X-ray at your home: the Business Process analysis of R@dhome service

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Abstract. This paper explores a modeling and simulation framework in healthcare following a process-centric approach. We focus on the use case of home radiology called R@dhome, a service that provides x-ray exams at the patient's home in an hospital of one of the biggest city in northern Italy. Our approach initially starts with data analysis to extract relevant information about this service to address modeling and simulation. In a second step we apply business process modeling, exploiting standard language to improve communications and the understanding with managers and stakeholders. Third, our framework includes the simulation of business process to detect weakness, bottlenecks, as well as performs scenario analysis. In particular, we describe this innovative health service and its benefits by suggesting the adoption of discrete-event process simulation. The paper provides an overview of the functioning of the actual process, taking into account relevant information such as time, costs and resources. The outcome of this framework allows hospital managers to investigate the hospitalization at home in a process-oriented approach to evaluate the extension of this kind of healthcare service.

Keywords: Process Modeling and Simulation · Hospitalization at home · Business Process Management

1 Introduction

The average age of population in western societies has increased in recent years and the incidence of elderly is still growing. In public health services this is associated with an increased prevalence of chronic diseases, often disabling as well as a progressive lengthening of life expectancy in conditions of chronic and disability (the so called fragile patients) [16]. The degree of fragility is very high as well as the risk that even trivial factors may trigger a cascading. Health policies have to prevent fragile people falling into a long-term hospitalization, which would imply strong functional losses and serious psycho-physical disturbances linked to the distancing from their usual life context. Among these patients, hospitalization often results in delirium, nosocomial infections, pressure sores, and falls. [24, 5, 11]. Already since 2005, the Italian Ministry of Health with an emergency report underlines the necessity "to identify an organizational model for the management of the chronic rehabilitation phase using not only dedicated facilities but also alternative facilities such as home hospitalization and integrated home care" [11].

The hospitalization at home [7] is increasingly matter of interest leading to a lower number of First Aid visitors compared to patients hospitalized in the hospital, with a reduction of costs [24]. These models of care are a "bridge" between hospital and territory, two pillars of public health having the task to achieve together the process of taking charge [18]. These innovative models also represent a challenge because, in addition to meet specific requirements of appropriateness, effectiveness, efficiency and safety, must fit into a political and economic context to relevant changes. The evolution of technology and cultural context allowed also x-Ray technologies to be transported out of the hospital. Home and territorial public radiology in Italy was born in Turin within the context of the actual City of Health in 2007. Therefore, Radiology acquires a growing role in patient management to work with almost all geriatric pathology without transferring patients to the hospital [11]. Other Italian Regions (e.g. Veneto, Tuscany and Liguria) are nowadays adopting this kind of service, which is already a reality in other European countries, e.g. in Sweden, Norway and Denmark [26] with encouraging outcomes [14, 22].

In the framework of Design Science [25], this work aims to support the healthcare organization by modeling the activities. From a management perspective, we focus the attention on simulation of the functioning of the organisation based on data stored in the information System (IS), by exploiting the most used discrete-event techniques [6] to evaluate the specific case study [21]. Similar work states how modeling allows early detection and resolution of critical issues [23]. In the context of healthcare studies, standard language BPMN acquires a certain consideration [19]. This is relevant as many healthcare organisation do not perceive the relevance of investigating their business processes by exploiting IS data to shape their activities, neither of adopting a Process-Aware Information System [10], as recently proposed in the framework of Business Process Management, with the promising Process Mining perspective [15]. In particular, we focuses on the following research questions: i) Modeling and simulation can be helpful in strengthening the attention of managers in business process analysis from real data obtained by the Information System? ii) In the context of Design Science, computer based simulation based on data from IS demonstrate the validity also in a particular healthcare service, such as hospital-at-home? This article focuses on a process-oriented approach to the activities of new service at home, as a first step of a Regional project with European Founds called "CANP"[3].

[3] See http://casanelparco-project.it/

In order to analyse business processes of this new type of hospital service, we exploit a Business Process Management (BPM) methodology. One of the main issue of BPM [2–4, 9] is change management. The adoption of process-centric approach relying on a process-aware information system [1, 13] allows the redesign of business processes in an organization. In the following Section we introduce our methodology, in the third Section we contextualize the R@dhome service case of study, its processes and their business simulation with the data analysis results. In Section 4 we provide our concluding remarks with some considerations about future work.

