MODELLING AND SIMULATION OF THE PATIENT PATHWAY WITH ARENA: CASE OF THE MOTHER-CHILD HOSPITAL AT MARRAKECH

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Abstract—**Healthcare quality improvement, operational performance increasing, patient satisfaction: such are the challenges of the hospital sector in Morocco and elsewhere. To tackle those challenges, it is necessary to start by studying the patient pathway from the entrance to the exit of the hospital in order to detect problems that can affect the proper functioning of the hospital processes. In this context, this paper intends to reduce the patient waiting times and provides solutions to improve the performance of the medical staff and healthcare quality. For that, a modelling and simulation of the patient pathway within the mother-child hospital at Marrakech is proposed in order to better understand the demand, to highlight the need in terms of human resources, and also to detect different sources of waste present in the value chain. Then, we will discuss the simulation results, evaluate the operational performance of the hospital and propose solutions to improve it.**

Keywords: hospital sector; modelling and simulation; performance improvement; healthcare quality;

I. INTRODUCTION

Nowadays, the healthcare sector represents one of the worldwide priorities. Several researches are conducted in this sector to improve its situation. Managing the patient flows is one of the principal missions of hospitals. The randomly arrival of patients causes a lack of demand control and sometimes an unavailability of human or material resources that causes the patient dissatisfaction. The main objective is to guarantee a fast management of patients especially in the case of the women and child, a demand control is compulsory. In this context, this paper tackles the problem of waiting time minimization in a hospital in order to improve its performance and then satisfy the patient. The study is done in the mother-child hospital at Marrakech. This paper includes four parts:

The first part proposes a small description of the health system situation in Morocco, its flaws and the efforts committed by the state to improve it. The second part provides a literature review on patient pathway modelling and the use of different tools of simulation to evaluate hospitals. The third part presents our study and simulation of the patient (mother) pathway in the mother-child hospital based on the queuing theory. This part will help not only to highlight the need in terms of human resources, but also to detect bottlenecks and different sources of waste present in the value chain.

Finally, the last part presents a discussion of the results obtained, some recommendations and prospects of this paper.

II. THE CURRENT CHALLENGES OF THE MOROCCAN HOSPITAL SYSTEM

This part presents the main problems that impact the hospital sector in Morocco:

A. Lack of financial and human resources:

The Moroccan hospital sector suffers from insufficient spending compared to other countries. According to the statistics shown by the Global Health Organization, the health expenditure in Morocco represents just 6% of GDP, while in other countries such as France; the healthcare budget represents 11.6% of GDP and over 15% in the US [1].

As regards the lack of human resources, Moroccan hospitals are unable to cover the needs of the entire population that tops 33 million by the available number of doctors and nurses. According to data provided by the Health Ministry in 2012, the annual average number of visits per doctor is 1015 [2], Morocco has just 46 doctors per 1000 people. This lack of medical staff is affecting the quality of services provided to citizens and increasing their waiting time in public hospitals.

B. Lack of medical staff motivation:

In addition to the lack of financial and human resources, a lack of motivation is a big problem too. In the health sector, several strikes were done in the aim of increasing doctors salaries. In addition, there is no remuneration system based on the workplace, this problem causes an unbalanced geographical distribution of the personnel, 44% of doctors are located between Rabat and Casablanca [2].

C. Disastrous hospitalization conditions:

Hospitalization conditions in Morocco are disastrous, a big number of citizens have not the possibility to benefit from the medical care due to the absence of health insurance. According to preliminary results of the survey "Panel de ménages" conducted by the National Human resources Development ONDH[1] in 2012 and presented at a seminar in Rabat January 28, 2015 [3], only 23.3% of the population was

