STROKE REHABILITATION TREATMENT LINE PERFORMANCE: DISCRETE-EVENT SIMULATION LESSONS FROM QUEEN ELIZABETH 1 HOSPITAL

Research-in-progress

Syed Nasirin
Faculty of Computing & Informatics, Universiti Malaysia Sabah, Labuan International Campus, Labuan, Malaysia

Fatimah Ahmedy
Faculty of Medicine & Health Sciences, Universiti Malaysia Sabah, Kota Kinabalu, Malaysia

Syahiskandar Sybil Shah
Department of Rehabilitation Medicine, Queen Elizabeth Hospital, Ministry of Health Malaysia

Abstract

The application of Discrete-Event Simulation (DES) modelling in Malaysia is gradually increasing with the aim of decreasing inpatient treatment lines' at public funded hospitals. Major premise behind this application is that such simulation models may be exploited in monitoring stroke treatment flows. The objective of this research-in-progress paper is to demonstrate the feasibility of applying DES modelling in understanding treatment line performance of stroke patients in a general inpatient rehabilitation ward at a major tertiary hospital in Kota Kinabalu, Sabah.

Keywords: Treatment Line Performance, Discrete-Event Simulations, Stroke Rehabilitation

---

We would like to thank the Director General of Health, Malaysia for the permission to publish this paper.

1.0 Introduction

Delivering inclusive, multidisciplinary rehabilitation interventions for inpatient care pathway has been shown to reduce death, dependency and institutionalisation among stroke patients (Bal, Ceylan & Tacoglu, 2017; Okazaki & Fatar, 2014). Provision of early inpatient rehabilitation in stroke improves final outcome, both neurologically and functionally. Many studies have argued that the best window period for early rehabilitation intervention is within the first 3-6 months post-stroke. Inpatient rehabilitation care is thus important and highly demanded in the background of increasing number of stroke survivors (Gul & Celik, 2018).

Multidisciplinary rehabilitation team members, therapeutic interventions and equipment are three major components of inpatient rehabilitation care. Key members include rehabilitation physicians, physiotherapists, occupational therapists, speech and language therapists, and nurses. In the state of Sabah, Malaysia, there is one dedicated inpatient Rehabilitation Ward catered for the whole state with multidisciplinary team members providing therapeutic interventions. As the ward is located in the largest tertiary hospital in Sabah, it accepts admission of stroke survivors within acute period (within one week post-stroke event). Given the high levels of uncertainty with such acute admissions to the inpatient Rehabilitation Ward, continuous change can severely affect patient outcomes, hence the need to understand the utilisation potentials of Discrete-Event Simulations (DES) modelling as a predicting tool in running the ward.

The obtainability of special-purpose simulation languages such as DES, of massive computing capabilities at decreasing cost per operation, and of advances in simulation methodologies have made simulation one of the most extensively used and acceptable tools in treatment flow planning and analyses (Soremekun, Takayesu & Bohan, 2011). Established applications of DES have been seen increasingly in the emergency department (ED), a department with high numbers of patients and multiple events occurring at the same time. Such developments are seen growing significantly in both developing and developed nations for the last ten years (Ahmed & Alkhamis, 2009; Ferreira, Coelli, Pereira & Almeida, 2008). Some of the applications of DES in ED include:

- Reducing emergency department overcrowding (Soremekun, Takayesu & Bohan, 2011).
- Verification of lean improvement for emergency room process (Yi, George, Paul & Lin, 2010).

In short, the general premise behind these studies is that such simulation models may be used to support the management of a department that consistently faces high overcrowding. In general, DES could be used for following purposes:

- The understanding gained during the designing of simulation model could be of value towards suggesting enhancement in the rehabilitation care pathway under investigation.
- Simulations could be used to test new rehabilitation policies prior to implementation, so as to formulate for what might happen.
- Simulation models designed for rehabilitation training make learning possible, without disrupting on-the-job instructions.
- Simulating different competencies for a rehabilitation equipment/device such as ultrasound modality could help determine its requirements.
- Clinical and departmental changes could be simulated, and the consequence of these alterations on the simulation model's behaviour could be observed.
- Changing simulation inputs and observing the resulting outputs could provide valuable insights about which variables are important and how variables interact.
- Animation could show a rehabilitation treatment system in simulated operation so that the proposal could be visualised.

