Forging the LongSWORD: Exaptation and Enhancement of the SWORD Framework for Workaround Detection

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Abstract. Full Paper - Regular Research Paper:
Workarounds are goal-driven adaptations of business processes that employees implement to overcome perceived constraints at work. While process deviations can be easily detected with data-driven methods like process mining, it is hard to distinguish workarounds from related, yet distinct, concepts. The SWORD framework constitutes a state-of-the-art method for the data-driven detection of workarounds in business process event logs based on pre-defined patterns extracted from support processes in the healthcare domain. However, currently, SWORD has solely been applied to highly standardized processes with low variation and knowledge intensity, while it can be assumed that workarounds more often appear in the latter and also bear bigger potential for innovating processes. Furthermore, SWORD neither comprises data preparation steps nor enables the analysis of workarounds and their implications for the organization. In this paper, we develop an exaptation of the existing SWORD framework, coined LongSWORD, together with two industrial case organizations. Our contribution to theory and practice is threefold. First, we present a framework that enables the preparation of a meaningful event log in alignment with according process model or routine. Second, the detection and analysis of workarounds in core industrial processes is enabled by adding two new cross-case patterns. Third, the LongSWORD method enables others to assess the implications of workarounds beyond its individual implementers.

Keywords: Workarounds · Workaround Detection · Process Science · Causal Inference.

1 Introduction

Process Mining provides methods and tools for the data-driven analysis and improvement of business processes. Corresponding techniques are classified into six subgroups: process discovery, conformance checking, performance analysis, comparative process mining, predictive process mining, and action-oriented process mining [1]. Organizations, however, regularly only implement two techniques—discovery and conformance checking. While process discovery enables the data-driven development of process models, conformance checking aims to detect deviations of process behavior in the data traces compared to to-be process models.

Traditional views of Business Process Management (BPM) assume that deviations from to-be process models refer to inefficiencies in process execution and need to be prevented [7]. Recent research has identified that, among others, such deviations can also refer to so-called workarounds [9,28]. Workarounds are goal-driven adaptations that participants implement individually to overcome obstacles induced by misfits [3]. They can trigger bottom-up process innovation by either adapting the process or resolving the underlying misfit [3]. However, manual identification and analysis is a complex and time-consuming task.

Alongside qualitative approaches such as interviews or observation [4], several data-driven approaches exist, which, e.g., leverage deep learning techniques [28]. These, however, require a considerable time investment or pre-existing knowledge about the regarded workarounds. One mature approach for the data-driven workaround detection in business processes is the so-called SWORD method (Semi-automated WORkaround Detection) method [25,26,27]. It leverages different patterns that manifest in the control flow, data, resource, or time perspective of a business process. However, pattern identification, the development of the detection method, and its demonstration were conducted in a healthcare [27] and public administration context [26]. Therefore, it still needs to be investigated whether the approach can be extended to other domains without adaptation.

In this paper, we follow the strategy of exaptation outlined by Gregor and Hevner (2013) [12] to revise and enhance the SWORD method to be applicable in an industry context. We instantiated the Design Science Research (DSR) methodology [21] and adapted, demonstrated, and evaluated our IT artifact coined *LongSWORD* in the production and procure-to-pay processes of two German organizations. From a theoretical perspective, we contribute by extending the SWORD method to allow for the application in an manufacturing context. Further, LongSWORD provides guidance on data preparation and the interpretation of process drift. From a managerial perspective, we provide a holistic method for identifying workarounds, which can be applied to diverse event logs.

The remainder of the paper is structured as follows. In section 2, we outline related work on workarounds and detection methods. In section 3, we present our DSR approach. In section 4, we develop and demonstrate the IT artifact. Section 5 discusses the theoretical and managerial implications of our results and concludes the paper in section 6.

2 Theoretical Background

The potential of workarounds as a trigger for bottom-up process improvements has been recognized only recently [3,5]. From a conceptual view, many related, yet distinct, concepts exist that describe individuals' deviations from prescribed activities in business processes [22]. However, compared to other concepts, workarounds highlight the creative problem-solving capabilities of actors to overcome misfits [3,13,15]. We take up the definition presented by Alter (2014) [2]: "A workaround is a goal-driven adaptation, improvisation, or other change to one or more aspects of an existing work system in order to overcome, bypass, or minimize the impact of obstacles, exceptions, anomalies, mishaps, established practices, management expectations, or structural constraints that are perceived as preventing that work system or its participants from achieving a desired level of efficiency, effectiveness, or other organizational or personal goals" [2].

