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Design and development of a digital diagnostic clinical pathway: evidence from an action research study

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Abstract

Purpose – The primary objective of this paper is to show a systematic and methodological approach for the digitalization of critical clinical pathways (CPs) within the healthcare domain.

Design/methodology/approach – The methodology entails the integration of service design (SD) and action research (AR) methodologies, characterized by iterative phases that systematically alternate between action and reflective processes, fostering cycles of change and learning. Within this framework, stakeholders are engaged through semi-structured interviews, while the existing and envisioned processes are delineated and represented using BPMN 2.0. These methodological steps emphasize the development of an autonomous, patient-centric web application alongside the implementation of an adaptable and patient-oriented scheduling system. Also, business processes simulation is employed to measure key performance indicators of processes and test for potential improvements. This method is implemented in the context of the CP addressing transient loss of consciousness (TLOC), within a publicly funded hospital setting.

Findings – The methodology integrating SD and AR enables the detection of pivotal bottlenecks within diagnostic CPs and proposes optimal corrective measures to ensure uninterrupted patient care, all the while advancing the digitalization of diagnostic CP management. This study contributes to theoretical discussions by emphasizing the criticality of process optimization, the transformative potential of digitalization in healthcare and the paramount importance of user-centric design principles, and offers valuable insights into healthcare management implications.

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Originality/value – The study's relevance lies in its ability to enhance healthcare practices without necessitating disruptive and resource-intensive process overhauls. This pragmatic approach aligns with the imperative for healthcare organizations to improve their operations efficiently and cost-effectively, making the study's findings relevant.

Keywords Clinical pathway, Action research, Digital transformation, Process management, Service design, Scheduling

Paper type Research paper

1. Introduction

Managing variation is a major challenge in all operational systems; reducing variation is a typical aim in efforts to improve performance (Zander, 2002; Holweg *et al.*, 2018). In service, and particularly public service systems, it is appropriate though to maintain the flexibility to absorb inevitable variation (Seddon, 2008). In healthcare, variation in clinical practice impacts on both efficiency and patient outcomes, and it is particularly important to distinguish between warranted (appropriate) and unwarranted (inappropriate) variation (Sutherland and Levesque, 2020). At minimum, unwarranted clinical variation leads to higher labor costs, supply chain waste or redundancy, treatment delays and communication problems (Hipp *et al.*, 2016). However, in an effort to manage variations, the impact of the workload on hospital staff should not be overlooked. Indeed, as showed in Aiken *et al.* (2014), an increase in nurses' workload increases the likelihood of patient complications. For this reason, soothing the workload of nurses and physicians across the week can be an objective, even at the expense of, for example, not maximizing operating room utilization (Aringhieri *et al.*, 2021).

A central approach to reducing unwarranted clinical variation is implementation of clinical pathways (CPs) (PedsCCM, 2004). A CP is a structured patient care plan, usually involving multiple healthcare disciplines, which specifies the expected steps in treating a patient with a particular condition. It aims to specify and operationalize high-quality medical services through a package of standardized and optimized care processes for patients with a specific health condition (Rotter *et al.*, 2010). CPs were first introduced in the US in the 1980s (Zander *et al.*, 1987) and are now widely used for process planning and management of patient care (Zander, 2002). Many studies have analyzed the effectiveness of CP implementation, showing that they can reduce the average hospital length of stay and costs, improve patient outcomes (Rotter *et al.*, 2008; Renholm *et al.*, 2002) and reduce the number of preoperative examinations, unnecessary hospital admissions and unscheduled readmissions (Panella *et al.*, 2003).

Implementation of a CP can be hindered by physicians' resistance if they consider it to be overly standardized ("cookbook medicine") and limiting their professional autonomy (Gurzick and Kesten, 2010), and what is warranted versus unwarranted variation is not always clear-cut (Sutherland and Levesque, 2020). Other limitations arise from paper-based implementation, such as limited space to record patient data on a form and collating a range of forms and charts, images and so forth, so that extracting and synthesizing requisite information for clinical decision-making can be laborious and error-prone (Chu and Cesnik, 1998). Furthermore, a paper-based CP is not accessible through the hospital information system, preventing real-time CP monitoring and rapid detection and handling of potential problems (Satria *et al.*, 2017).

Information technology (IT) can play an important role in the implementation of CPs. Computer implementation of CPs, especially in a web environment, can improve care quality and decrease costs (Chang *et al.*, 2002). IT enables automation of functions to increase efficiency and effectiveness, eliminating delays, administrative intermediaries and unnecessary transaction steps (Huq and Martin, 2006). Moreover, IT promotes patient data access, enhances collaboration among the hospital departments involved and enables more effective coordination of activities (Helfert, 2009; Hyde and Murphy, 2012; Bouamrane and Mair, 2014).

A useful distinction can be made between computer implementation of a CP (e.g. one already existing in paper form), that is, *digitization*, and using the additional capabilities afforded by IT to transform how the processes work, that is, *digitalization* (Gobble, 2018). Simple digitization of an "as-is" process can miss opportunities to improve or enhance it, and even make future change harder, as found, for example, with enterprise resource planning (ERP) IT-enabled production control in the automotive sector (Riezebos *et al.*, 2009).

As usually defined, a CP lists the sequencing and expected timing of interventions for a particular diagnosis or patients with similar characteristics, but it is not an aggregated *planning* instrument – it does not schedule resource use (Coffey *et al.*, 1992). For this reason, for CPs that require access to medical resources that are limited and also required by other CPs (as is very common), the adoption of an integrated scheduler can be useful to book the sequence of steps (such as diagnostic examinations). This can improve resource utilization, service levels, patient satisfaction and costs (Song *et al.*, 2015; Du *et al.*, 2013). In most hospitals, the planning of activities on CPs is decentralized, and each specialism and hospital department has their own objectives. Consequently, lack of communication and coordination can produce suboptimal resource allocation, leading to waste for both the hospital (e.g. higher equipment and staffing costs) and patients (e.g. additional visits to the hospital and longer waits) (Braaksma *et al.*, 2014).

This paper is centered on the digitalization of CPs applied to patients who arrive at the Emergency Department (ED) with specific urgent medical conditions, which, while requiring immediate attention, do not necessitate hospitalization. The patient is usually discharged to their home, awaiting a booked appointment for the first of a standard package of outpatient services. The time between discharge from the ED and the start date of the CP (the first appointment) is a critical issue since, in the interim, a patient could return to the ED with the same symptoms or even in a more critical condition, with consequent additional health risk and ED workload (failure demand (Seddon, 2008)).

In this study, we focus on the examination of the following research inquiries:

(1) How effectuate the digitalization of a pivotal clinical pathway (CP) is while maintaining continuity with core IT infrastructure and existing operational procedures?

(2) How to enhance the quality of communication and coordination between the ED and the respective hospital unit responsible for overseeing such CPs?

(3) What strategies can be employed to ameliorate the challenges associated with the manual scheduling of appointments for medical examinations?

These research questions address critical issues in healthcare management and service delivery. They probe into the intricacies of digitalization, inter-departmental coordination and operational efficiency; these topics are vital for improving patient care and healthcare system performance. In this paper, we undertake a methodological combination of action research (AR) and service design (SD) methodologies, embedded within the overarching framework of a digital transformation initiative. The central aim of this study is to reimagine and reconfigure CPs within the healthcare domain. Our focus centers on the CP dedicated to patients presenting at the Emergency Department of Policlinico Tor Vergata Hospital, a prominent general acute hospital located in Rome, presenting with symptoms of transient loss of consciousness (TLOC). This transformational endeavor is reinforced by the development and implementation of a patient-centric web application, crafted to streamline the management of CP procedures. Complementing this, we introduce an optimization tool expressly designed for the scheduling of the diverse diagnostic examinations that form an integral part of this intricate clinical pathway.

Throughout our research, we unveiled a constellation of challenges inherent to the current CP, which were well-recognized by clinical practitioners in the crucible of their daily experiences but had hitherto eluded integration into the formal planning system. Our study underlines the inherent value of fostering close, collaborative relationships with medical professionals, as this facilitates the extraction of tacit knowledge and makes it explicit and readily accessible for informed planning. These insights, drawn from the wealth of clinical experience, are a testament to the intrinsic worth of interdisciplinary collaboration in advancing healthcare optimization and quality enhancement.

The paper is organized as follows. Section 2 presents a review of the literature about the digitalization of CPs. Section 3 details the research methodology and the steps followed in the digitalization of our target CP. Sections 4 and 5 describe the content of the AR conducted in our host hospital. Section 6 reports the results of the simulation model used to test the effectiveness of the digitalization. Section 7 presents the implications of the study. Finally, Section 8 presents conclusions and topics for further research.

2. Literature review

This section investigates the literature on CP digitalization, to inform our practical work. The aim is to find references on possible ways to develop digital solutions for managing CPs and confirm the potential positive effects following their implementation. Since optimizing patient flows along a CP is a key component of our digitalization, we also review the application of scheduling in healthcare.