Many studies in the developed nations have shown the practicality of applying DES modelling as an instrument in management decision-making, especially involving systems that incorporate treatment lines including hospital wards (Ghanes et al., 2014). However, the core limitation of these studies was that they are contextual in nature. There is thus a need for those in other regions such as Malaysia to confirm (or falsify) what has been found in the previous studies.

The study of treatment lines is the primary objective of DES with the aims of defining certain parameters such as the length of the queue, that are relevant in circumstances whereby the state of the system changes at discrete instants of time. For this reason, constructing DES modelling as a solution towards problems with treatment line system in public funded hospitals is increasing in the past decade targeted to enhance quality of healthcare provision (Soremekun, Takayesu & Bohan, 2011). Nevertheless, development of DES with specific aims in investigating patient treatment line performance and treatment flow as an effort to decrease waiting lines of rehabilitation ward to an acceptable level has not been explored in great depth in Malaysia.

This research-in-progress paper intends to explore the feasibility of constructing a DES modelling to understand stroke patient treatment line performance and treatment flow in a general inpatient rehabilitation ward at a tertiary hospital in Kota Kinabalu, Malaysia. The primary objective of this simulation approach is aimed at ascertained the length of the queue (i.e. length of stay, length of treatments' duration).

2.0 Literature Review

Stipulation of rehabilitation interventions is influenced by availability of therapists and equipment. For example, interruptions in subsequent sessions with team members are anticipated as a result of under-manned staff in providing scheduled therapy to patients. It is thus imperative to appreciate inpatient treatment flow for stroke rehabilitation care and such objective could be explicitly observed through DES modelling. DES offers a credible method for assessment of capacity in a treatment line system, therefore creating ways in connecting industrial process reasoning towards healthcare improvement approaches. DES outcomes are analysed by numerical methods (i.e., considerable changes in the variables of system state are linked with events occurring at discrete time instances). Numerical methods use computational procedures to "solve" the mathematical models in DES modelling.

Moreover, presence of shifts in any of the points throughout the inpatient treatment flow could be detected with DES modelling. Such shifts may cause starvation and bottleneck effects that further delay therapeutic sessions (New et al., 2013). In short, major advantageous of DES modelling is that it integrates variations of patients' intricacy, rates of admission and delayed discharges (i.e., variations of patients' care pathway are expected based on each individuals). However, most DES modelling studies were observed in developed countries that possessed advanced healthcare system. In a developing country like Malaysia, a preliminary work in exploring feasibility of constructing DES modelling as an attempt to explore determinants influencing long waiting time was developed at a tertiary hospital emergency & trauma department in Sabah state (Gan, Nasirin, Awang Piut, Kheng, & Azura, 2017).

Particularly for stroke inpatient rehabilitation care pathway, the development of simulation models generally remains limited. Intuition and simple average based estimates are routine practice in estimating treatment line performance. However, these methods lead to underestimating capacity requirements for staffing and equipment. Majority of nationally governed and public funded hospitals in Malaysia consist of general wards (i.e. wards that do not cater for subspecialties) and most of inpatient rehabilitation wards in the country accommodate various conditions such as stroke, spinal cord injury and traumatic brain injury. Hence, appreciating inpatient treatment flow within the local setting signifies the importance of contextual factors in provision of rehabilitation care.

DES modelling outcomes may be manipulated to improve ward capacity management that heavily influenced by the governing hospital policy and performance indicators, for instance bed occupancy rate (BOR) and length of stay (Kortbeek, Braaksma, Smeenk, Bakker & Boucherie, 2015). For inpatient rehabilitation, length of stay is guided by therapeutic goals determined at admission and such policies and indicators may potentially affect quality of care, patients' progress and discharge.

3.0 Case Background

The inpatient Rehabilitation Ward is located at the largest tertiary hospital in Kota Kinabalu, Sabah. Admission to the ward is based upon non-pre-emptive priority and sources of admission are either directly from outpatient rehabilitation clinic and non-rehabilitation wards, or from other hospitals. The ward accommodates 26 beds and provision of rehabilitation services in this facility is governed by the needs to meet the minimum Bed Occupancy Rate (BOR) of 70%.

4.0 Research and Simulation Development Methodologies

Simulation development methodologies consist of 5 main steps that have and will be applied in developing both the research and simulations models.

