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Dynamic modeling of the patient journey in a Pediatric Emergency Department of CHRU of Lille

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ABSTRACT

The Workflow models of the patient journey in a Pediatric Emergency Department (PED) seems to be an effective approach to develop an accurate and complete representation of the PED processes. The model developed can drive the collection of comprehensive quantitative and qualitative service delivery and patient treatment data as an evidence base for the PED planning. Our objective in this study is to identify tension indicators and bottlenecks that contribute to over-crowding, the goal is to optimize these paths to improve the quality of the patient handling while mastering the time waiting. 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. The main aim of this paper is to present the overall design of the proposed Workflow model, emphasizing the simulation results in the normal situation and the crowding situation. Besides, we describe the crowding indicators in PED. Our survey is integrated into the French National Research Agency project, titled: “Hospital: optimization, simulation and avoidance of strain” (ANR HOST).

Indexing terms/Keywords

Pediatric Emergency Department (PED); Workflow; Modelling; Healthcare logistics; Healthcare management.

Academic Discipline And Sub-Disciplines

Healthcare Logistics; healthcare management; Pediatric Emergency Department.

SUBJECT CLASSIFICATION

Healthcare Logistic, Healthcare management

TYPE (METHOD/APPROACH)

Workflow modeling and simulation

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1. Introduction

In France, as in many countries of Europe, the emergency departments present the same difficulties whose reasons are multiple. These difficulties are not only linked to the health organization but also to the evolution of the western civilization [1]. The requirements concerning health care evolved in relation with a new approach to management of the time. Today, people require a fast and efficient handling. They reject the ageing, the illness and the death [2]. The arrival patient flow to the emergency department keeps increasing. This rise has generated a strategic interest in optimizing the technical and human resources while mastering the costs [3]. In order to reach these objectives, the health establishments have resorted to the tools and techniques of management borrowed from the industry domain [4] as the Workflow tool that will be used in this article. The use of Workflow methodology showed applicability and the interest of the company modeling method to reorganize a health establishment. It allowed improving the performance of different service and activities conduct system [5]. The Discrete Event Simulation (DES) techniques have been used a lot for modeling the operations of an Emergency Department (ED). The model was developed to test alternative ED attending physician-staffing schedules and to analyze the corresponding impacts on patient throughput and resource utilization, to help the ED managers understand the behavior of the system with regard to the hidden causes of excessive waiting times [6], to analyze patient flows and throughput time [7][8][9][10]. DES has also been used for estimating future capacities of new ED facilities or expansions [11] [12]. The main objectives of the present paper are: 1) To model the Pediatric Emergency Department (PED) using Workflow Methodology for better understanding the patient flow process through the PED, 2) To simulate using the same tool Workflow in order to identify and analysis the dysfunctions of the PED; Also, we propose and estimate prevention indicators of tensions

This article is structured into four sections. The first present the context of the survey. A state of the art workflow system in the field of health will be presented in the section two. In the third section, we explain the workflow modeling at the PED. In the fourth section, the results of simulation model and some experiments as well as conclusions are presented.

2. state of the art

The care for patients occurs in different modes related to the type of needed care [13]: planned treatment, care requiring (or not requiring) a hospital (ambulatory) and unscheduled care in an emergency (or non-emergency). The emergency medical assistance is an extremely important and sensitive issue. Solutions must be developed not only in French but also in Europe where the same problems exist. Thus, all European emergency medical assistance services met on 14 and 15 March 2005 in Paris to discuss their issues and how to improve their activities. More than 350 participants from 30 European countries participated in this discussion. The complexity of the concerned problems is illustrated by the diversity [14], the solutions (specialized call centers, dedicated emergency units, mobile crisis teams…) without any satisfactory results. The United Kingdom, to cope with these difficulties, has established protocols for management of the emergency, which now allow the National Health Service (NHS) display care delay less than 4 hours in a system previously heavily criticized for the length of its waiting time [15]. These protocols are accompanied by a reconfiguration of the activities, a redistribution of tasks between professional groups and the development of tools for communication and exchange. Furthermore, analysis of the system of health care services in Quebec and the transformation of the Montreal Network [16]. Show that the organization of services has not been able to adequately adapt to the rapid changes and budgetary constraints imposed on networks supported (Centre National Emergency Coordination [17], Emergency Management Guide). The Quebec, such as France [18], including the creation of a guide to management and organization of the emergency order to flatten the process and to standardize key stages: triage, patient observation time, demand consultation modality integration of personal processes, utilization management beds, liaising with teams. Thus, the discussed issues cover the scientific, technical, social, informational and human. Thus, a multidisciplinary approach is needed to mobilize expertise from different disciplines. It will allow for both the diagnosis and the architecture design and management models of the hospital crowding for their evaluation, to adopt a critical multi-view approach.

