Adopting Technological Devices in Hospital at Home: A Modelling and Simulation Perspective

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Keywords: Business Process Analysis, Hospital-at-Home, Modelling and Simulation, e-Health.

Abstract: This article introduces a framework to integrate Business Process Management and Simulation to e-Health solutions in the context of dehospitalization. Assistive technologies clearly have a direct and positive impact on the quality of life of patients, but they also improve the overall management of the organizational processes. In the framework of business process analysis, we introduce televisiting and telemedicine applications. In particular, we define modeling and simulation of hospital services as a base to investigate the role of technological innovations in order to explore the positive impact both on patient well-being as well as on business process management perspective.

1 INTRODUCTION

The ageing of the general population is gradually shifting the attention to integrate the classic hospital model to alternative care. This fact increasing interest in models of home care and focused on the needs of patients often suffering from multiple chronic diseases (Tibaldi et al., 2013; Ricauda et al., Marinello et al., n.a.).

Technological solutions have demonstrated a positive impact on health, well-being and quality of life. In particular, assistive technologies focus the attention on the concepts of patient-centered care, which is actually worldwide recognized an essential dimension for the quality of care, as well as the so-called patient empowerment. A recent literature review on the topic reveals how about the half of the articles focuses on technology applications to all knowledge areas of health, as in the case of patient education or medical information management (Calvillo et al., 2013). From an organizational perspective, Business Processes Management and Simulations address healthcare managers, to better allocate appropriate resources or to improve the responsiveness of care to patients (Martinho et al., 2016; Mans et al., 2015; Fernández-Llatas et al., 2011). The aim of "La Casa nel Parco" (CANP) project[1], financed by Regione Piemonte with European funds, is to show improved results in different wards (geriatrics, pneumology, neurology, physiotherapy) thanks to the application of Artificial Intelligence (AI), integrated devices and machine learning algorithms to e-Health software (Sulis et al., 2019b).

In this work, we will focus on the application of innovative telemedicine technologies supporting the care of elderly patients in the context of a Hospital at Home (HaH) for acute pathologies or exacerbation of chronic pathologies. In this project, a multi-disciplinary vision is adopted by the patient care service, to increase the skills and competencies of

[1] See website of the project: http://casanelparcoproject.it/

Amantea, I., Sulis, E., Boella, G., Crespo, A., Bianca, D., Brunetti, E., Marinello, R., Grosso, M., Zoels, J., Visciola, M., Guidorzi, E., Miolano, L., Ratti, G., Mazzoni, T., Zani, E. and Ambrosini, S.
Adopting Technological Devices in Hospital at Home: A Modelling and Simulation Perspective.
DOI: 10.5220/0009970801100119
In *Proceedings of the 10th International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH 2020)*, pages 110-119
ISBN: 978-989-758-444-2

patients/caregivers, rationalizing health processes and, consequently, the management of economic resources.

Furthermore, user experience is essential for a systematic improvement of the process in the so-called cognitive computing framework (Hull and Nezhad, 2016). Similarly, the individual behavior of stakeholders involved in business operation, as well as corresponding interactions, are at the core of the discipline "subject-oriented business process management" (Fleischmann et al., 2013). From a software engineering perspective, the attention to business strategies and software development has to be integrated with users' concerns, as in the framework of a Human-Centered Design (Forbrig, 2016). The recognition of the user experience is one of the main objectives to be achieved in the current business process analysis.

In the following section, we introduce our methodology. In the third, we contextualize the HaH service case of study, its processes, and their business simulation with the data analysis results and the two different platforms. In Section 4, we provide our concluding remarks with some considerations about future work.

2 METHODOLOGICAL FRAMEWORK

The framework involves four different stages:

- The analysis of the context aims to understand what the actual situation is and what could be the needs for improvements at different levels. In-depth user experience (UX) research with patients, caregivers, and hospital professionals leading to a detailed understanding of the context (AsIs), the definition of user requirements, and opportunities for innovative solutions.
- The business process analysis examines the actual situation of the organization intending to create the As-Is model of the process.
- The introduction of technological applications improves the healthcare process. In particular, we investigate some devices for telemedicine (Ticuro Reply platform), as well as prototype applications aimed at helping the staff with the management of visitors tour (GoCare platform).
- The business process analysis and simulation take into account performance indicators as well as managing changes in the new process (To-Be) via scenario analysis.

