Modeling and Simulation
of the Hospital-at-Home Service Admission Process

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Abstract: This article focuses on the analysis of the admissions to hospital-at-home service within the framework of Business Process Management. While traditional process analysis deal with internal hospital services, having a particular and specific scenario, e.g. a ward of an hospital, here we investigate a quite innovative service with a strong socio-territorial impact based on real data. In particular, we are interested in the understanding of the selection process in which staff discriminate cases of interest for the service. We describe here our methodological framework combining data and event log analysis, modeling with standard language and business process simulation with scenario analysis.

1 INTRODUCTION

Demographic and economic modifications occurred in last decades, together with the availability of new technologies, pushed the research of continuous improvements in healthcare. In Medicine, the most part of actual applications of artificial intelligence and computer science concerns diagnostic processes and performance analysis, mostly focusing on the application of new algorithms (e.g. machine learning). Nevertheless, an equally important aspect to investigate is the organization of health processes, by considering an holistic and systemic approach. In this direction, computer science gained a relevant role not only for computational reasons, but also for technical hardware and information systems improvements (Dumas et al., 2005). This is the case of Business Process Management (BPM) (Dumas et al., 2018; Van der Aalst, 2013), a discipline combining studies of management with data science to perform business process improvement and computational simulation as a management instrument for decision-making (Van der Aalst et al., 2010). A large number of modeling techniques investigates the actual process (As-Is) in order to propose a restructured one (To-Be) (Di Leva and Sulis, 2017). Modeling and simulation includes computer-based Discrete Event Simulation (DES) (Johnson et al., 2008), probably the most used approach to investigate the outcomes of simulated scenarios, as well as to estimate the performance of the system after introducing changes in the process model. Moreover, modeling the actual situation easily allows to detect the actual functioning of the workflow by facilitating the detecting inefficiencies, bottlenecks, constraints, and risks (Suriadi et al., 2014; Amantea et al., 2018).

We focus on a specific department in healthcare, one of the most relevant public service in developed countries (Vincent et al., 2016). Our interest here is the Hospital-at-Home Service (HHS) in Turin, one of the largest city of Italy, within a EU co-funded project by Regione Piemonte to investigate healthcare processes and telemedicine (Grosso et al., 2018). This service has a great tradition with more than thirty years of experience. As one of the main issue concerns the selection of patients, we focused the attention on the first part of the HHS process by modeling the functioning of admissions. Similar works about business process analysis in healthcare focused on process mining (Mans et al., 2015; Rojas et al., 2016), also addressing the specific task to model integrated home-care services (Russo et al., 2015). Our goal here is to investigate the organisation of HHS to create a repeatable model, as well as to propose the extension to other areas.

The scientific literature and the practical experiences within the domiciliary cares have underlined the particular utility and effectiveness of this type of

sanitary intervention in geriatric and oncology's areas, recognizing the function of the hospital structure to make more flexible integration between hospital and territory. In northern Italy, the Regione Piemonte defined in 2010 the hospitalization at home as a form of Sanitary Assistance characterized by the whole taking in charge of the patient from an hospital structure (Aimonino Ricauda et al., 2011). Such a service relies on own personnel, formed and with expressly and documented experience in the management of patients in acute phase directly at home.

The paper includes the following sections: we introduce our methodological framework and data about the admission process in section 2. Section 3 describes the model of the service, while the following section includes simulation results. We conclude the paper with future works in Section 5.

2 METHODOLOGY

Our methodological framework consists of three phases:

- *Context Analysis* - this phase aims to fix the overall strategic scenario of the enterprise and to determine the organizational components that are related to the process under analysis.

- *Process Engineering* - the initial purpose of this phase is the determination of the activities performed in the functions involved in the process and the causal relationships existing between them. The process is then reconstructed from facts external to the system, events and objects in input/output: this provides the Process diagram (sometimes referred to as process map or flowchart) that will be specified by adopting a standard language.

