# Systematizing Business Process Redesign Initiatives with the BPR:Assessment Framework

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***Abstract*— Business process redesign (BPR) has emerged as a widely accepted practice within organizations for delivering better products and services and ensuring measurable benefits. Despite the adoption of BPR, it largely remains the result of a creative process and there is a lack of approaches for evaluating the potential impact of a BPR method before investing in its implementation. This means that BPR initiatives are selected based on 'black-box' generic options that are not explicitly tailored to the culture, structure, and existing processes of the organization. This paper aims to address this gap by introducing the BPR: Assessment Framework, a conceptual model based on Design Science Research Process (DSRP). The framework is intended to assess the BPR capacity of process models based on their plasticity and external quality. The usability of the framework is presented in the following manner: (a) through the demonstration of the framework using a data-intensive workflow optimization method as an end-to-end paradigm, and (b) the BPR capability assessment of 15 business process models from literature, to better demonstrate the benefits of omitting ineligible models prior to BPR application. The categorization of the redesign capability of models was based on a tested cluster analysis method using the k-means algorithm. Based on the findings, a considerable number of process models proved to be either overly constrained for the application of redesign heuristics or did not possess the required external quality to be redesigned. The contribution of the approach lies in the fact that the framework can also be extended to apply systematic BPR to eligible BPs. The framework can serve as a reliable measurement of the redesign capacity of candidate process models and as an essential part of a systematic methodology for increased BPR effectiveness.**

***Keywords—business process, business process redesign, redesign assessment, redesign application***

## I. Introduction

Nowadays organizations are exposed to emerging concerns related to the rapidly evolving economy and market landscape; they are expected to provide high-quality products and services to survive through competition [1]. In this context, organizations need to apply both fundamental and incremental changes to their business processes (BPs) to get considerable improvement results, and this is performed primarily through Business Process Redesign (BPR). The necessity of BPR as a discipline is apparent, due to the increased attention it has received in the research community and the fact that it is embodied as a separate cycle step in most of the Business Process Management (BPM) Lifecycles.

Although extensive research has been carried out in the BPR area, the failure rate of BPR projects still remains high and there are limitations in existing research results [2], and in terms of generalization when studies investigate particular case studies [3]. Accordingly, there is no consideration in literature regarding approaches that evaluate the applicability of BPR prior to its implementation, a fact that could facilitate practitioners to perform more effective BPR. The aim of this paper is to address this gap by introducing the BPR: Assessment framework for assessing the redesign capacity of input models based on their plasticity and external quality. The framework has the potential to be incorporated in a comprehensive BPR methodology that puts into effect varying BPR methods in a systematic and effective manner. The objectives of this paper are: (a) to present how the BPR: Assessment framework evolved through an established methodology for Design Science Research (DSR) in Information Systems, (b) to present the phases and redesign components of the framework, (c) to showcase the application of the proposed approach for a cost-based optimization method, and (d) to demonstrate the application and usefulness of the framework by assessing 15 BP models from literature.

The rest of the paper is structured as follows: Section 2 provides the theoretical foundation and related work of the approach and section 3 presents the research methodology and how the framework was conceptualized with the use of DSRP. Section 4 presents the framework, an overview of its phases and a demonstration example using a a cost-based optimization method. Section 5 showcases the assessment of the redesign capacity of 15 selected models from literature. Section 6 presents how the framework can become a critical part of a comprehensive methodology. The paper concludes with section 7, the discussion and conclusions section.

## II. Related Work

Many methodologies, techniques, and tools have been introduced in literature to support BPR and similar Business Process Change (BPC) initiatives, such as Business process Improvement (BPI), Reengineering and Optimization (BPO). They are created as integrated approaches to address already known difficulties and challenges that practitioners face in the field of practice. BPR approaches commonly lack systematic implementation methodologies, actual technical directions to (re)design a BP, prior assessment of the initiative; they mostly focus on how to manage the changes at the organizational level instead of looking to the performance or structure of BPs.

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Our interest in this paper is clearly towards BPR methodologies that address the technical issues mentioned above and particularly the need for prior assessment of BPs. One established BPR methodology was introduced and further developed in [4] and is used for classifying best practices in BPR and indicating the major areas a practitioner needs to focus when redesigning a project. The methodology in inclusive in terms of the identified redesign heuristics and serves as a guide for applying best practices. Another approach is the model-based and integrated process improvement (MIPI) methodology introduced in [5]; The methodology is assumed to have captured the critical elements and success factors needed for developing an effective methodology for BPI. The MIPI methodology met the criteria of feasibility, usability and usefulness but needs further testing to prove its validity and generalization.

