Performance evaluation of a chemotherapy treatment unit through simulation

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Abstract

This paper presents a case study of a cancer center. A simulation model of the chemotherapy department was developed to model, analyze and improve the patient flow by reducing the patients' lengths of stay in the center. Simulation experiments show that the long waiting times are due to the variability in the patients' arrival, creating peaks in workload.

Keywords
Oncology, Chemotherapy, Discrete Event Simulation

1. Introduction

In recent years, healthcare systems have experienced many changes to meet the growing demand for medical services and the rising costs. Such is the case of cancer care centers. Cancer figures among the main cause of mortality in the world and the second main cause in Morocco, according to the Moroccan Ministry of Health. Statistics tell us that the number of cancer cases will continue to increase over the next few years until 70%, WHO (2014).

The complexity of cancer treatment and management lies in the rapid increase in cancer incidence rates, the diversity of cancer types and treatments, and the limited availability of human and material resources. The Hospital Cheikh Zaid Cancer center (HCZ) in Rabat provides treatment services including chemotherapy, radiation therapy, and surgical oncology. The chemotherapy department is facing problems of long patient waiting times and increased staff turnover due to high workload. A simulation model of the chemotherapy department was developed to analyze and improve the patient flow at HCZ Cancer center by reducing the patients' lengths of stay in the center.

2. Literature

Simulation is used to describe and analyze processes, test solutions and support decision making for problems. In healthcare, simulation has been applied for patient flow, healthcare costs, hospital operations, and treatment outcomes, according to Barett et al. (2008). Many studies have combined simulation and optimization to provide optimal solutions to complex healthcare problems. For example, Woodall et al. (2013) combined simulation with mathematical optimization to reduce waiting times by proposing an optimal nurse scheduling. Baesler et al. (2001) used simulation and metaheuristic to find the best combination of control variables that optimize the performance of the system.

In oncology, simulation is used to find the best scheduling and planning method of resources (nurses and beds), scheduling patients' arrival, and test the impact of different scenarios on performance (waiting times, resources utilization..).

Many simulation studies treated the chemotherapy treatment processes only without considering the oncologist consultation. For example, Woodall et al. (2013) developed a simulation model with the purpose of estimating patient waiting time and resources utilization. Then, an optimal nurse schedule was proposed using Mixed Integer Programming (MIP) modeling. Changes in nurse shifts starting times through simulation optimization combination reduced significantly waiting times. Huggins et al. (2014) first determines an optimal schedule reducing waiting times and maximizing resource (chairs, nurses, pharmacists) utilization while balancing the workload, using a MIP model, and then uses simulation to validate the mathematical model and compare actual and proposed scheduling. In order to reduce the patient's waiting time and increase the number of served patients, Ahmed et al. (2011) developed a scheduling template for patients' arrival based on the simulation of different scenarios. Masselink et al. (2011) and Godefridus et al. (2002) tested the impact of chemotherapy medicines preparation policy (make for stock or make on order) on waiting times and costs of wasted drugs, using simulation.

Other simulation studies focused on the use of simulation for both chemotherapy consultation and treatment settings. Laurainne et al. (2016) combined simulation and Lean manufacturing approaches to reduce waiting time in an outpatient cancer clinic. Baesler et al. (2001) used simulation and optimization with genetic algorithm to find the best combination of control variables that minimize waiting time and closing time while maximizing chairs and nurses utilization. A simulation model was created in Sepulveda et al. (1999) and Liang et al. (2014) to analyze the patient flow through the cancer center and evaluate the impact of many alternatives on process improvement. Sadki1 et al. (2010) used simulation to test the effectiveness of the proposed patient assignment strategy, for balanced bed utilization.

There are studies that used optimization methods to solve scheduling and planning problems. Mazier et al. (2010) proposed a working period planning of physicians for a balanced workload, based on Integer Linear Programming (ILP) model. Sadki2 et al. (2010) determine the working periods of oncologists to balance bed capacity requirements, based on a MIP model. Wineke et al. (2010) applied a business approach and Kaizen in oncology to improve the efficiency of the chemotherapy unit.

Table 1 summarizes the reviewed papers dealing with simulation modeling in chemotherapy. In our study, we developed a discrete event simulation (DES) model of the patient flow through chemotherapy consultation and treatment areas of the center.

3. Description of the system

The Hospital Cheikh Zaid (HCZ) is one of the hospitals in Rabat, the Capital of Morocco. The cancer treatment center of HCZ was built in 2013 with different services including chemotherapy treatment, radiation therapy, oncology pharmacy, laboratory, and medical consultations. Figure 1 shows the patients' flow processes that takes place at the cancer center. The whole system was studied but only chemotherapy processes for patients arriving to the cancer center will be modeled and simulated.

