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Article

A Roadmap to Critical Redesign Choices That Increase the Robustness of Business Process Redesign Initiatives

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Abstract: The elaborate analysis of a business process (BP) typically informs its potential for business process redesign (BPR), but the latter is usually conducted in a non-systematic way. The purpose of this paper is the introduction of the Business Process Redesign Capacity Assessment (BP-RCA) framework that assesses the redesign capability of BP models, prior to their implementation. This study combines key redesign features introduced by domain experts, to a conceptual framework that takes into consideration an inclusive set of BPR components in three consecutive phases, towards facilitating organizations in the practice of redesign decision making. In this paper, an illustrative case study is used to present the initial phase (selection) of the framework. To assess the usability of the BP-RCA, the authors reviewed twelve established redesign initiatives from literature which proved to implicitly follow similar steps to the proposed framework. The findings indicate that the BP-RCA framework provides a systematic exploration of fundamental redesign aspects and can be used as a reliable measurement of the redesign capacity of candidate BP models. The framework also provides practitioners with the necessary methodology for increasing the BPR effectiveness, the robustness of the varying initiatives and the overall innovativeness of businesses.

Keywords: business process innovation; business process redesign; redesign heuristics; process complexity

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1. Introduction

Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and to expand the markets for external use of innovation [1]. In this context, companies are working internally through business process innovation (BPI) for the reinvention and redesign of their BPs, aiming for the creation and delivery of business value [2]. At the same time, decision making based on business process management (BPM) is valuable for organizations that have the ultimate goal of increasing their organizational performance [3,4]. BPM is a multidimensional concept that organizations rely on "to achieve continuous process improvement, such as better performance and conformance of their processes" [3]. BPM tools and techniques facilitate the capture of knowledge in information systems and the reduction of manual effort through the automation of business processes [5,6]. A prominent approach to structure the BPM discipline is via BPM lifecycle models [7] and what is evident in the literature is that continuous process improvement through BPR is embodied in most BPM lifecycles [8,9]. In spite of the rigorousness of the initial design of the process, the need for process refinement and improvement stems from the urgency to: (a) adapt to the continuously evolving internal and external setting of an organization [10], and (b) fulfill the dynamic end-user requirements [11].

Although a detailed analysis of a BP typically sparks assorted ideas and perspectives for redesign, it is usually contacted in a non-systematic way, and is predominantly considered a creative activity [12]. Thus far, only a few redesign approaches in the literature have investigated how the improvement procedure can be methodologically supported, or executed to reduce the uncertainty from the AS-IS to the TO-BE process [13]. What is also overlooked is the evaluation of the BPR impact prior to its implementation, since the majority of approaches deal with BPR at runtime. Adesola and Baines [14] propose a business process improvement (BPI) methodology that bears enhanced feasibility, usability and usefulness, but the evaluation of the redesign criteria is not performed in conjunction with the available redesign method and most importantly it takes place after the execution and analysis of the process. In another approach, Lee [15] introduces BP redesign as a distinct step of a BP-integrated IT evaluation methodology. The redesign evaluation incorporates the study of existing BPs and the establishment of redesign objectives to construct the design of new processes. The redesign evaluation step is linked to the performance evaluation that provides feedback and revision–redesign options, which indicates that it is also conducted at runtime.

The lack of systematic exploration of the full range of redesign possibilities by practitioners means that many potentially effective redesign methods remain unidentified [16]. Some redesign options should be excluded, due to the fact that the varying organizational context renders their application irrelevant, impractical or ineffective. An evaluation of the stimulus, the focused performance criteria and the factors that influence the optimal selection of process redesign projects (PRPs) could reduce the eligible BPR methods, towards selecting the most appropriate one. By acknowledging the pertinence of a BPR method and the specified criteria, an organization may proceed to an optimal selection of BPR practices prior to their implementation. Moreover, the fitness of BPs with the intended BPR should be investigated, e.g., by examining if they are modeled in a BPR-compatible modeling technique or whether the process model type is manual or automated—including execution semantics. In the same sense, given the available BPR practices, the relevant practitioner should measure and evaluate critical BP quality indicators to assess the effectiveness of BPR, e.g., complexity. This procedure will assist in answering questions such as “should the available BPR method be implemented in the case of highly structured models?” and “how do complexity indicators related to control flow affect the anticipated BPR result?”.

In essence, what is missing from the literature is an approach for assessing the redesign capability of BP models that: (a) evaluates the BPR capability prior to its implementation through a systematic procedure, and (b) takes into consideration an inclusive set of criteria (available BPR technique, performance criteria, redesign heuristics and critical BP indicators). To address this research gap, the authors introduce the Business Process Redesign Capacity Assessment (BP-RCA) framework that provides a systematic procedure for assessing the BPR impact, prior to its implementation. The proposed framework is intended to provide considerable benefits to both the BPR practitioners and academia. For practitioners, the framework systematizes the commitment to critical BPR choices prior to implementation in a straightforward manner, a fact that promotes organizational excellence and improves the effectiveness and robustness of BPR initiatives. For academia, the BP-RCA framework is a new approach that evaluates BPR prior to implementation and may be incorporated into BPM lifecycles as either a new step or a sub-step of, e.g., process redesign. The focus of this paper is the initial *Selection Phase* of the framework, which constitutes a step-by-step methodology for committing to important redesign decisions. The remainder of the paper is structured as follows: the next section presents an overview of the BP-RCA framework that combines four principal redesign components in three consecutive phases. Section 3 presents the application of the initial *Selection Phase* of the BP-RCA framework to a cost-based optimization technique. In Section 4, the authors assess and compare existing BPR initiatives to the *Selection Phase* of the framework and Section 5 discusses the findings, contribution, limitations of the research approach and directions of future work.

2. Overview of the BP-RCA Framework

The aim of the BP-RCA framework (Figure 1) is to systematically evaluate the applicability of BPR to BP models prior to the implementation of a particular redesign technique.