Another approach aiming to address the challenges of BPR is the KBPI Framework [6], designed for the improvement of knowledge-intensive BPs (KBPI). The framework is comprised of a foundational theory of knowledge, an ontology for the representation of a BP, and a method for process audit, evaluation, and improvement. KBPI is intended to help organisations improve process performance by improving the way knowledge is managed within a process. An integrated environment for supporting semiautomated optimization during the process design, execution and analysis stages is the deep Business Optimization Platform (dBOP) [7]. The platform consists of data integration, process analytics and process optimization phases and has been successfully implemented, but its scope needs to be broadened to highlight its usefulness in "real world" application scenarios. The BPR methodological framework introduced in [8] aims to redesign BPs to support construction of supply chain integration (SCI). For each of the BPR methodology stages presented, relevant methods and techniques from literature were selected and combined. The methodology has also proved effective in the adoption of e-business for supply chain improvement. All presented approaches contribute to the BPR field from different perspectives but do not focus on measurable indicators for successful BPR prior to implementation. Moreover, there is no consideration of the applicability of redesign heuristics or critical – for the BPR – quality measures of candidate models.

An interesting approach is the BP model improvement based on measurement activities (BPMIMA) framework [9], which is based on measurement, evaluation of measurement results and model redesign activities. The main contribution of the approach is the validation of the support that indicators can provide, towards applying BPR in the context of the BPMIMA cycle. The limitations of the approach lie to the fact that: (a) the BPMIMA framework evaluates only the external quality of models, (b) the only acceptable notation is BPMN since the prototype tool BPMMET has been developed for the measurement activity and (c) the fact that the BPR method is restricted to the adhoc application of the guidelines called 7PMG (seven process modeling guidelines) proposed in [10]. A similar rationale is presented in [11] where an assessment mechanism measures the eligibility of a BPMN model and its capability to be optimized based on indicative complexity metric values. The mechanism evaluates the suitability of model type, the degree of complexity, the normalization and optimization capability of the candidate models. In the same sense, the Business Process Redesign Capacity Assessment (BP-RCA) framework [12] assesses the redesign capability of BP models, prior to their implementation by measuring three representative complexity metrics. This approach is an early attempt by the authors of the current paper that lacked the connection to an integrated BPR methodology, and the consideration of important measures related to BPR.

A few BPR approaches in literature provide systematized implementation methodologies and, in many of these cases, the support is not oriented towards technical issues of BPR. What is evident from the current research is that there is a lack of approaches in literature for the assessment of the redesign capacity of BP models prior to implementation, since they are mostly based on the execution feedback from process monitoring or mining. Moreover, the application of BPR methods is mostly carried out on an ad hoc basis and a systematic methodology that can be adopted regardless of the BPR initiative and encompasses essential redesign aspects, is missing.

## III. Research Methodology

The introduction of a framework that assesses BP redesign capacity of models and implements BRP falls under the category of quantitative research. The authors adopted the DSRP model [13], which is acknowledged as an established methodology for Design Science Research (DSR) in Information Systems (Fig. 1). The approach presented in this paper is centered to the research problem of inefficient optimization attempts and the lack of consistency in the execution logic between the AS-IS and TO-BE models, following BPR. The authors assume that these issues derive in many cases from the fact that an a priori consideration of a process model's characteristics is missing, especially regarding its capacity to be redesigned with a specific method that the organization plans to adopt. Moreover, BPR implementation is in many cases not performed following a concrete methodology, a fact that affects the efficacy and robustness of a BPR initiative [12]. Based on the nature of this research, the formulated hypothesis and the steps of the DSRP methodology and the main activities of this research are identified and depicted in figure 1.

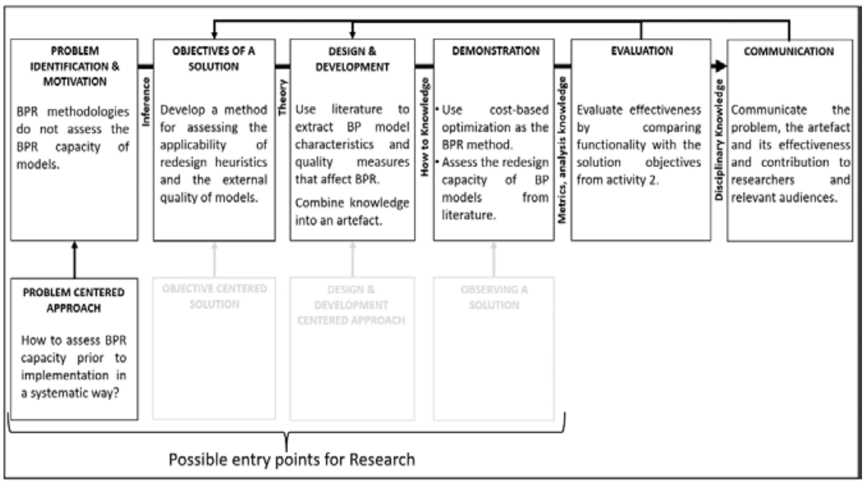


Fig. 1. DSRP Methodology followed for proposing the BPR framework

## A. *Problem identification and motivation*

This activity involves the definition of the specific research problem and the justification of the adding value of the solution. Initially, an extensive literature survey was carried out, for the authors to get accustomed to fundamental aspects of BPs and discuss the current state of research. Based on the primary focus on BPR, a literature survey was carried out with respect to the theoretical background of BPR, the methodologies for BPR implementation and BP measurement. Once the main subjects were selected, a thorough literature survey was conducted for attaining a clear understanding of the existing approaches and identifying the principal research problem.

