SURGERY

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

HOSPITAL

ORTHOPEDIC SURGERY

DENTAL SURGERY

NEUROLOGICAL SURGERY

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

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HOSPITAL

ORTHOPEDIC SURGERY

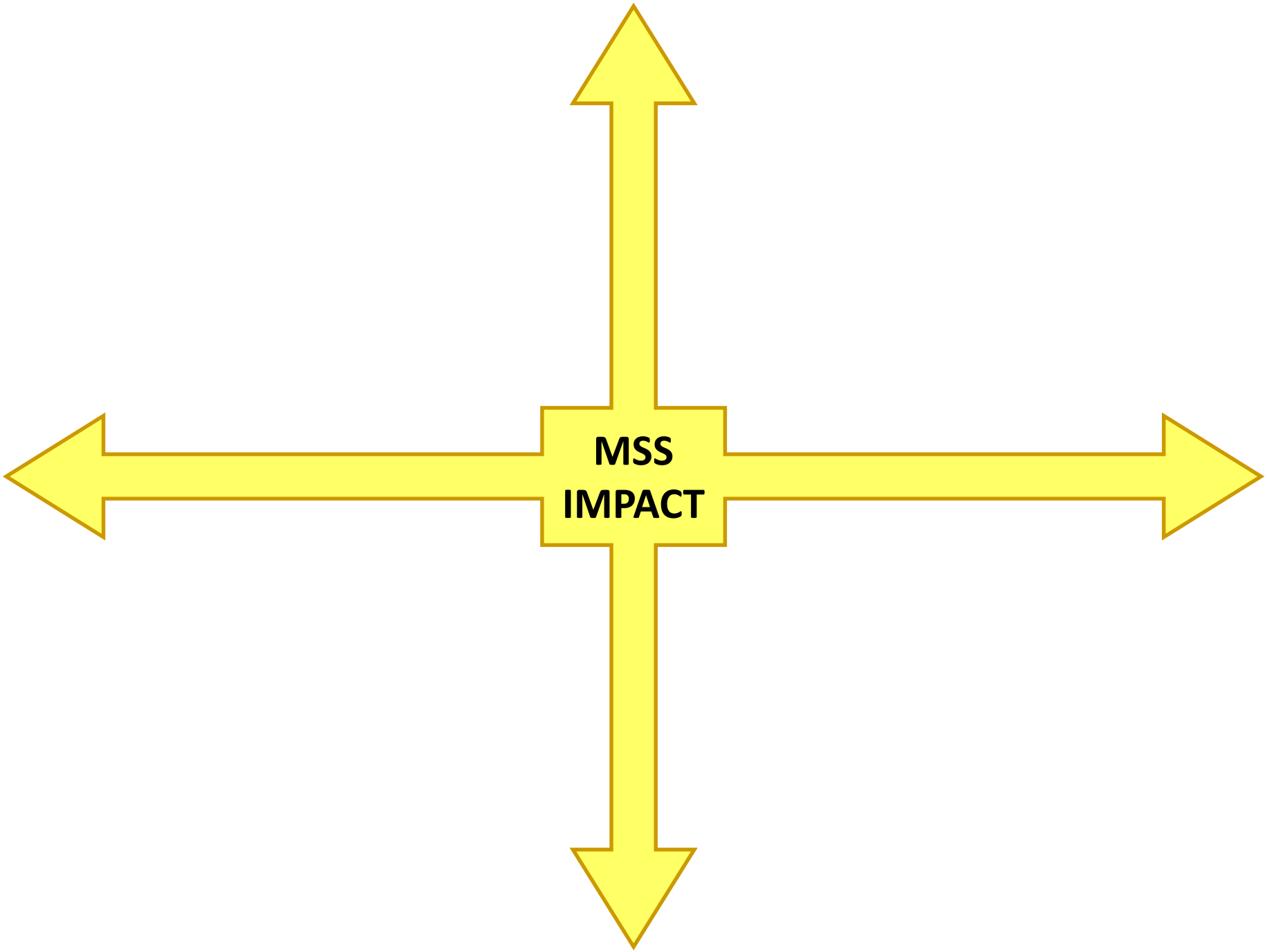
DENTAL SURGERY

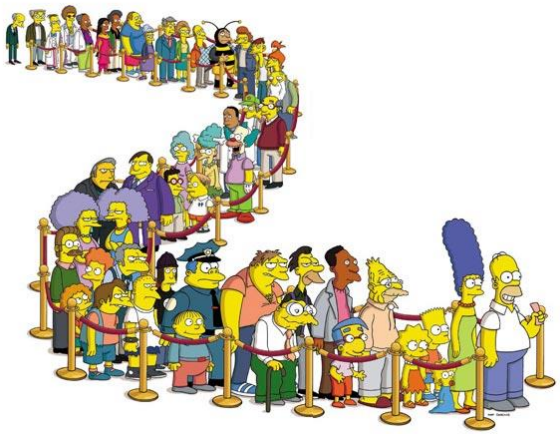
NEUROLOGICAL SURGERY

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

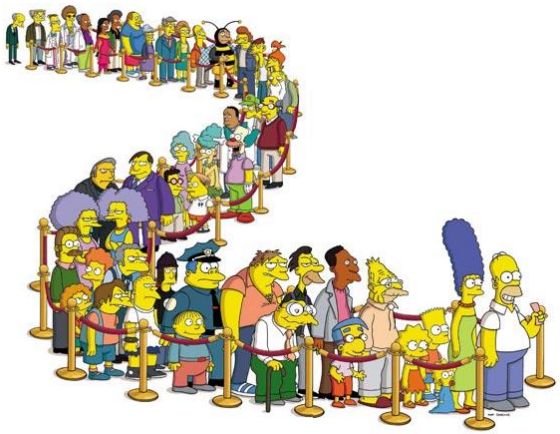
MASTER SURGERY SCHEDULE (MSS)


MSS
IMPACT



Patient waiting time / waiting list

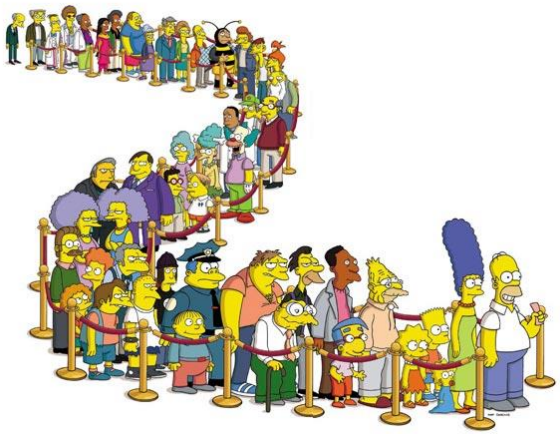
MSS
IMPACT



Patient waiting time / waiting list

Staffing /equipment requirements

MSS IMPACT

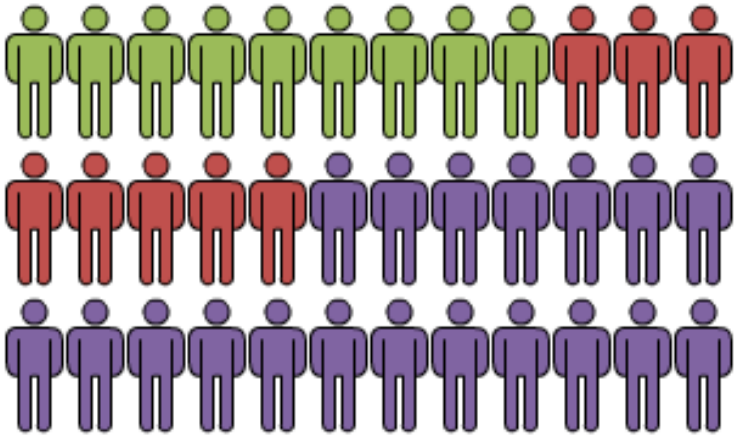


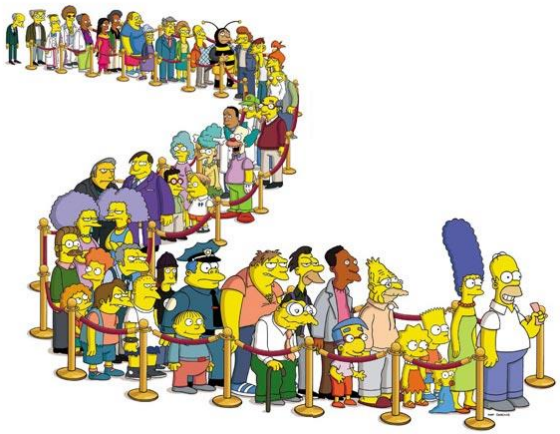
Patient waiting time / waiting list

Staffing /equipment requirements

MSS IMPACT

Patient mix





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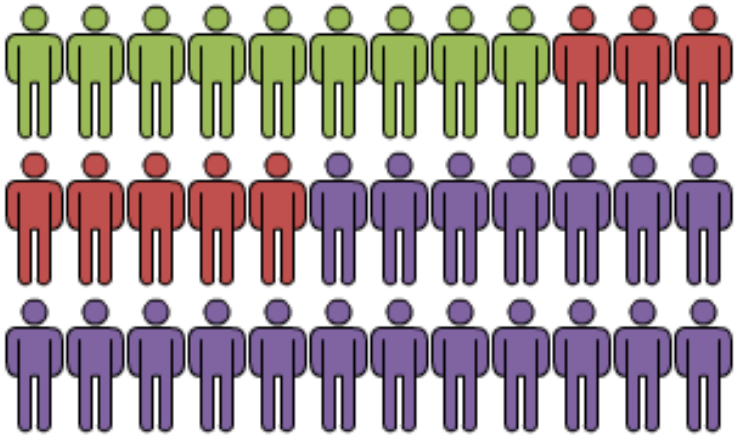
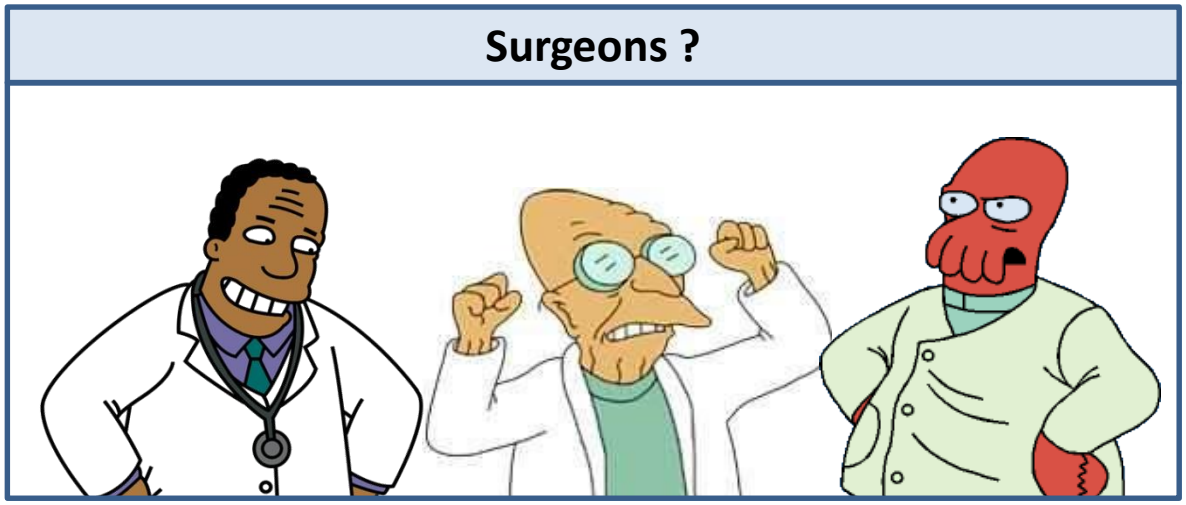


Hospital profitability

WHO SETS THE MSS?

WHO SETS THE MSS?

