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Workflow tool to Model and simulate patients paths in Pediatric Emergency Department

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Abstract: In this paper, we focus on treatment for patient journey at emergency department in hospitals. Modeling and optimized patients at emergency department is faced with a high amount of complexity due to the inherent dynamics of the processes and the distributed organizational structure of hospitals. The goal is to optimize these paths to improve the quality of the patient handling while mastering the wait time. The development of this model was based on accurate visits made in the Pediatric Emergency Department (PED) in CHRU of Lille (France). This modeling, which has to represent most faithfully possible the reality of the PED of CHRU of Lille, is necessary. Our survey is integrated into the project ANR HOST (ANR-11-TecSan-010)

Key words: Pediatric Emergency Department (PED), Workflow, modeling

INTRODUCTION

Modeling and Optimization patients at emergency department ED in hospitals is faced with a high amount of complexity. This complexity stems from the inherent dynamics of the processes and the distributed organization structure of hospitals, as they are divided into several autonomous wards and ancillary units. For treatment, patients visit different units according to their illness. However, the pathway of the patients through the Pediatric Emergency Department (PED) is confronted with uncertainties. Because it is in the nature of diagnostics to gain additional information about the patients' diseases, the necessary medical treatments are often not completely determined at the beginning of the treatment process. Further, the duration of the examinations and treatments are stochastic, due to the individuality of the patients. Additional problems for the patient-modeling in PED arise from complications and emergencies. The immediate need of treatment for emergency patients causes disturbances in the schedule. Complications, which may occur during a treatment, result in waiting times and changed pathways for other patients. This results in variable pathways and stochastic processing times. The main objectives of the present paper are; firstly to model the PED using Workflow methodology for better understanding the patient flow process through the PED and to simulate using the same tool Workflow in order to identify and analysis the dysfunction of the PED.

This paper is organized in fourth section the first section present the description of the survey. In the second section we describe the main problems faced at the PED. In the third section we describe of the approach Workflow and the roles of each process of the system. Simulation and experiment results in PED are presented in the fourth section. This article is closed with conclusions and an outlook to further work.

DESCRIPTION OF SURVEY

This article aiming at the creation of software to address various problems with the Pediatric Emergency Department in terms of management, particularly during peak of activity, a visit to this service at the University Hospital CHRU (Lille - Jeanne of Flanders Hospital) has allowed us to better understand the challenges faced service. This paper highlights the most important aspects that we have learned about the operation of the service Pediatric Emergency Lille, according to its specificities.

Let us first path the type of patient it can happen to Pediatric Emergencies by many distinct entries (spontaneous arrival SAMU, SMUR, Policeman…)

Upon his arrival in the Pediatric Emergency Department, if the patient is entered by the ER, it undergoes a first diagnosis made by a nurse, who can set a priority of patients entering in the service. This prioritization of patients based primarily on a scale of four levels of emergency to deal very quickly, if not immediately, the most serious cases. After a waiting period of more or less important depending on the congestion state of the service and the urgency of the case, the patient is then supported by a doctor [1].

PROBLEM IN THE PEDIATRIC EMERGENCY DEPARTEMENT

Based on detailed analysis of visits to multiple times in the Pediatric Emergency Department (PED) in CHRU of Lille (France).

The hospital CHRU have three operating rooms (Trauma, cardiac surgery, neurosurgery) with personnel on duty that allow operation at any time and services that can perform examination and analyses at any time: medical imaging (radiography, medical ultrasonography, computed tomography, angiography...) etc. The specialized service is managed by an emergency physician. An emergency physician must be on duty anytime, and a specialized physician can be called anytime depending on the specific pathology (i.e. on duty in the hospital, not in the emergency service). The team must have, in addition to the emergency physician: two nurses; care assistants, possibly child care assistants; a social worker; agent administrative; all must have a specific education for emergencies. A careful examination of the activity process at the ED reveals that the emergency departments are facing difficulties at the management level, which are mainly related to the unpredictable flow of patients, to the inability to control flows stream up and stream down, to the multiplicity of actors and to the reduced efficiency of care activity which consist of the interrupted tasks, qualification under or over used (i.e. a percentage of the time of the doctor is non-medical) and difficulty in quantifying (Who does what, when, how often?). So, the situation demands a system that works beyond these limitations. Then, we propose an approach capable of handling all patients of PED in order to minimize their waiting time as well as the costs of care, with the respect of the quality of care.