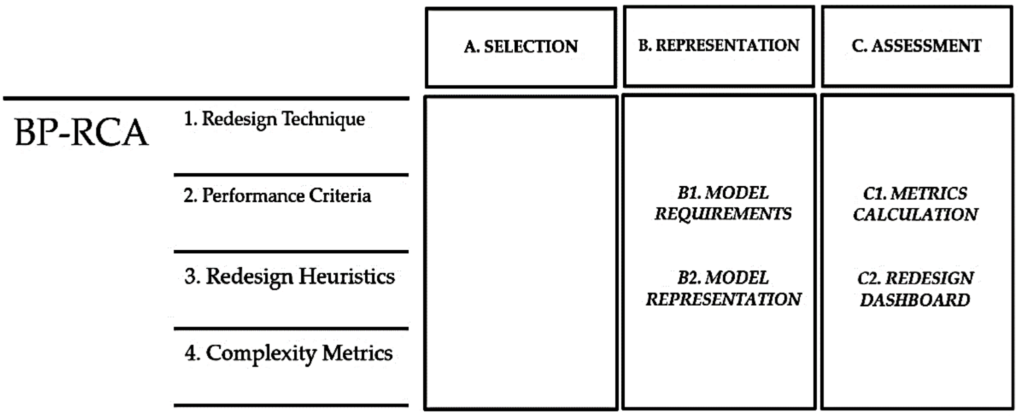

Figure 1. Overview of the BP-RCA framework.

The framework incorporates four redesign components that are construed in three consecutive phases (*Selection*, *Representation* and *Assessment*) to properly evaluate the redesign capacity of BPs through investigating the suitability of BP models. This section discusses the methodology for selecting and incorporating the components and the redesign phases in the framework. Such a tool may provide organizations with the necessary methodology for increased BPR effectiveness. This approach combines key redesign features introduced by domain experts, and correlates them into a conceptual framework, not in the course of process execution but at an earlier stage to avoid unnecessary risk.

2.1. Redesign Components of BP-RCA

After extensive study of existing redesign approaches [13,17–22], it appears that the redesign capacity of a BP model is subject to: (i) the available redesign technique, (ii) the specified performance criteria, (iii) the applicable redesign heuristics and (iv) specific BP quality characteristics. In more detail:

2.1.1. Redesign Technique

A redesign technique is the method to apply a generated process improvement idea [16]. BPR is a well-investigated area, but is mostly based on heuristics application rather than automated optimization solutions. According to van Hee and Reijers [23], there are two different categories of formal analysis techniques for redesigning BPs: *qualitative* techniques that focus on whether a process design meets a specific property, and *quantitative* ones that calculate (analytical) or approximate (simulation) the value of a specific property. Qualitative approaches primarily focus on improving diagrammatic process models, while quantitative ones are mostly related to formal modeling techniques on the mathematical models set. The latter is due to the fact that quantitative criteria, as tools for evaluating the applied BP improvements, allow for a more systematic optimization of BPs [24].

2.1.2. Performance Criteria

To better comprehend the BPR implementation through the application of redesign practices, it is important to concisely present performance criteria such as cost, quality, time and flexibility and how they correlate. These criteria are introduced in the Brand and van der Kolk [25] evaluation framework and they have been extensively used in established redesign approaches [26–30]. Despite the fact that redesigning a model should ideally improve it in all four dimensions, in reality, improving a process in one dimension may have a weakening effect on another. For instance, adding reconciliation tasks in a BP model results in both improving the quality of the delivered service, and deteriorating the time dimension via a drawback on the timeliness of the service delivery [31]. Brand and van der Kolk [25] refer to their model as the devil's quadrangle to signify the difficult trade-offs that sometimes have to be made.

2.1.3. Redesign Heuristics

BPR deals with rethinking and re-organizing BPs with the specific purpose of making them perform better [32]. This is conducted through a collection of problem-solving approaches which stretch out from the early analysis of a redesign initiative until the employment of the proposed changes. According to Dumas et al. [33], the spectrum of business process redesign methods varies depending on the ambition behind a redesign method (from transactional to transformational methods) and its nature (from analytical to creative methods). The context of the research presented in this paper naturally lies at the transactional analytical methods where heuristic process redesign, positive deviance, Six Sigma, theory of constraints (TOC) and the theory of inventive problem solving (TRIZ) are the most established methods. Heuristic process redesign is a method that has been derived from core ideas behind business process reengineering and lean and Dumas et al. [33] identify the methodological evaluation of a set of twenty-nine redesign heuristics from [31]. In [34], Dumas et al. discuss each redesign heuristic from the perspective of both the explicit target and the trade-off between time, cost, quality and flexibility, through the devil's quadrangle.

2.1.4. BP Quality Characteristic: Complexity

Model complexity is a critical characteristic of BP models that signifies their understandability and modifiability. The latter, as a measurable property, often appears in scientific literature, where several definitions exist [35]. According to Cardoso [36], the definition of BP model complexity is "the degree to which a system or component has a design or implementation that is difficult to analyze, understand or explain" [37]. A model's complexity cannot be directly determined by only one type of metric [38], a fact that has resulted in a plethora of complexity metrics for BP models [39]. This is shown in [40], where sixty-five process complexity metrics were systematically identified and analyzed. Many approaches provide simple metrics such as number of activities, joints and splits (NOAJS) and depth (maximum nesting of structured blocks in a process model) that can be effortlessly computed, however, they do not incorporate the heterogeneity of component structures present in the process model. On the other hand, metrics like coefficient of network complexity (CNC) or connectivity level between activities (CLA) consider the structural variation of the model, but appear to be complicated to compute, or difficult to comprehend for a designer.