## B. *Objectives of the solution*

This activity infers the objectives of the proposed solution from the problem definition. The conducted research aims to develop an artefact, as a solution to the problem that has the potential to evaluate the redesign capacity of BP models based on their external quality measures and the applicability of redesign heuristics. The objectives of the solution, as inferred rationally from the problem specification, are:

- To be able to quantitatively evaluate the applicability of varying redesign heuristics to BP models, based on structural quality measures.
- To be able to predict the necessary external quality of models for redesign through the calculation of relevant internal measures.
- To encompass a formal specification and a quantitative BP representation technique that both facilitates the calculation of internal measures and is suitable for cost based BPR application.
- To feature common steps between the introduced artefact and a BPR implementation artefact that would be combined in a comprehensive approach.

## C. *Design and development*

In this activity the artefactual solution is created. The authors reviewed literature to extract the BP model characteristics and external quality measures that affect the efficacy of BPR initiatives. This process required moving from "Objectives of a solution" activity to "Design and development", to bring knowledge of theory to the solution artefact. The extracted characteristics and measures along with the BP specification and representation were interrelated logically into the artefact's architecture.

## D. *Demonstration*

In this activity, the authors demonstrated the efficacy of the artefact to solve the research problem. This involves the use of the proposed artefact for a particular BPR method, namely data-intensive workflow optimization for BPs, a method originating from a related research field with considerable performance results. The demonstration of the artefact also involved the assessment of the redesign capacity of BPs from literature. What is required for the demonstration is effective knowledge of how the artefact solves the problem.

## E. *Evaluation*

In this activity, the authors observed and measured how well the artefact supports a solution to the problem. The activity involves comparing the objectives of the solution (activity 2) against the actual observed results from the use of the artefact in the demonstration. The effectiveness of the proposed artefact is evaluated by quantitatively measuring how it assesses the redesign capacity of the models serving as case studies. At the end of this activity, the authors decided not to iterate back to step 3 to try to improve the effectiveness of the artefact, even though there exists a multitude of redesign heuristics and the artefact focused solely on the behavior heuristics category. This decision is based on the nature of the research that renders such an iteration infeasible and the fact that further improvement could be achieved through subsequent projects.

# IV. BPR: Assessment Framework

This section presents the BPR: Assessment framework, the phases and components it encompasses, and a demonstration of how it is implemented for a cost-based optimization method.

## A. *Overview of the framework phases*

The BPR: Assessment framework (Fig. 2) incorporates six redesign components (Objectives, Method, Heuristics, Input Model, Plasticity and Quality) that are construed in four consecutive phases (Problem Formulation, Representation, Calculation and Assessment) to properly evaluate the redesign capacity of BPs through investigating the suitability of BP models. Each phase is consequently presented in detail.

### *Problem Formulation*

The problem formulation phase deals with the process of defining the specific problem being addressed and the context in which the assessment will be performed. Initial work of the problem formulation was presented in [12]. The redesign components are:

*1) Method:* Once the objectives are finalized, the BPR method is selected and defined in terms of applied methodology and algorithms. The framework is oriented towards analytical and transactional outward-looking BPR methods, according to the Redesign Orbit [14]. The approach also includes BP Improvement (BPI) and Optimization (BPO) initiatives.

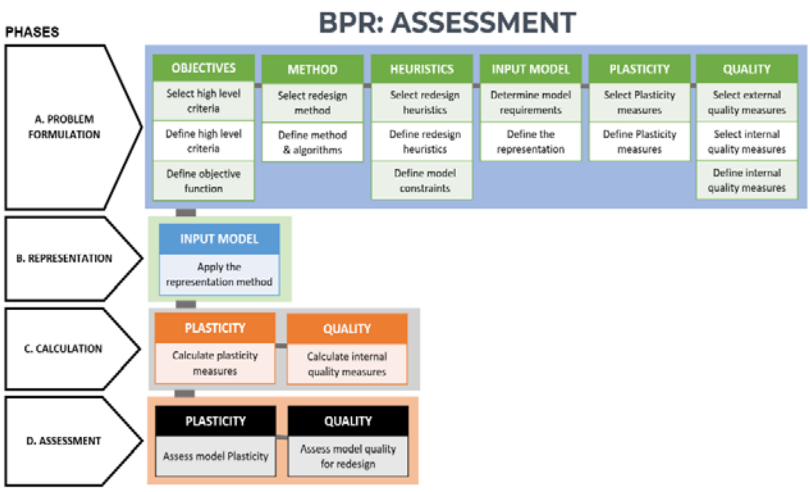


Fig. 2. The BPR: Assessment Framework

*2) Heuristics:* The next component refers to selecting and defining the redesign heuristics to be applied in the BPR application and defining the model constraint types that affect the BPR. In [14], Dumas et al. identify and categorize the full list of twenty nine heuristics introduced for Heuristic Process Redesign [4]. The authors refer to redesign heuristics either explicitly when Heuristic Process Redesign is selected, or implicitly when the method resembles specific heuristics.