2.1 Business Process Analysis

In order to analyse the business processes of this type of home hospitalization, we exploit a Business Process Management (BPM) methodology. One of the central issues of BPM (Dumas et al., 2018; Van der Aalst et al., 2010; Abo-Hamad and Arisha, 2013) is change management. Using a process-centric approach, due to describe the diagram of the process, we will adopt the Business Process Model and Notations (BPMN) standard language (Di Leva et al., 2020; Allweyer, 2016). Primarily, in the context of healthcare studies, BPMN standard language acquires a peculiar consideration (Amantea et al., 2020; Sulis and Di Leva, 2018; Müller and Rogge-Solti, 2011). The adoption of a process-centric approach relying on a process-aware information system combining with a simulation tool (iGrafx LCC, n.a.) allows the redesign of business processes in an organization.

A set of process performance measures (also called key performance indicators or KPIs) can address both the general and specific functioning of the process (Van Looy and Shafagatova, 2016). Typical performance metrics include the dimensions of time, cost, and quality. Several measures can be unambiguously determined also for HaH process. We focused our attention on the process performance dimensions of time. Firstly, we are interested in monitoring the throughput time to investigate the process from the start to the conclusion. Secondly, as we are interested in consideration about the workload of operators involved in the process, we included working time metrics. In particular, we adopt metrics about the average time worked by operators, as well as the average waiting time.

The business process analysis aims to define and engineer a model to be verified and validated with system experts, resulting in the so-called As-Is model. This step includes the creation of visual models of processes (i.e., process map or flowchart). These diagrams depict the sequence of activities and various crossroads (gateways), which lead to different routes depending on choices made. Other information integrated includes resources that perform the activities, their characteristics (capability, schedules, costs), the execution time of the activities, policy management, and the realistic workload. Thus, the simulation it is possible to obtain an evaluation of the performance indicators based on which the stakeholders can validate the model.

2.2 User Experience

Results stemming from UX research and ethnography activities, involving patients and staff of the Hospital at Home service, informed user-centered design processes. These were adopted to design a prototype concept for a solution aimed at meeting user requirements as identified during UX research activities. The prototype application value proposition takes into consideration major pain-point and user needs, specifically regarding the management of the HaH service, and the planning of logistics required for its delivery. The value proposition is then translated into a digital platform prototype designed for doctors and nurses who play a vital role in the delivery of the home hospitalization service.

The digital platform prototype, named GoCare, consists of software that enables medical staff to monitor the status of patients, schedule the home visit calendar, manage logistics and medical teams. The dashboard also allows the healthcare staff (during the visit and back in hospital) to update and share information helpful to manage the day-by-day visit reschedule. Moreover, the collected data allows health professionals to evaluate the workload of the HaH department and its capacity to accept new patients.

2.3 Telemedicine

Ticuro Reply (Santer, Reply S.p.A., Turin, To, Italy) is a suite for telemedicine (TM), telemonitoring, and the analysis of behavioral habits. It enables the processes of guaranteeing the management and continuity of care through real-time data monitoring by integrated medical devices. The suite also includes a secure channel that allows performing Tele-visit and Teleconsultation sessions, ensuring secure connections between patients and professional users or amongst professionals. The collected data and the possibility of remote and continuous assistance, allow health professionals to establish an interactive relationship with patients and their caregivers, providing them with personalized treatment paths, from anywhere.

2.4 Re-organizations and To-Be Model

The scenario analysis and process reorganization introduce a simulation of business processes to investigate changes in the As-Is model by generating the new To-Be version, including both discrete-event and agent-based simulation (Sulis and Di Leva, 2017).

This detailed phase includes the As-Is model solutions for restructuring the Process, improving the detection and understanding of inefficiencies, bottlenecks, constraints, and risks (Amantea et al., 2018; Sulis et al., 2019a).

In this case, the framework allows investigating the performance of the business process with the introduction of technological applications and e-Health technologies.

The simulation of the different scenarios, with the same workload (What-if analysis), allows for comparing the scenarios, amongst each other, and in relation to the starting As-Is model. In this way, we obtain a new model of the Process (the To-Be model), which should be implemented.

3 THE CASE STUDY

For more than 30 years, the “City of Health and Science” of Turin (Italy), has operated the Hospital at Home (HaH). A home care service, defined by Resolution DGR n. 85-13580 of 1 March 2010, as a form of health care hospital character, which provides for the organization of care in the home of patients suffering from acute diseases, but who do not require equipment with high technological complexity and intensive or invasive monitoring. On average, the service has covered half of the metropolitan city of Turin. Unlike most home care services; HaH Service handles acute patients or chronic patients undergoing exacerbation of a disease. Requests for activation of this service are made by the emergency or regular departments and by general medical doctors. After that, each patient is evaluated by the team in order to establish the feasibility of hospitalization under HaH. The service is available every day from 8 am to 8 pm. In the case of a night emergency, patients refer to the Regional Emergency Service, with which they have a specific memorandum of understanding. As an integrated care service, the team is multidisciplinary and includes 4 geriatric doctors, 14 nurses (including a nursing coordinator and a patient acceptance manager), 1 counselor, 1 social worker, 4 part-time physiotherapists. Patients are visited daily by medical or nursing staff, either jointly or by at least one of these two professionals. For the individual patient, the therapeutic objectives are programmed during collective team meetings according to the clinical trend, helping to offer the best possible care to the patient and optimize available resources. Telemedicine/Telemonitoring (TM) may represent a