- *Data analysis* - this phase aims to analyze the real data of the past years to understand and better represent the process the most truthful and and the more next to the reality as possible. The whole process model must be validated with the stakeholders involved in the process, using animation and simulation of specification, obtaining the so called *As-is model*.

2.1 Business Process Modeling Notation

We adopt *Business Process Modeling and Notation* (BPMN) (Allweyer, 2016), which is a standard modeling language developed to reduce the fragmentation that was witnessed between the existing modeling languages. We prefer such notation as it is suffi-

ciently generic to be easily extended, as well as easily understand by stakeholders. The actual version 2.0 is a "de facto" standard for process modeling (Allweyer, 2016). Our diagram includes the following figures: activities, delays, exclusive gateways, start and end events.

2.2 Business Process Simulation

Once modeled the process, we aim to simulate the arrival of patients in the workflow of resources. We adopt iGrafxProcess tool (iGrafx, 2015), used to implement the main phases of our methodological framework, as well as process simulation. The simulation model is driven by the arrival of patients, as detailed in the simulation section, following the flow of activities and events.

2.3 Data Analysis

We analysed data about the arrival of patients in previous year to identify patterns and define the workflow in the business process. As already mentioned, new patients are admitted to the service following a standard procedure which involves several qualitative information. The exploration of existing file about event and activities facilitates the preparation of the model and the analysis of the output results. We processed information about the arrival of patients by using *python* programming language and specific libraries for scientific computing *numpy*, *statistics*[1].

3 THE HOSPITAL AT HOME SERVICE

The Hospital at Home Service is operating in the City of Health in Turin. This is a service that provides diagnostic and therapeutic treatments by healthcare professionals at patient's home, in a condition that normally would require acute hospital in-patient care. Transport and acceptance are free for these patients, as part of the HHS service. In case of necessity, a quick admission to hospital is possible for examinations or interventions that cannot be carried out at home.

The service normally operates 12 hours a day (from 8 am to 8 pm), each day of the week. For some patients medical staff is available 24 hours a day. Caregivers are instructed in the emergency plan and encouraged to telephone if any problem arise. The multidisciplinary staff includes four geriatricians, 13

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[1]Cfr. https://www.python.org/

nurses, one nurse coordinator, two physiotherapists, one social worker, one counsellor. One of the main features of the service is that physicians and nurses work together as a team with daily meeting to discuss the needs of each patient and to organize individualized medical care plans and day-to-day work.

The three **most important aspects of the nursing activity** are: home visits to outpatients to give medical care as agreed with the doctors; daily team meeting; secretarial work, receiving applications for hospitalization, stocking pharmaceuticals and sanitary material, sending and collecting laboratory analysis, transporting patients for particular consultations or exams which can be done only in hospital.

Services and Treatment Provided: physician and nursing visits; standard blood tests; pulse oximetry; electrocardiogram; spirometry; echocardiogram; internistic ecographies and Doppler ultrasonographies; oral and intravenous medication administration, including antimicrobials and cytotoxic drugs; oxygen therapy; blood product transfusion; central venous access (PICC, Midline); surgical treatment of pressure sores; X-rays; telemonitoring; physical therapy; occupational therapy; counselling

The daily activities at home of patients are defined on the basis of different clinical necessities of the patients. The team of care (physicians and nurses) guarantees an answer in 20-30 minutes in case of emergency. Hospital-at-home patients are considered hospital patients, and all services are provided by the hospital, which retains legal and financial responsibility for care. If the patient needs instrumental examinations or consultations that are not practicable to the domicile the performance as hospitalized patient. Hospital team booked and organized the move in the hospital with the ambulances service for the necessary time, then the patient returns to his/her own domicile. All the medical equipment (e.g. the medicines) are brought to the patient's domicile during the daily visits and furnished from the hospital. A documentation exists for each patient always available at the patient's home, with an updated report available in the HHS office.