*3) Input Model:* This component refers to the specification of model requirements that arise from the redesign decisions taken and the adoption of a - compatible to the BPR - representation method. The outcome is a list of essential information and metadata each input model should necessarily feature, to be fit for the BPR.

*4) Plasticity:* BP model plasticity is introduced in [15] and reflects the redesign capability of models prior to implementation. There is a direct association between the plasticity of models and the applicability of redesign heuristics. In this component, the practitioner selects and defines the internal model measures that affect the plasticity of the input model, given the selected heuristics earlier in the phase.

*5) Quality:* In this component, the external quality measures are initially selected by considering the quality characteristics the input model should necessarily feature for the BPR. As presented in [16], internal structural measures affect cognitive complexity which in turn indicates the external quality of models. For the selected external quality measures, a set of internal quality measures is selected and defined.

In the problem formulation phase, critical parameters related to the redesign application are systematically selected and defined.

*Representation*

The representation phase is a transitional phase where the input model is been represented, using the selected representation method. The latter is amenable to the BPR method and is oriented towards the facilitation of internal metric calculation. Apart from the purposes of the BPR: Assessment framework, the output (representation) of this phase can directly be used, in the redesign implementation of feasible models.

*Calculation*

In the Calculation Phase, the set of internal measures related to the plasticity and external quality of input models is calculated.

*Assessment*

The Assessment Phase provides an overview of the intended BPR and a degree of identified risk, through an analytical dashboard that quantifies the redesign capacity of each input model. The analytical dashboard includes the calculated metric values of both plasticity and external quality. These are similar in the sense that they can be examined in contrast to specified thresholds (as in [11], [17]) to advance or abort the redesign procedure. Regarding model plasticity, thresholds exist for the applicability of the resequencing (RESEQ) heuristic in [15] and there is ongoing work for producing thresholds for other BP behavior heuristics (parallelism and knockout). Regarding model quality, there is a plethora of validated internal measure thresholds for external quality measures like understandability, modifiability, modularity, correctness, etc. (e.g. in [18]). In total, the redesign dashboard of the framework facilitates the decision making, by weighing each BPR initiative, through a measurable index of the redesign capacity of input models.

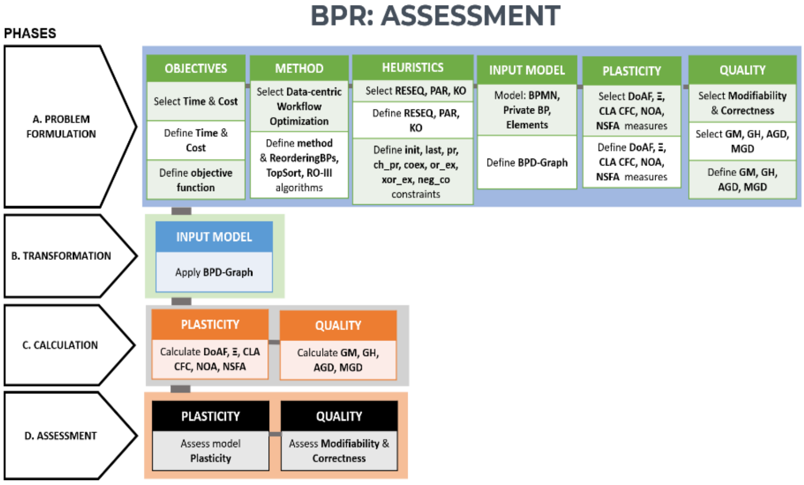


Fig. 3. The BPR: Assessment for Data-Centric Workflow Optimization

## *B. Demonstration on a Cost-based Optimization Method*

In this subsection, the components of the BPR: Assessment framework are demonstrated for data-centric workflow optimization (Fig. 3).

*Problem Formulation*

In previously published work [12], an initial selection and justification of a subset of critical parameters related to the application of this redesign method was presented. The selection of high-level criteria is considerably dependent upon the specific problem being addressed by the organization. In this case, we assume the problem related to low performance of specific BPs which need to be improved in terms of quantitative criteria. The selected objectives are: (a) Monetary Cost/Resource Consumption, defined by the human and machine costs, and (b) Cycle time that represents the average time between the start of a process execution and its completion time.