potential and strong ally in the management of the patient admitted under the HaH regime. The use of communication systems in the remote management of the patient could improve treatment outcomes, increase access to care, and reduce health costs (Caplan et al., 2012).

3.1 The As-Is Hospital at Home Service

Hospital at Home could be considered as an alternative to the traditional ward for elderly patients.

The service of hospitalisation is a geriatric department for taking charge of patients in acute phases still in their own homes. We present the service by dividing it into acceptance of the patients in Figure 1 and the real tour for the visits for each patient in Figure 2. All activities in the images represent the whole As-Is service. Due to limitations of space, we cannot describe each in detail, so we will only describe some in the To-Be section, activities that may change with the introduction of healthcare devices that use artificial intelligence to provide a superior experience. The detail for the acceptance process is published in the paper (Amantea et al., 2019).

3.2 GoCare Platform

The Experientia prototype platform named GoCare is a management tool that helps doctors and nurses optimize organization and logistic tasks management. The platform provides medical staff with a visual and interactive dashboard to manage and organize the patient's assignment, grouping them into different visiting equips and time slots according to the impact of specific indices (Figure 3). The most relevant are the medical and nursing complexity care, as well as the condition of the caregiver and the geographical location of the various patients. Such indexes are already evaluated manually by the medical staff to schedule and prepare the visits. As shown in Figure 4, it is possible to see on a map how patients are distributed within the territory, and the dashboard allows manual changes. Also, the platform provides doctors and nurses the possibility of accessing the personal patient page (Figure 5). Here it is possible to update all information regarding the patient trend (including complexity and priority indices), exams to be considered, supplies and drugs required to be prepared for the next visit, and a section to fulfill with notes, useful to analyze and evaluate patient's status. The possibility to quickly update this information as soon as the visit is complete allows for time savings and reduction of risk of having stray information. Also, unlike the current procedure, which consists of transcribing handwritten notes on paper and then returning them to the hospital, it allows having all information in one single shared place accessible to all the relevant medical staff.

3.3 Ticuro Reply Platform

During the intervention group each patient/main caregiver pair will be given the necessary tools for the TM via Ticuro Reply platform (Santer, Reply S.p.A., Turin, To, Italy), these include sphygmomanometer, pulse oximeter, balance, thermometer, glucometer, electrocardiograph, spirometer (see attached technical datasheet). Upon delivery of the instruments, a brief training will be given to the primary caregiver and, if possible, the patient, about the operation of the various equipment by specially trained nurses. During pre-established time slots, the caregivers should carry out the detection of arterial pressure, peripheral arterial hemoglobin saturation, and tympanic body temperature twice a day, or once a day concerning body weight. The glucometer will be used exclusively by healthcare professionals in the case of patients requiring capillary blood sugar monitoring. The electrocardiograph will be used according to the clinical progress of the patient, always by the health care professional. The data recorded by the instruments will be automatically sent to the data collection platform Ticuro Reply and will be viewable by medical and nursing staff on the same platform (as shown in Figure 6), to allow for timely interventions.

3.4 The To-Be e-Health Hospital at Home Service

In Figure 1 and 2 there are some activities in other colors. Activities in full or half color are those affected by the improvement of healthcare devices. The blue ones represent activities improved by the GoCare platform, the yellow ones represent activities improved by the Telemedicine of Santer, and the ones in blue and yellow are affected by both of the new technologies.

The acceptance process (Figure 1) represents an assessment of the patient's suitability for this service as an alternative to the usual hospital admission. The activities of this process consist purely of medical evaluations and explanations of the service to patients and caregivers. Following these interviews,