Our model aims to make possible to identify a medical actor available at a given time and to assign to him, depending on both of the flow of patients and the medical practices, a set of tasks. Where he can perform those tasks and has an aspect of flexibility relates to the possibility that could have a human resource to perform various tasks with appropriate skills (degree of knowledge). The model proposed a architecture interact to improve completeness and accessibility of information which is a key element to get better the quality of care at the PED.

WORKFLOW MODELING OF THE PED OF CHRU OF LILLE

Architecture of the proposed system

At one level a workflow is a high-level specification of a set of tasks and the dependencies between them that must be satisfied in order to accomplish a specific goal. For example, a data analysis protocol consisting of a sequence of pre-processing, analysis, simulation and post-processing steps is a typical workflow scenario in e-Science applications. At the level of representation and execution,
a workflow is a computer program and it can be expressed in any modern programming language. However, the task of writing a computer program in Business Process Model and Notation (BPMN) [2] to orchestrate a set of tasks on a wide-area distributed system goes well beyond the modeling skills or patience of most scientific users.

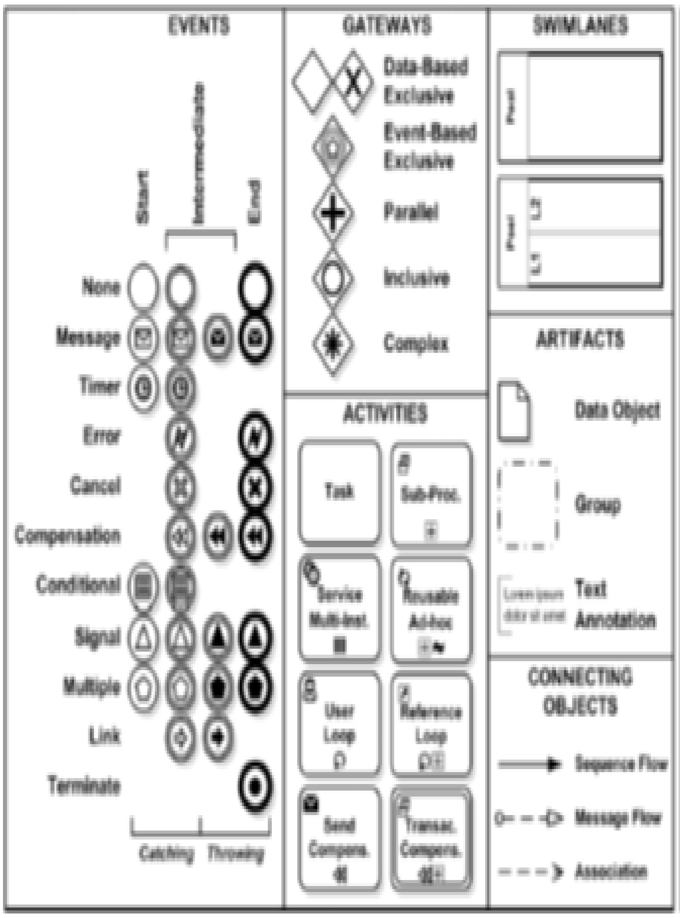

Figure 1 BPMN element's summary [2]

The goal of e-Science workflow systems [3] is into provides a specialized programming environment to simplify the programming effort required by scientists to orchestrate a computational science experiment. In general we can classify four different phases of the workflow Lifecycle:

1. Composition, Representation and Data Model: the composition of the workflow (abstract or executable) through a number of different means e.g. text, graphical, semantic.
2. Mapping: Involves the mapping from the workflow to the underlying resources.
3. Execution: Enactment of the mapped workflow on the underlying resources.
4. Metadata and Provenance: The recording of metadata and provenance information during the various stages of the workflow lifecycle.