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[1] ONDH : Observatoire National de Développement Humain

covered in 2012 by a health insurance. The investigation showed that the inability to bear the costs of consultation is the cause number one not allowing to access to health care with a proportion of 60.2%. Despite the launch of health services plan for the economically disadvantaged persons (RAMED)[2], the number of citizens receiving no basic medical coverage remains very high, and even people benefiting from RAMED complain about its inefficiency. It does not allow them to enter all forms of medical care. As regards the health of mother and child, figures are alarming: an average of 5 women and 20 children died every month (statistical data released by the mother-child hospital at Marrakech in 2014). The situation of pregnant women is critical too. Some pregnant women, at the moment of their childbirth, wait to be supported by medical staff in vain. Some of them give birth on the floor of the hospital without any doctor intervention, but the health plan launched by Morocco the 13 November 2013 suggests a better future for the woman and child [4]. According to a paper published on the website of the World Health Organization: This plan aims to improve the quality of care and reduce by 2015 the mortality of children under five years of 70% and the mortality of mothers 82% compared to 1990 levels [5].

In accordance with the objectives of this plan, our paper aims to improve the performance of a hospital specialized on mother and children treatment and to minimize their waiting time, and more precisely, mother's one. For this, a modeling and simulation of the mother pathway is necessary for the understanding of the distribution of waiting times on healthcare activities. The following part presents a literature review of some researches in hospital management based in modeling and simulation of the patient pathway.

III. LITTERATURE REVIEW

Many researchers are interested in studying the hospital system trying to improve its performance. For the purpose of the development of an understanding of the functioning of the complete system and the patient's needs, the first step of any study is supposed to be mapping the patient pathways [6]. It's used at many researches in the hospital sector. Jihène J., El Mhamedi A. and Chabchoub H. propose a new approach that allows the patient pathway modelling at an emergency department [7]. In order to reduce waiting time in an emergency department (ED) and improve the doctor's efficiency, T Wong, A Guinet, A Belaidi and B Bésombes represent a modelling and simulation of the patient pathway using ARIS and ARENA. In their model, authors assume that the patient's arrival can be approximately considered as stochastic event independent of time and then it follows a Poisson distribution. The results obtained prove that the waiting time could be largely reduced and doctor's efficiency improved, and further healthcare costs reduced. They give also a comparison between the two business process re-engineering (BPR) software tools: ARIS and Arena. They conclude that arena is better when it's about a simulation-oriented modelling [8]. For the same purpose, El oualidi, J. Saadi, L. El hiki, A.

Artiba, (2009) conducted a model of patient flow within the hospital Ibn Rochd of Casablanca through the SADT method [9].

TABLE I. SUMMARY OF SOME HOSPITAL MANAGEMENT RESEARCHES USING MODELLING AND SIMULATION AND THEIR OBJECTIVES

Objectives	References
Improving the decision-making organization and reducing the duration of hospitalization	[14]
Reducing the waiting time in emergencies	[8], [9], [15]
Reducing the patient time spent in the emergency services and improving its performance	[16]
Restructuring of a hospital	[17]
treatment of medical personnel assignment problem	[18]
Minimizing the pharmaceutical logistics expenditures	[19]

a. hospital management researches using modelling and simulation and their objectives

Once the system modeled, then comes simulation, one of the popular methods in the study of complex systems such as hospital systems in order to present the dynamic aspect of the system. It allows evaluating the performance of the existing process and realizing impossible tests or ones that are very expensive to perform in reality. This step requires a well studied model for reliable results.

A model of the patient pathway in an emergency department was proposed and simulated using Aris to detect bottlenecks in the system and make it faster [10]. L. Trilling performs a simulation of a medico-technical platform process to determine staffing requirements and hire an overall performance improvement of the plate process [11]. Queuing theory is also used in a variety of studies analyzing the patient pathways in different types of healthcare processes. De Bruin, A. M., van Rossum, A. C., Visser, M. C Koole, and G. M., (2007) applied it to model the flow of hospitalized patients suffering from cardiac pathology [12]. J-S Tancrez, Roland, Cordier, and Riane, (2011) are based on Markov chains to study the disruption caused by emergencies in the operating theater. The modelling and simulating of the hospitalized patient flow in emergencies help identify the impact of emergencies unpredictable arrival and operations times on the original schedule of operations [13].

This short literature review shows that modelling and simulation of the patient pathway are used for the treatment of a multitude of healthcare problems. Thereby, table I shows some researches in this context and their desired objectives.