2 Methodological Framework

In our case, the absence of an events log traced by the current information system forces us to adopt a traditional methodological framework consisting of five main phases:

1. **Context and Data Analysis**: it is an initial phase that focuses on organizational analysis. It aims is to set the overall strategic scenario relevant to the company and determine the functional components related to the processes under analysis. The outcome of this phase should include the selection of a set of Process Performance Indicators - PPI (eg cycle times, costs, resource allocation, etc.), the evaluation of the current value of these indicators and the estimate of the values that they should assume at the end of the re-engineering phase of the process under analysis.
2. **Process Analysis**: the initial purpose of this phase is the determination of the activities performed in the company functions involved in the process and the causal relationships existing between them. The process is then reconstructed starting from facts external to the system (events and objects in input-output to the process). In this way, the process diagram (sometimes referred to as process map or flowchart) is derived, which will be specified using the Business Process Model and Notation (BPMN) language [2]. The process diagram must therefore be integrated with all the information concerning: a) the resources that perform the activities of the process, b) the characteristics (capability, schedules, costs and so on) of the resources themselves, c) the execution time of the activities, d) the queue management policy in the process, and other features that allow to build a virtual model of the reality as close as possible to the reality itself. The model must be simulated with respect to a realistic modeling of the workload of the process, thus obtaining an evaluation of the performance indicators to be compared with the current values of these indicators. The comparison allows to validate the model when the two sets are reasonably similar. The model obtained in this way is called the As-is model of the process under analysis.
3. **Scenario analysis and Process Reorganization**: the objective of this phase is the introduction in the As-is model of one or more corrective actions that allows to construct different evolutionary scenarios (and the respective

models). The simulation, with the same workload, of the different scenarios (What-if analysis) allows comparing the scenarios, among themselves and with respect to the starting As-is model. This phase includes solutions for restructuring the process, improving the detection and the understanding of inefficiencies, bottlenecks, constraints and risks [15]. The comparison takes place on process indicators that are evaluated with different simulations and compared with the desired values of the indicators determined in the Context Analysis phase, until a solution is reached that is accepted by the company management. In this way, we obtain a new model of the process (the To-be model) which should therefore be implemented. The framework allows investigating the performance of business process with the introduction of technological applications, such as telemonitoring devices or informative systems improving drugs prescription.

4. **Process Implementation**: in this phase, the changes required to move from the As-is process to the To-be process are prepared and performed. Each activity of the To-be model is specified using a Use Case and a Class Diagram (UML). The use cases will then be implemented using the services that the CANP architecture will provide. The class diagrams will in turn be integrated into the CANP application data schema and managed through the Data Base Management System of the CANP architecture.
5. **Process Monitoring and Controlling**: while the redesigned process is ongoing, relevant data will be collected and analyzed to determine the efficiency of the process. Bottlenecks, recurrent errors or new problems may then arise, requiring the cycle to be repeated on a continuous basis.

In this article only the first two phases of the methodology will be applied as the case study that will be illustrated represents a pilot project for the analysis of the processes within the above mentioned CANP project.

3 Case study: R@dhome

R@dhome was born as an experimental project of home radiology in Piedmont Region , as a sub-department of the Radiology Hospital in the City of Health and Science of Turin, since 2007 [7]. This project represents the first experience in Italy and among the first in the world to be carried out in the public and the radiological territorial activities are perfectly integrated with the ICT through the implementation of a system of sending images at distance, respecting the rules in place, which uses broadband [17].

The Socio-Health Plans and Territorial Assistance of the Piedmont Region from 2007 to 2016 affirm the need for technological and social research in the field of ageing and ICT [17].

R@dhome Research Group pointed out that the execution of the x-rays in the patients home has a “protective” effect against the behavioural disorders and/or pain and, therefore, indirectly, contributes to an improvement in the quality of life of patients; clinical-diagnostic quality of the radiograms performed at home is certainly comparable to that of the hospital examinations and the exposure risk is contained both for operators and the population, costs are lower, patient satisfaction is very high and the relationship sick-professional is very favored, with great benefit and satisfaction of both sides [11].

