Service Reconfiguration in Healthcare Systems: The Case of a New Focused Hospital Unit

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Abstract In the last years, hospitals have been pushed to change their services in the final attempt to maximize both care effectiveness and efficiency. In particular, emergent trends are prompting hospitals to reorganize current activities around patients and their diagnoses rather than in discipline focused departments. This research aims to support service reconfiguration by proposing a methodology exploiting the benefits of process mining techniques in the healthcare systems. In order to support decision makers during this process, the method mainly identifies/analyzes the patient flow and estimates the resources necessary for specific classes of patients. A case study also shows evidence deriving from its application to a new Patient-Focused Care Unit.

Keywords Process mining · Service configuration · Resource planning Patient-Focused Care (PFC) · Healthcare · Service Planning

1 Introduction

In the last 25 years, hospitals have taken sundry strategic improvement initiatives in the organization of care activities.

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P. Cappanera et al. (eds.), *Health Care Systems Engineering*, Springer Proceedings in Mathematics & Statistics 210, https://doi.org/10.1007/978-3-319-66146-9_16

The benefits of a multidisciplinary approach in patient care, for example in treating cancer but also in many chronicle diseases, has been widely recognized in the healthcare literature [22] and boosted the dissemination of Patient-Focused Care (PFC) principle [14]. In this direction, one of the most relevant initiative is the creation of hospital service lines (or product line), in which care is organized around an identifiable service (e.g. cardiac care), a segment of market (e.g., child patients), or some combination of these two [12].

Positive expectations deriving from a centralized approach to specialist services are mostly linked to the potential to reduce variations in care. Thus, innovative "patient-centric" organizational models (e.g. specialized care units and patient care pathways) were proposed and implemented in numerous healthcare organizations in the attempt to offer patients the best chance of (1) receiving high quality medical procedures, (2) being served by a team of specialists, which is able to tailor treatment, and (3) guaranteeing access to specialist counselling, supportive care and rehabilitation. Evidence of such a trend can be found in the cases of specialist Breast Centres [2] and other specialized units which are currently largely diffused in all Europe. See the German case for Prostate Cancer Units, and the British Urological Malignancies units.

This emergent trend is prompting hospitals to reorganize current activities around patients and their diagnoses rather than in discipline focused departments [13]. However, devising service lines, around a specific group of patients with similar diagnosis and needs, entails the most substantial reconfiguration of hospital operations and has a huge impact on the care process, particularly when the resources to serve these patients are physically co-located [12]. Most critical decisions belong to planning the necessary resources, organizing the workflow of activities and the coordination of internal/external processes, defining the best layout for the new unit [12]. In fact, while addressing the aim of improving the care effectiveness, other conditions call for reducing costs by improving the system efficiency. Therefore, a methodology supporting managerial decisions during the reconfiguration process is extremely valuable.

Concluding, reorganizing activities for a specialized unit or simply a pathway requires effort for process analysis and planning in order to explore the feasibility of solutions: effective/efficient methods for pathways identification and analysis, demand planning and forecasting, resource allocation and optimization systems. This work aims to support decision makers in such reconfiguration process by proposing a feasible and efficient method for patient flow identification/analysis and for resource allocation. In so doing we also set the basis for an integrate modelling and planning of activities within healthcare organizations.

2 Theoretical Background: Resource Planning and Patient-Flows

The planning of resources in healthcare organizations requires the balancing of two opposite objectives: maximizing service levels and minimizing resource/capacity costs [5]. More resources (like doctors, instruments, beds) reduce patient waiting time, staff workloads and congestion. On the other hand, more resources increase the operating costs of the unit. In balancing these two goals, the main problems are the stochastic nature of the healthcare demand and the wide diversity of patients' conditions. For this last reason, this context appears to be similar to the engineer-to-order [11] or make-to-order environment in manufacturing.