2.2. Redesign Phases of BP-RCA

The BP-RCA framework progresses through three consecutive phases: (a) the *Selection Phase*, where the key decisions regarding each component are taken, (b) the *Representation Phase*, where the BP input model requirements are defined and a fitting representation method is adopted and applied and (c) the *Assessment Phase*, where complexity and heuristic metrics are calculated, and the redesign dashboard is generated. This paper focuses on the elaboration of the *Selection Phase* that is showcased along with a detailed case study in the following section. The development of the *Representation* and *Assessment Phases* is currently in progress, and they are briefly discussed below.

2.2.1. Representation Phase

The Representation Phase aims to initially determine the input model requirements that arise from the redesign decisions taken in the *Selection Phase*, and then to adopt and apply a—compatible to the redesign technique—representation method. The outcome will be a list of essential information and metadata each input model should necessarily feature, in order to be fit for the particular BPR. The Representation Phase is a transitional phase resulting in an input model representation that is amenable to the redesign technique and is oriented towards the facilitation of metric calculation in the next phases of the framework. Apart from the purposes of the introduced framework, the output (representation) of this phase can directly be used, in the redesign implementation of feasible models. At this research stage, the application of the Representation Phase is extensively tested on varying process models and for different redesign techniques. The initial work is introduced in [41] where a hybrid representation method is presented to account for cost-based optimization techniques.

2.2.2. Assessment Phase

The *Assessment Phase* aims to provide decision makers with an overview of the intended redesign approach and a degree of identified risk, through an analytical dashboard that quantifies the redesign capacity of models. This phase will include the composition of an analytical dashboard with the selected redesign technique, the overall application methodology and the required characteristics of the input model. The dashboard will measure the compliance of the organization's BPs with the redesign initiative. Regarding performance criteria, the dashboard will provide the selected performance metrics, their specification and computing formulas, along with the required elements and metadata of the input model. It will also include the selected redesign heuristics, the required model characteristics (constraints) that affect redesign and the heuristic metric values for each BP model that depict their applicability. Finally, it will include the selected complexity metrics that affect redesign, the model characteristics needed for complexity calculation and the computed metric values. The calculated metric values for both complexity and heuristics are similar in the sense that they can be examined in contrast to specified thresholds (as in [12,42]) to advance or abort the redesign procedure. In total, the redesign dashboard of the BP-RCA *Assessment Phase* will facilitate the decision making, by identifying and presenting crucial redesign information and weighing each initiative, through a measurable index of the redesign capacity of input models.

2.3. The BP-RCA Framework through an Open Innovation Perspective

As in [43], we interpret innovation as the set of incremental changes and activities of a company, which holistically lead to the introduction of a novel or improved product, service or process. According to [44], there are three archetypes of core processes in companies following an open innovation approach, i.e., the outside-in process, the inside-out process and the coupled process. In Table 1, there is a direct association of these core innovation processes with the innovativeness of the BP-RCA framework. What is evident is that the BP-RCA framework is consistent with the open innovation approach and is aligned to the three core open innovation processes. Apart from measurable benefits like the avoidance of computational and resource costs in the cases with low redesign capacity, the implementation of the framework also bears benefits of inbound and outbound open innovation [45], as presented in Table 1.

Table 1. Alignment of BP-RCA framework with open innovation.

Core Process	Description from [44]	Alignment of BP-RCA Framework
Outside-in process	A company's innovativeness is increased by merging the external knowledge (e.g., from customers and external alliances) for enriching the company's own knowledge.	The systematic redesign assessment of candidate BPs is based on the inflows of knowledge from the customers and suppliers (e.g., the need for redesigned processes with better performance attributes or the increased complexity of AS-IS BPs) and external knowledge sourcing (e.g., new BPR techniques, redesign heuristics and their connection with performance criteria).
Inside-out process	Inversely, the dissemination of internal knowledge and ideas leads to the external exploitation of ideas in different sectors and industries.	The BP-RCA methodology constitutes an improved intra-organizational service for the assessment of BP redesign and is a distinct act of innovativeness. The dissemination of such systematic methodologies leads to an increase in external knowledge since it can be applied for redesign initiatives in other sectors or be adapted to become more efficient.

Table 1. *Cont.*

Core Process	Description from [44]	Alignment of BP-RCA Framework
Coupled process	The interrelation of the outside-in and inside-out processes for the exchange of knowledge and the collaboration of companies for mutual success.	The BP-RCA framework advances partnership and collaboration with external entities (clients, suppliers, companies, analysts, etc.), resulting in both the provision of improved products and services and the avoidance of computational and resource costs.

3. BP-RCA: Selection Phase

This section presents the *Selection Phase* of the BP-RCA framework, showcasing the steps and decisions that it entails with an example (i.e., constructing a redesign initiative based on a set of initial critical choices). The aim of the *Selection Phase* is to commit to specific decisions for each of the redesign components of the framework. The authors argue that this phase directly impacts the success of the redesign initiative. As a case study, we selected an optimization method involving BPR through cost-based optimization techniques, initially proposed for data analytics workflows [46,47]. This work is structured and presented as a use case based on the *Selection Phase* of the BP-RCA to help demonstrate the critical importance of initial planning and decision making regarding the implementation and robustness of a BPR approach.

3.1. Selection of Redesign Technique

The selection of an appropriate redesign technique is essential to every organization for avoiding unnecessary risk in fulfilling their cause. Many techniques may prove ineffective and costly after the redesign implementation, while a fitting technique bears many benefits, such as improvements in critical, contemporary measures of performance and process automation. Given the plethora of available redesign techniques, an organization seeking to apply BPR should select the optimal one(s) to maximize these benefits. Varying factors affect this selection, such as the particular BP characteristics [48], available funding [49,50], resources to support BPR [22,51] and the alignment of the redesign technique to the organizational strategic plan [52,53]. The authors of this paper state that by following an upfront selection of the redesign technique, business analysts can promptly and efficiently determine the performance criteria that can be improved by considering the particular characteristics of the selected technique (e.g., available tool, methodology, employed algorithms).