On CP digitalization, we searched Scopus and Web of Science abstract and citation databases. The reference period was from 1996, the year the National Library of Medicine introduced the term "critical pathway" (European Pathway Association (EPA), 2004), up to the present. We limited the results only to journal articles, excluding book chapters, conference papers, discussions and opinion articles. Moreover, we considered only English language articles. Our search string used keywords and Boolean operators: ("IT support" OR "web app*" OR "web platform" OR "web based" OR "digitization" OR "digitalization" OR "digitisation" OR "digitalisation" OR "digital transformation" OR "computerized" OR "computerised" OR "computerization") AND ("clinical path*" OR "critical path*" OR "care path*" OR "care map" OR "case management plan").

For the review, only articles that met three eligibility criteria were considered: (1) they had to be focused on CPs; (2) they had to implement digital solutions for managing CPs; (3) the developed tool had to be intended for managing CPs by clinicians in the hospital. Therefore, tools for home care and patient self-management were excluded from the review. The screening was undertaken independently by two reviewers, and any disagreements during the screening process were resolved through consensus discussion. The search strategy identified 908 titles (Figure 1). After removing duplicates, 580 papers were screened by title and abstract. Of these, 482 papers were excluded. Thus, 98 papers remained, and 8 additional papers were identified through searching the reference lists. For these 106 papers, we retrieved and reviewed the full text, excluding 75 according to the eligibility criteria. The final set for the review was thus 31 papers, as listed in detail in Appendix 1. Analysis of these papers suggests three main categories of approaches: *CP computerization* (which can be identified as digitization of CPs), *CP modeler* and *clinical decision support systems* (which can be identified as digitalization of CPs).

The approach described in the first category consists of converting the paper documents of a CP to computerized form, providing electronic forms for recording useful data like patient information, medication, clinical examination and consultation. The computerized CPs can be directly integrated with the hospital information system (Tschopp *et al.*, 2009; Schlieper *et al.*, 2017; Norra *et al.*, 2021) or with the electronic health record system (Katzan *et al.*, 2015; Hawley

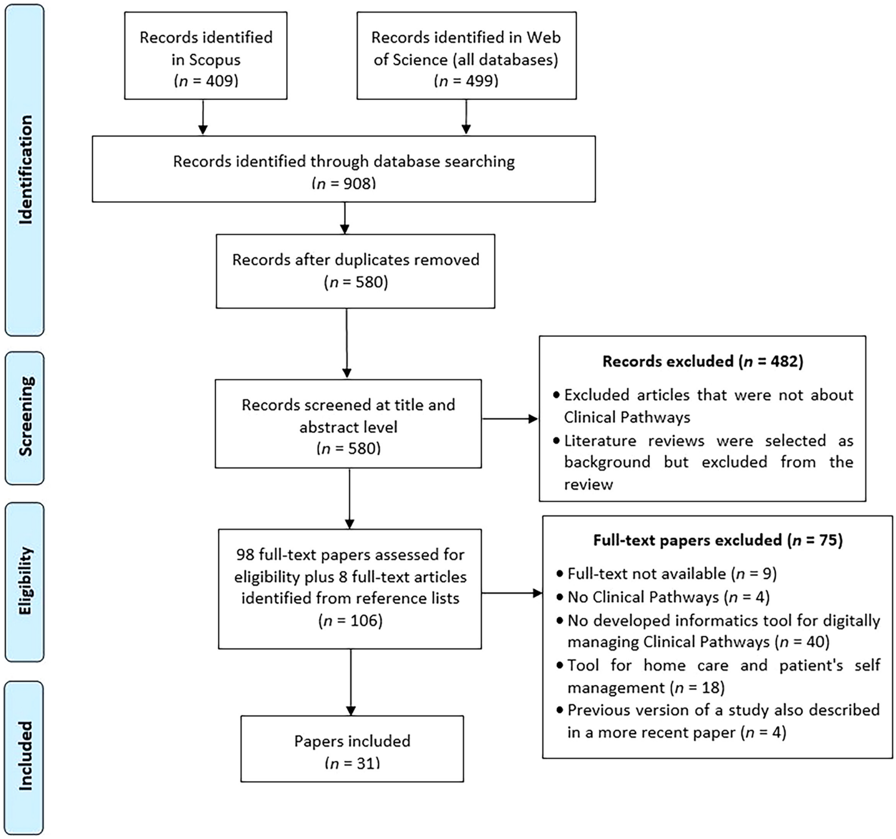


Figure 1.
PRISMA flow diagram

Source(s): Author's own creation/work

et al., 2021). Alternatively, stand-alone systems that share patient information with an existing electronic medical record system have been implemented, using web technologies (Chang *et al.*, 2002; Hsu *et al.*, 2008; Daniyal *et al.*, 2009; Bouamrane and Mair, 2014; Wang *et al.*, 2015), or as a software tool to be installed on hospital computers (Chu, 2001; Hayward-Rowse and Whittle, 2006; Wakamiya and Yamauchi, 2006; Hyde and Murphy, 2012; Alahmar *et al.*, 2020; Talevski *et al.*, 2020). This solution avoids having to replace or modify the hospital information system already in use, avoiding great expense for the hospital. As another approach, some studies have used tools such as digital pen and paper technology (Derhy *et al.*, 2009), a web application for a personal digital assistant (PDA) (Okada *et al.*, 2005) or a mobile application for tablet to be used during an appointment with the patient (Hawley *et al.*, 2021), which enable clinicians to input data when and where it is generated, reducing transcription errors. The studies in this category show how computerization helps to reduce barriers to CP implementation. First, it improves data capture, improving data reliability, completeness and quality (Hyde and Murphy, 2012; Katzan *et al.*, 2015; Schlieper *et al.*, 2017; Hawley *et al.*, 2021). Moreover, it allows nurses and clinicians to analyze and manage any practice variation, thus providing a more timely response by the clinicians and shortening hospital length of stay

(Chang *et al.*, 2002; Okada *et al.*, 2005; Wakamiya and Yamauchi, 2006; Hsu *et al.*, 2008; Derhy *et al.*, 2009; Tschopp *et al.*, 2009; Wang *et al.*, 2015). Some studies found significant improvements in quality of care and treatment (e.g. reduction of mortality rate) after the implementation of a digital CP (Chu, 2001; Derhy *et al.*, 2009; Katzan *et al.*, 2015; Norra *et al.*, 2021). Finally, some studies assessed clinicians' attitudes toward introducing an IT tool, since it can represent a significant change for hospital staff (Hayward-Rowse and Whittle, 2006; Wakamiya and Yamauchi, 2006; Hyde and Murphy, 2012; Hawley *et al.*, 2021). Results highlighted that staff perceive digital CPs as useful to improve communication with patients and between different hospital departments, encouraging the multidisciplinary involvement crucial for improving the quality of care.

The second category, *CP modeler*, includes the studies that graphically represented all the events of a CP (i.e. diagnoses, treatments, procedures). As highlighted in Balatsoukas *et al.* (2015), workflow visualization has a positive effect on the user experience because clinicians can easily monitor patient progress, and hospital managers can extract and manipulate statistical information (e.g. number of patients entering a specific event). Visual representation of a CP also allows display of the potential precedence/interdependency relationships among the events of the same CP or different CPs. Chu and Cesnik (1998) used the precedence diagramming method to implement a prototype electronic care map planner. It allowed an effective linkage of patients' health problems, clinical services performed and the assessment results to define a useful clinical information data set.

Finally, the studies in the third category described the design and implementation of clinical decision support systems (CDSSs), health information technology systems aiming to assist clinical decision-making tasks in CPs. A CDSS provides clinicians with recommendations about investigations and therapeutic interventions to perform based on patient clinical data (Blaser *et al.*, 2007; Courbis *et al.*, 2018; Rotenstein *et al.*, 2018), aligned with clinical practice guidelines (Gardetto *et al.*, 2008; Van Erps *et al.*, 2010). It can also send a warning message when symptoms of a severe underlying disease are noted (Filippopulos *et al.*, 2020). Some CDSSs can generate a patient-tailored CP automatically from a computer-interpretable representation of clinical practice guidelines (Sánchez-Garzón *et al.*, 2013; Ray *et al.*, 2019), as well as manage comorbidity conditions that involve two or more CPs (Patkar *et al.*, 2012; Abidi, 2017). Results showed how the standardization of treatment practices significantly increased pathway compliance and concordance with clinical practice guidelines (Blaser *et al.*, 2007; Patkar *et al.*, 2012), reducing clinician stress, mistakes and decisional conflicts (Sánchez-Garzón *et al.*, 2013; Courbis *et al.*, 2018; Rotenstein *et al.*, 2018), and improving clinician performance (Blaser *et al.*, 2007; Gardetto *et al.*, 2008).