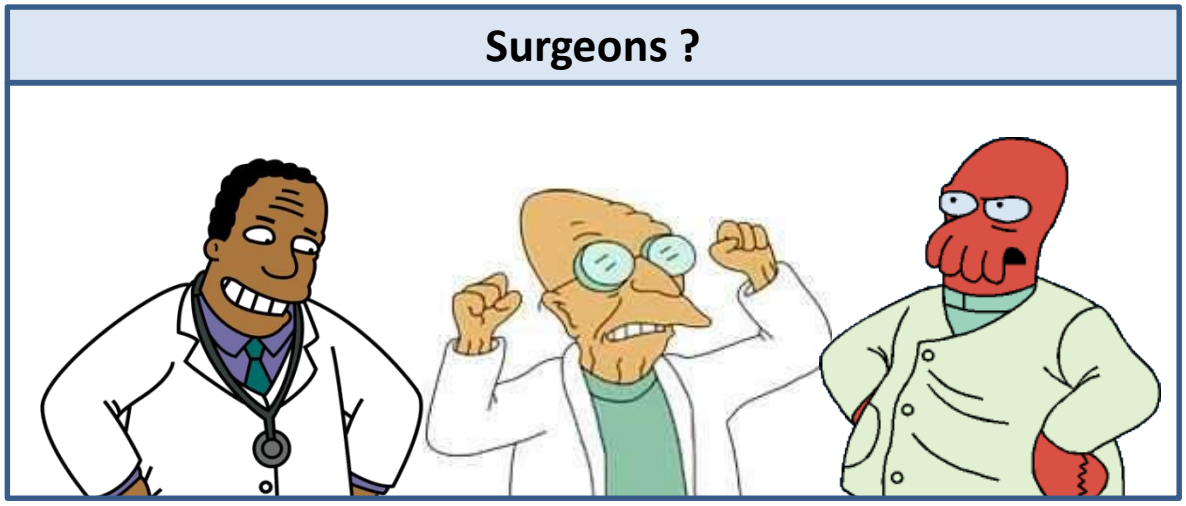
Surgeons ?



WHO SETS THE MSS?

Hospital management ??

Surgeons ?

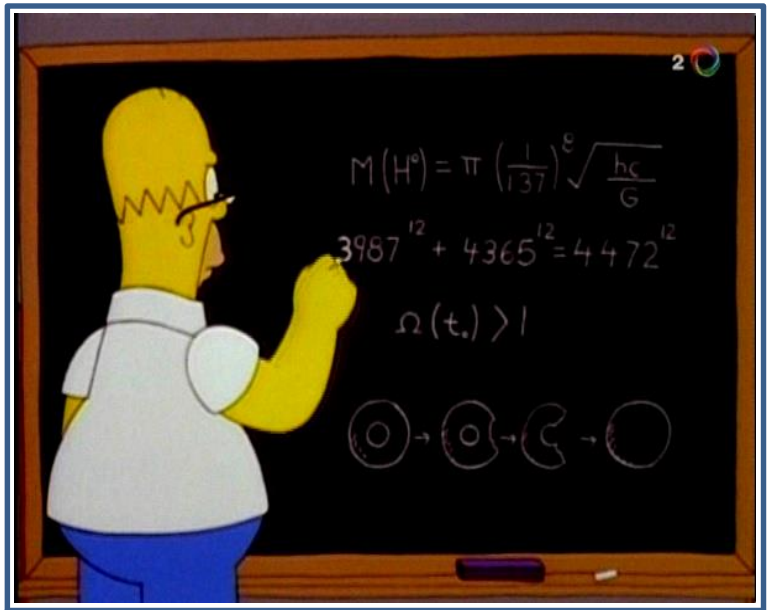


WHO SETS THE MSS?

Hospital management ??

The patient ????

Surgeons ?



A mathematical model ???????

WHO SETS THE MSS?

Hospital management ??

The patient ????

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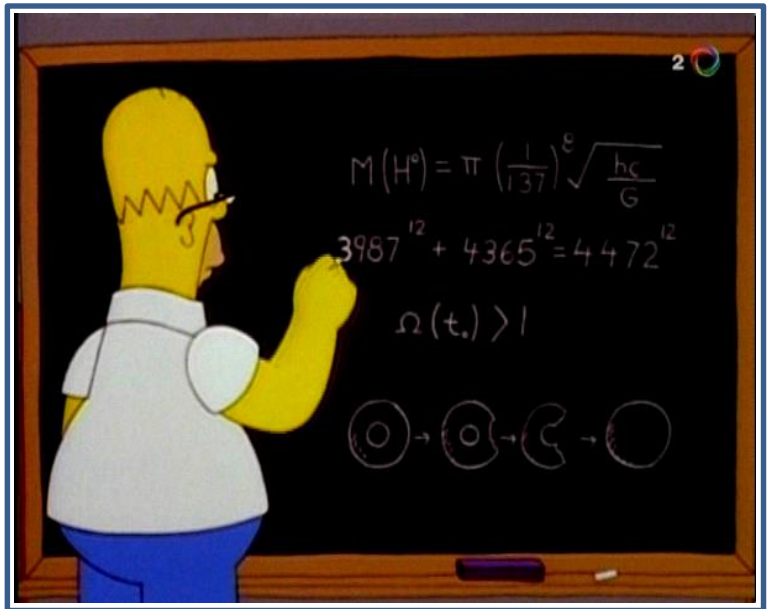

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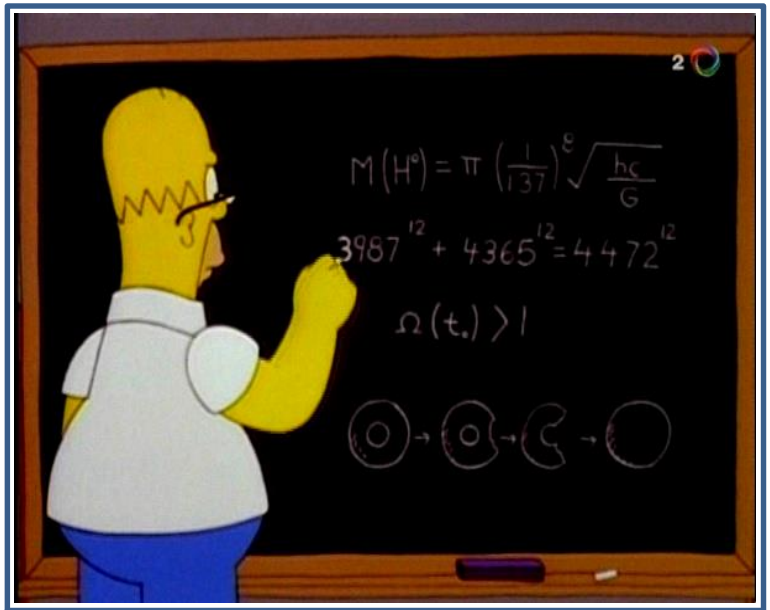
WHO SETS THE MSS?

Hospital management ??

The patient ????

Surgeons ?



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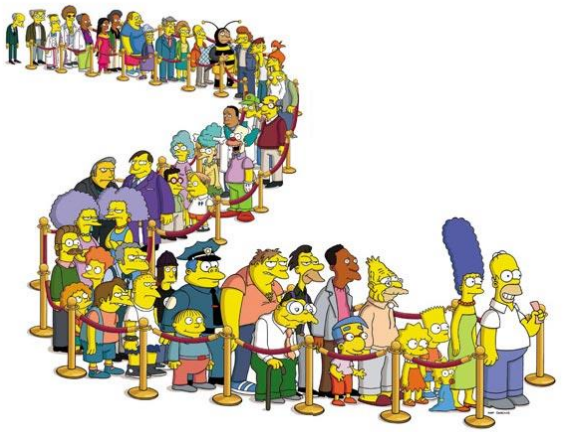
MINIMIZE

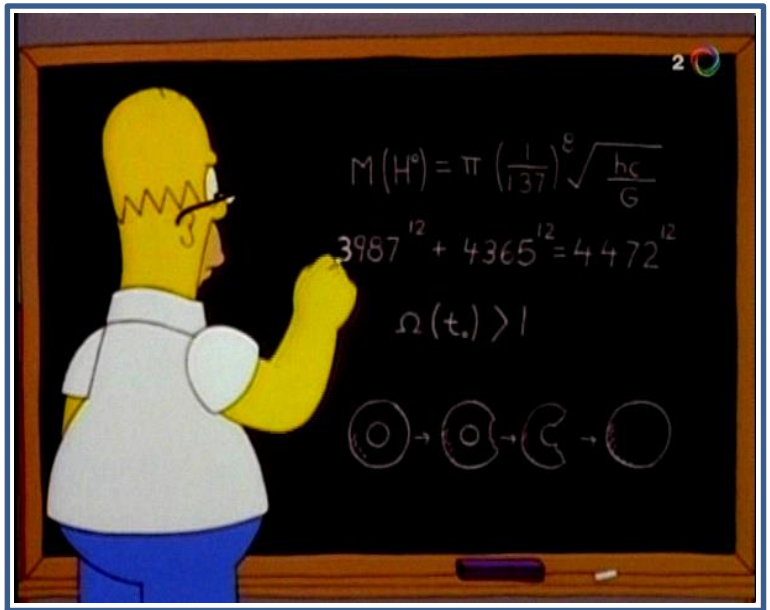


Weighted patient waiting time

WHO SETS TH MSS?

Surgeons ?

The patient ????



A mathematical model ???????

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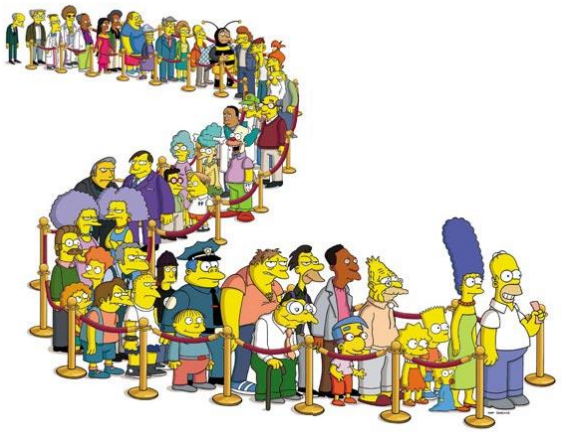
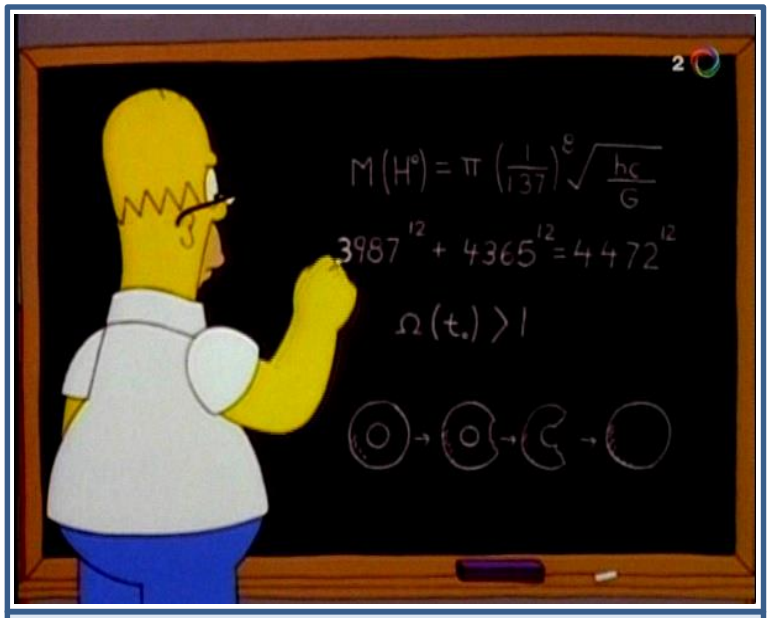


Weighted patient waiting time

McKinsey&Company

41% of US patients choose a hospital based on nonclinical factors (e.g., waiting time, ease of making an appointment etc.)