In our example (Figure 2a), we begin to formulate a redesign initiative by selecting data-centric workflow optimization It involves the transformation of a Business Process Model and Notation (BPMN) model to a Directed Acyclic Graph (DAG) with the use of initial symbol mapping [46], and the application of state-of-the-art algorithms initially developed for data-centric workflow optimization (e.g., in [54,55]). The redesign approach promises automated performance optimization of BP execution and has exhibited considerable optimization results (e.g., more than 25% reduction in running time of the more constrained cases). The advantage of this approach is that BPs can benefit from recent advances in data-intensive workflow optimization.

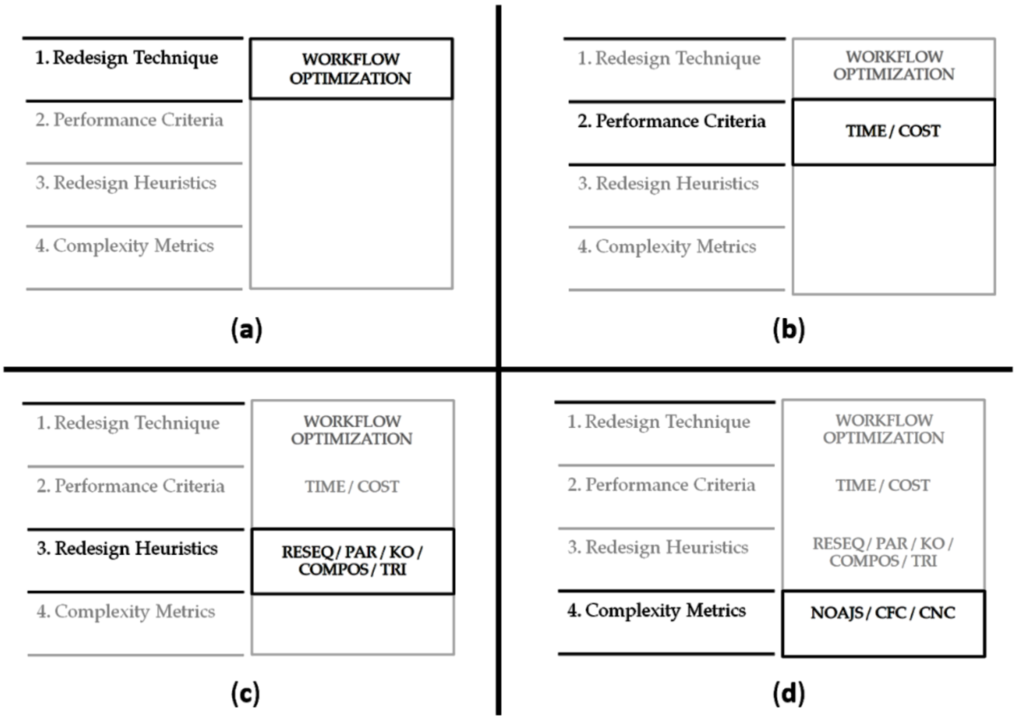

Figure 2. *Selection Phase* of: (**a**) redesign technique; (**b**) performance criteria; (**c**) redesign heuristics; (**d**) complexity metrics.

3.2. Selection of Performance Criteria

The selection of performance metrics is considerably dependent upon the redesign technique(s) selected by the organization. For instance, when the redesign technique involves the execution of optimization algorithms, the focused performance metrics are in most cases time and/or cost. On the other hand, a qualitative redesign technique, e.g., one that moves different checks and reconciliation operations of a BP towards the customer [56], intends to primarily improve process quality (e.g., due to customer's satisfaction). Thus, given the selected redesign technique, the feasible performance criteria can be derived. In accordance with the Mansar and Reijers [26] approach, the selected performance criteria or—more directly—the performance targets formulated for a redesign effort are also firmly connected to the applicable redesign heuristics. Our redesign example involves cost-based optimization that heavily relies on quantitative metrics across several process instantiations. Based on previously published work [47], the authors consider the following commonly used in BPR optimization objectives (Figure 2b), either separately or in combination (multi-objective optimization):

- **Monetary cost/resource consumption**, which is defined as the sum of the human and machine costs. Human cost refers to the human resource consumption (e.g., human operators, process participants) required to complete a BP execution, while machine cost reflects the consumption of other resources (e.g., cooperative computer systems, BPM systems, machinery) that are necessary for the BP execution.
- **Cycle time** that represents the average "processing time" between the initialization and completion of a process execution [57]. In this case, cycle time is defined as the sum of the processing times of the executed activities belonging to the critical path of a BP. The critical path is obtained from the longest path of a process model, from a source to an end [58].

3.3. Selection of Redesign Heuristics

The commitment to these specific performance criteria directly points to the application of particular redesign heuristics. The selection of heuristics can be achieved by assessing the devil's quadrangle of each heuristic (as presented in [26,27,32]) and the extent to which the focused performance criteria are improved. It is important to note that the resulting set of heuristics may seemingly improve the selected performance criteria, but not all heuristics are necessarily applicable. Their applicability is dependent upon (a) the redesign technique, i.e., whether a heuristic is deployed by an optimization algorithm, and (b) the characteristics and complexity of the organizational BPs.

According to Dumas et al. [33], the BP behavior view is a notion that deals with the execution order of activities and the way they are scheduled and assigned for execution. This category is the most relevant to database-like optimization [46], and for the use case, we focus on the following three heuristics: resequencing (RESEQ), parallelism (PAR) and knockouts (KO). Other noticeable model features, that may potentially support the application of optimization techniques, initially proposed for data-centric workflows to BPs, are directly attached to particular BP operation heuristics. The latter consider the implementation of a BP in terms of its activities and the heuristics that can be combined with BP behavior heuristics in this BPR approach are triage (TRI) and activity composition (COMPOS). For instance, dividing a large activity into two workable smaller ones (TRI), only the first of which is required to run subsequent knockout checks (KO), and moving (RESEQ) the non-necessary part either after all knockout activities or in parallel with them (PAR), can yield improvements in resource consumption and process cycle time. The *Selection Phase* of redesign heuristics is shown in Figure 2c.