The selection of redesign method(s) by the organization is considerably dependent upon the selected performance metrics. In our case, the selected redesign initiative is data-centric workflow optimization. The method involves the transformation of a BPMN model to a Directed Acyclic Graph (DAG) using the symbol mapping in [19], and the application of state-of-art data-centric workflow optimization algorithms from [20], [21]. The optimized DAG is subsequently retransformed back to an optimized BPMN model.

The commitment to the specific performance criteria and redesign method directly points to the application of redesign heuristics. The selection of heuristics is performed by assessing which heuristics improve the selected performance criteria from the Devil's Quadrangle [4], [22] and whether the deployed optimization algorithms resemble the execution of specific heuristics. In this case, the most relevant to database-like optimization is the BP behavior category [14], and for the use case, the authors focus on Resequencing (RESEQ), Parallelism (PAR) and Knockouts (KO). The phase also involves the selection of the model constraints that affect the applicability of the heuristics. As in [15], the applicability of RESEQ is dependent upon the init(a), last(a), coexistence(a,b), xor_existence(a,b), or_existence(a,b), precedence(a,b), and chain_precedence(a,b) constraints.

The selected BPR method involves the transformation of BPMN models to DAGs prior to the execution of optimization algorithms. Moreover, according to the proposed symbol mapping in [19] what is transformed is the execution logic of the model, a fact that further determines the acceptable input model type and elements. The input model requirements are defined as follows:

- The input BPs are modelled in BPMN2.0, the established standard for designing workflows [23].
- Private executable BPs is the model type of choice, as the far-reaching aim of the motivating approach [19] is automated performance optimization.
- The authors focus on a subset of BPMN elements that represent the control flow of BPs, i.e., activities, events, gateways, sequence flows and swimlanes.

To capture and measure execution time and/or cost of the input model, the latter should necessarily include the corresponding quantitative metadata, i.e., cost per task, execution time per task and selectivity. These performance criteria are essential for measuring the improvement of performance between the AS-IS and TO-BE model:

- **Cost per task** is defined as the monetary cost/resource consumption per task.
- **Execution Time** per task is defined as the time between starting and completing a task. In the same sense to the previous criterion, a set of execution times per task is required.
- **Selectivity per task** defines the (average) ratio of the output to the input tokens for each task.

For capturing, visualizing and expressing the input models in a quantitative way, the authors selected the representation method introduced in [24]. The BPD-Graph allows both the evaluation of input models in terms of redesign capacity, and the optimization of feasible input models using the selected cost-based redesign method.

Regarding BP model plasticity, the authors have applied a state-of-the-art method in [15] for calculating internal measure thresholds for the RESEQ heuristic, based on regression analysis and the application of the Bender method on empirical data. Even though discrete thresholds for PAR and KO heuristics have not been published yet, the authors assume that reliable results will be obtained from the artefact, since these heuristics are specific forms of RESEQ. The internal measures that predict the plasticity of input models are Degree of Activity Flexibility (DoAF), Sequentiality (Ξ), Connectivity Level between Activities (CLA), Control-flow Complexity (CFC), Number of Activities (NOA) and Number of Sequence Flows between Activities (NSFA).

Regarding BP quality, the authors assume that the external quality measures of interest are Modifiability and Correctness. According to ISO/IEC 25010:2011 [25], modifiability is "the degree to which a product or system can be effectively and efficiently modified without introducing defects or degrading existing product quality". Correctness on the other hand is the degree to which a model syntactically and semantically correct [26]. A model bears the necessary correctness when it follows allowed modeling primitives, their combination is according to predefined rules, and it is formally correct and consistent with the real world. The authors reviewed literature and selected the most frequently used internal measures for predicting modifiability and correctness, i.e., Average Gateway Degree (AGD), Maximum Gateway Degree (MGD), Gateway Mismatch (GM) and Gateway Heterogeneity (GH). This selection is based on: (a) the fact that they are extensively used in similar approaches (e.g. in [9], [26], [27]), (b) the existence of validated thresholds values for these measures and (c) the need to keep the selection to a relatively small number of metrics to avoid an extended and time-consuming BP measurement.

*Representation*

The next phase involves the quantitative representation of the BPMN model, using the method in [24]. The output of this phase is the BPD = (O, F, P, S, C) graph.

*Calculation*

This phase deals with the calculation of the selected internal measures for plasticity and quality (modifiability and correctness). The values of DoAF, Ξ, CLA, CFC, NOA, NSFA, AGD, MGD, GM and GH are aggregated in lists for further analysis and assessment.

