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SPECIAL SECTION PAPER

A process mining-based analysis of business process work-arounds

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Abstract Business process work-arounds are specific forms of incompliant behavior, where employees intentionally decide to deviate from the required procedures although they are aware of them. Detecting and understanding the work-arounds performed can guide organizations in redesigning and improving their processes and support systems. Existing process mining techniques for compliance checking and diagnosis of incompliant behavior rely on the available information in event logs and emphasize technological capabilities for analyzing this information. They do not distinguish intentional incompliance and do not address the sources of this behavior. In contrast, the paper builds on a list of generic types of work-arounds found in practice and explores whether and how they can be detected by process mining techniques. Results obtained for four work-around types in five real-life processes are reported. The remaining two types are not reflected in events logs and cannot be currently detected by process mining. The detected work-around data are further analyzed for identifying correlations between the frequency of specific work-around types and properties of the processes and of specific activities. The analysis results promote the understanding of work-around situations and sources.

Keywords Business process work-arounds · Process mining · Compliance checking

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1 Introduction

Compliance management has received much attention in recent years. The business necessity of meeting standards such as ISO and legislations such as Sarbanes Oxley act has driven technological solutions, most notably process mining techniques [5], intended to check and measure compliance of actual business processes to required procedures.

In the general research area of compliance management, several types of activities have been identified [13,14,26]. In particular, these include compliance checking, which checks whether certain constraints are or will be met, and compliance improvement, where actions are proposed for improving compliance. Compliance checking can be further divided into forward compliance checking, targeting the design and implementation of processes where compliance is enforced, and backward compliance checking, focused on the detection and diagnosis of non-compliant behavior. Compliance improvement modifies the process to improve compliance. This can be done based on diagnostic information resulting from backward compliance checking, and with the use of forward compliance checking techniques.

Considering business processes that are designed to meet the necessary constraints and support organizational and business rules, incompliance can stem from various reasons. Compliance improvement actions should address the reasons that underlie the incompliant behavior. For example, if the reason for incompliance is lack of knowledge of the required procedures, compliance can be improved by training activities and by providing better employee guidance and monitoring through the process management system. Incompliance can also stem from exceptional situations, which are not defined as part of the normative business process. If such exceptions occur frequently, the process model can be amended to accommodate them and standardize the way exceptions are handled.

More problematic is intentional incompliance, namely, when employees are fully aware of the procedures they are required to follow, but decide for their own reasons to act differently. As an example, consider a situation where a customer is urgently requesting some goods and a truck is about to embark in his direction. An employee might decide to immediately load the goods on the truck, while the "paperwork" of registering the order and the delivery will be done afterward in retrospect. Compliance improvement actions in such situations need to address the specific reasons for the incompliant behavior and may include management and disciplinary actions, process redesign, modifications in the information system, and more. A first step would be detection and quantification of this behavior, followed by investigation of its sources.

This paper addresses backward compliance checking targeted at intentional incompliant behaviors, termed business process work-arounds. This term refers to the employees' perception of required procedures as an obstacle for some goals they wish to achieve, when intentionally working around these procedures. Poelmans [22,23] defines a work-around as a coping strategy that deviates from the strategies that have been defined in the workflow system. Work-arounds are generally considered as a negative phenomenon, assuming the standard process has been designed and optimized to achieve desired business performance. However, since these are intentional actions of employees, we assume they are performed for certain reasons. Poelmans [22,23] points out that end users work around the system to save time and/or efforts or to avoid the limitations of the system. Our previous findings described in [19] indicate that work-arounds can be motivated when the defined business processes are rigid and not designed to accommodate situations that might arise, requiring an appropriate response. Additionally, work-arounds might be performed when the process design or its support system does not satisfy all the stakeholder needs and expectations. Additional cases might be when employees decide to act upon their own personal goals rather than to follow the defined procedures.

Detecting work-arounds and investigating their sources can serve organizations striving to compliance improvement and to the design of better processes where work-arounds will be reduced. However, systematically detecting work-arounds and differentiating them from other incompliant behavior types are not easy. Various compliance checking techniques have been proposed in recent years as part of the process mining stream of research [1]. These techniques utilize event logs for detecting incompliance to specific constraints, procedures, and process models [3,7,28]. However, while indicating non-compliant behavior in general, these techniques fully rely on log information; thus, they cannot indicate the source of incompliance and distinguish intentional cases.

Furthermore, the starting point of these techniques is the event log and the technological capabilities. It is therefore not certain that all the forms of work-around behavior are addressed by them. To distinguish work-arounds from incompliance in general, our starting point is what types of behavior are perceived by process participants as work-arounds. In the work reported in [19], we have conducted a qualitative study exploring work-arounds in business processes of several organizations. He suggested a list of six generic work-around types, all indicated in interviews as intentional incompliance with process definitions. Building on this list, our aim is to explore whether and how work-arounds of each of these types can systematically be revealed based on an event log. The list of generic work-around types captures the intentional aspect of work-arounds and enables distinguishing them from other types of incompliance. Moreover, as opposed to technology-driven compliance checking research streams, our starting point is anchored in organizational practice. It enables us to look for specific patterns that may exist in the log and to understand what types of work-arounds are still not possible to detect based on the log, if any.

Note that our goal is not to develop new mining techniques. Rather, we wish to explore the capabilities of current technology, commercially available to organizations facing the given work-around types. To this end, we have used Fluxicon Discovery platform (http://fluxicon.com/disco) and applied it to logs of five processes taken from three organizations over 2 years. To generalize the findings, we further discuss capabilities of state-of-the-art technology for addressing these situations. Using Fluxicon Discovery, we show how quantification of work-arounds of four types is achieved for the investigated processes. Based on this quantification, we further investigate the work-around phenomenon and relate their occurrence to properties of the process, such as activity duration and number of actual and authorized participants. Indicating such relationships should be valuable for deciding on appropriate compliance improvement actions.

The remainder of the paper is structured as follows. Section 2 presents the six generic work-around types identified in [19]; Sect. 3 discusses the patterns that should be detected in logs with respect to each of the work-around types; Sect. 4 reports the findings that were obtained for five real-life processes; Sect. 5 presents additional analysis performed based on the work-around quantification, correlating work-around frequency with some situation characteristics; the results presented in Sects. 4 and 5 are discussed in Sect. 6. Related work and available state-of-the-art technologies are discussed in Sect. 7, and conclusions are given in Sect. 8.