The Emergency department (ED) crowding is an international problem that may affect the quality and access of health care. There are different commonly studied causes, effects and solutions for the ED crowding. Firstly, the studied causes include non-urgent visits, "frequent-flyer" patients, influenza season, inadequate staffing, inpatient boarding, and hospital bed shortages. Secondly, the studied effects correspond to patient mortality, transport delays, treatment delays, ambulance diversion, patient elopement, and financial effect. Finally, the studied solutions of crowding include additional personal, observation units, hospital bed access, non-urgent referrals, ambulance diversion, destination control, crowding measures and queuing theory. The results illustrated the complex, multifaceted characteristics of the ED crowding problem. Additional high-quality studies may provide valuable contributions toward better understanding and alleviating the daily crisis.

3. The Workflow model and the patient journey in ped

The main objective of our survey is to identify the dysfunctions of the PED and also to propose crowding simulation. To achieve this objective, it is necessary to have a global Workflow model of the PED and its environment. Before optimizing and simulation of the PED, it is necessary to analyze and to characterize the PED structure. It requires the use of Workflow methodology to represent the functional and process view of the PED and its related parts.

Two models were created: one representing the operation of the service in normal time, when the input stream is not too large, and the other representing the operation in the saturation of the service (Crowding situation). At first, we discuss the ongoing modeling normal time, which was also the first made; it is the simplest effect because the resources are available in sufficient quantity to meet the needs of all comers with normal use. So you can easily find the resources used by a patient and to know what path he has made. After, we will look at the saturated complex modeling because resources are not assigned to tasks according to predefined amounts to manage the inflow too much resource are shared and if you prefer reproduce a normal process. It is sometimes necessary to use rooms or divide time for different tasks more unusual ways. This translates into an increased number of possible routes and thus complicates the modeling.

3.1 Workflow Method

Was implemented a structured method research design which comprised five major steps:

1) Several visits were piloted in the PED of CHR of Lille with researchers and physicians (the HOST ANR project partners) to build a model of the patient path and PED treatment processes as the basis for a patient map-ping form to collect data;

2) Each Research Assistant (RA) partner of the project spent a continuous 10 days mapping exercise during which they independently observed and manually recorded patient journeys through the PED for a sample of presentations;

3) In order to validate all-day observations, a PED staff meets the re-search assistant regarding their observations of patient flow;

4) The analysis of data obtained during steps 1-3 to construct dynamic models of the process. This model will be constructed with the BPMN graphical language which is an international standard.

5) Model simulation and its comparison with the real scenarios of patient path. The goal of this step is to optimize the model.

The methodology included is important design characteristic that distinguished it from published PED patient flow modeling projects. The use the workflow approach and especially the Business Process Management Notation (BPMN) graphical tool enables the verification and validation of the processes directed with the PED staff. The Workflow produces a model that describes precisely the activities flow in the patient path. Also, by using an internationally standardized language (BPMN) [2], the benefits of common understanding with precise semantics are realized. This language is based on five basic features (Figure 1): the events, the gateways, the activities, the connectors and the pools (or lanes) to support processes.

