International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:12, No:3, 2018

A Discrete Event Simulation Model to Manage Bed Usage for Non-Elective Admissions in a Geriatric Medicine Speciality

Muhammed Ordu, Eren Demir, Chris Tofallis

***Abstract*—**Over the past decade, the non-elective admissions in the UK have increased significantly. Taking into account limited resources (i.e. beds), the related service managers are obliged to manage their resources effectively due to the non-elective admissions which are mostly admitted to inpatient specialities via A&E departments. Geriatric medicine is one of specialities that have long length of stay for the non-elective admissions. This study aims to develop a discrete event simulation model to understand how possible increases on non-elective demand over the next 12 months affect the bed occupancy rate and to determine required number of beds in a geriatric medicine speciality in a UK hospital. In our validated simulation model, we take into account observed frequency distributions which are derived from a big data covering the period April, 2009 to January, 2013, for the non-elective admission and the length of stay. An experimental analysis, which consists of 16 experiments, is carried out to better understand possible effects of case studies and scenarios related to increase on demand and number of bed. As a result, the speciality does not achieve the target level in the base model although the bed occupancy rate decreases from 125.94% to 96.41% by increasing the number of beds by 30%. In addition, the number of required beds is more than the number of beds considered in the scenario analysis in order to meet the bed requirement. This paper sheds light on bed management for service managers in geriatric medicine specialities.

***Keywords*—**Bed management, bed occupancy rate, discrete event simulation, geriatric medicine, non-elective admission.

I. Introduction

THERE has been a considerable increase in the number of admissions to the UK inpatient specialities. The number of non-elective admissions has increased approximately 32% in the period covering from April, 2008 to November, 2018 [1]. There exist many important reasons (e.g. increasing population, growing of elderly population, infectious diseases and so on) which cause increases in the hospital demands. Significant increase in hospitalization complicates the effective use of existing resources and this situation forces hospitals to work under intense pressure. Thus, hospitals will continue to struggle to plan and use their resources effectively.

A number of parameters such as longer length of stay increases bed occupancy rates in inpatient specialities, which have limited number of beds, and are the need for additional beds. Geriatric medicine speciality is one of the specialities that have longer length of stay. In addition, non-elective admissions can cause difficulties in bed management since their admission dates are not estimated previously. In this study, we develop a discrete event simulation model to provide better management of bed usage for non-elective admissions in a geriatric medicine speciality in the UK.

In the literature, there have been many studies of simulation applied to healthcare. A number of studies focused on modelling accident and emergency (A&E) departments and the development of A&Es' performances. For example, triage systems in A&E [2]-[4], patient classification and prioritization [5], [6], scenarios in order to develop performance of A&E [7]-[9]. In addition, performances were investigated in outpatient and inpatient departments and tested different scenarios to improve system performances [10]-[12]. Discrete event simulation modelling was used in capacity planning in healthcare systems [13]-[16]. A number of studies focused on bed occupancy rate and bed management [17]-[20].

Section II explains greater details related to discrete event simulation model. Section III discusses the results of case studies and scenarios. Section IV presents the conclusion of the study.

II. A Discrete Event Simulation Model

Discrete event simulation (DES) is a successful simulation method which simulates stochastic processes and has been widely used in the literature [21]. In other words, simulation is a reflection of any system and its features within a computer environment and is a method which enables user to run many experiments [22]. Inputs of the system including decision points, components of system, human resources are represented in the simulation. Therefore, a model is developed to capture reality within a computer simulation environment. Banks et al. [23] mentioned advantages of simulation as follows:

1) Systems are better understood.
2) Critical points such as components of the system and bottlenecks are determined.
3) Different scenarios can be tested in computer without affecting the real system and how these scenarios affect the performance of the system can be analysed.

In addition, Pidd [22] emphasized that simulation is cheaper than the real experiments and stated it is a method which can be used in long term projects.

Before building a simulation model, firstly, components of

Mr Muhammed Ordu, Dr. Eren Demir, and Dr. Chris Tofallis are with the University of Hertfordshire, Hertfordshire Business School, Hatfield, AL10 9EU (e-mail: m.ordu@herts.ac.uk, e.demir@herts.ac.uk, c.tofallis@herts.ac.uk).

a system are determined and their relationships among each other are conceptualized [22]. Fig. 1 shows the high-level flow diagram of a typical inpatient speciality which was verified by a number of directors in the hospital.