4.1 Problem formulation and overall project plans

Treatment line topics essential for focus group interviews were developed following an agreement with the studied hospital focusing on stroke patients admitted to the Rehabilitation Ward. Topics were delivered to the ward in advance, allowing the model users (i.e., rehabilitation ward team members) sufficient time preparing for the interview. The research and simulation objectives were jointly established between the model users and the simulation modellers. Overall project plans and the model users involvement are two major key factors that influence the success at this stage. Enhanced likelihood of strong implementation is anticipated if the model users are heavily involved in the entire model-building process and appreciate the nature and functions of the DES model developed.

4.2 Model conceptualisation

The primary objective of the simulation exercise is to understand stroke patients' treatment performance in the ward. For this purpose, two DES models are considered; 1) a single-server service node with immediate feedback and 2) a simple inventory system with delivery lag. The secondary DES objective is to formulate the treatment line discipline. To achieve these objectives, simulation modellers undertook non-participatory field observations and in-depth face-to-face focus group discussions with the model users. The main goal of focus group discussion is to develop an overall picture of the treatment line flow or commonly known as an 'As-Is' simulation model. Table 1 and Table 2 further illustrate admission to discharge tabulated tasks, and planned task on daily basis respectively, of a stroke patient in the rehabilitation ward.

Step	Task/ Interventions	In-charged personnel	Time taken to complete task	Dependent
1	Admission clerking (once)	Nursing staff	30mins	
2	Admission clerking (once)	Medical officers	60mins	
3	Medical officer ward round – daily basis	Medical officers	10mins/day for 7x/week = 140mins	
4	Specialist round – daily basis	Rehabilitation Medicine Specialist	10mins/day for 5x/week = 100mins	
5	Medications (3x/day)	Nursing staff	15mins/day = 210mins	
6	Physical therapy session	Physiotherapist	30mins/day for 5x/week = 300mins	Inpatient gym
7	Occupational therapy session	Occupational therapist	60mins/day for 5x/week = 600mins	Inpatient gym
8	Caregiver training	Caregiver	60mins/day for 7x/week = 840mins	
9	Nursing & hygiene care – (vitals monitoring 6x/day, hygiene care 5x/day)	Nursing staff	6x5mins/day + 5x20mins/day = 1820mins	
10	Discharge preparation (once)	Medical officers	60mins	

Table 1: Tabulated task from admission to discharge (inpatient stay for 14 days)

Time	Task/ Interventions	In-charged healthcare personnel	Time taken to complete task	Dependent
2am	Vitals monitoring	Nursing staff	5mins	
6am	Vitals monitoring	Nursing staff	5mins	
6.10am	Bladder & hygiene care	Nursing staff	20mins	
7.30am	Medication (morning)	Nursing staff	5mins	
8am	Medical officer ward round	Medical officers	10mins	
9am	Specialist ward round	Rehabilitation specialist	10mins	
9.15am	Physical therapy session	Physiotherapist	30mins	Inpatient gym
10am	Vitals monitoring	Nursing staff	5mins	
10.10am	Bladder & hygiene care	Nursing staff	20mins	
11.00am	Wound care	Nursing staff	20mins	
11.30am	Caregiver training	Caregiver	30mins	
1.30pm	Medication (afternoon)	Nursing staff	5mins	
2.00pm	Vitals monitoring	Nursing staff	5mins	
2.10pm	Bladder & hygiene care	Nursing staff	20mins	
2.30pm	Occupational therapy session	Occupational therapist	60mins	Inpatient gym
4.00pm	Caregiver training	Caregiver	30mins	
6pm	Vitals monitoring	Nursing staff	5mins	
6.10pm	Bladder & hygiene care	Nursing staff	20mins	
9.30pm	Medication (nigh time)	Nursing staff	5mins	
10pm	Vitals monitoring	Nursing staff	5mins	
10.30pm	Bladder & hygiene care	Nursing staff	20mins	

Table 2: Tabulated task (planned) on daily basis (weekdays)

4.3 Data collection and model translation

Based upon non-participatory observations and face-to-face interviews with the model users, triangulation of primary data collected offers substantial information on the presence of bottlenecks and starvations for constructing more realistic simulation model. These data collection methods are mutually supportive for understanding the model users' 'worldview', permitting an in depth observation of the bottlenecks and starvations areas.

4.4 Verification and validation

Verification pertain to the computer program has been prepared for the simulation model while validation will be measured through the calibration of the simulation model, an iterative process of comparing the simulation model against actual system behaviour.