The metropolitan city of Turin consists of 316 municipalities with a total of 2,300,000 inhabitants. In the territory of the metropolitan city there are:

– 88 public and private accredited Social Assistance Residences (RSA). They are residential extra-hospital structures aimed at providing accommodation, health and rehabilitation services, protection and rehabilitative treatment to elderly people in conditions of lack of physical and mental self-sufficiency, without family support.
– 1600 Doctors of General Practitioner (GP) that operate and throughout the Piedmont Region the patients in Integrated Domiciliary Assistance are about 25,000 and in the metropolitan city are about 9,000.

R@dhome is a service available to fragile people of the metropolitan city of Turin, for boh patient in charge of the hospital but located outside the hospital's wall and patient not in charge.

– External to the hospital:
  - RSA
  - GP

– In charge of the hospital but out of the hospital's wall:
  - IRV Department for patients in post-acute phase. It is an hospital department but located elsewhere.
  - OAD Department for geriatric patients in acute phase that are hospitalize at their home.

The assessments in terms of technological investment and human resources are therefore calibrated in a first phase on this basin; the extension on all the regional territory can be made projecting the needs of the territory, in the light of experience gained and appropriate adjustments based on demographic data [17]. The real geographical area covered by the R@dhome technician radiologists during the year 2017 is shows in Fig. 1).

The inclusive categories are very narrow. Home diagnostics makes sense when, clinically, only those examinations for which the same quality as would be achieved if the patient were examined in a residential radiological facility are performed. This consideration has a strong impact on the economic aspect: R@dhome is cost effective only when the service is provided to the right patient and in the right setting [8, 11, 17].

3.1 Processes engineering

R@dhome office department seizes the City of Health and Science's hospital but is physically stationed in another place outside of it. The service cover the whole

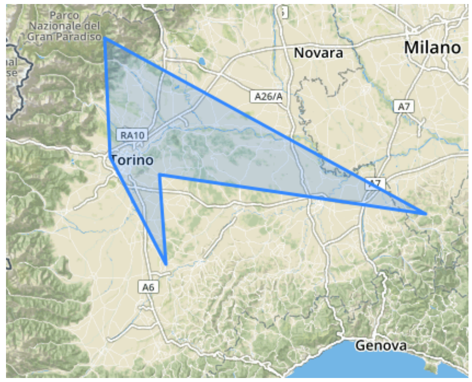

Fig. 1. Geographical area covered by R@dhome in 2017.

metropolitan city of Turin and employs three radiologists plus a responsible radiologist and a car.

The service open at 9:00 am in the morning (*Start* in Fig. 2)). At first, personnel check if any requests have arrived (**Check requests**). At any time of the day, prescriptions can attain. They have been stored on voice mail, on mail address and into the HIS. The methodology of the arrival depends on the applicant source (gateway *Request type?*). The internal requests are generated by the internist on IS and are related to patients already in hospital charge, therefore they only need to the technical evaluation made by the radiographer (**Technical evaluation**). It evaluates: the schedule visit and some technical aspects. The external requests are made by the physician of general medicine external to the hospital on an on-line format (because they don't have direct access to IS) and are related to patients not already in charge to the hospital. That is why they need a medical radiologist evaluation (waiting time *Medical radiologist evaluation*) before the technical once (**Technical evaluation**). If the request is approved (gateway *Approved request?*) the staff make the upload in the IS and the taken in load (**Upload in IS + take in charge**), otherwise they propose to the patient an alternative path and eventually make calls to re-book the patient for the right visit (**Create alternative run**).

All the accepted requests in one day will be fulfilled in the next few days workflow, unless otherwise indicated. From the arrive of the request the staff takes on average 24-72 hours to visit the patient. At about 9:30 am (*Tour*) staff organizes the visit route of the day (**Schedule path**). If there are not particular problem (gateway *Issues?*) the tour involves two technician radiologists (**Organize path with 2 tech + 1 car**). Otherwise, there could be two types of issues (gateway *Issues type?*):

– An additional radiographer is required (**Organize path with 3 tech + 1 car**), for example in the case of an overweight patient or in the case where the patient lives in a house without a lift or where there are known architectural barriers.