Inpatient process involves six steps: 1) Admission, 2) Pre-Assessment Process, 3) Theatre Process, 4) Daycase Process, 5) Inpatient Stay and 6) Discharge Process. According to the flow diagram, an inpatient speciality in the UK includes typically two types of admissions: elective and non-elective. Elective patients are referred by a healthcare provider to an inpatient speciality before admission date, whereas non-elective patients are admitted urgently to an inpatient speciality. In this study, patients, who are admitted to the geriatric medicine speciality, consist of non-elective patients (i.e. 99.33% of total number of patients) as shown in Table I.

TABLE I
TYPE OF ADMISSION IN THE STUDY

Types of Admissions	Percentage (%)
Elective	0.67%
Non-Elective	99.33%
Total	100.00%

Methods of admissions in the geriatric medicine speciality for non-elective admissions are presented in Table II [24]. For example, 95.82% of all admissions are referred by A&E department or dental casualty department. Then, patient is registered at the reception desk and a pre-assessment is conducted by a nurse. If patient does not need any operation or procedure, day-case process is carried out or patient is admitted to a ward and utilises a bed. Finally, patient is discharged in the following ways as shown in Table III [24]:

1) Discharged by a clinic
2) Self-discharge
3) Death
4) Other

TABLE II
METHOD OF ADMISSION IN THE STUDY

Methods of Admission	Percentage (%)
- A&E or dental casualty department of the Health Care Provider	95.82
- General Practitioner	2.34
- Consultant Clinic, of this or another Health Care Provider	0.14
- Other means	1.33
- Admitted post-partum	0.02
- Transfer of any admitted patient from other Hospital Provider other than in an emergency	0.35

TABLE III
METHOD OF DISCHARGE IN THE STUDY

Methods of Discharge	Percentage (%)
- Discharged on clinical advice or with clinical consent	91.55
- Self discharged, or discharged by a relative or advocate	1.10
- Died	7.35

By considering the pathway (see Fig. 1), the geriatric medicine speciality for non-elective admissions was better understood and the simulation model was developed by using Simul8 software.