The professional experience of the staff and important clinical studies described the advantages in terms of clinical improvement, reduction of the complications, reduction of the re-entry in the hospital, the impact on the quality of patient's life, as well as a reduction of the costs (i.e., from 400 Euro/day to 155 Euro/ day on average).

3.1 The Admission Process: The Challenge to Balance Qualitative and Quantitative Variables in a Diagram

The admission process have only one human resource, that is the Case Manager (CM), who have to evaluate all the requests and each one case according to some guideline to understand if the patient have some characteristics to allow him to take in charge to this type of hospitalization. It seams a simple process but is full of qualitative variables, over the quantitative once, which make the process very more complex of that it seems. At the end of this evaluation, for the taken in charge of a patient, a real contract of collaboration is created. It sees on one side the hospital, and in specific the staff of the department of HHS, and from the other side the patient with the caregiver and the possible family, which can be coincide or not with the figure of the caregiver in itself. Besides it is important that this type of collaboration remains as established to the beginning for the whole time of the duration of the service. Otherwise, for instance in case of caregiver missing or family exhaustion, the patient is immediately moves to hospital and hospitalize classically inside the hospital wall.

Firstly, every morning the Case Manager (CM) have to evaluate the available numbers of possible posts (**Evaluation n° places available**, that correspond to the maximum numbers of patients that she could accept in this day. In this evaluation the CM spent about 45 minutes because she have to evaluate:

- The number of patient that during the day will be probably release.

- The number of staff available: for example if we are near Christmas or summer holiday sorely staff are fewer, so patients must be proportionate.

- How long each patients, they already have in charge, been: some patients have some pathology that must imply more time then other, for example blood transfusions are longer then bandages that are longer then giving a medicine. First type of patient occupy two slot, second type of patients occupy one slot and an half and the third type occupy only one place.

This first evaluation imply both type the variables, qualitative and quantitative, it is based on the best experience of the Case Manager made by years of experience, and it is a very important task because it determinate the future workload of all the staff involve in the service.

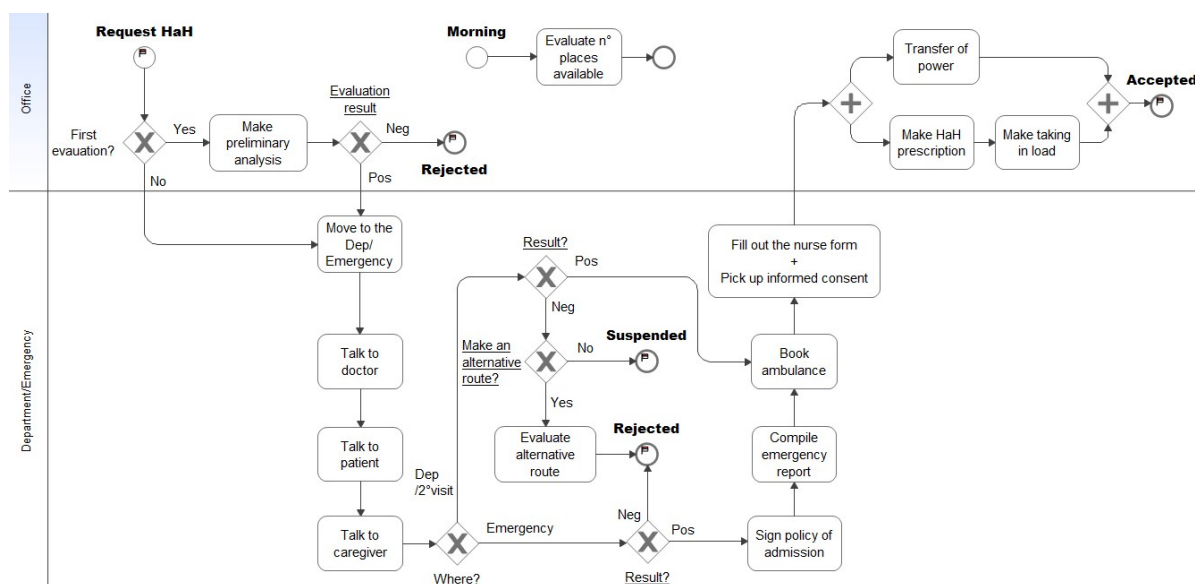At the same time requests can arrive by telephone from the emergency department as well as from any

Figure 1: Process of acceptance of requests for the HHS.

other hospital departments. The requests are made by the responsible doctors of the departments that made a first quick evaluation.

