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Mapping patient path in the Pediatric Emergency Department: A workflow model driven approach

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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. This model can drive the collection of comprehensive quantitative and qualitative service delivery and patient treatment data as an evidence base for the PED service planning. Our objective in this study is to identify crowded situation indicators and bottlenecks that contribute to over-crowding. The greatest source of delay in patient flow is the waiting time from the health care request, and especially the bed request to exit from the PED for hospital admission. It represented 70% of the time that these patients occupied in the PED waiting rooms. The use of real data to construct the workflow model of the patient path is effective in identifying sources of delay in patient flow, and aspects of the PED activity that could be improved. The development of this model was based on accurate visits made in the PED of the Regional University Hospital Center (CHRU) of Lille (France). This modeling, which has to represent most faithfully possible the reality of the PED of CHRU of Lille, is necessary. It must be detailed enough to produce an analysis allowing to identify the dysfunctions of the PED and also to propose and to estimate prevention indicators of crowded situations. Our survey is integrated into the French National Research Agency (ANR) project, titled: "Hospital: Optimization, Simulation and avoidance of strain" (HOST).[1]

1. Introduction

In many countries, Emergency Departments are facing problems associated with increased demand in their services [1,14,18–20]. The arrival patient flow to the Emergency Department is stochastic and keeps increasing. This rise has generated a strategic interest in optimizing the technical and human resources while mastering the costs [3]. Especially, Pediatric Emergency Departments (PEDs) have limited resources and/or staff trained, in addition of busy and noisy environment, combined with acuity. This situation creates a set of unique challenges for the patient, family, and care providers [15–17].

This real problem is the main challenge of the HOST[2] project. The objective is to elaborate an innovative methodological approach for the anticipation of the crowded situation of the complex care production system and more especially of the emergency paths in the PED of the CHRU[3] of Lille in France. The tension-reduction strategy, the performance assessment and traceability of the patient course are integrated into the suggested approaches.

The scientific fallouts expected of this project are:

- A prospective vision of the modeling and the monitoring of global PED activity handling system.
- A good tool to anticipate the crowded situations of the PED.
- A scheduling tool for the programmed and not programmed health tasks, taking into account the medical staff skills.

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[1] Hôpital: Optimisation, Simulation et évitement des Tensions (ANR-11-TecSan-010: http://host.ec-lille.fr/wp-content/themes/twentyeleven/docsANR/R0/HOST-WP0.pdf).

[2] "Hospital: Optimization, Simulation and avoidance of strain" Hôpital: Optimisation, Simulation et évitement des Tensions (ANR-11-TecSan-010: http://host.ec-lille.fr/wp-content/themes/twentyeleven/docsANR/R0/HOST-WP0.pdf).

[3] Regional University Hospital Center (CHRU) of Lille (France).

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- The fallouts for emergency paths actors will consist in establishing the methods and operational tools allowing:
  - o To bring the recommendations for the emergency paths conception and reengineering for health establishments,
  - o To improve the handling efficiency and the quality of the service returned to the patient,
  - o To assure a better internal and external coordination with the other actors of the emergency path when the crowded situations cannot be avoided.

Our work represents the first step of the national project (HOST) realization and discusses the emergency handling system. Modeling patients' paths at PED 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 PED staff perceived a number of problems in the management of the PED processes which generate peaks of activity. That is why we have to look for ways to model and then to optimize the PED processes within an environment of increasing demand. To achieve this goal, it is imperative that the associated activities are accurately identified and fully understood.

Modeling of the PED process to investigate problems such as long waiting times and delays in admissions have been extensively reported. PEDs have investigated and adopted a variety of process modeling approaches from business and industry sectors as well as academic disciplines, in an effort to improve efficiency and increase productivity [21–23,4].

The objective of this paper is to provide a complete picture of the PED delivery processes and detailed data on all aspects of the patient journey in order to identify bottlenecks that potentially contribute to overcrowding. For that, we study and analyze the patients' paths in the PED of CHRU of Lille in France, focusing on the identification of the service dysfunctions.

In the present paper, modeling has been used to create an accurate picture of the patient journey within the PED and to clearly depict activities of particular concern to the PED staff. The workflow methodology has shown its efficiency improving the performance of complex business processes and especially health processes [4]. These latter are of significant importance to the early design phase of a software development project since they provide a procedural view on the business. A fundamental problem in this context is the selection of an appropriate notation for defining business process models. Several flowchart-like languages are currently used in practice, including languages like Event-driven Process Chains (EPCs) [38], or diagrams offered by the Unified Modeling Language (UML), most notably Activity Diagrams [27]. Recently, standardization efforts between the Object Management Group (OMG) and the Business Process Management Initiative (BPMI) have led to the definition of the Business Process Model and Notation (BPMN) (OMG, 2011).

The BPMN is a common standardized graphical language which allows the design of a workflow model [24]. It offers the following advantage: including the events, sub-processes, activities, gateways, data and conversations in the same model representing the considered processes. These are critical to our study because we have to model the patient journey as many detailed interconnected processes and sub-processes.

In this paper, we explain how we capture the data necessary to build BPMN models to represent the patient journey through the PED. We then describe how analysis of these models enabled subsequent models (sub-processes) to be constructed to provide more detailed views of the patient journey and sources of delays to be identified.

Therefore, the main contribution of this paper is the introduction of a novel model workflow, approach based on the optimization of the patient path in the Pediatric Emergency Department.

A state of the art workflow system in the field of health will be presented in the second section. In Section 3, we describe the methods of workflow system in the PED. Experiment results are presented in Section 4. After describing the results of the model workflow in Section 6, we present in Section 5 a discussion concerning patient path in the PED. Many limitations are presented in Section 7, This article is closed with conclusions and an outlook to further work.

2. State of the art

2.1. Emergency Department Management

The care of patients occurs in different modes related to the type of needed care: planned treatment, care requiring (or not requiring) a hospital (ambulatory) care 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 [25,26]. 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 illustrated by the diversity [12] of 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[4] (NHS) display care delay less than 4 h in a system previously heavily criticized for the length of its waiting time [13]. 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 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 (CCNU) (2002), Emergency Management Guide). The Quebec, such as France [28], 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

[4] http://www.droit-medical.com/perspectives/9-variations/418-national-health-service-nhs.

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 approach to multi-view.

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 personnel, 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.

2.2. The crowding situations

Many reports and studies provide a status table for the health system in moral, demographic and financial crisis [5–7]. This situation is the result of the accumulation of new constraints combined with the high structure rigidity [8–10]. Thus, health systems and ED meet increasingly difficulties to carry out their missions. However, there is a current overall change of the hospital and health system in French. The enhancement of the patient quality of care depends on an effective management of the health expense, the risk and the quality management. This has resulted, for many years, by various strategic and operational actions in the area of health care. An important lever for success of this evolution is the optimization of the organization.

In the management of the health care production systems, the control of the hospital flows and the crowding anticipations are major issues. The awareness of this issue is becoming stronger. Thus, the problems observed at present in hospital services and care sectors are largely due to mismanagement of patients flow.

The actors in the healthcare organizations must also overcome the problems associated to process flows (ie, patient information, products, equipment's) and restructuring. This latter corresponds internally to the resources pooling and especially to the technical platform. However, health professionals are neither prepared nor trained to solve such problems, it appears that they are poor in methodologies and tools for decision support and management adapted to the requirements involved in their future modes of operation.

Two main situations represent the emergence of major crowded situation and justify thinking about avoidance strategies because they have impacts in the economic, social and human health regulatory contexts. Thus, such a system should contributed to:

1. To best limit the peaks of activity of medical personnel and material resources. The best is to effectively organize the general work plan by distributing the most judicious manner possible tasks of care between health care providers, taking into account the skills and material resources to care. This prevents clogging of health facilities in order to limit excessive waiting times for patients by ensuring the quality of their care and safety and to balance the flows between institutions incoming patients from neighboring health directing them to the nearest establishment and less congested.
2. Limit the trigger white plan is a specific emergency institutions public or private health level. It is intended to deal with an exceptional situation or an increased activity of a hospital and must help organize the reception of a mass casualty accident, disaster, epidemic or a murderer and sustainable climate event. The white-heavy plan is to develop the economic and regulatory perspective, identifies ways that can be mobilized, defines the conditions of their employment, provides the means by which the necessary personnel can be maintained on site and where appropriate, recalled when the situation warrants.

In setting up an effective collaboration between clinicians, health care, academic and industrial researchers, it is possible to model the crowded situation and propose anticipation.

The first step is to notify the existence of a crowding situation within the hospital. This involves identifying and modeling the correspondent crowding indicators. The second step of this work is to provide avoidance strategies crowded situations thanks to a Decision Support System. To do this, it is necessary to assess the relevance of forecasting models proposed previously and then develop recommendations for avoidance strategies crowded situations.

2.3. The emergency path in the PED

Emergency Path is a longitudinal organization of the patient's handling. It is not a structure but an operative concept. The patient flow can vary from patient to patient based on acuity level and diagnosis [11,12]. The hospital establishments are confronted to a challenge for which does not exists satisfying answer at the present time. This challenge is resulting from the permanent interferences between the programmed and non-programmed activities, and more especially the urgent non programmed activity. We can define two operational concepts that will intervene in the description of the PED: (1) the incoming flows: programmed or non-programmed, with almost periodic or uncertain variation, (2) the retiring flows: constituting the downstream of the PED. The emergency path, the incoming and the retiring flows are three concepts that describe the PED like a complex system in interaction. We proceeded to the modeling of the survey project at the PED of the CHRU of Lille. The phases of workflow of the PED modeling are:

- Description of the features of each element of the global process and its sub-processes in the PED.
- Modeling the PED (flow and resources organization) and its interactions with the other internal components of the CHRU of Lille.
- To define a typology of the patients admitted in the PED of the CHRU of Lille.