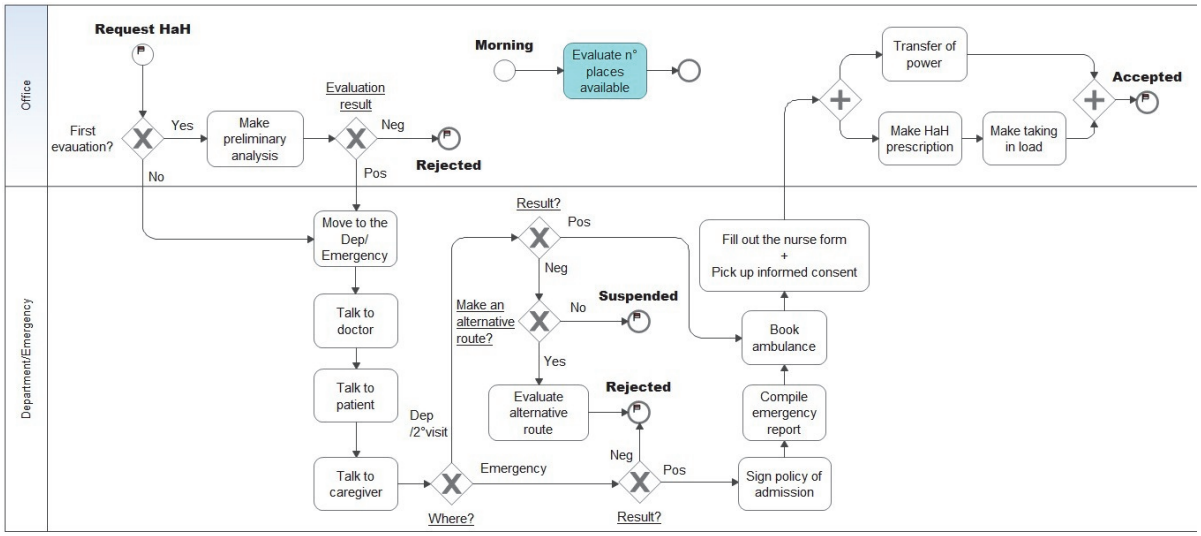

Figure 1: Process of acceptance of requests for the HaH service.

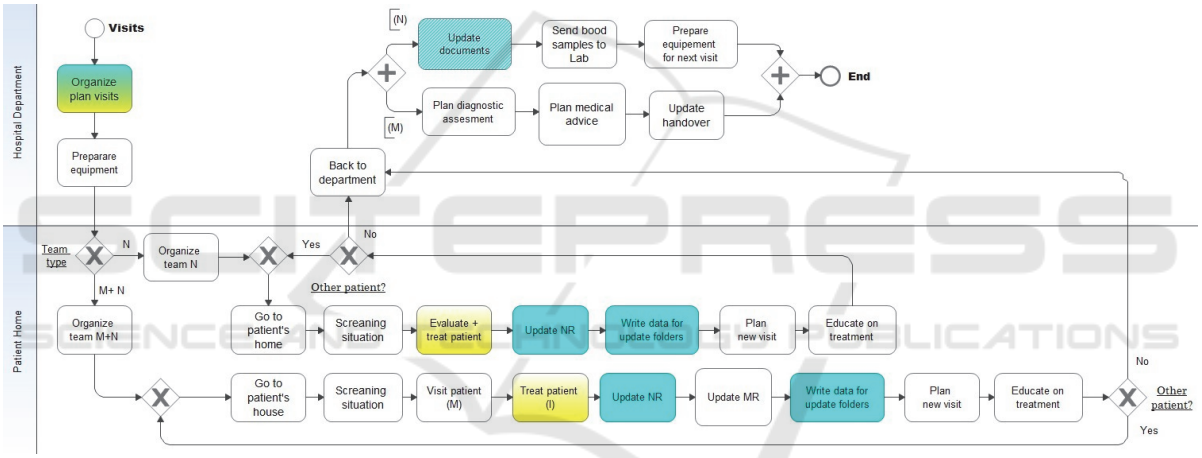

Figure 2: Process of domicile visits.

the hospital's manager will decide whether the patient is suitable and, on the other hand, the patient and the caregiver will decide whether to accept this type of hospitalization or whether to opt for the traditional one. Therefore, the only activity that can be supported at this stage is the evaluation of the actual workload. As there are no physical beds, the maximum number of patients that can be accepted by the department each day is calculated based on the complexity of the patients they are already in charge of and the staff available. The average patient load is about 28, but the more complex the patients' conditions are, the more this number will tend to drop; likewise, close to holidays staff will reduce, and so will the maximum number of patients, and vice versa. Table 1 shows the differences between As-Is and To-Be processes in terms of Activities, Actions, Human Resources, Equipment Resources, and Time on average.

Regarding the real visits tour (Figure 2), there are different possible improvements. For planned visits, the GoCare platform could support the organization before leaving the hospital. During this phase, the medical staff has to check the measurements of the vital parameters measured with the telemedicine devices. These results may affect the choice of pharmaceuticals to bring to home patients. Currently, these vital parameters are detected by the nurse for each visit as a first step.