Workarounds can be detected with qualitative [4] and quantitative approaches [28]. Qualitative approaches mostly refer to interviews and observations. However, while they can be used to detect workarounds and other types of process deviations [17], such techniques do not allow continuous monitoring of identified deviations due to resource intensity. This property limits their applicability in organizations and reinforces the need for efficient (semi-)automated methods.

Quantitative approaches employ data analytics techniques to identify workarounds based on data traces of business processes and the analysis of additional external information [27]. Beyond the SWORD method, Weinzierl et al. (2022) [28] leveraged a deep learning approach, evaluated on a synthetically enhanced dataset containing manually labeled workarounds in the training set. Wijnhoven et al. (2023) [29] present a process mining approach to identify workaround candidates by comparing the de jure model and the de facto process models. However, human input is still required to categorize the identified workaround candidates and assess their potential impact. Earlier approaches indicate similar challenges and discuss the importance of domain knowledge [18].

The SWORD method [19,25,26,27] is the most recent data-driven method for detecting workarounds in event logs. The method applies 22 pre-defined workaround patterns identified in a healthcare and retail context. These patterns are sorted into the four categories "Control Flow" (eight patterns), "Data" (three patterns), "Resource" (five patterns), and "Time" (six patterns), where each checks for common deviations from the intended process model, such as unexpected activities, data values outside boundaries, etc. A notable limitation is, that each pattern can only indicate a workaround, the validation is still done by a domain expert. The updated version of the method [27] is streamlined to optimize the use of domain experts' time and provides more orientation concerning the strength of deviations and the (ex-post) evaluation of the usefulness of patterns. However, the method has predominantly been applied in healthcare [27] and public administration processes [26].

3 Applying the Standard SWORD Patterns

The SWORD method's patterns, initially developed in healthcare [25], and applied to public administration procurement processes [19]. Consequently, current limitations of the approach stem from healthcare-specific factors—such as regulations, financial constraints depending on the patient, and ethical considerations—that potentially constrain the innovation potential of workarounds. Thus, adapting the method for other contexts enables considering a broader range of workaround types [8]. In this paper, we develop a data-driven method for discovering and evaluating workarounds in business processes. We enhance the SWORD method for workaround discovery in healthcare [5,27] by iteratively adapting it to manufacturing processes based on two case companies.

Safety Solutions Inc. is a German SME with international clients, 240 employees, and a revenue of 43 million Euros in 2022. They produce pressure relief technology using a knowledge-intensive Industry 4.0 process, prioritizing product quality due to the critical nature of their products. The standard process is linear, starting with an unrecorded preparation and scheduling task. The first logged event is batch number assignment, followed by production, quality control, and optional packaging. Quality control may also be performed during production. Re-producing faulty products, including partially completed or completed orders, is part of the production step. The event log (2019-2023) contains 252,850 events across 41,526 orders. 21,097 orders (50.8%) follow the standard process.

Fuel Logistics Inc. specializes in industrial gases, hydrogen, energy solutions, and petrol stations. This family-owned company operates over 20 sites in Germany, the Netherlands, Belgium, France, Switzerland, and Austria, with 2,000 employees and a 2022 revenue of 2.3 billion Euros. The Purchase-to-Pay (P2P) process, supported by an enterprise system, includes Order Requests, Purchase Orders, Order Confirmations, Goods Receipts, Invoice Receipts, and Billing Document activities. The event log (2022-2023) includes 21 ERP system tables comprising 336,734 observations in 103,625 cases.

We used different BI-tooling methods like PowerBI to identify the different SWORD patterns. We further used R and respective packages for the analysis, including a process map generated with bupaR [14] in both cases. In the following, we will explore the applicability of the provided patterns and their findings. However, several patterns were not applicable due to the properties of the process or the event log. These are marked in Table 1. We generally categorized the outcome as follows: "True Positives" denote found and verified workarounds, and "True Negatives / False Negatives" denote no findings or workarounds, which remained hidden. "False positives" denote candidates that were no workaround according to domain experts.