75% of patients are willing to switch hospitals based on the timely conduction of scheduled appointments



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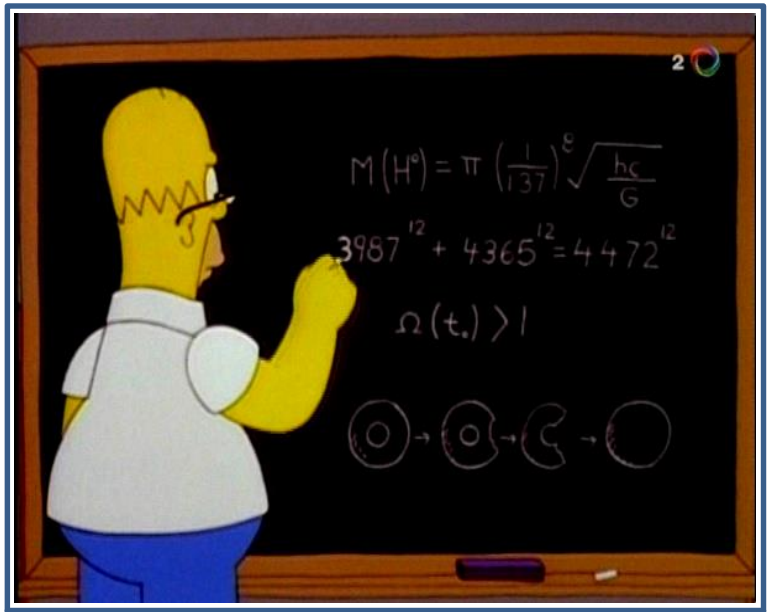
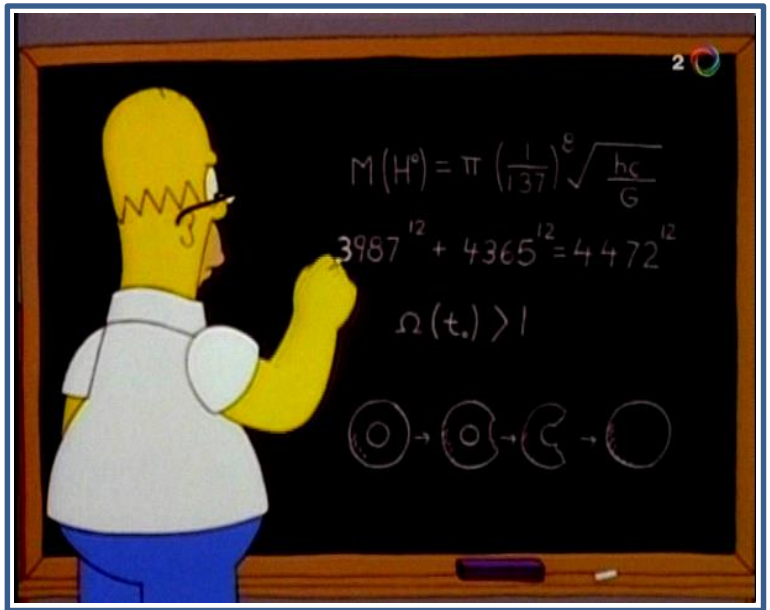


A mathematical model ???????

Any given MSS or block allocation

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN



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Any given MSS or block allocation

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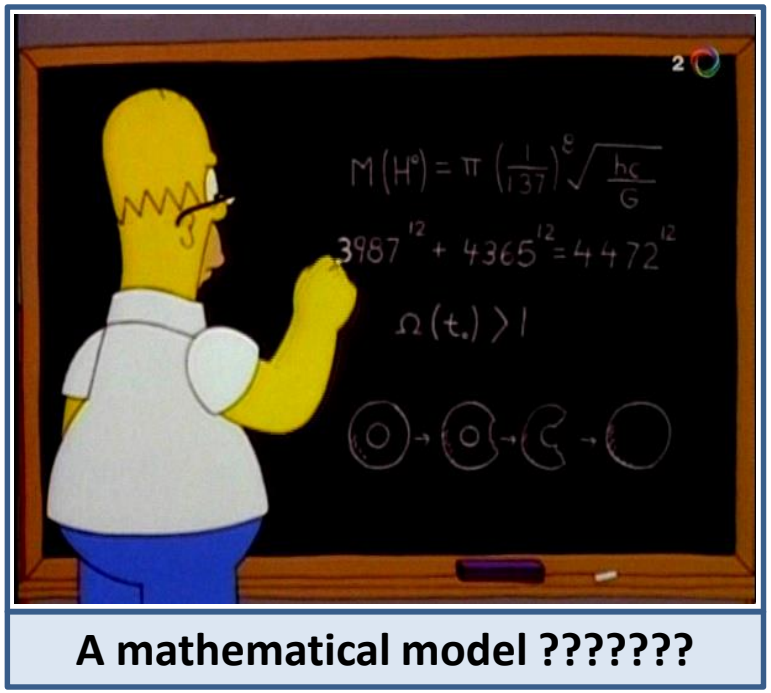
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

Markov model



A mathematical model ???????

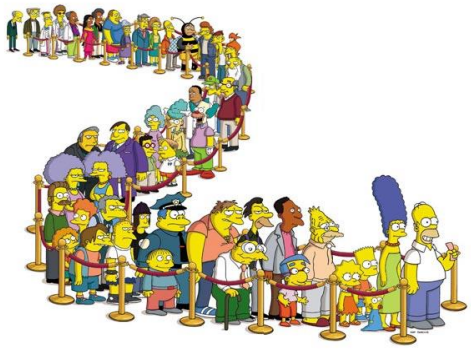
Any given MSS or block allocation

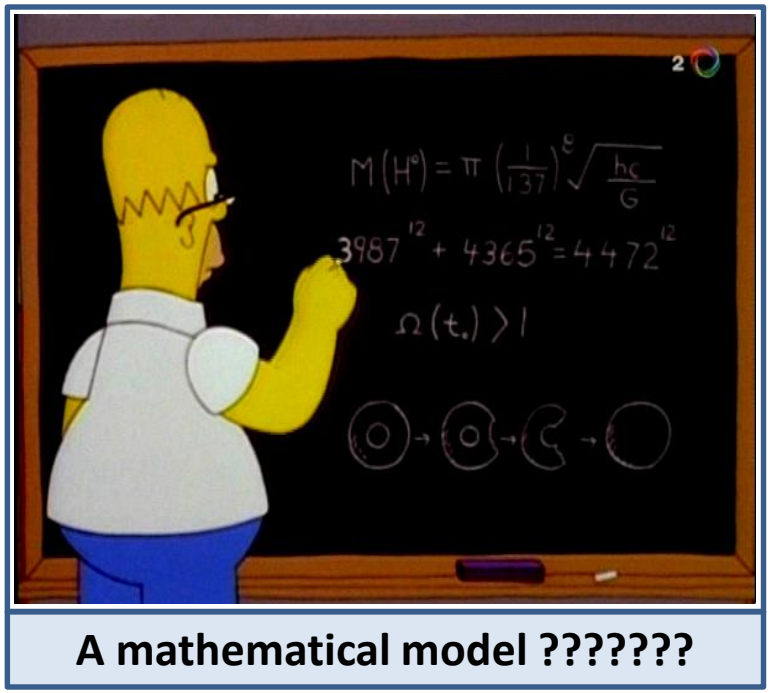
OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

Markov model

Waiting time for each patient type





A mathematical model ???????

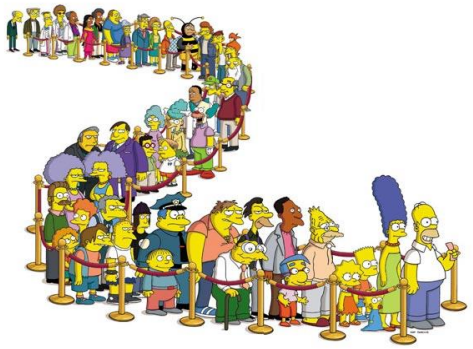
Any given MSS or block allocation

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

Markov model

Waiting time for each patient type



Optimization procedure generates MSS until optimal weighted patient time has been found

A mathematical model ???????

Any given MSS or block allocation

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

Markov model

Waiting time for each patient type

Optimization procedure generates MSS until optimal weighted patient time has been found

ORTHOPEDICS

WAITING LIST (ORTHOPEDICS)

WAITING LIST (ORTHOPEDICS)

WEEK 1	...	WEEK 34	...	WEEK 45

OPERATING THEATRE 1

MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2

MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 1

MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2

MON	TUE	WED	THU	FRI	SAT	SUN

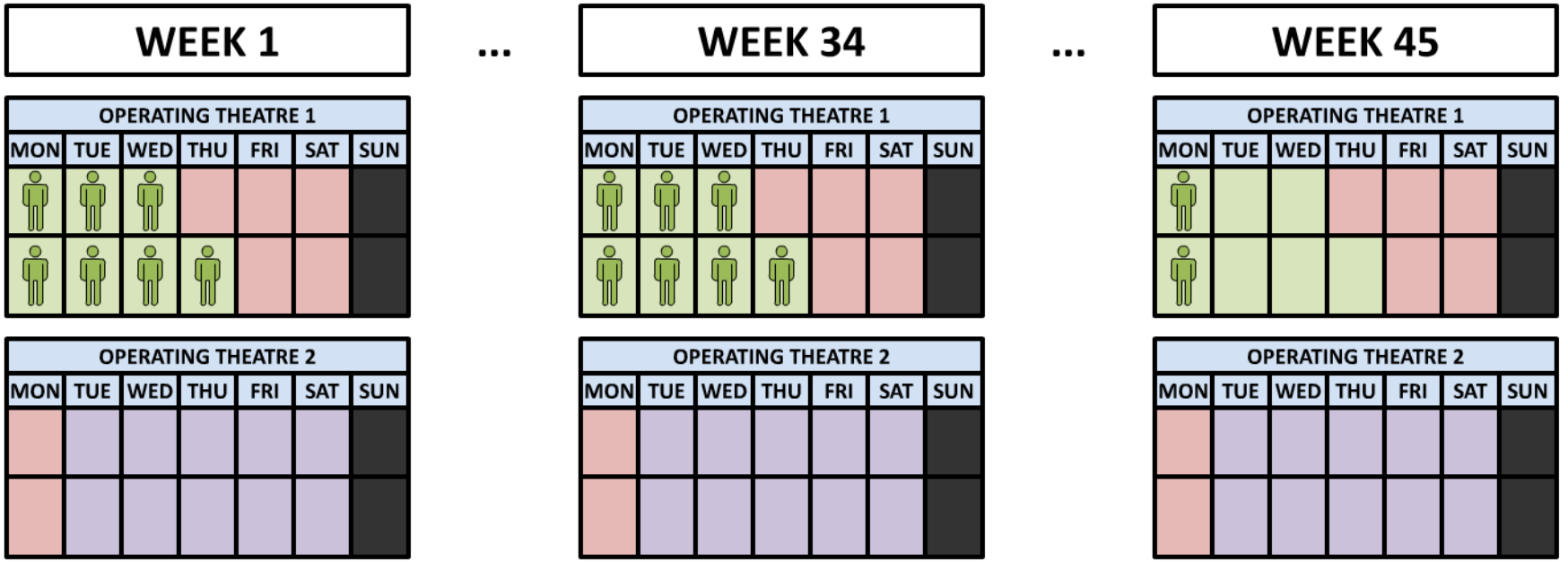
OPERATING THEATRE 1

MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2

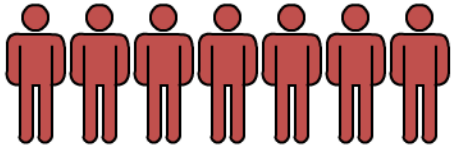
MON	TUE	WED	THU	FRI	SAT	SUN

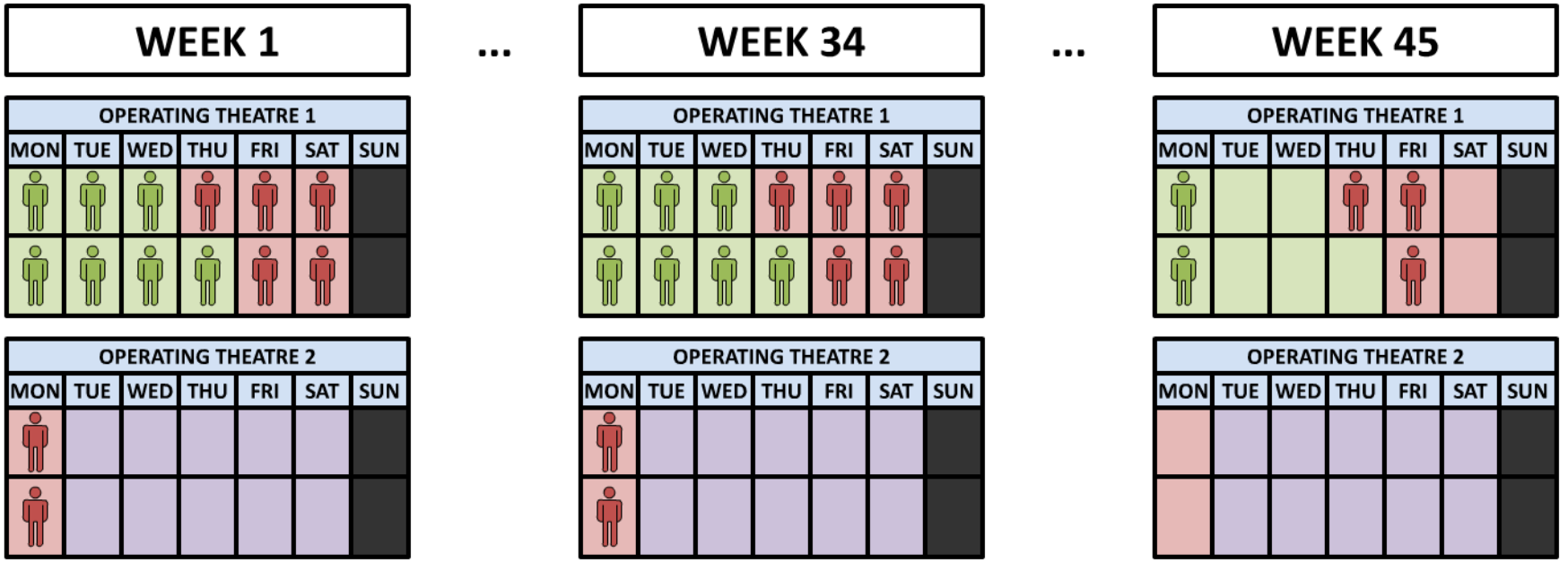
WAITING LIST (ORTHOPEDICS)