The problem of planning resources and activities could be addressed with different decision horizon length. Hans et al. [11] and Vissers et al. [26] in their healthcare planning frameworks identified the strategic level (very long term), the operational level (short term), and an intermediate level (medium/long term) recognized as the tactical level. Until now, the researches focused particularly on the operational level (OR scheduling and bed management), with very few works at strategic level and, to a lesser extent, at tactical level [9, 11].

Literature shows a lack of efficient approaches for handling resource planning at strategic-tactical level in healthcare systems. This is mostly due to the peculiar characteristics of healthcare environment like heterogeneity, patient participation in the service process, simultaneity of production and consumption [11]. Specifically, one of the main limit in the medium-long term is the poor knowledge of the patient-flows that instead is very important in order to plan resources and organize/reorganize processes [4, 6, 10, 25].

Healthcare processes are in fact difficult to study: they are deeply interconnected, dynamic, multidisciplinary in nature, numerous, and ad hoc for a single patient [1, 7, 15, 18, 27]. Thus, traditional approaches to business process analysis are low effective and scarcely efficient in this context: they are often very time-consuming and might not provide an accurate representation of the processes and patient-flows.

More recently, the pervasive adoption of information systems within healthcare organizations and the development of effective data analysis techniques (e.g. process mining) have raised data availability and contributed to overcome such problems in finding and mapping patient-flows and analyzing the related healthcare processes [17, 18, 21, 23, 24].

As a combination between data mining and traditional model-driven Business Process Management, process mining aims to discover, analyze and improve processes exploiting the event logs available in the information systems [23]. In so doing, it tries to understand how processes are actually performed and which resources are involved, rather then what is prescribed or supposed to happen [16].

Though various authors have already shown its suitability [17, 19], the use of process mining technique to support healthcare management is a relatively new and unexplored field still valuable to investigate in order to support the planning of activities and resources inside healthcare organizations.

3 Research Design

3.1 Research Objective

This research aims to develop a methodology supporting service reconfiguration in healthcare systems. It exploits the process mining approach for identifying the service workflow of activities and the related resources, which are necessary for a specific class (/group) of patients. Knowledge is extracted from event logs by using the information stored in the hospital information systems.

Specifically, supporting the process discovery, analysis and monitoring phases, the following expected contributions can be identified:

1. Improvement of healthcare services planning: e.g. reduction of services fragmentation. Space, resources and timing of services could be easily analyzed and reconsidered coherently to a patient-centric perspective.
2. Enhanced resource allocation. Resources (space and beds, equipment and staff) could be organized more effectively and efficiently to provide sufficient resources for the involved classes of patients. In a shorter view, the efficiency of the method could allow managers to dynamically update and review plans.
3. Enabling an integrated resource planning at Hospital level. An extension of this modelling approach to all classes of patients served by the hospital may support managers to develop effective and integrate planning of resources in the medium-long term.

In this paper, we report some preliminary evidence deriving from the application of the methodology for the creation of a Patient-Focused Care Units, a Lung Cancer Unit in Italy. The method was applied concurrently to the traditional approach usually adopted by the management in order to test its suitability and compare benefits/costs.

3.2 Methodology

The methodology draws on the process mining approach [3, 8, 23] and goes through the following five main phases: Problem Statement; Log Preparation; Log Inspection; Process Discovery; Activities and Resources Evaluation.

1. *Problem Statement* aims to define the unit of analysis i.e. the class(es) of patients under investigation. For example, some selected groups of patients taken over by a hospital focused unit, a specific Diagnostic Related Group (DRG) or any other patient group identifiable inside the hospital.
2. *Data Retrieval and Log Preparation* create an adequate event log by preprocessing the event data gathered from one or more information systems.