The review has found potential favorable effects of digitalization of CPs on both clinical (improved quality of care and treatment) and management aspects (improved communication and clinician performance). It also highlighted a gap concerning diagnostic CPs. Indeed, the studies included in the review mainly focused on the digitalization of CPs involving hospitalization and/or surgery, neglecting that an efficient diagnosis process can lead to an increase in the quality of the patient's health. Moreover, the analyzed digital tools did not include features able to schedule an optimized appointment plan. To improve the quality of medical services, it is crucial to define a plan of the order of all activities necessary to complete a CP. One of the main challenges in healthcare is to match capacity and demand under variability and unpredictability. For this reason, hospitals generally adopt appointment scheduling to coordinate patient visits and the availability of specialists and resources (Denton and Gupta, 2003). In the CP context, it is central to consider multi-appointment scheduling since patients must undergo several consultations and tests. The review by Marynissen and Demeulemeester (2018) highlights factors which must be considered in multi-appointment scheduling since each of them impacts on attempts at optimization. First, the type of patients treated: outpatients or inpatients. Another central aspect is the choice about what to optimize. Indeed, hospital management can decide to focus on patient satisfaction or on hospital's profits. In the first case, the objective function usually aims to minimize access time to hospital services (Braaksma *et al.*, 2014; Ala *et al.*, 2021), or the period to complete all examinations (Du *et al.*, 2013; Azadeh *et al.*, 2014). Instead, in the second case, the objective function aims to maximize the number of patients scheduled (Conforti *et al.*, 2011) or minimize resources' idle time (Chern *et al.*, 2008; Kortbeek *et al.*, 2017). Additionally, it is relevant to choose the optimization strategy. Hospitals generally adopt two strategies, online or offline scheduling. In online scheduling (Pérez *et al.*, 2013; Braaksma *et al.*, 2014), an algorithm can provide updated schedules each time a new patient planning request is received or a constraint changes. In this case, patients are considered in the order in which their requests arrive. In offline scheduling (Conforti *et al.*, 2011; Gartner and Kolisch, 2014), a new patient is added to a waiting list pool, and the algorithm is run periodically, selecting patients from this list. Since some CPs involve several hospital departments, it is also important to consider multidisciplinary planning, which implies more constraints to take into account, such as precedence between examinations and the availability of resources from different departments.

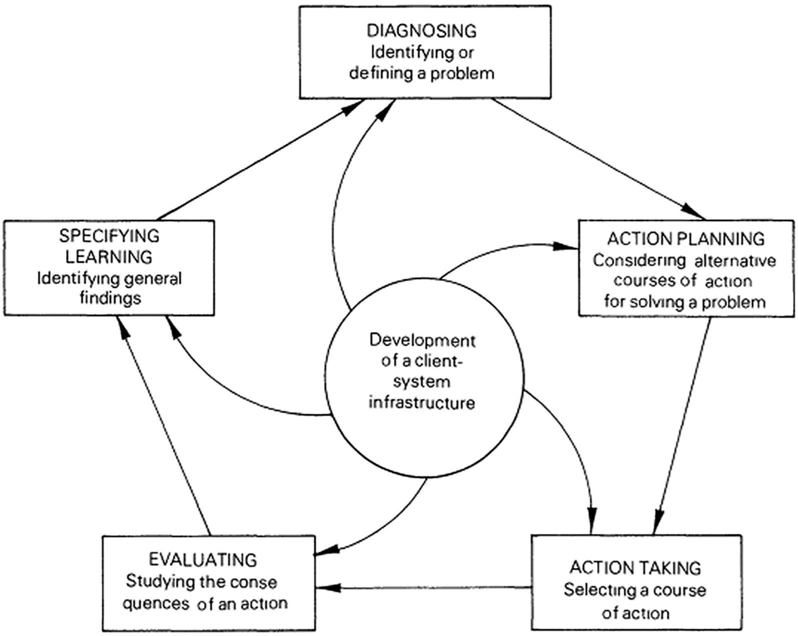
In the contemporary landscape of rapid technological advancements, organizations are increasingly recognizing the imperative of digital transformation. This transformation is not merely a technological shift but a holistic organizational endeavor that entails fundamental changes in how businesses operate and thrive in the digital age (Sia *et al.*, 2021). It emphasizes the critical need for agility, adaptability and employee engagement in harnessing the potential of digital technologies (Solberg *et al.*, 2020). Organizations must revaluate and adapt their operational models to align with the changes driven by digital transformation. The digitally enabled operational model should seamlessly integrate with the overall business strategy to enhance overall performance (Correani *et al.*, 2020).

3. Methodology

Commencing in 2018, this research project represents a year-long collaborative effort, SD and AR based (Coughlan and Coghlan, 2002), between the Department of Enterprise Engineering at the University of Rome "Tor Vergata" and the Policlinico Tor Vergata Hospital in Rome, Italy. Specifically, our research focuses on optimizing the patient pathway for individuals who present at the ED with TLOC. This critical CP was identified as an area in need of improvement within the hospital. The primary objective for hospital management was the activation and execution of this pathway, which presented challenges. The use of paper-based documentation hindered effective communication and coordination between the ED and the Complex Operating Unit (COU), responsible for managing this specific CP. Furthermore, the absence of an optimized scheduling system for diagnostic examinations within this CP could determine unnecessarily prolonged patient waiting times within the pathway. In essence, through systematic investigation and iterative improvements, we seek to enhance the overall quality of care provided to patients experiencing TLOC, while also optimizing the operational processes within this critical clinical pathway. In this way, we contribute to the academic discourse on healthcare management and offer actionable insights for healthcare practitioners seeking to enhance patient care pathways and operational efficiency. AR methodology was particularly appropriate for these purposes because it is a useful approach for developing and implementing new processes, understanding and overcoming problems encountered and documenting the factors facilitating or hindering the problem solving process (Coughlan and Coghlan, 2002; Farooq and O'Brien, 2015). As stated in Ross *et al.* (2006), AR has four important characteristics: (1) it emphasizes the complex and multivariate nature of the problem domain; (2) it simultaneously addresses solving the practical problem (here digitalization of a target CP) and expanding research knowledge (here of digital healthcare innovation); (3) it is a collaborative effort between researchers and managers; (4) it is primarily applied to understanding the effects of change. The approach aims to change a specific organizational system in which participants are involved (Ballantyne, 2004). Such participation contrasts with traditional research where actors in the system are merely objects of the study (Coughlan and Coghlan, 2002).

Classic AR follows cycles of change and learning, organized into iterative phases which alternate action and reflection (Dick, 2001; Ballantyne, 2004). In our methodology, we took the cyclical five-step process described by Susman and Evered (1978) (Figure 2) as a reference for a comprehensive definition of AR. As many cycles as necessary to solve a problem can be conducted. AR has as desired outcomes solutions to immediate issues and meaningful learning from the process to contribute to scientific knowledge and theory (Coughlan and Coghlan, 2002).

A purposive sampling procedure was meticulously employed to ensure comprehensive access to relevant data, enabling the deliberate selection of stakeholders closely associated with the CP. These individuals were chosen strategically due to their potential to contribute valuable insights and experiences that could enhance our understanding of and, in certain instances, elucidate the focal area of inquiry. In addition to university-affiliated researchers, key personnel from the hospital, including the General Director, the ED Medical Director, the COU Medical Director and the Hospital Controller, were involved. This selection of participants aimed to provide a well-rounded perspective on the CP and foster a more comprehensive exploration of the subject matter. The selection of the three distinct analysis units (Table 1) – namely, the patient, the organizational units (specifically, the ED and the COU involved in the CP) and the process (i.e. CP) – is integral to comprehensively investigate



Source(s): Susman and Evered (1978)

Figure 2.
The cyclical process of action research

Analysis unit	Characteristics
Patient	– Conditions with a high risk to health – High probability of recurrence – Lack of evidence supporting hospitalization due to reduced acuteness in the ED
Organizational units (ED, COU)	– Potential problems of overcrowding – Allocation challenges regarding medical personnel – Scheduling of CP examinations
Process	– Examination and management of patients presenting with high-risk, recurrent conditions – Workflow within the ED to address these cases efficiently

Source(s): Author's own creation/work

Table 1.
Analysis units and relative characteristics

and analyze the healthcare dynamics associated with a medical condition characterized by a high risk to health, a high probability of recurrence and a lack of evidence supporting hospitalization due to reduced acuteness after ED access, exemplified in this case by TLOC. The patient, as the central figure in the healthcare context, is paramount in understanding the dynamics of their condition. In the case of TLOC, which poses a high risk to health and has a propensity for recurrence, patient perspective and characteristics impact healthcare journey. The ED and COU are crucial organizational units that directly interface with patients presenting TLOC. Their roles are pivotal due to the condition's characteristics. TLOC episodes can vary in severity, and determining the appropriate level of care, whether immediate admission or observation in the COU, is a complex decision. Studying these organizational units helps identify bottlenecks, resource allocation issues and the effectiveness of care pathways. Furthermore, understanding how these units coordinate and communicate is essential for optimizing patient flow and care quality. The CP represents the standardized procedures and protocols that guide the assessment, diagnosis, treatment and management of patients with TLOC. Given the condition's complexity and the lack of clear evidence supporting hospitalization for all cases, the CP becomes a critical focal point. Analyzing the CP elucidates the clinical decision-making processes, the utilization of diagnostic tests and the appropriateness of interventions. It also facilitates the identification of potential gaps or inefficiencies in the care pathway. By studying the CP, researchers can recommend evidence-based modifications to enhance the quality and efficiency of care delivery for patients with TLOC.

This research focuses on two core processes: the initial ED visit, followed by the patient's discharge, and, subsequently, the execution of the CP. A pivotal concern lies in the time gap between the ED discharge and the start of the CP. It is in this temporal transition between ED discharge and CP initiation that gaps in patient care continuity become evident. This gap can result in several complications, such as a lack of immediate follow-up, potential exacerbation of the patient's condition and increased healthcare costs. Moreover, it poses a considerable challenge to medical personnel responsible for ensuring the patient's well-being.