3. Methods

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

(1) Several visits were piloted in the PED of CHRU of Lille with researchers and physicians (the HOST project partners) to build a model of the patient path and PED treatment processes as the basis for a patient mapping 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 an all-day observations, a PED staff meets the research 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 two important design characteristics that distinguished it from published PED patient flow modeling projects:

– The first design characteristic.

Previous observational measures of healthcare worker fail to provide adequate standard operating procedures [2]. Thus, this study uses an observational tool, done by the EVALAB partner of our project (HOST), in a way that addresses these deficiencies. In this context, EVLAB provides an ergonomic interface tool which allows an effective collect of data by observations.

This EVALAB observation tool is one of the essential elements for success of our project to build the most realistic model for the PED functioning. This tool takes into account the effective utility and usability aspects which ensures user adoption. The most effective way of supporting these aspects is the compliance with the ISO standard EN 9241-210: "Process of human-centered design for interactive systems" (Fig. 1).

This tool guarantees data impartiality, data reliability, and obtaining important data that was not recorded in the PED CHRU information system. A crucial example of key data not routinely collected was the waiting time, the visit time of the doctor to the patient and also the time at which a bed was assigned by the hospital bed manager, following a request for patient admission from the PED.

– The second design characteristic.

The use the workflow approach and especially the 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), the benefits of common understanding with precise semantics are realized. This language is based on five basic features (Fig. 2): the events, the gateways, the activities, the connectors and the pools (or lanes) to support processes.

3.1. The design of the workflow activity diagram and the data collection form

Several all-day workshops were held between September 2011 and September 2012 with a medical staff representative of all roles in the PED of CHRU of Lille. All aspects of patient treatment and management processes were examined, and staff perceptions of problems and issues that potentially inhibit patient flow recorded.

In this context, and according to this information, we developed a workflow activity diagram to model the sequence of cares' tasks and actions associated with each stage of the patient path through the PED. The model was verified by an expert PED medical staff that participated in the workshop. So, the workflow activity diagram was modified to show the main Decision Points (DPs) of a patient path in the PED. These DPs allow the reorientation of the patient towards, for example, the imaging, the intensive care, etc. Then, the model was validated by the head of the PED service. No changes were made as a result of validation. The data collection form was then constructed for the patient mapping exercise, using the workflow activity diagram as a basis for the layout of the form. For example, the Fig. 3 corresponds to the recording interface form used by nurses in order to record patients coming to the PED.

For each step of the patient journey, expressed within the workflow model, we developed the correspondent interface form to minimize the possibility of recording errors. So the data record can be done in real time according to the progress of the patient path process in the PED. The workflow model is connected to a real data base which allows the data storage. This data, collected through the interfaces, will be useful for future analyses which will be displayed in output simulation interfaces (see Fig. 4).

3.2. Quantitative data collection

Patient flow mapping through the PED was carried out in a continuous 2 years period from January 2011 to December 2012. The RAs manually tracked patients in real-time as they proceeded through the PED and recorded activity times, patient characteristics and treatment details on the data collection forms. All observations were made independently of routine PED data collection mechanisms. For each patient, the workflow model generates the correspondent process instance. Furthermore, the workflow engine can take into account patients' processes overlap. So human and material resources are shared correctly between simultaneous patients and data is collected through devoted separated interfaces. The 2 years data collection was approved by the HOST consortium.

3.3. Qualitative data collection

One month after the design of the patient flow mapping, a focus group composed of a PED medical staff and a research medical team, directed by our EVALAB partner, was held in order to obtain additional qualitative data. Some parts of the model are correct but others were improved according to some observations that not have been included in the collected data.

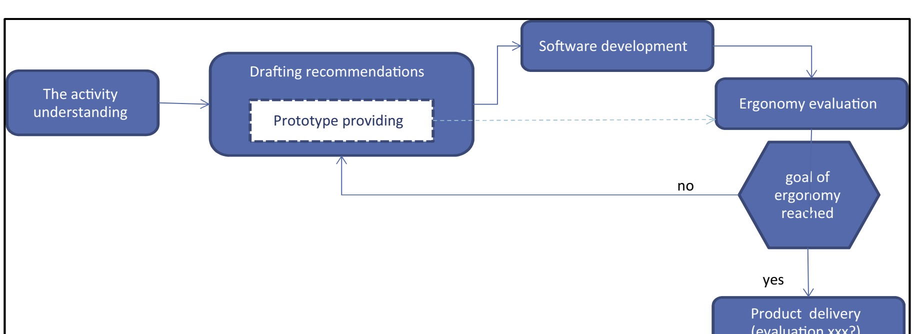

Fig. 1. The ISO standard EN 9241-210.

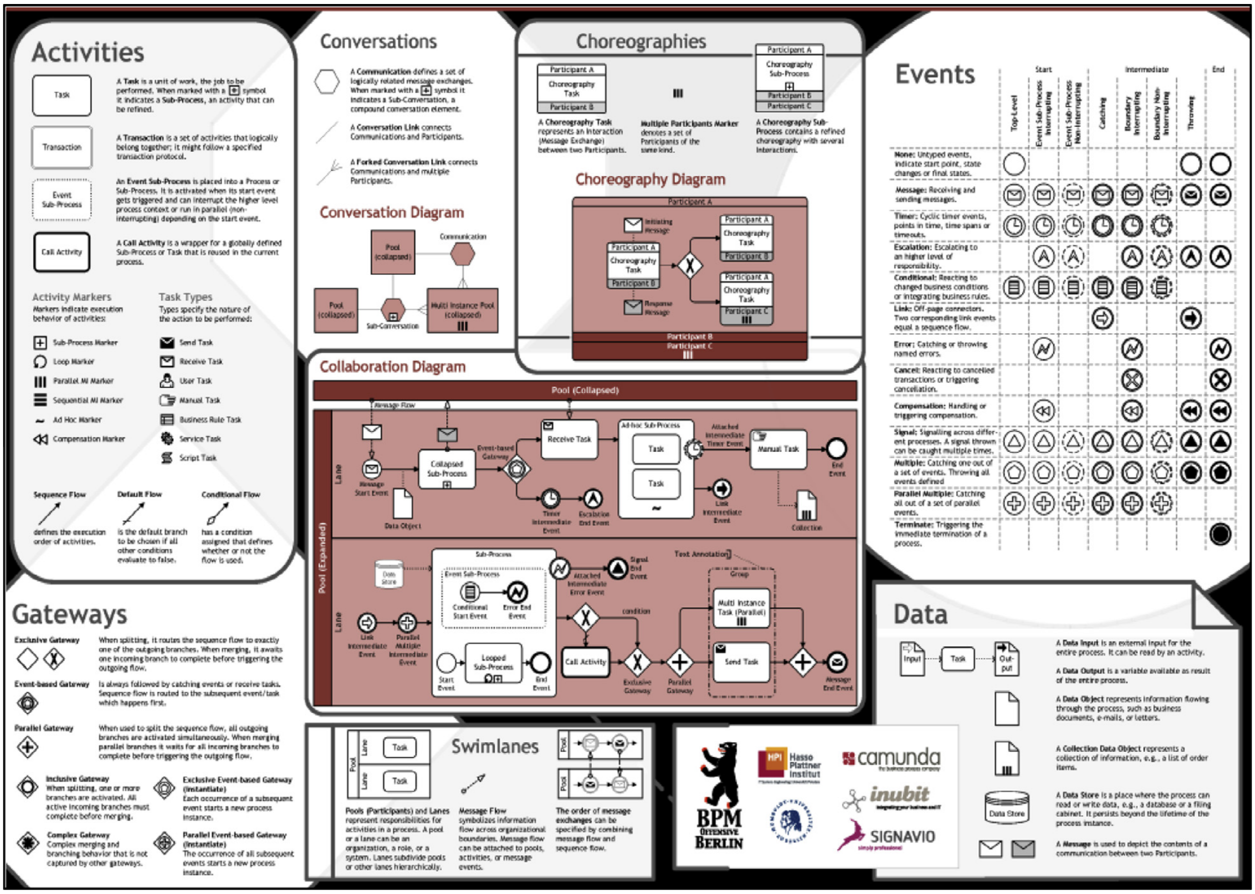

Fig. 2. The BPMN graphical language. *Source:* http://bpmb.de/poster.

Fig. 3. The example of the recording interface form of the patients.

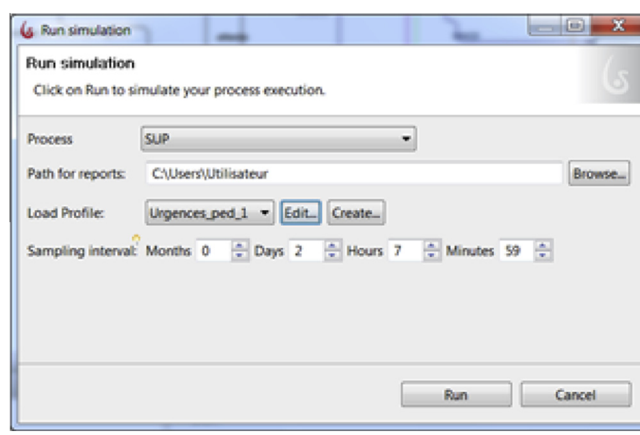

Fig. 4. Simulation load profile.