3. The *Log Inspection* offers first insights about the followed patient-flows, permits to filter incomplete and/or outlier cases, and provides some useful descriptive statistics as the number of cases, the total number of events, the number of different sequences, etc.
4. *Process Discovery* phase aims to find the patient-flows under investigation, starting from the event log. It is possible to apply many techniques to act process discovery like α-Algorithm, heuristic miner, fuzzy miner, genetic miner and region-based miner. For complex environment, the most promising approaches seems to be heuristic mining, genetic mining and fuzzy mining [23]. However, in order to point out clear patient-flows it is sometimes useful to combine more process maps obtained using various process mining algorithms. In this phase, the involvement of experts (medical staff, physicians, nurses) can support to review, refine and validate the achieved patient-flows.
5. *Activities and Resources Evaluation* aims to estimate the activities consumptions and the related resources required for a specific class(es) of patients, starting from the patient-flows and using the process mining tools. Process mining tools like ProM and Disco®, can help decision makers to identify an "average" patient-flow with the correspondent expected demand of activities. In order to connect the activities to the related resources, a Bill Of Resources (BOR) could be used. The BOR is a BOM-like structure that includes all the resources needed to perform a specific class of activity [20], including people (doctors, physicians, nurses), instrumental resources, and materials.

4 Case Study

The methodology was applied to support a real case of service reconfiguration at the University Hospital of Pisa. The management was considering to reorganize the service for the lung cancer patients, by evaluating the creation of a Lung Cancer Unit in order to provide a better care to this serious class of patients. Management agreed that before to launch the new Patient-Focused Care Unit, it is important to known the main patient-flow, the most relevant activities, their interactions and the related resources. This is also interesting in order to evaluate the best layout for providing the service.

As a first step, we started formalizing the patients with lung cancer as the class of patients under investigation in order to set up a Lung Cancer Unit. Then, we created an adequate event log with the all the relevant instances, by aggregating and refining data coming from different information systems. We collected data of lung cancer patients served in the year 2014. The generated event log comprised more than 10000 events.

After a first inspection of log, we removed the outlier cases (after this operation, the dataset contained 470 cases) and obtained some relevant statistics about the process, such as the number of different activities, the number of different sequences/paths etc. For instance, descriptive stats revealed that the patients utilized 61 different activities, but that the 10 most frequent covered more than 95% of total events.

During the process discovery phase, we applied different process mining algorithms using two process mining tools (ProM and Disco®): the heuristic miner, the fuzzy miner, and the inductive miner. Along with the medical experts, we reviewed and refined the various process models obtained in order to achieve the most correct patient-flow. Figure 1 shows the resultant patient-flow expressed in BPMN language. We excluded from the map the less frequent and not pertinent activities. Thanks to this evidence, it was possible to support the new service planning with the purpose of reducing the services fragmentation in term of time, resources and space. In fact, doctors and managers can get a tangible proof of which activities are critically interconnected, those more relevant, which could be performed on the same day, like general physic examination and CT scan, and thus they might