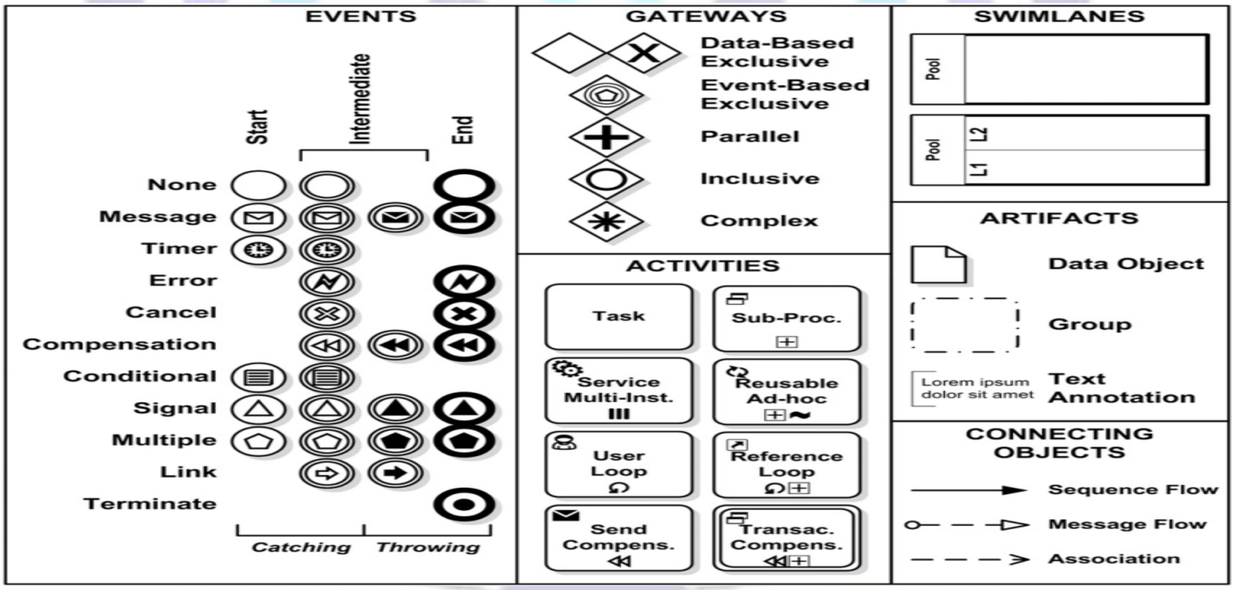

Figure 1 Basic items of the BPMN language

3.2 Modeling of normal situation

It reflects the organization of the pediatric emergency department during normal operation, it is relatively easy given the modest size of the service and the fact that the majority of the causes of the coming emergencies are recurrent and doctors accustomed to forward to a kind of patient -specific pathology or injury he suffers route deviation. Thus all patients coming for common diseases during episodes of epidemic winter flu or gastroenteritis have similar paths, and for patients with a fracture.

The workflow model (Figure 2) shows the major stages, activities and actions of the patient journey in the PED. There are three major stages: Stage 1, (Patient Arrival and Initial Assessment), Stage 2, (Patient (re)orientation and treatment) and Stage 3 (Patient Destinations). The patient can be orientated or reoriented to one of these units knowing that some of them are represented by a sub-process in the global process workflow model:

- Box Unit (BU), corresponding to an In-cubicle treatment;
- Sub-process External Care Unit (ECU),
- Sub-process Unit of Short Term Hospitalization (USTH),

- Traditional Hospitalization Unit (THU),
- Sub-process Vital Emergency care Unit (VEU).

On another hand, we note the uncertain environment in the patients care in the PED and the risks that can emerge during their paths. This uncertainty confirms the complexity of the emergency care system. It is also interesting to see that some activities of these processes are decisional. These decisions are expressed in the model by six Synchronization Points SPi (1≤i≤6) called gateways, in the Figure 5. These graphical items are used to control the behavior of the sequence flows within a process. The decision points SPi (1≤i≤6) of the global workflow model are detailed as follows:

- SP1: shows the kind of the arrival perceived by the patient: urgent and not urgent. If the patient supposes that his case is urgent, he goes directly to the reception and orientation desk. Otherwise he goes to the registration one.
- SP2: controls the registration and the orientation of the patients.
- SP3: has the role to direct the patient to vital emergency or waiting room.
- SP4: this point is central because it represents the input bottleneck point of the global model. It directs the patients into the suitable unit care depending on their pathologies.
- SP5: this point is important because it represents the output bottleneck point of the global model. It redirects the patients into one of these places:
    - Waiting room: in this case, the patient has to wait before the continuity of his care. For example, he has to wait the results of the MRI scans.
    - Other units: in this case, the patient must returns to one of the PED units. These units are: ECU, USTH, VEU, BU and THU. We note that in the USTH and VEU, the bed and room resources stay available for the same patient during his care. This information is very important for the establishment of the scheduling process.
    - Transfer: in this case, the patient will be carried to another care establishment with a emergency stretcher bearer.
    - Complementary Exams Unit (CEU): the patient has to do complementary exams for this pathology diagnosis.
    - Home: the patient returns at home with a good quality of care thanks to our system.
- SP6: after the complementary exams, the patient will return to waiting room or USTH.

These decision points, at which the patient journey is dependent on a combination of treatment characteristics and the availability of physical resources, are represented by gateways in the global model.

