ORIGINAL ARTICLE

Bottleneck analysis of emergency cardiac in-patient flow in a university setting: anapplication of queueing theory

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Capacity decisions in Dutch hospitals are generally made without the help of OR model-based analyses. For several years hospital managers have been under pressure to reduce bed capacity and increase occupancy rates in the name of operational efficiency. This strategy is questionable. Variability in arrival process and length of stay (LOS) can have a major impact on hospital operation and capacity requirements. If this variability is neglected during modeling an unrealistic and static representation of reality will emerge. Such a model, based on average numbers, is not capable of describing the complexity and dynamics of in-patient flow. Too often, management does not consider the total care chain from admission to discharge, but mainly focuses on the performance of individual units. Not surprisingly, this has often resulted in diminished patient access without any significant reduction in costs.

Relevance

The number of refused admission at the first cardiac aid is significant and, consequently, numerous patients are turned away to other surrounding hospitals. In the last three years approximately one out of every eight arriving patients was refused admission. This means that, roughly, one patient per day is turned away. This is unacceptable and puts great pressure on the required service level. More and more hospitals have to account for the quality of care that they deliver. An admission guarantee for all patients entering the emergency department is one of the main goals of the hospital. In the case of a heart attack, the sooner the patient reaches the emergency room, the better is his/her chance of not only surviving, but also of minimizing heart damage following the attack.

Objectives

1. To analyse the cause of bottlenecks in the emergency care chain of cardiac in-patient flow. The primary goal was to determine the optimal bed allocation over the emergency care chain, given a required service level (max. 5% refused admissions).

2. To provide further insight into the relation between natural variation in arrivals and length of stay and occupancy rates.

Setting

Emergency in-patient flow of cardiac patients in a university medical centre in Amsterdam. Computerized records of 2,813 patients entering the first cardiac aid (FCA) were used to describe patient flow. Approximately 90% of cardiac in-patient flow is emergent and therefore difficult to control. The average number of patients arriving per day was 7.8. Unscheduled arrivals at the FCA were modeled as a Poisson process with intensity $\lambda = 7.8$, which means that the inter-arrival times were exponentially distributed. The Poisson arrival assumption has been shown to be a good one in studies of unscheduled arrivals.[1]

Methods

This particular patient flow is characterized by time-varying arrivals at the FCA, the department where emergency cardiac patients enter the hospital. The strong variability of health care processes duration is considered during modeling. The coefficient of variation (CV) of LOS is typically very close to 1.0. This motivated us to approximate the LOS with an exponential distribution. After accessing the FCA patients move to the coronary care unit (CCU) before they are discharged from the normal care clinical ward (NC). This study applies a stationary 2-D queueing system with blocking to analyze such congestion in emergency care chains.

Results, specific

1. Refused admissions at the FCA are primarily caused by unavailability of beds downstream the care chain.

2. Investment in expensive and flexible CCU beds is more cost-effective than increasing normal care bed capacity. This is counterintuitive.

Results, general

1. Variation in Length of Stay (LOS) and fluctuation in arrivals result in large workload variations at nursing units. Hence, flexibility in staffing levels is critical for maintaining operational efficiency.

CCU beds \ NC beds	12	13	14	15	16	17	18	19
5	22,4	23,35	24,3	25,25	26,2	27,15	28,1	29,05
6	24,6	25,55	26,5	27,45	28,4	29,35	30,3	31,25
7	26,8	27,75	28,7	29,65	30,6	31,55	32,5	33,45
8	29	29,95	30,9	31,85	32,8	33,75	34,7	35,65
9	31,2	32,15	33,1	34,05	35	35,95	36,9	37,85
10	33,4	34,35	35,3	36,25	37,2	38,15	39,1	40,05
11	35,6	36,55	37,5	38,45	39,4	40,35	41,3	42,25
12	37,8	38,75	39,7	40,65	41,6	42,55	43,5	44,45
13	40	40,95	41,9	42,85	43,8	44,75	45,7	46,65
14	42,2	43,15	44,1	45,05	46	46,95	47,9	48,85
15	44,4	45,35	46,3	47,25	48,2	49,15	50,1	51,05

Servicelevel too low Blocking% >5% · Solution area Blocking% ~ 5% · Servicelevel too high Blocking% <5% · Optimal solution for minimum costs

TABLE Relation between costs and bed distribution

2. The group of patients with extended hospital stay is relatively small but must not be neglected. In terms of total resource consumption (TRC) this group is critical for overall performance of the care chain.

3. Substantial buffer capacity is required to maintain blocking percentage under given limit.

4. The LOS of health care processes is not a constant of nature. The 'waiting time' can be as high as 20-30% of total LOS. This is often due to chain effects.

5. Larger service systems can operate at higher utilization levels than smaller ones while attaining the same percentage of blocking. Hence, in general merging departments has a positive effect on operational efficiency due to the economies of scale.

6. The strong focus on utilization rates of hospital management is unrealistic and counterproductive.

Conclusion

Operational Research techniques were successfully used in describing emergency cardiac in-patient flow. Bottlenecks have been identified and the impact of fluctuation in demand has been described. The optimal bed capacity distribution over the care chain for cardiac patients has been calculated.

References

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