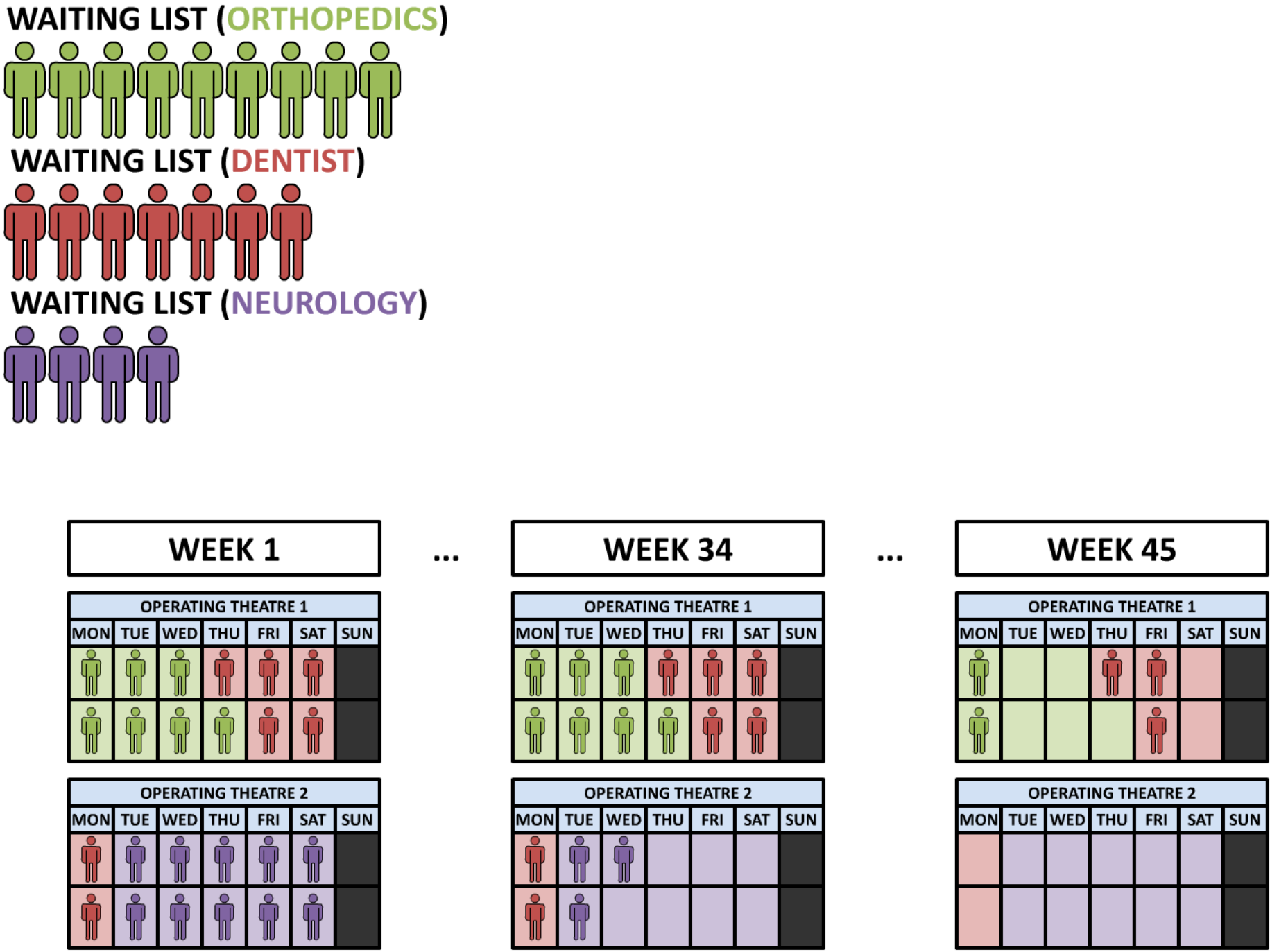


WAITING LIST (ORTHOPEDICS)

WAITING LIST (DENTIST)






WAITING LIST (ORTHOPEDICS)
WAITING LIST (DENTIST)
WAITING LIST (NEUROLOGY)
WEEK 1
...
WEEK 34
...
WEEK 45
OPERATING THEATRE 1
MON TUE WED THU FRI SAT SUN
OPERATING THEATRE 2
MON TUE WED THU FRI SAT SUN
OPERATING THEATRE 1
MON TUE WED THU FRI SAT SUN
OPERATING THEATRE 2
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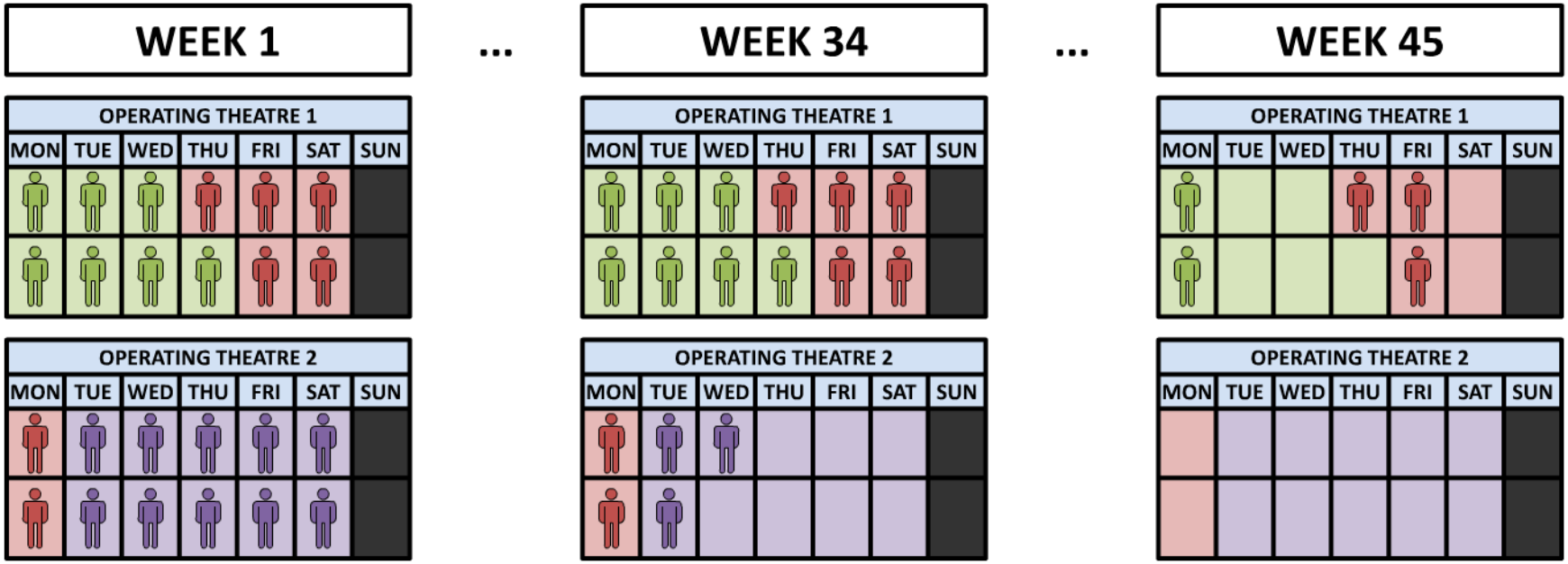
OPERATING THEATRE 1
MON TUE WED THU FRI SAT SUN
OPERATING THEATRE 2
MON TUE WED THU FRI SAT SUN

WAITING LIST (ORTHOPEDICS)

WAITING LIST (DENTIST)

WAITING LIST (NEUROLOGY)

WEEK 1: PATIENT ARRIVAL (ORTHOPEDICS)



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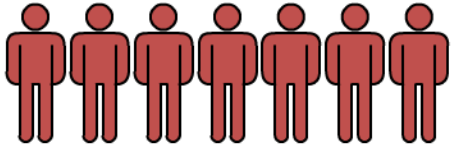

WAITING LIST (NEUROLOGY)

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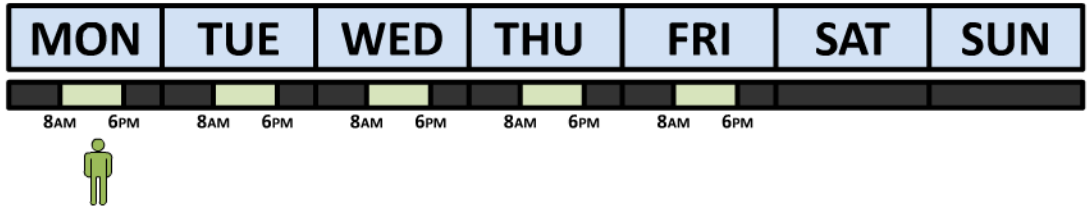

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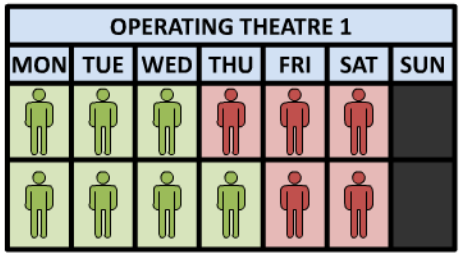