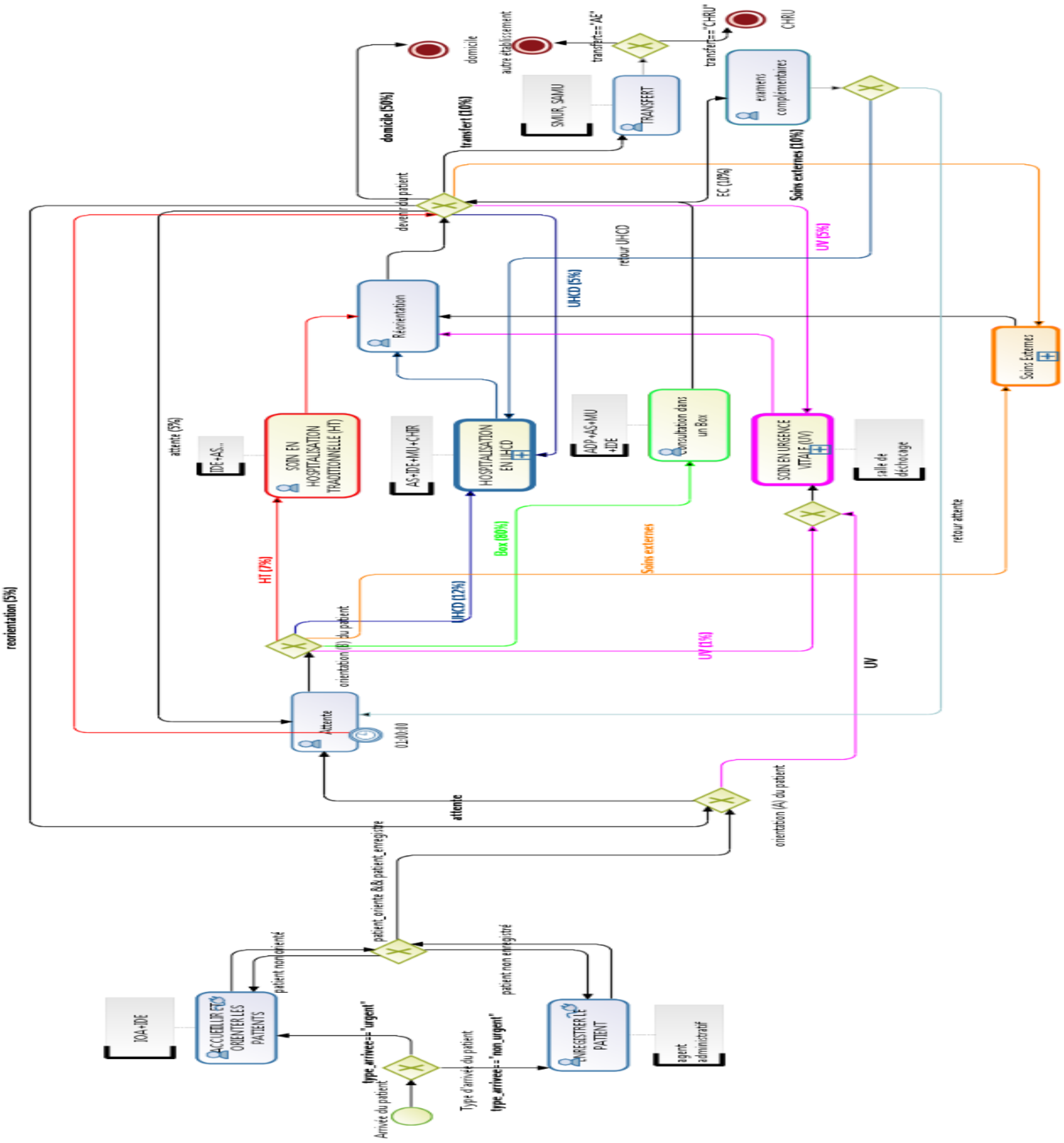

Figure 2 Global Model Workflow of PED (normal situation)

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.

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).

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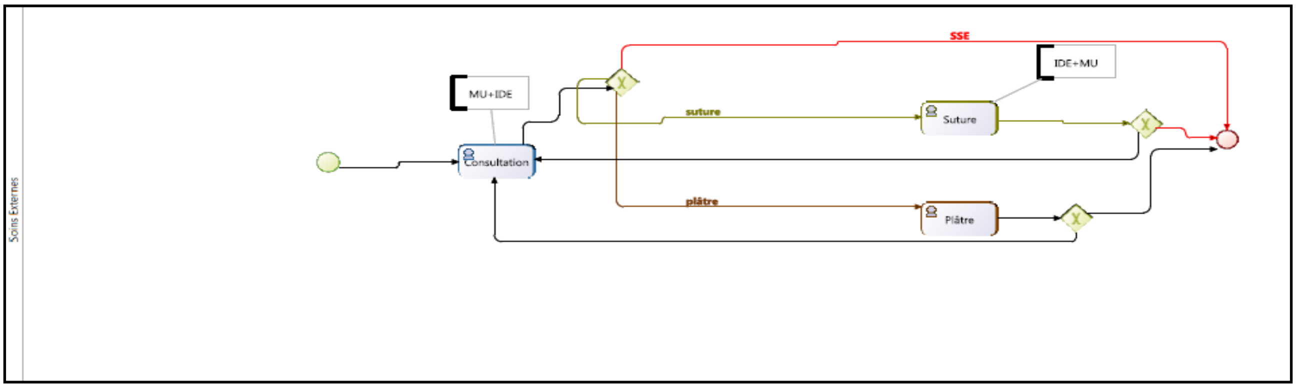

Figure 3 Workflow Model of the External Care

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.