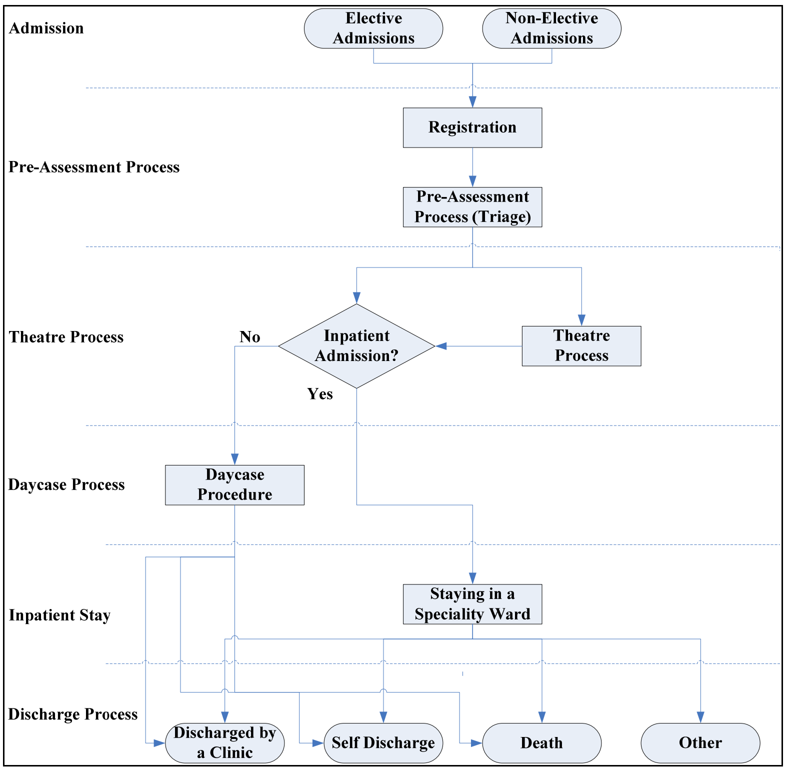

Fig. 1 General inpatient speciality pathway in high level

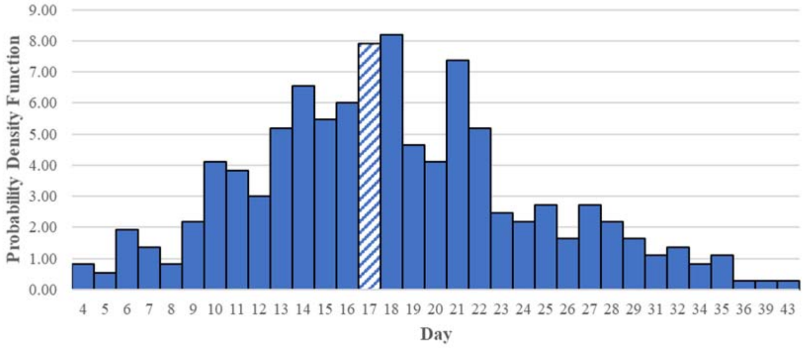

Fig. 2 Observed frequency distribution for Admissions

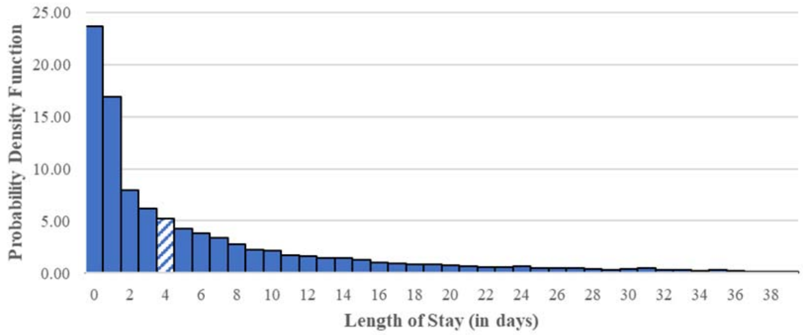

Fig. 3 Observed frequency distribution for length of stay

A. Data

The data, which are related to the non-elective admission and the length of stay, were obtained from the national hospital episodes statistics (HES) dataset in the UK. The data covering in the period (April, 2009 – January, 2013) were extracted from the national HES. Some inputs (e.g. patient admission date, demographic features, discharge date, etc.) were obtained from this dataset. Table IV shows the demographic features of patients and average age of patients is 72. The geriatric medicine speciality employs 111 beds in the hospital.

TABLE IV
DEMOGRAPHIC FEATURES OF THE SAMPLE IN THE STUDY

Demographic Features	Value
Gender	
- Male	44.33%
- Female	55.67%
Age	
- Average Age	72.44

We estimated the observed frequency distributions for admissions and length of stay. Fig 1 illustrates the probability density function used as the distribution input into the simulation model. For example, according to Fig. 2, a total of 17 patients are admitted to the speciality at 8% of total days in a year.

We used (1) to calculate length of stay for each patient in days. According to (1), length of stay for a patient is determined by taking difference between admission date and discharge date.

$$Length\ of\ Stay_i = Discharge\ Date_i - Admission\ Date_i \quad (1)$$

where $i = 1, \ldots, N$ patients.

According to Fig. 3, approximately 5% of patients stayed for 4 days in the Geriatric Medicine's ward.

B. Verification and Validation

The simulation model was verified by a number of directors in the hospital. The model was run for the period February, 2012 – January, 2013 and the simulation results (number of admission and average length of stay) were obtained for the validation of the model. We compared these simulation results against actual data. To do this, a paired t test as in (2) was used.

$$t_0 = \frac{\bar{d} - \mu_d}{S_d / \sqrt{K}} \quad (2)$$

where $\bar{d}$ represents average observed differences, μ_d is mean differences of actual data, S_d denotes the standard deviation of actual data and K is the total number of observations (or patients) [23].

$t_{\alpha/2,K-1}$ at 95% significance level is bigger than $|t_0|$ and therefore, the simulation model was validated. Table V gives all details related to the results of the validation test.