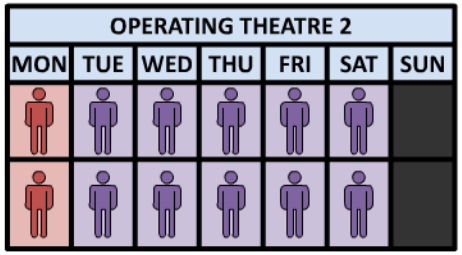

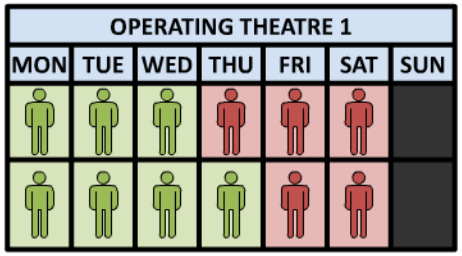

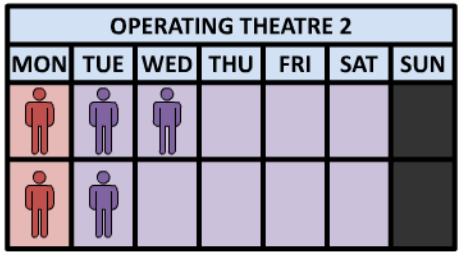

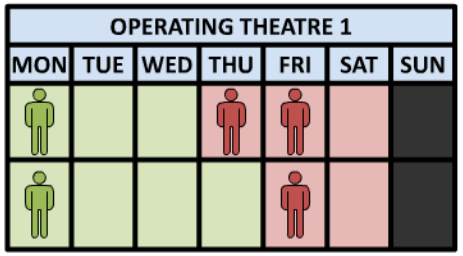

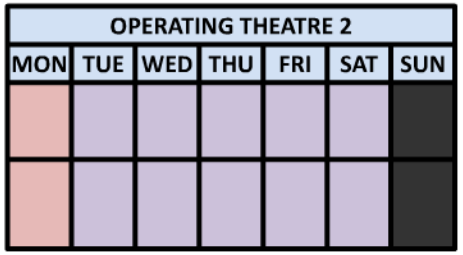

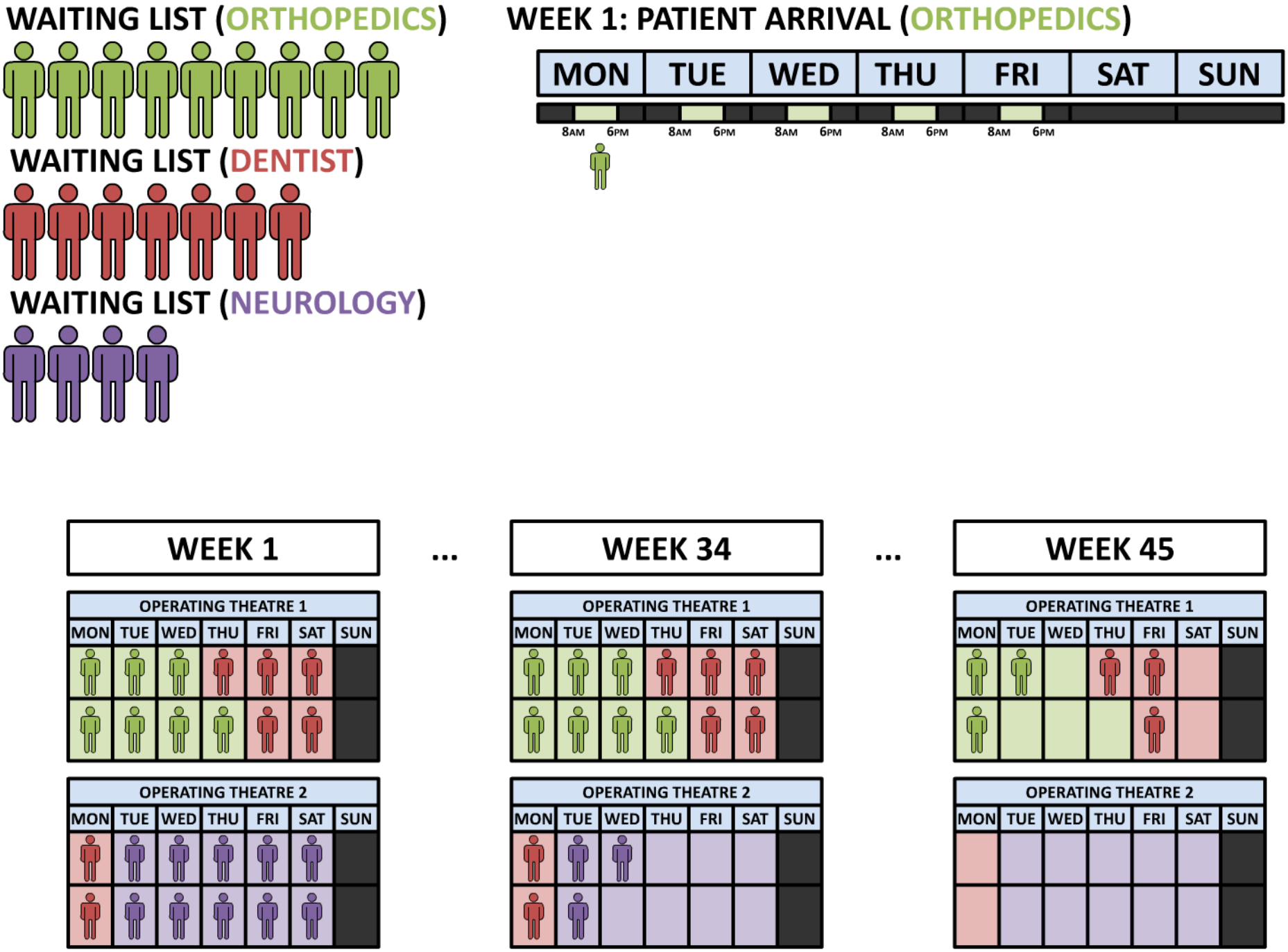
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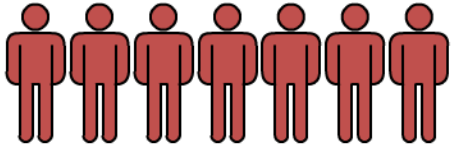
WEEK 1: PATIENT ARRIVAL (ORTHOPEDICS)
MON
TUE
WED
THU
FRI
SAT
SUN
8AM
6PM
WEEK 1
...
WEEK 34
...
WEEK 45
OPERATING THEATRE 1
OPERATING THEATRE 2

WAITING LIST (ORTHOPEDICS)

WAITING LIST (DENTIST)



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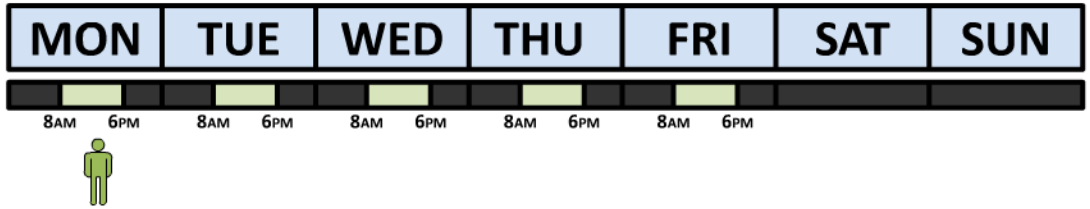

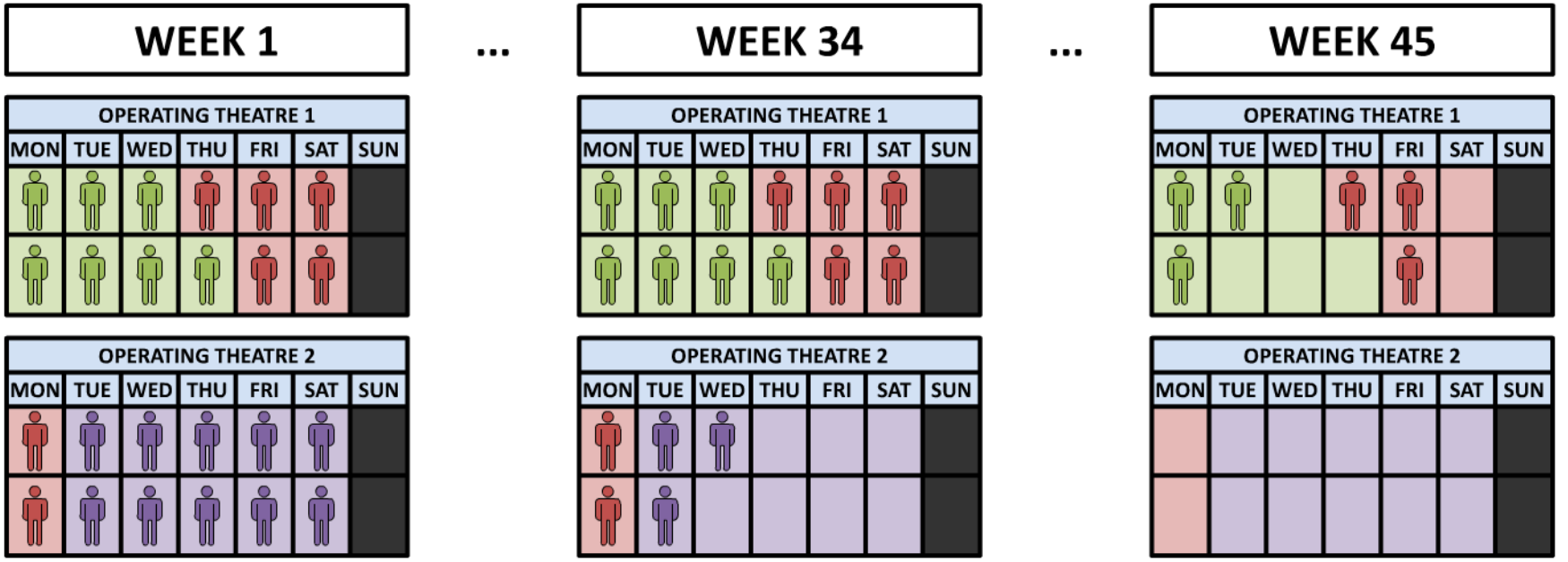

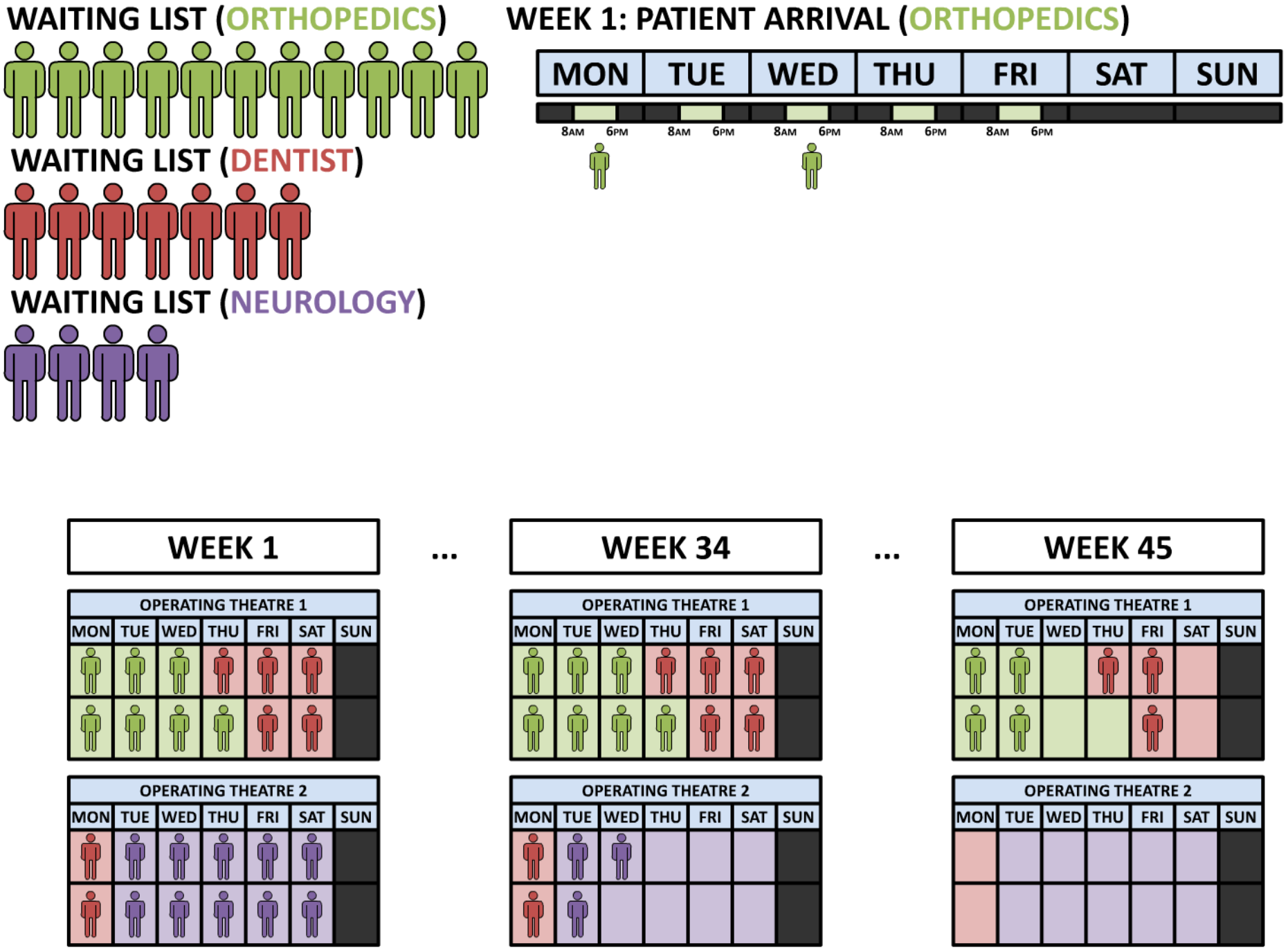
WAITING LIST (ORTHOPEDICS)
WAITING LIST (DENTIST)
WAITING LIST (NEUROLOGY)
WEEK 1: PATIENT ARRIVAL (ORTHOPEDICS)
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8AM
6PM
WEEK 1
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WEEK 34
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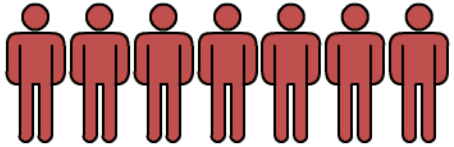
WEEK 45
OPERATING THEATRE 1
OPERATING THEATRE 2