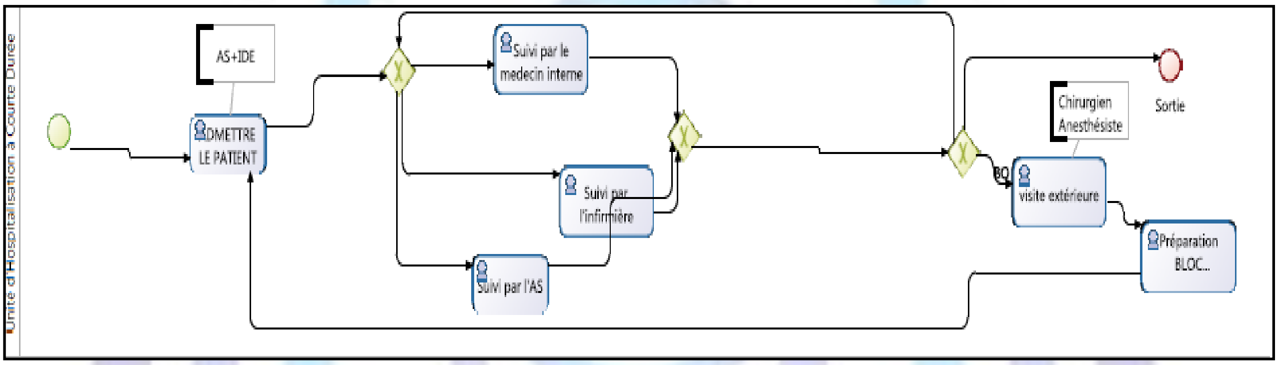

Figure 4 Workflow Model of the Unit of Short Term Hospitalization ((USTH)

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.

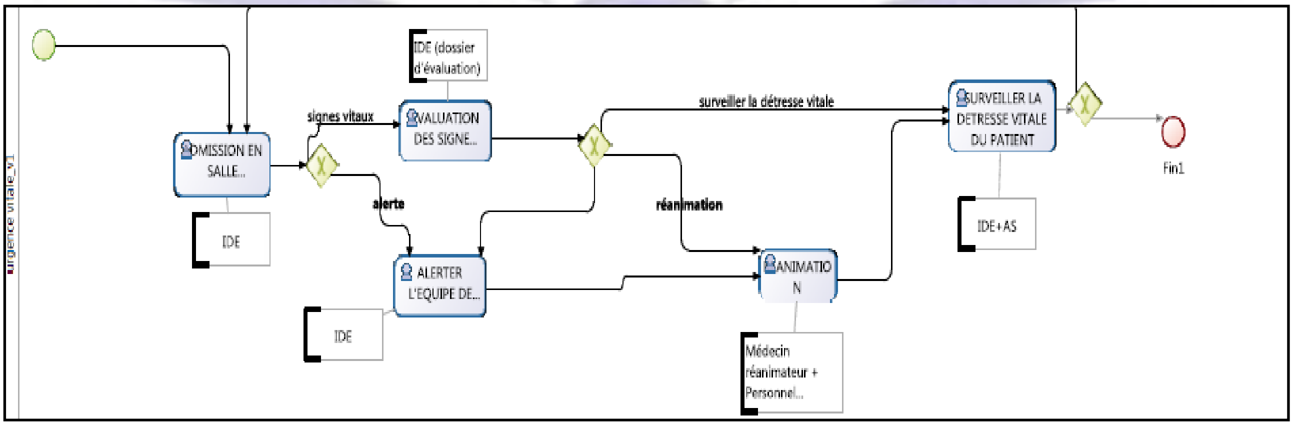

Figure 5 Workflow Model of the Care Emergency Vital

3.3 Modeling crowding situation

During peaks of activity, the emergency pediatrics department is overwhelmed since it is the main entrance for children, whatever their symptoms are. The waiting room is not wide enough, mothers pile up in tight halls of the department with their young children and their waiting time keeps increasing. The department swings into a new stage of operating, called the “crowding situation”, in order to make the stream of patients more fluid. From now on, the “room” or “bed” resources and even some human resources are not dedicated anymore for the execution of some tasks. For instance, a consultation that is usually carried out in a consultation room can now be done in a stitch/plaster cast room if it is available. These new operating rules maximize the use of resources available in the emergency pediatrics department in order to reduce the waiting time while maintaining high quality of medical care.

