Business Process Reengineering and Modelling in healthcare: a systematic literature review and research agenda

Andrea Rossi [a)], Lorenzo Tiacci [b)]

a. *Dipartimento di Ingegneria ., University of Perugia, Via Duranti 97, 06125 – Perugia– Italy (andrea.rossi16@studenti.unipg.it)*

b. *Dipartimento di Ingegneria ., University of Perugia, Via Duranti 97, 06125 – Perugia– Italy (lorenzo.tiacci@unipg.it)*

Abstract: Business Process Reengineering (BPR) has always been important in the industrial sector, being processes improvement the basis of quality management systems. BPR can also be applied to other sectors outside the industry, including those offering services. In recent years, the healthcare sector is more welcoming towards adopting reengineering practices to improve the existing processes performances. Healthcare processes are in fact quite complex, so the application of techniques that can lead to improve their efficiency through cost reduction, workforce, and resource utilization has a great managerial implication. In this paper a systematic literature review of the existing modelling and reengineering approaches of healthcare processes has been conducted. The results from the literature review give evidence of the modelling challenges that are encountered in this field, and of the techniques that are typically utilized. Based on these results, a research agenda is proposed that highlights which topics and methodologies can be the focus of future research. In particular, we think that the formalization of generalized models that have been successfully tested on real cases is essential to form a shared knowledge base that can serve as a reference and become a benchmark for various application contexts.

Keywords: Reengineering, healthcare, modelling, review

I. INTRODUCTION

The healthcare sector is composed by many different processes. From a managerial point of view, the efficiency with which the processes are carried out is fundamental in terms of cost, resources utilization and patient satisfaction. Process improvement is a methodology that has always been a well-researched topic in the industrial sector. In recent years, supported by the development of information systems and digital transition, these techniques, already tried and tested in the industry, are being applied with growing interest in the healthcare sector (De Mast et al., 2011). The approach of process re-engineering, which starts with the analysis of a process in its current state and then proposes improvement actions and a future state, can be partly superimposed on that of process modelling. In fact, the modelling that aims for the standardization of a process is itself an action of reengineering (Barbagallo et al., 2015). Standardization can lead to significant benefits, such as improved outcomes for patients, better interdisciplinary work, improved management of clinical resources, better hospital efficiency, and continuous improvement in the quality of care. In the field of healthcare process management, there are different applications inherently different from each other in term of destination and resource involvement, e.g., patient workflow, emergency department or operating rooms management, inventory management etc. As a result, the aspects to optimize are also different. Another crucial factor is that, unlike the industrial sector, in which the product is a passive entity in the system, in many of the healthcare processes, the patient is an active entity, adding another level of complexity.

In this paper a Systematic Literature Review (SLR) following the Preferred Reporting Items Systematic reviews and Meta-Analyses (PRISMA) methodology (Moher et al., 2009) on healthcare process reengineering and modelling is carried out, with the aim to analyse the state of the art and find research gaps to exploit for further research. The current study aims to provide a general analysis of the state of the art, giving evidence of the most common application fields, the related approaches adopted, before choosing a specific application field to research further. The paper is organized as follows, in Section II the materials and methods

utilized to conduct the literature research are described, in Section III the discussion about the results of the analysis will be conducted, in Section IV future research agenda will be described and in Section V the conclusion are drawn.

II. Materials and Methods

The review is conducted on peer-reviewed articles following the PRISMA guidelines (Moher et al., 2009). The systematic literature review according to PRISMA is based on a set of guidelines for the conduct, presentation, and transparency of SLRs. The guidelines also provide a systematic procedure for study identification, screening, eligibility, and inclusion. In Fig. 1 the detail of the workflow is reported.