During workflow composition the user creates a workflow either from scratch or by modifying a previously designed workflow. The user can rely on workflow component and data catalogs. The workflow composition process can be iterative, where portions of the workflow need to be executed before subsequent parts of the workflow are designed. Once the workflow is defined, all, or portions of the workflow can be sent for mapping and then execution. During that phase various optimizations and scheduling decisions can be made. Finally, the data and all associated metadata and provenance information are recorded and placed in a variety of registries which can then be accessed to design a new workflow. Even though we delineate data recording as a separate phase of the workflow lifecycle, this activity can and often is part of the workflow execution. In the following four sections, we examine these four areas in detail by extracting a feature set within each category to define the common aspects of functionality that are inherent across workflow systems in general [4].

Workflow methodology

To model the health system, a lot of company modeling methods has been used. The company modeling is the representation of the enterprise in terms of strategy, structure, functionalities, behavior, organization, evolution and relations with the environment. One of these methods is the Workflow methodology. It has been used for modeling, diagnosis and conception of a hospital system [5]. This work permitted to demonstrate applicability and the interest of the company modeling methods to reorganize a health establishment.

The objective of the development and description of the workflow model is to assess the overall processing capabilities of the flow in order to support various joint activities between medical staff that is temporally and spatially dispersed. Control of the workflow for the purpose of optimizing the placement of limited medical resources, both personnel and equipment, on the medical scene is an important issue. Since typical unforeseen circumstances will frequently occur in the PED environment, there is a need for an effective model, capable of dynamic control in workflow descriptions, for medical treatment. Thus, for descriptions of the workflow in this paper, we have used the BPMN standard graphical language, which is easy for users to express and is readily comprehensible [6].

Dynamic behavior of the system

We are going to model all paths exist at PED of the CHRU Lille. We are going to represent the physical system service and the PED to have a complete idea of the patient flows.

In this paper, we will start with the representation of the physical system in the PED and the emergency paths of external care, Unit of short term hospitalization and Care emergency vital. We will represent only the models that will be analyzed after modeling the whole paths of the PED of the CHRU Lille in the ulterior stages of our survey. The physical systems of the PED and the emergency paths that we have just mentioned previously are represented by the figures1, 2, 3 and 4. The set of the functional models presented in this paper have been achieved with the Bonita soft software Workflow. The objective of the development and description of the workflow model is to assess the overall processing capabilities of the flow in order to support various joint activities between medical staff that is temporally and spatially dispersed. Control of the workflow for the purpose of optimizing the placement of limited medical resources, both personnel and equipment, on the medical scene is an important issue. Since typical unforeseen circumstances will frequently occur in the PED environment, there is a need for an effective model, capable of dynamic control in workflow descriptions, for medical treatment. Thus, for descriptions of the workflow in this paper, we have used the BPMN standard graphical language, which is easy for users to express and is readily comprehensible [7] [8].

We present in the figure 2 the overall process of care of patients at the Emergency Department Pediatric CHRU of Lille. We remark that these models are characterized by the diversity of the activities and the big number of people that intervenes in the patient handling process and its diagnosis nature. We note in more the uncertain criteria in the patients handling and the risks that can emerge during his path. The aggravation of a patient's state can already stimulate the change of his cares process anticipated. It confirms us the complexity of the emergency handling system. It is also interesting to see that some activities of these processes are decisional. These decisions are not management decisions but the choices in the patient (Care traditional hospitalization, external care, Unit of short term hospitalization, Care as a matter of emergency vital, Consultation in a cubicle). The simulation of this model will allow us to provide for each sub-process some interesting results such as the number of patients per hour, their waiting time, peak activity of the medical staff and the number of abundant.