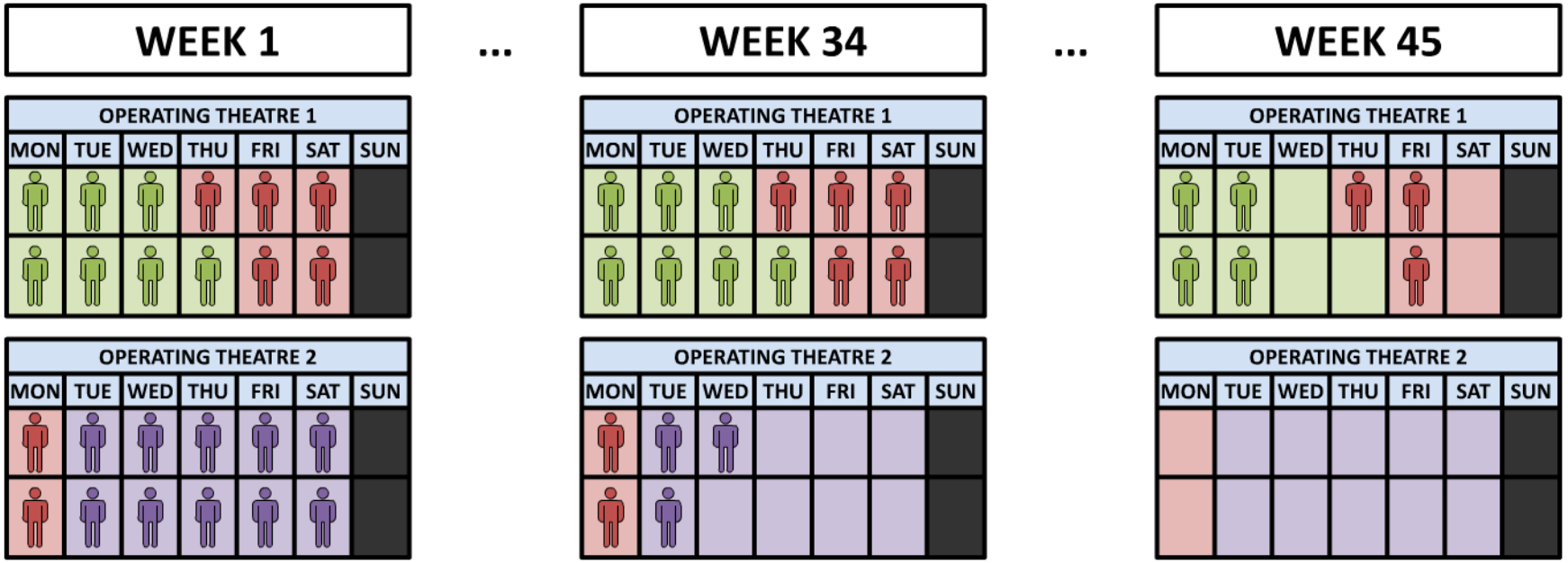
WAITING LIST (ORTHOPEDICS)

WAITING LIST (DENTIST)



WAITING LIST (NEUROLOGY)

WEEK 1: PATIENT ARRIVAL (DENTIST)

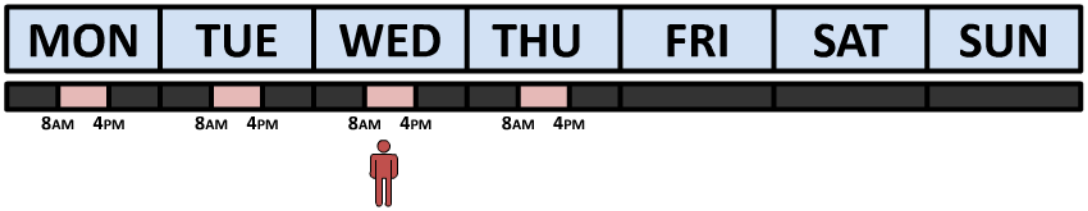


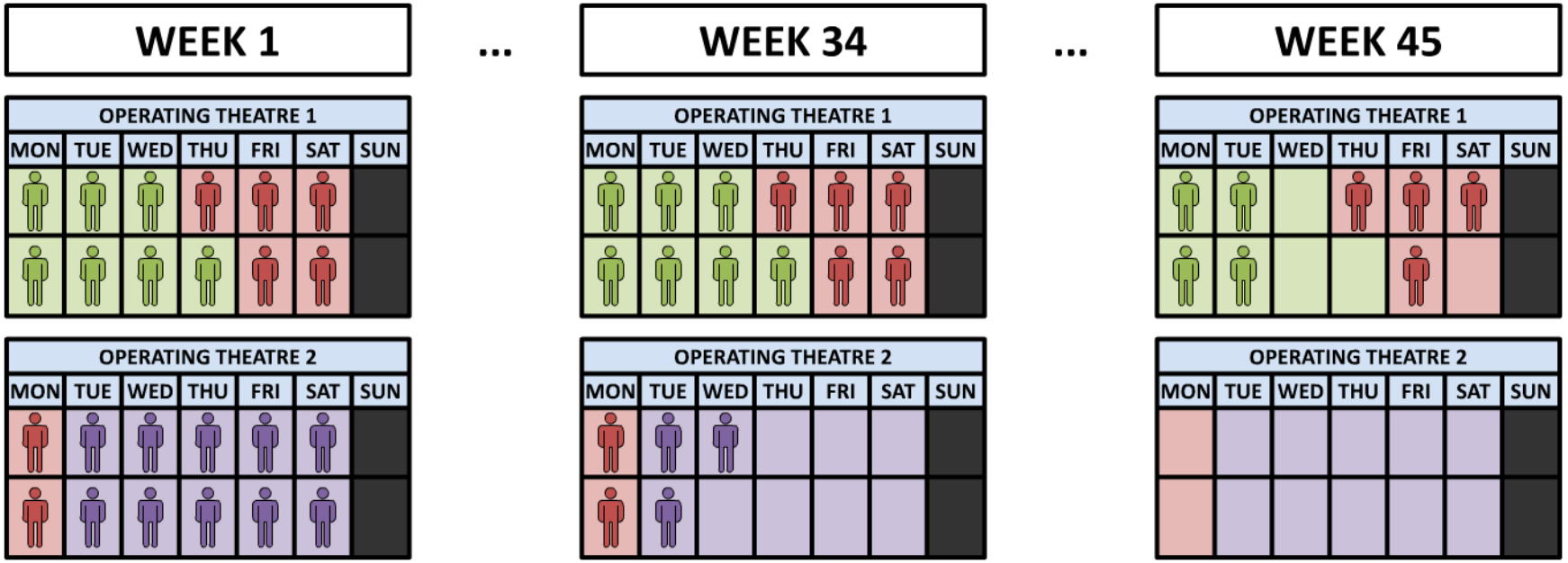
WAITING LIST (ORTHOPEDICS)

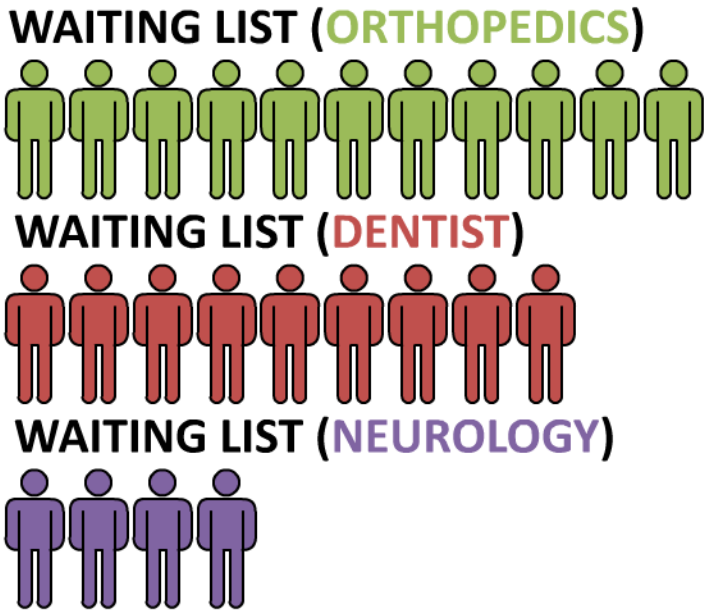
WAITING LIST (DENTIST)

WAITING LIST (NEUROLOGY)

WEEK 1: PATIENT ARRIVAL (DENTIST)



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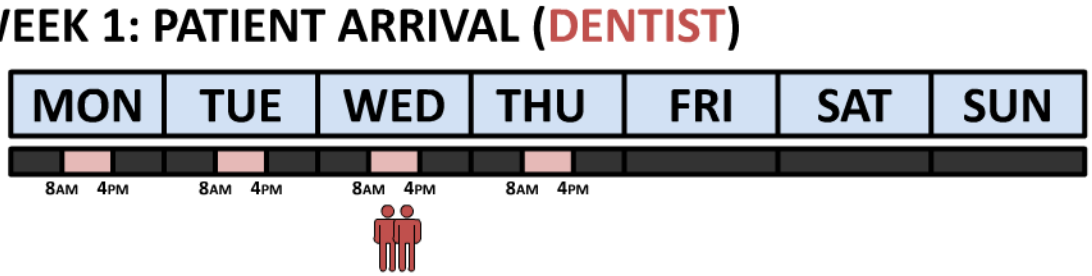
WEEK 1: PATIENT ARRIVAL (DENTIST)
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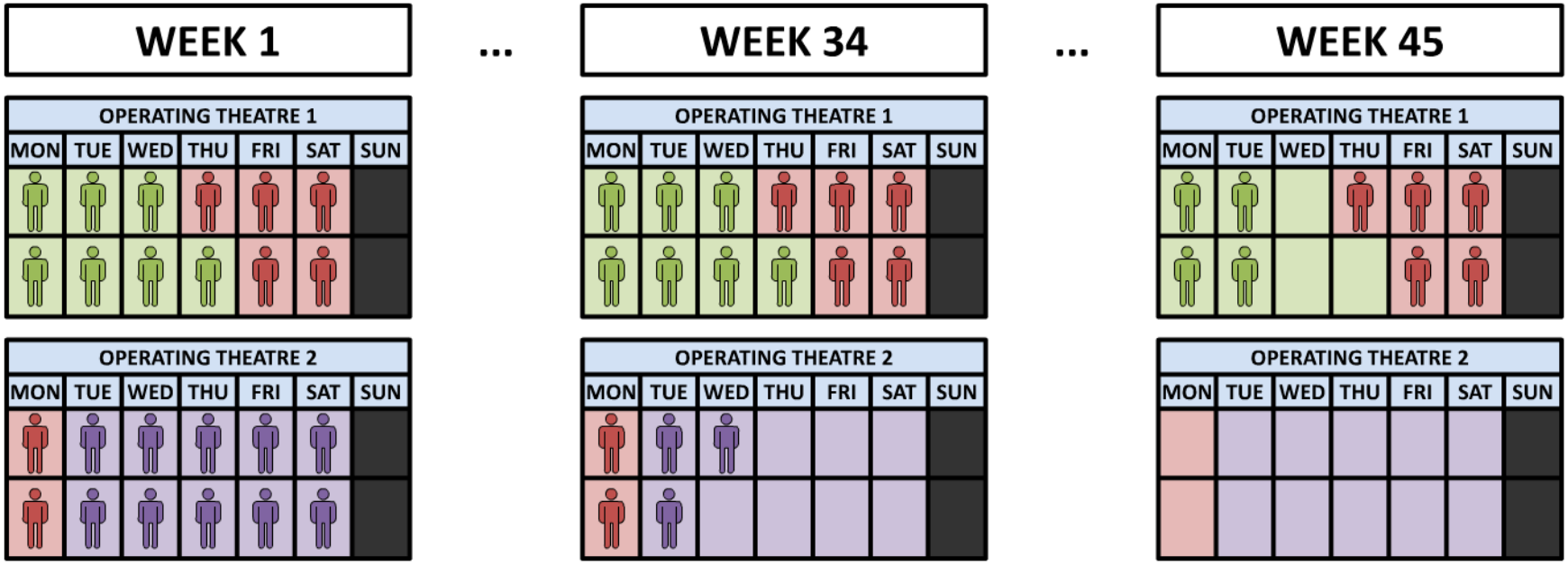
WEEK 1
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OPERATING THEATRE 1
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WAITING LIST (ORTHOPEDICS)