The arrival of a request by phone at the Hospital at Home (HaH) (generator **Request HaH**) implies an initial evaluation (gateway *First evaluation?*) by the doctor and the CM or the chief nursing (**Make preliminary analysis**). If there are really features not complying with this type of hospitalization (gateway *Evaluation's result?*) the request is immediately rejected (end of the process **Rejected**). Otherwise, CM moves to the department to evaluate the patient (**Move to the Dep/Emergency**). At first, the CM talks to the requested doctor to evaluate clinical conditions (**Talk to doctor**). All patients are in acute disease but they must not be in state of bleeding or risk of reanimation. Then the CM talks to the patient, if he is conscious and capable of understanding and willing (**Talk to patient**), as well as to the family and the caregiver (**Talk to caregiver**).

During this meeting the Case Manager explains to the patient, if possible, and to the family:

- The characteristics of the service.

- The organization of the service.

- The necessity that a person of the family, or someone else, collaborates with the hospital's team.

Already from this phase:

- Evaluation of clinical, functional and cognitive aspects.

- A run of diagnosis, care and assistance are establish to optimize the existing human and material

resources, that is finalized to a held result the best possible, reducing the days of hospitalization.

- If necessary, a solution of suitable relief is evaluate.

- Since the possible taking in charge of the patient that possible problem list are analyzed for the future resignation.

- Predispose the applications for the supply of aids and garrisons that can be useful to the domicile (for instance, it is possible to require with procedure of urgency the liquid oxygen that will be delivered in a few hours to the patient's house).

The requisite to access the service are:

- As quantitative variable:

  – Patient's residence in the Piedmont Region.

  – Patient's domicile in the geographical area coverage by the service (half city of Turin).

  – Clinical characteristics to be asked for hospitalization without an invasive or intensive monitoring. Are exclusion criteria the need of mechanical ventilation, a monitoring more frequent than every 2 hours of blood pressure or haemogasanalysis, patients with an heart attack or with very low levels of oxygen in the blood or with a serious acidosis or alkalosis or with a suspect of pulmonary embolism.

- As qualitative variable:

  – Signature of the informed consent of the patient and/or of the family, that imply the consent of and the will to access to this service.

– Suitable family support.

Through this structured interview of mutual knowledge, Case Manager attentively appraises the real availability to accept the cares to house, if it is possible to identify a caregiver, so the avaaility of taking in charge the patient in this type of hospitalization.

The requests could be forward both from each departments of the hospital and from the emergency department. For both of them the activities already shown are always the same, but after having talked to all the interested parts, the decisional trial is different according to where they are (gateway *Where?*).

If they are in the emergency department there is an urgent need to free up beds. Any bed of the emergency department can be busy for more than 24 hours. Therefore, the evaluation result must be immediately positive or negative (gateway *Result?*). If it is negative the request is definitively rejected (**Rejected**). Probably the patient have not the requirement and he is transferred in a classical departments. If the parts (CM-patient-caregiver-patient's family) reach the accord to hospitalize at home the CM signs the policy of admission (**Sign policy of admission**), the emergency department's doctor compiles the emergency report (**Compile emergency report**) and then the CM books the ambulance for the transport to the patient's domicile through ambulance of the service of transport settled with the hospital (**Book ambulance**) and finally the CM fill out the nurse form asking dates to the patient/caregivers, collects some patient's information, give to the patient and to his family some information about the service including an "Informative Card" with information on the service and about organization of the next tasks and at the end makes to sign and pick up informed consent to the patient, or to the caregiver if the patient is unable (**Fill out the nurse form + Pick up informed consent**).