In the same context, our research presents a modelling and simulation of the mother pathway in the mother-child hospital at Marrakech. For this, we are based on the queuing theory.
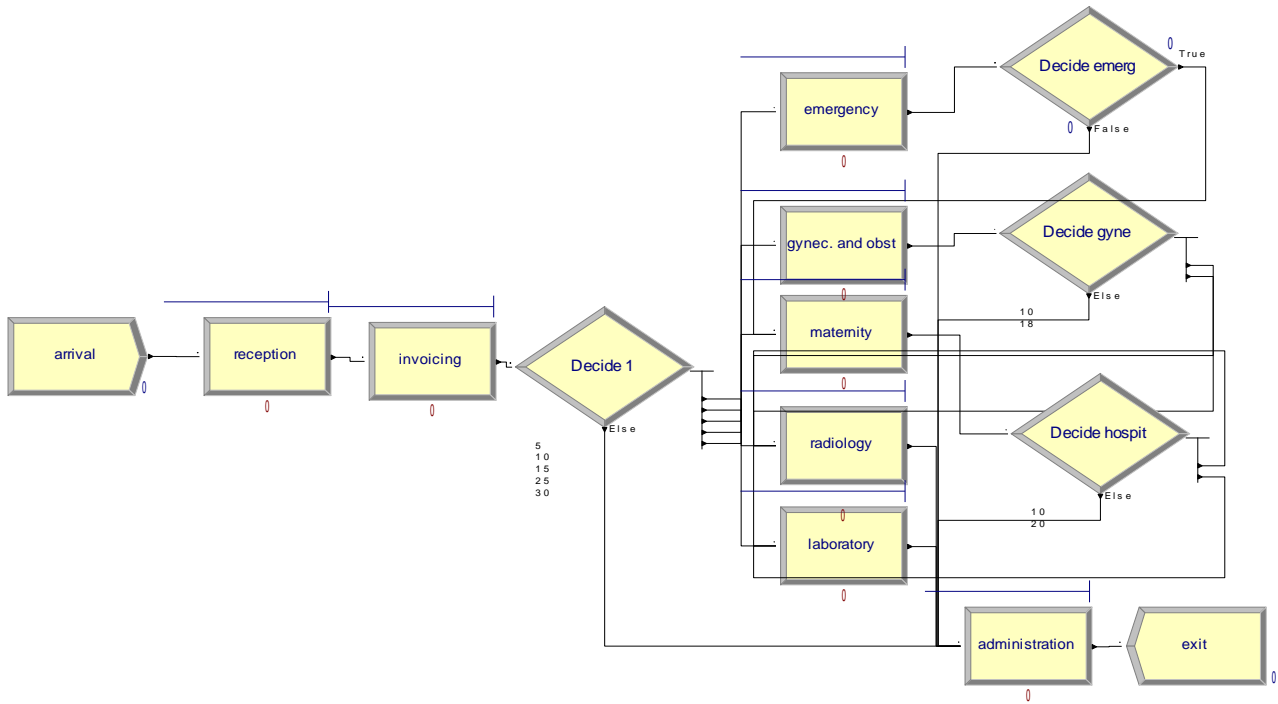
Figure 1.   The mother pathway model in the mother-child hospital at Marrakech

The real challenge of hospitals is to improve the quality of care and to allocate staff resources reasonably in order to make the patient pathway faster and efficient [8]. As mentioned before, one of the big problems faced by Moroccan hospitals is insufficient human resources. This problem affects the quality of care offered to patients and generates their dissatisfaction. This lack of resources is very critical in mother services, where the speed of decision making and the availability of medical personnel are required. To determine the optimal number of human resources needed in the services involved, a model of the mother's pathway is needed to better understand hospital processes and to better control its development. This control allows determining different forms of waste present in the hospital, reducing patients waiting time and furthering to satisfying them.
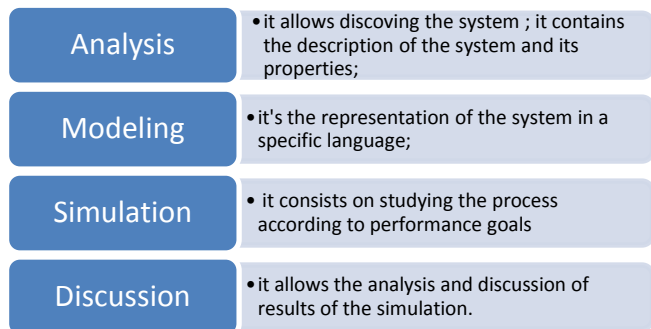