To address this issue effectively, this study proposes the utilization of digital transformation as a comprehensive solution. This transformation is not limited merely to technological advancement and adoption but encompasses all the ecosystem influenced by the processes. Key components of this transformation include integration of patient data, medical records and historical information. The evolution of digital technologies has catalyzed profound changes in healthcare systems worldwide, necessitating a reevaluation of existing CPs. To undertake this transformative journey effectively, we have harnessed the power of service design (SD) and its integration within the digital transformation of CPs for reshaping clinical services. SD, as espoused by Blomkvist *et al.* (2010) and Meroni and Sangiorgi (2011), prioritizes the needs and experiences of end-users. By placing patients, healthcare professionals and other stakeholders at the forefront of the design process, SD ensures that digital transformation initiatives are rooted in empathy and user-centricity; also, SD thrives on stakeholder collaboration (Sanders and Stappers, 2012; Sleeswijk Visser *et al.*, 2005). The active involvement of diverse stakeholders in co-design activities fosters a culture of interdisciplinary collaboration, which is pivotal in reshaping clinical services for the digital age. The iterative nature of SD aligns perfectly with the dynamic nature of healthcare systems. Also, the iterative approach allows for continuous improvement and adaptation, enabling healthcare organizations to stay agile and responsive to evolving needs (Wetter-Edman *et al.*, 2018).

We performed several full AR cycles where each cycle planned the next refinement of the digitalized CP's procedures and software tools, with clinicians collaborating and giving feedback. For brevity and clarity, the detailed discussion of each AR cycle is reported in Appendix 3. Instead, in the sections we consolidate the details of the new CP procedures and software tools, developed over the iterative cycles.

Within the AR cycles, important methods used included process mapping for analyzing procedures and semi-structured interviews of the stakeholders for collecting data, with written summaries of the interviews as supporting reference material. We chose semi-structured interviews because they are less formal than structured interviews, with generic foci and/or a set of themes, allowing the interviewees a degree of freedom to explain their thoughts (Jennings, 2005). Two semi-structured interviews were carried out with two participants, the ED Medical Director and the COU Medical Director, to elicit and document the "as-is" hospital CP process (Table 1 and Table 2 – Appendix 2). Through these conversations, it became increasingly evident that collaboration was an indispensable factor in attaining sustained transformation and in guaranteeing the harmonization of digital initiatives with the overarching strategic objectives of the organization. For drawing the process maps, we adopted Business Process Modelling Notation (BPMN 2.0), and used the Bizagi Process Modeler software for our BPMN process maps since it is a free-license tool, easy to use and provides logic-validation support (Chinosi and Trombetta, 2012).

Following a cycle of exploring and learning about the "as-is" CP with the stakeholders, the project team identified and agreed that there were particular problems with the subprocesses involved in the activation (initiation) of the CP for each patient and the scheduling of their subsequent outpatients visits for examinations and consultations. These needed to be reengineered and supported with an informatics tool and a scheduler to optimize the calendar of patient's visits. Further cycles developed and updated the "to-be" process map and the operationalization of the design, with their *action taking* phases focusing on (1) reengineering the CP activation process, (2) developing a patient-centered web application, (3) developing a model to optimize care plans and (4) developing a scheduler embedding this model.

In the *evaluation* phase of each AR cycle, all team members met to systematically study the latest developments (e.g. running through the logic with the staff and demonstrating prototypes using sample data). We drew on feedback from stakeholders to gradually improve the web application and the scheduler, similar to the process used by others using AR in developing systems for clinicians (Visintin *et al.*, 2017). For the evaluation phase of the last cycle of the AR, we choose the simulation approach for testing the potential positive impact of digitalization. In a context of service innovation in healthcare, the implementation in hospital of a new process would lead to delays followed by issues in patient care. Moreover, simulation is a useful analysis and improvement tool for systems with high levels of complexity and uncertainty (Law and Kelton, 2000) that can support improvement in operational performance by assessing how potential strategic and operational changes would impact the process (Bisogno *et al.*, 2016).

Particularly important in AR, and distinguishing it from practical consulting, is the explicit *specifying learning* phase. This can be considered to consist of two steps (Dick, 2001): a critical review of what was done and with what results; then, planning the next action in the light of what has been learned. Extracting generalizable learning from this is important for contribution to academic knowledge.

4. Context and issues to be addressed

4.1 CP implementation process

The parent health region (Lazio region) has identified a priority need to progressively move some inpatient care provision to outpatient settings, which is clinically more appropriate (Regional Council Decision no. 731/2005, with subsequent updates and additions). Consequently, a new category of CP has been established: the complex outpatient package (COP). It consists of a standard set of multidisciplinary, integrated services to manage diagnosis and/or therapy for a complex health condition, to be provided over a limited period. Unlike a traditional outpatient service, the patient becomes the responsibility of the referring doctor (a COU clinician) who plans and coordinates the care path and manages the clinical documentation and the final report. The COP must be scheduled to reduce patient visits to the hospital. If not specified otherwise in the definition of a particular COP, the maximum time between the first and the last examination may not exceed 30 days.

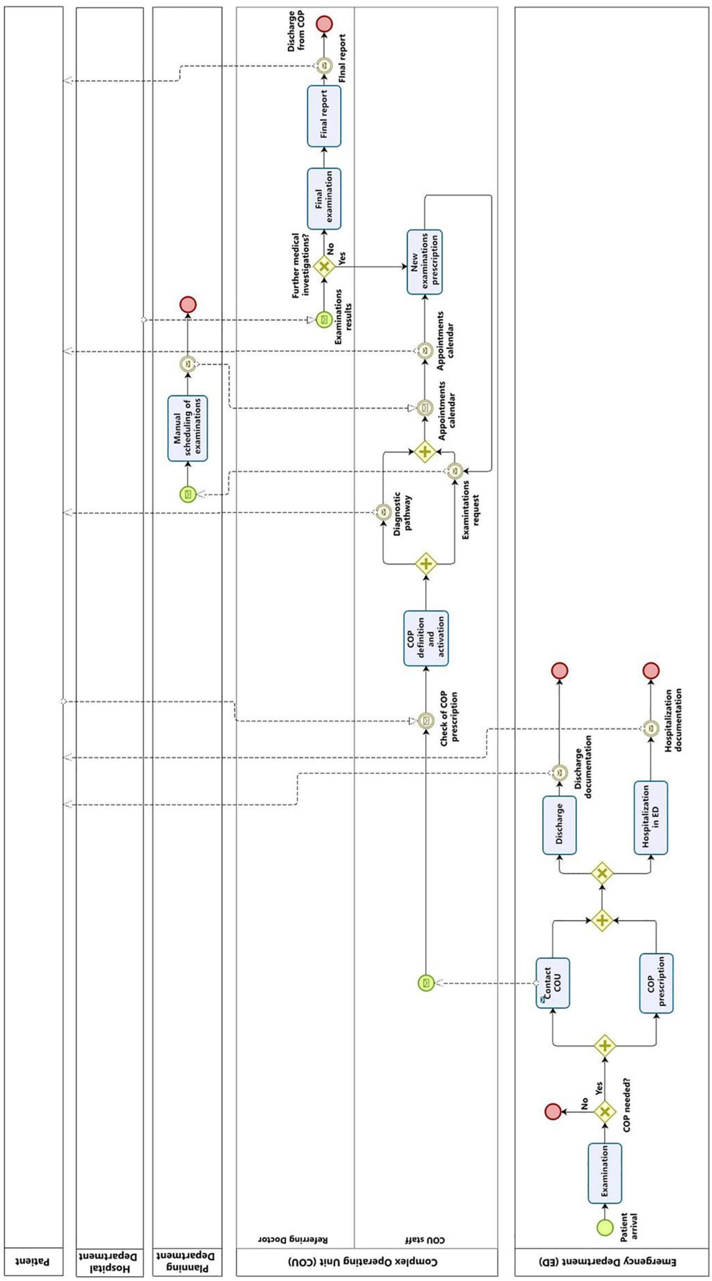
This paper takes as its test case one such CP at the Policlinico Tor Vergata Hospital: the COP for TLOC. According to the European Society of Cardiology guidelines, non-traumatic TLOC is divided into syncope, epileptic seizures, psychogenic and miscellaneous causes (Moya *et al.*, 2009). We focused on syncope, defined as a TLOC due to transitory global cerebral hypoperfusion. It is characterized by rapid onset, short duration and spontaneous and complete recovery. This type of COP was chosen because it was considered by hospital staff to be a representative example of those currently managed inefficiently in the hospital. Moreover, it is of great concern to hospital clinicians since syncope is a pathophysiology that can have several causes, including very serious conditions like heart disease or be the first sign of a potentially fatal cardiac event. According to the Hospital Controller, about 800 syncope cases present at the ED each year, and about 70% of these are potentially assignable to the TLOC COP.

When the causes of syncope are unclear, time is critical. The COP must be activated and completed as rapidly as possible to identify the causes and prevent recurrence with more severe consequences.

Figure 3 shows the "as-is" TLOC COP process. This BPMN-format process map is the result of cycles of revisions, iterated until we obtained the agreement of hospital staff that it was representative. As shown in the process map, the pathway is not activated in the ED. Instead, ED clinicians must inform the COU about an eligible patient and schedule an appointment at which the diagnostic plan will be set up. Then, the patient can be discharged from the ED. The schedule of diagnostic examinations is determined by the hospital's Planning Department, following the request from the COU. Once the patient has completed all required diagnostic examinations, if no further medical investigations are needed, the COP is completed.