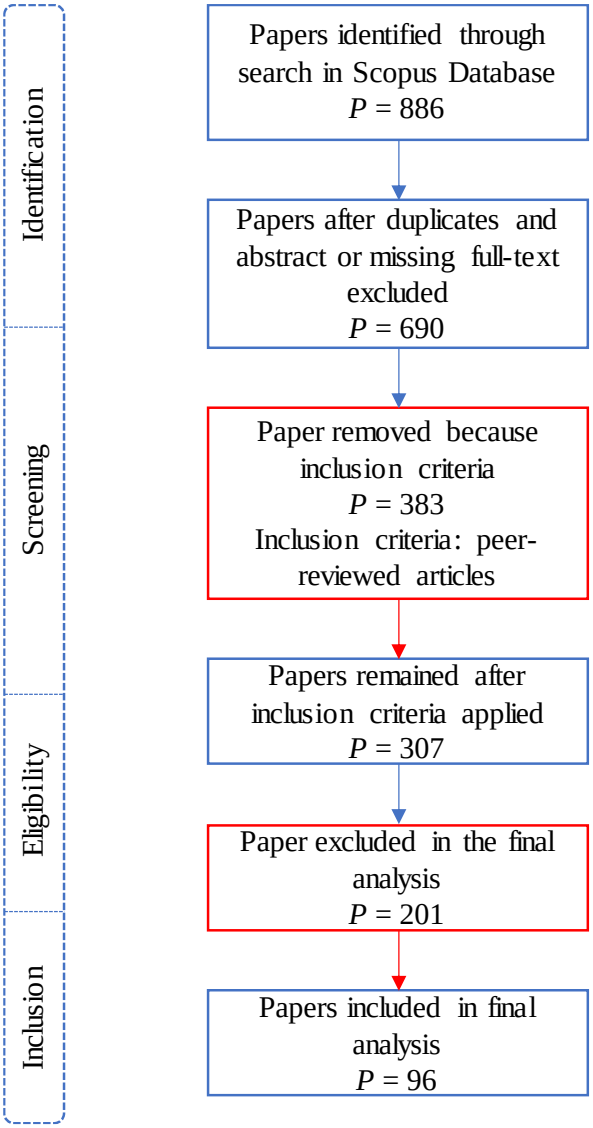

Fig. 1 Paper inclusion strategy

A. *Identification*

The review was conducted on the Scopus database, up to 31 March 2023. Scopus is a source neutral database that has more than 27000 active sources, 290000 standalone books and 90 M records (*Scopus Content Coverage Guide*, 2023).

The search starts from the definition of the search query to utilize. As already mentioned, the two main topics to explore were "business process reengineering" and "modelling" in the healthcare sector. To capture the different application possible in the search not only "healthcare" but also "hospital", "clinical" and "surgical" keyword are included. Furthermore, in order not to collect the woks purely oriented on medical or clinical studies, in the search query, only title and abstract are considered, because we noted that including also the keywords gave raise to these types of papers. Finally, the adopted query is the following:

TITLE-ABS((healthcare OR "health care" OR clinical OR surgical OR hospital) AND business AND ((process reenginering) OR (process modeling))) AND (LIMIT-TO(LANGUAGE,"English")).

The search provided 886 records. Then the duplicate records and the papers with no abstract or full-text available have been discarded, for a total of 196 papers.

B. *Screening*

At this point there are 690 papers remaining. In the screening phase, to reduce the number of papers to further analyse and include in the review, we decided to focus on only peer-reviewed articles The number of papers excluded applying this criterion is 383, leaving 307 papers remaining for eligibility.

C. *Eligibility*

At this stage, the abstracts of all articles were reviewed to check whether the topic of the article corresponded to context of the review. Among 307 papers, 201 were excluded because either the application field or the techniques proposed were not inherent to the business process reengineering and modelling approaches.

D. *Inclusion*

Finally, a total of 96 papers remained to conduct further analysis. The analysis will be conducted identifying applications sector, techniques adopted and objectives.

III. Discussion

The analysis conducted on the articles identified by the systematic review in this section will cover the temporal evolution of the identified scientific production and the analysis of the main fields of

application with detail on the objectives pursued and the techniques adopted. Special attention will be paid to the modelling and languages adopted.

A. *Temporal evolution*

The analysis of the temporal evolution of the scientific production, depicted in Fig. 2, highlights how the interest of the healthcare sector towards process reengineering has grown a in recent years. This goes on par with the digital transition and the introduction of proper Information Technology (IT) systems support in healthcare structures. The presence of an information system that support care delivery operations may improve patient management and patient outcomes (Wilk et al., 2020).

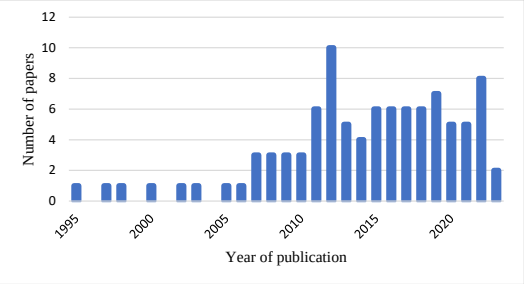

Fig. 2 Temporal evolution of scientific production

B. *Applications sectors*

The possible applications found are very different between them. Fig. 3 shows the distribution of the application sectors. While topic as Operating Rooms (OR), Emergency Department (ED) and materials management are more specific, the other sectors, Clinical Practice Guidelines (CPGs), Clinical Pathways (CP), disease treatment process and IT integration cover a more general area of applications. Whereby the individual applications are indeed ascribable to that particular sector, but at the same time they are declined in more specific cases, e.g., the paediatric clinical pathway rather than the gynaecological one. For this reason, the focus in this paper will be more on OR, ED and materials management, which, besides being a specific field of application, also account for 51% of the papers found.