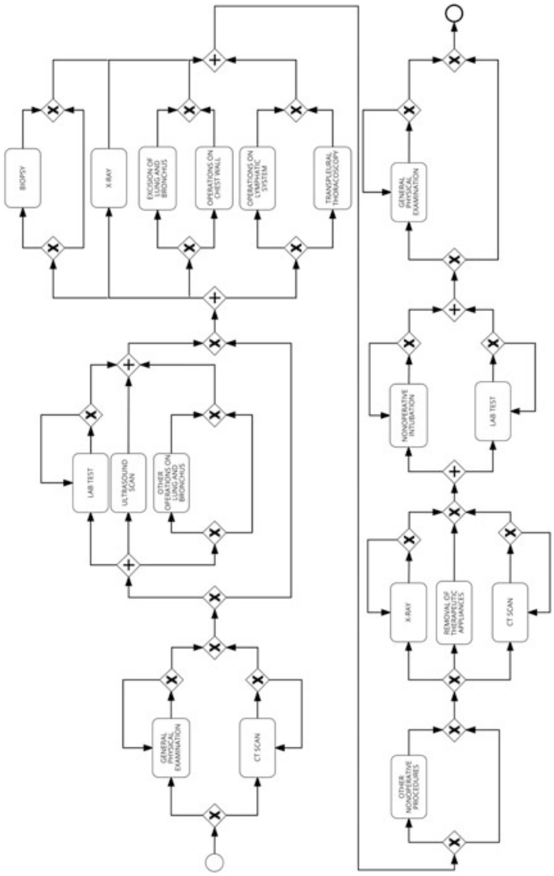

Fig. 1 Patient-flow resultant for lung cancer patients

Activities	Average demand per patient
Lab test	8.14
Physical examination	4.51
X-ray	2.60
Non-operative intubation	1.29
CT scan	0.89
Excision of lung and bronchus	0.86
Other operations on lung and bronchus	0.56
Removal of therapeutic appliances	0.55
Ultrasound scan	0.49
Operations on lymphatic system	0.34
Transpleural Thoracoscopy	0.24
Operations on chest wall	0.20
Other procedures non-operative	0.09
Biopsy	0.08

Fig. 2 Activities for an average lung cancer patient

organize appointments and physical layout accordingly. Furthermore, the process map makes also possible to get relevant information on how to streamline the current patient-flow and devise an ideal one for future improvements.

The last step, activities and resources evaluation, provided us the average volume of activities required by a patient affected by lung cancer. Exploiting ProM and Disco®, it was possible to estimate the overall demand of activities requested by the lung cancer patients. Starting from the total volumes of activities and observing the patient-flow, we could calculate the activities necessary for an "average" patient. Figure 2 reports the average demand of activities by a lung cancer patient.

Showing the average demand of activities, possibly its variability in time, and related resource consumption, outcomes from this last step could really support managers in taking decisions about the creation/implementation of the new Lung Cancer Unit. For example, they can easily estimate the needing resources for the service, starting from the average demand of activities and using the number of patients as a parameter (in term of space, beds, equipment, and staff). Also, they can evaluate the feasibility of the new focused unit in respect to a number of variables as such as available space and resources, law and regulations concerning to the specialized staff etc.

On a next step of the research, we aim to finalize the BORs in order to complete the overall analysis of resources related to the patient-path. Moreover, this information could also drive decisions about new investments or resource centralization/sharing and enable what-if analysis, simulations, and other more in-depth analysis.

5 Discussion and Conclusions

This work respond to the need of a methodology supporting decision makers when a healthcare organization is considering to reorganize the delivery of cares or to introduce a new service in its portfolio. This is an increasingly frequent situation in this service context [12]. The relevance of the proposal is confirmed by a lack of efficient approaches and tools for supporting activity and resource planning in the medium-long term, able to handle the peculiar characteristics of healthcare systems [9, 11].

Findings suggest that the proposed approach can profitably support managers during the re-organization of services (e.g. a new Patient-Focused Care Unit) by estimating the patient-flows and the activities/resources which are necessary for different classes of patients. This is valuable in order to improve the overall service planning, reduce the services fragmentation and optimize resource allocation. A deep comprehension of the patient-flows, in fact, enables to streamline business processes and can support performance analysis.

Moreover, evidences from the case application also show that the proposed method is quite efficient and easy to apply in a real environment. Thus, managers could also periodically review the path in order to check if the service flow and the related demand of activities and resources have changed. This would allow to dynamically modify the service planning and resource allocation.

As an addition, the extension of the proposed approach to the entire organization could enable an integrated planning of the activities and resources within the healthcare organization. Specifically, the method would help managers firstly to investigate each class of patients and the related patient-flows, and then to aggregate their demands for activities and resources. In so doing, it could also provide interesting insights to set-up (new investments) and manage efficiently several hospital subunits (like X-ray) or other shared resources.

Finally, discovering the activities and resources linked to the different classes of patients, this method could support cost accounting in an Activity Based Costing perspective.

Clearly, some critical issues still remains, as for example the possible coexistence of two or more diseases in the same patient. The service and resource planning for these cases of comorbidity could be more difficult. Moreover, the case application we assessed concerns just a single class of patients, therefore this circumstance could affect meaningfulness and generalizability of our investigation.

Nevertheless, the positive results of this preliminary study encourage us to extend the research to a wider set of services and patient classes.

Acknowledgements We thank the Direction of the University Hospital of Pisa, and in particular Dr. Marco Nerattini, for their support and precious contribution to the research.

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