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A rule-based method to effectively adopt robotic process automation

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Abstract

Robotic Process Automation (RPA) is an emerging software technology for automating business processes. RPA uses software robots to perform repetitive and error-prone tasks previously done by human actors quickly and accurately. These robots mimic humans by interacting with existing software applications through user interfaces (UI). The goal of RPA is to relieve employees from repetitive and tedious tasks to increase productivity and to provide better service quality. Yet, despite all the RPA benefits, most organizations fail to adopt RPA. One of the main reasons for the lack of adoption is that organizations are unable to effectively identify the processes that are suitable for RPA. This paper proposes a new method, called Rule-based robotic process analysis (RRPA), that assists process automation practitioners to classify business processes according to their suitability for RPA. The RRPA method computes a suitability score for RPA using a combination of two RPA goals: (i) the RPA feasibility, which assesses the extent to which the process or the activity lends itself to automation with RPA and (ii) the RPA relevance, which assesses whether the RPA automation is worthwhile. We tested the RRPA method on a set of 13 processes. The results showed that the method is effective at 82.05% and efficient at 76.19%.

KEYWORDS
business process modeling, business rules, goal-oriented requirements language, robotic process automation

1 | INTRODUCTION

Robotic Process Automation (RPA) is a software technology for automating manual, repetitive, and error-prone tasks in business processes. RPA uses software robots to perform tasks quickly and more accurately. These robots interact with existing systems the way a human does, through the UI, to process transactions and manipulate data.[1] RPA is a low-cost technology that sits on top of the IT infrastructure: it automates business processes without requiring extensive changes to the IT infrastructure.[2,3] RPA differs from the business process management (BPM) approach in two major aspects[4]: (i) RPA does not require programming skills, and (ii) it is lightweight because it does not require reengineering either the existing processes or the information systems; it rather sits on top of them.

The use of software robots provides organizations with several benefits. RPA can cut data entry costs by up to 70% because robots can work 24/7.[5] According to the Institute for Robotic Process Automation & Artificial Intelligence ([1]), RPA allows organizations to: (i) increase productivity,

(ii) provide better service quality, (iii) reduce delivery time while automating business processes, and (iv) free up their employees from tedious and repetitive tasks.

To ensure that RPA adoption is successful and provides the desired benefits, organizations are constantly looking to identify processes that are suitable for automation using the RPA technology.[6] A key success factor for implementing RPA is to carefully analyze the processes to assess whether they are suitable for RPA automation.[7] While the assessment of process suitability for RPA plays a crucial role in the success of process automation, existing approaches that have been proposed in the literature including Costa et al.[8–12] have limitations in terms of usability and implementation. Indeed, proposed methods either (i) use complex techniques, such as analytic hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS), or (ii) do not provide a clear process/steps to follow, or (iii) do not propose easy-to-use tools, or (iv) require human judgment and intervention. These problems limit the usability of the existing methods in practical real-world applications. This problem raises the following research question:

RQ. How to determine, through a usable method, whether a business process is suitable for automation with the RPA technology?

By usable, we mean a method that allows process automation practitioners to identify processes that are suitable for RPA with *effectiveness* and *efficiency*. By answering this question, we will provide organizations with a method that helps them to effectively adopt RPA for automating their business processes.

The proposed method is called rule-based robotic process analysis (RRPA). RRPA relies on the analysis of the decision logic that underlies the target process activities to assess their suitability for RPA automation. To the extent that decision logic can be captured with *business rules* (see, e.g., previous works[13]), we argue that different *classes* of business rules have different automation potential for RPA.[9] To that end, RRPA computes an RPA suitability score that relies on (i) the categorization of the decision logic inherent to each *user activity*[*] and (ii) the execution context of the business rule that governs the process activity, which includes the software application used by the user activity, the type of the data handled by the rule (structured vs. unstructured), the state of the rule (e.g., stable vs. unstable), and the number of exceptions and alternatives.