International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:12, No:3, 2018

TABLE V
THE RESULTS OF THE VALIDATION TEST

Parameters	$\lvert t_0 \rvert$	*t* Critical Value	Average Value (Monthly)	95% CI
NoA	0.60	2.20	564	(522, 606)
ALoS (in days)	1.11	2.20	7.54	(7.02, 8.06)

ALoS = Average Length of Stay, CI: Confidence Interval, NoA = Number of Admission.

C. Determination Replication Number and Warm up Period

We applied the Fixed-Sample-Size Procedure and Welch's Method [25] for calculating optimum replication number and warm up period, respectively. We determined the replication number as 10 replications and the warm-up period for the simulation model was determined as 4 months.

D. Model Outputs

We developed a DES model to better understand bed occupancy rates and required number of beds for projection using possible increases on demand. NHS takes into account (3) to calculate bed occupancy rate for an inpatient speciality or ward.

According to the Royal College of Psychiatrists, the average bed occupancy rate should be 85% [26]. Therefore, we considered 85% as our target level for the bed occupancy rate when determining required number of beds for the speciality. Equation (4) is used for calculating required number of beds.

$$Bed\ Occupancy\ Rate\ (\%) = 100x \frac{The\ number\ of\ occupied\ bed\ days}{Total\ number\ of\ beds\ x\ Number\ of\ days\ in\ the\ period} \quad (3)$$

$$Required\ Number\ of\ Bed = 100x \frac{The\ number\ of\ occupied\ bed\ days}{Target\ Level\ x\ Number\ of\ days\ in\ the\ period} \quad (4)$$

E. Case Studies and Scenario Analysis

In this study, we developed four case studies based on increased number of non-elective admissions in a Geriatric medicine speciality in a UK hospital. As shown in Table VI, Case 1 is the base model and represents the existing model of the Geriatric medicine speciality. Case 2, 3 and 4 involve 5%, 10% and 15% increase on demand, respectively. In addition, we take into account four scenarios regarding number of beds for each case study, which is related to increases on demand. Scenario 1 does not apply any changes on the model. Scenario 2, 3 and 4 employ 10%, 20 and 30% additional beds, respectively as presented in Table VII.

TABLE VI
CASE STUDIES IN THE STUDY

Case Studies	Percentages of Increase on Number of Non-Elective Admissions
Case 1	Base Model
Case 2	5%
Case 3	10%
Case 4	15%

TABLE VII
SCENARIOS IN THE STUDY

Scenarios	Percentage of Increase on Number of Beds
Scenario 1	Base Model
Scenario 2	10%
Scenario 3	20%
Scenario 4	30%

Table VIII gives the combination of the experimental analysis in the study. The rows represent possible increase on non-elective admissions and accordingly, the columns mean the considered increase on number of beds. Therefore, 16 experiments are carried out to better understand the future demand and capacity balance of the speciality.

TABLE VIII
COMBINATION OF THE EXPERIMENTAL ANALYSIS IN THE STUDY

	Scenarios			
Case Studies	(BM, BM)	(BM, 10%↑)	(BM, 20%↑)	(BM, 30%↑)
	(5%↑, BM)	(5%↑, 10%↑)	(5%↑, 20%↑)	(5%↑, 30%↑)
	(10%↑, BM)	(10%↑, 10%↑)	(10%↑, 20%↑)	(10%↑, 30%↑)
	(15%↑, BM)	(15%↑, 10%↑)	(15%↑, 20%↑)	(15%↑, 30%↑)

BM: Base Model

III. RESULTS AND DISCUSSIONS

We modelled an English Geriatric medicine speciality for non-elective admissions in order to capture its bed occupancy rates and required number of beds in the future. All results of the study are presented in Table IX and Figs. 4, 5. Firstly, all scenarios are analysed for Case 1. In the existing model, bed occupancy rate (BOR) is 125.94% which means the speciality runs overcapacity. The service managers have solved this problem by transferring the patients to other specialities' wards. Each scenario decreases the BOR for the speciality and Scenario 4 (30% increase on number of beds) provides a BOR with 96.41%.