Table 1: Papers dealing with chemotherapy operations problems

Reference	Scope	Methods
Woodall et al. (2013)	Chemotherapy treatment	DES, MIP, Optimization
Laurainne et al. (2016)	Chemotherapy treatment + Consultations	DES, Kaizen
Baesler et al. (2001)	Chemotherapy treatment + Consultations	DES, Genetic algorithm
Sepulveda et al. (1999)	Chemotherapy treatment + Consultations	DES
Huggins et al. (2014)	Chemotherapy treatment	DES, MIP, Optimization,
Ahmed et al. (2011)	Chemotherapy treatment	DES
Liang et al. (2014)	Chemotherapy treatment+ Consultations	DES, Mathematical programming model
Godefridus et al. (2002)	Chemotherapy treatment	DES
Masselink et al. (2011)	Chemotherapy treatment	DES, Stochastic modeling, Markov Chain
Sadki1 et al. (2010)	Chemotherapy treatment + Consultations	Simulation, MIP
Wineke et al. (2010)	Chemotherapy treatment	Lean thinking, Benchmarking
Mazier et al. (2010	Chemotherapy treatment + Consultations	ILP
Sadki2 et al. (2010)	Chemotherapy treatment + Consultations	MIP ,Heuristic

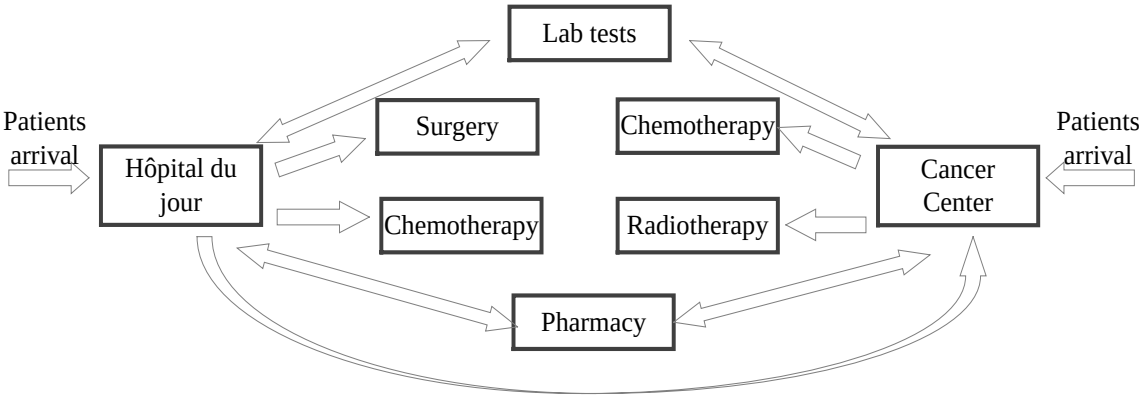

Figure 1: Patient flow among the HCZ Cancer center

3.1. The chemotherapy treatment process at HCZ

The chemotherapy treatment is delivered according to the processes in the Unified Modeling Language (UML) activity diagram in figure 2. The process begins by patient registration at the reception for a first visit. Otherwise, receptionists perform the patient check-in process, goes to the waiting room until a physician and exam room become available. Consultations usually last between 10 and 30 min. In the case of medical decision for chemotherapy, the doctor prescribes the treatment plan.

Patient arrives at the treatment area bringing blood test results, carried out at the hospital or in an external laboratory. Before each chemotherapy session, blood test is required. Treatment is given in chairs, and could last

between 60 to 360 minutes. Chemotherapy treatment administration is assured by nurses through installing patient in chairs, premedication and treatment infusion.