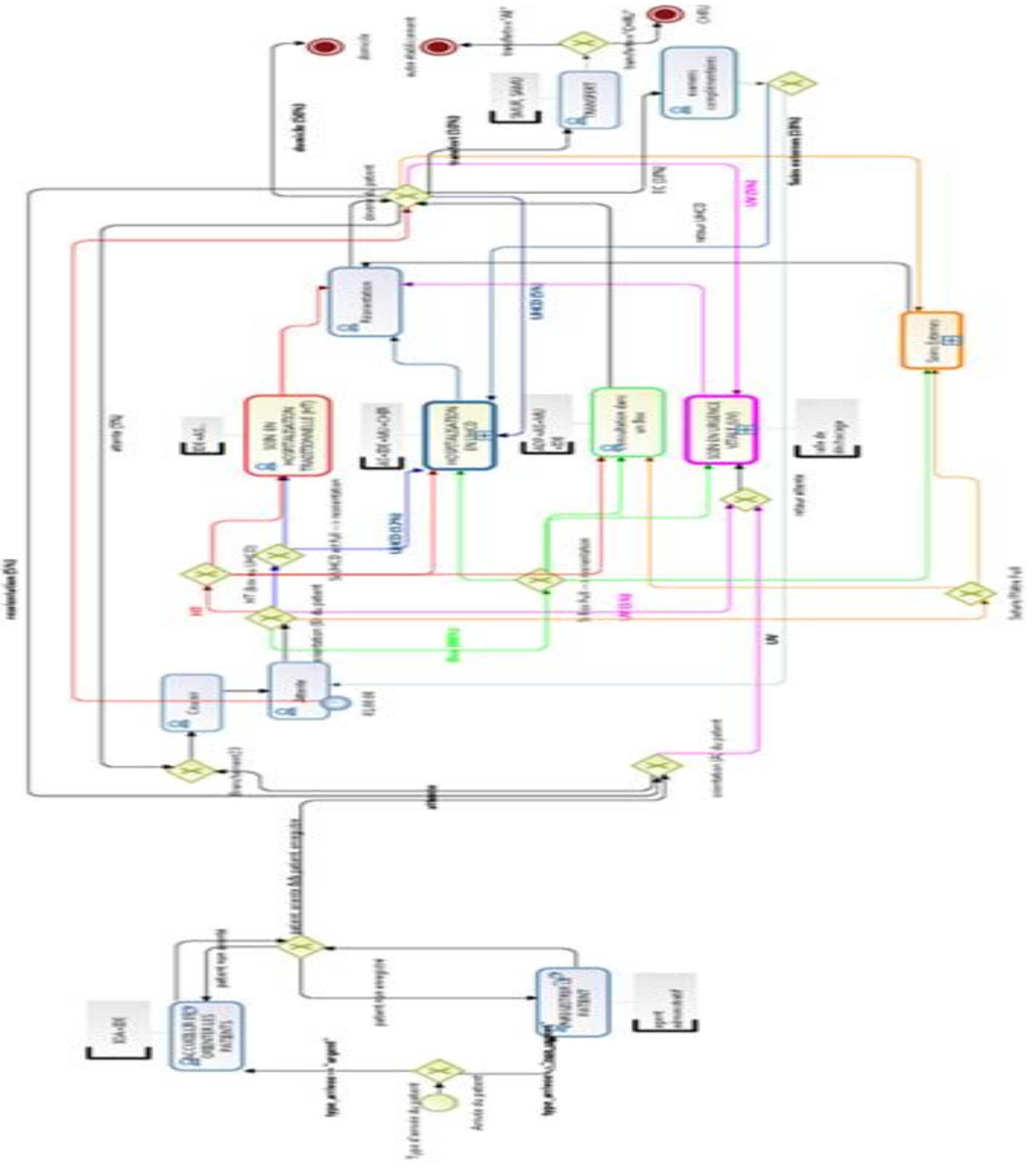

Figure 6 Global Model Workflow of PED in crowding situation

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4. Pediatric Emergency department simulation

4.1 Simulation parameters

The Business Process Model and Notation (BPMN) is the de-facto standard for representing in a very expressive graphical way the processes occurring in virtually every kind of organization. At the present, the state-of-the-art in the field is represented by BPMN (Business Process Model and Notation) [1], the leading standard in the frame of business processes and workflow modeling languages. It is possible to identify three different application domains for modeling languages: pure description, simulation and execution of processes.

Simulation parameters are set in the simulation module of the Bonita software. Figure 6 shows main interface of the simulation module which allows the edition and the modification of the load profile:

- Injection period : corresponds to the time window of the staff medical activity
- Number of the instances: corresponds to the number of patient cases distributed with a repartition type. For this example, we injected 1000 patients' cases.
- Repartition type: there are two kinds of repartitions : The constant repartition: dispatches instances injection in a constant way along the period, the direct repartition: dispatches instances injection in the start of the period