3.4. Data analysis

The dataset obtained from the data collection exercise (after improvement) will be injected in the simulation module of our workflow tool Bonita software. Simulation parameters can be chosen according to a special load profile (Fig. 6):

- 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.
- Repartition type: there are two kinds of repartitions: The constant repartition: dispatches instances injection in a constant way along the period and the direct repartition which dispatches instances injection in the start of the period.

Thanks to this simulation tool, we can measure the waiting time, each resource's consumption, and at any time, we can find the service states for each patient process for the entire patient journey in the PED.

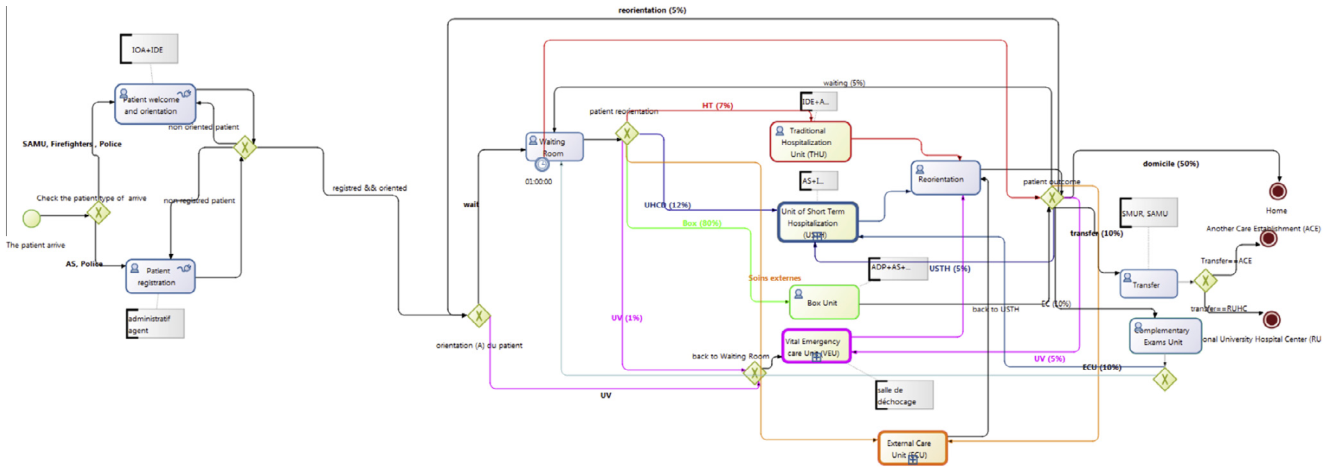

Fig. 5. Global workflow model for the PED.

4. Results

4.1. The workflow model and the patient mapping form

4.1.1. Global model and decision points

The workflow model (Fig. 5) shows the major stages, activities and actions of the patient journey in the PED as identified by the workshop participants managed by EVALAB partner. 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 ($1 \leqslant i \leqslant 6$) called gateways, in the Fig. 5. These graphical items are used to control the behavior of the sequence flows within a process. The decision points SPi ($1 \leqslant i \leqslant 6$) 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:
    - o 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.
    - o 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.
    - o Transfer: in this case, the patient will be carried to another care establishment with a "brancardier".
    - o Complementary Exams Unit (CEU): the patient has to do complementary exams for this pathology diagnosis.
    - o 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.

4.1.2. Sub-processes

4.1.2.1. The External Care Unit (ECU). The sub-process corresponding to the ECU is presented by the Fig. 6. The operations scheduled in these two rooms (suture and platter rooms) require medical resources and are previously planned. So these operations are not really urgent and they represent a degree of freedom in the decision process when some perturbations occur in the PED.

4.1.2.2. The Vital Emergency care Unit (VEU). The sub-process corresponding to the VEU is presented by the Fig. 7. This room is a vital emergency venue within the PED where the patients are examined in order to assess their vital signs. The results of these assessments allow the medical staff to direct the patient to intensive care if necessary alerting the intensive care team. Indeed the monitoring of the health of the patients is necessary in this unit. The equipment of the vital emergency room is checked daily and after each use.

4.1.2.3. The Unit of Short Term Hospitalized (USTH). The USTH, presented by the Fig. 8, receives patients requiring observation period and or require additional tests and/or admitted to the operating room for possible surgery. The patient in the USTH monopolizes human resources in many cycles' periods. Indeed, the length of the smoothing period of the peak of activity of the medical staff

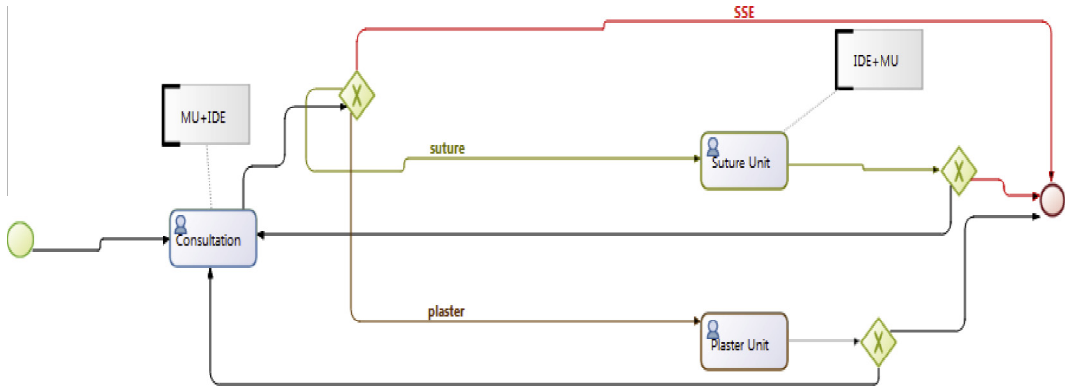

Fig. 6. Workflow model of the ECU.

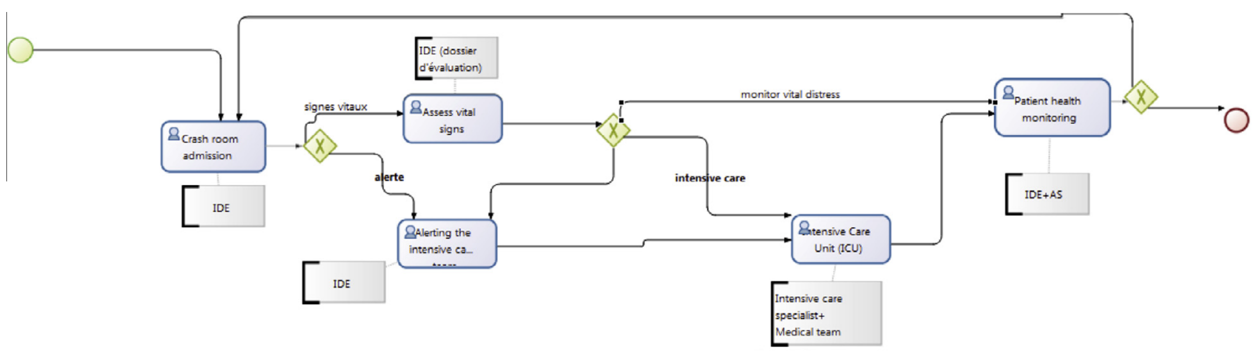

Fig. 7. Workflow model of the VEU.

depends on these cycles' periods. At the end of the USTH process, the patient leaves the PED and he is returned at home, admitted to another PED or admitted to another care establishment.

4.2. Quantitative data collection

Due to the 2-years data collection in the PED of the CHRU of Lille, we have information about 23,150 patients' admissions in 2011 (Table 1) and 24,039 in 2012 (Table 2). In order to protect individual privacy, the patients should remain anonymous. So we made sure that the data do not contain any identifying information about them.

We gathered all the data and list them according to categories. Each category should combine a number of days that follow, and have roughly the same admission profiles depending on the time of day. This is what we called a period. This latter should reflect the state of the activity in emergencies. The profiles of the same period is roughly similar, we were able to take a day to the image of the period, which we called a "Day Type".

For the data analysis, we implemented a simple algorithm based on a data classification technique. The aim is to divide a year on several periods accurately. We identified 12 periods (see Table 3).

4.3. Qualitative data collection

Some data were found to be uncompleted or duplicated several times and in different periods. These were excluded from analysis after a meeting with the focus group. Following this, we adjusted the number and duration of periods found previously.

