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Complexity Analysis of a Business Process Automation: case study on a Healthcare Organization

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Abstract

Healthcare organizations have been struggling to get Business Process Management (BPM) and associated Information and Communication Technologies (ICT) properly aligned to improve their patients' service and quality of care. Nevertheless, the highly structured nature of larger organizations such as hospitals hampers this alignment, and commonly ICT is applied to isolated tasks or fragments of processes. In this paper, we present and discuss the results, in terms of complexity, of the introduction of a new scheduling system within the medical appointment and exam business processes of a large hospital. During the case study, we began by modelling the processes using the Business Process Modelling and Notation (BPMN) standard. We then used abstract metrics to compare the complexity between old (before the introduction of the scheduling system) and new processes, and interpreted the obtained results. Finally, we derived important conclusions that will help guide us in further business process optimization endeavors.

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1. Introduction

Business Process Management (BPM) has recently been used as a broader concept that includes the activities of modelling, deployment, execution, monitoring, analysis and optimization of business processes[1,2]2.

The relation between the use of Information and Communication Technology (ICT) and business process reengineering has also been long explored, with proved results in several industries, from primary activities such as logistics and manufacturing, to supporting activities such as accounting and overall management[3].

Nevertheless, the healthcare domain is still to see a fair adoption of BPM, even if we consider discretely each BPM main activity. Healthcare is craving for BPM[4], mainly due to the need of being flexible in their processes, the existence of many distinct and non-interoperable ICT within a healthcare organization, and the need to monitor efficiently and improve they resource usage and overall patient satisfaction.

The use of ICT to improve business processes can be measured under 4 distinct levels of risk/return: automation, rationalization of procedures, business process reengineering (BPR) and paradigm shift[5]. Automation regards to the transformation of a certain manual task of a business process into a task that can be performed or assisted by ICT, while rationalization involves streamlining existing activities and resources to increase process effectiveness. BPR is concerned on a higher return/higher risk approach, by using ICT to perform a complete redesign of a certain business process or set of correlated business processes, while in a paradigm shift ICT changes the business itself.

In this paper, we describe a case study where we analyzed the impact of a new medical appointment scheduling system (ICT) deployed in a large hospital in Lisbon, Portugal. We use complexity (design time) process metrics to measure this impact, considering the affected business processes. Then, a comparison between old (before the new scheduling system) and new processes is driven to analyze not only the differences, but also to conclude about the suitability of these kind of metrics, regarding the level of impact observed by the introduction of the new system.

This paper is organized as follows: section 2 presents related work on the use of BPM in healthcare organizations, the associated ICT and the complexity metrics adopted. Section 3 presents an example on the changes observed in a fragment of one of the affected processes, using the Business Process Model and Notation (BPMN)[6] standard. In section 4 we present the results obtained from our complexity analysis, and section 5 concludes the paper and presents future work.

2. Related work

Despite of Business Process Management Systems (BPMS) being around for more than 20 years, and the continuity of care being discussed over 50 years, healthcare organizations still strive for an effective the use of ICT to deliver better service to their patients[7]. The lack or misuse of ICT and the strict organizational structures of hospitals that increase the difficulty of optimizing processes with ICT often result in problems. These include, among others, in patients having to wait, medical procedures becoming impossible to perform, results being needed urgently but missing, deriving on repeated tests and exams. These commonly result in the increase of patients stays and overall running costs[4].

Adding to this, ICT-related hazards such as its failure and negative effects on patients or users have been reported[Erro! A origem da referência não foi encontrada.]. Also, higher rates of Hospital Information Systems (HIS) were rejected or misused due to user-resistance[9]. Therefore, a good balance between the introduction of ICT and Business Process Reengineering (BPR) is often difficult to achieve, since it includes several and correlated critical success factors, such as user training, management commitment, clear tangible goals as well as a sponsor for BPR project[3].

On the other hand, cases of pure automation of process activities have been successfully reported in healthcare, as they can improve managing recorded information about patients and improve clinical workflow regarding storage and retrieval of information[10]. Additionally, they are subjected to less critical success factors, since the main goal is to achieve operational return on small parts of the process and/or single activities. Examples include the use of BPM in Ilahi *et al.* to model and improve telemedicine and home healthcare processes[11], or the use of ICT to support single clinical tasks such as diagnosis[12].

To evaluate the complexity of business processes, two kinds of metrics are proposed in Cardoso[13]: 1) activity complexity; and 2) control flow complexity (CFC). The first one only calculates the number of activities a process has. While these metrics are very simple, they are important to complement others[13]. The number of activities in a process (NOA) counts the number of basic activities while the number of activities and control-flow elements in a process (NOAC) also counts other kinds of process elements, including decision nodes, forks and joins.

For the control-flow complexity (CFC), we use two correlated metrics: 1) absolute control-flow complexity (CFC_{abs}), which is the sum of the CFC regarding each type of gateway (OR, XOR and AND gateways); and 2) relative control-flow complexity (CFC_{rel}), which is given by CFC_{abs}/(sum of gateways). Rolón *et al.* analyse and validate also these metrics for business processes modelled with the BPMN standard[14].