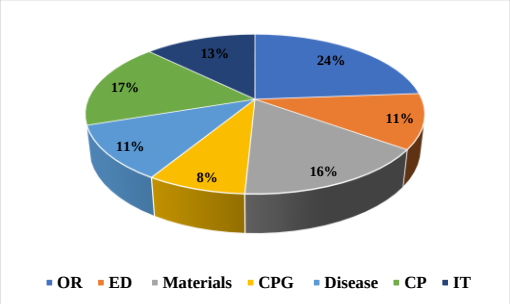

Fig. 3 Application sectors distribution

Operating rooms management

The operating theatre is the most expensive department for an hospital, consisting of about 40% of the budget (Barbagallo et al., 2015). The main objective in this area is to increase efficiency and resource utilization in order to reduce costs incurred while maintaining an adequate level of service. The surgical path is a complex process that involves many different figures. Therefore, when carrying out the optimization process is important to correctly model the flow, to not have a weakly structured process (Wiemuth et al., 2017): among the modelling languages adopted in the literature the Business Process Modeling and Notation (BPMN), developed by the Object Management Group (Object Management Group, 2014a) is the one frequently adopted, not only on modelling the ORs workflow, but also in other healthcare application. This notation is utilized by Barbagallo et al. (2015) to model the workflow in the surgery ward, to better understanding timing and resources involved. Also, they propose the utilization of a scheduling model to further optimize the performances, resulting in an increase of 20% of room utilization rate and 30% more patients. Scheduling models for operating rooms represent a well-developed topic in the research literature, but in this work, it will be not treated in detail because the aim is to offer a more general view. Proudlove et al. (2017) the BPMN notation is utilized as support to the formalization of conceptual models that will be further utilized to generate simulation models. (Wiemuth et al., 2017) and (Sobolev et al., 2008) focus instead on the operations regarding the perioperative process, standardizing the path. The second one also simulates the patient flow in this phase. A different approach, more qualitative is the one by Just et al. (2021), that proposed an informatic tool to compile checklist during a surgery, to obtain a more precise surgical documentation, instead of relying on the memory of the physician that must write the documentation after finishing the surgery. This helps also to reduce the time spent by physician in writing these reports.

Emergency department management

The emergency department is a crucial entity within an hospital. The quality of the care and the patient outcomes provided by this department is strictly related to the Length Of Stay (LOS) of each patient (Kolker, 2008). One of the biggest challenges is overcrowding, that results in increased length of stays and poor-quality care (Sulis et al., 2020). Also, in EDs, the staff is required to make decision based

on the emergency of the patient and the availability of doctors, increasing the level of complexity. For this reason, (Sulis et al., 2020) developed an agent-based simulation coupled with a genetic algorithm as support for decisions about the next patient to be admitted. Other research like (Wang et al., 2013) and (Chan et al., 2012) approach the problem of overcrowding reduction through formulation of mathematical models. (Chan et al., 2012) coupled a mixed model with a decision tree to obtain better decision. A different approach is the one in (Kolker, 2008) that provide a discrete event simulation model to conduct scenarios analysis to better understand the relationship between ED performances and the patient LOS.

Materials management

Pharmaceutical products represent large cost in healthcare industry both for their significant purchase cost and storage costs, and for control requirements (Bertolini et al., 2011), so awareness of logistic become widespread in research (Iannone et al., 2013). Related papers found in the literature deal with case studies following the typical steps of business process reengineering: as-is state definition, Key Performance Indicators (KPI) definition and measurement, to-be state definition, comparison as-is to-be. Bertolini et al. (2011) studied the drug management problem for more hospitals and proposed a centralized warehouse instead of different hospital warehouse located close to each other, introduced in the personnel knowledge the concept of considering an analytical reorder point and its associated lead time, and introduced automation. This led to the reduction of the cost associated. In the reengineering phase they used Icam DEFinition for Functional modeling (IDEF0) as support to the modelling and activity-based costing as support to the costing evaluation. In the work of (Iannone et al., 2013), they utilized BPMN to model the different process frames related to materials management and proposed a mathematical formalization of the inventory management requirements, according to an MRP technique. They carried out a simulation to evaluate the performance of the to-be scenario on a case study. (Gawrońska-Błaszczyk, 2016) analysed three case studies of polish hospitals, focusing on how the introduction of a structured management supported by IT technology, affected the service time and labour time performances. Other works like (Pereira et al., 2016) and (Chanpuypetch & Kritchanchai, 2018) analysed case studies with the support of BPMN to find critical issue to address and redesign.