4.4. Data analysis

In this section, we focus on the minimum, maximum and average waiting times over the time for each care task and the

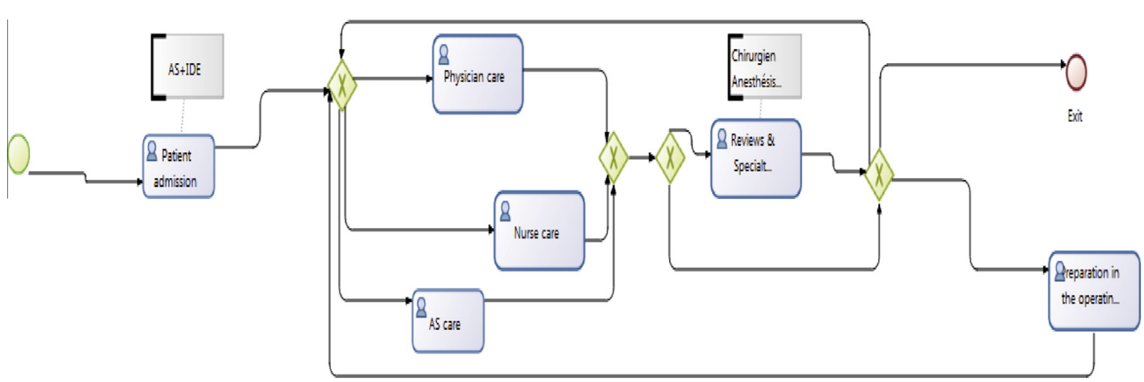

Fig. 8. Workflow model of the USTH.

Table 1
Anonymous data collection in 2011.

N°	Ar. date	Addressed by	Ar. mean	Origin	Transit time	Exit date	Traumatology	Residence CAC	Status	Age (months)	Sex	Main diagnosis	CCMU	Imaging	Ultrasound	Scanner	Radiology	GEMSA	Destination
1	01/01/2011 00:02	NON	Perso	Domicile	39	01/01/2011 00:41		3091	Médical	90	F	Otite moyenne aiguë suppurée	1	Non	Non	Non	Non	2	DOMICILE
2	01/01/2011 00:11	NON	Perso	Domicile	499	01/01/2011 08:30		3092	Médical	9	F	Commotion cérébrale, sans plaie intracrânienne	2	Non	Non	Non	Non	2	DOMICILE
3	01/01/2011 00:21	NON	Perso	Domicile	47	01/01/2011 01:08		3091	Médical	34	F	Rash et autres éruptions cutanées Non spécifiques	1	Non	Non	Non	Non	2	DOMICILE
4	01/01/2011 01:02	NON	Perso	Domicile	24	01/01/2011 01:26		3092	Médical	62	F	Difficulté liée à l'environnement social, sans précision	1	Non	Non	Non	Non	4	pneumo
5	01/01/2011 01:31	NON	Perso	Domicile	57	01/01/2011 02:28		3091	Médical	17	M	Pharyngite (aiguë), sans précision	1	Non	Non	Non	Non	2	DOMICILE
6	01/01/2011 02:09	NON	Perso	Domicile	72	01/01/2011 03:21		3091	Médical	3	F	Rhinopharyngite (aiguë) [rhume banal]	1	Non	Non	Non	Non	2	DOMICILE
7	01/01/2011 02:20	NON	Perso	Domicile	80	01/01/2011 03:40		3091	Médical	9	F	Pharyngite (aiguë), sans précision	1	Non	Non	Non	Non	2	DOMICILE
8	01/01/2011 03:43	NON	Perso	Domicile	63	01/01/2011 04:46		3091	Médical	17	M	Pharyngite (aiguë), sans précision	2	Non	Non	Non	Non	2	DOMICILE
9	01/01/2011 04:26	NON	Perso	Domicile	61	01/01/2011 05:27		3091	Médical	6	M	Gastroentérites et colites d'origine infectieuse, autres et non précisées	1	Non	Non	Non	Non	2	DOMICILE
10	01/01/2011 06:49	NON	Perso	Domicile	176	01/01/2011 09:45		3092	Médical	2	M	Insuffisance respiratoire aiguë	3	oui	Non	Non	oui	4	pneumo
11	01/01/2011 07:02	NON	Perso	Domicile	61	01/01/2011 08:03	N	3091	Médical	22	M	Otite moyenne, sans précision	1	Non	Non	Non	Non	2	DOMICILE
12	01/01/2011 09:34	NON	Perso	Domicile	78	01/01/2011 10:52	N	3091	Médical	6	M	Néphrite tubulo-interstitielle aiguë	2	Non	Non	Non	Non	2	DOMICILE
13	01/01/2011 09:46	NON	Perso	Domicile	72	01/01/2011 10:58	N	3091	Médical	6	F	Rhinopharyngite (aiguë) [rhume banal]	2	Non	Non	Non	Non	2	DOMICILE
14	01/01/2011 10:13	NON	Perso	Domicile	84	01/01/2011 11:37	N	3091	Médical	64	F	Pharyngite (aiguë), sans précision	2	Non	Non	Non	Non	2	DOMICILE
15	01/01/2011 10:25	NON	Perso	Domicile	122	01/01/2011 12:27	N	3091	Médical	62	F	Gastroentérites et colites d'origine infectieuse, autres et non précisées	1	Non	Non	Non	Non	2	DOMICILE
16	01/01/2011 10:50	NON	Perso	Domicile	1500	02/01/2011 12:19	N	3092	Médical	14	M	Convulsions, autres et non précisées	2	Non	Non	Non	Non	4	NEUROPED
17	01/01/2011 10:56	AUTRE MEDECIN	Perso	Domicile	105	01/01/2011 12:41	N	3091	Médical	10	M	Balano-posthite	2	Non	Non	Non	Non	2	DOMICILE
18	01/01/2011 11:14	NON	Perso	Domicile	60	01/01/2011 12:14	N	3091	Médical	25	M	Otite moyenne, sans précision	1	Non	Non	Non	Non	2	DOMICILE
19	01/01/2011 11:27	NON	Perso	Domicile	155	01/01/2011 14:02	N	3091	Médical	41	F	Plaie ouverte de la lèvre et de la cavité buccale	2	Non	Non	Non	Non	2	DOMICILE
20	01/01/2011 11:42	NON	Perso	Domicile	362	01/01/2011 17:44	N	3092	Médical	20	F	Insuffisance respiratoire aiguë	3	oui	Non	Non	oui	4	pneumo
21	01/01/2011 12:11	NON	Perso	Domicile	30	01/01/2011 12:41	N	3091	Médical	125	F	Varicelle (sans complication)	2	Non	Non	Non	Non	2	DOMICILE
22	01/01/2011 12:21	NON	Perso	Domicile	89	01/01/2011 13:50	N	3091	Médical	2	F	Rhinopharyngite (aiguë) [rhume banal]	1	Non	Non	Non	Non	2	DOMICILE
23	01/01/2011 12:26	NON	Perso	Domicile	132	01/01/2011 14:38	N	3092	Médical	6	F	Insuffisance respiratoire aiguë	2	Oui	Non	Non	oui	4	epidemio
24	01/01/2011 12:37	NON	Perso	Domicile	167	01/01/2011 15:24	N	3091	Médical	35	M	Nausées et vomissements	2	Non	Non	Non	Non	2	DOMICILE

Table 2
Anonymous data collection in 2012.

N°	Ar. date	Addressed by	Ar. mean	origin	Transit time	Exit date	traumatology	Residence CAC	Status	Age (months)	Sex	Main diagnosis	CCMU	Imaging	Ultrasound	Scanner	Radiology	GEMSA	Destination
1	01/01/2012 00:15	NON	MOYENS PERSONNELS	SERVICE URGENCE AUTRES URG	1 h 4 m	64	01/01/2012 01:19		3091	Médical	32	M	Commotion cérébrale, sans plaie intracrânienne	1	Non	Non	Non	Non	2
2	01/01/2012 01:19	NON	MOYENS PERSONNELS	CONSULTATION OU DOMICILE	0 h 51 m	51	01/01/2012 02:10	O	3091	Chirurgie	182	M	Plaie ouverte du cuir chevelu	2	Non	Non	Non	Non	2
3	01/01/2012 01:58	SAMU / CENTRE 15	AMBULANCE PRIVEE	SERVICE URGENCE AUTRES URG	9 h 32 m	572	01/01/2012 11:30		3092	Médical	181	F	COMA : intoxication ALCOOL	2	Non	Non	Non	Non	2
4	01/01/2012 03:00	NON	MOYENS PERSONNELS	SERVICE URGENCE AUTRES URG	8 h 7 m	487	01/01/2012 11:07	N	3084	Chirurgie	187	M	Affections du testicule et de l'épididyme au cours de maladies classées ailleurs	2	Oui	Non	Non	Oui	4
5	01/01/2012 03:51	SAMU / CENTRE 15	SAMU-SMUR	SERVICE URGENCE AUTRES URG	2 h 29 m	149	01/01/2012 06:20	N	3092	Médical	4	M	Bronchiolite (aiguë), sans précision	3	Non	Non	Non	Non	5
6	01/01/2012 06:02	NON	MOYENS PERSONNELS	CONSULTATION OU DOMICILE	5 h 47 m	347	01/01/2012 11:49	N	3091	Médical	36	M	Otite moyenne aiguë suppurée	2	Oui	Non	Non	Oui	2
7	01/01/2012 06:49	NON	MOYENS PERSONNELS	CONSULTATION OU DOMICILE	1 h 17 m	77	01/01/2012 08:06	N	3091	Médical	16	F	Otite moyenne aiguë suppurée	2	Non	Non	Non	Non	2
8	01/01/2012 08:25	NON	MOYENS PERSONNELS	CONSULTATION OU DOMICILE	1 h 12 m	72	01/01/2012 09:37		3091	Médical	12	F	Rhinopharyngite (aiguë) [rhume banal]	1	Non	Non	Non	Non	2
9	01/01/2012 09:49	MEDECIN TRAITANT	MOYENS PERSONNELS	CONSULTATION OU DOMICILE	2 h 43 m	163	01/01/2012 12:32		3091	Médical	53	M	Douleur thoracique, sans précision	2	Oui	Non	Non	Oui	2
10	01/01/2012 10:39	NON	AMBULANCE PRIVEE	SERVICE URGENCE AUTRES URG	1 j 0 h	1440	02/01/2012 10:54		3092	Médical	12	F	Fièvre, sans précision	2	Oui	Non	Non	Oui	2
11	01/01/2012 11:04	NON	MOYENS PERSONNELS	CONSULTATION OU DOMICILE	3 h 15 m	195	01/01/2012 14:19		3091	Médical	9	F	Commotion cérébrale	1	Non	Non	Non	Non	2
12	01/01/2012 11:10	MEDECIN HOSPITALIER	MOYENS PERSONNELS	CONVOCATION PAR L'HOPITAL	2 h 24 m	144	01/01/2012 13:34		3091	Médical	175	M	Gastroentérites et colites d'origine infectieuse, autres et non précisées	1	Non	Non	Non	Non	2
13	01/01/2012 11:44	NON	MOYENS PERSONNELS	CONSULTATION OU DOMICILE	0 h 49 m	49	01/01/2012 12:33		3091	Chirurgie	39	M	Plaie ouverte d'autres parties de la tête	2	Non	Non	Non	Non	2