In the next section, we provide a BPMN example of a fragment of the medical appointment scheduling process, and perform a complexity analysis under these metrics.

3. Medical appointments scheduling process models – an example

We present in Figures 1 and 2 an example of two changes occurred in the medical appointment scheduling process by the introduction of the new scheduling system. The complete model of this process is actually larger, and in Figures 1 and 2 we only show a fragment of it (there were more changes within the entire process, as well as in other correlated processes).

In Figure 1 we can observe that the administrative staff had to select, within the *old* process, each physician of a certain medical specialty to find an available timeslot for the medical appointment, in case the previous physician did not have a free timeslot within clinical time. Clinical time is the maximum delay time to schedule a medical appointment (after, for example, a certain medical procedure).

The *new* process in Figure 2 reveals that the new scheduling system can suggest for the next timeslot available for all physicians within a certain specialty, without having to select them one by one, as it occurred in the *old* process. Consequently, the "Check for more specialty physicians" task in the *old* process was removed, as well as the associated decision node. These changes are signaled in both Figure 1 and 2 with (orange) dotted rectangles.

For the example in Figure 1, we have the following calculations regarding the NOA, NOAC, CFC_{abs} and CFC_{rel} complexity metrics:

- NOA (number of activities) = 9;
- NOAC (number of activities + number of gateways) = 11;
- CFC_{abs} (absolute control-flow complexity) = sum ($CFC_{XOR\_gateways}$) = $= CFC_{XOR\_gateway(clinical\ time)} + CFC_{XOR\_gateway(specialty\ physicians)} = 2 + 2$ (number of alternative paths out of each gateway) = 4.
- $CFC_{rel} = CFC_{abs}$/(sum of gateways) = 4/2 = 2.

Table 1 shows the calculations for the complexity analysis of the *old* (Figure 1) and *new* (Figure 2) fragments of the medical appointment scheduling process.

Table 1. Complexity analysis for the process fragments of Figures 1 and 2

Complexity metric	*Medical appointment scheduling fragment*	
	Old process (Fig.1)	*New process (Fig.2)*
NOA	9	8
NOAC	11	9
CFC_{abs}	4	2
CFC_{rel}	2	2

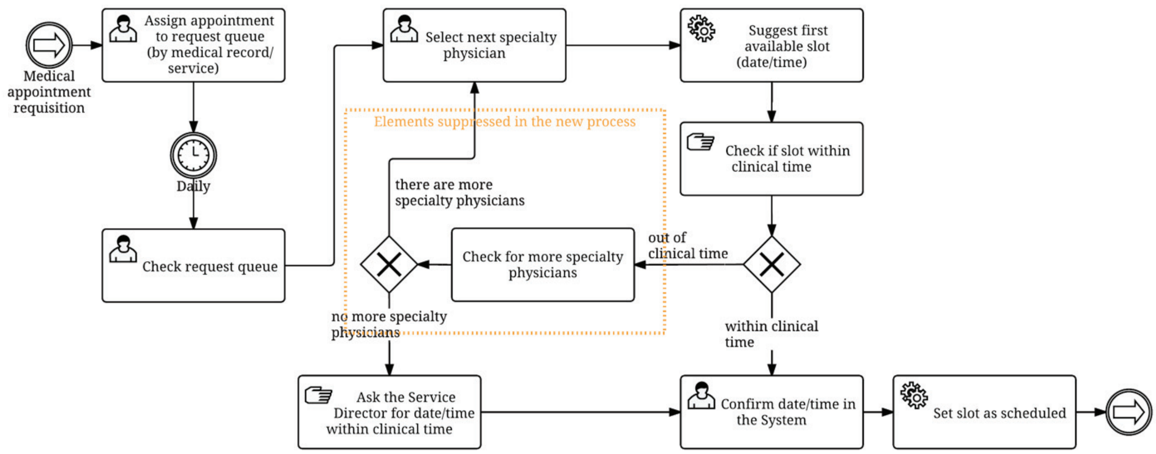

Fig. 1. BPMN model for a fragment of the *old* medical appointment scheduling process.