  For this example, we assume a constant repartition

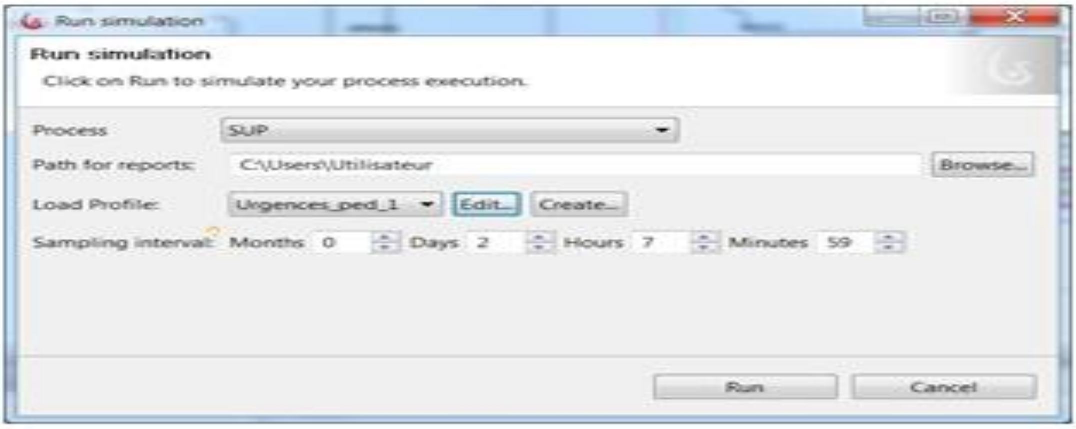

Figure 7 simulation profile

4.2 Simulation of normal situation

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]. To start a simulation, several parameters must be entered: resources play the key role in the realism and reliability. For each task it is necessary to specify the resources for its development. Whenever the task is done it consumes resources. If some are not available when the task should start, it is expected that all the missing resources are available again to actually start the job. We must then define an incoming flow of patients to run the simulation. We developed from the database provided by the hospital different profiles of typical loads. As a first step, we defined the days of winter-type summer and spring / autumn. The difference between the profiles is characterized by the number of patients and the time of arrival, which vary according to time of year .The results are curves showing the minimum, maximum and average time to complete the various tasks involved with these processes and utilization of resources. The wait is actually recorded at each task. Once the previous completed, the patient arrives in the next task and expected within this time it is powered. So we can know the contribution of each part of the course in the final waiting experienced by the patient. Our goal, using the permanent model is determined by these factors voltage curves of the plan to try to limit them to reduce waiting times at most. We chose to simulate a period of two days to see the impact of the first day of the second.

We first tested a light load profile that transcribes the rather low activity of the pediatric emergency department in the summer. We note that the average waiting time in the service is between 30min and 2h30, with a peak between 18h and midnight.

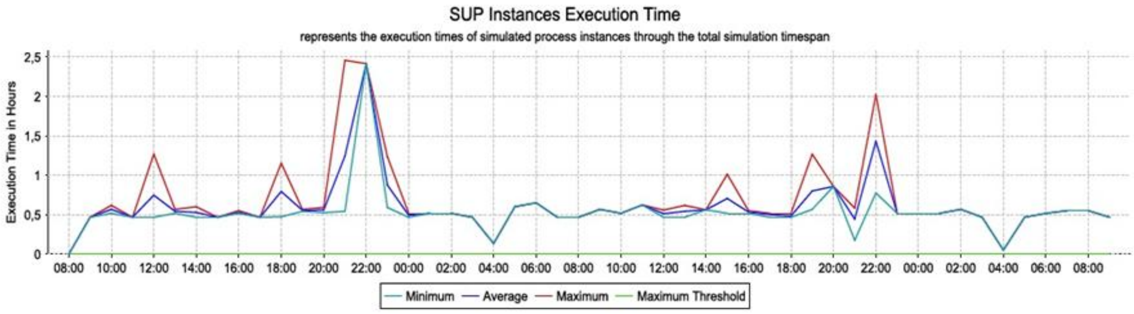

Figure 8 Average wait time (summer)

The winter profile disrupts benefit service since the average waiting time is now between 1 and 4 o'clock with a peak at midnight.

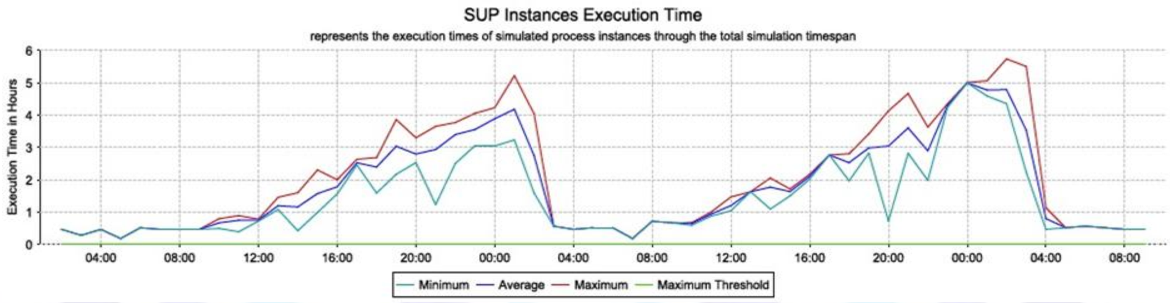

Figure 9 average wait time (winter)

Profile crisis highlights the limits of the pediatric emergency department because the average waiting time diverges and estimated ten hours. The staff cannot handle both the patients present in the hospital and those arriving.