Table 3
Identified period in 2011.

Periods	Duration
P0	2011/01/01–2011/02/11
P1	2011/02/12–2011/02/19
P2	2011/02/20–2011/03/01
P3	2011/03/02–2011/03/11
P4	2011/03/12–2011/04/13
P5	2011/04/14–2011/04/18
P6	2011/04/19–2011/05/01
P7	2011/05/02–2011/06/20
P8	2011/06/21–2011/08/28
P9	2011/08/29–2011/09/25
P10	2011/09/26–2011/11/24
P11	2011/11/25–2011/12/31

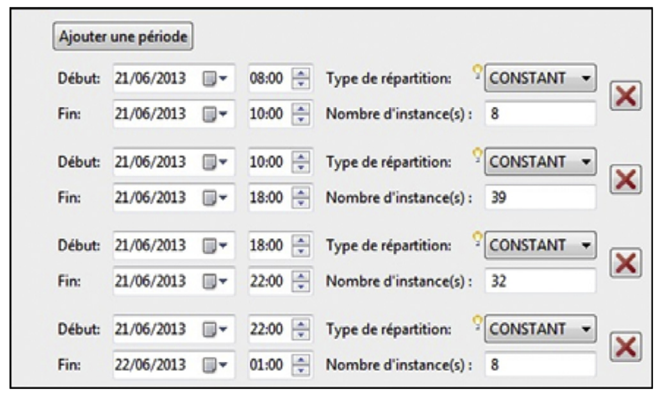

Fig. 9. Simulation parameters.

utilization of different resources to perform them in the PED. Our goal is to determine from these curves the crowding indicators in order to identify the main causes of crowded situations which increase the waiting time of patients.

4.4.1. The number of patient by time slot according to the "day-type" profile

As explained above, we have to identify the day-type. So from collected data, we have identified three profiles: summer profile (Fig. 10), winter profile (Fig. 11) and crisis profile (Fig. 12) knowing that we used the same simulation parameters (time slots) for all these profiles (Fig. 9). The simulation results show the injected number of patients by time slot according to the focused profile.

4.4.2. Waiting time and resources allocation according to the "day-type" profile

4.4.2.1. The summer profile. The Fig. 13 represents the average waiting time for the summer profile within a no crowded period. We note that the average waiting time in service is between 30 min and 02h30, with a peak between 18h00 and midnight.

The time required for the reception and orientation of the patient is about 10 min which is quite reasonable. It is the same for the patient registration. We note also that the workload is of 40% for the staff. For example, the Care Assistant (CA) is a medical resource which is rarely used simultaneously (Fig. 14).

However, the nurses are occupied up to 70% throughout the day and the BUs are used at 33%.

4.4.2.2. The winter profile. The winter profile further disrupts the service since the average waiting time is now between 1 and 4 h with a peak at midnight (Fig. 15).

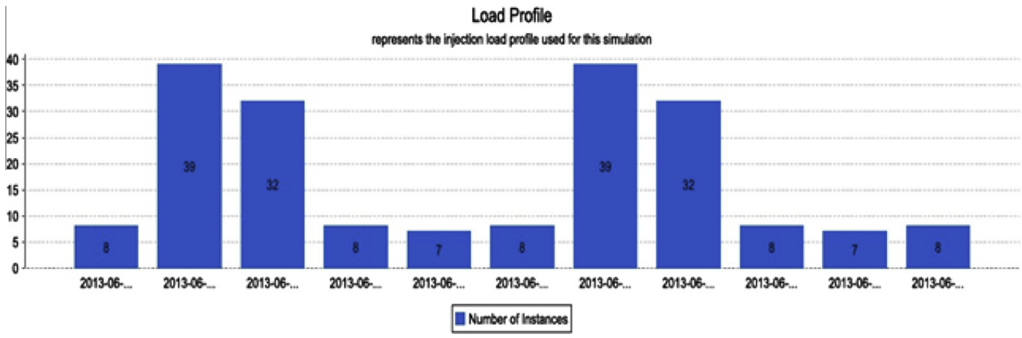

Fig. 10. The summer profile simulation.

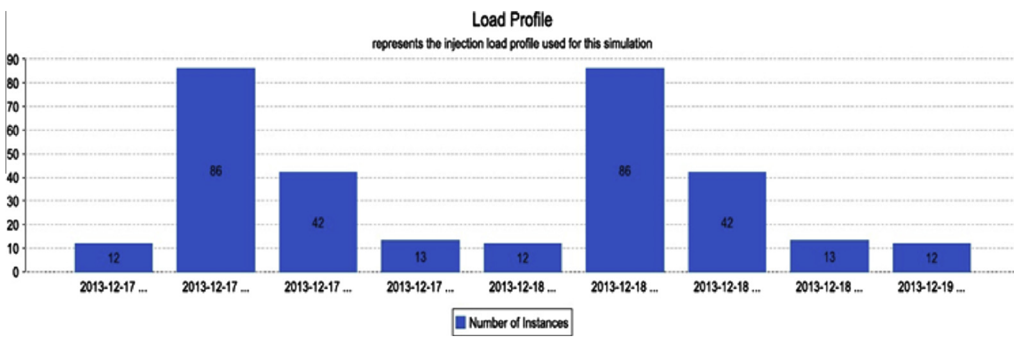

Fig. 11. The winter profile simulation.

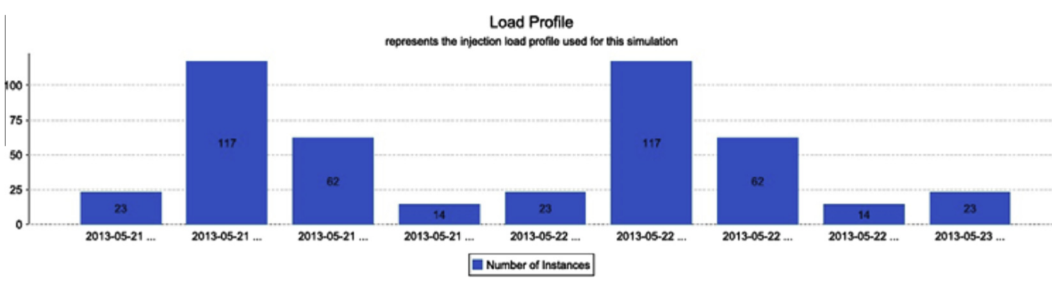

Fig. 12. The crisis profile simulation.

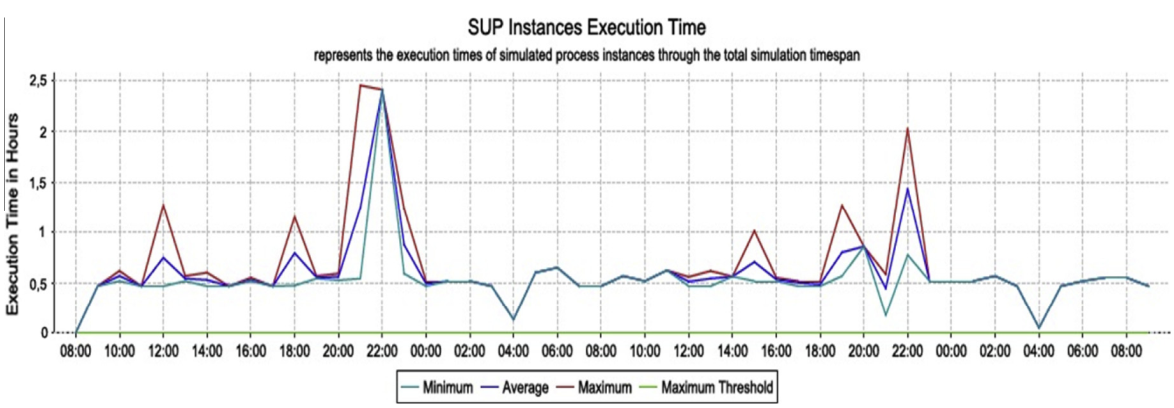

Fig. 13. Average waiting time (summer profile).