C. Healthcare process modelling

The fields of application analysed so far show how there is a tendency to rely on process modelling when approaching a problem. Fig. 4 shows the number of papers that adopted modelling techniques: about 66% of the articles make use of modelling, demonstrating how useful these techniques are.

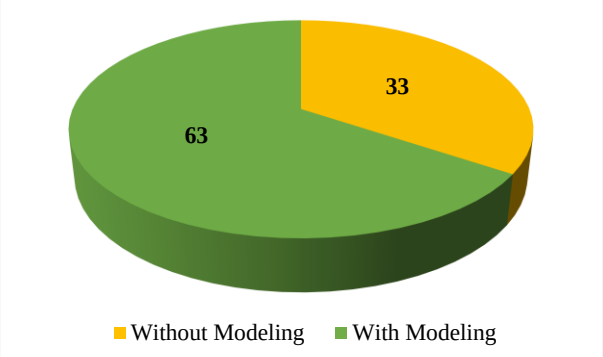

Fig. 4 Adoption of modelling techniques

Indeed, process modelling helps to achieve standardization of clinical procedures and decision-making, minimizing variability. It allows different kind of process analyses and serves as guide in the automation of activities and information flows (Pufahl et al., 2022). Some of the adopted modelling language found in literature are BPMN, Unified Modeling Language (UML), IDEF0, Decision Management and Notation (DMN), Case Management and Notation (CMMN), Role Activity Diagram (RAD). Fig. 5 shows the percentage of adoption of each modelling language, in the 63 papers. Among them the most adopted are BPMN, IDEF0 and UML. The class "Other" refers to either to other languages or to modelling practice that do not use structured languages.

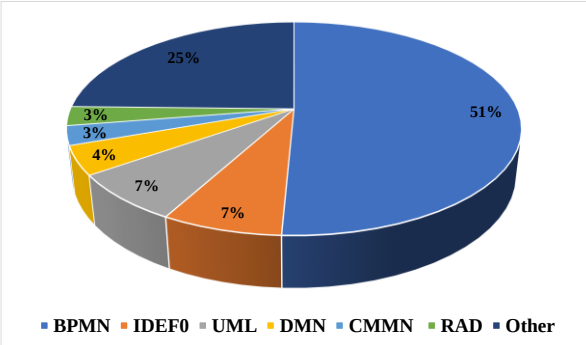

Fig. 5 Modelling languages distribution

BPMN is the one that find major success on the research field (more than 50%): it is a modelling language from (Object Management Group, 2014a) that provides a graphical notation for specifying business process in a business process diagram, that

is intended to be easily understandable by the users and also allows to translate diagrams into software process components. Apart from the fields of application already covered, where BPMN is often used, it also has a place in other applications like modelling CPGs and helping the software integration (Martínez-Salvador et al., 2023; Yang & Zhang, 2021), modelling of the CP (Iglesias et al., 2022; Szelągowski et al., 2022) and workflows (Combi et al., 2019; Ramos-Merino et al., 2018), and in the modelling of disease treatment processes (Kopecky & Tomaskova, 2020; Lauk et al., 2022; Tomaskova et al., 2019). The Object Management Group offers also other model notation as DMN (Object Management Group, 2015) and CMMN (Object Management Group, 2014b), that are designed to work alongside, to provide precise specifications of business decisions and rules (DMN) and to express a case as an interchange format for exchanging cases (CMMN). The works (Wiemuth et al., 2017; Yang & Zhang, 2021) shows how to make use of the combination of these techniques combined.

In Fig. 6 a summary of the approaches adopted and objectives in each application field is reported. To summarize the findings in the analysed literature, we can say that BPMN is the most common modelling language for the healthcare process modelling due to its easy comprehension and its capacity of being easily understandable. It also emerges how the papers that focus on process modelling are more qualitative respect other papers that apply more quantitative methods to the related applications.