Control Flow Patterns: Patterns (2), (3), and (7) were frequently observed in the Safety Solutions Inc. data set. Despite the linear to-be process, domain experts had reasonable explanations for the workarounds. Therefore, we classified them as false positives. Pattern (4) yielded a true positive, identifying a pre-packaging step used in cases with limited time or storage space. At Fuel Logistics Inc., this pattern revealed cases where invoices are received before the booking of the goods delivery. Exploring pattern (6) at Safety Solutions Inc., we identified a true positive, where a batch number assignment was followed by a quality control task, which was a workaround to deal with large orders. At Fuel Logistics Inc., in some cases, "Goods Receipt" was followed by "Order Confirmation", deviating from the to-be process model, this however was a false positive, as it was a rare, but intended edge case. Pattern (7) "Occurence of directly repeating activities" and (8) "A specific activity is missing in the trace" were not identified at Fuel Logistics Inc. A relevant number of Safety Solutions Inc. production cases are *priority orders* with severe time pressure. For such cases, the documentation of events is a subsequent activity. If performed at the end of the process, it invalidates all timestamps for these cases, therefore yielding a false positive for the pattern (7). A similar workaround of delayed documentation was found in the original SWORD paper [25] and labeled as 'batching.'

Data Patterns: The data pattern (9) "Objects with value outside boundary" was not applicable in both cases since the data sets did not contain appropriate fields. The data pattern (10) "Change in between events" was also not applicable at Safety Solutions Inc. since no intermediate data are stored, with only the final state of the process data being available. At Fuel Logistics Inc., the enterprise system logged changes automatically. Nonetheless, anomaly detection only revealed an audit-related data change, which cannot be classified as a workaround. The data pattern (11) "Information is logged in free-text fields instead of dedicated fields" was applicable and led to identifying multiple potential workarounds at Safety Solutions Inc. Test-runs were marked with a prefix in a free text field as well as the production of half-products. In the Fuel Logistics Inc. dataset, only a few text fields exist with slight variance, thus leading to no findings.

Resource Related Patterns: Due to system constraints, resource patterns were either not applicable or did not yield any interesting results for Fuel Logistics Inc. At Safety Solutions Inc., pattern (13) "Activities executed by multiple resources" led to the identification of a pre-packaging step. Pattern (14) is only a false positive, as we found some intentionally automated process instances.

Time Related Patterns: The patterns for the time component are also only applicable to a limited extent. For example, there are no unusual time windows at Fuel Logistics Inc. (17) due to, e.g., emergency assignments taking place on weekends, on public holidays, or outside standard working hours. Timestamps solely exist if an activity was completed. However, the "duration from the start of a trace to an activity" (18), the "duration between activities" (19), and the "duration of a complete trace" (21) can be analyzed, which yielded false positives, where the duration of trace was exceptionally short or long, but covered the handling of rare edge cases. At Safety Solutions Inc., patterns (17) to (21) were applicable, with pattern (18) revealing a workaround, which covers the early creation of quality-related documents. The other patterns led to false positives. Interestingly, we also identified test data within the productive system by applying the patterns, which did not qualify as workarounds.

4 LongSWORD: An Exaptation of the SWORD Method

We added activities around the core pattern application based on our findings and experience applying the SWORD method. We created two additional patterns, introducing a cross-case perspective. Thus, LongSWORD extends the original method in both temporal directions. We first explain our extension to the core patterns before elaborating on the added steps.

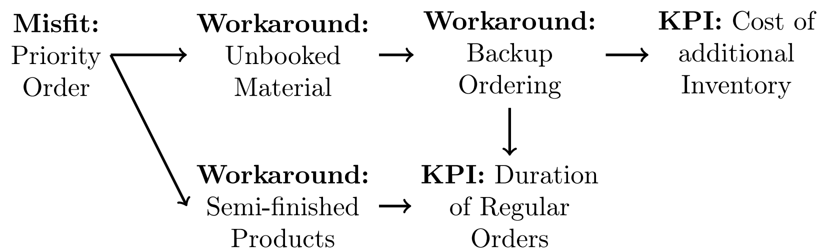
Pattern 23: Cross Case—Workaround Chains: Upon closer inspection of the Safety Solutions Inc. data set and analysis of the interviews, it became clear that workaround chains might exist. For example, the existing misfit of time pressure in *priority orders* leads to the workaround of using unbooked material. This uncertainty created in the inventory leads to backup ordering of larger quantities of raw materials to make sure that *priority orders* can be performed quickly from the stock of raw materials at all times.