If they are measured by caregivers several times a day, this action is not necessary during the tour visit. At the moment, nurses have paper folders in which they take notes; once in the office, they transcribe these in three different paper dossiers.

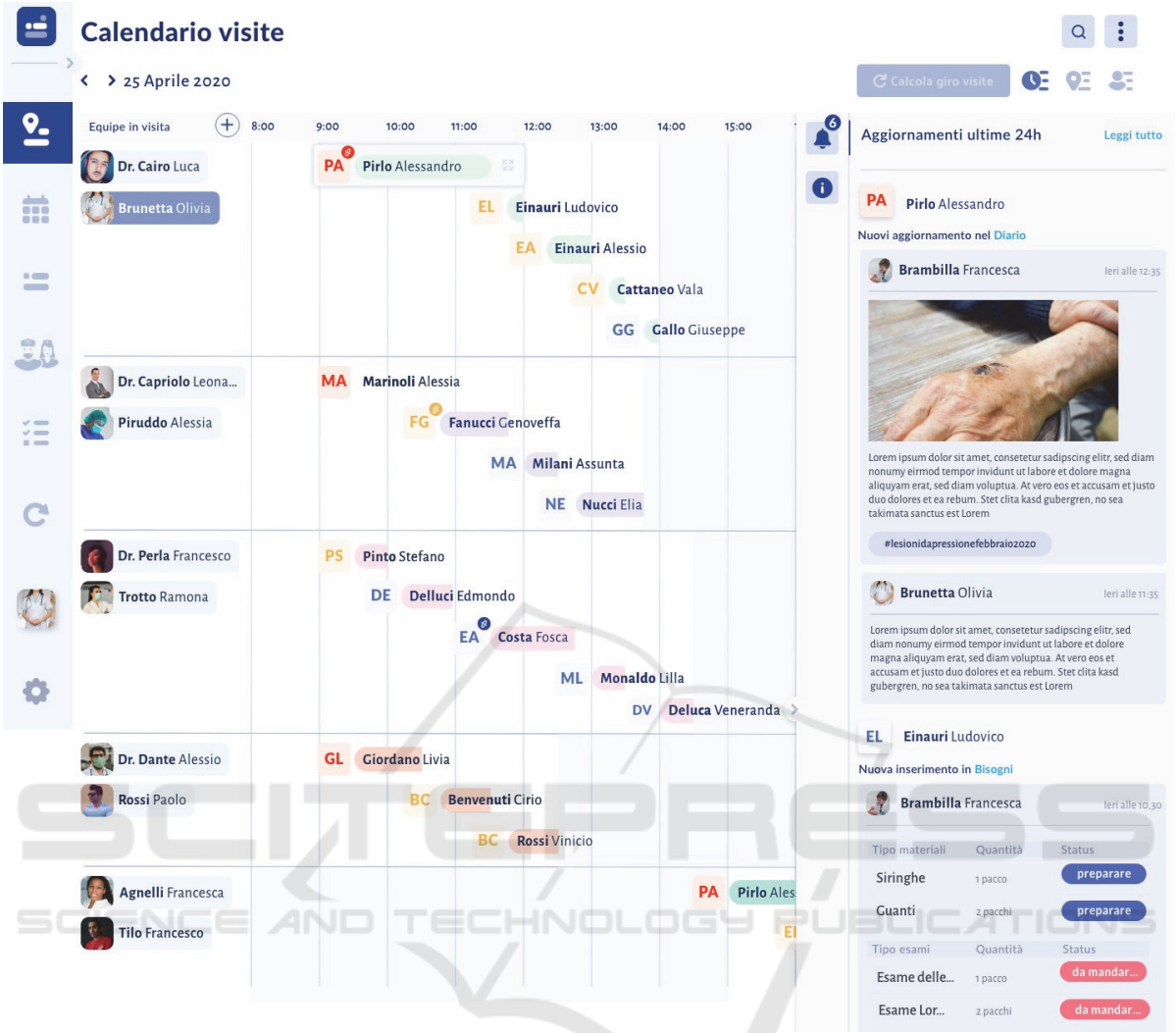

Figure 3: Screenshot of the tool that shows the team composition and assignment of patients to teams, distributed over the potential expected working time of the different patients based on the inserted complexity indices.

Table 1: Comparison between the As-is and the To-be model for the acceptance process.