Application field	Approach	Objective
Operating Rooms	Discrete event simulation, Scheduling algorithms, IT intergration	Efficiency, resource utilization
Emergency department	Agent based simulation, decision trees, decision support models	Lenght of stay, overcrowding, bed utilization
Material management	Activity based costing, mathematical models, MRP formulation	Cost reduction, service time, labour time
Process modeling	BPMN, UML, IDEF0, DMN, CMMN	Standardization, resource allocation

Fig. 6 The applications fields

The studies with quantitative approaches are mostly the ones are related to the three main application field mentioned earlier. In these papers is often present the analysis of a real case study to support the research, because the model should be validated and tested to measure effectiveness. However, this approach could be tailored to the case study and inflexible to possible challenges not present in the particular case. Discrete Event Simulation (DES) is a typical approach that can support quantitative studies. It is useful in application that involves patient flow, to evaluate the possible changes in the organisational model (Sobolev et al., 2008) and their influence on performances, such as resources utilization (Williams et al., 2010). Al-Safadi & AL-Sulaiman (2011) simulated the patient flow in a clinic under different number of resources available (e.g., number of receptionists, nurses and physicians), in order to give a prediction of performance indicators to support management decisions. They found out how increasing the number of receptionists eliminates the waiting time for check-in but increases the waiting time for examination. They also noticed how the number of nurses does not change the doctor's utilization, but can change the waiting time before examination etc. Based on the results obtained by the simulation they reported some recommendation to follow. Some relevant application of simulation related to patient flow in literature are (Lesselroth et al., 2011) that simulates the patient flow in a check-in and medication ambulatory clinic kiosk, while (Williams et al., 2010) simulates the flow related to operating rooms also measuring physician, operating room and bed utilization. They proposed an improvement scheme of patient arrivals that leads to reduced waiting times of patients and reduced average hours employed of the resources. As already mentioned also in the works of (Kolker, 2008; Sobolev et al., 2008) the simulation is utilized to support the patient flow in a quantitative way. What the current literature lacks the most is the formalization of standardized process models, that should be adaptable depending on the real case study problems through the formalisation of best practices.

IV. RESEARCH AGENDA

From the discussion about the present work in literature there is evidence of how the approaches to a reengineering or a modelling problem are often addressed to specific case studies. While in quantitative terms is almost necessary the analysis of a case study, both for data retrieval and model

validation, from a modelling point of view the analysis of a specific case study may not be strictly needed. Instead, the direction in which the research could go may be toward the formalisation of general models, which can later be easily adapted to specific needs. In this regard, a similar approach was pursued by (Pufahl et al., 2022), that have identified modelling challenges and proposed some best practices. A similar approach could be extended to entire processes (e.g., emergency department, or operating rooms) to provide best practices that consist in model of process frames, that can also be combined on necessity in form of business process models. The idea is to offer a modular framework, composed by model blocks of best practice, to cover a large set of possible activities and to provide an easy merging with other model blocks. The proposed framework should be also validated, so the application to case studies is needed. However, wanting to reach a formulation which is robust towards different tailored specification, we need to observe different scenarios. On this regard, we will have the possibility to gather data from several hospitals in Umbria region, and to simulate different scenarios using discrete event simulation as support.

The formalization we want to obtain, could provide to hospitals managers and coordinators best practices to follow when approaching a problem, that integrates and extends the clinical practice guidelines already in place, helping also in terms of documentation and personnel training. Also, it will function as benchmark once the reengineering phase is completed. The steps to arrive at the formalisation should be the following:

1. selection of application field.
2. Further analysis of the literature related to the field.
3. Identification of most challenging issues and solutions applied.
4. Identification of KPIs to measure the performances.
5. Building of references models using BPMN.
6. Data collection to conduct simulation studies.
7. Simulation studies on set of case studies.
8. Evaluation of the best model. If needed, return to step 5.
9. Establishment of model blocks.

V. CONCLUSIONS

In this paper a systematic literature review on business process reengineering and modelling was conducted, with the aim of having a general overview on what are the scientific approaches adopted on this field. A discussion about the main application fields found and the approaches adopted has been carried out. The main application discussed are the operating rooms, emergency department, material management and process modelling. We found that most of the work tend to provide quantitative support with real case study, however, this may result in a greedy point of view, that focus on the optimization of that specific environment. From a managerial point of view and from a pure business process reengineering perspective, this is completely justified, however a more general approach to problems, through the formalisation of best practices could lead to an overall growth of the sector. It is also important to push the digital transition to obtain a direct integration of the process model and the related information and documentation with the information system. The limitation of the current study lies in its generality: being the way we decided to explore the process reengineering applications in the literature general and not focused on a certain application field, the analysis conducted cannot go too much in detail for every aspect. Furthermore, in order to develop the general process model formalization further literature review about each specific process to model will be needed, because for a better standardization and modularity, all the variables must be taken into account to be included. In the future research agenda, using the data from a network of Umbria region hospital, the research toward the definition and validation of models that serves as benchmark will be carried out.

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