Figures 3 and 4 demonstrate the devil's quadrangle of the selected heuristics of behavior and operation view categories [32], in which the enhancement of the selected performance dimensions (time and cost) is apparent. In particular, Figure 3 shows that RESEQ has an equally positive effect on cost and time dimensions, while PAR enhances the time dimension to a great extent, having opposite effects on the cost dimension, due to a practical increase in resource consumption. The KO heuristic results in considerable enhancement of the cost dimension, due to an increased frequency of early process terminations resulting from knockout parts, while the time dimension is relatively unaffected. Figure 4 demonstrates that the TRI heuristic provides substantial improvement to the model's quality [33] and time and cost dimensions are also improved, due to better allocation of resources. The COMPOS heuristic improves the time dimension, e.g., in terms of setup time reduction, yet composing tasks that are too large can result in negative effects such as lower model quality, due to unworkable activities. This redesign practice also results in moderate improvement of the cost dimension and, at the same time, reduced flexibility due to the composition of larger rigid tasks. In total, the selected redesign heuristics are applicable through the available cost-based optimization technique and induce the improvement of time and cost performance dimensions, as shown in Figures 3 and 4.

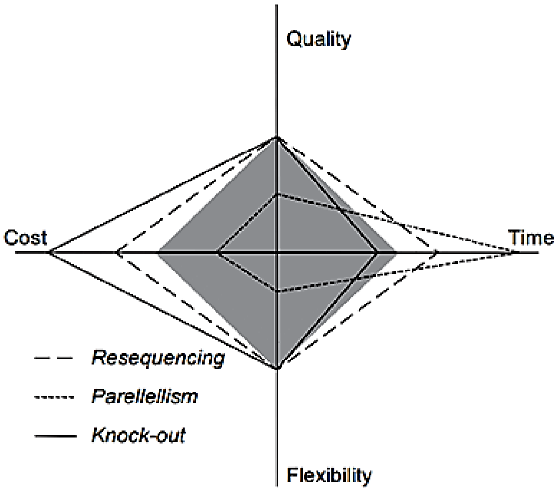

Figure 3. Devil's quadrangle for the selected BP behavior heuristics.

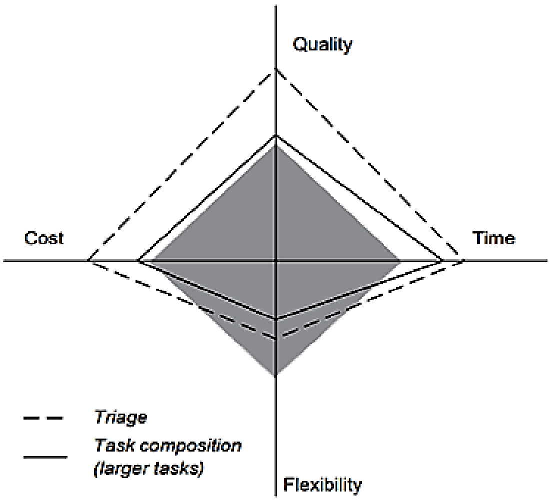

Figure 4. Devil's quadrangle for the selected BP operation heuristics.

3.4. Selection of Complexity Metrics

The act of evaluating and ultimately reducing a model's complexity provides substantial benefits, primarily in enhancing the correctness, maintainability and understandability of BP models [59]. An increased value of a complexity metric may signify high possibility of redesign ineffectiveness, error probability or intricate implementation [60]. The selection of complexity metrics that may affect a BPR initiative is achieved by answering the research question: *What BP indicators facilitate or complicate the applicability of redesign heuristics?*

In this case study, the selection of metrics should primarily focus on control flow complexity, since the redesign approach intends to transform the control flow of the BPMN model to a DAG, prior to optimization. This entails that the transformation of a model with high value of control flow complexity will have a high probability of being a complex procedure with an uncertain outcome. Nevertheless, following the review on related research, the authors selected (Figure 2d) three established and representative complexity metrics (NOAJS, CNC and CFC), that primarily focus on the size, control flow and structuredness of a process model. This selection was based on the fact that they have been extensively used (e.g., in [61–63]), their calculation is straightforward and, most importantly, each metric plays a vital role in transformation initiatives between different modeling techniques [64,65]. It should be noted that, according to Cardoso [66], the CFC metric should not be used in isolation to effectively evaluate the overall BP complexity, because it only analyzes a process from the control flow point of view. Similarly, metrics like NOA and NOAJS are useful and straightforward to calculate, but should accompany other complexity metrics to depict overall complexity. Altogether, these metrics will provide a sense of the BPMN model's capability for transformation to a DAG, prior to redesign.

3.5. Remarks on the Selection Phase Applied to the Case Study

The BP-RCA *Selection Phase*, as presented in this paper (Figure 5), is important in the sense that crucial aspects of the redesign approach are determined by examining each component. The selected redesign method is data-centric workflow optimization and since this is a cost-based optimization method, the deduced performance metrics are execution time and/or cost. These performance metrics are improved with the use of established dataflow optimization algorithms that resemble the selected redesign heuristics (RESEQ, PAR, KO, COMPOS, TRI). Finally, the redesign method determines the BP quality indicators that facilitate or complicate its implementation regarding the model complexity. These indicators refer to the BP's size, control flow and structuredness and representative metrics of these indicators are NOAJS, CFC and CNC, respectively. The selection of these crucial redesign components of the BPR use case is performed with a systematic and progressive approach, with potentially notable benefits, contrary to an intuitive one. The redesign decisions are interrelated in the sense that each component is directly dependent upon the selection of the previous one. Therefore, committing to the decisions taken in the *Selection Phase* is essential for the *Representation Phase*, where they determine both the BP input model requirements and a fitting BP representation method for the BPR approach selected.