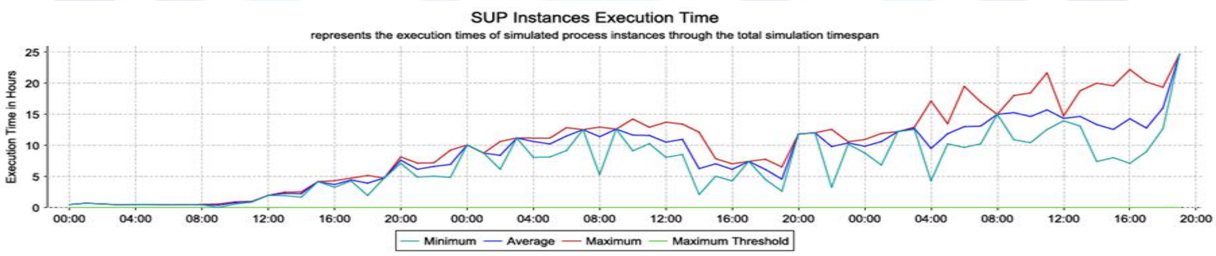

Figure 10 Average wait time (Crisis)

4.3 Simulation of crowding situation

In order to obtain comparable to normal situation results, we used the same simulation parameters. Thus, resources are identical, and load profiles are also the same, namely a "summer" rather quiet profile, "winter" profile a little more responsible and a profile of "crisis" very busy. From this last load profile, we get the following results with respect to the total execution time of the journey, including waiting time for a patient.

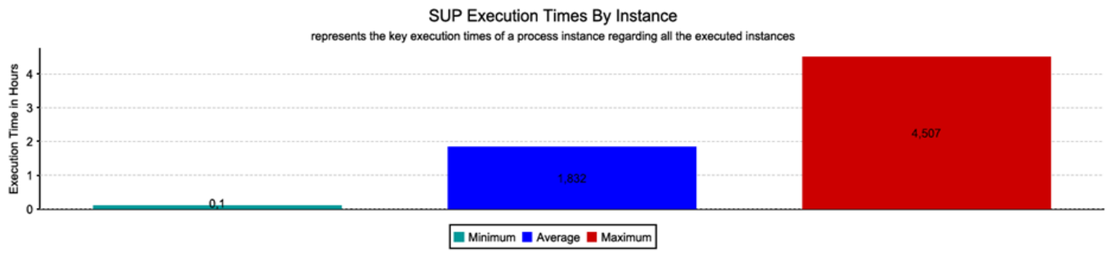

Figure 11 Waiting time by instance (Crisis)

The "maximum" time is of great importance. It corresponds to the worst case happened during the simulation, so here is spent in the Emergency Department Pediatric 4:30. Note that these times may be slightly lower than those actually measured since the simulation has limitations, due inter alia to the discretization of data, and therefore may not exactly match the reality. We dwell on simple consultations represent the vast majority of cases handled by the Pediatric Emergency Department: 78% in our model. These consultations are not the most urgent cases, quite the contrary. Thus, the patient wait is concentrated here, and the management of the sector has an impact that is automatically very important to the average waiting time of patients passing through the Pediatric Emergency Department.

In our crowding simulation, these consultations can be done mainly in two different types of rooms: the box, as normal and room's casts and sutures. The curve describing the box occupancy is:

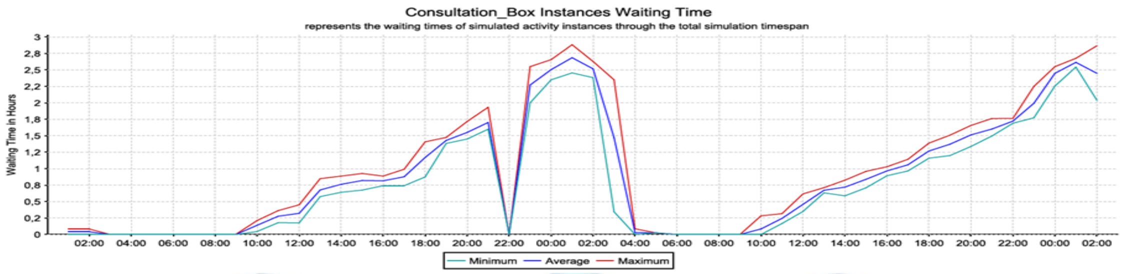

Figure 12 Box occupancy (Crisis)

So we end up with a consistent result in terms of the hospital since the waiting time increases gradually during the day from 9am and then descends abruptly around 1 hour at 2am. There is still a quiet waiting period anywhere on the rest of the night (3h/4h - about 9am). Thus, the service restarts vacuum the next day, as is the case in reality, and therefore not cumulative pending his patients a day on the other.

5. Conclusion

The major contribution of this research is that a method of integrating workflow systems and simulation in crowding situation is developed, and its potential capability has been demonstrated through a prototype implementation. The approach enables us to analyze the performance of newly designed processes before actual execution. One difficulty using crowding simulation technology is estimating various parameters. For example, task processing time in a workflow system is usually set to a value, while a simulation assumes a probability distribution for it. A user must input the data. However, if it is possible to use statistical data that can be obtained during execution of the workflow system, it can enhance the accuracy of the simulation. This means that parameter adjustment forms an important future research issue.

In the future, we aim to develop planning tools materials and medical personal in order to achieve optimal use of those resources. Also, we propose an alliance between Multi-Agent System MAS and Optimization.

ACKNOWLEDGMENTS

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