The geriatric medicine speciality is not able to achieve less than 100% BOR in Case 2 and 3 despite all scenarios. Total number of beds is not sufficient in all case studies. The speciality does not achieve the expected BOR in the target level although the rate is less than 100% in the combination of Case 1 and Scenario 4.

Table IX illustrates the required number of beds and their confidence intervals (lower and upper values at 95%). These required numbers of beds are calculated by (4) through simulation outputs. In the current situation, the speciality needs 54 additional beds to achieve the 85% target level. This number of requirements goes up 26 more beds if 15% increase on demand takes place over the next 12 months. However, if Scenario 4 is applied in Case 4, 46 additional beds are enough as shown in Table X.

TABLE IX
BOR (%) AND CONFIDENCE INTERVALS FOR NON-ELECTIVE ADMISSIONS IN THE GERIATRIC MEDICINE SPECIALITY

Case Studies (Increased Demand)	Scenarios (Increased Number of Beds)			
	Scenario 1 (Base Model)	Scenario 2 (10% Increase)	Scenario 3 (20% Increase)	Scenario 4 (30% Increase)
Case 1 (Base Model)	125.94 (124.69, 127.18)	113.65 (112.53, 114.78)	104.32 (103.29, 105.35)	96.41 (95.46, 97.36)
Case 2 (5% Increase)	132.72 (131.59, 134.03)	119.77 (118.75, 120.96)	109.94 (109.00, 111.03)	101.60 (100.73, 102.60)
Case 3 (10% Increase)	139.33 (137.96, 140.71)	125.74 (124.50, 126.98)	115.42 (114.28, 116.56)	106.66 (105.61, 107.72)
Case 4 (15% Increase)	145.51 (144.27, 146.95)	131.31 (130.19, 132.61)	120.53 (119.51, 121.73)	111.39 (110.44, 112.49)

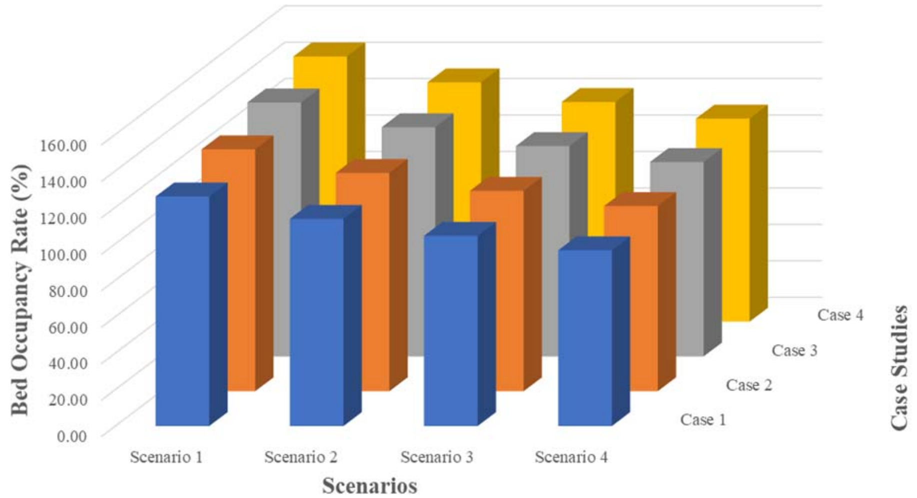

Fig. 4 Bed Occupancy Rates (%)

TABLE X
REQUIRED NUMBER OF BEDS AND CONFIDENCE INTERVALS FOR NON-ELECTIVE ADMISSIONS IN THE GERIATRIC MEDICINE SPECIALITY

Case Studies (Increased Demand)	Scenarios (Increased Number of Beds)			
	Scenario 1 (Base Model)	Scenario 2 (10% Increase)	Scenario 3 (20% Increase)	Scenario 4 (30% Increase)
Case 1 (Base Model)	54 (52, 56)	42 (40, 44)	31 (29, 33)	20 (18, 22)
Case 2 (5% Increase)	63 (61, 65)	51 (49, 53)	40 (38, 42)	29 (27, 31)
Case 3 (10% Increase)	71 (70, 73)	59 (58, 61)	48 (47, 50)	37 (36, 39)
Case 4 (15% Increase)	80 (78, 81)	68 (68, 69)	57 (55, 58)	46 (44, 47)

