Soft loss systems

Jan van der Wal

Eindhoven, 30 September 2010

Alternative title

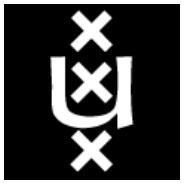
Intensive Care Queues

Costs of an IC bed

- If you stay overnight in a hospital, you'll probably pay at least $500. Plus another $500 if you got there in an ambulance
- An ICU bed costs you about $3500 a night
- A kidney transplant operation only costs 4K

- In NL about 2000 IC beds
- IC units are different
- Within a radius of 7 km 4 hospitals

TU/e



Linda Green

- Waiting for an IC bed is difficult
- Accepting IC as a loss system is doubtful
- What to do?

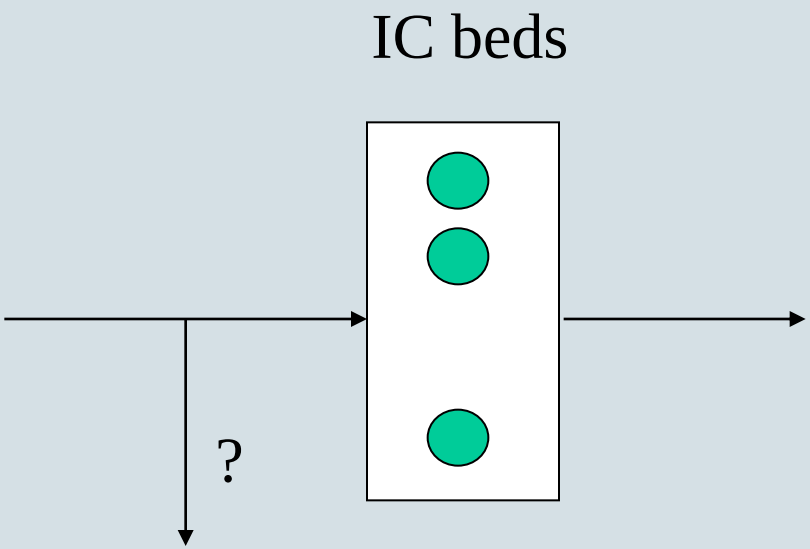
Aim

- Get some insight into what happens
- Get a feeling for what might be useful models

Outline

- Playing with a number of simple models
- Looking at numbers
- Hoping to get some insight

Simple Models



Model 1: Pure loss

- Poisson arrivals (in all models)
- Parameters
  - Beds
  - Load
- Performance
  - Blocked patients

Loss formula

$$B(\rho, s) = \frac{\rho^s / s!}{\sum_{l=0}^{s} \rho^l / l!}$$

How much load?

- Given a loss probability
- Given the number of beds

Loss probability 0.1

s	Total off load	Acc load / bed	Beds / patient
4	2.046	0.460	2.172
6	3.758	0.564	1.774
8	5.597	0.630	1.588
10	7.510	0.676	1.479
12	9.474	0.711	1.407
14	11.474	0.738	1.356
16	13.500	0.759	1.317
18	15.546	0.777	1.287
20	17.613	0.793	1.262

Loss probability 0.05

s	Total off load	Acc load / bed	Beds / patient
4	1.524	0.362	2.764
6	2.960	0.469	2.133
8	4.543	0.540	1.854
10	6.216	0.590	1.694
12	7.950	0.629	1.589
14	9.730	0.660	1.515
16	11.545	0.685	1.459
18	13.386	0.706	1.415
20	15.248	0.724	1.381

Model 2: temporary overflow

- If all beds are occupied, the patient is taken care of elsewhere (wrong bed)
- As soon as a bed becomes available, the patient is moved to the right bed

In wrong bed; off load 0.7, 0.8 and 0.9

s	0.7	0.8	0.9
4	0.253	0.394	0.571
6	0.242	0.420	0.661
8	0.222	0.428	0.725
10	0.201	0.426	0.773
12	0.181	0.419	0.811
14	0.161	0.408	0.840
16	0.143	0.395	0.864
18	0.127	0.382	0.883
20	0.113	0.367	0.898

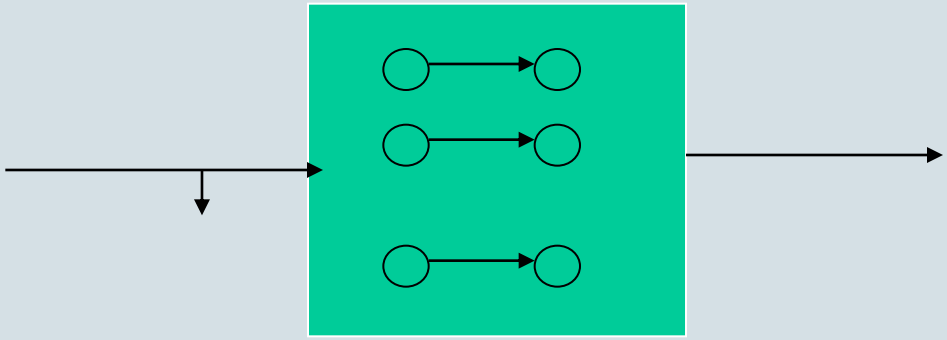
Model 3; priority

- One reserved bed for emergency patients
- Two types 50/50
- Exponential stay times, mean 3 days
- Offered load 0.8 per bed