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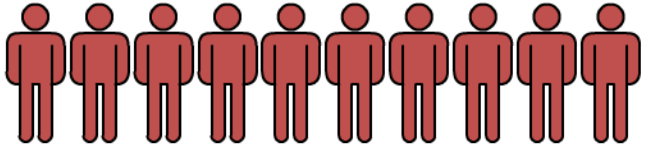
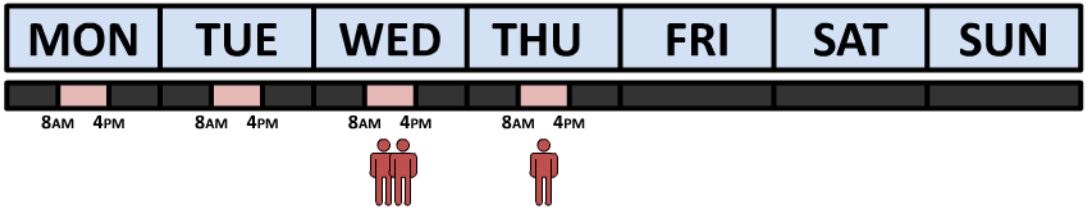
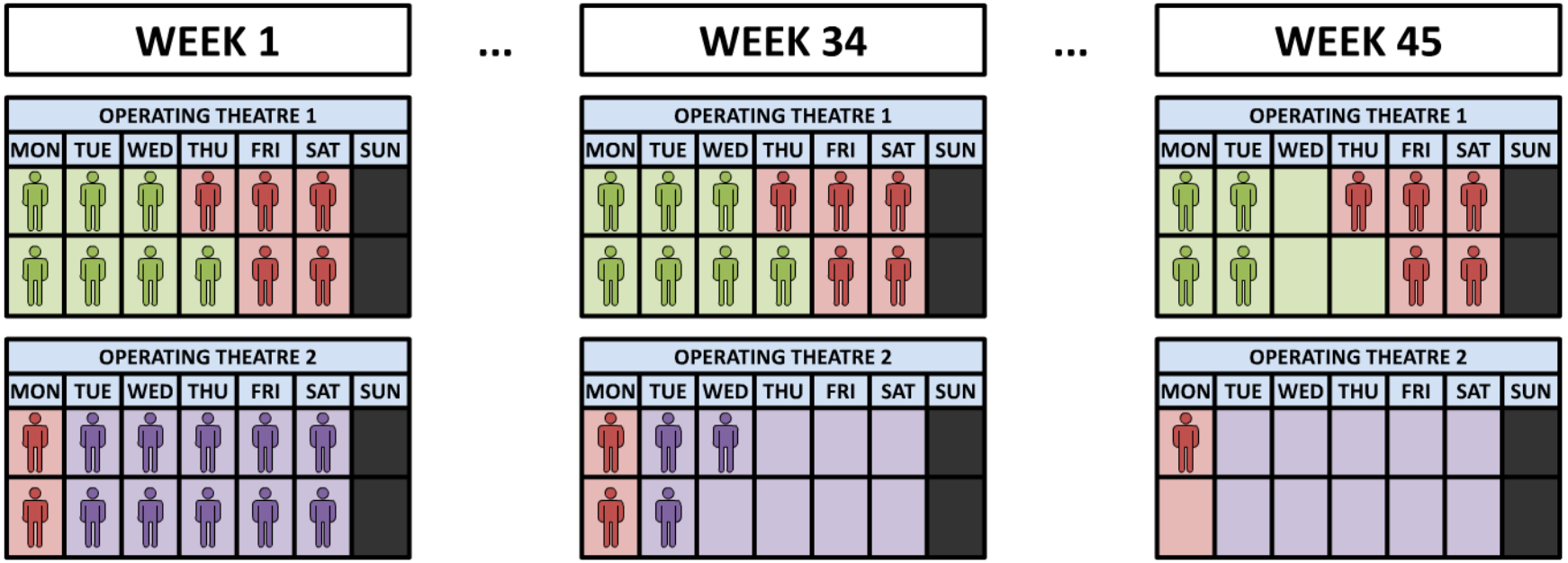


WAITING LIST (NEUROLOGY)

WEEK 1: PATIENT ARRIVAL (DENTIST)





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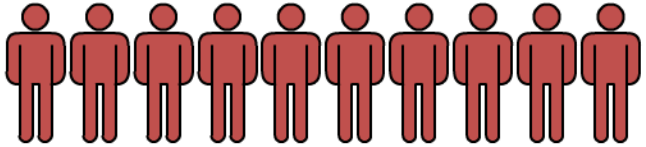

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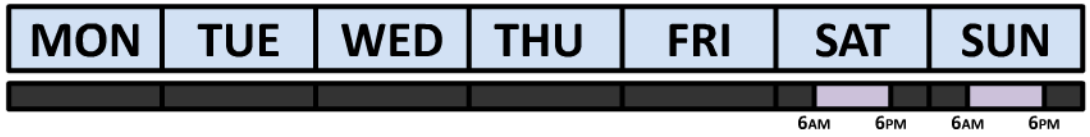

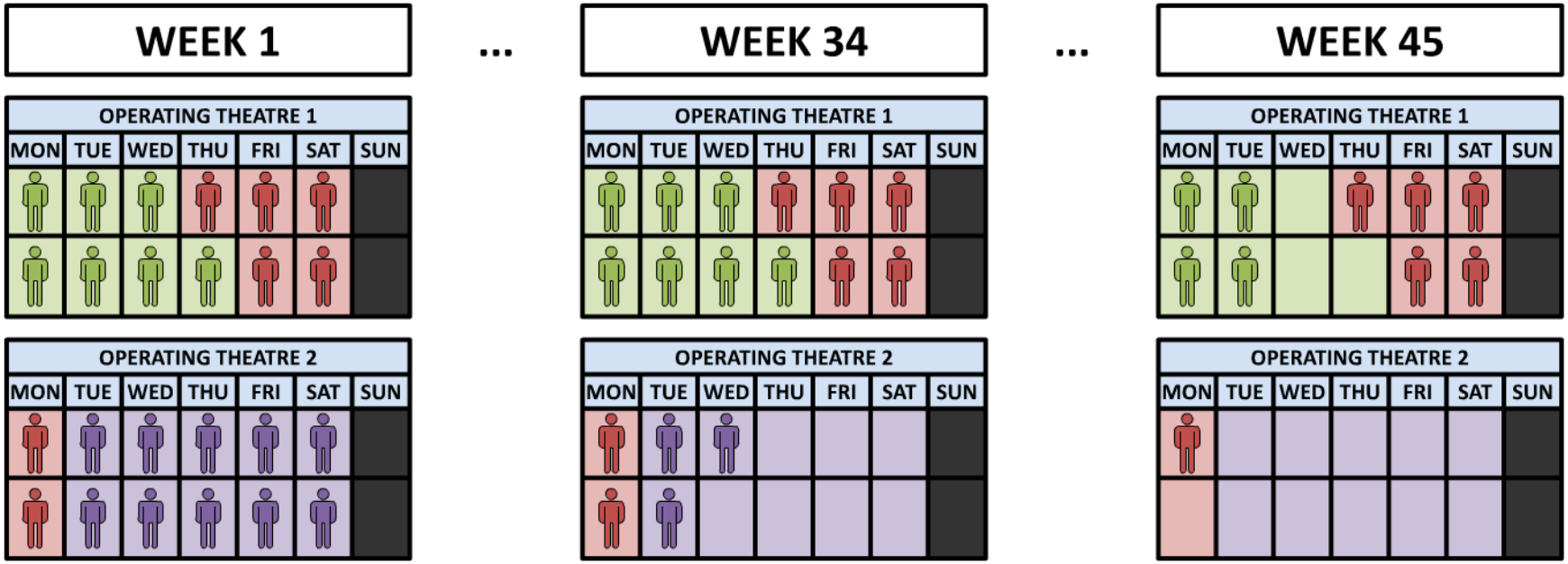

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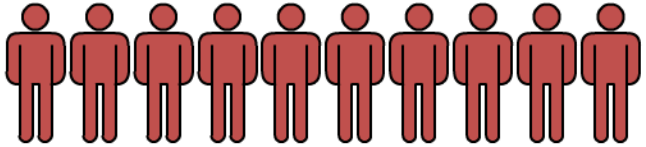

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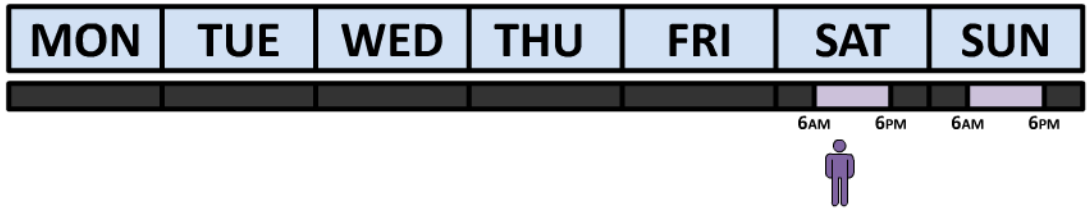

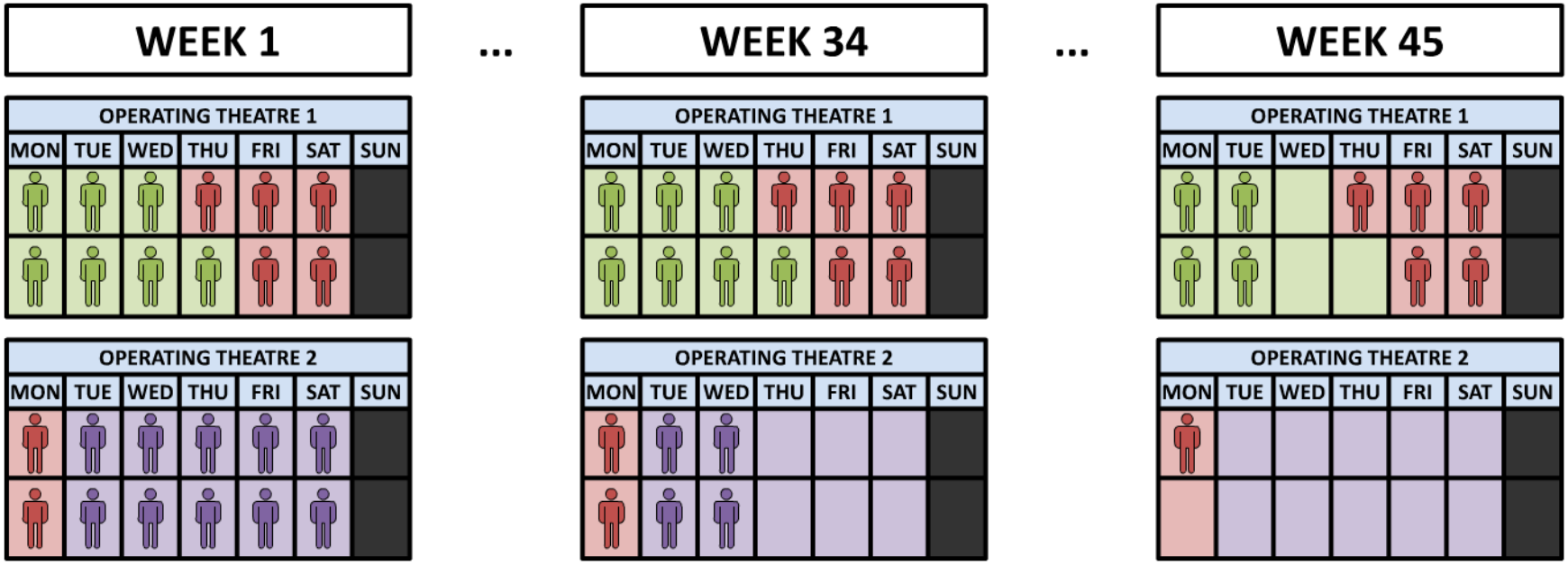

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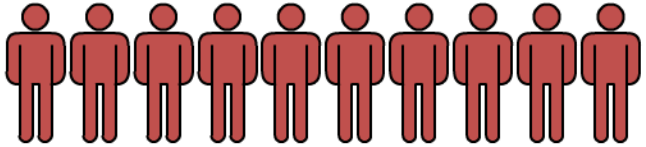