This paper extends the work presented in previous works[9] by (i) extending the business rules classification, (ii) refining the RPA suitability score to take into account the classes of business rules and their execution context, and (iii) reporting the results of an empirical experimentation that validates the effectiveness and the efficiency of the method. The effectiveness means that RRPA is effective in assessing the suitability of business processes for RPA automation. The efficiency means that RRPA does not require scarce advanced technical skills in RPA to perform.

To design the RRPA method, the present paper uses the design science research (DSR) approach as proposed by Peffers et al.[14] The DSR approach aims to answer questions related to relevant issues through the design, creation, and evaluation of innovative artifacts.[14] The artifact proposed in this paper is a rule-based method that helps organizations to effectively adopt RPA technology. Note that the DSR steps of *Design and Development* and *Demonstration* are merged to better explain the proposed method.

The remainder of the paper is organized as follows. Section 2 surveys related work on RPA adoption and business rules. Section 3 defines the objectives for a solution (i.e., RRPA method). Section 4 describes each step of the method in order to assess the suitability of business processes for automation with RPA. Section 5 presents the results of evaluating our approach on 13 business processes from the ERP literature and the manufacturing domain. Section 6 concludes by highlighting the contribution and directions for future research.

2 | LITERATURE REVIEW

A limited number of research efforts have been proposed to tackle RPA adoption. First, this section surveys existing work that falls within the field of RPA adoption by providing methods and approaches that assess the suitability of RPA to automate business processes. Then, it presents a literature review on business rules, because the proposed method is rule-based.

2.1 | RPA

RPA is defined as a technology that uses software robots that follow business rules and a predefined process choreography to execute tasks. RPA is suitable when (i) the process is mature, (ii) the volume of transaction is high, and (iii) the process business rules are well-defined.[15,16] According to Aguirre et al.,[3,16–18] a business process is suitable for RPA when it is highly standardized, rule-based, conducted manually by humans in a repetitive manner and requires access to multiple systems. In addition to these properties, authors in previous works[17,18] propose a more complete set of criteria to identify the processes that fit RPA, such as low cognitive requirements, high proneness to human error, and limited need for exception handling. According to Willcocks et al.,[4] processes with low complexity and a high workload are appropriate for RPA automation. For Lowers et al.,[19] RPA fits with standardized and repetitive processes that follow well-defined business rules, consume a significant amount of time, and require manual interaction with a system interface. Madakam et al.[20] suggested that RPA is suitable for specific process industries. These processes include accounts payable and receivable, invoice processing, purchase to order, payroll, hiring, customer service, cards activation, claims processing, and some specific processes from the banking and insurance domains. Madakam et al.[20] noted that emerging technologies such as artificial intelligence (AI) will push RPA limits further by making robots able to achieve complex and cognitive tasks, such as processing unstructured data. For Hofmann et al.,[21] AI technologies will allow RPA specialists to design intelligent robots that are able to execute their own configuration and develop new robots based on their experience.

A number of research works proposed to identify processes that are suitable for RPA using process mining. In previous works,[10] Leno et al. proposed a method called robotic process mining (RPM). RPM uses the UI logs that record interactions between human actors and applications to (1) systematically collect processes, (2) identify and rank candidate processes based on the relevance of using RPA, and (3) capture the candidate processes' specifications in a way that supports their translation into RPA scripts. The authors distinguish two types of processes: (1) fully deterministic and (2) partially deterministic. The former are processes that can be fully automated without any human assistance, whereas the latter require the intervention of a human. In previous works,[22] authors proposed to use process mining techniques to capture user interactions in the context of RPA. Process discovery methods are used to analyze UI logs in order to gather knowledge about individual user interactions. The discovery technique generates flowcharts that are suitable for automation using RPA. Cabello et al.[12] proposed a human-robot hybrid approach. They argued that activities with a lower volume of transactions and where cognition is required are best suited for human interaction, whereas systematic activities with a high volume of transactions are best suited for robots; they propose process mining as an approach for identifying processes or activities that lend themselves to the hybrid approach. Although these methods provide good results, there are many challenges in selecting relevant actions to be recorded, filtering the noise events not related to the process and the candidate routine identification that can be automated.