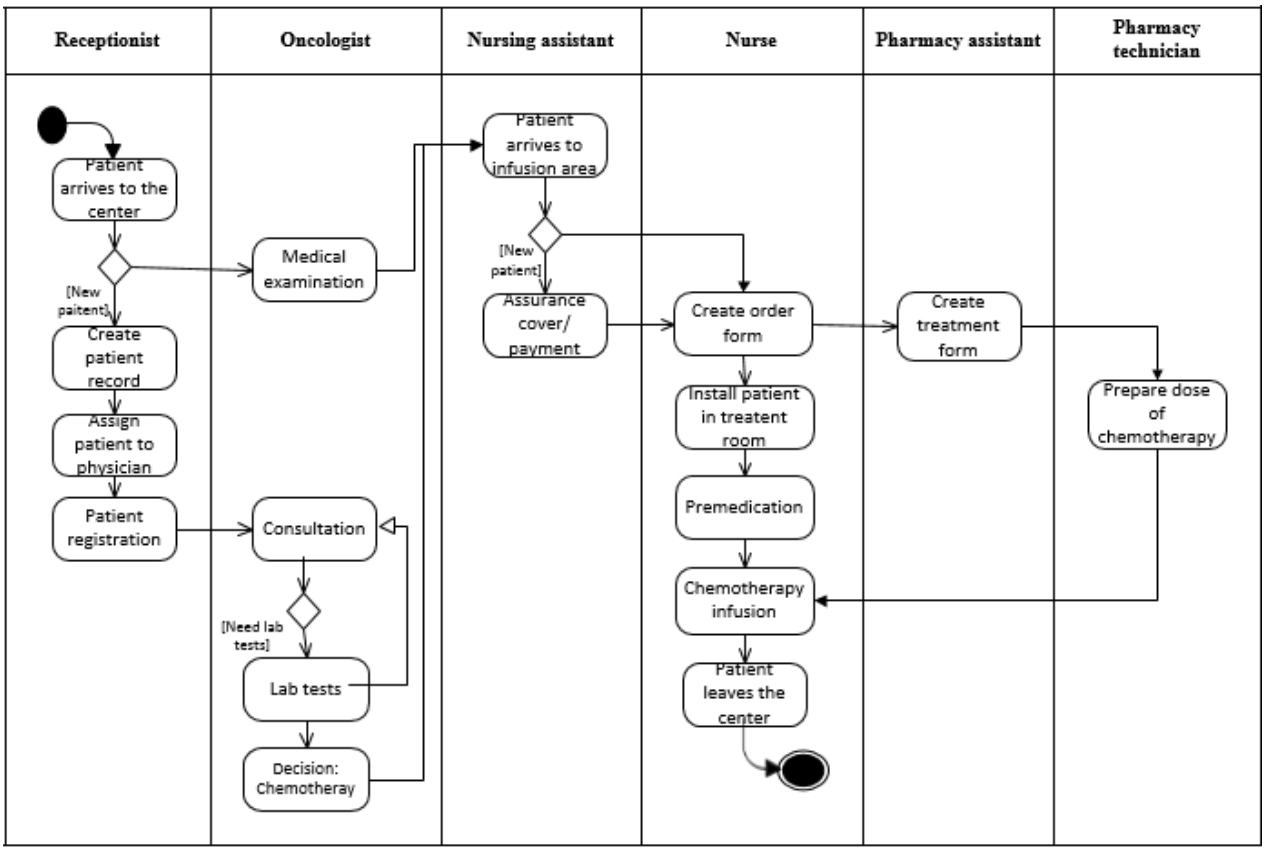

Figure 2: UML activity diagram of the chemotherapy treatment process

Medical consultations take place at the first floor of the center, where patients go to visit an oncologist for consultation or control. Three consultation rooms and waiting room are located in the same area. Patients receive chemotherapy treatment in the infusion treatment area which is located at the second floor. The infusion area has 9 chairs and 6 individual rooms with beds where patients get their treatment. Chemotherapy treatments are prepared by the oncology pharmacy in the preparation room. Pharmacy and preparation room are located in the same second floor.

4. Data collection

ARENA Rockwell Software Student Version was used to build the simulation model. Data were collected through the information system, direct observations, and interviews with oncologists, head nurse, and pharmacist.

4.1. Time distributions

From the historical data, we estimated the probability distributions using ARENA Input Analyzer. Due to a lack of available data, some distributions are determined based on time studies and interviews. Table 2 summarizes the probability distributions selected for the simulation input.

Table 2: Probability distributions included in the simulation model

Process	Location	Distribution
Consultation patient arrival	Consultation area	7 + ERLA(0.552 , 7)
Registration	Consultation area	Uniform (10, 15)
Consultation	Consultation area	Uniform (10, 30)
Chemotherapy patient arrival	Infusion Area	7 + LOGN(3.18 , 1.51)
Payment	Infusion Area	Uniform (10, 60)
Order form creation	Infusion Area	Uniform (5, 10)
Treatment form creation	Infusion Area	Uniform (5, 10)
Chemotherapy preparation	Infusion Area	Constant (30)
Infusion	Infusion Area	Uniform (60, 480)

4.2. Resources

Types and number of resources in the chemotherapy department are given in Table3.

Table 3: Chemotherapy consultations and treatment resources

Location	Resource	Number
Consultation area	Receptionist	1
	Nurse	1
	Oncologist	5
Infusion treatment Area	Nursing assistant	2
	Nurse	3
	Pharmacist	1
	Pharmacy assistant	1
	Pharmacy technician	2
	Treatment beds	15

5. Simulation model and experiments

A simple model of the system was created with ARENA Software. Several assumptions have been established for the simulation model.
The simulation model has been validated using animations, once the personnel approved the results.