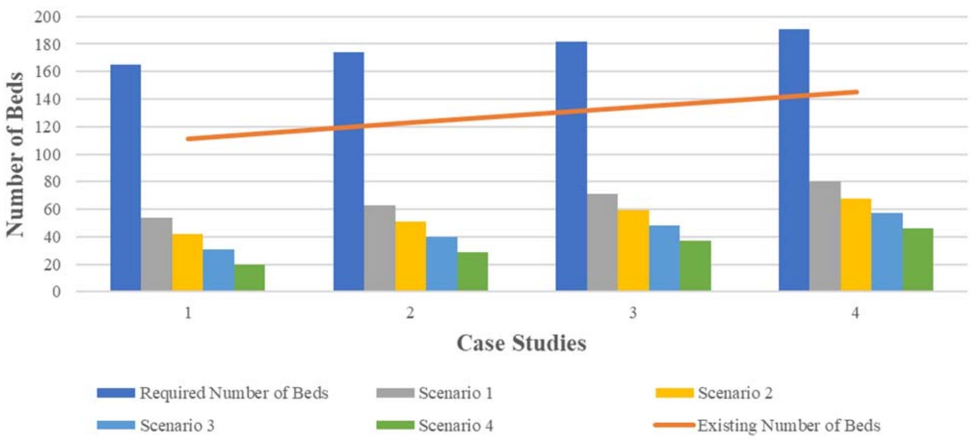

Fig. 5 Existing and Required Number of Beds

IV. Conclusion

Over the past decade, the non-elective admissions in the UK have increased by approximately 32%. Taking into account limited resources (i.e. beds), the related service managers are obliged to manage their resources effectively due to the non-elective admissions which are mostly admitted to inpatient specialities via A&E departments. This paper presents a simulation study to determine BOR and the required number of beds in an English Geriatric medicine speciality for non-elective admissions. Experimental results given in Figs. 5, 6 and Tables IX, X were generated by a validated simulation model. All these results are an anticipation for the future of the geriatric medicine speciality by obtaining its BOR and required number of beds. Therefore, this study allows better management for bed usage in the geriatric medicine specialities and provides an insight into bed requirements in the future. This means that service managers will be able to investigate how many beds the geriatric medicine speciality might require in the future for better services.

Acknowledgment

Muhammed Ordu would like to thank the Ministry of National Education (Republic of Turkey) due to the scholarship for postgraduate study abroad.