Therefore, it seems reasonable to investigate workarounds' causes and effects in a forward/backward analysis. Thereby, analysts can find related workarounds as well as their underlying misfits and generate an understanding of the overall effects of a workaround. Potential tools are root cause analyses as discussed in the process quality literature, six-sigma or the Theory of Constraints [11].

Pattern 24: Cross Case—Drift of process KPI: A workaround can be dominant and effectively replace the former To-Be process. Therefore, it becomes invisible for all methods that rely on variance detection in a given time frame, even if the analysis is not limited to individual cases. Hence, we propose a drift analysis [23] as an additional SWORD pattern on the global scope. Unlike the existing SWORD patterns, this pattern does not analyze specific process instances but merely identifies hints of process evolution on the process level. Using changes in KPIs as sensors enables estimating the consequences a potential workaround might have on a process or organizational level.

Before—Choose relevant patterns: Besides the additional patterns, we extend the core method by several activities. Applying the SWORD method is resource-intensive because it requires both (data) analytics skills and domain knowledge. We propose that only patterns relevant to the case should be applied. Employing causal-directed acyclic graphs (DAG) can help identify the relevant dimensions ex-ante. We will explain this procedure with the following example:

Before & After—Process Instance Interference and Causal Effects: We build upon the example in pattern 23: The *priority order* process at Safety Solutions Inc. will regularly brush aside planned schedules for a day, including the production of semi-finished products. This aligns with the organization's goals and is expected for *priority orders*. Hence, it cannot be identified by investigating variance within *priority order* process data. When investigating regular processes, *priority order* effects are indistinguishable from other delay or quality issues. However, a correlation of *priority order* frequency and regular order performance could indicate the existence of the semi-finished products workaround.



To evaluate the impact of this workaround, it is necessary to investigate the duration of regular orders as a target variable in the same time frame. With workarounds and target variables in the same graph, it is evident that we need to consider the effect of backup orders on the duration of regular orders as well. If the workaround is effective, the duration effect of repurposed material will be reduced at the cost of additional inventory.

In summary, we show a causal-directed acyclic graph (DAG) [20], where workarounds can be considered as treatment variables. Because after we discovered a workaround, it could be encouraged or discouraged. This decision can be made by investigating the average treatment effect (ATE). Martini et al. (2015) introduce the technical debt metaphor, where short-term and long-term prioritization needs to be balanced and rely on the awareness of the interest that needs to be paid in the future [16]). These DAGs evolve iteratively during the application of the LongSWORD method. Primarily, they help to identify relevant patterns, while secondary, helping to estimate effects and derive actions based on these.

During—Iterative Guidance: While the SWORD method [27] is presented as a linear process, which expects a fixed to-be process and event log, LongSWORD stresses the necessity to focus on both IT artifacts and contextual aspects before and after conducting the activities of the SWORD method iteratively. This is based on the following observations:

1. To-be processes can be a starting point of reference. However, the event data might be on a lower level, where informal rules and organizational routines have to be gathered and codified into the new reference.
2. The event log quality and the corresponding understanding evolve over time. Its first version is often incomplete. Hence, new data sources must be added and integrated with existing data to make workarounds better visible.

The data set and the to-be process evolve iteratively during the analysis and in cooperation with the domain experts. Besides these methodical changes and additions, we also added two new patterns, which take a cross-case perspective.