2 Generic work-around types

This section summarizes the findings of our previous work [19] which form the basis for the current study. These are findings obtained in a qualitative exploratory study aimed at characterizing types of behaviors perceived as work-arounds as well as the reasons that drive them. The study was performed in five organizations of different sizes and lines of business, but addressed comparable processes across these organizations—purchasing and intake processes. It included 25 semi-structured interviews with employees of different roles in these organizations as well as process modeling and additional documents collection. A qualitative analysis of the interviews' text and the process models yielded six generic types of work-arounds and a list of situational factors that characterize each of these types, as summarized below. For additional details, we refer the reader to [19].

2.1 Work-around type A: bypass of process parts

Short description: A process instance where certain parts are bypassed, so activities that should be performed at later steps of the process are performed before their time. The activities that were bypassed can be performed in retrospect, or skipped altogether.

Example: a purchasing process, where a participant first places a purchase order and only afterward initiates the formal approval process.

Additional details: According to [19], this work-around type appears to be common in practice and is associated with many situational factors that may indicate reasons that drive its performance. Some factors are related to the process support system, e.g., poor user friendliness and a lack of integration among systems, which burden the users and motivate bypassing specific process parts. Other factors relate to process design, which can be complicated and cumbersome, hard to understand, involving many different roles, or not in line with the actual needs and the way the process is practiced. A strongly indicated driver of these work-arounds is uncertainty and lack of information available to the user regarding the progress of the process. This is a result of poor information flow and a lack of feedback about the process status to the process initiator, combined with delays and long execution times. Facing such uncertainty (e.g., how long will it take for my request to be handled?), users are motivated to bypass process parts and ensure the desired outcome.

2.2 Work-around type B: selecting an entity instance that fits a preferable path

Short description: A process instance that applies to an entity instance which does not correspond to the actual one, and is selected to fit a preferable process path (according to known criteria).

Example: a purchase approval process, where transition conditions require additional approvals if the price is over a certain threshold. Employees who know the rules might split purchase requisitions, whose price exceeds the threshold. Instead, they place several requisitions, each at a relatively small price, to avoid long approval trails.

Additional details: usually, employees who perform this type of work-around are experienced and knowledgeable, and thus, they are familiar with the "rules of the game." Consequently, the work-arounds are performed systematically and sophisticatedly. These work-arounds are mainly associated with complicated and inflexible transition conditions defined in the process. They can also be amplified by delays and long execution times in the process or by lower success chances of certain paths, which motivate employees to take the short or safe path even when it should not be taken.

2.3 Work-around type C: post-factum information changes

Short description: This type refers to situations where process participants modify data values after these have been used for decision-making. There are two variants of this work-around type.

C.1 the data modifications reflect values which were known a priori and falsely entered with the intention of manipulating the decision-making.
C.2 the modifications reflect new information or error correction, but no reiteration of the previous decision is made.

Examples: (C.1) a purchase requisition approval process, where participants enter false information (amounts, purchase items, suppliers, quantities, etc.) which allows the process to move "smoothly" and quickly. Only once the approval steps are completed, do they change the information to reflect the real needs. Entering the correct information at the initial stage would have required a different path of approvals and control. (C.2) only after the approval of a purchase requisition, it is found that the required quantity is higher than the requested and approved quantity. Rather than initiating the approval process again, the quantity is modified (possibly with some informal notification to the approving managers).

Additional details: similarly to work-arounds of type B, type C.1 work-arounds are performed sophisticatedly by experienced employees, who exploit loosely defined access control policies and poor authorization management. In contrast, type C.2 can stem from low awareness of the implications of deviating from the required procedures, as well as poor control policies.

2.4 Work-around type D: incompliance to role definition

Short description: a process instance where participants perform operations which are not under their responsibility.

Example: a purchasing process, where an approved requisition should be handled by a purchasing clerk, who obtains price quotations and selects a winning supplier. As a work-around, the initiating participant makes inquiries and selects a supplier, and only then transfers the requisition to the purchasing department with the results ready for continued handling.

Additional details: These work-arounds typically occur when responsibility assignment is not perceived as matching the knowledge required for certain tasks (e.g., a purchase clerk might not have sufficient technical knowledge to evaluate the available product configurations). Additionally, it might stem from a lack of clear responsibility definitions. An enabling factor of this work-around type is poor access control implemented in the process management system. In turn, a possible consequence is again associated with a poor level of control, namely incompliance to the "four-eye rule," where the resulting product of an employee is inspected by a different person.

2.5 Work-around type E: fictitious entity instances

Short description: Fictitious entity instances are created for monitoring and documentation of process steps or variants that exist but are not supported by the process management system. Typically, these instances are marked (e.g., ItemID 99999) and serve the employees for keeping trace of the unsupported parts of the process.

Example: In a student intake process, it is impossible to perform an acceptance interview with a candidate before he registers (and has a record). However, the candidate might not wish to register before an interview takes place. To overcome this, the secretary creates a fictitious registration in order to continue the process and invite the candidate for an interview. She immediately assigns the candidate to a fictitious room (to mark that the candidate is awaiting an interview).

Additional details: Work-arounds of this type are usually performed by employees to compensate for missing or incomplete process definition and support. Although the intention that drives these work-arounds is to improve the performance of the process, overcoming problems and increasing the level of control, it is still an intentional (and systematic) deviation from the defined procedures.

2.6 Work-around type F: separation of the actual process from the reported one

Short description: A process where at a certain stage work is performed manually. At a separate point in time, the actions that were performed (or should have been performed) are reported in a post hoc manner.

Example: In a purchasing process, a purchase requisition might wait a while for a manager's approval, although the chance that it will not be approved is extremely low to nonexistent. Facing this, process participants might move forward with the actual process without waiting. Once the approval is obtained, the actions that have been performed (e.g., ordering from the supplier) can be recorded in a post hoc manner.

Additional details: Such work-arounds are typically performed in processes that include administrative steps that do not make real contribution or affect the achievement of the process goal, especially if these steps are likely to cause delays and entail long waiting times. It is also reported that work-arounds of this type may occur when the process moves back-and-forth between organizational units.

3 Detecting work-arounds in an event Log

This section addresses the possibility to detect the six work-around types in an event log. For each type, we specify patterns that should indicate its occurrence in an event log, or explain why such pattern cannot be defined.

3.1 Type A: bypassing process parts

This type is characterized by skipping and bypassing certain process parts. Process instances where such work-arounds take place are, hence, incompliant with the prescribed process model and can be identified using compliance checking techniques. Yet, not every incompliant behavior can be classified as work-around of this type. Specifically, we are looking for activities that are performed while their immediate predecessor (or predecessors) required by the process model has not been performed. The immediate predecessors of an activity can be another activity (if it is in a sequence), several alternative activities (in case the activity follows an OR merge), or several activities that should all be performed (in case the activity follows a synchronization point). We denote the collection of these as $\mathrm{PR}(a)$—the set of immediate predecessors of activity a.