4.2 Pathway issues identified

In AR cycle meetings, the project team identified the serious issues facing the hospital with the "as-is" TLOC COP process. Firstly, the TLOC COP has a critical bottleneck in the activation procedures. Since ED clinicians must wait for the COU to schedule an appointment for the patient before discharging him/her, the patient must remain in the ED unnecessarily,



Source(s): Author's own creation/work

Figure 3.
As-is process for the activation of a TLOC COP

sometimes for as long as 24–72h, contributing to ED overcrowding and hospital costs. In addition, the use of paper-based documentation hinders communication and coordination between the ED and other hospital departments. It results in longer delays between the attendance at the ED and the start of COP.

Finally, the scheduling of examinations is not optimized, delaying the completion time of the COP. In fact, the hospital's Planning Department does not use any optimization tools and tries to schedule all examinations to be on a single day and so require only a single patient return visit. Diagnostic resources are limited, so there may not be a suitable gap in the calendar of future bookings until long after the triggering attendance at the ED, and so there may be a long delay until the COP first visit (start date).

These shortcomings can lead to two negative consequences: patients may present again at the ED with the same symptoms or decide to seek care at another provider, with (as noted earlier) implications for hospital finances and (in some cases) patient outcomes.

5. The redesigned COP setup process

To redesign the COP setup process, the project team agreed to focus on three critical aspects:

(1) Communication: the information exchange between ED clinicians and COU staff;

(2) Activation time: the time patients wait for the activation of a CP (their first scheduled COP visit) following their discharge from the ED;

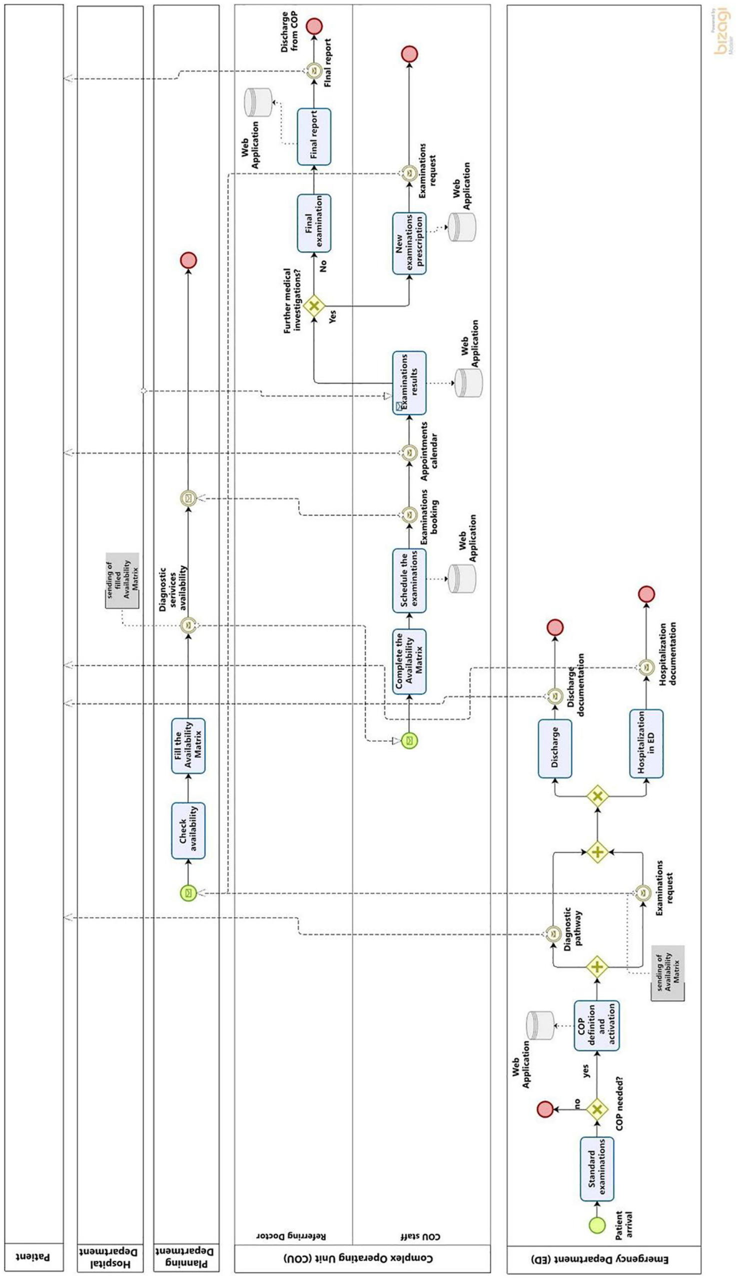
(3) Completion time: COP duration, that is, the number of days needed to complete a CP following its start date.

We recommended designing a reengineered COP supported by a web-based software tool. We anticipated this software approach would have several benefits. First, a low upfront development cost since there is only a server-side component to be developed and tested with different browsers without additional, bespoke, software development needs. Another advantage is cross-platform support, which allows developers to write the source code once and deploy it to multiple platforms instantly. Web applications are also easy to maintain and update, leading to a low total cost of ownership in the long term. Finally, web applications can also be accessed on mobile devices (Bal, 2013). The hospital staff proposed to transform the old routines allowing that through the web application the ED would activate the COP and define the diagnostic plan without contacting the COU. The new routines would introduce new ways of organizing clinical work for the management of the COP. This is clinically feasible because the TLOC COP consists of a standard set of examinations for all patients presenting at the ED following an episode of syncope. Moreover, they suggested that when an ED doctor activates a COP for a patient, a request for the necessary examinations would automatically be sent to the Planning Department requesting information about services availability.

To improve the scheduling, we decided to develop an optimization model embedded in a scheduling tool. The scheduler would allow the user to change particular parameters to reflect hospital and/or patient needs without affecting the general optimization model. An effective appointment scheduling system would better support the timely access to health services, which is important for achieving both good clinical outcomes and patient satisfaction (Gupta and Denton, 2008).

5.1 Web application development

The aforementioned proposals were developed in a full AR cycle, in which the clinicians helped refine our ideas. This cycle produced the "to-be" process design, illustrated in the



Source(s): Author's own creation/work

Figure 4.
To-be process for the activation of a TLOC COP

process map of Figure 4, which was validated by the hospital staff. To operationalize this CP design, we developed a patient-centered web application, the Information System for the management of Complex Outpatient Packages (ISCOP) representing a digitalization of the TLOC COP.

From a technical point of view, we adopted client-server architecture in which a user (client) connects generically to a server to use a specific service. The main advantage of adopting this computing model is improved data sharing between designated users regardless of their hardware platform or operating system. Moreover, system maintenance is easier since server and clients are using separate computers. It also has higher inherent data security.

The front-end consists of three types of user accounts: ED clinician, COU clinician and referring doctor. For the *ED clinician* account, we implemented three features to avoid work overload.

Firstly, ISCOP can capture an eligible patient's data from the ED information system, reducing administrative duplication.

Second, standard templates of COP examinations are set-up (Figure 5), which can be assigned automatically to a patient's care plan, saving time and reducing omissions. Third, the ED clinician can send a request to the Planning Department for information about the availability of the clinical services they are assigning to the care plan. The request consists of a matrix edited automatically by ISCOP, just showing the examinations included in the patient's COP. The Planning Department has to respond by entering the available

TRANSIENT LOSS OF CONSCIOUSNESS (TLOC) PATHWAY ▾

Code	Examination Name	Price	#
P78002	First visit and management of the COP	25,00	☑
89.01	Anamnesis and Evaluation	12,80	☑
88.72.3	Colour Doppler Echocardiography	62,00	☑
89.52	Electrocardiogram (ECG)	11,60	☑
89.50	Dynamic Electrocardiogram (Holter monitor)	62,00	☑
89.41	Cardiac Stress Test	55,80	☐
89.59.2	Tilt Table Test (TTT)	52,00	☐
89.13	Neurological examination	13,60	☐
89.7	Specialist examination	13,60	☐
89.14	Electroencephalography (EEG)	23,20	☑
Cod.	Blood test		☑

Initialize COP and Alert the COU

Source(s): Author's own creation/work

Figure 5.
ED clinicians screen used to define the diagnostic CP

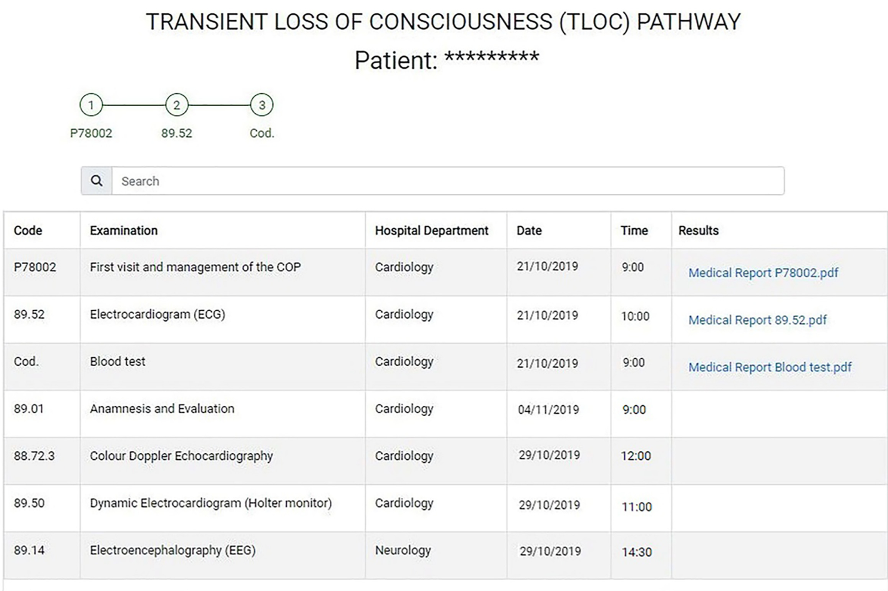
appointment slots (days and times) for each clinical service and sending this completed matrix to the COU.