*Assessment*

The Assessment phase aims to provide decision makers, with a degree of identified risk, through an analytical dashboard that quantifies the redesign capacity of models. The calculated metric values for both plasticity and external quality are examined in contrast to specified thresholds to advance or abort the redesign procedure. As a total, the redesign dashboard facilitates the decision making, by weighing each initiative, through a measurable index of the redesign capacity of input models [12]. The implementation of the BPR: Assessment framework for a particular BPR method showcases how critical redesign choices can be layered in a systematic manner towards the assessment of candidate BP models. The output of the framework is a communicative and comprehensive dashboard that assists in critical redesign decisions.

TABLE I. USE CASES FROM LITERATURE

| No | Process | Source |
|---|---|---|
| 1 | Concept Management Process | [29] |
| 2 | Account opening process | [30] |
| 3 | Admission Process | [31] |
| 4 | Surgical Patient Process | [32] |
| 5 | Boarding Process | [11] |
| 6 | Airline Company Process | [33] |
| 7 | Loan Request Process | [34] |
| 8 | Credit Application Process | [35] |
| 9 | Call Management Process | [36] |
| 10 | Hardware Retailer Process | [37] |
| 11 | Maintenance Process | [38] |
| 12 | Car Rental Process | [39] |
| 13 | Emergency Ward Process | [40] |
| 14 | Banking Process | [41] |
| 15 | Healthcare Scenario Process | [42] |

## V. Assessment of BPs from Literature

The usefulness of the BPR: Assessment framework is presented in this subsection by assessing the plasticity and external quality of BP models from relevant literature. The experimental material consisted of 15 BPMN models with varying size and structural complexity (Table I). The authors calculated the internal measures for each BP case and compared the values against the extracted thresholds for plasticity [15], modifiability and correctness [27], [28].

TABLE II. Calculated Plasticity Measures

| No | DoAF | Ξ | CLA | CFC | NOA | NSFA |
|---|---|---|---|---|---|---|
| 1 | 0,625 | 0,400 | 1,333 | 6 | 8 | 6 |
| 2 | 0,700 | 0,294 | 2,500 | 4 | 10 | 4 |
| 3 | 0,750 | 0,565 | 1,600 | 6 | 16 | 10 |
| 4 | 0,789 | 0,655 | 1,583 | 7 | 19 | 12 |
| 5 | 0,737 | 0,433 | 1,727 | 11 | 19 | 11 |
| 6 | 0,833 | 0,275 | 2,769 | 19 | 36 | 13 |
| 7 | 0,200 | 0,143 | 5 | 4 | 5 | 1 |
| 8 | 0 | 0,060 | 7 | 5 | 7 | 1 |
| 9 | 0,200 | 0,105 | 5 | 5 | 10 | 2 |
| 10 | 0,250 | 0,060 | 8 | 6 | 8 | 1 |
| 11 | 0,143 | 0,118 | 3,500 | 7 | 7 | 2 |
| 12 | 0,500 | 0,250 | 2,500 | 3 | 10 | 4 |
| 13 | 0 | 0,059 | 7 | 5 | 7 | 1 |
| 14 | 0,435 | 0,091 | 5,750 | 12 | 23 | 4 |
| 15 | 0,412 | 0,206 | 2,429 | 7 | 17 | 7 |

Table II presents the calculated metric values against their thresholds, where the values are colored from red (very inefficient plasticity) to green (very efficient plasticity). There are processes with metric values indicating high (e.g., 5 and 6) or low plasticity (e.g., 7, 8 and 10), while the rest ones have values that range from very inefficient to very efficient plasticity. This is a fact that complicates the evaluation of overall model plasticity and ultimately decision making. The authors use a cluster analysis evaluation method introduced in [17] to group the BP models in categories called clusters, based on the metric values indicating plasticity. The selected algorithm is simple K-means, one of the most popular ones for unsupervised learning problems and is found to deliver reliable results [43]. The authors selected to partition the data to three clusters (Low, Moderate and High plasticity), since more clusters would partition the data into very small groups that would not facilitate a trustworthy interpretation. Finally, the selected proximity measure is Euclidean distance, which is commonly used as the default metric for a plethora of cluster analysis tools [44].

TABLE III. Final Cluster Centers (Plasticity)

| | Cluster | | |
|---|---|---|---|
| | *1* | *2* | *3* |
| **DOAF** | 0,291 | 0,833 | 0,625 |
| **SEQ** | 0,165 | 0,275 | 0,390 |
| **CLA** | 4,648 | 2,769 | 2,618 |
| **CFC** | 5,000 | 19,000 | 8,600 |
| **NOA** | 8,000 | 36,000 | 18,800 |
| **NSFA** | 2,444 | 13,000 | 8,800 |

TABLE IV. Overall Plasticity of BP Models

| Plasticity Clusters | | | | | |
|---|---|---|---|---|---|
| *Low* | | | *Moderate* | | *High* |
| BP 7<br>BP 8<br>BP 9 | BP 10<br>BP 11<br>BP 12 | BP 13<br>BP 14<br>BP 15 | BP 1<br>BP 2<br>BP 3 | BP 4<br>BP 5 | BP 6 |

The cluster analysis was performed by using the IBM SPSS software and the final cluster centers are presented in Table III. The number of cases in each cluster are 9, 1 and 5 for clusters 1, 2 and 3 (low, moderate and high overall plasticity) and the BP models are categorized in Table IV. It is observed is that process number 6 has a high overall plasticity, a fact that it is also evident in Table II where all metric values indicated either rather or very efficient plasticity. Processes 1 to 5 have a moderate overall plasticity which is also attributed to half of the values indicating very efficient plasticity and the remaining processes vary from moderately efficient to rather inefficient. Lastly the processes 7 to 15 were categorized to have a low overall plasticity as most metric values where from moderately efficient to rather inefficient plasticity.