Type A pattern: Consider a trace where activity a appears in the ith position. If for all $r \in \mathrm{PR}(a)$, r is not included in positions $1 \ldots i-1$ of the trace, then the trace includes a type A work-around (bypassing process parts). This is checked for all the activities in positions $2 \ldots n$ of the trace.

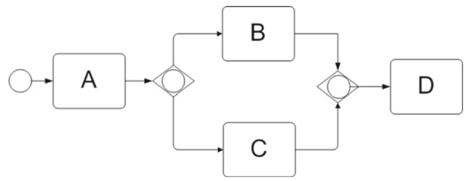

Fig. 1 Example model

Note that we do not require the immediate predecessors of a to appear immediately before it, since there might be incompliant traces where other activities have been inserted between a and its immediate predecessors. As an example, consider the model in Fig. 1, where B and C are immediate predecessors of D. The traces ABD, ACD, and ABCAD do not correspond to type A work-around, while the trace AD does.

Also note that *Type A pattern* forms a general condition, and it might be too coarse-grained to capture all bypass cases. However, it can be refined and tailored for specific situations. Specifically, it might be required to check the existence of the immediate predecessors of an activity only in part of the trace, after a certain point. For example, if the process includes loops, the immediate predecessors should be found in the trace between consecutive occurrences of the activity.

Figure 2 provides an example of a mined model of a purchase requisition approval process, where bypasses are marked (arrows 1, 2, and 3). As an example, according to the required procedures, the immediate predecessors of *Closed* are either *Authorized* or *Declined*. The mined model indicates instances where neither was included in the trace preceding *Closed* (e.g., *Draft -> Closed*, or *Draft -> Auth Process -> Closed*). These are classified as work-arounds of Type A.

3.2 Type B: selecting an entity instance that fits a preferable path

Process instances where this type of work-around is committed can be fully compliant in terms of control flow. In fact, they might seem legitimate in every process aspect. Yet, they are not accurate reflections of the real-life process. Using process mining techniques that relate separately to every instance (every trace), we cannot indicate patterns for detecting work-arounds of this type. When specific selection types are known to exist based on domain knowledge (e.g., splitting purchase requests), it might be possible to formulate identifiable patterns that would help quantifying these specific behaviors. Since every trace by itself is compliant, these patterns would relate to an aggregation of recurrent behavior in a cross-trace analysis. Still, these patterns would not be applicable for discovering other cases of this work-around type (e.g., entering a false customer age to allow a reduced price). It might be possible that data mining techniques aimed at fraud detection (e.g., [21]) can be used for this purpose. However, this is beyond the scope of this paper.

3.3 Type C: post-factum information changes

Work-arounds of this type can be located at specific steps of the process. Specifically, update data operations are performed after the data have been used by decision-making steps (e.g., approval). However, not every modification in the value of a data item that takes place after the data have been used is illegitimate (e.g., errors can be identified and corrected). For a data update to be considered work-around of this type, three conditions should hold:

1. An update is performed to a data item that has been used previously in the process.
2. The previous use was for decision-making.
3. After the data update, the process instance does not iterate back to the decision-making step (for revisiting, the decision based on the updated value).

Clearly, these conditions cannot be directly checked in an event log without additional domain knowledge that would indicate which data are used for decision-making at which process steps. Without such indication, skipping reiteration after the update of the data would appear like bypassing process steps (work-around type A).

Using domain knowledge, we can identify data update activities and decision activities relying on the relevant data item.

Type C pattern: Consider a data update activity u, and let d be an activity where these data are used as a basis for decision-making. Assume u appears in a given trace in the ith position, while d can appear in position $j,\ j < i$. If d is not included in the trace in position $k,\ k > i$, then this trace includes a work-around of type C.

Note that more than one decision activity might be needed according to the process definition. It should be possible to similarly check the existence of several activities in the remaining part of the trace (at least one or all together).

Figure 2 provides an example of post-factum updates, where purchase requisitions that are already closed are reopened for updating their data (update activity) and then closed again. One related decision activity that should follow reopening is *Authorized*. In the mined process, 485 of the 660 instances that were reopened were then closed (while the remaining ones, which reiterated to approval steps, have been filtered out in the analysis).

Type D—incompliance to role definition these work-arounds are characterized by situations where participants perform activities outside the realm of their responsibility.

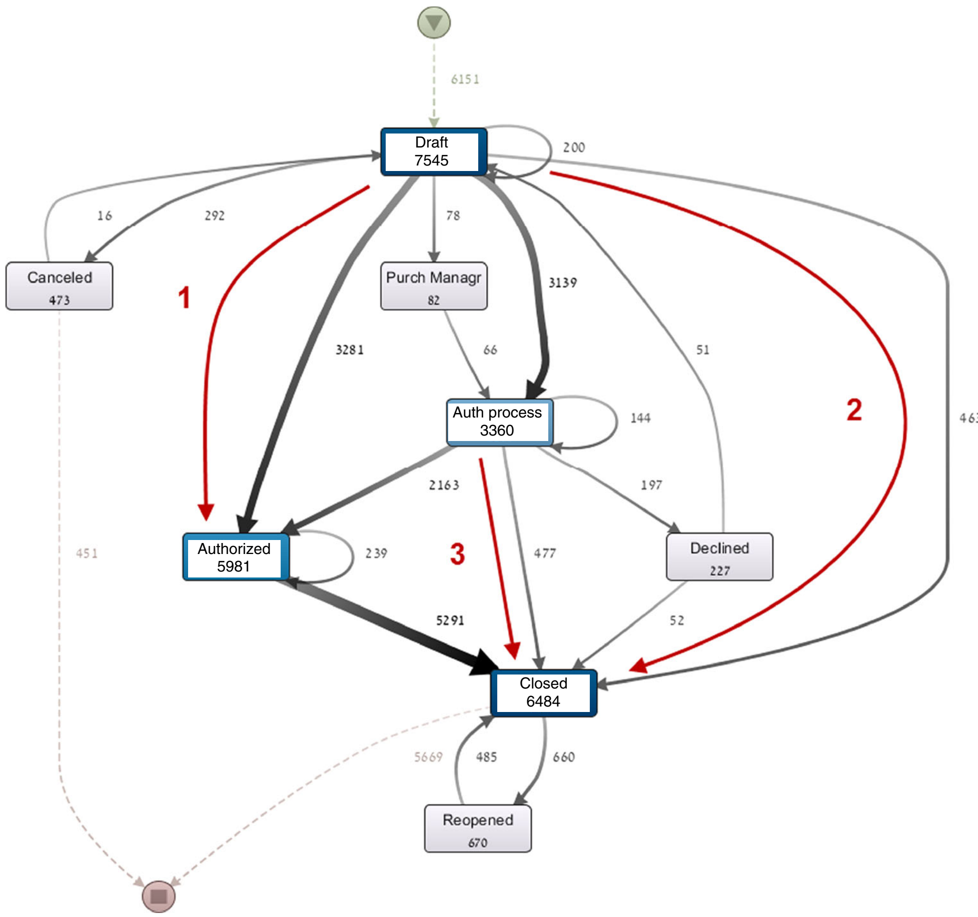

Fig. 2 Bypassing process steps in a purchase requisition approval process (case study 3)