Figure 2.   The procedure followed to study the patient pathway

The achievement of the results of our study will reduce the burden on the medical staff, making it satisfied and more efficient. The figure 2 presents the procedure followed in our study, it consists of four steps: analysis, modeling, simulation and discussion.

A. System analysis

In the following paragraphs, our system will be limited to the mother's pathway from her access to the mother-child hospital at Marrakech until its exit. Once at the hospital, the mother goes through admission, where she makes registration and constitution of his medical file, and then she goes to billing, then she goes to desired healthcare service. Finally, she goes through the administration service before leaving the hospital. The figure 1 presents the mother pathway in the mother-child hospital.

Our system studied is limited, in addition to the emergency service, to four services namely: gynecology and obstetrics, maternity, radiology and analyzes laboratory. This system is characterized by the following properties:

- Discipline of services: in a queue, it is the priority rule followed when choosing the next patient to serve; in our case, it is the FCFS (First Come First Served). The emergency service is an exception that follows another discipline called IAO. It consists on prioritizing the urgent cases of patients

- System Capacity: the number of patients that can be simultaneously present in the system, it may be finite or infinite. A finite capacity "c" means that if a patient comes and

finds "c" patients in the queue, he left immediately without getting the desired service. These are called lost customers. In our case, it is assumed that no patient is lost. We say that the system capacity is infinite.

B. System modelling

The modelling of the patient pathway requires the knowledge of laws followed by the patients' arrival at the hospital and the services in question. According to a study conducted by Dehas and al (2006) [20], the patient arrival process follows a Poisson law while healthcare services follow the exponential law. In what follows, we'll assume that result and validate by statistical tests then we'll calculate parameters of arrival and services processes.

Arrival process:

The hospital mother child receives an average of 45 mothers daily. We consider the event "patient arrival" which occurs on average $\lambda \epsilon R$ per unit of time.

X is the random variable representing the number of times the event occurs per unit of time. The patient arrival process satisfies the following conditions:

- The probability of arrival at time s> t does not depend on what happened before time t. This is the so-called property "without memory."

- The numbers of arrivals recorded in two separate intervals of the same length follow the same probability distribution. This is the so-called property "stationary".

- X (0)=0

The three conditions above present the case of Poisson process with a parameter λ.

To confirm that result, we time arrivals in the intensive care unit, and note for each arrival the time corresponding.

$$\lambda t = \sum_{k=0}^{n} \left(k \frac{f_n}{L} \right) \qquad (1)$$

L: the sum of frequencies.
f_n: the occurrence of the number of patients n during L.

TABLE II.   NUMBER OF PATIENTS ARRIVED PER A DAY DURING A MONTH

Number of patients per a day	occurrence of the number of patients at a month
0	21
1	32
2	24
3	11
4	4
5	0

b. number of arrivals per a day

After calculating durations between every sequential arrival, we calculate the distribution average λt given by the equation (1).

Using data presented on the table II, $\lambda t=1.4$

The use of a statistical test is necessary to verify if the distribution of the arrival process follows a Poisson law or not. One of the most used tests is $\chi 2$. This test consists on calculating theatrical frequencies using the formula (2). We calculate $\chi 2$ and we compare it to the one that we'll identify in the khi-deux table.

$$f_{th} = 100. \frac{(\lambda t)^n}{n!} \exp(-\lambda t) \qquad (2)$$

For that, we need to calculate the dof (degree of freedom) using the following formula:

$$dof= c-p-1 \qquad (3)$$

C: the number of clusters (in our case 5)

p: the number of parameters gotten from the distribution (1 and it's the average λt)

So dof=5-1-1=3

According to the $\chi 2$ table, for 3 degrees of freedom, $\chi^2_{0.9}=0.5844$. Since the $\chi 2$calculated in the table III is lower than $\chi^2_{0.9}$, then the distribution is following the Poisson low with a parameter $\lambda=1.4$/day.