In,[8] Costa et al. proposed to adopt RPA by selecting processes for automation using a Multi-Criteria Decision-Making (MCDM) method. The latter combines two techniques: the AHP and the TOPSIS. AHP is used to determine weights of the decision criteria. The method uses nine criteria including the types of business rules and data structure, complexity of the process, and process execution frequency and duration. The TOPSIS techniques are used to evaluate and prioritize the processes according to their suitability for RPA.

In previous works,[11] Engel et al. proposed a method to assess the automation suitability of processes with cognitive reasoning requirements. This method includes nine steps that, among others, allow the practitioner to assess the suitability of a process and to prioritize processes with the use of an Impact-Effort Matrix to ease decision-making. The Impact-Effort Matrix evaluates the estimated resources invested in the project and the expected saved time following a successful implementation.

Some other works proposed to identify processes that are suitable for RPA using rule-based approaches. In previous works,[6] authors presented a method that analyzes business processes and classifies them from "Not suitable" to "Highly suitable" using an RPA quadrant. The classification is based on (i) the process maturity and standardization, (ii) the business rules that govern process activities, (iii) the use of interfaces with a software application, (iv) the volume of transactions, and (v) the level of complexity of the process.[6] In a more recent work, Leshob et al.[9] proposed to classify business rules and assign an RPA automation weight to each rule class. Authors assessed the feasibility of RPA automation of a process activity based on the weight of the business rules classes that underlie it. This weight is computed based on RPA criteria such as well-defined rules and well-specified interactions with software applications. This approach sounded reasonable on toy examples but proved unworkable with real-life business processes. Indeed, some RPA criteria depend on the execution context of the business rules (e.g., use of structured data, stability of the system). To solve this problem, one solution consists to design a rule classification model, which takes several variants (subclasses) into account (e.g., production rule with structured data and production rule with unstructured data). This solution will lead to a deep and complex rules hierarchy model. This paper proposes to tackle this limit by computing an automation score based on the *mechanics* of the user activity and its *decision* content; the latter *being* more complex to assess. Recall that the aim of the present research effort is also to design a method that is easy to implement without having to become a specialist on process automation.

2.2 | Business rules

A number of research efforts propose to classify business rules depending on their level of enforcement (i.e., guideline vs. mandatory), scope (e.g., data vs. behavior), and others.[23–27] For Graml, Bracht, and Spies,[28] a business rule is defined depending on the perspective to be addressed. From the business perspective, a rule is a directive intended to govern, guide, or influence the business behavior.[28] From the IT perspective, a business rule is defined as a piece of reusable logic that is specified declaratively.[28] Hay and Healy[23] propose three classes of business rules: structural assertion, action assertion, and derivation. A structural assertion is a statement that expresses a structure aspect of an organization.[23] An action assertion represents a constraint or a condition that limits or controls the actions.[23] A derivation is a statement of knowledge that is derived from other knowledge.[23]

According to Steinke and Nickolette,[26] business rules fall into four classes: inference, definition, guideline, and mandate. An inference is a rule that creates a new value/fact that is derived from one or more business rules. Definitions include all terms that are specific to the business. Guidelines are rules that may or may not apply: they *should* be followed but can be overlooked in particular contexts. Mandates, on the other hand, are action rules that apply in *all* circumstances.[26]

In previous work,[24] Wagner proposes five categories of business rules: integrity, derivation, reaction, production, and transformation. Integrity rules express constraints to data. Derivation rules create derived facts from other known facts. Reaction rules initiate actions after verifying a condition once a particular event is triggered. Production rules (condition-action rules) verify a condition before initiating an action. Unlike reaction rules, production rules do not depend on any particular event to test a condition. Transformation rules restrict changes to objects within a system.