Apparently, it is easy to detect such work-arounds by comparing the user of every activity with the list of users who are permitted to perform it. However, these work-arounds can only take place if the permissions defined in the system are not tight enough, so unauthorized users can perform the activities. Hence, for accurately detecting these work-arounds, the permission assignment should be prepared by the process owner independent of the existing system permissions. Based on such list, identifying activities that are performed by unauthorized users is straightforward.

Type D pattern: Let AT(a) be the set of users who are authorized to perform activity a. Consider a trace where a is performed by user u, if $u \notin \mathrm{AT}(a)$ then the trace includes a work-around of type D.

As an illustration, Table 1 presents the authorized and actual users of activities in a process taken from one of the organizations that were studied. As can be seen, some activities are performed by unauthorized users. In particular, financial approval (3,022 out of 3,326 times performed by the user P9) and final approval (3,065 out of 3,303 times performed by P11) are performed by several other users who are not authorized to perform them.

However, it might be that a temporary permission has been granted, e.g., P8, to perform these activities when the employee responsible for them was away. If that is the case, then along the time, the instances where P8 performed these activities should appear in one or several relatively short periods. This was not found in our case, where the instances involving P8 in these activities were scattered along the 2 years whose logs were analyzed.

Type E: fictitious entities: in work-arounds of this type, a fabricated entity instance is created, to allow the users manage and document process parts that are not included in the formal process (and hence cannot be properly monitored and documented). The resulting process instances appear like legitimate process instances (although they would typically not cover the entire process, but only specific parts).

Following this, mining the control flow of the process would not provide any indication of these work-arounds. However, employees who perform work-arounds of this type typically mark the fictitious entities by specific codes, so they can distinguish them from real ones. For example, in the student intake process described above, fabricated students were always assigned to Room 1000 (which was fabricated

Table 1 Authorized versus actual users of activities

Activity	Participant												Total
	Authorized	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	
Create PR	All	454	1,185	0	223	1	0	175	343	44	1,263	0	3,688
Manager approval	P1, P10	376	0	0	0	1	0	0	0	0	1,121	0	1,498
Financial approval	P9	0	38	170	35	16	0	0	44	3,022	1	0	3,326
Director approval	P11	0	0	0	0	0	0	0	0	0	0	190	190
Buyer approval	All	0	1,119	1,308	160	26	0	169	311	3	0	0	3,096
CEO approval	P5	0	0	0	0	3,307	0	0	0	0	0	2	3,309
Final approval	P11	1	13	0	2	0	96	9	102	0	15	3,065	3,303
Cancel PR	All	11	30	9	1	3	0	20	5	3	8	0	90
Close PR	All	356	1,109	1	184	0	0	163	341	3	1,125	0	3282
Reopen PR	All	0	0	0	0	0	0	0	10	0	1	0	11
Total		1,198	3,494	1,488	605	3,354	96	536	1,156	3,075	3,534	3,257	21,793

too). This information is usually known to all the involved process participants, sometimes even anchored in informal procedures. If this "marking" information is provided by a domain expert, the relevant process instances can be identified, but this would only serve for quantification of a known phenomenon, not for discovery of unknown ones.

Type F: separation of the actual process from the reported one: these work-arounds entail manual performance of process parts (which cannot be reflected in the log), and reporting the actions to the system just for the record, at some unrelated time. While it is not possible to tell what actually took place in the (manual) process, the post hoc recording would usually reflect a "normal" and legitimate process execution, compliant with the required procedures.

Still, we suggest that at least some of these work-arounds can be tracked by situations of substantial delays in the process, immediately followed by a bundle of transitions appearing one after the other in an unreasonably short time (as compared to the "normal" process transition times, e.g., three activities performed within a few minutes). For example, consider the instance of a purchase requisition approval process depicted by the log in Table 2. The activity of *Director approval* takes an extremely long time (compared with the activities that precede it) and is followed by two activities whose duration is less than 1 min. It is reasonable to believe that the process has in fact progressed before the *Director approval* has been formally given and that *Approve PR* and Close PR are just reported in a post hoc manner.

It can hence be concluded that instances including work-arounds of this type might seem legitimate in terms of their control flow, but can be detected based on activity durations. For each activity a, we need to define an upper duration threshold $\mathrm{UDT}(a)$ and a lower duration threshold $\mathrm{LDT}(a)$.

Type F pattern: For a given trace, if two consecutive activities a and b are found, such that their durations satisfy $\mathrm{d}(a) \geq \mathrm{UDT}(a)$, and $\mathrm{d}(b) \leq \mathrm{LDT}(b)$, then the trace includes a work-around of type F.

Table 2 An example log part demonstrating work-around type F

Activity	Date	Start time	Duration
Create PR	11.10.2011	12:27:00	9 min
Buyer approval	11.10.2011	12:36:00	2 h, 52 min
Financial approval	11.10.2011	15:28:00	6 h, 11 min
CEO approval	11.10.2011	21:39:00	10 h, 10 min
Director approval	12.10.2011	07:49:00	15 days, 46 min
Approve PR	27.10.2011	08:35:00	<1 min
Close PR	27.10.2011	08:35:00	<1 min

The duration thresholds can be defined based on the log, e.g., by setting a range that covers the durations of a defined ratio of the activity instances in the log. For example, assume that 80 % of the executions of a certain activity take 15–90 min. However, note that the upper threshold might even be slightly above the average duration, but the lower threshold needs to be such that the activity cannot possibly be executed within this time. Often, there would be several activities, whose durations are below the lower threshold, performed one after the other. These would be all the activities that have been performed off-line and reported in retrospect.

Table 3 summarizes this section by providing a brief summary of the patterns suggested for the work-around types, and the types for which log patterns could not be found.