	As-is	To-be
Activity	Evaluate places available	Evaluate places available
Action	Evaluate workload	Evaluate workload
HR	Case Manager	Case Manager
ER	Paper dossier of: patient organize, patient visits, nursing records for each patient	Tablet
Time	90 min	15-20 min

This process leads to problems: waste of time in reporting the same things twice, increasing the chance of making mistakes and since the files are the same for all the patients and the staff comes back at about the same time, every nurse will have to wait that the previous ones finish the transcript. Thanks to the GoCare platform, the nurses can write directly on a personal tablet at the patient's house, saving both the transcript activity in the office and the wait to do it.

The differences from As-Is and To-Be processes are shown in detail (potential for changing actions), Human Resources, Equipment Resources, and Time on average for each activity.

Table 2 shows the difference made with the implementation of GoCare platform, and Table 3 shows the difference made with the implementation of the Ticuro Reply platform.

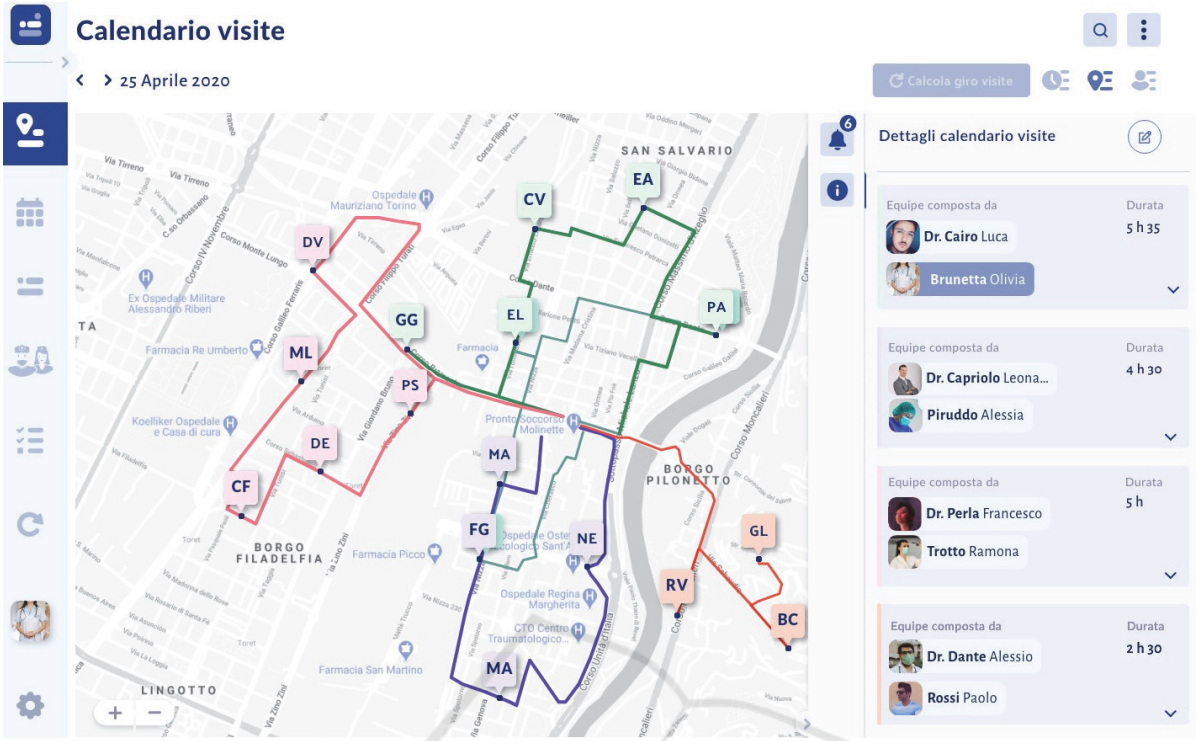

Figure 4: Screenshot of the tool that shows the geolocation of the various patients, the assignment of patients to teams, and the proposed road hogs.