The reception and orientation process of the patient reaches 1 h between 20 h and midnight. The using of the AS resource rises to 50% while the resource IDE is about 95% during the day (Fig. 16). We note that only three of 10 boxes are used during the day when we should observe an increase (see Fig. 18).

4.4.2.3. The crisis profile. The crisis profile highlights the limits of the PED because the average waiting time diverges and is estimated to 10 h (Fig. 17). The staff cannot handle both the patients present in the hospital and those arriving. So the reception and the orientation of patients is increasingly longer (Fig. 19).

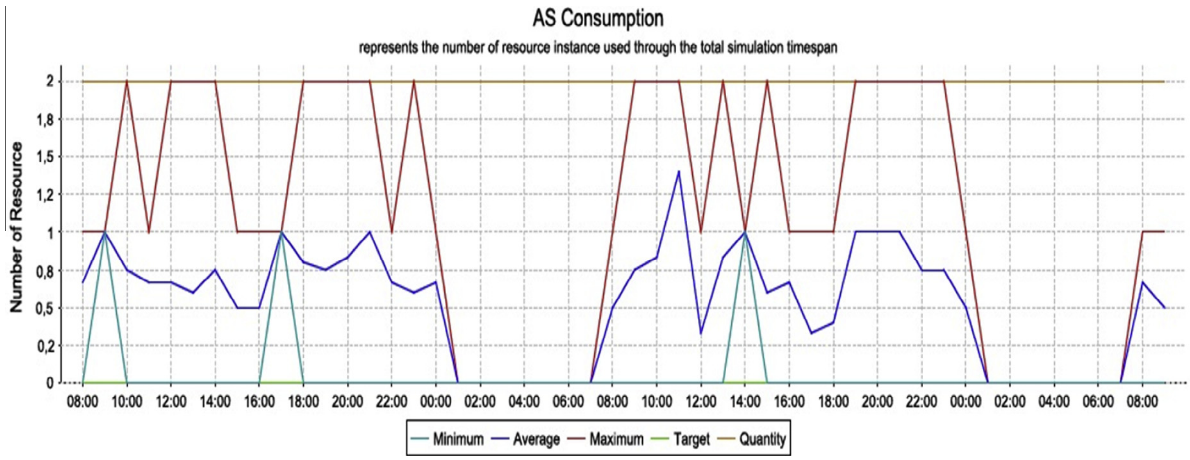

Fig. 14. Number of resource use CA (summer profile).

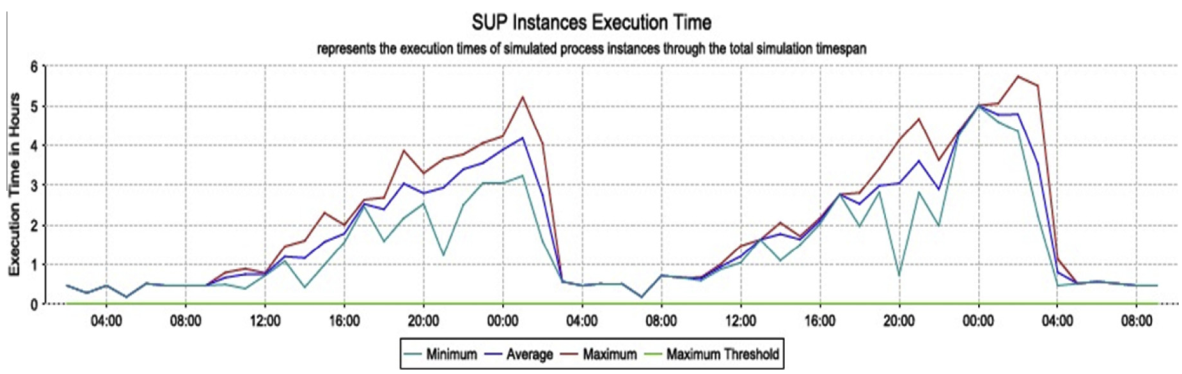

Fig. 15. Average waiting time (winter profile).

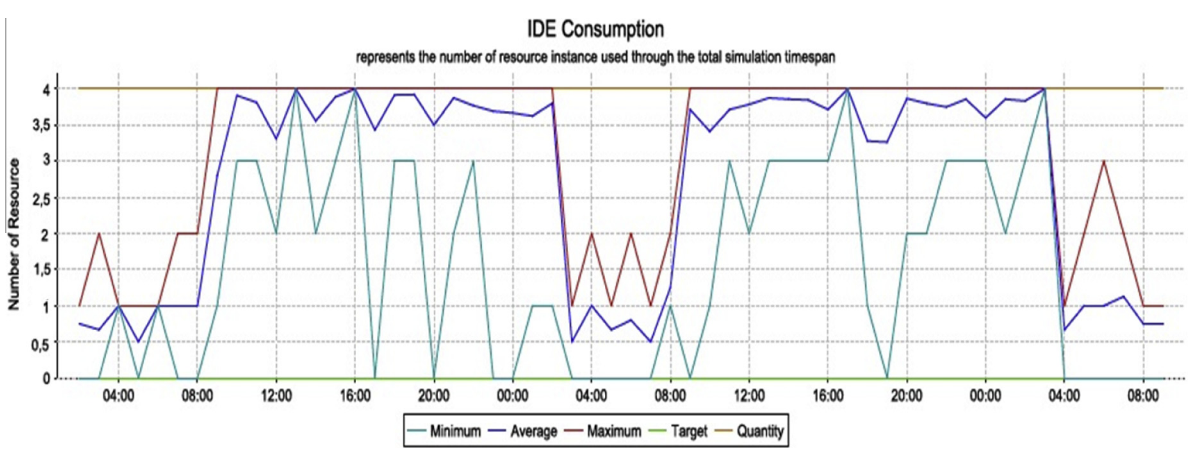

Fig. 16. IDE resource consumption (winter profile).

The waiting time in USTH can reach 4 h the first day between 8h00 and 12h00 and 6 h the second day. It is the same for external services such as the installation of plaster or stitches. The major problem concerns the four IDE working without interruption during the two days of testing (Fig. 19).

5. Discussion

The CHRU of Lille had expressed a need for empirical data relating to the patient flow and journey through the PED as there was a lack of evidence to support proposals for improvements. Therefore, the main objective of this work is to gain a better understanding of delaying factors in the patient path and to provide an efficient base for service scheduling within the PED of the CHRU of Lille. There are examples in the literature that utilized models and identified factors contributing to patient delays in the PED patient journey [30] or stages of the journey [31,32]. However, most studies focused on use of models to improve [33–35] patient flow rather than to document a detailed understanding for purposes of service planning.

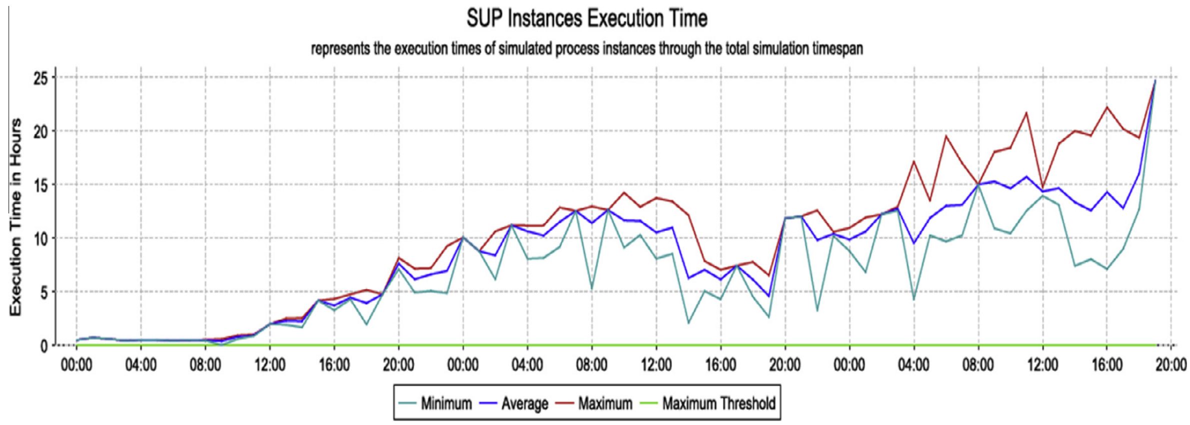

Fig. 17. Average waiting time (crisis profile).