4 Application to real logs

The previous section provided means for identifying four of the six work-around types in event logs. This section reports

Table 3 Log patterns for work-around types

Type	Description	Log pattern
A	Bypassing process parts	Let PR(a) be the set of immediate predecessors of activity a according to the process model. Consider a trace where activity a appears in the ith position ($i = 2 \dots n$). If for all $r \in \text{PR}(a)$, r is not included in positions $1 \dots i-1$ of the trace, then the trace includes a type A work-around (bypassing process parts)
B	Selecting an entity instance that fits a preferable path	Not found
C	Post-factum information change	Consider a data update activity u, and let d be an activity where these data are used as a basis for decision-making. Assume u appears in a given trace in the ith position, while d can appear in position j, $j < i$. If d is not included in the trace in position k, $k > i$, then this trace includes a work-around of type C
D	Incompliance to role definition	Let AT(a) be the set of users who are authorized to perform activity a. Consider a trace where a is performed by user u, if $u \notin \text{AT}(a)$, then the trace includes a work-around of type D
E	Fictitious entity instances	Not found
F	Separation of the actual process from the reported one	Let UDT(a) and LDT(a) be upper and lower thresholds for the duration of activity a, respectively. For a given trace, if two consecutive activities a and b are found, such that their durations satisfy $\text{d}(a) \geq \text{UDT}(a)$, and $\text{d}(b) \leq \text{LDT}(b)$, then the trace includes a work-around of type F

Table 4 Processes whose logs were analyzed

Process	Title	Organization description
1	Purchase requisition approval	Academic organization, 500 employees
2	Purchase requisition approval	Manufacturer of control and monitoring systems, 300 employees
3	Purchase ordering	
4	Purchase requisition approval	Marketing organization, importing and selling medical equipment, 300 employees
5	Purchase ordering	

the results obtained for logs of five processes taken from three organizations over 2 years. We aimed at addressing processes whose roles are similar in different organizations, as detailed in Table 4. In fact, the selected processes were a subset of the ones addressed by the qualitative study [19], where a log could be obtained.

As discussed in the introduction, we have decided to use Fluxicon Discovery as a commercial process mining platform, currently available to organizations. The patterns introduced in Sect. 3 were operationalized using the necessary domain knowledge which was obtained from the process owners. The detailed conditions were then implemented as separate filters over the event logs. The logs were first screened for outliers (e.g., uncompleted instances, instances whose data values are clearly incorrect—like process duration of over a year), which were filtered out. The number of remaining instances served as a baseline for measurement. We then used Fluxicon Discovery with each of the pattern-designated filters separately, to calculate percentage of the instances with respect to the baseline population.

Table 5 provides the findings that were obtained. Note that each work-around type was addressed separately, so summarizing all types together would not make sense, since there are instances where more than one work-around type was detected. Moreover, some work-arounds can be classified into more than one type. For example, when work-arounds of type F (actual process vs. reported one) are performed, often the same person reports several operations, including ones outside his/her role (thus, they can also be classified as work-arounds of type D).

As can be seen in Table 5, organizations as well as processes within the same organization differ from one another in the frequency of work-arounds and in their types. In general, work-arounds of type A (bypassing) are the most frequent ones. Difference among organizations is especially evident with respect to organization 1, whose number of work-arounds is extremely low in the purchase requisition approval process. In contrast, in the other two organizations, the purchase requisition approval process has a much higher work-around rate than the purchase ordering process. In organizations 2 and 3, the requisition approval process entails a high number of work-arounds, especially of type A (bypassing). In organization 2, type D (incompliance to role definition) is also frequent, and in organization 3, types F (actual

Table 5 Work-around percentage by type

Organization	Process	Number of instances	% Instances with work-arounds by type			
			A (%)	C (%)	D (%)	F (%)
1	PR approval	3,688	5.1	1.3	2.7	5.9
2	PR approval	6,920	53.2	8.8	22.3	12.0
	Purchase ordering	4,211	6.8	7.2	24.4	12.6
3	PR approval	21,289	75.3	25.0	3.5	68.1
	Purchase ordering	5,217	11.9	4.8	9.0	4.1
Average in all processes			30.5	9.4	12.4	20.5

vs. reported process) and C (post-factum information change) are often taken.

5 Analyzing features of work-around situations

As shown in Table 5, the frequency of work-arounds is different for different processes. To select appropriate compliance improvement actions, organizations need to understand the specific reasons that drive work-arounds. Our qualitative study reported in [19] suggested a list of situational factors, related to each of the work-around types, characterizing the typical situation in which these work-arounds are performed and explaining the motivation for performing them. The list of factors relied on a qualitative analysis and a series of interviews. In this section, we use the process mining data for a quantitative analysis of situational factors that can be associated with work-arounds. Note that while the factors identified qualitatively relate to a variety of aspects—technological, managerial, organizational, and process properties, a quantitative analysis can only relate to log data. Hence, we focus on activity durations, number of participants, and work handover.

5.1 Activity durations

One of the main situational factors indicated in [19] was delays, bottlenecks, and long activity durations. Following these indications, we hypothesized the existence of a positive correlation between activity durations and the frequency in which these activities are worked around. To corroborate this hypothesis, we decided to focus on work-arounds of type A (bypassing process parts) since their identification and duration information based on the logs are more reliable than for the other work-around types.

We have considered all the activities of the five investigated processes, except for the first and last activity in every process. After removing 25 activities, which are first, last, or not mandatory in the process flow (e.g., cancelation, correction), we have examined 20 activities. For every activity, we have calculated the following metrics:

Work-around frequency (WF): the number of cases where the activity was bypassed divided by the total number of cases available in the log of that process.

Normalized duration (ND): the average duration of the activity divided by the average duration of the process.

Normalized duration was used since the absolute duration is not comparable for processes of different length. It is possible that an activity whose duration is, e.g., 2 h, would be considered a bottleneck in one process, while in a different process it would be considered relatively short. Taking the process duration as a baseline provides an indication of the relative time taken by the activity and is comparable across processes. Furthermore, for calculating the normalized durations, we filtered out the activity instances identified as type F work-arounds (actual vs. reported process), since their logged duration cannot be considered as an indication of their real duration. The hypothesis that was formulated was hence:

H1 *There exists a positive correlation between the work-around frequency (WF) and normalized duration (ND) of an activity.*

The Pearson correlation found between the work-around frequency and the normalized duration is 0.613, significant with $p = 0.004$ (two-sided). This finding supports our hypothesis H1 of a positive correlation between activity durations and the frequency of work-arounds.