The *COU clinician* user will run the scheduler (see section 5.3) to solve the optimization model (see section 5.2) for that patient and copy and paste the solution into ISCOP to be sent to the patient and the Planning Department. Finally, the COU can also upload the results (medical reports) from each completed diagnostic examination to ISCOP.

The *referring doctor* user type can monitor the progress status of the patient on their COP, a feature which clinicians find useful (Balatsoukas *et al.*, 2015), and display the uploaded examination results to decide if further investigations are needed (Figure 6).

5.2 Optimization model development

As noted earlier, a CP is not a planning tool, and so digitization is insufficient to better address the appointment scheduling problem. Extending CP transformation to digitalization, the project team agreed to develop a deterministic optimization model specifically designed for the COPs. In this context, it was appropriate to adopt the multi-appointment scheduling approach since patients must undergo different consultations and diagnostic tests. As a TLOC COP is a diagnostic CP, the type of patients treated are exclusively outpatients. Thus, in the model, we did not have to consider hospital bed capacity. Considering what to optimize, the model's primary aim was to minimize the completion time of the CP. Furthermore, the team agreed to adopt an online scheduling strategy based on the first-come-first-served approach for two main reasons. Firstly, this was a specific request from the stakeholders since time is a critical factor as syncope can have clinically serious causes. Secondly, the available slots for medical services for any type of COP are limited, and also other hospital departments require access to the services included in the TLOC COP. This means that the optimization model must be solved for each



Code	Examination	Hospital Department	Date	Time	Results
P78002	First visit and management of the COP	Cardiology	21/10/2019	9:00	Medical Report P78002.pdf
89.52	Electrocardiogram (ECG)	Cardiology	21/10/2019	10:00	Medical Report 89.52.pdf
Cod.	Blood test	Cardiology	21/10/2019	9:00	Medical Report Blood test.pdf
89.01	Anamnesis and Evaluation	Cardiology	04/11/2019	9:00	
88.72.3	Colour Doppler Echocardiography	Cardiology	29/10/2019	12:00	
89.50	Dynamic Electrocardiogram (Holter monitor)	Cardiology	29/10/2019	11:00	
89.14	Electroencephalography (EEG)	Neurology	29/10/2019	14:30	

Source(s): Author's own creation/work

Figure 6. Referring doctor screen showing the CP status progress and the medical reports

Indices	
$d = \{1, 2, \ldots n\}$	Days on which clinical services will be performed
$s = \{1, 2, \ldots m\}$	Clinical services, where *m* corresponds to the final visit with the referring doctor
Sets	
D	Set of days in the planning horizon, indexed d
S	Set of clinical services, indexed s
$S' \subseteq S$	Set of the requested clinical services
Parameters	
A_{s_i,d_f}	$= \begin{cases} 1, \text{if service } s_i \in S \text{ is available on day } d_f \in D \\ 0, \text{otherwise} \end{cases}$
P_{s_i,s_j}	$= \begin{cases} 1, \text{if service } s_i \in S' \text{ must precede service } s_j \in S' \\ 0, \text{otherwise} \end{cases}$
S_{s_i,s_j}	$= \begin{cases} 1, \text{if } s_i \in S' \text{ must be provided on the same day as } s_j \in S' \\ 0, \text{otherwise} \end{cases}$
$L \geq 0$	Minimum number of days between the last clinical service and the final visit *m*
$N \geq 0$	Maximum number of days permitted on which a patient must come to the hospital (maximum visits)
$M > 0$	Large number
Variables	
x_{s_i,d_f}	$= \begin{cases} 1, \text{if service } s_i \in S' \text{ is scheduled on day } d_f \in D \\ 0, \text{otherwise} \end{cases}$
y_{d_f}	$= \begin{cases} 1, \text{if at least one service has been scheduled on day } d_f \in D \\ 0, \text{otherwise} \end{cases}$

Source(s): Author's own creation/work

Table 2. Scheduling problem indices, sets, parameters and decision variables

patient individually, in the order in which the requests are made. Finally, the mixed-shop system (Nguyen and Bao, 2016) is particularly suited to TLOC COPs where a patient first has an admission consultation, followed by multiple examinations with precedence constraints, but with some flexibility in the sequence, and finishes with a final consultation in which the doctor presents the results (Matta, 2009; Saremi *et al.*, 2015). The problem is formulated based on the notation included in Table 2.

Mathematical formulation

$$\min \sum_{s_i \in S'} \sum_{d_f \in D} d_f x_{s_i d_f} \tag{1}$$

Subject to:

$$\sum_{d_f \in D} x_{s_i d_f} = 1 \qquad s_i \in S' \tag{2}$$

$$x_{s_i d_f} = 0 \qquad s_i \in S',\ d_f \in D : A_{s_i d_f} = 0 \tag{3}$$

$$\sum_{\substack{d_f \in D \\ d_f \leq d_g}} x_{s_i d_f} \geq \sum_{\substack{d_f \in D \\ d_f \leq d_g}} x_{s_j d_f} \qquad s_i \in S',\ s_j \in S',\ d_g \in D : P_{s_i s_j} = 1 \tag{4}$$

$$x_{s_i d_f} = x_{s_j d_f} \qquad s_i \in S',\ s_j \in S',\ d_f \in D : S_{s_i s_j} = 1 \tag{5}$$

$$\sum_{d_f \in D} d_f x_{s_i d_f} + L \leq \sum_{d_f \in D} d_f x_{s_m d_f} \qquad s_i \in S',\ s_m \in S' : s_i \neq s_m \tag{6}$$

$$\sum_{s_i \in S'} x_{s_i d_f} \leq M y_{d_f} \qquad d_f \in D \tag{7}$$

$$\sum_{d_f \in D} y_{d_f} \leq N \tag{8}$$

$$x_{sd} \in \{0, 1\} \tag{9}$$

$$y_d \in \{0, 1\} \tag{10}$$

In this formulation, the objective function (1) minimizes the sum of the days on which all the CP services are assigned, giving priority to a solution with an early start. In other words, it minimizes the time needed to complete a COP. Equation (2) ensures that each clinical service is assigned in the planning horizon, and equation (3) states that a clinical service can be assigned only to the day on which it is available. If a clinical service must be performed before others, this precedence is guaranteed by equation (4). In contrast, if two or more clinical services must be performed on the same day, this simultaneity is ensured by equation (5). The assignment of a clinical service corresponds to the occupation of a human resource that must perform the service. Equation (6) enforces that the final visit, which defines COP completion, must be performed at least a predetermined number of days (L) after the last examination. Equations (7) and (8) limit the number of days on which the patient should come to the hospital (N). In our problem, M corresponds to the number of examinations included in the TLOC COP. Finally, expressions (9) and (10) are binary constraints that define the domain of the variables. If there is no feasible solution within the planning horizon (D), there are two possible remedies: increasing the limit on the number of days on which the patients must come to the hospital (the number of visits, N) or extending the planning horizon. The latter involves having to send back the availability matrix to the Planning Department to request availability data about further days.

This model has two main limitations. First, it does not jointly plan the CP for multiple patients. We opted for this simplification in order to satisfy the aforementioned request, by clinicians, to activate a TLOC COP as soon as possible due both to the nature of syncope and the limited resources available for the COPs. Because patients with syncope present at the ED singly and randomly, the model is run each time a patient is ready to be assigned to the pathway, to avoid delay. Second, we did not consider the variability and uncertainty of input parameters like the actual duration of appointments – we assume each will occupy one time slot. In this way, the model does not consider any delays and/or overlapping examinations.

5.3 Scheduler

The model is embedded in a user-friendly scheduler for use by the Planning Department and the COU. The scheduler consists of two Excel files: *Availability* and *Calendar*. We decided to implement this in Excel format since it is already familiar and available to all users and files can easily be shared between hospital departments.

The *Availability* file (Figure 7) contains the availability matrix in which the Planning Department and the COU can enter:

(1) Length of the planning horizon.

(2) Days and times available for each of the examinations requested in the COP.