TABLE III.   THE X^2 TEST TO THE IDENTIFICATION OF THE LAW FOLLOWED BY THE ARRIVAL PROCESS

N	f_n	f_{th}	$|f_{th}-f_n|$	$|f_{th}-f_n|^2/ f_{th}$
0	21	23	2	0.17
1	32	34	2	0.12
2	24	25	1	0.04
3	11	12	1	0.008
4	4	4	0	0
			$\chi 2$	0.41

c. calculation of the $\chi 2$

Services processes

We consider a sequence of random variables Y1, Y2... Yi is where the patient's service time (i = 1, 2 ...). The variables Y1, Y2 ... are independent and identically distributed; it is the case of an exponential distribution with parameter μ. 1 / μ is the average time of patients' pathway in the service.

The table V shows the average number of patients served per unit of time. We'll take the example of the service of maternity to show steps followed to calculate different parameters of services processes distribution. The table IV clusters the service durations in 7 clusters and present the occurrence of the event (patient served in the maternity) in each cluster.

Using the data of the table IV, the average of the distribution is:

m=(0.5*61+1.5*32+2.5*15+3.5*6+4.5*3+5.5)/61+32+15+6+4

m=1.32

Using the test of χ2, we will be able to know if the service distribution follows an exponential law with a parameter μ=0.75 (μ=1/m).

Service duration (d)	Number of services observed
d<1 hour	61
1<d<2 hours	32
2<d<3 hours	15
3<d<4 hours	6
4<d<5 hours	3
5<d<6 hours	1
6 hours<d	0

d. durations of the maternity service

The χ2 calculated equals 0.86; the χ2 identified from the khi-deux table with dof=4 is equals to 1.0636 and is superior than the one calculated; so the distribution of the service of maternity follows the exponential low.

Service i	μ_i
Gynecology and obstetrics (extern consultations)	0.35
Maternity	0.75
Laboratory	0.87
Radiology	0.36

e. parameters of the services distribution

<u>The performance:</u>

The literature shows a multitude of indicators to assess the performance of a service such as hospital bed occupancy rates, utilization of human resources, the period of appointment, the waiting time, the mortality rate, average length of stay, etc ... The aim of our research is to minimize the waiting time of the mother in the mother-child hospital in Marrakech. For this, we'll try to model the average waiting time in what follows.

A patient waiting time is the sum of waiting times at each activity in his pathway in the hospital. To model the waiting time, we will classify the activities of the value chain in two categories: non-value-added activities for the patient (secondary activities: reception, invoicing and administration) and those with added value (gynecology and obstetrics, maternity, radiology and laboratory) which represent the heart of the hospital business.

The average waiting time is: $T_{wa} = T_{wva} + T_{wnva}$ (4)

This term is to minimize, so two key performance indicators are chosen to evaluate the performance of the hospital processes. The first one is the average rate of waiting, in other words, it's the percentage of waiting time compared to the total time spend by the patient within the hospital.

$$I_1 = \frac{T_{wa}}{T} \ (5)$$

The second one is the percentage of time spent on non-added value activities. It's defined as follows:

$$I_2 = \frac{T_{nva}}{T} \ (6)$$

C. System simulation:

The stage of the simulation of the patient's pathway in the mother-child hospital in Marrakech will allow to evaluate the performance and further to offer a solution to improve it in terms of human resources. The inputs of the simulation are the number and work schedule of medical and paramedical staff and the laws of distribution of arrivals time and services and their parameters.

The simulation is done under the following assumptions:

- It is assumed that there are no medical machines failures in the considered services.

- There is no medical personnel absence throughout the simulation.

- The deterioration of the performance is equal to 0.7; which means that 70% of the medical staff time spent in the hospital is a value-added time.