5.2 Number of participants

The situational factors indicated in [19] do not point directly toward a clear hypothesis related to the number of process participants. Still, several directions could be checked. First, it could be assumed that a process where a large number of participants can be involved (across all cases) would be less controlled than a process confined to a relatively small number of employees. We would hence expect a positive correlation between the number of participants in a process and the work-around frequency. However, since this can only be

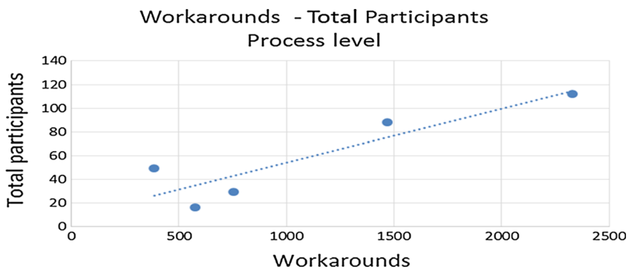

Fig. 3 Work-arounds versus total number of participants in the studied processes

measured with respect to the entire process, our sample is not large enough for a statistical analysis. As a qualitative indication, Fig. 3 presents the number of work-arounds versus the total number of participants in the five processes that were studied. The general trend in the figure supports our expectation.

Considering each activity separately, a similar assumption can be made—that a large number of participants who perform an activity can indicate a loose control. The resulting hypothesis would hence expect a positive correlation between the number of participants who actually perform an activity (Number of Participants: NP) and the work-around frequency (WF) of that activity.

H2 *There exists a positive correlation between the number of participants (NP) and work-around frequency (WF) of an activity.*

The Pearson correlation found between NP and WF is 0.636, significant with p=0.003 (two-sided), and thus, the hypothesis H2 is supported. H2 relates to the actual number of users participating in an activity. These may or may not be authorized participants. The relationship between the actual and authorized participants performing an activity was operationalized as follows:

P_AP: the number of actual participants divided by the number of authorized participants in the activity.

We expected some correlation between this metric and the work-around frequency. However, the direction was not straightforward to expect. A plausible assumption would be that if an activity has a relatively low number of authorized participants, it might become a bottleneck which motivates work-arounds. However, the ratio P_AP relates to actual versus authorized participants. A high value of P_AP implies that the actual access control is loose, enabling unauthorized users to perform the activity. In such cases, since the activity can easily be performed by an unauthorized user, it is not likely to become a bottleneck, and thus, a negative correlation with the work-around frequency can be expected. Recall, the work-around frequency relates to type A work-arounds, where the activity is bypassed. A negative correlation can be interpreted as a trade-off between work-arounds of type A and type D (incompliance to role definition). Based on this, we formulated the following hypothesis:

H3 *There exists a negative correlation between the ratio of actual participants to authorized ones (P_AP) and the work-around frequency (WF) of an activity.*

The Pearson correlation found is indeed negative −0.393. It is significant for the one-sided test that relates to H3 with $p = 0.0435$ (one-sided). Note that although this is a sufficient corroboration for H3, it is with a borderline significance. Yet, given that our sample is relatively small, higher significance should be expected when testing additional activities.

5.3 Work handover

Another situational factor that could be checked was the required work handover, namely, the extent to which work is handed over, moving back-and-forth among organizational units. This factor, indicated in [19] as contributing to work-arounds of type F (actual vs. reported process), relates to a process where the work should be shifted back-and-forth between organizational units. To measure this, we have defined the following metric, calculated for every activity based on the process model:

Handover indicator (HI): Considering a sequence of activities a_{j-1}, a_j, a_{j+1}, if the organizational unit responsible for a_j is the same as for a_{j-1} and a_{j+1}, then for a_j HI = 0; If the organizational unit responsible for a_j is different than for a_{j-1} OR for a_{j+1}, then for a_j HI = 1; If the organizational unit responsible for a_j is different than for a_{j-1} AND for a_{j+1}, then for a_j HI = 2.

Note that this handover indicator is different than the handover metrics used for organizational mining [29] in two main aspects. First, HI relates to an activity while handover metrics relate to process participants and measure the extent to which work is handed over among them. Second, HI is based on the process model, reflecting handover requirements, while the handover metrics are calculated from a log.

Since the work-around frequency we refer to relates to work-arounds of type A rather than F, we hypothesized a correlation but could not anticipate its direction.

H4 *There exists a correlation between the handover indicator (HI) and work-around frequency (WF) of an activity.*

The Pearson correlation found was negative −0.498, significant with $p = 0.025$ (two-sided). This finding implies that when work needs to be handed over between organizational units, this requirement forms some control measure that discourages employees from activity bypassing. When a sequence of activities is under the responsibility of one organizational unit, bypassing parts of this sequence would be easier.

Note that this might still not affect the commitment of type F work-arounds: Assume role X is responsible for a_{j-1} and for a_{j+1}, while role Y is responsible for a_j. Role X could perform a_{j-1} and immediately continue with a_{j+1}, but report it only after role Y performs a_j. To test the correlation of work handover with type F work-arounds, recall that these are detected in a log by a combination of several activities: An activity whose duration is exceptionally long followed by at least one activity (but many times several) whose duration is exceptionally short. The general form of the trace would appear as $LS_1S_2S_3\ldots$, where L is the long activity, and S_i are the short activities that follow it. The long activity L is where the work-around is initiated: rather than waiting for it to finish, the process continues with the activity (or activities) S_i that follow it. Finally, everything is reported in retrospect. Considering this mechanism, we can expect that after such work-arounds start at an activity L (which may or may not entail work handover), the following activities (S_i) would continue (manually) as long as no major handover of work is required. In order to formulate hypotheses for this work-around type, we define the following metrics for every activity.

Work-around F frequency of short activities (WFFS): the number of cases where the activity is exceptionally short divided by the total number of cases available in the log of that process.

Work-around F frequency of long activities (WFFL): the number of cases where the activity is exceptionally long divided by the total number of cases available in the log of that process.

For the short activities, we expect a negative correlation with work handover.

H5 *There exists a negative correlation between the handover indicator HI and the work-around type F frequency of short (continuing) activities (WFFS) of an activity.*

For the long activities, where the work-around is initiated, we wish to test the existence of a positive correlation with work handover.

H6 *There exists a positive correlation between the handover indicator (HI) and the work-around type F frequency of long (initiating) activities (WFFL).*

Considering H5, the Pearson correlation found was negative -0.576, significant with $p = 0.008$ (two-sided), and thus, H5 is supported. The data imply that indeed the "short" activities (as reported in retrospect) in type F work-arounds involve a low work handover. Considering H6, we did not find a significant correlation, and thus, H6 cannot be accepted. In summary, we did not find evidence indicating that work handover is related to the initiation of type F work-arounds. However, we found that continuing manual work detached from the system is promoted by a lack of handover requirements.