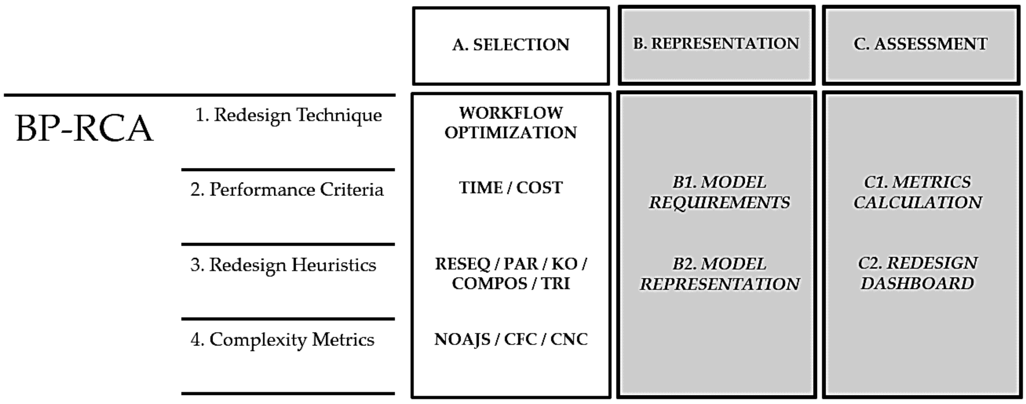

Figure 5. An overview of indicative redesign choices in the BP-RCA *Selection Phase*.

4. Assessment of Existing BPR Initiatives Based on BP-RCA

This section presents different BPR initiatives from the literature in comparison to the proposed framework. What is examined is the degree to which the authors of each case study implicitly followed the same—or similar—steps to the BP-RCA *Selection Phase* steps, to ground their selection of the redesign approach. To accomplish this, the authors selected twelve redesign initiatives and studied the decisions taken on critical BPR aspects. Table 2 presents the applied redesign technique, methodology, performance criteria, redesign best practices (heuristics) and model characteristics of these twelve initiatives. The methodology column provides the adopted methodology for redesign application and/or tool availability. Many redesign practices found in the literature are performed manually (e.g., through methodological steps, heuristic rules, guidelines) while others result from framework implementations (e.g., BPR framework, dBOP, evaluation framework). The majority of the twelve case studies did not rely on an explicit consideration of the heuristics set to create TO-BE scenarios. Similarly to [67], we assumed that a best practice is implicitly applied if part of the intervention is highly similar to the description of a heuristic, as introduced in [32].

Mansar and Reijers [26]: In this paper, Mansar and Reijers introduce the BPR framework to help the process designer in choosing the correct redesign practices. Mansar and Reijers [26] implicitly follow a similar methodology to the BP-RCA framework methodology for the BPR decisions taken, since the performance criteria determined the selected redesign best practices and the BP complexity played a vital role in their applicability. The difference to our approach is that the performance criteria were pre-selected by the municipality and the public works office. In addition, the complexity of the case studies was only considered by the authors for selecting the redesign heuristics to be applied, but no process model or complexity indicator was presented in the paper.

Niedermann et al. [68]: Niedermann et al. used a pattern-based optimization technique through the deep Business Optimization Platform (dBOP). Based on the redesign technique, they determine their performance criterion (reduction in process time) and the selection of heuristics is based on the meta-information of each pattern in the pattern catalogue. We deduce that there is an explicit association between the selection of the redesign heuristic and the previously defined performance criteria, in a similar manner to the BP-RCA *Selection Phase*. The application of the patterns was successful in reducing the average process duration but a previous analyst confirmation was required to ensure their applicability. What would potentially facilitate automation is the consideration of how complexity indicators of a BP affect the heuristic applicability.

Zapf and Heinzl [69]: In [69], a framework for evaluating generic process design patterns is developed and tested. Zapf and Heinzl used process partitioning strategies through simulation and performance criteria based on the behavior and outcome on the performance evaluation models involved. The applicability of process partitioning is dependent upon the quality characteristics of each case study. The redesign aspects of the [69] approach are selected in a similar manner to the *Selection Phase* of the BP-RCA framework. What is overlooked is the consideration of the BP's suitability for the heuristic application.

Table 2. Existing business process redesign initiatives compared to BP-RCA framework.

No.	Ref.	Redesign Technique	Method	Performance Criteria	Redesign Heuristic(s) [1] [33,70]	BP Characteristics and Complexity
1	[26]	Simulation (WFM support)	BPR framework	Time (reduction in average service time)	ELIM, RESEQ, COMPOS, NUM, SPEC, TECH	No process model is presented.
2	[26]	Simulation (WFM support)	BPR framework	Time (reduction in average service time)	ELIM, COMPOS, PAR, ASSIGN, EMP, TECH	No process model is presented.
3	[26]	Simulation (WFM)	BPR framework	Time (reduction in average lead time)	INT, ELIM, CASEB, RESEQ, COMPOS, ASSIGN, EMP	No process model is presented.
4	[68]	Pattern-based optimization	dBOP Platform	Time (reduction in process time)	ELIM, KO, PAR	Simple process model with 9 tasks and 1 gateway.
5	[69]	Partitioning strategies and simulation	Evaluation framework	Quality efficiency	TRI, SPEC, NUM, REDUC, FLEX	No process model is presented. It consists of two tasks and 210 agents.
6	[71]	Rule-based redesign (WFM)	N/A	Time (reduction in lead time)	ELIM, AUTO, KO, PAR, MAN, TYPE	Simple sequential process model with 10 tasks and 4 XOR gateways.
7	[71]	Rule-based redesign (WFM)	N/A	Time (reduction in lead time)	AUTO, ELIM, CASEB,	Simple process model with 13 tasks and 2 XOR gateways.
8	[72]	Workflow optimization	N/A	Time (reduction in cycle time)	RESEQ, TRI, COMPOS	No process model is presented. It is applicable to low-complexity processes.
9	[73]	Simulation modeling and optimization	N/A	Time (reduction in waiting patients)	TRI, RESEQ, SPEC, ADD, XRES	Overview of simple simulation model structure with 13 activities is presented.
10	[74]	Resource management optimization (WFM)	N/A	Time (reduction in cycle time) Cost (reduction in resource consumption)	SPEC, CENTR, TRI, XRES	Moderately complex workflow containing 22 tasks, 8 OR and 2 AND gateways.
11	[75]	Participative rule-based redesign	N/A	Time (reduction in throughput and service times)	COMPOS, TECH, CASEB, XRES, REDUC, EXCEP, RESEQ, TRI, AUTO, ELIM, INTG, PAR, EMP	Workflow of 21 tasks, 2 XOR and 1 AND gateways, and 9 role resources (low complexity).
12	[76]	Simulation	Process Handbook (PH)	Time (reduction in cycle time and queue waiting time) Cost (actor's utilization)	RELOC, REDUC, COMPOS, TECH, PAR, RESEQ, XRES, AUTO	No complete process model is presented. The overview of the process contains 25 tasks and collapsed subprocesses.