The whole LongSWORD method is depicted in Figure 1. It represents an iterative method that acknowledges that the structure of the data set and the understanding of the To-Be process will likely (or strategically) evolve during its application. First, it starts with the existing step to determine the applicable patterns based on the provided dataset. From there, an initial causal DAG is derived based on the targeted processes. The estimated effects will then give a

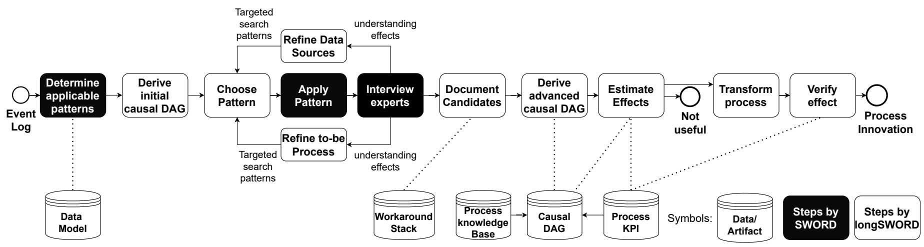


Fig. 1. The LongSWORD method and key artifacts

hint on which patterns are relevant. Now, as in the original method, the patterns are applied, and the results will be shared with the domain experts. Depending on the outcome, we propose an iterative cycle, where the to-be processes and the data sources will be refined. This shall be repeated until maturity is reached when no additional workarounds can be identified. This procedure is comparable to data science methods such as CRISP-DM [30]. The original SWORD method ends after presenting and confirming the found workarounds with the domain experts. However, we suggest continuing by documenting the found candidates, such that they are known and findable within the workaround stack of the organization [3]. Subsequently, the analysts should refine the causal DAG further to estimate the potential effects of the workaround. This iscrucial for deciding whether to leverage, prohibit, or tolerate the workaround. The approach ends here, in case no action is needed, or it will be continued by transforming the process and verifying the effect estimated in the DAG. Transforming the process is, of course, no trivial task. Early research on this topic, such as a workaround-to-innovation process, exists, which shall help structure such efforts [6].

5 Discussion

At Safety Solutions Inc., 17 out of 24 patterns were applicable, and seven successfully led to verified workarounds, denoted as true positives in Table 1. Further, a significant amount of eight false positives were found. Only two were applicable, yet no findings were yielded. At Fuel Logistics Inc., our analysis resulted in one true positive, five false positives, and eleven true or false negatives.

However, it should be noted that the respective ERP systems and, therefore, the data and its format limit the analysis. Overall, without the iterative approach regarding the process data as well as the to-be process and organizational routine, the number of findings would have been smaller as, in general, fewer patterns would have been applicable. Nonetheless, it was shown that not all patterns are always applicable in each use case, which does not have to be a weakness of the method, but is a limitation induced by the focal case. In retrospect, the approach to searching predefined patterns in a defined data structure could not be executed as efficiently as planned. Investigating data structures, understanding the inner workings of IT systems, and uncovering known edge cases not yet represented in available process models required considerable effort, especially as an external data analyst. Moreover, data integration challenges and data quality issues proved to be time and resource-consuming. The level of detail regarding process documentation and data documentation, especially regarding customized IT systems, appear to be major determinants for the effort required for workaround detection using LongSWORD. Furthermore, the efficiency of these cyclic activities is primarily constrained by the availability of domain experts and their willingness and openness to discuss workarounds.

So far, the effort of this approach to workaround detection can only be justified since the application of the method yielded other qualitative effects that have their own return on investment. That means, since applying the LongSWORD approach generated an improved understanding of the processes at hand, the interpretation of process trace data, and the causal structure of the KPIs involved, both companies appear to be better prepared regarding the following challenges. First of all, the cross-functional knowledge elicited and documented is valuable in itself from a knowledge management and business continuity point of view, i.e., as a reduction of process debt [15]. Numerous known special cases require special treatment not hitherto covered in normative process documentation.

We started our development process with the observation that the SWORD method [27] cannot fully be applied to an industrial manufacturing context. In its original form, it shows several limitations, for which we provide specific enhancements. First, the method does not provide insights into which patterns should be used for which process. Therefore, we added a loop in the mid-section of the method regarding both the data set and the to-be process. Further, we introduced causal DAGs to the method [20], supporting organizations to choose the relevant patterns and data snippets for the case at hand.