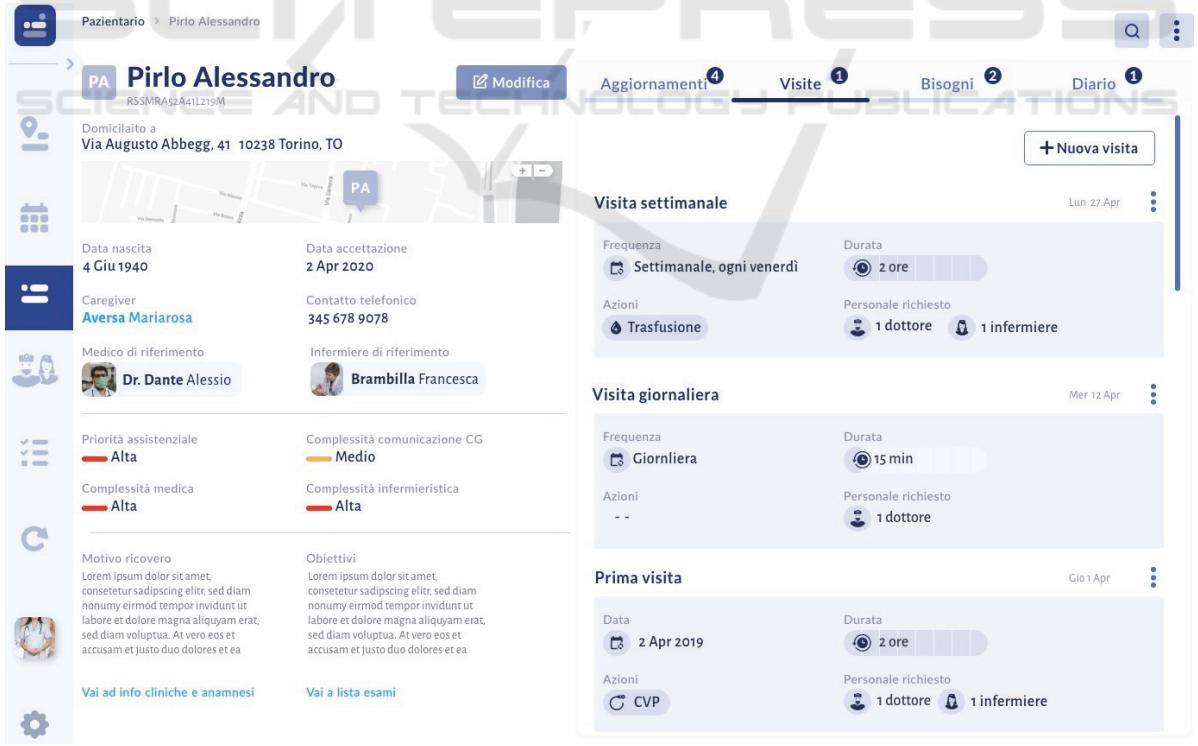

Figure 5: Screenshot of the tool that shows the patient's page where it is possible to consult and update the patient's actual data, his level of complexity, and information about the visit he needs.

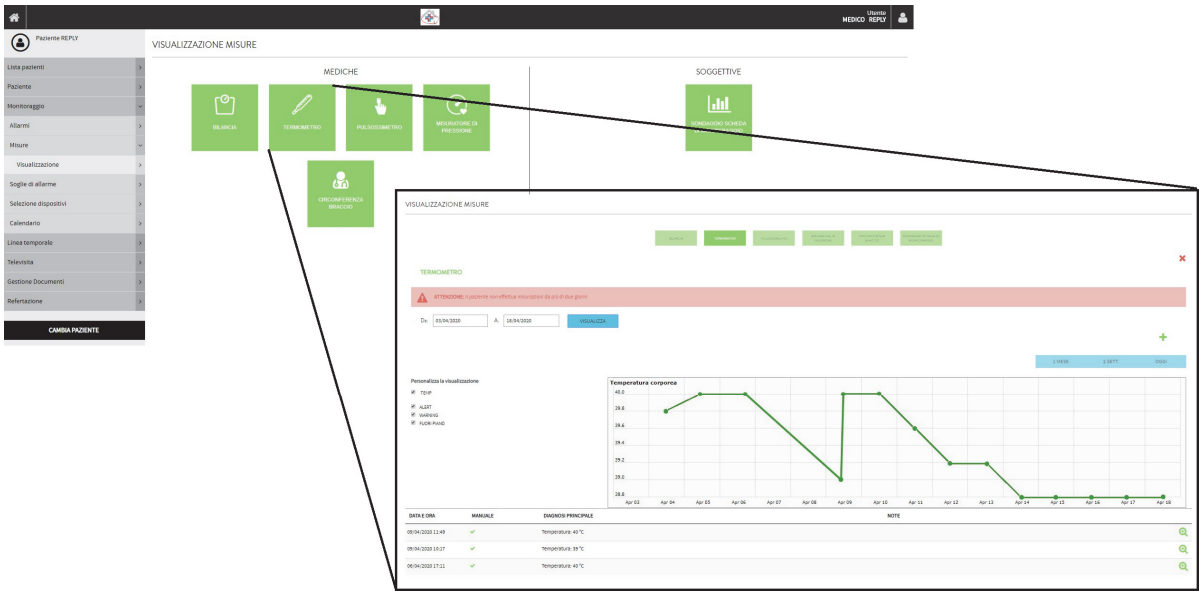

Figure 6: Example of Ticuro Reply platform screen visible to hospital staff. For each patient active telemedicine devices are visible and for each device it is possible to view the data collected directly concerning the patient.