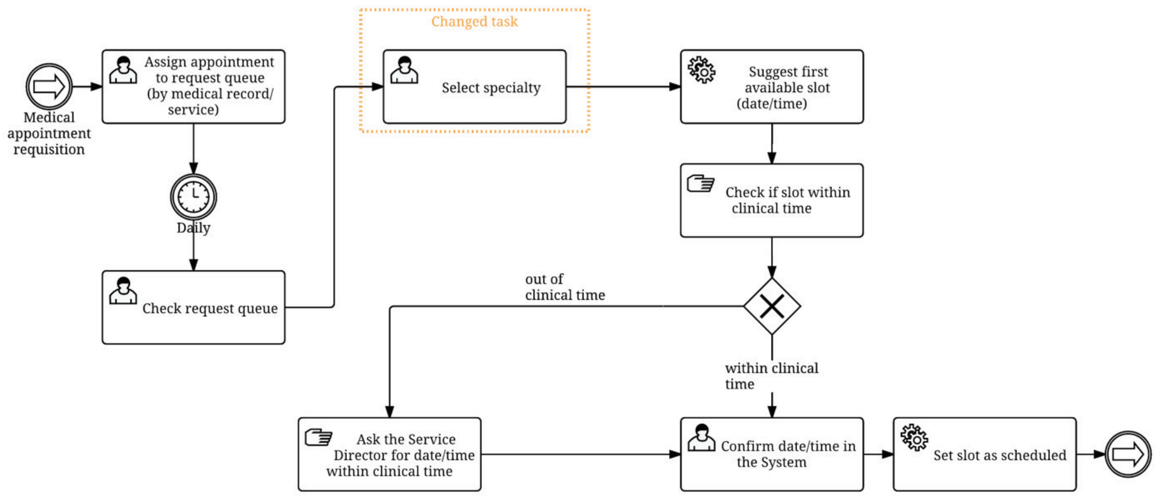

Fig. 2. BPMN model for a fragment of the *new* medical appointment scheduling process.

In spite of this example being in favor of a decrease on the complexity regarding the fragment of the business process involved, not all changes introduced by the new scheduling system resulted the same way. Next section illustrates the overall complexity analysis, considering one more business process highly affected by the scheduling system (exam scheduling), as well as a combined version of these two isolated processes.

4. Complexity analysis

Based on the complexity process metrics described in section 2, we present in Table 2 the comparison results concerning the complete *old* and the *new* processes, namely:

- *Medical appointment scheduling* process, which deals with the scheduling of an isolated medical appointment;
- *Medical exam scheduling* process, which deals with the scheduling of an isolated medical exam;

- *Medical appointment and exam scheduling* process, which deals with the scheduling of a combined medical appointment and exam scheduling.

Table 2. Complexity comparison between the *old* and the *new* medical appointment scheduling process

Complexity metric	*Medical appointment scheduling*		*Medical exam scheduling*		*Medical appointment and exam scheduling*	
	Old process	*New process*	*Old process*	*New process*	*Old process*	*New process*
NOA	25	26	22	23	50	49
NOAC	33	33	27	27	52	65
CFC_{abs}	16	14	10	8	31	33
CFC_{rel}	2	2	2	2	2,07	2,06

The results illustrate that, overall, the new scheduling system did not have much influence on the number of activities (NOA), all around the three analyzed processes. As to the number of activities and control-flow elements (NOAC), a significant difference can be observed on the combined medical appointment and exam scheduling process, which registered an increase of 13.

Regarding absolute control-flow complexity (CFC_{abs}), we can only observe little differences between the *old* and *new* versions of the three considered processes. While both isolated processes were decreased by 2, the combined process was increased by 2. Finally, the relative control-flow complexity (CFC_{rel}) practically remained the same all over the new versions of the processes that used the new scheduling system.

5. Conclusions and future work

We presented in this paper a complexity analysis comparing the business processes that were changed by the introduction of a new scheduling system in a big hospital. It is important to clarify that this kind of business process reengineering in these processes was, in a short term, the only one possible to implement. This is mainly due to the technologies already used in main Hospital Information System (from the same provider of the new scheduling system), and the number of different ICT systems and applications that are somehow dependent and/or integrated with this main system.

We used BPMN to model both *old* (before the scheduling system) and *new* (with the new scheduling system) versions of the processes, and performed the necessary calculations to achieve the values regarding the used complexity metrics. These are defined in Cardoso, which take into account the number of activities (NOA), control-flow elements (NOAC) and the control-flow complexity (CFC).

We can derive the following conclusions from the obtained results:

- The complexity metrics used helped us discover that the new business processes practically remained as they were, and that the new scheduling system did not bring a significant reduction on the processes' complexity, taking into account the number of activities, control-flow elements, and overall control-flow complexity;
- This is clearly a case of the "Automation" level, regarding the impact of a new ICT in an organization, as defined in Laudon & Laudon[5];
- For a complete complexity analysis by using these metrics, we will need to apply them also to the resource and data perspectives of the business processes;
- The main return observed in the field by the introduction into the processes of the new scheduling system cannot be observed by using (design time) abstract complexity metrics. We will need to analyze these processes taking into account (runtime or case-based) performance metrics such as the number of scheduled medical appointments per day or the rate of occupancy of a certain medical exam equipment;
- A possible runtime optimization achieved by the new scheduling system can also be observed on subsequent processes and related metrics, such as the medical appointment process and the subsequent rate of attendance/no-show.

As future work, we are planning to proceed with the calculus of the main return on this scheduling system and/or other ICT-based systems by comparing runtime process key performance indicators (KPIs - such as the ones mentioned above).

We are also already including these business process-related KPIs within an Enterprise Architecture (EA)-based platform (see Rijo *et al.*[15]). Here, the correlation between processes, supporting ICTs and main process KPIs can be better observed and communicated throughout the entire hospital, involving management, ICT department and healthcare professionals.

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