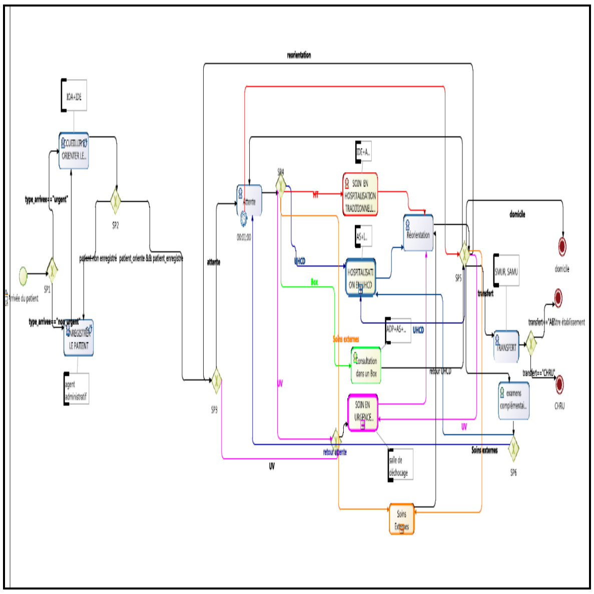

Figure 2 Global Model Workflow of PED

The majority of children with PED consultant are supported outpatient. This requires several steps involved: AS, IDE, MU and sometimes social assistants (see figure 3).

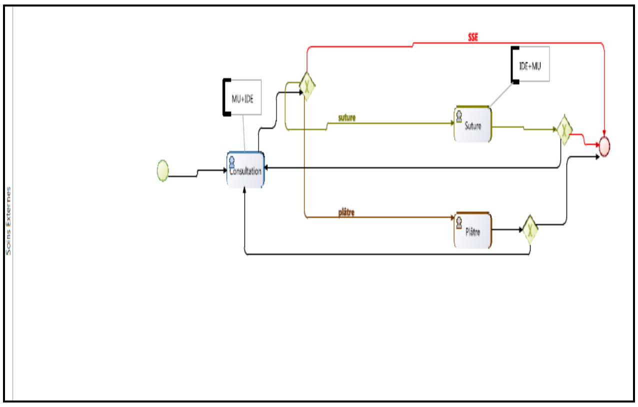

Figure 3 Workflow Model of the External Care

The Unit Short term Hospitalized (USTH) receives patients requiring observation period and or require additional tests and / or admitted to the operating room for possible surgery. At the end of the USTH process, the patient leaves the pediatric emergency department and he is returned at home, admitted to another PED or admitted to another care establishment.

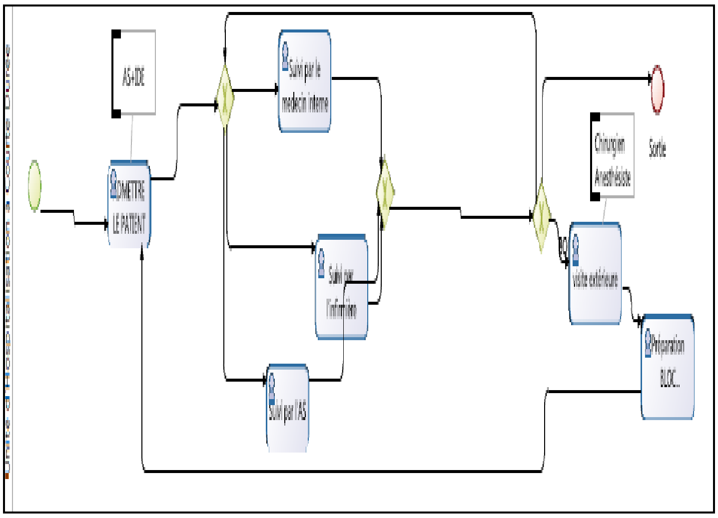

Figure 4 Workflow Model of the Unit of Short Term Hospitalization ((USTH)

The reception room is a vital emergency venue within the pediatric emergency department, patients with vital distress existing or potential.

This room has been created to enable the processing and fault monitoring of vital functions pending transfer to another service pediatric teaching hospital or to another hospital.

The equipment of the vital emergency room is checked daily and after each use.