Eijndhoven et al.[25] distinguish two categories of business rules. Constraints and rules that influence the business process. Constraints are statements that limit the structure, behavior, and information of an organization or a system. Rules that influence the process include *derivation rules* (rules that use deduction or computation to enact information of a process) and *action rules* (condition-action rules and event-condition-action rules).[26]

In previous works,[29] Ezekiel et al., classified business rules in the context of workflow management into four distinct categories: (1) initiation rules, (2) execution rules, (3) termination rules, and (4) data rules. Initiation rules represent the conditions or the events that will initiate a process workflow. Execution rules contain process rules and flow rules. Process rules describe event rules that occur during the execution of a workflow. Such rules can be time-based (e.g., pause the process if a specific event occurs). On the other hand, flow rules manage the flow of the process. Termination rules end the process by ensuring the previous tasks were completed (e.g., terminate process upon reception of the payment). Data rules maintain the integrity of the process flow by ensuring the input and output data are compliant with the rules in place (e.g., the set of legal data).

This literature review highlights that a number of works have proposed various business rules classifications. Some classes appear with different names. Therefore, we grouped rule classes sharing similar definitions under a single name. Table 1 summarizes the business rules classification from the literature review. We will use the rule classes from Table 1 to design the RRPA method.

3 | DEFINITION OF THE OBJECTIVES

This phase of the DSR methodology corresponds to the definition of the objective for a solution. The primary objective of this research is to provide the organizations with a method to ensure that RPA adoption is successful and provides the desired benefits. For that, this paper attempts to solve the previously identified problem related to poor RPA adoption resulting from (i) the lack of methods and frameworks for selecting suitable processes for RPA technology and (ii) the implementation complexity of existing methods.

The objective of this research work is twofold: (i) It proposes a method that helps process automation practitioners assess whether a given business process is suitable for automation using RPA (Objective 1), and (ii) it designs and develops a method that is easy to implement and perform without having to become a specialist on business process automation (Objective 2).

To ensure that the method achieves these objectives, it will be evaluated to assess its effectiveness (Objective 1) and efficiency (Objective 2) in 13 real-world business processes from the ERP literature and the manufacturing domain. The evaluation will also assess the applicability and the relevance of the techniques used by the method.

4 | DESIGN AND DEVELOPMENT OF THE RRPA METHOD

4.1 | Principles of the RRPA method

Hammer and Champy[30] defined a business process as "set of activities that, together, produce a result of value to the customer." RPA focuses on process activities that are performed by human actors with the assistance of one or more information systems. These activities typically involve: (1) getting data from one or several IT systems, (2) performing some decisions, and (3) entering the outcome into one or several systems. For the

TABLE 1 Summary of business rules classification from the literature review.

Group	Business rules
Production rules	Production rules, mandate, action rules[24–26]
Event-condition-action rules	Event-condition-action rules, reaction rules[24,25]
Constraint rules	Constraint rules, integrity rules, action rules[23–25,29]
Inference rules	Inference rules, derivation rules[23–26]
Guidelines	Guidelines[26]
Workflow rules	Initiation rules, execution rules, termination rules[29]

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rest of the paper, we use the Business Process Model and Notation (BPMN) ([31]) nomenclature, which uses the term *user activity* to refer to such activities. Indeed, BPMN defines a user activity as "a typical workflow task where a human performs the task with the assistance of a software application."[31] RPA technologies aim to automate user activities with the use of software robots.

According to Alberth and Mattern,[32] the decision logic that underlies *user activities* can be expressed as business rules. Leshob et al.[9] argued that different *types* or *classes* of business rules have different automation potential and thus, different RPA feasibility levels. Accordingly, the RRPA method classifies the business rule logic inherent to each user activity of the business process to assess its suitability for RPA.

To assess the suitability of a user activity for RPA, the method computes a score, called *RPA suitability score*: the higher the score, the higher the suitability for RPA adoption. Conversely, a lower RPA suitability score means that the activity is less appropriate for RPA adoption.

To compute the RPA suitability score for a business process, the proposed method evaluates two RPA *suitability factors*: the *RPA feasibility* and the *RPA relevance*. The *RPA feasibility* assesses the extent to which each user activity lends itself to automation—for example, involves well-defined business logic. The *RPA relevance* assesses the extent to which RPA automation is worthwhile for each user activity—for example, the activity has a high volume of transactions involving manual operations.