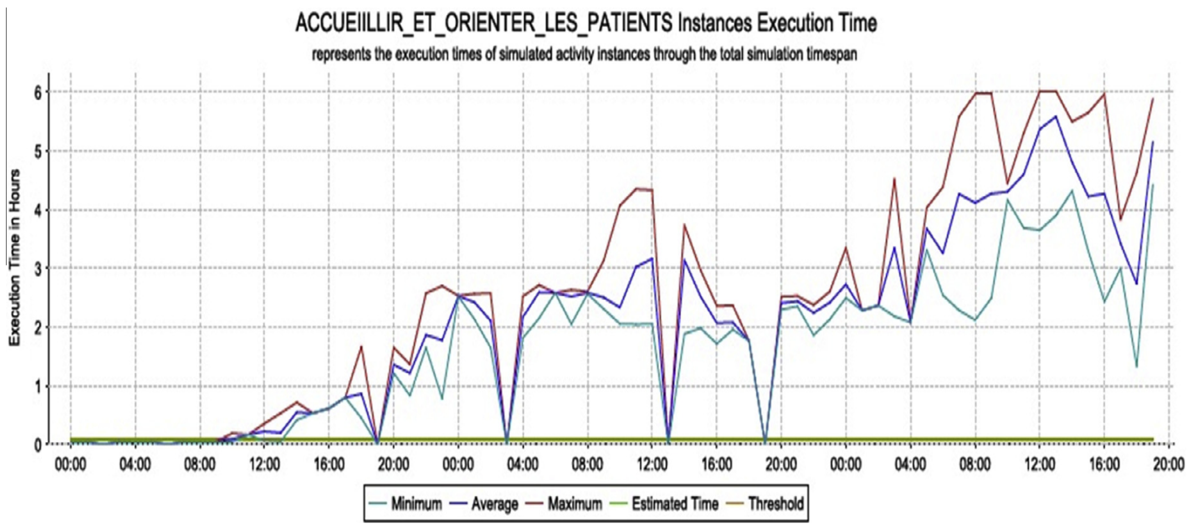

Fig. 18. Average waiting time for the reception and orientation process.

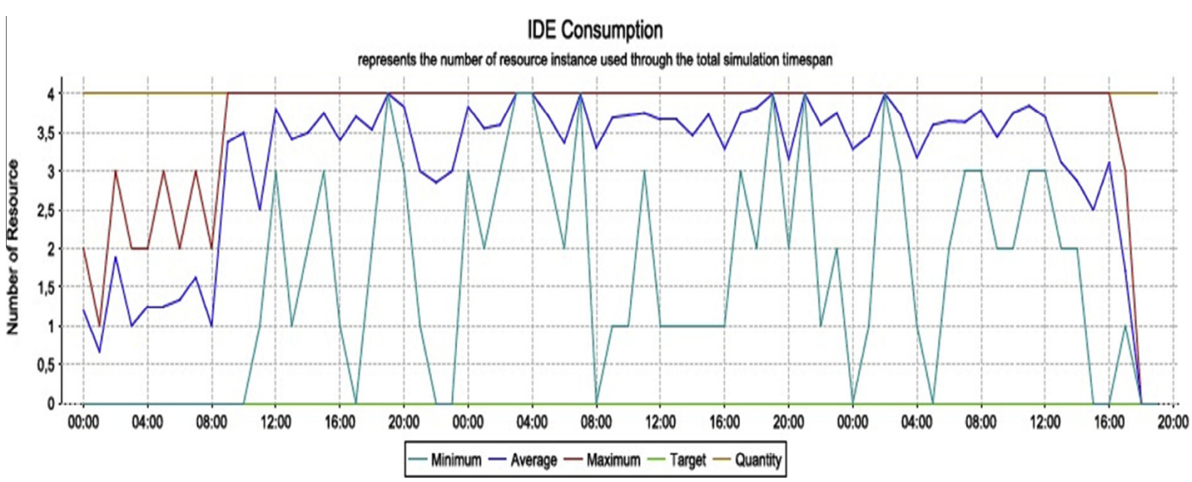

Fig. 19. IDE resource consumption (crisis profile).

The using of an adapted workflow approach to design and simulate the PED functioning makes this study more efficient. Consequently, most other studies were not directly comparable because different methods and sources were used to obtain the data and other types of models were constructed. For example, Laskowski et al. [36] have used a combination of simulated and actual data to create agent based and queuing models. However, Martin et al. [29] used UML modeling approach to design the PED activities in Bendigo Health which is a public health provider in regional Australia. This work is interesting but the UML modeling approach is not the better way to design PED activities because this latter is adapted to software design and the simulation need an external module while the workflow approach is adapted to the process management and integrate the simulation mechanism.

There are three major stages: Stage 1, (Patient Arrival and Initial Assessment), Stage 2, (Patient (re)orientations and treatment), Stage 3 (Patient Destinations). The results associated with the four major stages in the patient journey (Fig. 5) are discussed in turn.

– **Stage 1:** Patient Arrival and Initial Assessment

The EVALAB partner and the RAs participants of our ANR project had identified a number of dysfunctions related to the Patient Arrival and Initial Assessment that unsatisfied them: physical layout of the PED entrance (triage area), overloading at triage, duplication of documentation, the need for extra staff and computers for data entry as well as more efficient and effective methods for fast-tracking patients, the box allocation and retrieving patient records. There are two physical layouts of the PED entrance. These latter correspond to two distinct triage area. The first one concerns the area of the patient reception and registration and the second one corresponds to the area of the patient orientation.

The quantitative data demonstrated that (Table 1 Table 1. Anonymous data collection in 2011 and Table 2, despite the identified problems during the workshops, patient entry and initial assessment was very efficient over the period of the mapping exercise. The RAs commented on the high standard and professionalism of the clinical personnel carrying out the triage process, the clerical personnel carrying out the data entry and collection of patient medical records, and the communication between the ambulance staff and the PED staff.

The problems recognized in the workshop, whereas not being clearly evident in the quantitative data, clearly become important in high volume situations when the impact of resource limitations was greatly highlighted.

The mean waiting-room times were 10 min (80th percentile (18 min) for admitted patients and 45 min (80th percentile 73 min) for discharged patients. The distribution of waiting times for discharged patients was strongly distorted and there were periods of bottleneck, despite the mean waiting times being quite acceptable according to triage guidelines. The relatively high proportion of patients who did not wait (NWPs) is about (10.5%) of presentations may result from bottleneck. This was also observed by RAs who recorded notes such as "PED busy" on some of the NWPs forms. Further, an additional 35.5% of presentations at the triage station, comprising PED enquiries (20.6%) and non-PED enquiries (8.9%), were not recorded in the PED patient information system. This unmeasured workload also potentially contributes to the congestion experienced at triage.

– **Stage 2:** (re)orientation and treatment

In the workshop activity, the participants perceived turnaround times for in-box investigations and clinical consultancies as a source of delay in patient flow. Hence the expected result from the mapping exercise was that the recorded turnaround times might represent a substantial proportion of the total length of stay and might provide an opportunity for improvement. Researchers [32] have demonstrated, thanks to a three months simulation scenario, that reducing turnaround times, allows the improvement of the ED throughput.

However delays due to long waits for the results of tests and consultation by external specialists that were identified in the workshop as inhibiting patient flow were not evident to represent in our workflow model. Indeed, the RAs' observation was that the turnaround time for investigations was excellent, but that there were delays due to the lack of a mechanism for alerting PED medical staff when results were available. In some cases staff may not have been available, or able to act on the results more quickly. The use of advanced information management systems such as the computerized whiteboard system described by Aronsky et al. [37] may be beneficial. In this context, this lack will be resolved thanks to our graphical workflow forms allowing the just-in-time information.

– **Stage 3:** Patient Destinations

The destination of particular interest was the admission of a patient to a hospital ward. This was because the main problem identified by the workshop participants in regard to patient destination was bed availability (crowded situations indicators). During this waiting period the PED limited equipment resources (e.g. boxes, vital rooms, etc.), are occupied by the waiting patient and not available for treating new patients. The situation represents potential bottleneck in the final stage of the patient journey (crowded situations indicators).

The combined mean time from a bed request to exit of approximately 4 h, if applied to the mean admission rate of 30 admissions per day requiring a bed in a hospital ward, corresponds to 120 h of "lost" box capacity. These amounts to (almost) 5 of the 14 boxes effectively unavailable for use 24 h per day. There is clearly the opportunity to improve patient flow by addressing the resource limitations that contribute to the delays in admission.

The workshop participants also identified shortcomings in the PED exit processes. This was consistent with the observations of RAs concerning dropouts and the duplication in the decision-to-admit processes and apparent lack of well-defined exit processes for both admitted and discharged patients.

6. Limitations

The workflow mapping model was limited to the PED itself. Therefore, the outcomes are valuable, primarily, for internal PED management.

Nevertheless, the mapping process does shed light on the impact of external factors such as inpatient bed availability (first crowded situation indicator) and on the impact of internal factors such as the sudden increasing of patient flow (second crowded situation indicator). This latter indicator generates a peak of activity of medical staff then a bottleneck (third crowded situation indicator).

The data were collected during two years (2011–2012) within a specific PED and is limited in its general application to other time periods and departments. There were some patients for whom admission was sought, but inpatient beds were unavailable. The patients were eventually discharged after stays in excess of 10 h, having been treated in the PED. The statistical impact was to increase mean time in the PED for discharged patients. On the other hand the mean time interval from bed request to bed availability was artificially reduced due to the removal of the data for these patients from the admitted patients list.

Another limitation is the connection of the workflow model with the database which is not already established to automate the simulations. In fact, for the moment, we inject manually data in the simulation module in order to generate graphs. This is planned for a following project.

7. Conclusions

The use of workflow approach to design the patient journey through the PED of CHRU of Lille was effective in facilitating the application of a combination of qualitative and quantitative data to depict and analyze the entire PED activity spectrum. The workflow diagrams modeled the complete patient journey, whilst the simulation module enabled the strengths and weaknesses of the PED processes to be identified and the impact of bottlenecks within the patient journey to be measured. These models have the added advantage of being easily validated by the user in the system because the graphical elements are easily understood. In addition, there is the possibility to connect them directly to the real PED database in order automate the simulation and then to analyze in real time the crowded situation indicator through an effective scoreboard.