If the request came from a classical department of the hospital the result of the evaluation (gateway *Result?*) could be:

- Positive: the patient is taken in charge, so the CM books the ambulance, give and take different information, compile the nurse form and make sign the informed consent to the patient, like the previous process (**Book ambulance** and **Fill out the nurse form + Pick up informed consent**).

- Really negative: CM suggest an alternative route to the patient (gateway *Make an alternative route?*) and the request for this type of hospitalization is definitively rejected (**Rejected**).

- Negative but really Suspended: often the family need time to organize themselves or to required

medical products or it is necessary to talk also to the "real" caregiver that remain with the patient or to other family members, so it is a temporary reject (**Suspended**), but the CM takes another appointment.

To establish this contract of trust and collaboration among patient and hospital is essential that the CM talks to the whole family nucleus to narrow contact with the patient, that must take care and divide assignments and responsibility and finally with the caregiver, that could be a relative or not. It is necessary that all these people are informed, aware and give the consent to the service, otherwise there could be severe consequences in terms of collaboration that could affect the patient's care.

In this case, the Case Manager will have other tour (gateway *First evaluation* arrow 2° visit). These others visit are in average 1, 2, 3 or at most 4 in particular cases, maybe if there is the need to wait some medical products that have to be order. These other visit are not made by the different doctor with other requests, but the Case Manager take the appointment on a case-by-case bases directly with the patients. The activities remain the same but need to less time then the firsts. This second evaluation could be exist only in the department (gateway *Where*, 2° visit), for reasons already explained. In all these visits is possible both taken in charge the patient, or a rejected the request or a suspended it for another visit and the trial can be repeated until the patient will be taken in charge, or the service will be refused, or the patient will die or will be discharge.

In all cases in which the patent go at home in a different day from the request of the HHS, the Case Manager autonomously goes to the patient before he goes away, with the purpose to make sure that all the information are clear. It imply the remake of the three activities already explain but in less time.

At the end of this trial with the patient the Case Manager came back to her department's office and make the administrative tasks for the patients just taken in charge. On the hospital's computer system the CM has to make the prescription of the Hospitalization at Home (**Make HaH prescription**) and the formal taking in charge in the department of the Hospitalization at Home (**Make taking in charge**). In the meantime, as soon as the doctors and the nurses arrive the CM informs them about the new patients (**Transfer of power**). At this time the request is also formally accepted and the patient is definitively in the workload of the department of the Hospital at Home (**Accepted**).

4 SIMULATING BUSINESS PROCESSES

4.1 Analysis of Input Requests

We analyze and simulate the real date of the hospital in the years 2017 and 2018.

The arrival of patients follows a not uniform distribution and this is because activation of the service can happen:

- On direct application of the physician of general medicine in alternative to the dispatch of the patient in Emergency Department.

- On application of the physicians of the departments of hospitalization of the hospital.

- Directly from the Emergency Department for patients transferred home within few times (in average 7-8 hours), after the necessary diagnostic checks.

Doctors makes requests for this type of hospitalization mainly in three occasions:

- When the patients request this service because he already use it and the conditions of the pathology are conform to this type of hospitalization.

- When doctor is enough convinced that the patient would have great benefits with this type of hospitalization.

- When there are few department's beds and some patients could profit of this type of hospitalization freeing beds, especially in the emergency department.

Today, approximately 60% of the HHS department's patients are referred by the Emergency Department (ED), 25% by hospital wards and 15% by specialist or general physicians in the community.

Table 1: Daily distribution of the arrival request.