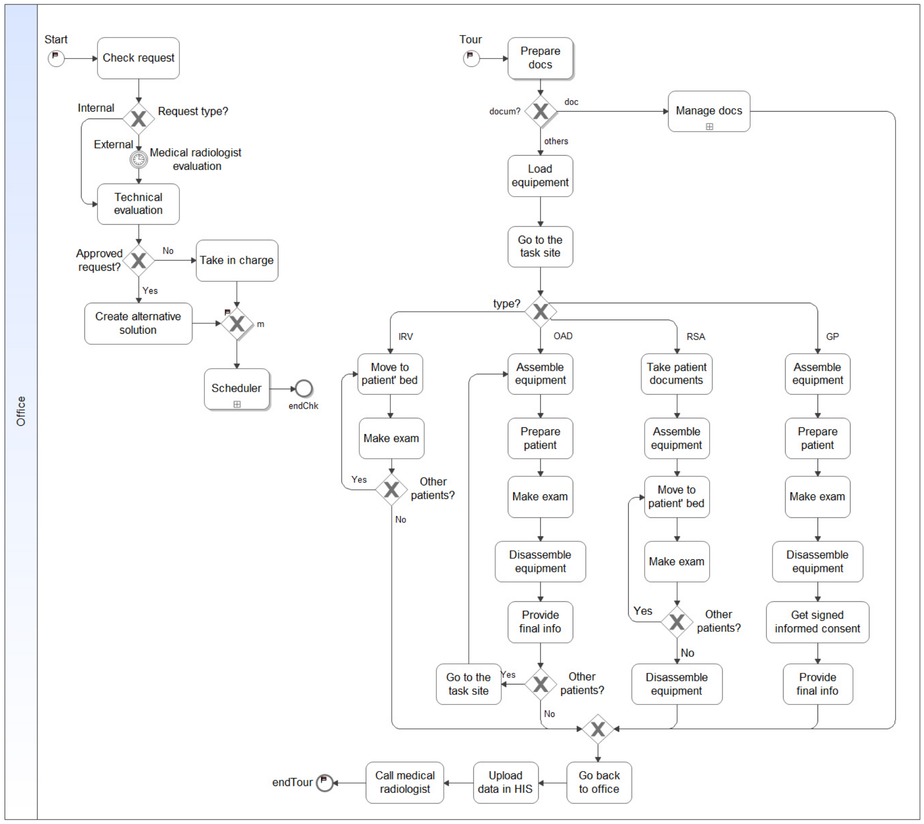

Fig. 2. Main process of R@dhome.

– An additional car is required (**Organize path with 3 tech + 2 car**) for example, if there is a heavy workload in few different setting. In this case they have to book one more hospital's car and one technician goes to hand over the documents, while the other two make the normal visits paths.

The department have only one car, so in this last case they have to book an hospital's car and they have to go to take it in the hospital car parking by their car and came back (**Going to take 2 car to Main Hospital**).

When the working team are ready they can load the equipment in the car (**Load equipment**) and leave the base (**Go to the task site**). They can have two different destinations (gateway *Where?*): The Main Hospital to take or leave patient documentation (**Manage docs**)(in detail see the process in Fig. 3)) or to the patients. In this case the staff can make or an inspection of the place (**Make inspection**), e.g. for prepare a specific room in a RSA, or make the real exam (**Make exam**) (see in detail Fig. 4)).

At the end of the exam if there are other patients to visit (gateway *Other step?* they go to the next patients house (**Go to the task site**) and they remake the process. Otherwise they came back to their office. On the route one technician drive the car, in the meanwhile the other try to upload the x-ray images in the HIS (**Back to office + upload data in HIS**).

When they arrive to the office if the data are not all upload to the HIS (gateway *Data uploaded?*), they finish to do it (**Upload data in HIS**). At the end of this they call the medical radiologist (**Call medical radiologist**), that is in the main hospital, to warn him that he can begin the reportage.

The delivery or collection of clinical documents or medical report in the main hospital, as shown in Fig. 2) (**Manage docs**), contain in its inside another sub-process, shown in the Fig. 3).

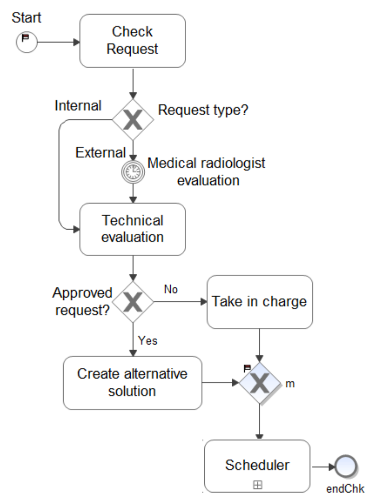

Fig. 3. Process of delivery or collection of clinical documents or medical report in the main hospital.