Horizon	First visit and management of the COP	Anamnesis and Evaluation	Colour Doppler Echocardiography	Electrocardiogram (ECG)	Dynamic Electrocardiogram (Holter monitor)	Electroencephalography (EEG)	Blood test
21/10/2019	9_00		11_00	10_00	10_00		9_30
22/10/2019	9_00		9_30			14_30	9_30
23/10/2019					11_00		
24/10/2019	9_00			10_00		15_00	9_30
25/10/2019	9_00			11_00			9_30
26/10/2019							
27/10/2019							
28/10/2019			12_00	10_00			
29/10/2019	9_00		12_00	10_00	11_00	14_30	9_30
30/10/2019	9_00		11_00	10_30	10_30		9_30
31/10/2019			9_30		10_00		
01/11/2019							
02/11/2019							
03/11/2019							
04/11/2019	9_00	9_00	12_00	10_00			9_30
05/11/2019		9_00	11_00	10_30		14_45	9_30
06/11/2019	9_00			10_00	10_30		9_30
07/11/2019			9_30		10_30		
08/11/2019		9_00					
09/11/2019							
10/11/2019							
11/11/2019		9_00					
12/11/2019	9_30	9_00	11_00	10_00	11_00		9_30
13/11/2019				10_30			
14/11/2019						15_00	
15/11/2019		9_00					
16/11/2019							
17/11/2019							
18/11/2019	9_30		12_00		11_00		9_30
19/11/2019		9_00	12_00	10_30	11_00	14_30	

Source(s): Author's own creation/work

Figure 7.
Example of *Availability* matrix, as completed by the Planning Department

The Planning Department will receive a new matrix for each patient and needs to enter only the slots available.

The Calendar file comprises two spreadsheets: *Parameters* and *Output*. On the Parameters spreadsheet, the COU can set the following data:

(1) Maximum number of days on which the patient must come to the hospital (N).

(2) The number of days between the last examination and the final visit with the referring doctor (L).

(3) Precedence and/or simultaneity among the examinations.

In the *Output* spreadsheet, the COU can run and view the optimal solution.

5.4 Feedback from stakeholders

This section summarizes the results of the evaluation phases of all AR cycles, driven by SD principles, performed in the study. During the development process, ED and COU Medical Directors were involved in periodic meetings, so that we could use their feedback to enhance the system iteratively. During the development cycles, the system was improved as follows:

(1) Ability of the COU to modify in the scheduler the parameter representing the maximum number of days on which the patients must come to the hospital (N). This addresses the potential of there not being any feasibility solution within the planning horizon and also accommodates an explicit request by a patient.

(2) Addition of automatic coordination and communication between the ED and the COU. When the ED initializes a new COP, the system automatically alerts the COU via email, displaying the patient's information and the corresponding CP.

(3) Adding a mobile app (mobile client) for the patient's exclusive use to manage and improve communication. We designed this and implemented it through the IONIC framework, chosen because it is an open-source tool for cross-platform mobile app development, allowing creation of apps for Android and iOS exploiting HTML5 (though so far we have only developed an Android version). Thanks to this tool, the development process is fast and cost-efficient and requires little maintenance. When the ED clinician saves the patient's information in ISCOP, the system automatically emails the patient a link to download this mobile app. The app allows the patient to receive their diagnostic plan and displays the hospital department, date and time for each appointment (Figure 8).

5.5 Lessons learned

This section gathers together what we learned during the AR cycles. As usual with AR, there were twin aims: to conduct practical work (here develop a digitalized CP) and to generate generalizable knowledge (theory).

On the practical content, our approach proved a successful method to achieve staff consensus on the "to-be" process design for the digitalized CP, with reengineered activation procedures, examinations scheduling processes and communications mechanisms. We found we could conceptually validate the new process, and from it designed and developed a software system for digitalizing the TLOC COP: a web application for activating and managing the CP, an optimization model-based scheduler for setting the calendar of appointments and a mobile app for communicating with patients.

On general knowledge generation, we found that the stakeholders (particularly clinicians) have vital tacit knowledge and that collaborative communication is an effective way of

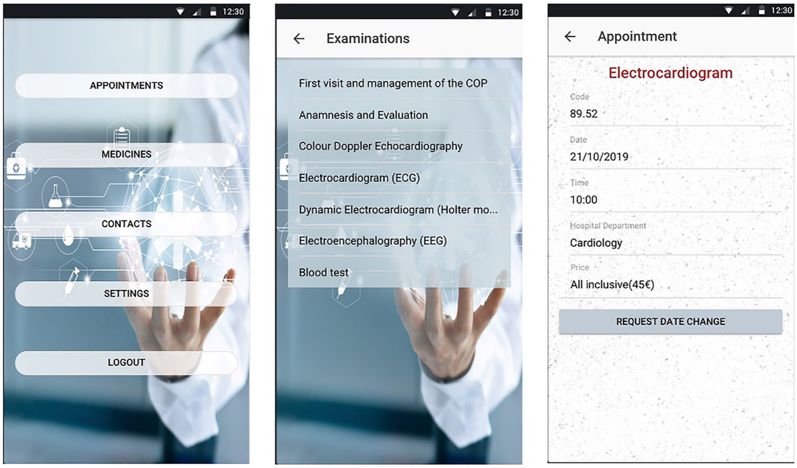


Figure 8.
Mobile app screens showing the patient calendar

Source(s): Author's own creation/work

sharing this to inform researchers about study context. We found in-depth semi-structured interviews to be a suitable method for eliciting these type of data. The periodic meetings in each cycle created a bond with hospital staff, so they came to consider the main researcher as one of their own team members, bridging the gap between the academic and hospital worlds. These aspects were crucial for developing a solution without a radical disruption of existing procedures. Moreover, both SD and AR were useful in creating a new intersubjective awareness of the phenomenon of organizational culture (Sparre, 2020). Indeed, the sharing of knowledge allowed the stakeholders to overcome their own subjectivity, analyzing the TLOC COP from multiple perspectives, and develop mutual recognition of the critical issues by the respective departments regarding the management of CP.

6. Simulation

The simulation module of Bizagi Modeler software has been used in this work. Bizagi Simulation follows BPSim (Business Process Simulation) standard that allows enhancement of business process models captured in BPMN to support rigorous methods of analysis.

The simulation model was built and validated on data provided by clinicians during the periodic meetings for the development of ISCOP. The Hospital Controller provided the number and interval rates of the patients admitted to the TLOC COP, the time between the admission of patients in the ED and the start date of the COP, and the time between the last examination and the final visit with the referring doctor for the first six months of 2017. In the current situation, the average process throughput time, intended as the time between arrival in the ED and the final visit of the TLOC COP, was about 85 days (i.e. 45 days the mean time

Table 3.
KPIs for the "as-is" situation measured by simulation

KPI	Measure	Result
KPI_1	Completion rate	0.77
KPI_2	Throughput time	0.96

Source(s): Author's own creation/work between arrival in the ED and the start of the COP, and 40 days the mean completion time of the COP).

We defined and calculated two KPIs (Table 3).

- Completion rate of COPs: it is a measure of the completed process instances (i_c) compared to COP's started process instances (i_s) in the reference time horizon:

$$KPI_1 = \frac{i_c}{i_s}; 0 \leq KPI_1 \leq 1.$$

Throughput time: it measures the process throughput time (ThT) variation compared to the benchmark value for the process throughput time (ThT*), obtained minimizing the waiting times:

$$KPI_2 = 1 - \frac{ThT^*}{ThT}; 0 \leq KPI_2 \leq 1.$$

The measure of KPI_1 shows that 23% of activated COPs have not been completed in the reference time horizon, while the measure of KPI_2 reveals the current completion time is significantly higher than the benchmark one ($ThT^*/ThT = 0.04$).

Next, we examined two different "to-be" scenarios, in which the TLOC COP can be scheduled at most on three or four different dates (the last date corresponds to the final visit with the referring doctor). We considered the same rate of patients' arrivals in the ED of "as-is" situation. Instead, regarding the waiting days for the start of the COP and the days among the first, the second and the third examinations' date, we had no knowledge of them since the procedures of the digitized COP are not tested yet in the hospital. To overcome this issue, weekly availability of each examination has been estimated in consultation with the clinicians, in order to fill the availability matrix. Next, considering the arrival days of the "as-is" process, we used the scheduler for planning the COP examinations. Finally, we estimated the mean waiting days distribution for the examinations' dates.

Table 4 shows the measure of the KPIs calculated for the two "to-be" scenarios, and their variations (ΔKPIs) compared to the "as-is" situation. From the analysis of the results, we can observe that a significant improvement can be gained for both KPIs in scheduling the COP examinations on four dates (ThT = 27 days) rather than on three (ThT = 32 days). Indeed, the completion rate (KPI_1) shows a positive variation of 18% in the case of three dates, and 21% in the case of four dates, pointing out an increase in the number of COPs completed in both options. Similarly, the throughput time (KPI_2) shows a negative variation of 6% in the case of three dates, and almost 8% in the case of four dates, emphasizing a decrease in the waiting time and thus the completion time of the COP. However, the improvement of performance indicators may worsen other aspects, like the number of times patient should go to the hospital. However, if the hospital priority is the reduction of the completion time of the

Scenario	KPI_1	ΔKPI_1	KPI_2	ΔKPI_2
As-is	0.77	–	0.96	–
To-be (3 dates)	0.91	+18%	0.91	−6.06%
To-be (4 dates)	0.93	+21%	0.89	−7.45%

Source(s): Author's own creation/work

Table 4. KPIs for two to-be scenarios, and variations of KPIs compared to the as-is situation

TLOC COP, the best improvement is that obtained by the second "to-be" scenario, that is, four dates.