	R + CM visit	R rej. by phone	Total
2017	468	96	558
2018	516	103	619
Total	*994*	*199*	*1,193*

Analyzing hospital data base, it is shown, in Table 1, the number of the requests that have wanted at least one CM visit (**R + CM visit**) and the number in average of the request that are immediately rejected by phone, without a CM visit (**R rejected by phone**), in years 2017 and 2018. The number of request immediately rejected are an average number because they don't report this call in the data base. This value has been arranged with the CM.

4.2 Case Manager Workload: Data Analysis

The workload of the Case Manager depend not only by the real number or the request made by the different doctors, but also, as shown in the process (Figure 1), by the other appointment on a case-by-case basis that the CM autonomously take with the patient.

Starting to the Table 1 and according to the data base analysis we can estimate about that the workload of the Case Manager is incremented of the 57% by the visits after the first.

Table 2: Increasing of the CM's workload by the seconds visits, in 2017-2018.

Tot.R+CM visits	Tot.CM visits	Diff.(%)
994	1,742	43%

Table 2 considers the sum (**Total**) of the column **R + CM visit** of Table 1 comparing the results of the Case Manager database of the HHS.

The increasing of the workload of the CM, almost 50%, shows how much balancing all these variables, above the qualitative once, increase the workload. This is made with the purpose to create a clear collaboration, stable in time that will lead advantages in the workload of the team that will go home and to the patient's care.
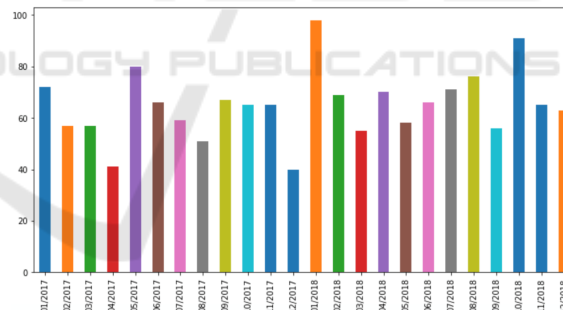

Figure 2: Arrivals of patients at the HaH service in 2017 and 2018 in the different months.

Therefore, Figure 2 describes how the CM's workload changed monthly in last two years. For example, in January or autumn there were some peaks, mostly related to periods of flu. On the contrary, near (Italian) festivity days (i.e. April 2017) there were less requests, maybe because people are less available to move out from the city.

Another analysis that we made concerns the difference of the CM's workload made by the Emergency department and the other classical department. This analysis is shown in Figure 3.

It is notable the difference as the requests by the Emergency department imply only one visit, a more
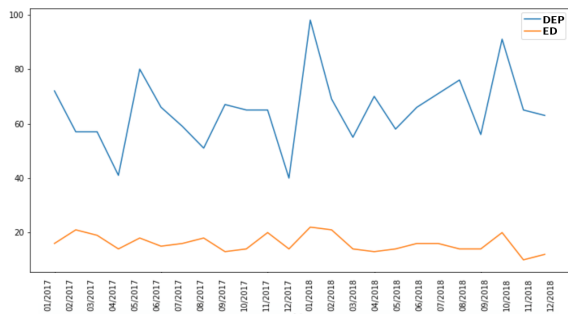
Figure 3: Worload of the Case Manager of HHS in 2017 and 2018 from Hospital Departments (DEP) and from Emergency Department (ED).

Figure 4: Patients taken in charge in the HHS in 2017 and 2018, from Hospital Departments (DEP) and from Emergency Department (ED).

quickly decision and two more documents for each patients. The request provided by the different department, in addition to the fact that the departments are more then one, there is some more time and the visits are frequently more then one.

We also computed the average daily arrival of patients by day, which is about 3.5 with a standard deviation of about 2. Interestingly, the distribution varies across days with a peak in the first part of the week. Table 3 describes the average value of patients the modal value and the standard deviation for each day by considering the period between 2017 and 2018.

Table 3: Daily distribution of the CS's workload: average (Avg), modal value (Mode) and standard deviation (StDev).