In some particular cases, to make the medical report it is necessary have some historical patient's documentation. In this case, when the technician go to make the x-ray they also collect these documents that they will deliver in the main hospital (**Delivery documents to Main Hospital**). If it is not possible to make soon the clinical review (gateway *Clinical review soon?*), maybe because the medical radiologist is not there or he is too busy, they leave the documents and come back to their office department or to visit some patient, otherwise they wait the clinical review (time delay *Wait clinical review*). When it is ready, if (gateway *Patient origin*) the patient came from the General Practitioner, they collect all the documents together and leave it at the hospital's secretariat (**Attach all doc + leave at hospital's secretariat**) because the withdrawal of documents is the responsibility of the patient himself. If the patient came from an RSA they have to take the exam report to deliver it to the patient's home, the RSA (**Delivery doc to RSA**).

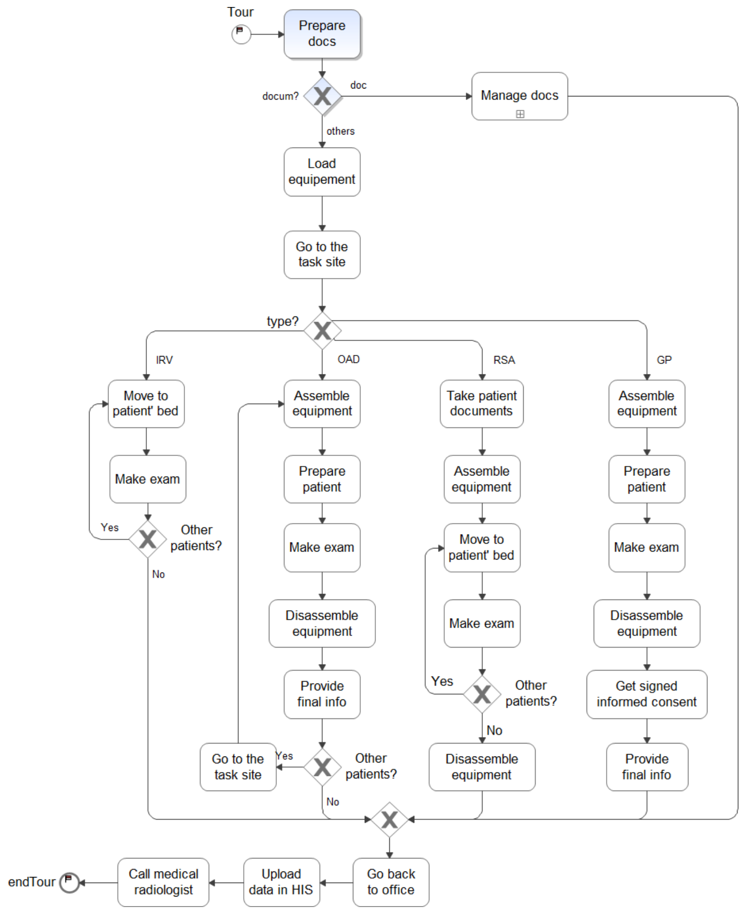

Fig. 4. Typology of arrival requests of x-ray exams.

As already said, there are two typology of requests: internal and external (see Fig. 4).

The internal are for patients already in charge for the hospital. These requests arrive from both IRV and OAD. **IRV** is an hospital department, so when the technician arrive, they have to go at the correct floor, talk to the nurses, take eventually some documents, find the patient's bed (**Find a patient's bed**) and make the x-ray exam (**Make exam**). Than, if there are other patients (gateway *Other patients?*), go to make the other exams, otherwise go away. For patients hospitalize in **OAD**, they are physically in their own house, so when the technician arrive the first things is to analyze if the exam is possible (e.g. there is the electric current available to connect the x-ray machines). If the exam is available (gateway *Available?*) they assemble the x-ray machine and the other equipment (**Assemble equipment**), they talk to patient and the eventually care-giver to give and take some information that concern the exam or previous important medical information (**Talk to patient**), they make the x-ray exam (**Make exam**) and, at the end they disassemble the equipment (**Disassemble equipment**) and taking leave, giving the last information to the patient (**Taking leave**).