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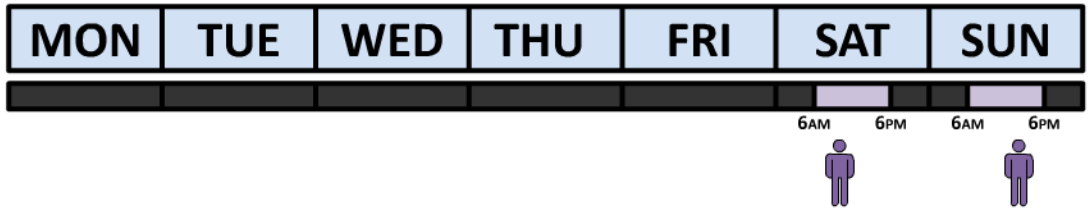

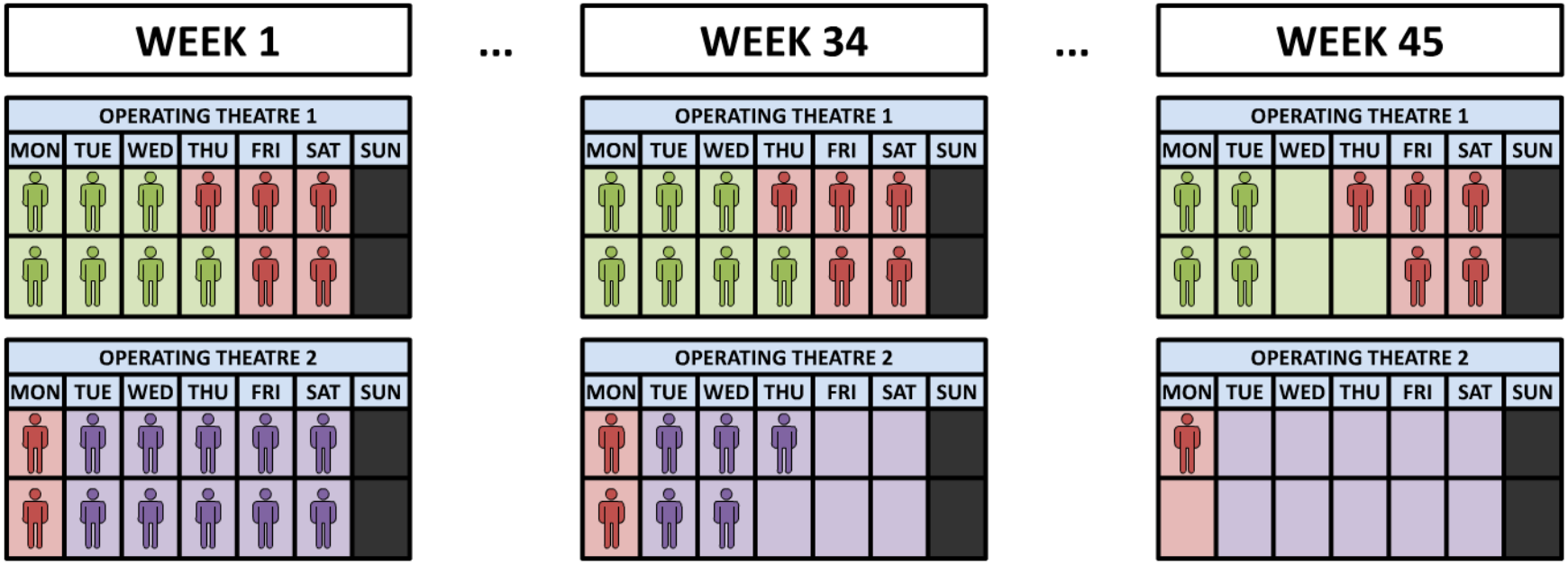

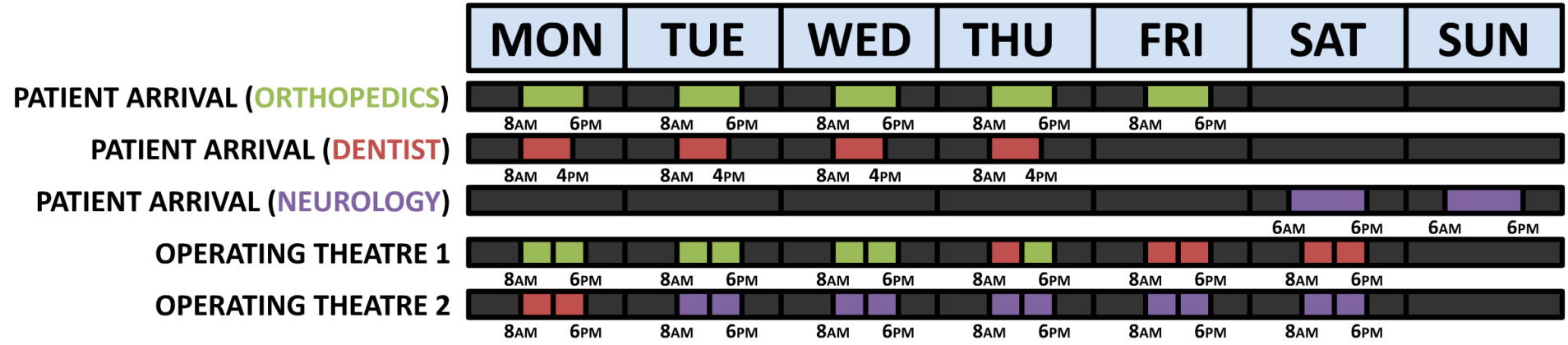
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PATIENT ARRIVAL (NEUROLOGY)
6AM 6PM 6AM 6PM
OPERATING THEATRE 1
8AM 6PM 8AM 6PM 8AM 6PM 8AM 6PM 8AM 6PM 8AM 6PM
OPERATING THEATRE 2
8AM 6PM 8AM 6PM 8AM 6PM 8AM 6PM 8AM 6PM 8AM 6PM

Naïve approach requires 4 dimensions

1. The number of patients in queue for each patient type
2. The phase of the arrival process for each patient type (we allow general interarrival times)
3. The current system state (i.e., what events can take place?)
4. The phase of the process that keeps track of system state transitions

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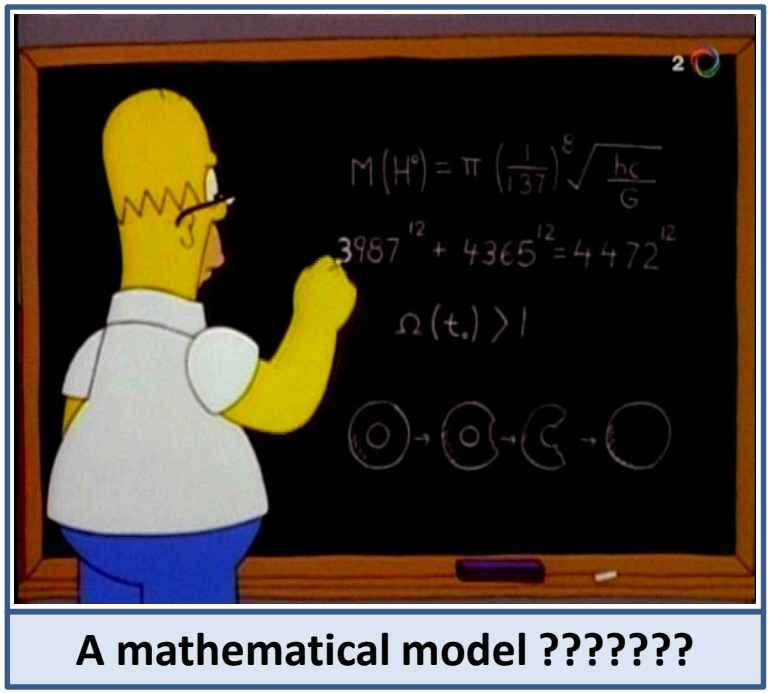
Our approach

1. Uses sets of two-dimensional Markov chains.
2. Very fast!
3. Exact!

=> Can be used for optimization purposes!



A mathematical model ???????

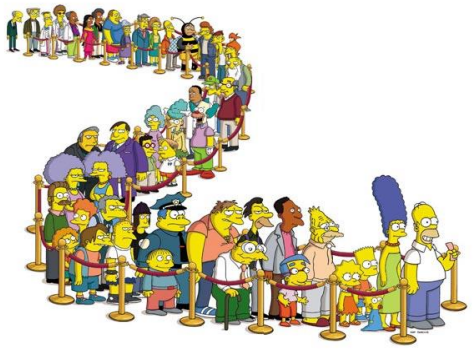
Any given MSS or block allocation

OPERATING THEATRE 1						
MON	TUE	WED	THU	FRI	SAT	SUN

OPERATING THEATRE 2						
MON	TUE	WED	THU	FRI	SAT	SUN

Markov model

Waiting time for each patient type



Optimization procedure generates MSS until optimal weighted patient time has been found

A mathematical model ???????

Any given MSS or block allocation

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MON	TUE	WED	THU	FRI	SAT	SUN

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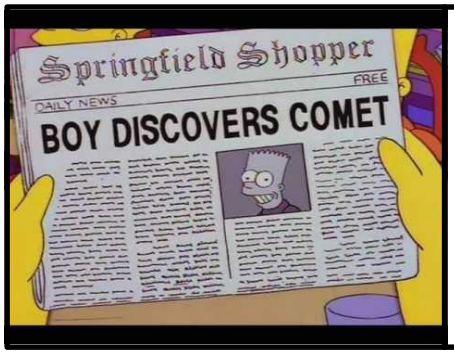
Markov model

Waiting time for each patient type

Optimization procedure generates MSS until optimal weighted patient time has been found

Optimal procedure for small problems

Step-wise heuristic for large problems



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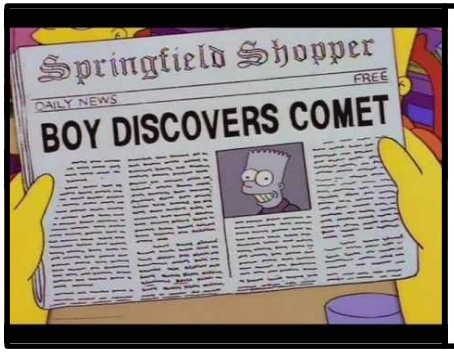

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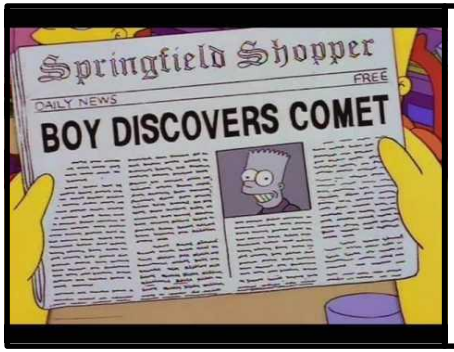
Contribution

We developed a new queueing model that allows to identify the optimal block allocation such that the weighted patient waiting time is minimized



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Future research

1. Also observe what happens during service itself => include server idle time, overtime etc.
2. Add additional constraints (staffing/equipment)