Recording primary data through EVALAB graphical interfaces, independently of the hospital data acquisition processes, ensured data integrity for the HOST project, and also provided important data that is not routinely recorded. In particular, time data such as the decision to admit time, time of notification of bed availability, and the time at which investigations are requested and then results are subsequently accessed were key data for the study.

Along with shorter studies conducted internally by CHRU of Lille, the body of evidence arising from this project has contributed to plans for re-designing and resourcing of the PED and to inform the development of an intelligent business system aimed at the timely identification of impending access block so that action can be taken to alleviate serious PED over-crowding. It is a strong example of a university/hospital collaboration contributing to evidence-based health service planning.

Acknowledgment

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References

[1] Vander Aalst WMP, Van Dongen BF, Herbst J. Workflow mining: a survey of issues and approaches. Data Knowl Eng 2003;47:237–67.
[2] Chinosi Michel, Trombetta Alberto. BPMN: an introduction to the standard varese (VA). Comput Stand Inter 2012;34(1):124–34.
[3] Navas J-F, Artéta C, Hadjes PS, Jiménez F. Construction et simulation d'un modèle de flux de patients dans le service d'urgences d'un hôpital colombien, « Formato de Atencion Inicial de Urgencias, en Procesos Operativos de Urgencias », Documentos confidenciales Servicio de Urgencias Fundacion CardioInfantil. Agosto; 2003.
[4] Ducq Y, Vallespir B, Doumeingts G. Utilisation de la méthodologie GRAI pour la modélisation, le diagnostic et la conception d'un système hospitalier. 2ème conférence francophone en Gestion et Ingénierie de Systèmes Hospitaliers (GISEH). Mons; 2004.
[5] Rossetti MD, Trzcinski GF, Syverud SA. Emergency department simulation and de-termination of optimal attending physician staffing schedules. In: Farrington PA, Nembhard HB, Sturrock DT, Evands GW, editors. Proceeding of the simulation conference, winter, vol. 2; 1999. p. 21532–40
[6] Ruby BE, Darrell SW, Wendy AS, Mary HC. The use of simulation to evaluate hospital operations between the emergency department and a medical telemetry unit. In: WSC '03 proceedings of the 35th conference on winter simulation: driving innovation; 2003. p. 1887–93.
[7] Samaha Simon, Armel Wendy S, Starks Darrell W. The use of simulation to reduce the length of stay in an emergency department. In: Proceedings of the winter simulation conference; 2003. p. 1907–11.
[8] Mahapatra S, Koelling CP, Patvivatsiri L, Fraticelli B, Eitel D, Grove L. Emergency departments II: pairing emergency severity index5-level triage data with computer aided system design to improve emergency department access and throughput. In: The WSC '03 proceedings of the 35th conference on winter simulation: driving innovation; 2003. p. 1917–25.
[9] Takakuwa Soemon, Shiozaki Hiroko. Functional analysis for operating emergency department of a general hospital. In: Proceedings of the winter simulation conference, vol. 2; 2004. p. 2003–11.
[10] Baesler Felipe F, Jahnsen Hector E, Da Costa Mahal. Emergency department I: the use of simulation and design of experiments for estimating maximum capacity in an emergency room. In: WSC '03 proceedings of the 35th conference on winter simulation: driving innovation; 2003. p. 1903–6.
[11] Wiinamaki Allan, Dronzek Rainer. Using simulation in the architectural concept phase of an emergency department design. In: Chick S, Sanchez PJ, Ferrin D, Morrice DJ, editors. Proceedings of the 2003 winter simulation conference; 2003. p. 1912–6.
[12] Rossetti MD, Trzcinski GF, Syverud SA. Emergency department simulation and de-termination of optimal attending physician staffing schedules. In: Simulation conference proceedings, winter, vol. (2); 1999. p. 1532–40.
[13] Souf N-B, Renard J-M, Régis B. Dynamic workflow model for complex activity in intensive care unit. Int J Med Inform 1999;53(2/3):143–50.
[14] Komashie A, Mousavi A. Modeling emergency departments using discrete event simulation techniques. In: WSC '05 proceedings of the 37th conference on winter simulation; 2005. p. 2681–5.
[15] Fraisse A, Le Bel S, Mas B, Macrae D. Pediatric cardiac intensive care unit: current setting and organization. Arch Cardiovasc Dis 2010;103(10):546–55.
[16] Gausche-Hill M, Schmitz C, Lewis RJ. Pediatric preparedness of US emergency departments: a 2003 survey. Pediatrics 2007;120(6):1229–37.
[17] Tracy MA. Improving pediatric quality care in general care emergency departments. J Emergency Nurs 2007;33(4):399–401.
[18] Sinclair D. Emergency department overcrowding-implications for paediatric emergency medicine. Paediatr Child Health 2007;12(6):491–4.
[19] Trunkey DD. Emerging crisis in trauma care: a history and definition of the problem. Clin Neur 2007;54:200–5.
[20] Forero R, Hillman K. Access block and overcrowding: a literature review. Report commissioned by the Australasian College for Emergency Medicine. The Simpson Centre for Health Services, University of New South Wales; 2008. p. 1–26.
[21] King DL, Ben-Tovim DI, Bassham J. Redesigning emergency department patient flows: application of lean thinking to health care. Emerg Med Austral 2006;18(4):391–7.
[22] Brailsford SC, Lattimer VA, Tarnaras P, Turnbull JC. Emergency and on-demand health care: modelling a large complex system. J Oper Res Soc 2004;55:34–42.
[23] Andersson A, Hallberg N, Eriksson H, Timpka H. A management information system model for process-oriented health care. In: Fieschi M, Coiera E, Yu-Chan JL, editors. Medinfo 2004: proceedings of the 11th world congress on medical informatics. IOS Press; 2004. p. 1008–1012.
[24] Ottensooser Avner, Fekete Alan, Reijers Hajo A, Mendling Jan, Menictas Con. Making sense of business process descriptions: an experimental comparison of graphical and textual notations. J Syst Software 2012;85(3):596–606.
[25] Reix A. Etude de l'organisation des différents systèmes d'urgence dans six pays européens: La France, le Royaume Uni, la Belgique, la Suède, la Finlande et la Norvège. Memory of thesis for the diplôma of doctor state in medicine; 2002.
[26] Chodosas M. Etude de l'organisation des différents systèmes d'urgence dans cinq pays européens. La France, l'Allemagne, l'Espagne, l'Italie et le Portugal, Mémoire de thèse pour le doctorat en médecine: 20; 2002.
[27] Wohed Petia, van der Aalst Wil MP, Dumas Marlon, ter Hofstede Arthur HM, Russell Nick. Pattern-based analysis of BPMN – an extensive evaluation of the control-flow, the data and the resource perspectives. In: Proceedings 4th international conference on business process management (BPM 2005), LNCS; 2005. p. 1–5.
[28] Nolan JP. European resuscitation council guidelines for resuscitation. Resuscitation 2010;81:1219–76. journal home page.
[29] Martin Mary, Champion Robert, Kinsman Leigh. Mapping patient flow in a regional Australian emergency department: a model driven approach. Int Emerg Nurs 2011;19:75–85 [received 2.02.10, received in revised form 23.03.10; accepted 25.03.10].
[30] Miro O, Sanchez M, Espinosa G, Coll-Vinent B, Bragulat E, Milla J. Analysis of patient flow in the emergency department and the effect of an extensive reorganization. Emerg Med J 2003;20(2):143–8. Discussion 148.
[31] Lyons M, Brown R, Wears R. Factors that affect the flow of patients through triage. Emerg Med J 2007;24:78–85.
[32] Storrow AB, Zhou C, Gaddis G, Han JH, Miller K, Klubert D, et al. Decreasing lab turnaround time improves emergency department throughput and decreases emergency medical services diversion: simulation model. Acad Emerg Med 2008;15(11):1130–5.
[33] Jensen K, Crane J. Improving patient flow in the emergency department. Health Care Financ Manage 2008;62(11):104–6. 108.
[34] Medeiros DJ, Swenson E, DeFlitch C. Improving patient flow in a hospital emergency department. In: Proceedings of the 40th conference on winter simulation. Winter simulation conference. Miami, Florida; 2008. p. 1526–31.
[35] Welch SJ, Jones SS, Allen T. Mapping the 24 h emergency department cycle to improve patient flow. Joint Comm J Qual Patient Safety 2007;33(5):247–55.
[36] Laskowski M, McLeod RD, Friesen MR, Podaima BW, Alfa AS. Models of emergency departments for reducing patient waiting time. PLoS ONE 2009;4(7):6127.
[37] Aronsky D, Jones I, Lanaghan K, Slovis CM. Supporting patient care in the emergency department with a computerized whiteboard system. J Am Med Inform Assoc 2008;15(2):184–94.
[38] Mendling J. Declarative vs. imperative process modeling languages: the issue of maintainability proceedings of the 1st international workshop on empirical research in business process management (ER-BPM'09), Ulm, Germany, September 2009. LNBIP, vol. 43, Springer-Verlag. pp. 477–88.