The external are for patients not in charge from the hospital. These requests arrived from both RSA and GP. In **RSA** often the patients are (gateway *Patient location*) on their bed, like the IRV. When the technician arrive the process is almost the same of the IRV. Rarely patients are able to move, alone or helped, in this case it is possible prepare an ad hoc room, after a previous inspection in previous days. In these cases they can collect all the patients in this room, assemble the equipment only one time, make all the exam, one by one, and disassemble the equipment only one time at the end. For patients that came from the **GP** the exam process is almost the same of the OAD. The particularity is that they get sign informed consent (**Get sign informed consent**) (patients that are already in charge in hospital or in another structure signed this document at the taking in load) and before taking leave, they provide all the information for the medical report withdrawal (*Provide info for medical report withdrawal + taking leave*), that is a patient's responsibility to pick it up at the hospital. At the opposite, as mentioned above (in Fig. 2), for the RSA, will be the technicians who will return to deliver the reports. For both for RSA and GP patients it may happen that technicians will take some previous historical useful documents for the medical radiological report. If this happens technicians will have to go to the main hospital to deliver them before the radiologist writes the report (**Delivery doc to Main Hospital/Home**), according the process shown in Fig. 3).

3.2 Simulation

The process diagram is integrated with a description of how each activity treats a transaction, how long it takes and what resources are needed to perform it. Furthermore, it is necessary to specify how the transactions are introduced in the model and how long the simulation must last. The integrated As-is model can be simulated by means of a design and simulation environment, based on the iGrafx Process tool [12].

We will consider a workload that includes about 670 requests managed during the year 2017. In the Fig. 5 are shown the accepted (ACC) and rejected (RIF) requests arrived to the department and divided by month.

The sum of the two constitute the first generator of the simulation (Start) in the Fig. 2, while the line *ACC* correspond to the output *Accepted* and the line *RIF* correspond to the output *Discharged* of the same process mentioned above. The only accepted requests correspond to the patients actually visited (transactions entering the sub-process shown in Fig. 4. These transactions are then divided into two main group, Internal (already in charge by the hospital) and *External* (not in charge by the hospital) requests, divided into two other sub-groups each: OAD - IRV as Internal; RSA - GP as External.

Below are shown the results of real work load analysis carried out in 2017:

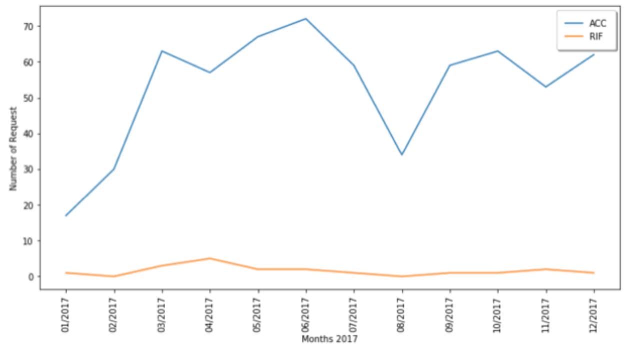

Fig. 5. R@dhome workload in the year 2017.

- Internal: 81% of the whole accepted requests
  - OAD: 24% of the whole accepted requests and 30% of the Internal requests
  - IRV: 57% of the whole accepted requests and 70% of the Internal requests
- External: 19% of the whole accepted requests
  - GP: 17% of the whole accepted requests and 90% of the External requests
  - RSA: 2% of the whole accepted requests and 10% of the External requests

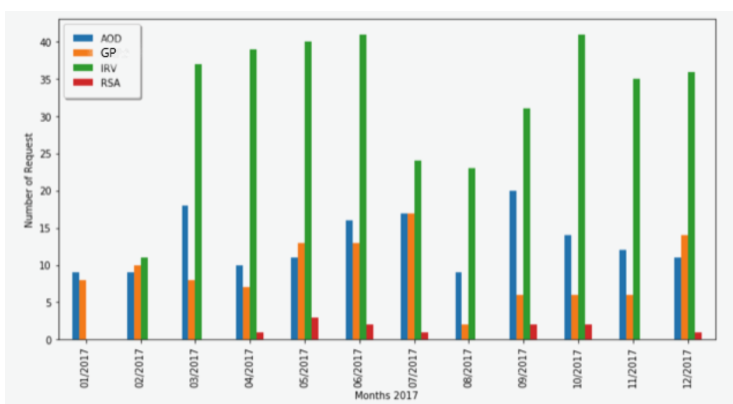

Fig. 6. Typology of arrival requests of an x-ray exam.