5.1. Variations in patients' arrival time:

The problem of waiting times occurs mainly before the consultation of oncologists, and in case of beds and nures shortage for a chemotherapy session.
The long waiting times for consultation result from the variability in the patients' arrival. As shown in Figure 3, 52,6% of patients arrive between 9am and 11am, creating peaks in the patient demand.

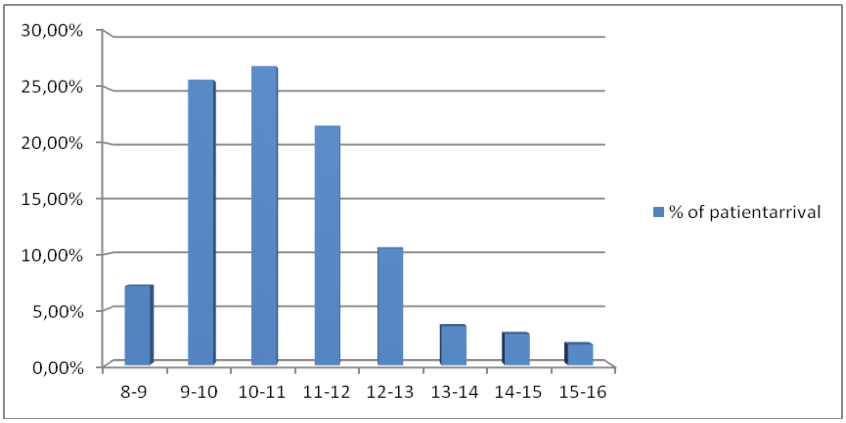

Figure 3: Distribution of patients' arrival time for consultation

6. Conclusions

In this article, we presented a case study of a chemotherapy treatment unit. Based on the real data collected, a simulation model of the system has been developed and validated to evaluate the current state. The results of simulation indicate that the issues behind the long waiting time before consultations are related to the variability in patients' arrival. Thus, further work will be conducted for scheduling of patient appointments.

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References

World Health Organization, *World Cancer Report*, 2014.

Barett, J.S., Mondick, J.T., Narayan, M., Vijayakumar, K., Vijayakuma, S., Integration of modeling and simulation into hospital-based decision support systems guiding pediatric pharmacotherapy, BMC *Medical Informatics and Decision Making*, **8**:6, 2008.

Woodall, J. C., Gosselin, T., Boswell, A., Murr, M., Denton, B.T., Improving Patient Access to Chemotherapy Treatment at Duke Cancer Institute, *Interfaces*, vol. 43, no. 5, pp. 449–461, 2013.

Baesler, F., Sepulveda, J.A., Multi-objective simulation optimization for a cancer treatment center, *Winter simulation conference*, pp. 1405 to 1411, 2001.

Huggins, A., Claudio, D., Perez, E., Improving Resource Utilization in a Cancer Clinic: An Optimization Model, *Industrial and Systems Engineering Research Conference*, 2014.

Ahmed, Z., Elmekkawy, T.Y., Bates, S., Developing an efficient scheduling template of a chemotherapy treatment unit: a case study, *Australasian Medical Journal*, page 1539 to 1546, 2011.

Masselink, I., Mijden, T., Litvak, N., Vanberkel, P., Preparation of chemotherapy drugs: Planning policy for reduced waiting times, *Omega*, page 181-187, 2011

GODEFRIDUS, G., Groothuis, S., Schoenmakers, M., Boersma, H., Simulation Studies and the Alignment of Interests, *Health Care Management Science*, p 97-102, 2002.

Laurainne, P., Jobin, M., Cordeau, J., Shanti, A., Kurtz, J., Gourieux, B., Becker, G., Optimisation du parcours patient en Hôpital de Jour en oncohématologie par simulation intégrée à une démarche kaizen, 2016.

Sepulveda, J. A., Cahoon, L., The use of simulation for process improvement in a cancer treatment center, *Winter simulation conference*, page 1541 to 1549, 1999.

Liang, B., Turkcan, A., Ceyhan, M., Stuart, K., Improvement of chemotherapy patient flow and scheduling in an outpatient oncology clinic , *International Journal of Production Research* , 2014.

SADKI, A., XIE, X., CHAUVIN, F.,Patients assignment for an Oncology Outpatient Unit, *6th IEEE Conference on Automation Science and Engineering*, 2010.

Mazier, A., Xie, X., Scheduling physician working periods of a chemotherapy outpatient unit, *IFAC Symposium in Information Control Problems in Manufacturing*, Russia, 2009.

SADKI, A., XIE, X., CHAUVIN, F.,Bedload balancing for an oncology ambulatory care unit, *MOSIM'10*, Tunisia, 2010.

Wineke, A.M., Goedbloed, N., Harten, W.H., Improving the efficiency of a chemotherapy day unit: Applying a business approach to oncology, *European Journal of Cancer*, p 800-806, 2009.

Biography

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