TABLE V. Calculated Quality Measures

| | Modifiability | | | | Correctness | | | |
|---|---|---|---|---|---|---|---|---|
| No | AGD | MGD | GM | GH | AGD | MGD | GM | GH |
| 1 | 3,333 | 4 | 2 | 0 | 3,333 | 4 | 2 | 0 |
| 2 | 3 | 3 | 0 | 0 | 3 | 3 | 0 | 0 |
| 3 | 3,333 | 4 | 2 | 0 | 3,333 | 4 | 2 | 0 |
| 4 | 3,333 | 4 | 7 | 0 | 3,333 | 4 | 7 | 0 |
| 5 | 3,333 | 4 | 0 | 0,276 | 3,333 | 4 | 0 | 0,276 |
| 6 | 3 | 3 | 6 | 0,3 | 3 | 3 | 6 | 0,3 |
| 7 | 2 | 2 | 4 | 0 | 2 | 2 | 4 | 0 |
| 8 | 2 | 2 | 0 | 0,276 | 2 | 2 | 0 | 0,276 |
| 9 | 2,166 | 3 | 1 | 0,301 | 2,166 | 3 | 1 | 0,301 |
| 10 | 2 | 2 | 0 | 0,477 | 2 | 2 | 0 | 0,477 |
| 11 | 3 | 3 | 0 | 0,631 | 3 | 3 | 0 | 0,631 |
| 12 | 3 | 3 | 2 | 0,579 | 3 | 3 | 2 | 0,579 |
| 13 | 3 | 3 | 3 | 0,579 | 3 | 3 | 3 | 0,579 |
| 14 | 3,154 | 4 | 6 | 0,628 | 3,154 | 4 | 6 | 0,628 |
| 15 | 3,111 | 4 | 1 | 0,625 | 3,111 | 4 | 1 | 0,625 |

Regarding modifiability, the calculated metric values indicate that the models are either easy or very easy to modify, a fact that entails that no further analysis is needed to categorize the BP cases. For the external measure of correctness, the same internal measures were compared to the thresholds in [27] and produced the results in Table V. There are only two applying categories for correctness, the one colored red that indicated a high probability of errors in the model and the green for low probability of errors. For the cluster analysis, the authors selected to partition the data also to 3 clusters (Low, Moderate and High correctness) and the final cluster centers are presented in Table VI.

TABLE VI. Final Cluster Centers (Correctness)

| | Cluster | | |
|---|---|---|---|
| | *1* | *2* | *3* |
| **AGD** | 2,500 | 2,827 | 3,161 |
| **MGD** | 2,500 | 3,200 | 3,667 |
| **GM** | 3,500 | 0,800 | 6,333 |
| **GH** | 0,290 | 0,317 | 0,309 |

TABLE VII. Overall Correctness of BP Models

| Correctness Clusters | | | | |
|---|---|---|---|---|
| *Low* | *Moderate* | | | *High* |
| BP 4<br>BP 6<br>BP 14 | BP 1<br>BP 2<br>BP 3<br>BP 5 | BP 8<br>BP 9<br>BP 10<br>BP 11 | BP 12<br>BP 15 | BP 7<br>BP 13 |

The number of cases in each cluster are 3, 10 and 2 for clusters 1, 2 and 3 (low, moderate and high overall correctness) and the BP models are categorized in Table VII. What is evident is that the processes numbered 7 and 13 have high overall correctness (low probability of errors) a fact that is justified from the values in Table V where they all indicate a low probability of errors. The processes numbered 4, 6 and 14 on the other hand have a low overall correctness indicating a high probability of errors. Lastly, the second cluster includes processes numbered 1, 2, 3, 5, 8, 9, 10, 11, 12 and 15, which have a moderate correctness, based on the values of the applying metrics.

To sum up, we observe that most of the BP models either do not have the necessary plasticity for BPR or correctness. Model number 6 has a high overall plasticity but appears to have a low correctness measure, a fact that entails a high probability of semantic or syntactical errors. On the other hand, the models numbered 7 and 13 have high correctness, but do not appear to have the considerable plasticity for BPR, which may be attributed to high overall complexity or constrained activities. The models numbered 1,2,3 and 5 appear to have moderate overall plasticity and correctness, indicating their potential for successful BPR application.