In details, Fig. 6 shows the number of patients visited by the technician of R@dhome, in OAD, GP, IRV and RSA, divided by mouths, during the year 2017.

3.3 Data Analysis

As shown in Fig. 4 each one of the four path have different tasks, but moreover some tasks that are the same imply different range of time depending of the working environment. Furthermore the x-ray exam can be performed at different body parts. In the Fig. 7 are shown the number and the exam type performed during the year 2017 in the four different pathways.

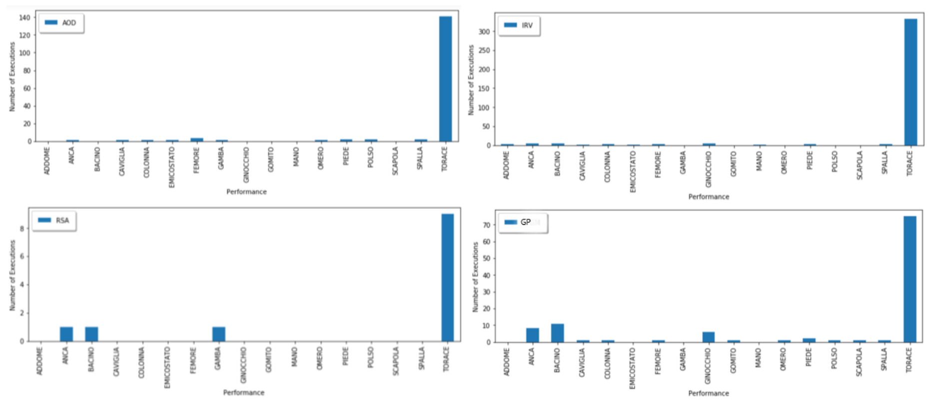

Fig. 7. Typology of arrival requests of an RX-ray exam.

Observing the graphs we find that the most generally required x-ray exam is at thorax (*TORACE*).

It is important underline, however, that the x-ray exam imply different range of time depending to the body part to be examined. In average we can group the exams in 4 macro sets and estimate a range of time for each category, as shown in Table 1.

Table 1. Average times used for each macro exam sets.

Body Part	**Average time for exam**
Thorax	5 - 10 min
Arts and Ends	10 - 15 min
Trunk, Rachis, Spine segment	15 - 20 min
Hip and Pelvis	15 - 25 min
Whole spine	35 - 45 min

Observations can therefore be made, for example, although the thoracic x-ray exam is the most required, it is also the one that takes the least time to be performed on average.

3.4 First results

In this section we introduce the first results obtained by discrete-event simulation. In particular, we focused on working time as a Key Performance Indicator.

Table 2 summarizes main results for relevant monitoring metrics introduced to measure the functioning of the process. Working time is defined as the period of time that an operator spends at paid labor. The average waiting time for accepted or discharged processes are respectively of 36 and 25 minutes. In addition, the most relevant activities in our simulation results are the management of requests for both OAD and RSA. This output has been carefully examined and evaluated by operators and manager staff, providing a good test for the validation of the simulation model.

Table 2. Working times results as Key Performance Indicator.

Monitor	**Average working time**	Count
Accepted	36.24	77
Discharged	25.21	3
DOCrequests	69.26	20
IRVrequests	132.27	16
OADrequests	187.17	15
RSArequests	167.83	3
GPrequests	122.01	1

4 Conclusions and future work

In this work we addressed a specific healthcare process analysis. Around 70-80% of global health resources are now spent on chronic disease management. Recent epidemiological projections estimate that in 2020, they will account for 80% of all diseases in the world and prevention and early detection are the most effective weapons to hinder the progression of these diseases and reduce the risk of mortality and disability avoidable in the short to medium term [20].

Hospital at home provides an opportunity of high profile interventions of public health with effective and efficient diagnostic services to the purpose to protect the weakest bands of population [11]. R@dhome is currently able to respond to the actual needs of the whole Metropolitan City area. A first scenario to investigate is the extension of the service to the entire Piedmont region, by monitoring how to optimize time, costs and resources. A second configuration involves for the main hospital the possibility to modify some parts of the actual process, e.g., to check the availability of a car by web or email by monitoring IS. In a third scenario, as in some Italian regions there is a regional unified electronic medical record, we are interested in modeling and simulating the impact of unified electronic medical record. In this case the whole sub-process of the delivery documents (Fig. 3) would no longer be necessary.

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