In contrast to the original SWORD method [27], applying LongSWORD requires more time from the domain experts but less time from data analysts. The diverging resource intensity of both methods enables organizations in diverse contexts to employ one or the other method based on the availability of specific resources. However, the application of both methods is relatively resource-intensive, but at the same time, it results in beneficial side effects regarding improved process and data understanding within the organization. Thus, it may be beneficial to approach the idea of systematic workaround detection for process innovation together with a data quality initiative, a process mining or redesign initiative, and culture-focused initiatives for continuous process improvements to benefit from the synergetic effects [10].

Beyond efficiency, the original SWORD method is limited to only providing a single case view while neglecting cross-case effects [24]. In contrast, the LongSWORD method comprises two additional patterns to investigate potential workaround chains and process drift [23]. In our case organizations, we noticed that workarounds may trigger other workarounds as a direct effect. Additionally, because patterns that rely on data variance struggle to identify the frequency

Perspective	Pattern	Fuel Logistics Inc.	Safety Solutions Inc.
Control flow	1. Occurrence of an activity	-	-
	2. Occurrence of recurrent activity sequence	*TN/FN*	*FP*
	3. Activity frequency out of bounds	*TN/FN*	*FP*
	4. Occurrence of activities in an order different from process model	**TP**	**TP**
	5. Occurrence of mutually exclusive activities	-	-
	6. Occurrence of unusual neighboring activities	*TN/FN*	**TP**
	7. Occurrence of directly repeating activity	*TN/FN*	*FP*
	8. Missing occurrence of activity	*TN/FN*	*TN/FN*
Data	9. Data object with value outside boundary	*TN/FN*	*TN/FN*
	10. Change in value between events	*FP*	-
	11. Specific information in free-text fields	*TN/FN*	**TP**
Resource	12. Activity executed by unauthorized resource	-	-
	13. Activities executed by multiple resources	*TN/FN*	**TP**
	14. Activities executed by a single resource	*TN/FN*	*FP*
	15. Activity frequency out of bounds for a resource	*TN/FN*	-
	16. Value frequency out of bounds for a resource	-	-
Time	17. Occurrence of activity outside of time period	-	*FP*
	18. Delay between start of trace and activity is out of bounds	*FP*	**TP**
	19. Time between activities out of bounds	*FP*	*FP*
	20. Duration of activity out of bounds	-	*FP*
	21. Duration of trace out of bounds	*FP*	*FP*
	22. Delay between event and logging is out of bounds	-	-
Cross-Case	23. Workaround Chains	*TN/FN*	**TP**
	24. Drift of process KPI	*FP*	**TP**

-: Not applicable
TN/FN - True Negative / False Negative: No candidate(s) detected
TP - True Positive: Workaround candidate(s) detected
FP - False Positive: Candidate detected, but not identified as workaround by domain expert

Table 1. Overview of patterns and findings

with which workarounds are already enacted in a process, a drift analysis can counteract this shortcoming.

One major issue we encountered was the dependency of the SWORD method on available to-be process models. In both of our case organizations, process models solely existed on an abstract level. At the same time, the established routines of the employees were more precise and represented the ground truth of process activities—an issue already observed for SMEs [29]. This aligns with the fifth definition of workarounds found by Ejnefall et al. (2019) [9]. There, workarounds are deviations from the ostensive aspects described by Alter (2014) [2], which includes formal to-be processes and routines. This perspective should be kept in mind if using either the SWORD or the LongSWORD method.

6 Conclusion, Limitations, and Outlook

In this paper, we applied the SWORD framework [27] to two industrial case organizations within the manufacturing context and adapted it to the domain.

This includes enhancing the framework by taking additional steps before, during, and after the core pattern application, including an iterative segment and two additional patterns enabling cross-case comparison. The resulting method, LongSWORD, provides guidance for both practitioners and researchers.

Naturally, our results are subject to limitations. First, the artifact was developed with solely two case organizations. Applying LongSWORD to more organizations from diverse contexts would strengthen its robustness. For example, in the Safety Solutions Inc. case, the flexibility and variance of the process posed the main challenge for its analysis. In contrast, in the Fuel Logistics Inc. case, the (statistically speaking) lack of variance was challenging for its analysis and the detection of workarounds, thus leading to a relatively small amount of findings. We expect to find more diverse challenges in other organizations, for example, referring to external dependencies of the process, sufficient freedom for process participants, and data coverage for identifying interesting workarounds as potential process innovations.

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