One reserved bed

s	B1	B1/yr	B2	B2/yr
4	0.129	25.1	0.451	87.7
6	0.097	28.3	0.339	99.1
8	0.078	30.3	0.272	106.0
10	0.065	31.5	0.227	110.3
12	0.055	32.2	0.193	112.9
14	0.048	32.6	0.168	114.1
16	0.042	32.7	0.147	114.5
18	0.037	32.6	0.130	114.1
20	0.033	32.3	0.116	113.1

Model 4: two phases, push ahead



Details

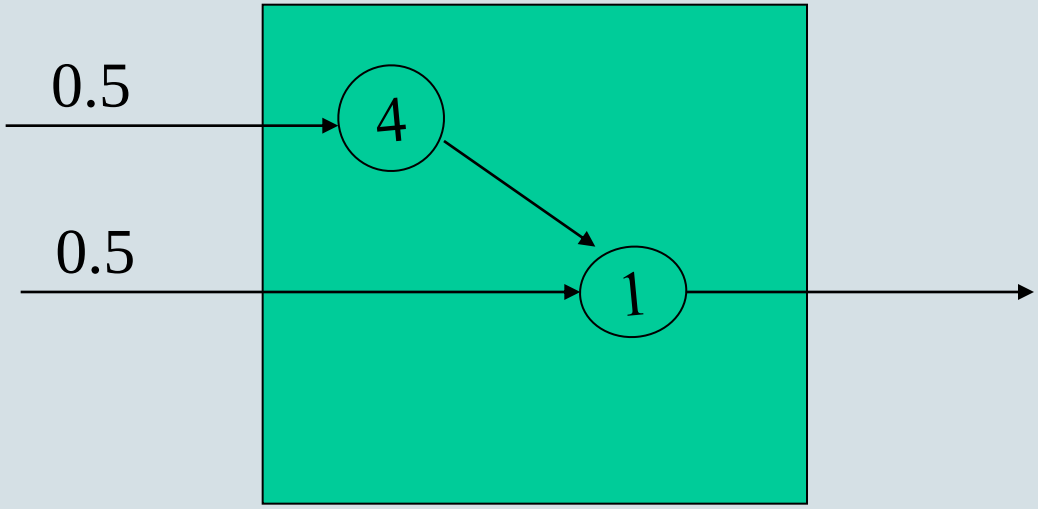
- Phase 1: exponential, mean 2 days (more critical)
- Phase 2: exponential, mean 1 day (almost ok)
- If full and new arrival: a phase 2 patient leaves
- Offered load 0.8 per bed

Two phases; leaving early

s	P earlier	P full
4	0.2170	0.1094
6	0.2022	0.0636
8	0.1854	0.0394
10	0.1690	0.0253
12	0.1535	0.0166
14	0.1392	0.0111
16	0.1263	0.0075
18	0.1146	0.0051
20	0.1040	0.0035

Model 5; variant of model 4

More variation; $c^2 = 13/9$



Details

- Phase 1: exponential, mean 4 days
- Phase 2: exponential, mean 1 day
  - Average time 3 days
- If full and a new phase 1 arrives: a phase 2 leaves

Dismissed faster if full

s	P Faster	B1	B1/yr	B2	B2/yr
4	0.121	0.109	21.3	0.301	58.6
6	0.111	0.064	18.6	0.251	73.3
8	0.101	0.039	15.3	0.215	83.9
10	0.091	0.025	12.3	0.188	91.4
12	0.082	0.017	9.7	0.165	96.6
14	0.074	0.011	7.6	0.147	99.9
16	0.066	0.007	5.8	0.131	101.8
18	0.060	0.005	4.5	0.117	102.6
20	0.054	0.003	3.4	0.105	102.4

Summary; load 0.8 and 10 beds

- 1: Loss 0.122

Summary; load 0.8 and 10 beds

- 1: Loss 0.122
- 2: To wrong bed 0.28, in wrong bed 0.43

Summary; load 0.8 and 10 beds

- 1: Loss 0.122
- 2: To wrong bed 0.28, in wrong bed 0.43
- 3: Loss 1 0.065, Loss 2 0.23

Summary; load 0.8 and 10 beds

- 1: Loss 0.122
- 2: To wrong bed 0.28, in wrong bed 0.43
- 3: Loss 1 0.065, Loss 2 0.23
- 4: Loss 0.025, Early 0.17

Summary; load 0.8 and 10 beds

- 1: Loss 0.122
- 2: To wrong bed 0.28, in wrong bed 0.43
- 3: Loss 1 0.065, Loss 2 0.23
- 4: Loss 0.025, Early 0.17
- 5: Loss 1 0.025, Loss 2 0.19, Early 0.09

Conclusions

Conclusions

- Many relevant models

Conclusions

- Many relevant models
- No clear answers

Conclusions

- Many relevant models
- No clear answers
- Small IC units are very expensive and inefficient