Finally, recall that the main objective of the proposed method is to compute a suitability score at the process level to identify among the organization processes those that are best suitable for RPA automation. Until now, we have discussed the RPA suitability score at the activity level. The RPA suitability score of a business processes is computed as the average of the RPA suitability score attributed to each of the user activities that compose the business process.

4.2 | Overview of the method

Figure 1 presents the proposed method. The goal of the first step is to compute the RPA *feasibility score* of each user activity in the process. To this end, this step relies on the business rules classes that govern each user activity and their execution context. The second step computes the RPA *relevance score* for each user activity. The last two steps compute the *RPA suitability score* of each user activity using the previously computed two scores: the feasibility score and the relevance score. To this end, the proposed RRPA method views the *RPA suitability* as a high level goal that depends on two sub-goals: *RPA feasibility* (i.e., the activity must lend itself to automation with RPA) and *RPA relevance* (i.e., RPA automation is worthwhile). To satisfy the RPA suitability goal, the sub-goals *RPA feasibility* and *RPA relevance* must be satisfied. The *RPA feasibility* sub-goal implies that the user activity has the potential to be automated using the RPA technology—for example, involves well-defined business logic. The *RPA relevance* sub-goal implies that automating process activities using RPA brings value to the organization—for example, the activity has a high volume of transactions and involves manual operations. Thus, the third step builds a *goal model* that links process activities to the RPA suitability goal (high-level goal) through the feasibility and relevance sub-goals using the *Goal-Oriented Requirements Language (GRL).*[33] The last step computes the RPA suitability score of the process automatically using a GRL evaluation algorithm.

The remainder of this section is organized as follows. Section 4.3 presents the techniques used to compute the RPA feasibility score, including an overview of the suitability criteria in the RPA literature, and a business rules classification. Sections 4.4, 4.5, 4.6, and 4.7 describe the steps of the method as presented in Figure 1.

4.3 | RPA feasibility

Table 2 presents the criteria we use to assess whether a user activity lends itself to automation using RPA. The criteria for RPA automation fall in two categories: the *mechanics* of the user activity and the *cognitive* or *decisioning* content of the activity. The *mechanics* of the user activity have to be well-defined, and this is reflected in criteria C1 (access to software applications with well-specified interactions), C7 (use of structured data), C8 (availability of digital data), and C9 (limited number of exceptions/alternatives). The *cognitive/decisioning* aspects are captured by criteria C2

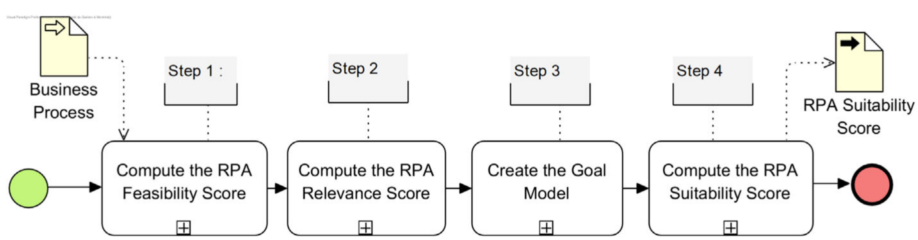

FIGURE 1 Overall process for assessing business processes suitability for RPA.

TABLE 2 Criteria for implementing RPA. *Source*: Adapted from previous works.[6,17]

Id	Criteria	Description
C1	Access to software applications	The activity is performed by a human actor with the use of a system or multiple systems.
C2	Unambiguous and clearly documented rules	The activity is based on well-defined and unambiguous rules.[17] Ambiguous rules have more than one interpretation or meaning. Each rule formulation should not leave room for misinterpretation. It must unambiguously describe the rule behavior.
C3	Stable rules	The activity is based on stable and unchanging rules.
C4	Enforced rules	The rules are strictly enforced during the execution of the activity, as opposed to being considered as just *guidelines*. Business rules that guide behavior require enforcement.[34]
C5	Low cognitive requirements	The activity/rule does not require creativity or complex interpretation efforts.
C6	Stable context	The activity is executed within stable context. All interactions between the process activities and software applications are well-specified and predictable.
C7	Use of structured data	The activity/rule uses available structured data.
C8	Use only digital data	All the data needed by the activity/rule are available in digital format. This is required as RPA is a software-based solution.[2]
C9	Limited number of exceptions/ alternatives	The rule has no or few exceptions or alternatives.