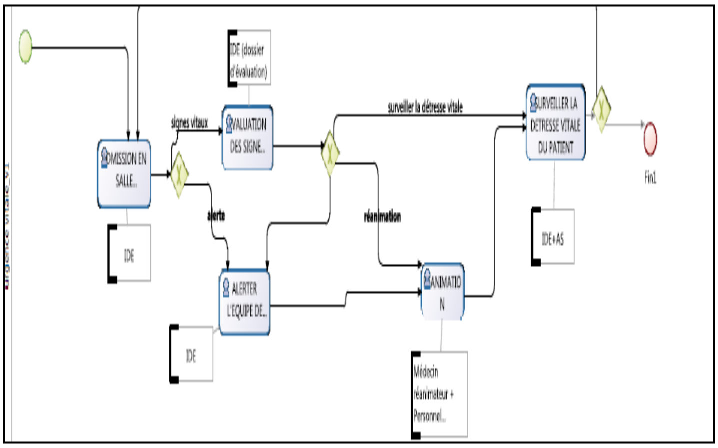

Figure 5 Workflow Model of the Care Emergency Vital

METHODOLOGY OF SIMULATION MODELING

Simulation with Workflow is a powerful tool for process analysis and improvement. One of the main challenges is to create simulation models that accurately reflect the real-world process of interest. Moreover, we do not want to use simulation just for answering strategic questions but also for tactical and even operational decision making. To achieve this, different sources of simulation-relevant information need to be leveraged. In this paper, we present a new way of creating a simulation model for a business process supported by a workflow management system, in which we integrate design, historic, and state information.

Our approach, we consider the setting of a workflow system that supports some real-world process based on a workflow and organizational model. Note that the workflow and organizational models have been designed before enactment and are used for the configuration of the workflow system [9] [10] [11].

Simulation results and discussion

Setting Tool: The tool is divided into several parts completely configurable

- ✓ Knowledge model: Elementary treatment of patients path, functions of random actors and activities together with the values of their attributes.
  The figure shows the interface to configure each patient path with all attributes defined in the diagram below: These results are presented as a PivotTable and they can be viewed by day, area of assignment, or by planning and resource type, the kind of output

date d'arrivée	adresser par	moyen d'arrivée	origine	temps de passage	date de sortie	traumatolog	CAC du séjour	Statut	age en mois	age ans	sexe	diagnostic princi
01/01/2011 00:02	NON	perso	domicile	0h 39m	01/01/2011 00:41		3091	Médical	90	8	F	Otite moyenne aiguë
01/01/2011 00:11	NON	perso	domicile	8h 19m	01/01/2011 08:30		3092	Médical	9	1	F	Commotion cérébral
01/01/2011 00:21	NON	perso	domicile	0h 47m	01/01/2011 01:08		3091	Médical	34	3	F	Rash et autres érup
01/01/2011 01:02	NON	perso	domicile	0h 24m	01/01/2011 01:26		3092	Médical	62	5	F	Difficulté liée à l'env
01/01/2011 01:31	NON	perso	domicile	0h 57m	01/01/2011 02:28		3091	Médical	17	1	M	Pharyngite (aiguë),
01/01/2011 02:09	NON	perso	domicile	1h 12m	01/01/2011 03:21		3091	Médical	3	0	F	Rhinopharyngite (ai
01/01/2011 02:20	NON	perso	domicile	1h 20m	01/01/2011 03:40		3091	Médical	9	1	F	Pharyngite (aiguë),
01/01/2011 03:43	NON	perso	domicile	1h 3m	01/01/2011 04:46		3091	Médical	17	1	M	Pharyngite (aiguë),
01/01/2011 04:26	NON	perso	domicile	1h 1m	01/01/2011 05:27		3091	Médical	6	1	M	Gastroentérites et c
01/01/2011 06:49	NON	perso	domicile	2h 56m	01/01/2011 09:45		3092	Médical	2	0	M	Insuffisance respira
01/01/2011 07:02	NON	perso	domicile	1h 1m	01/01/2011 08:03	N	3091	Médical	22	2	M	Otite moyenne, sans
01/01/2011 09:34	NON	perso	domicile	1h 18m	01/01/2011 10:52	N	3091	Médical	6	1	M	Néphrite tubulo-inter
01/01/2011 09:46	NON	perso	domicile	1h 12m	01/01/2011 10:58	N	3091	Médical	6	1	F	Rhinopharyngite (ai
01/01/2011 10:13	NON	perso	domicile	1h 24m	01/01/2011 11:37	N	3091	Médical	64	5	F	Pharyngite (aiguë),
01/01/2011 10:25	NON	perso	domicile	2h 2m	01/01/2011 12:27	N	3091	Médical	62	5	F	Gastroentérites et c
01/01/2011 10:50	NON	perso	domicile	1j 1h	02/01/2011 12:19	N	3092	Médical	14	1	M	Convulsions, autres
01/01/2011 10:56	AUTRE MEDECIN	perso	domicile	1h 45m	01/01/2011 12:41	N	3091	Médical	10	1	M	Balano-posthite
01/01/2011 11:14	NON	perso	domicile	1h 0m	01/01/2011 12:14	N	3091	Médical	25	2	M	Otite moyenne, sans
01/01/2011 11:27	NON	perso	domicile	2h 35m	01/01/2011 14:02	N	3091	Médical	41	3	F	Plaie ouverte de la l
01/01/2011 11:42	NON	perso	domicile	6h 2m	01/01/2011 17:44	N	3092	Médical	20	2	F	Insuffisance respira
01/01/2011 12:11	NON	perso	domicile	0h 30m	01/01/2011 12:41	N	3091	Médical	125	10	F	Varicelle (sans com
01/01/2011 12:21	NON	perso	domicile	1h 29m	01/01/2011 13:50	N	3091	Médical	2	0	F	Rhinopharyngite (ai
01/01/2011 12:26	NON	perso	domicile	2h 12m	01/01/2011 14:38	N	3092	Médical	6	1	F	Insuffisance respira
01/01/2011 12:37	NON	perso	domicile	2h 47m	01/01/2011 15:24	N	3091	Médical	35	3	M	Nausées et vomisse
01/01/2011 12:46	NON	perso	domicile	2h 33m	01/01/2011 15:19	N	3091	Médical	107	9	F	Gingivo-stomatite et
01/01/2011 13:05	NON	perso	domicile	7h 26m	01/01/2011 20:31	N	3092	Médical	29	2	M	Intoxication par méd