6 Discussion

The aim of this paper is to provide means for organizations who wish to increase compliance in their processes and specifically to reduce intentional work-arounds. To achieve this, we have developed patterns that can be detected in a log using commercially available process mining tools and performed correlation analysis with specific process characteristics, indicating typical situations where work-arounds are performed.

We note that considering our notion of work-arounds, the detection might include both false positives, cases that are falsely indicated as work-arounds, and false negatives, actual work-arounds that are not detected. Specifically, we define work-arounds not just as incompliant behavior, but as one that involves intentional defiance of known procedures. Clearly, we have no means for assessing user intention from event logs. To this end, we rely on the list of work-around types, which was obtained through interviews where users indicated what they perceive as work-arounds. It might be that the resulting patterns also include incompliant behavior performed for different reasons.

For example, the cases identified as work-arounds of type C (post-factum information change) might include error corrections (where data should be modified to correct the error). According to the regulations, reiterations to the decision steps (e.g., approval) were required. It might be that this was done informally by e-mails or phone calls, but the system has no track of these. Hence, officially these cases are considered as work-arounds. Similarly, identified cases of type D (incompliance to role definition) might include cases where a temporary permission was granted by the authorized user. We tried to detect these cases by examining the distribution of these occurrences over time. However, one-time permissions cannot be detected this way.

False negatives would relate mainly to types A (bypassing) and F (actual process vs. reported one). Bypasses (type A) can be performed manually (e.g., ordering goods by phone) and not reported, while the process as reflected in the log appears to progress according to the required procedures. Considering separation of the actual process from the reported one (type F), our detection method is based on the assumption that this can be reflected in the log as exceptional durations of activities (exceptionally long duration of one activity followed by one or more exceptionally short durations). This assumption does not necessarily apply in all cases. Specifically, the post hoc reporting might be performed at different points in time for different activities, which would not appear as exceptional activity durations.

Still, even with these limitations, we believe that quantification like the one in Table 5 is valuable for organizations. In particular, it can serve as a starting point for investigating the work-arounds that are performed and lead to corrective actions that should address the reasons that drive these work-arounds. The result of such actions should be improved processes with improved compliance.

Considering the correlation analysis between situational factors and work-around frequency, this analysis used data taken from three specific organizations in Israel. It should be noted that work-around behavior, as a specific form of organizational misbehavior [30], is culture dependent. Additional investigation of data taken from additional organizations in various parts of the world would be required for establishing a more universal understanding of work-around situations. Yet, the observations from a case study in Belgium, reported in [22,23], indicate that work-arounds are motivated when additional effort and time are required. This is consistent with some of our findings (e.g., correlation between activity duration and work-around frequency).

Furthermore, these findings indicate correlation which is not necessarily causality. However, in combination with the qualitative findings of [19], they can be interpreted to provide some initial understanding of the mechanism that drives work-arounds.

Based on our findings, we suggest that for work-arounds to be committed, both motivation and opportunity are needed. Considering the data we have analyzed, motivation can correspond to activity durations—long durations may create a motivation for bypassing and working around these activities. Opportunity might vary for different work-around types. In general, a low level of control over the process (typical when many participants are involved) makes work-arounds easier to perform, as reflected by the positive correlation between number of participants and work-around frequency. In particular, poorly managed access permissions form an opportunity for performing type D work-arounds, so when a motivation exists, employees would perform tasks by themselves (rather than bypassing them or waiting for the authorized person to perform them). Work handover requirements are a means of control that may discourage activity bypassing. This is well known as the four-eye principle. Our findings indicate a negative correlation between the handover indicator and type A work-arounds (bypassing) and can thus be considered an empirical corroboration of the effect of this principle. A similar effect holds for type F work-arounds—continuing the process manually and reporting in a post hoc manner. Our findings indicate a negative correlation between the handover indicator and the post hoc reported activities of this work-around, but not with its initiation. Note that the qualitative findings of [19] indicate that handover could motivate the initiation of type F work-around. This indication was not corroborated by our correlation analysis and might hence be anecdotal rather than a general behavioral pattern.

Summarizing this discussion, Table 6 provides a list of the correlations that were corroborated by our findings. Note that the table is organized in relation to work-around types, and thus, H3 is referred to twice, in relation to two work-around types: A and D.

We also note that, as already explained, the factors we have addressed are only the ones that could be measured through process mining and are a small part of the factors indicated by our previous work [19]. However, we believe that other factors can also be classified as motivating factors and opportunity-providing factors, where different opportunities can be associated with different work-around types.

Finally, we note again that two types of work-arounds were not possible to detect from the logs, yet they are likely to exist. Being aware of this possibility, organizations can apply targeted means for identifying and addressing them. Fictitious entities (type E), for example, usually involve practices which are well known among the relevant users, sometimes even anchored in departmental documents and procedures. Typically, they are marked by specific IDs that would enable the users to track them. It should hence be rather easy to specifically elicit them from the employees and make appropriate modifications to the process. work-arounds of this type usually attempt to compensate for incompleteness in the process definition, and their detection can contribute to process improvement efforts. Intentionally selected entity instances (type B) would be more difficult to expose, especially since these are performed by sophisticated employees with the intention to avoid the required process paths. As discussed, data mining techniques might be of assistance.

7 Related work

While much attention has been given to compliance management in general [6] and compliance checking in particular [27], the specific phenomenon of intentional work-arounds has not been extensively investigated. Early qualitative inves-

Table 6 Corroborated correlations

H#	Work-around type	Correlation	Situational characteristic	Comments
1	A (frequency)	Positive	Activity duration	Relative to process duration (normalized)
2	A (frequency)	Positive	Actual number of activity participants	
3	A (frequency)	Negative	Execution by unauthorized participants	
3	D (number of users involved)	Negative	Activity bypassing frequency (type A work-around)	
4	A (frequency)	Negative	Work handover	Four-eye principle
5	F (continuation)	Negative	Work handover	Four-eye principle

tigations based on a case study were reported by Polemans [22,23]. The proposed explanation of work-arounds there relates to the concept of distributed viscosity, where additional effort is required of users by the defined process, and this effort is perceived as extraneous to their goals (although it is intended for other goals to be achieved in the organization). An initial discussion of work-around detection through log patterns appeared in [20]. Still, on a more general level, these patterns can be detected by some of the existing compliance checking approaches. This section reviews the relevant literature and indicates the work-around types that can be detected by each of the existing approaches.