(unambiguous and clearly documented rules), C3 (stable rules), C4 (enforced rules), C5 (low cognitive requirements), and C6 (stable context). The *mechanics* of a user activity are easy to assess. However, the *cognitive/decisioning* content of the activity is more complex to assess. Our work proposes to tackle this aspect.

The *business rules approach* recommends representing the decision logic inherent to repeatable business processes using the business rules formalism. The business rules approach covers the full life cycle of decision logic, from analysis to automation, deployment, and maintenance.[27] Accordingly, we propose to use the business rules approach to assess the RPA feasibility: if the business rules that govern a user activity lend themselves to automation under the business rules approach, then the user activity lends itself to RPA– regardless of the automation technology used by RPA.

To design the RRPA method, we elaborated the UML-based RPA business rule meta-model shown in Figure 2. Recall that RPA focuses on activities performed by users with the use of information systems in order to replace human actors by software robots. RPA rules (`RPA Business Rule class`) are behavioral rules that govern process activities through the use of information systems. The model proposes four main rule classes: `Generic Rules`, `Guidelines Rules`, `Workflow Rules`, and `RPA Loader rules`.

1. `Generic Rules` (`ECA Rule`, `Constraint Rule`, `Inference Rule`, and `Production Rule`) are rules that operate within information systems through well-specified interactions. These rules are well-defined, unambiguous, and strictly enforced.
2. `Guidelines Rules` are rules that operate within information systems through well-specified interactions. Guidelines serve as general recommendations; they are not mandatory or required. Unlike `Generic Rules`, guidelines are not enforced and often not clearly documented (see previous works[26]).
3. `Workflow Rules` control the flow of the processes. Not all flow rules depend on user activities. Process flow elements, which are governed by flow rules (e.g., gateways in BPMN), may be fully automated. RRPA is interested in the implementation of RPA and therefore in automating user tasks. Thus, RRPA focuses on workflow rules that are based on the outcome of applying business rules within user activities. For example, in a credit card application approval process, the user first uses specific systems to retrieve and process credit information. The flow is then directed depending on whether the credit file history (data obtained from the previous user activity) is originated from the country of the financial institution or a foreign country. Workflow rules are well-defined, unambiguous, and are strictly enforced. They can be either simple or complex. Simple workflow rules (e.g., or, xor, and) may have at most one exception, which will be raised if no flow condition is satisfied, and there is no default path. Complex rules have multiple alternatives to activate a flow path, as with activating tokens in BPMN.[31]
4. `RPA Loader` rules govern user activities that connect and use information systems to simply load digital raw data (e.g., reading a file) that are processed later by other process activities. These activities require the user to perform simple manual processing such as copying, pasting, and validating data in forms. These rules are well-defined, unambiguous, strictly enforced and have a limited number of exceptions.

As shown in Figure 2, RPA rules (`RPA Business Rule class`) implement an interface (`Measurable`) to compute a class feasibility score and a context feasibility score. The class feasibility score is computed using the rule class definition without taking into consideration the context