Figure 6 Data Base of patient path 2011

date d'arrivée	adresser par	moyen d'arrivée	origine	temps de passage	date de sortie	traumatolog	CAC du séjour	Statut	age en mois	age ans	sexe	diagnostic princi
01/01/2011 00:02	NON	perso	domicile	0h 39m	01/01/2011 00:41		3091	Médical	90	8	F	Otite moyenne aiguë
01/01/2011 00:11	NON	perso	domicile	8h 19m	01/01/2011 08:30		3092	Médical	9	1	F	Commotion cérébral
01/01/2011 00:21	NON	perso	domicile	0h 47m	01/01/2011 01:08		3091	Médical	34	3	F	Rash et autres érup
01/01/2011 01:02	NON	perso	domicile	0h 24m	01/01/2011 01:26		3092	Médical	62	5	F	Difficulté liée à l'env
01/01/2011 01:31	NON	perso	domicile	0h 57m	01/01/2011 02:28		3091	Médical	17	1	M	Pharyngite (aiguë),
01/01/2011 02:09	NON	perso	domicile	1h 12m	01/01/2011 03:21		3091	Médical	3	0	F	Rhinopharyngite (ai
01/01/2011 02:20	NON	perso	domicile	1h 20m	01/01/2011 03:40		3091	Médical	9	1	F	Pharyngite (aiguë),
01/01/2011 03:43	NON	perso	domicile	1h 3m	01/01/2011 04:46		3091	Médical	17	1	M	Pharyngite (aiguë),
01/01/2011 04:26	NON	perso	domicile	1h 1m	01/01/2011 05:27		3091	Médical	6	1	M	Gastroentérites et c
01/01/2011 06:49	NON	perso	domicile	2h 56m	01/01/2011 09:45		3092	Médical	2	0	M	Insuffisance respira
01/01/2011 07:02	NON	perso	domicile	1h 1m	01/01/2011 08:03	N	3091	Médical	22	2	M	Otite moyenne, sans
01/01/2011 09:34	NON	perso	domicile	1h 18m	01/01/2011 10:52	N	3091	Médical	6	1	M	Néphrite tubulo-inter
01/01/2011 09:46	NON	perso	domicile	1h 12m	01/01/2011 10:58	N	3091	Médical	6	1	F	Rhinopharyngite (ai
01/01/2011 10:13	NON	perso	domicile	1h 24m	01/01/2011 11:37	N	3091	Médical	64	5	F	Pharyngite (aiguë),
01/01/2011 10:25	NON	perso	domicile	2h 2m	01/01/2011 12:27	N	3091	Médical	62	5	F	Gastroentérites et c
01/01/2011 10:50	NON	perso	domicile	1j 1h	02/01/2011 12:19	N	3092	Médical	14	1	M	Convulsions, autres
01/01/2011 10:56	AUTRE MEDECIN	perso	domicile	1h 45m	01/01/2011 12:41	N	3091	Médical	10	1	M	Balano-posthite
01/01/2011 11:14	NON	perso	domicile	1h 0m	01/01/2011 12:14	N	3091	Médical	25	2	M	Otite moyenne, sans
01/01/2011 11:27	NON	perso	domicile	2h 35m	01/01/2011 14:02	N	3091	Médical	41	3	F	Plaie ouverte de la l