	Mon	Tue	Wed	Thu	Fri
Avg	4.05	4.05	4.09	3.35	2.56
Mode	4.00	4.00	3.00	3.00	2.00
StDev	2.04	2.04	2.03	1.72	1.62

The actual process has been validated by managers of the hospital department as well as accurately verified in actual and future simulation results. In particular, besides changes related to the arrival of patients, we investigate variations in the execution times of workers and organizational changes.

4.3 Output with Different Arrivals

The output of the Case Manager evaluation directly affect on the workload of the HHS department, so on the job of the team doctor+nurse that day by day have to go to the different patient's home.

The team looks after 25 patients per day and 500 patients per year, on average. Figure 4 show the accepted requests, so the patients taken in charge in 2017 and 2018, from Hospital Departments (DEP) and from Emergency Department (ED). Curiously, the accepted requests by the Emergency Department follow a similar trend of the provided requests. This
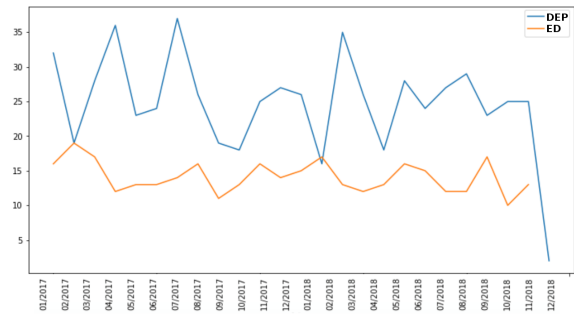
is because, if it is possible, it is easier to free a bed of the Emergency Department avoiding simply to move the patient to another bed of a classical department. The number of patient in charge each day has to be balanced with the patients that leave the service, in order to guarantee an adequate workload for the team and an adequate level of care, according to the first evaluation activity explained in Figure 1 (**Evaluate n° place available**).

Table 4: Description of the requests accepted and rejected in 2017 and 2018.

	2017	2018
Patients taken in charge	468	489
Patient rejected from DEP	10	22
Patient rejected from ED	2	5
Request rejected by phone	96	103

Table 4 describes the number of patients taken in charge in two last years. The fact that the rejected patients are very few is also thanks to an adequate information and collaboration between the doctor of the Emergency and other classical departments and the staff of the HHS.

4.4 Scenario Analysis

Beside scenario As-Is, we plan to modify some features of the organisation as the introduction of different execution time of workers (i.e. stagiest versus expert workers) in expert-stagiest scenario, the restructuring of the whole process with different activities in re-engineering scenario, or the working shift of staff in part-time scenario. The interest of managers in considering the introduction of different execution time of workers concerns the ability to produce more realistic scenario including young specialist nurses and doctors besides actual experienced workers. In other analysis some tasks in the flow can be slightly modified, to investigate the outcome on the whole

time execution of the process. Finally, by introducing part-time worker shift some considerations can be added with respect to different organisation planning, i.e. obeying to some special request from workers.

5 CONCLUSIONS

This research describes a methodological framework to model and simulate an hospital admission process. We applied the standard language modeling BPMN to introduce a simulation effort based on real data. In future works, we consider to investigate the remainder of the process, as well as the trajectories of the operators on the territory towards the patients' home with social network analysis by combining geographical information systems and agent-based modeling to improve the analysis and simulation of the HHS process (Sulis and Di Leva, 2017). Moreover, we plan to investigate several scenarios to provide some suggestions to managers by offering insights on organisational aspects, also including an increment of patients as in the case of an extension with respect to the actual service. In addition, we aim to explore different options concerning the arrivals of patients by investigating the extension of the service to another area of the same city. As the HHS actually involves only the southern part of Turin, we plan to investigate the extension to the northern area: that would mean mostly doubling the arrivals of patients. In particular, we afford this research question to manage such increment of patients by planning different configuration settings, also involving the staff dimension, in order to produce optimal results for decision-makers.

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