- According to the statistical data collected in the unit of statistics of the hospital, patients are approximately distributed within the hospital as follows: emergencies (30%), consultations (15%), laboratory (20%), radiology (8%), and maternity (27%).

The report of the simulation gives a standby rate of 68%, i.e the patient spends 68% of his time in the hospital waiting to be served. In addition, I_2=0.07, that means that 7% of the patient time is spent at the NAV activities. To reduce the first rate, it is proposed initially to increase the number of medical and paramedical staff. Several simulations are performed to determine the optimal number of human resources within hospital services in question, we changes in each simulation the number of human resources in the different services. At the end of each simulation, we compare the performance indicators with predetermined objectives. The simulation shows that this is effectively a lack of human resources in the maternity service. Increasing the medical staff in this service may decrease the number of trips to the emergency and perhaps the number of death concerning women.
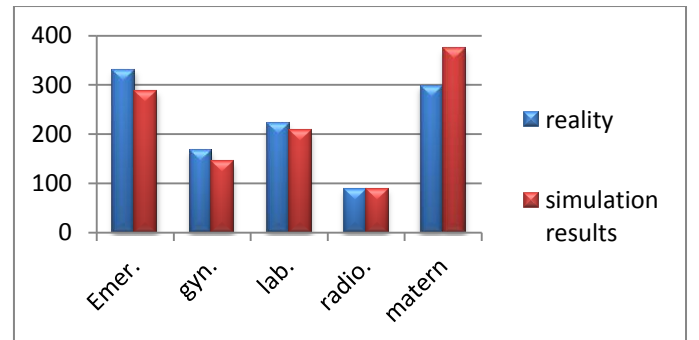

Figure 3.   The number of patients on each service per month in the mother-child hospital at Marrakech

In order to confirm the simulation results, it's necessary to compare them with the data that represent the real situation. The figure 3 presents the number of patients treated by each service during a month that are closed to the simulation results.

D. Discussion of results:

After many simulations, we conclude that there are two services that affect the most the patient waiting time, which are: the invoicing and maternity services. According to the simulation results, it's possible to reduce the standby rate to only 15% just by adding two people in the invoicing service and two others in the maternity service. But this solution assumes that the staff are well motivated and did its job efficiently, which is not true in the case in public hospitals due to the big workload that they're facing every day. Besides, increasing the number of staff also implicates rising material resources within the concerned service, which requires a significant financial budget; and as it is very tight in the Moroccan hospital sector, this solution is not adequate to the situation.

In order to minimize the waiting time for patients, we must explore another improvement way which is to follow a methodology of Lean implementation to manage motion, time and workload of the staff of this service and increase its performance; this approach starts from the modeling of the patient pathway to detect bottlenecks of the system, and proposes solutions using different tools with a continuous improvement spirit.

V. CONCLUSION:

To evaluate the performance of the hospital system, two steps must be followed: the modeling and the simulation. The first step helps us to have a general vision of the system and relationships between its components. Also, it's necessary to obtain good results on the simulation. In fact, the modeling requires also laws followed by arrival and service distributions. In this paper, we were able to find the different laws and parameters of distributions that are present in the patient (women) pathway in the mother-child hospital at Marrakech. The second step allows studying the system in a long period, detect bottlenecks and search solutions to improve the global performance. In a health network where resources are limited, a good governance of the existing means is required; small improvements such as the reduction of over-treatment of waste (e.g switch to radiology to detect the problem before performing the visual stage) or medication waste, etc ... provide significant and lasting time and money. The healthcare sector requires a new spirit of working for continuous improvement and listening to employees to benefit from their ideas and potential skills. A Lean approach well adapted to the specificities of the hospital sector will be very beneficial. We note as prospects of our work, the proposal of a Lean healthcare approach and its implementation in a Moroccan hospital.

REFERENCES

[1] Global Health Observatory Data Repository, Health expenditure ratios of all countries at 2014.

[2] Studies and health information service, Department of Planning and Financial Resource, "Santé en chiffres 2012" edition 2013.

[3] National Human resources Development ONDH, "Panel de ménages", 2012.