4.5 Model Implementation

Multiple runs of 'To-Be' models shall be developed to properly estimate the set key performance index of the ward, particularly for the stroke inpatient rehabilitation treatment flow designs. The success of the implementation phase depends on how well the previous steps have been performed.

5.0 Summary

DES modelling should be the preferred tool for problems solving, particularly involving systems with inpatient treatment line such as rehabilitation of acute stroke in a highly demanded tertiary hospital. DES may not be the only solution for the treatment line challenges faced by the ward, but DES assists in evaluating such challenges. DES modelling is not a total answer to the waiting line bottleneck and starvation challenges faced, but just a proposed simulation model that is innately appealing to many medical doctors and hospital administrators as it has a strong aptitude to fully mimic what happens in a real treatment line system.

Moreover, with significant levels of uncertainty, continuous change and where marginal operational understanding can affect patient outcomes, it is vital to let the department test changes in a risk and cost-free situation to identify and implement the most practical solutions. We have proven that the simulation results not just revealed the performance of the existing treatment lines, but also helped the department to objectively visualise the effect on the performance of the treatment lines as result of addition or subtraction of manpower and other related resources. Consequently, a better projection and allocation of staffing can be made in advance.

References

Afrane S, Appah A. Queuing theory and the management of waiting-time in hospitals: The case of Anglo Gold Ashanti Hospital in Ghana. International Journal of Academic Research in Business and Social Sciences 2014; 4(2): 34.

Ahmed, M. A., & Alkhamis, T. M. (2009). Simulation optimization for an emergency department healthcare unit in Kuwait. *European journal of operational research*, *198*(3), 936-942.

Bal, A., Ceylan, C., & Taçoğlu, C. (2017). Using value stream mapping and discrete event simulation to improve efficiency of emergency departments. *International Journal of Healthcare Management*, *10*(3), 196-206.

Banks J. Handbook of simulation: principles, methodology, advances, applications, and practice. John Wiley & Sons; 1998.

Ferreira, R. B., Coelli, F. C., Pereira, W. C., & Almeida, R. M. (2008). Optimizing patient flow in a large hospital surgical centre by means of discrete-event computer simulation models. *Journal of evaluation in clinical practice*, *14*(6), 1031-1037.

Gan, S., Nasirin, S., Awang Piut, S., Kheng, C. P., Bahar, A., & Azura, I. (2017). Discrete-Event Simulation Modelling Trials in Government Hospital: Preliminary Evidence from the Women and Children Hospital Sabah. *In Proceedings of the Pacific-Asia Conference on Information Systems (PACIS) 2017.*

Ghanes, K., Jouini, O., Jemai, Z., Wargon, M., Hellmann, R., Thomas, V., & Koole, G. (2014, December). A comprehensive simulation modelling of an emergency department: A case study for simulation optimization of staffing levels. In *Proceedings of the 2014 Winter Simulation Conference* (pp. 1421-1432). IEEE Press.

Gul, D. M., & Celik, E. (2018). An exhaustive review and analysis on applications of statistical forecasting in hospital emergency departments. *Health Systems*, 1-22.

Günal MM, Pidd M. Discrete event simulation for performance modelling in health care: a review of the literature. Journal of Simulation 2010; 4(1): 42-51.

Kortbeek, N., Braaksma, A., Smeenk, F. H., Bakker, P. J., & Boucherie, R. J. (2015). Integral resource capacity planning for inpatient care services based on bed census predictions by hour. *Journal of the Operational Research Society*, *66*(7), 1061-1076.

New, P. W., Racp, F., Stockman, K., Cameron, P. A., Olver, J. H., & Stoelwinder, J. U. (2015). Computer simulation of improvements in hospital length of stay for rehabilitation patients. *Journal of Rehabilitation Medicine*, *47*(5), 403-411.

Okazaki, S., & Fatar, M. (2014). The role of national guidelines while staying abroad with an acute stroke. *Cerebrovascular Diseases*, *38*(3), 161-162.

Soremekun, O. A., Takayesu, J. K., & Bohan, S. J. (2011). Framework for analysing wait times and other factors that impact patient satisfaction in the emergency department. *The Journal of Emergency Medicine*, *41*(6), 686-692.

Yi, P., George, S. K., Paul, J. A., & Lin, L. (2010). Hospital capacity planning for disaster emergency management. *Socio-Economic Planning Sciences*, *44*(3), 151-160.