References

[1] National Health Service England (2018). Bed Availability and Occupancy. https://www.england.nhs.uk/statistics/statistical-work-areas/bed-availability-and-occupancy/, accessed 11 February 2018.
[2] L. G. Connelly and A. E. Bair, "Discrete event simulation of emergency department activity: a platform for system-level operations," *Academic Emergency Medicine*, vol. 11, no. 11, pp. 1177–1185, Nov. 2004.
[3] M. Gunal and M. Pidd, "Understanding accident and emergency department performance using simulation," in *Proc. 39th Winter Simulation Conference*, Monterey, 2006, pp. 446–452.
[4] D. J. Medeiros, E. Swenson and C. DeFlitch, "Improving patient flow in a hospital emergency department," in *Proc. 41st Winter Simulation Conference*, Miami, 2008, pp. 1526–1531.
[5] A. Ozdagoglu, O. Yalcinkaya and G. Ozdagoglu, "Ege Bölgesindeki bir araştırma ve uygulama hastanesinin acil hasta verilerinin simüle edilerek analizi (A Simulation Based Analysis of a Research and Application Hospital Emergency Patient Data in Aegean Region)," *İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi*, vol. 8, no. 16, pp. 61–73, Dec. 2009.
[6] A. Virtue, J. Kelly and T. Chaussalet. "Using simplified discrete-event simulation models for health care applications," in *Proc. 44th Winter Simulation Conference*, Phoenix, 2011, pp. 1154–1165.
[7] C. Duguay and F. Chetouane, "Modeling and improving emergency department systems using discrete event simulation," *Simulation*, vol. 83, no. 4, pp. 311–320, Apr. 2007.
[8] L. Y. Meng and T. Spedding, "Modelling patient arrivals when simulating an accident and emergency unit," in *Proc. 41st Winter Simulation Conference*, Miami, 2008, pp. 1509–1515.
[9] J. Wang, J. Li, K. Tussey and K. Ross, "Reducing length of stay in emergency department: A simulation study at a community hospital," *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transaction*, vol. 42, no. 6, pp. 1314–1322, Nov. 2012.
[10] F. C. Coelli, R. B. Ferreira, R. M. V. R. Almeida and W. C. A. Pereira, "Computer simulation and discrete-event models in the analysis of a mammography clinic patient flow," *Computer Methods and Programs in Biomedicine*, vol. 87, no. 3, pp. 201–207, Sep. 2007.
[11] P. T. VanBerkel and J. T. Blake, "A comprehensive simulation for wait time reduction and capacity planning applied in general surgery," *Health Care Management Science*, vol. 10, no. 4, pp. 373–385, Dec. 2007.
[12] A. Komashie, A. Mousavi and J. Gore, "Using discrete event simulation (DES) to manage theatre operations in healthcare: An audit-based case study," in *Proc. 10th International Conference on Computer Modeling and Simulation*, Cambridge, 2008, pp. 360–365.
[13] J. Bowers and G. Mould, "Ambulatory and orthopaedic capacity planning," *Health Care Management Science*, vol. 8, no. 1, pp. 41–47, Feb. 2005.
[14] S. R. Levin, R. Dittus, D. Aronsky, M. B. Weinger, J. Han, J. Boord and D. France, "Optimizing cardiology capacity to reduce emergency department boarding: a system engineering approach," *American Heart Journal*, vol. 158, no. 6, pp. 1202–1209, Dec. 2008.
[15] N. Ahmad, N. A. Ghani, A. A. Kamil, R. M. Tahar and A. H. Teo, "Evaluating emergency department resource capacity using simulation," *Modern Applied Science*, vol. 6, no. 11, pp. 9–19, Nov. 2012.
[16] E. Demir, M. M. Gunal and D. Southern, "Demand and capacity modelling for acute services using discrete event simulation," *Health Systems*, pp. 1–8, Mar. 2016.
[17] P. Landa, M. Sonnessa, E. Tanfani and A. Testi, "A discrete event simulation model to support bed management," in *Proc. 4th International Conference on Simulation and Modeling Methodologies, Technologies and Applications*, Vienna, 2014, pp. 901–912.
[18] A. Kumar and J. Mo, "Models for bed occupancy management of a hospital in Singapore," in *Proc. The 2010 International Conference on Industrial Engineering and Operations Management*, Dhaka, 2010, pp. 242–247.
[19] K. S. Mathews and E. F. Long, "A conceptual framework for improving critical care patient flow and bed use," *Annals of the American Thoracic Society*, vol. 12, no. 6, pp. 886–894, Jun. 2015.
[20] E. Martin and K. Haugene, "Proposals to reduce over-crowding, lengthy stays and improve patient care: Study of the geriatric department in Norway's largest hospital," in *Proc. 35th Winter Simulation Conference*, New Orleans, 2003, pp. 1876–1881.
[21] M. M. Gunal, "A guide for building hospital simulation models," *Health Systems*, vol. 1, no. 1, pp. 17–25, Jun. 2012.
[22] M. Pidd, *Computer Simulation in Management Science*. Chichester: John Wiley and Sons, 2004, pp. 3–4, 35–36.
[23] J. Banks, J. S. Carson II, B. L. Nelson and D. M. Nicol, *Discrete-Event System Simulation*. New Jersey: Pearson, 2005, pp. 5–6, 374–378.
[24] NHS Digital (2017), Hospital Data Dictionary: Admitted Patient Care. Accessed on 5th February 2018. Available at: http://content.digital.nhs.uk/media/25188/DD-APC-V10/pdf/DD-APC-V10.pdf.
[25] A. M. Law and W. D. Kelton, *Simulation Modeling and Analysis*. New York: McGraw-Hill, 2000, pp. 505–515, 519–525.
[26] National Health Service England (2016). Bed Occupancy Rate. https://www.nhs.uk/Scorecard/Pages/IndicatorFacts.aspx?MetricId=8120, accessed 11 February 2018.