[4] Ministère de la santé, "Plan d'action 2012 – 2016 pour accélérer la réduction de la mortalité matérnelle et néonatale ", Novembre 2013

[5] World Health Organization, "Le Maroc adopte un nouveau plan en faveur des mères et des enfants", Janvier 2014.

[6] Gillian Mould, John Bowers, Mikhail Ghattas, "The evolution of the pathway and its role in improving patient care" , Quality and safety in healthcare, Vol.19, No. 5, pp 1-6, 2010

[7] Jihène J., El Mhamedi A., Chabchoub H., « Modélisation et analyse du parcours de patient dans le Service d'Urgence : Cas de l'hôpital de Sfax », GISEH 2006.

[8] Tao Wang, Alain Guinet, Aissam Belaidi and Béatrix Besombes, "Modelling and simulation of emergency services with ARIS and Arena. Case study: the emergency department of Saint Joseph and Saint Luc Hospital", Production Planning & Control, Vol. 20, No. 6, pp 484–495, Septembre 2009

[9] Moulay ali .El oualidi, Janah Saadi, Lahcen. El hiki, Abdelhakim Artiba, "Modélisation et analyse du flux des patients au service des urgences. Cas de l'hôpital Ibn Rochd à Casablanca" (Maroc), CPI'2009-Fes

[10] Tao Wang, Alain Guinet, S. Meyran, "Modélisation et simulation du processus de passage des patients aux urgences à l'aide d'ARIS : Étude de cas au SAU du Centre Hospitalier Saint Joseph et Saint Luc", GISEH, pp.529-537, septembre 2006

[11] Lorraine TRILLING, "Aide à la décision pour le dimensionnement et le pilotage des ressources humaines mutualisées en milieu hospitalier". Thèse de doctorat à L'Institut National des Sciences Appliquées de Lyon, 2006

[12] de Bruin, A. M., van Rossum, A. C., Visser, M. C Koole, G. M., "Modelling the emergency cardiac in-patient flow: an application of queuing theory", Health Care Management science. Vol. 10, No. 2, pp 125–137, 2007

[13] Jean-Sébastien TANCREZ, Benoît ROLAND, Jean-Philippe CORDIER, Fouad RIANE, "Étude de la perturbation par les urgences du planning opératoire" , Logistique & Management, Vol. 19, N°2, pp 43-52, 2011

[14] Gérard FONTAN, Daniel DUROU, Colette MERCÉ, "Analyse et modélisation du parcours du patient, Logistique et management"

[15] Miller Ferrin, D.M. et Messer, M.G. " Fixing the emergency department: a transformation journey with EDsim. Dans: Proc. of the 2004 Winter Sim. Conf., pp. 1988-1993 , 2004

[16] Navas, J.F., Arteta, C., Hadjes, P.S. et Jimenez, F. "Construction et simulation d'un modèle de flux de patients dans le service d'urgences d'un hôpital colombien". Actes de la Conférence Francophone en Gestion et Ingénierie des Systèmes Hospitaliers GISEH, Septembre 2004.

[17] Romeyer, C., Boireaux, A., Dupre, V., Geindre, C., Matray, N. et Meyznnier, C. "Modélisation par les processus : une méthode préalable indispensable à la mise en oeuvre d'un système d'information communicant centré sur le patient.", GISEH, Septembre 2004.

[18] MA El Oualidi, J Saadi, "Problème d'affectation des infirmières: un état de l'art et modélisation. Cas du service des urgences de l'hôpital Ibn Roch de Casablanca", April 2012

[19] Christine Di Martinelly, Alain Guinet , Fouad Riane, "Chaîne logistique en milieu hospitalier : modélisation des processus de distribution de la pharmacie", 6e Congrès international de génie industriel – 7-10 juin 2005 – Besançon (France)

[20] Dehas.N., A.Djamil, A.Smaïl, A.Hayette. "Evaluation des Performances d'un Système de Santé : Cas de l'Hôpital Khellil Amrane (Béjaïa)", GISEH, septembre 2006 LuxeBorg.