4 RESULTS

By integrating telemedicine and user experience into an already innovative service like home hospitalization, we could see that every transaction could gain on average from 1.3 to 4 hours. Starting from the premise that the entire visits tour must be within the working time of the hospital staff and the time of care cannot decrease because it would diminish the service quality, the geographical area of the service and the number of the patients in charge is limited. Thanks to these improvements maintaining the service quality with the current human resources, two different scenarios would be possible:

- It would be possible to increase the overall number of patients in charge. The service could be available for about 6 12 more patients, depending on the severity of the patients' clinical conditions and the time of year (hospital staff decreases in periods like Christmas or holidays).
- It would be possible to increase the extension of the geographical area covered by the service. Currently, the movements from one patient to another (and the related search for parking, not always easy in a metropolitan city like Turin) is between 5 and 25 minutes. Therefore, it appears that the displacements between one patient and another could increase by a range of about 9.36 28.8 min. It would be potentially possible for the service to cover the entire geographical area of the city.

5 CONCLUSIONS

This paper introduced a framework of modeling and simulation effort concerning an innovative hospital service. The main goal is to define and implement a robust technological and organizational model in a healthcare context and obtain high adherence, compliance, and engagement of users.

Furthermore, it supports the long-term sustainability and efficiency of health and social care systems by providing a solution that allows people to live longer in their homes and to ease communication with the healthcare and social care systems. The proposed framework demonstrates how to improve patient's wellbeing and autonomy, and how better and more sustainable healthcare interventions may lead to a reduction of healthcare and social costs. The expected implementation results of this framework of business process analysis suggest an improvement of professional and informal care processes, leading to a higher patient's autonomy during acute, post-acute, and rehabilitation phases.

Additionally, thanks to the innovativeness, adaptability and diffusion on the territory of this service, it is able to give a significant positive

Table 2: Visits tour comparison between the As-is and the To-be model after the implementation of GoCare platform.

	As-is	To-be
Activity	Organize Plan Visits	Organize Plan Visits
Action	Organize plan visits	Organize plan visits
HR	All staff	All staff
ER	Paper dossier of: patient organize, patient visits, addresses, nursing records	Tablet
Time	90-120 min	30-50 min
Activity	Update NR	Update NR
Action	Update on paper	Update on platform
HR	Nurse	Nurse
ER	Nurse record/ folder	Tablet
Time	10min	10-20 min
Activity	Update documents	No activity
Action	Update paper dossier patient organize, patient visits, delivered materials, nursing records,	-
HR	All nurses	-
ER	Paper dossier	-
Time	1 patient organize for all, 1 patient visits for all, 1 delivered materials for all, 1 nursing records for each, (30 min X 6 nurses)	0 min

contribution even in a state of emergency. In these days, the TELEMACO project[2] was launched. The purpose of this study is to test the use of telemedicine (TM) device to support the management of patients suspected of COVID-19 or discharged from the hospital departments with diagnosis of COVID-19, hospitalized under HaH service. We suppose to have soon some significant results.

As other future work, we plan to exploit data from devices by applying process mining techniques. Considering the intersection between data mining and business processes modeling and analysis is promising and aim to automatically discover and measure processes, by adopting automatic recordings of healthcare events (so called "event logs"). In the context of our BPM framework, we plan to exploit process mining techniques to improve both clinical and administrative processes analysis.

[2] Telemedicine for elderly patients COVID-19 positive treated by Hospital at Home Service, approved by the Ethics Committee on 6 May 2020.

Table 3: Visits tour comparison between the As-is and the To-be model after the implementation of the telemedicine of Ticuro Reply platform.

	As-is	To-be
Activity	Organize Plan Visits	Organize Plan Visits
Action	-	Check vital signs for all patients
HR	All staff	All staff
ER	-	Tablet
Time	-	15-20 min
Activity	Evaluate+ Treat patient	Evaluate+ Treat patient
Action	Evaluate+treat +Check vital signs	Evaluate+treat -Check vital signs
HR	Nurse	Nurse
ER	Medical equipment	Medical equipment
Time	Treat+(3-15 min)	Treat+ 0 min
Activity	Treat patient	Treat patient
Action	Treat+ Check vital signs	Treat- Check vital signs
HR	Nurse	Nurse
ER	Medical equipment	Medical equipment
Time	Treat+(3-15 min)	Treat+0 min

ACKNOWLEDGEMENTS

This research was conducted in the project "CANP CAsa Nel Parco" of Regione Piemonte funded by POR FESR PIEMONTE 2014-2020. We are grateful for the collaboration of the "City of Health and Science" of Torino (Italy).

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