## VI. The Next Phase: BPR Application

The next phase to the current research involves the introduction of a BPR application artefact that supplements the BPR: Assessment framework in a comprehensive BPR methodology. The conceptual artefact is presented in figure 4 and incorporates four redesign components (Objectives, Method, Heuristics, Input Model) that are construed in four consecutive phases (Problem Formulation, Transformation, Redesign and Assessment) to systematically apply a selected BPR method.

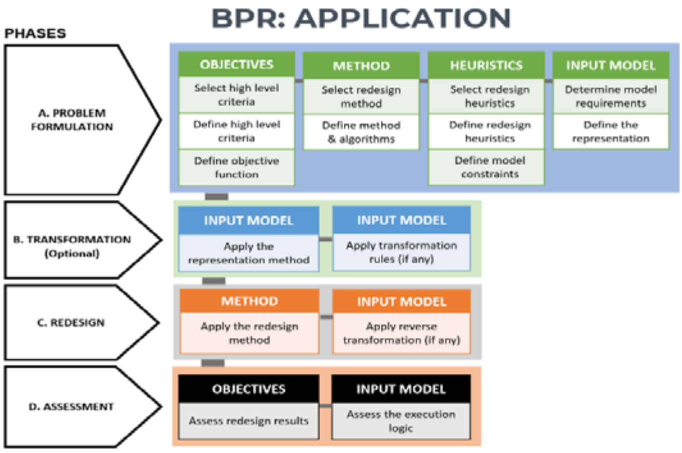


Fig. 4. The BPR: Application Artefact

The problem formulation phase defines the specific problem and the context in which the BPR will be applied. The redesign components are duplicated from the problem formulation of the BPR: Assessment framework. Following the steps presented in section IV, critical redesign choices related to objectives, method, heuristics, and input models are determined. The transformation is an optional phase of the artefact and is only performed in the case that an alternative representation method or further transformation rules should be applied for the BPR application. The redesign phase involves the application of the selected redesign method and reverse transformation rules. Finally, the assessment phase includes the assessment of the redesign results in terms of improvement of the high-level performance criteria and the assessment of the preservation of the execution logic of the diagram. The latter is achieved by examining whether the initial model constraints are still in effect.

Once the BPR artefact is finalized and tested, it will be used either as a distinct tool for the systematic application of BPR methods, or as a part of a comprehensive methodology that assesses models prior to implementation. The latter initiates with the BPR: Assessment framework (Fig. 2) where the problem is formulated, the input model is represented, internal model measures are calculated, and the redesign capacity of the input model is assessed using a dashboard. In the case that the model does not bear the necessary redesign capacity, the BPR would be inefficient and either a more drastic change or further measurement and analysis should be applied. If the input model has the necessary redesign capacity, the practitioner can proceed with the BPR: Application framework (Fig. 4). The artefact for BPR application is also comprised of a problem formulation phase which is a subset of the problem formulation phase of the BPR: Assessment framework and is therefore omitted. The rest phases will involve the (optional) transformation of the input model, the BPR and the assessment of BPR results.

## VII. Discussion & Conclusions

This paper presented the BPR: Assessment framework, aiming to systematically evaluate the redesign capability of models prior to implementation. The conception of the framework was based on the established DSRP methodology and is comprised of six essential redesign components considered in four consecutive phases, towards the final model assessment. Following the introduction of the framework, it was implemented for data-centric workflow optimization to highlight how important parameters related to the redesign application are selected in a systematic and rational manner. The output of the framework is a communicative and comprehensive redesign dashboard that assists practitioners in critical redesign decisions.

Regarding the assessment of BP models in section V, the authors highlighted the usability of the BPR: Assessment framework by quantitatively evaluating the plasticity and external quality of 15 process models from relevant literature. What is concluded is that in many cases the BP models are not eligible for BPR since the applicability of redesign heuristics is considered low and/or critical quality indicators like modifiability and correctness have values that discourage practitioners from BPR. To address the problem of contradictory metric values, the authors applied cluster analysis method and the k-means algorithm. The results indicated that three out of 15 BP models scored either high plasticity or correctness, a fact that helped make transparent the decision on whether to proceed to redesign. Another set of four BP cases scored a moderate overall plasticity and external quality, which renders them as eligible models to be redesigned. This analysis proved that the proposed framework could play an essential decision-making role in organizations, to provide tangible benefits in terms of time, cost, and resources.

Finally, the next step of this research was presented in an attempt to showcase the context and highlight how the proposed assessment framework can be extended in a comprehensive BPR methodology. When models have the necessary redesign capacity, BPR can be implemented in a systematic manner by following the steps of a supplementary artefact. This entails that the BPR: Assessment framework may constitute a broadly applicable methodological tool for effective BPR.

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