01/01/2011 11:42	NON	perso	domicile	6h 2m	01/01/2011 17:44	N	3092	Médical	20	2	F	Insuffisance respira
01/01/2011 12:11	NON	perso	domicile	0h 30m	01/01/2011 12:41	N	3091	Médical	125	10	F	Varicelle (sans com
01/01/2011 12:21	NON	perso	domicile	1h 29m	01/01/2011 13:50	N	3091	Médical	2	0	F	Rhinopharyngite (ai
01/01/2011 12:26	NON	perso	domicile	2h 12m	01/01/2011 14:38	N	3092	Médical	6	1	F	Insuffisance respira
01/01/2011 12:37	NON	perso	domicile	2h 47m	01/01/2011 15:24	N	3091	Médical	35	3	M	Nausées et vomisse
01/01/2011 12:46	NON	perso	domicile	2h 33m	01/01/2011 15:19	N	3091	Médical	107	9	F	Gingivo-stomatite et
01/01/2011 13:05	NON	perso	domicile	7h 26m	01/01/2011 20:31	N	3092	Médical	29	2	M	Intoxication par méd

Figure 7 Data Base of patient path 2012

- ✓ Human Resource Management: resource allocation to patients and human resource planning
- ✓ The system load : the number of beds, number and characteristics of patients present in the (PED)

The results obtained: model results was defined with users, the result is presented using a software Bonitasofet that give access to indicators graphically performance

For a simulation in the different department, the main gotten results are the next one. The validation of model is a priority before the experimental phase. We have done a lot of testing to review and adjust the setting and control model to approach reality as finely as possible

In figure 8 below is the curve of the number of patients treated in the PED for a month based on actual data from last year. The PED is overcrowded in March, 17th, 27th, 2012.

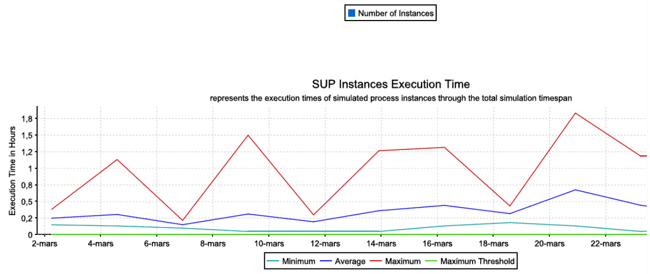

Figure 8 Distribution of patient in Pediatric Emergency Department

The curve in the figure 9 shows the number of patients processed in the box. This simulation gives us an idea about the Box using as a critical resource over time.

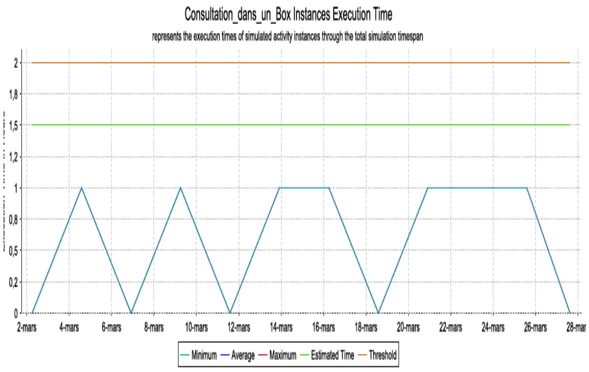

Figure 9 Average waiting time for patient in the Box

The figure 10 shows a peak of activity in the traditional hospital unit which focus on the maximum of peak activity at March 12th, 2012.