Results shows how ISCOP may be a valid solution for improving COPs' performance, highlighting how it would be worth testing the developed solution in the hospital in order to confirm the positive impact showed by the simulation experiments.

7. Discussion

This study highlights a relevant healthcare topic, the importance of an efficient urgent outpatient diagnostic pathway following symptoms that drive a patient to attend the ED. Often symptoms represent a warning of more severe pathologies that, if not rapidly diagnosed, can lead to a future return to the ED, to inpatient hospitalization or even be fatal. The efficiency of these critical CPs can, therefore, lead to an increase in the quality of the patient's health and a reduction of overall healthcare costs. This work reported a specific case to provide useful operational guidance to other healthcare organizations facing similar problems.

In this context, digital innovation plays an important role in improving healthcare processes. The literature contains several studies assessing the effect of digitalization on a healthcare organization's performance. Kraus *et al.* (2021), in their systematic review, highlighted that digitalization impacts operational efficiencies and organizational factors. First, a positive correlation between the adoption of digital technologies and patient satisfaction has been demonstrated (Hong and Lee, 2017). An increase in the quality of care by reducing the response time of clinicians due to improvement in administrative processes has been found (Laurenza *et al.*, 2018). Digital technologies enhance data sharing (Cucciniello *et al.*, 2016) and support both administrative tasks and cooperation with stakeholders, playing a central role in business process improvement (Laurenza *et al.*, 2018; Agostini *et al.*, 2019). Chakraborty *et al.* (2020) pointed out how patient record tracking by clinicians increases the responsiveness and the agility of a health organization, while data sharing enhances flexibility. Finally, Buntin *et al.* (2011), in their review, showed that the adoption of digital technologies leads to positive overall effects in several types of outcome measures such as access to care, increased preventative care, patient safety and satisfaction, and effectiveness and efficiencies of care. As would be expected, studies also emphasize the importance of clinical staff buy-in and a participatory development process to realizing positive effects from the implementation of digital systems (Cucciniello *et al.*, 2016).

Guided by this evidence and paying attention to the critical issues an organization must face during a digital transformation process, our study describes the digitalization of a test CP, the diagnostic pathway activated when a patient presents at ED following a syncope episode.

We defined a proper and clear strategy for remodeling the hospital procedures to incorporate digital technology across appropriate facets to achieve an improvement of the CP performance (Correani *et al.*, 2020). We started assessing the current state to be able to identify potential roadblocks; next, we defined the prioritized goals of the digital transformation and, finally, we established a plan of action. The AR driven by SD was the most suitable methodology for developing and implementing the new digitalized processes. In particular, we implemented a patient-centered web application (ISCOP) and an optimization model embedded in a scheduling tool, developing features to make them effective and easy to use. First, we focused on cross-departmental hospital communication needs, as found effective by Laurenza *et al.* (2018). Secondly, similar to Okada *et al.* (2005), we developed a system usable via PC, smartphone and tablet. Thirdly, we developed a flexible scheduler to allow the referring doctor to deal with different scenarios and objectives (Baiyere *et al.*, 2020); he can set some crucial parameters (maximum number of patient visits to the hospital, minimum number of days between the last examination and the final visit and sequencing among the examinations included in the COP), according to a patient's particular condition and situation.

Usually, digitalization requires profound changes in organizational structure (Latilla *et al.*, 2019). Indeed, the proliferation of digital technologies has led companies to reconfigure their traditional activities to adapt them to the adoption of digital tools, thus radically changing an existing business model or shifting to a new one (D'Ippolito *et al.*, 2019).

In our study, the last reflective phase of AR cycles was a crucial driver of learning that allowed us to aim for material benefits without a *radical* reengineering of current processes by supporting the core activities using digital tools and capabilities. Digitalization does not always have to be disruptive to an organization, but can be effected by incremental steps toward better serving customer need (Furr and Shipilov, 2019). This allows to avoid the typical barriers faced when implementing new technologies in the healthcare sector; indeed, the more disruptive the application of the new technology and approach, the greater the barriers that the technology has to overcome (Kulkov *et al.*, 2023). Moreover, the active participation of stakeholders (especially clinicians) in the digital transformation process made it possible to prevent potential obstructions by employees to the digitalization of procedures (Solberg *et al.*, 2020). The perspectives and experiences shared by these stakeholders lent empirical support to the notion that cohesive cooperation among diverse functional units and teams is an imperative prerequisite for realizing lasting change within the healthcare institution. This understanding is pivotal for making informed decisions and adjustments during the digital transformation journey. The methodological approach has created organizational change in intersubjectivity, creating a shared perception among clinicians about the adoption of the new routines. The involvement of stakeholders allowed us also to access their latent knowledge about organizational issues with the CP and identify the specific critical points to improve. This way, we did not need to completely transform the execution process of the TLOC COP. To create the conditions for improvement, in addition to the development of a web application to digitally manage the TLOC COP and the implementation of a basic optimization model to schedule the examinations, we redesigned the activation procedures, utilizing already-existing resources involved in the execution of the TLOC COP (Sia *et al.*, 2021). In particular, according to the new routines, the ED clinician can automatically assign a diagnostic plan to a patient and request to the Planning Department for the availability of the clinical services assigned to that diagnostic plan. This incremental organizational change led to a significant reduction in the process throughput time (days between the arrival in the ED and the final visit) compared to the current situation, as confirmed by the results of the simulation. It means a decrease in the probability of a patient returning to the ED and/or hospitalization due to the worsening of his/her condition, thus improving both health outcomes and patient experience.

The fusion of SD and AR has emerged as an effective and holistic framework facilitating the digital transformation of CPs. This symbiotic amalgamation leverages the distinctive strengths of both approaches to address the multifaceted challenges inherent in healthcare innovation. The synergy between SD and AR represents a pivotal milestone in the digital transformation of CPs. This union not only reaffirms the importance of human-centeredness and adaptability in healthcare service redesign but also equips stakeholders with the tools and insights required to navigate the complexities of healthcare systems. The implication of this amalgamation is that it fortifies healthcare professionals and researchers in their endeavors to usher in an era of creative service redesign and digital innovation, ultimately enhancing the quality and effectiveness of healthcare delivery for the benefit of patients and society at large.

7.1 Managerial implications

To put the aforementioned in managerial terms, we have found that:

(1) A CP can be digitalized (both digitized and provided with inbuilt decision support tools) without radical changes to core IT or reconfiguring to organizational structures.

(2) This allows access by all required users, across several departments, on a range of devices and at the locations where the data are generated and required.

(3) Fairly sophisticated optimization tools can be made available, and user-configured.

(4) Such digitalization of CPs can proceed incrementally and lead to an improvement in both health outcomes and patient and clinician experience.

(5) On the last point, this is a small step on the road to much more comprehensive coordination of patient care across a health organization (and even across a wider system) using data analytics to manage and streamline patient pathways and resources. Several US healthcare providers are pursuing this "smart hospital" concept through a "Mission Control Centre". Probably, furthest along this journey is Virginia Mason Franciscan Health, which launched its system in 2019, inspired by NASA and working with GE Healthcare as IT provider (Schlicher *et al.*, 2021). The organization was already world-renowned for its deep use of lean (Virginia Mason Production System), with direct help from Toyota (Graban and Toussaint, 2018), and is now, in turn, helping other healthcare systems, including the English NHS (Smith *et al.*, 2020). Building on a strong electronic heath record infrastructure, frontline staff access the system via a role-specific set of apps. The primary aim of their digitalization has been patient flow efficiency, and they report material benefits including increased treatment capacity and earlier discharge. However, other benefits have included triggers for critical safety interventions and timely conversion of patient observation cases to inpatient admission as their conditions worsened. An important feature has been that clinical staff are heavily involved in development and in manning the central control-center room. They also report it being welcomed by clinicians to give them reassurance in their patient-management decisions and patient monitoring.

8. Conclusion and future research

In this paper, we have presented a study that aims to digitalize the processes and procedures necessary along a diagnostic CP in the Policlinico Tor Vergata Hospital in Rome, Italy. As fusion of SD and AR, this study contributed to both practice and theory. The main contribution concerned demonstration of the development of a web application and an optimization model for managing and optimal scheduling of a digitalized CP in order to provide patient care continuity, confirming the digitalization effectiveness on health outcomes and process measures such as patient and clinician satisfaction.

The described solution (web application and optimization model) was developed particularly for TLOC COP as a test case. However, future research should consider adoption for all types of CPs managed in the hospital, both those activated by the ED and those activated by COUs. Almost all diagnostic CPs use similar processes. Therefore, changes to adapt ISCOP to the other diagnostic CPs would mainly concern the optimization model, in which further constraints may be introduced. Extending the proposed solution to also support CPs requiring surgical interventions is more complex. ISCOP should, in that case, also interface with the hospital departments managing admissions and the scheduling of operating rooms.

Finally, ISCOP can be widely applied also in other hospitals since it was developed referring to the national guidelines about the execution of the CPs provided by the hospital staff. However, there should be local process analysis to evaluate the interaction mode among the people involved in the CP and, if needed, modify this aspect of the system.

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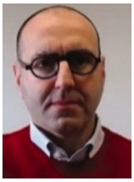
Appendix

The supplementary material for this article can be found online.

About the authors



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