Several approaches, reviewed by [11], address model-log comparison and specifically backward compliance checking. Main research streams are replaying-based techniques (e.g., [4,7–9,28]), where a process is replayed on the log against the required process model, and rule checking techniques, where rules can be defined using Linear Temporal Logic (LTL) [3,16] or Petri net representation [10,12,17,18,24]. Replaying-based techniques address and measure incompliant behavior in general, as opposed to the specific set of behaviors we address in this paper. Behavior types that would be detected by these techniques include some of the work-around-related patterns, as well as additional ones, such as activity repetition, or performance of additional or different activities as compared to the process definition. Furthermore, focusing on conformance measures, these techniques do not provide diagnostic information, indicating the specific incompliant behaviors. In contrast, rule-based conformance checking can relate to specifically defined rules (including those related to work-arounds). Hence, we focus on this group of approaches.

Ramezani et al. [24] define 15 categories of control flow compliance rules. Four of these categories are relevant in our context of work-around detection. *Existence rules* limit the occurrence or absence of a given event within a scope—these can be used for identifying work-arounds of type A (bypassing) by identifying the absence of immediate predecessors of an activity. They can also be used for detecting work-arounds of type C (post-factum information change), combining the occurrence of data updates after decision activities and the absence of recurrent decisions after the update. *Precedence rules* require or limit the occurrence of a given event in precedence to another event—these can be useful for detecting work-arounds of type A, since a violation of such rule implies that activities have been bypassed. *Response rules*, which require or limit the occurrence of a given event in response to another event—can be used for detecting work-arounds of type C, where a post-factum information change is considered as work-around only if it is not followed by reiteration of decision steps. *Between rules* require or limit the occurrence of a given event between two other given events—can be used for detecting bypassing (type A) in a process which includes loops. Guidance in the creation of compliance rules through configuration of rules in a rule library is suggested by [25].

These compliance rules can be checked by LTL-based approaches [3,16], which are easily capable of specifying these kinds of constraints. Petri net-based methods specify a rule as a Petri net segment and then find a best alignment with the log [2,24,26]. While LTL-based rules address only the control flow of the process and are thus relevant for detection of the two aforementioned work-around types (A and C), the alignment seeking Petri net-based approaches can handle other aspects as well.

Ramezani et al. [24] addresses compliance to data and organizational aspects, which enables detecting work-arounds of type D (incompliance to role definition). The data-related techniques are extended in [26] to address temporal constraints, which are capable of capturing the exceptional activity durations that characterize work-arounds of type F (actual vs. reported process). It can hence be concluded that the alignment-based methods provide powerful means that enable specifying appropriate rules and detecting the four work-around types that are reflected in event logs.

Compliance can also be observed and enforced at runtime, using compliance monitoring techniques. Compliance monitoring challenges and approaches are reviewed by [15] along 10 identified compliance monitoring functionalities. Four of these functionalities relate to types of constraints that can be monitored, including time and ordering constraints, data constraints, resource constraints, and constraints on relationships between sub-activities in a complex activity. These constraints can help detecting work-arounds of types A, C, and D at runtime, while type F can only be identified in retrospect.

Still, as discussed above, we have not been able to define patterns that would enable detecting work-arounds of two types in a trace and indicated that these types require analysis of accumulated process data from multiple cases over time. Currently, to the best of our knowledge, there are no techniques capable of identifying such behavior. However, prediction techniques (e.g., [5]) use accumulated information of multiple cases and are capable of identifying recurrent patterns in them. Current techniques focus on tying control flow properties with performance indicators, such as completion time. Nevertheless, they might be possible to extend for detecting recurrent behaviors while taking data into account.

Finally, considering the correlation analysis of situational factors and work-around frequency, we are not aware of any similar attempt performed so far. Compliance monitoring functionalities, reviewed by [15], include the ability to explain the root cause of a violation. However, they only relate to root-cause analysis in terms of relating specific events to the detected violation and not to the situation that drives it.

8 Conclusion

Work-arounds are often performed in business processes. Compliance management literature has not addressed them as a distinct phenomenon so far, but rather as part of incompliant behavior in general. We believe that intentional defiance of known procedures should receive special attention, since revealing this behavior and the reasons that motivate it can expose many underlying problems that need to be solved, and drive focused compliance improvement actions.

To define appropriate compliance improvement actions, organizations need to be able to detect and quantify the work-arounds performed in their processes, and to understand their sources. The paper takes a step in this direction.

The contribution of this paper is threefold. First, it is in approaching this issue from a practice perspective. As opposed to existing works in the area of compliance checking, which focus on the capabilities of technology to be utilized, this paper departs from behavior types that exist in practice and are perceived by employees as intentional work-arounds. It uses six generic behavior types identified in organizations and seeks for technological solutions that can serve for detecting these behaviors. It does so by analyzing and characterizing the log patterns that can be associated with the considered work-around types. We have specified patterns that enable detecting four work-around types in event logs and demonstrated their ability to quantify the occurrence of each type in logs of five real-life processes.

A second contribution is the indication of two work-around types that leave no recognizable trace in the log and hence cannot be generically identified by existing process mining techniques. Still, additional domain knowledge can be used for defining-specific patterns that might be identified in logs. This highlights the limitations of generic process mining techniques and can guide organizations in further directions that need to be taken to completely address the work-around phenomenon.

The third contribution of the paper is the correlation analysis, tying factors that characterize process situations with the frequency of work-around commitment. This analysis sheds light and promotes the understanding of work-arounds. Developing an understanding of the work-arounds that take place would be valuable for improvement efforts. Corrective actions can include redesigning the processes, improving the data flow, the permission and control mechanisms, role definitions, and also training and disciplinary actions. In particular, the factors identified here as correlating with work-arounds can be handled by targeted efforts to reduce specific activity times, by increasing control and specifically designing work handovers, by improving access permissions to prevent unauthorized execution of activities, and by monitoring work-arounds and taking disciplinary actions. These actions are expected to lead to improved performance as well as compliance.

Note that there are still many possible situational factors that could not be quantitatively analyzed from the logs. Future research will aim at investigating these factors as well. Another research direction would be to develop mining techniques that would be able to detect the two work-around types that are currently undetectable. As discussed, these would apply cross-case analysis to establish recurrent patterns over time.

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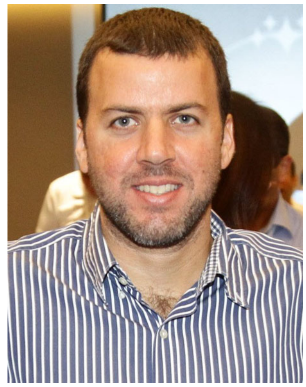

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