[1] The acronyms in this column refer to particular heuristics according to [33,70]: Activity Elimination (ELIM), Numerical Involvement (NUM), Specialist–Generalist (SPEC), Technology (TECH), Case Assignment (ASSIGN), Empower (EMP), Integration (INT), Case-based Work (CASEB), Contact Reduction (REDUC), Flexible Assignment (FLEX), Activity Automation (AUTO), Case Manager (MAN), Case Types (TYPE), Control Addition (ADD), Extra Resources (XRES), Resource Centralization (CENTR), Exception (EXCEP), Integration (INTG), Control Relocation (RELOC).

Jansen-Vullers et al. [71]: In [71], Jansen-Vullers et al. apply rule-based redesign on e-commerce (EC) BPs, with WFM technology support. What is indicated in the research paper is that the application of redesign heuristics is directly associated with the pre-selected performance criterion, and their applicability is dependent upon the special characteristics of each BP. Jansen-Vullers et al. [71] seem to implicitly follow the same steps as the BP-RCA framework in grounding their redesign perspective, apart from the consideration of the BP's complexity in the applicability of the redesign heuristics.

Dewan et al. [72]: The authors in [72] present a practical methodology for identifying profit-maximizing changes in the structure of administrative processes. Both the redesign technique and the selected performance criterion have delimited the applicable set of redesign heuristics (RESEQ, TRI and COMPOS). A limitation of this approach is that it is mostly applicable to administrative processes with low complexity and relatively stable task structures, such as order fulfillment by mail order distributors and mortgage processing [72]. The redesign decisions taken by the authors prove to be similar in context and sequence to the *Selection Phase* of the BP-RCA framework, but a consideration of the BP model's complexity is also missing.

Ashton et al. [73]: A simulation-based project is used to facilitate managers and health professionals to recognize existing problems, and investigate redesign ideas for health care processes. The decisions taken for the redesign technique, the performance criteria and applied heuristics were interrelated in a similar concept to the *Selection Phase* of the BP-RCA framework. The differences to our approach are based on the fact that they considered varying parameters (as referred to earlier) for investigating the redesign heuristics' application, and that the model's complexity is not examined.

Barkaoui et al. [74]: The outcome of a workflow research project for the redesign of hospital organization BPs is presented in this paper. The redesign heuristics selected mostly pertain to the Organization heuristics category which relates to the structure of the organization and especially allocation of resources [34]. The authors spotted a similar rationale in the redesign decisions taken in this paper to the *Selection Phase* of the BP-RCA framework. The redesign technique (resource management) plays a vital role in both the performance criteria (time and cost) and the selected redesign heuristics that primarily focus on allocation of resources. Nevertheless, there is a lack of consideration of the effect of the model's complexity on the heuristic applicability.

Jansen-Vullers and Reijers [75]: In [75], a participative ruled-based redesign approach for BPs of the healthcare domain is presented. Comparing the decisions taken in this redesign method and the *Selection Phase* of the BP-RCA framework, they particularly seem to differ in the logic and methodology. This is due to the fact that the [75] approach is a participative and relatively unstructured method for applying redesign heuristics as rules of thumb. This does not mean that they do not share common characteristics, such as the consideration of the effect of performance criteria on the selection of heuristics and the suitability of process models for the redesign implementation.

Kim [76]: The author in this paper [76] presents a coordination theory approach to organizational process change by applying the Massachusetts Institute of Technology Process Handbook (PH) with a simulation technique. Kim [76] suggests that the applied redesign heuristics are selected by identifying bottlenecks and redundant processes towards improving performance. This entails that there is a direct relation between the selection of performance criteria and redesign heuristics. What is deduced is that the redesign decisions taken in this paper are in accordance with the ones taken during the *Selection Phase* of the BP-RCA framework. What is overlooked is the effect of the BP's characteristics and complexity on the applicability of heuristics.