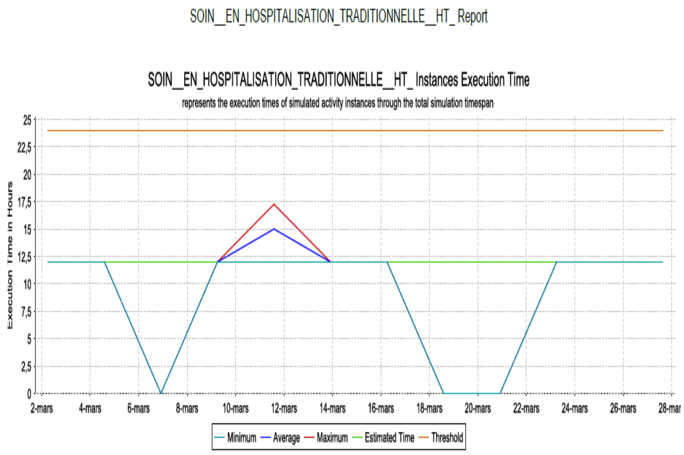

Figure 10 Patient cares in Traditional Hospitals

The figure 11 are some statistics collected from the simulation run with process instances, figure 11 is a graphic interface of the progress monitor module showing the turn-around times of the nurses (i.e., process instances). In this figure 11 shows the utilization of each participant. In this particular case, the average turn-around time, the average resource utilization is (2 nurses in the morning 3 in the afternoon and 2 nurses in the evening), considering this number is sufficient in 80% of cases represent the steady state of the service which is running in normal activity.

We can conclude that the nurses scheduling activity process is heavily unbalanced. That is, there are severe job delays while the resources are underutilized. However, it should be noticed that the simulation results show only the behavior of the system during an initial transition period.

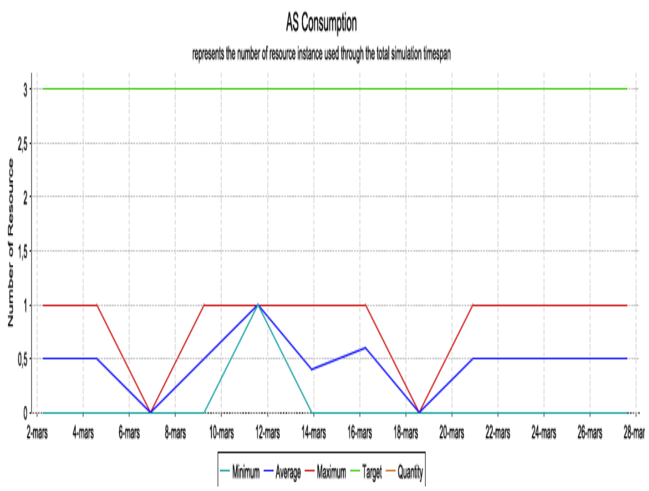

Figure 11 Distribution of the nurses' resource in the PED

For a rigorous simulation analysis, steady-state simulation runs need to be made to observe key system performances such as the distribution, the profile of pending jobs, the profile of pending workitems for each participant, and the utilization of medical staff.

CONCLUSION

In this paper, we have proposed a Workflow system for the care of patients at PED. This application demonstrates the utility of the methodologies proposed by this system. On the other hand, our system provides the modeling of PED's patients which generates their treatment plan and manages the interaction between the modeling and simulation to take care of patients at the PED. We are considering implement this tool and interoperate it with other tools such as the optimization tools for planning and timetabling beds planning tool.

In future work we aim to establish the scheduling tools of materials and medical staff resources in order to achieve the optimal use of these resources. We also propose an articulation tool between the PED steady-state and the PED transistor-state.

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