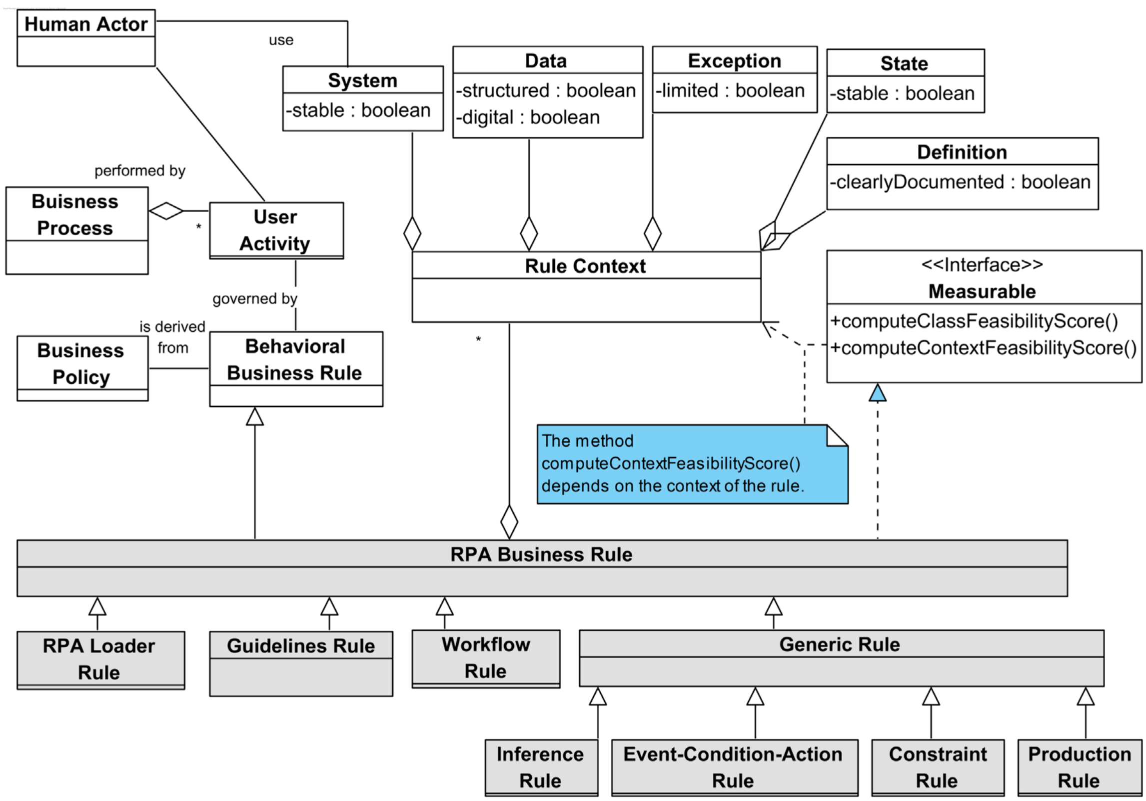

FIGURE 2 RPA rules meta-model. Classes in gray color are rule classes.

in which the rule is executed. On the other hand, the context feasibility score is based on the execution context of the rule. The rule context (`Rule Context class`) depends on the specific business process execution context and is determined by (i) the system that supports the user activity (`System class`), (ii) the data (`Data class`), (iii) the rule exceptions and alternatives (`Exception class`), and (iv) the rule state (`State class`).

For the time being, RRPA focuses on user activities that require low cognitive requirements. We believe that, in due time, AI technologies such as machine learning and natural language processing will enable us to extend RPA to handle more cognitive tasks.

Table 3 shows the class feasibility score of each RPA business rules class (see Figure 2). The maximum feasibility score of each criterion is 1/8 (eight represents the number of RPA criteria shown in Table 2 excluding the criterion C5). The value 1 means that the rule class satisfies the criterion. The value 0 means that the rule class does not satisfy the criterion. The value PC means that the feasibility score of the criterion is PC specific and can only be determined by the execution context of the process (i.e., systems, data, rules exceptions and alternatives, and rule states). Note that we assigned the same weight to all the criteria. However, users of the method, such as business analysts, can customize these values according to their specific needs.

Figure 3 illustrates the detailed process for assessing business processes suitability. The following subsections detail the operation and the execution of the RRPA method using the generic accounts payable process shown in Figure 4. For the sake of simplicity, we shortened the process to include two *user activities* and one *service activity*, that is, an automated activity. The process starts upon the receipt of an electronic invoice from a supplier. The activity (*A1: Import supplier invoice data*) involves accessing a software application such as an ERP to import the supplier's invoice data. The business rule that governs this activity is classified as *an* `RPA Loader rule` as it simply loads data using an information system. The process continues thereafter depending on the total amount of the invoice: if the total amount is under 2000$, the invoice is automatically approved. Otherwise, the invoice must be approved by the manager using two *when-then* rules. First, the manager verifies that the complete shipment has arrived. Second, she/he performs a three-way match to identify any discrepancies between the purchase order, the order receipt, and the invoice. These two rules are classified as *RPA production rules* because the decision logic underlying the activity checks conditions before initiating actions. Production rules fall under the `RPA Generic rule` class (see Figure 2). Finally, once the invoice is approved, by the manager or automatically, the payment is submitted through an automatic service activity (A3: Submit payment). The process ends by sending a notification to the supplier (using the BPMN end event).