The twelve case studies discussed above implicitly follow similar steps to the *Selection Phase* of the BP-RCA framework for determining their redesign technique, performance criteria and redesign heuristics. In the majority of cases (eleven out of twelve), the focused performance criteria are directly associated with the selected redesign heuristics for application. The only redesign approach that seems to be different is a participative method [75] for applying redesign heuristics as rules of thumb, rather than a redesign initiative with a pre-determined redesign technique. Regarding the performance criteria, they were either selected to fit the available redesign technique (three out of twelve cases), or were pre-defined by the authors and the BP practitioners in real-life BPs (nine out of twelve). This means that the real-life BPs and the performance criteria were pre-determined, and the redesign technique was subsequently selected, a fact that justifies the lack of an explicit association between the redesign technique and the performance criteria. Moreover, in seven cases, the authors claim that there is a direct interrelation between the characteristics and complexity of the BP model and the applicability of the heuristics, but a formal method for the consideration of this applicability is missing in all cases. This has proved a considerable limitation, since they do not explore how BP models with varying size and complexity respond to each BPR approach. Following the brief analysis of each model characteristic, it is deduced that in six cases the process models are either missing or not fully presented (e.g., regarding control flow) and the majority of case studies are relatively simple models with small to moderate size and complexity. Even in approaches with high complexity [71], the authors have omitted the process steps for reasons of clarity, decreasing the model size and complexity.

5. Discussion

This paper presented an overview of the BP-RCA framework and elaborated on the *Selection Phase* with a detailed redesign initiative and a critical review of twelve existing approaches. The BP-RCA framework is a methodological tool for systematically evaluating the redesign capacity of candidate BPs, prior to BPR implementation. The framework is composed of four essential BPR components (available redesign technique, focused performance criteria, applicable redesign heuristics and critical complexity metrics) considered in three consecutive phases (*Selection, Representation and Assessment*), towards clarifying the necessary redesign decisions and ultimately facilitating decision making. The *Selection Phase* was demonstrated for data-centric workflow optimization, where crucial aspects of the redesign approach were determined by examining each redesign component. Taking into account the nature of the redesign method, the authors deduced the focused performance criteria (execution time and/or cost). The selection of redesign heuristics (RESEQ, PAR, KO, COMPOS and TRI) was based on the consideration of the performance criteria improvement in the devil's quadrangle and the existence of established dataflow optimization algorithms that replicate these heuristics. Finally, the methodology for applying the selected redesign heuristics determined the BP quality indicators that facilitate or complicate its implementation. The selected indicators refer to the BP size, control flow and structuredness and representative complexity metrics of these indicators are NOAJS, CFC and CNC, respectively. Ultimately, the implementation of the framework's *Selection Phase* for the particular BPR approach led to a progressive and systematic commitment to the essential redesign choices.

The authors further performed an analysis of BPR approaches in the literature and the methodology they adopted for grounding their redesign decisions. The analysis involved the comparison of each adopted methodology with the one presented in the *Selection Phase* of the BP-RCA framework, to demonstrate similarities and differences in perception. It appears that in the majority of cases, authors or practitioners implicitly followed similar steps to the *Selection Phase* for determining their redesign technique, performance criteria and redesign heuristics. Moreover, in seven out of twelve cases, the adopted approaches show that the characteristics and complexity of the BP model directly affect the applicability of redesign heuristics, but they do not explore how BP models with varying size and complexity respond to each BPR initiative. In more detail, the presented approaches: (a) lack a systematic procedure for assessing the BPR impact prior to its implementation, (b) adopt similar steps to the BP-RCA framework for grounding their redesign decisions, (c) interrelate most of the BP-RCA components (redesign technique, performance criteria, redesign heuristics, BP complexity) during BPR application, (d) lack a method that quantifies the applicability of redesign heuristics based on model characteristics and complexity, and (e) use simple process models with low to moderate complexity to demonstrate their effectiveness.

A crucial benefit of the BP-RCA framework lies in the progressive consideration of redesign components of the *Selection Phase*, as it systematizes the commitment to redesign choices in a straightforward manner, increasing the robustness of the BPR initiative. This commitment is important due to the variability of critical information, such as process characteristics and focused performance criteria. The a priori usage of the framework facilitates redesign decision making, since critical failure causes are excluded prior to implementation (e.g., processes with increased complexity). It is also evident that in the case of BPs lacking BPR capacity, an organization or business will not proceed to BPR implementation, a fact that increases BPR effectiveness and reduces overall costs. Moreover, the BP-RCA framework is consistent with the open innovation approach and is aligned to the three core open innovation processes. Apart from measurable benefits like the avoidance of computational and resource costs in the cases with low redesign capacity, the implementation of the framework also bears benefits of inbound and outbound open innovation. The contribution of this research work to the relevant literature lies in the novelty in evaluating BPR initiatives prior to implementation. To our knowledge, a similar approach is lacking as the assessment of BPR is conducted after the execution of TO-BE process models and based on process monitoring, control and conformance/performance insights. The framework may also be incorporated into BPM life cycles as either a new step or a sub-step of, e.g., process redesign.

A limitation of the BP-RCA framework is the fact that it takes into account model complexity in general as the focused BP quality characteristic. Based on the fact that there exists a plethora of BP quality characteristics, such as modifiability, understandability and correctness, a more extensive analysis of the last BPR component of the framework would provide a better insight into the eligibility of a BP model for redesign. Towards addressing this limitation, the authors are conducting research on incorporating a more analytical view of this BPR component. Another limitation is that the BP-RCA framework only facilitates BPR practitioners in manually committing to redesign choices. Ideally, this should be supported with a prototype tool for automated assessment of BPR initiatives.

Since the BP-RCA framework is designed to constitute a broadly applicable methodological tool for BPR, the authors are extensively testing it on different BPR approaches, e.g., simulation modeling and optimization, rule-based redesign, pattern-based optimization and evolutionary multi-objective optimization. The next steps of our approach involve finalizing the *Representation* and *Assessment Phases* of the BP-RCA framework. The research work on the *Representation Phase* involves the application of different input model requirements (level of overall complexity and external quality) and representation methods. Regarding the *Assessment Phase,* the authors are working on metrics that quantify the applicability of the most commonly used redesign heuristics of the BP behavior and operation heuristic categories. Lastly, the authors are examining different options for evaluating the calculated values of complexity metrics. An option that is currently under research is the assessment of a model's overall complexity through utilizing a cluster analysis technique that leverages selected complexity metrics and combines them into a single weighted measure, offering an integrated scheme for evaluating complexity.

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