TABLE 3 Rules and their class feasibility scores. The value 1 means that the rule class satisfies the criterion. The value 0 means that the rule class does not satisfy the criterion. The value PC means that the feasibility score of the criterion is process context (PC) specific.

Business rule class		Criteria C1	C2	C3	C4	C6	C7	C8	C9	Class feasibility score
Generic rule		1	1	PC	1	PC	PC	1	PC	$\frac{4}{8}$
Workflow rule	Simple	1	1	PC	1	PC	PC	1	1	$\frac{5}{8}$
	Complex	1	1	PC	1	PC	PC	1	0	$\frac{4}{8}$
Guidelines		1	PC	PC	0	PC	PC	1	PC	$\frac{2}{8}$
RPA loader rule		1	1	PC	1	PC	PC	1	1	$\frac{5}{8}$

4.4 | Step 1: Compute the RPA feasibility score

The goal of the first step is to compute a score that evaluate the feasibility of automating process user activities with RPA technologies. Recall that the RPA feasibility assesses the extent to which the activity lends itself to automation. RPA feasibility consists of two scores. The first one relies on the business rules classes inherent to each user activity. The second score relies on the execution context of the business rules that govern the process activities, such as the type of the data handled by the rule (structured vs. unstructured), the state of the rule (e.g., stable vs. unstable), and the number of exceptions and alternatives.

4.4.1 | Step 1.1: Compute the RPA feasibility score using rules classes

The goal of this step is to compute the potential to automate user activities based on their governing RPA rule classes. This is the first step to compute the RPA feasibility score. It consists of two sub-tasks:

1. Categorizing the decision logic that underlies user activities by identifying the types of RPA rule classes (Figure 2) that are inherent in that decision. A single activity may involve different RPA classes.
2. Assigning to the activity, the feasibility score of the RPA rule class using Table 3. In case the activity involves more than one rule, the class feasibility score must be computed using the average of the values associated with the rule classes. Thus, the RPA class score (A.classScore) of a user activity `A` governed by *n* RPA rules is computed as follows:

$$A.classScore = \frac{\sum_{i=1}^{n} c_i.classScore}{n}$$

where $c_i.classScore$ is the feasibility score of the RPA rule class c_i.

For the running example of Figure 4, we pointed out that there were two rule classes associated with the activity A1: a `Loader rule` and a `Simple Workflow rule,` whereas activity A2 involves two rules of the same class (`RPA Generic Rule`). Therefore, the class feasibility score of A1 is $\frac{\left(\left(\frac{5}{8}\right)+\left(\frac{5}{8}\right)\right)}{2}$ where the class feasibility score of A2 is $\frac{\left(\left(\frac{4}{8}\right)+\left(\frac{4}{8}\right)\right)}{2}$ (see Table 3).

4.4.2 | Step 1.2: Compute the RPA feasibility score using rules context

This step computes the potential to automate each user activity based on the context of the business rules. A rule context is determined on the specific business PC. It is established by the: (i) system or systems that supports the user activity, (ii) data used by the rule(s), (iii) rule state, (iv) rule documentation (for Guidelines) and (iv) rule exceptions and alternatives.

To compute the context score of a user activity, we adopted a question-based approach to capture the rule's context. Five binary (yes/no) questions were designed for the criteria C2, C3, C6, C7, and C9 as follows:

- Question 1 (for guidelines rules): Are the guidelines unambiguous and clearly documented?
- Question 2: Is the rule stable?
- Question 3: Does the rule use stable system(s)?

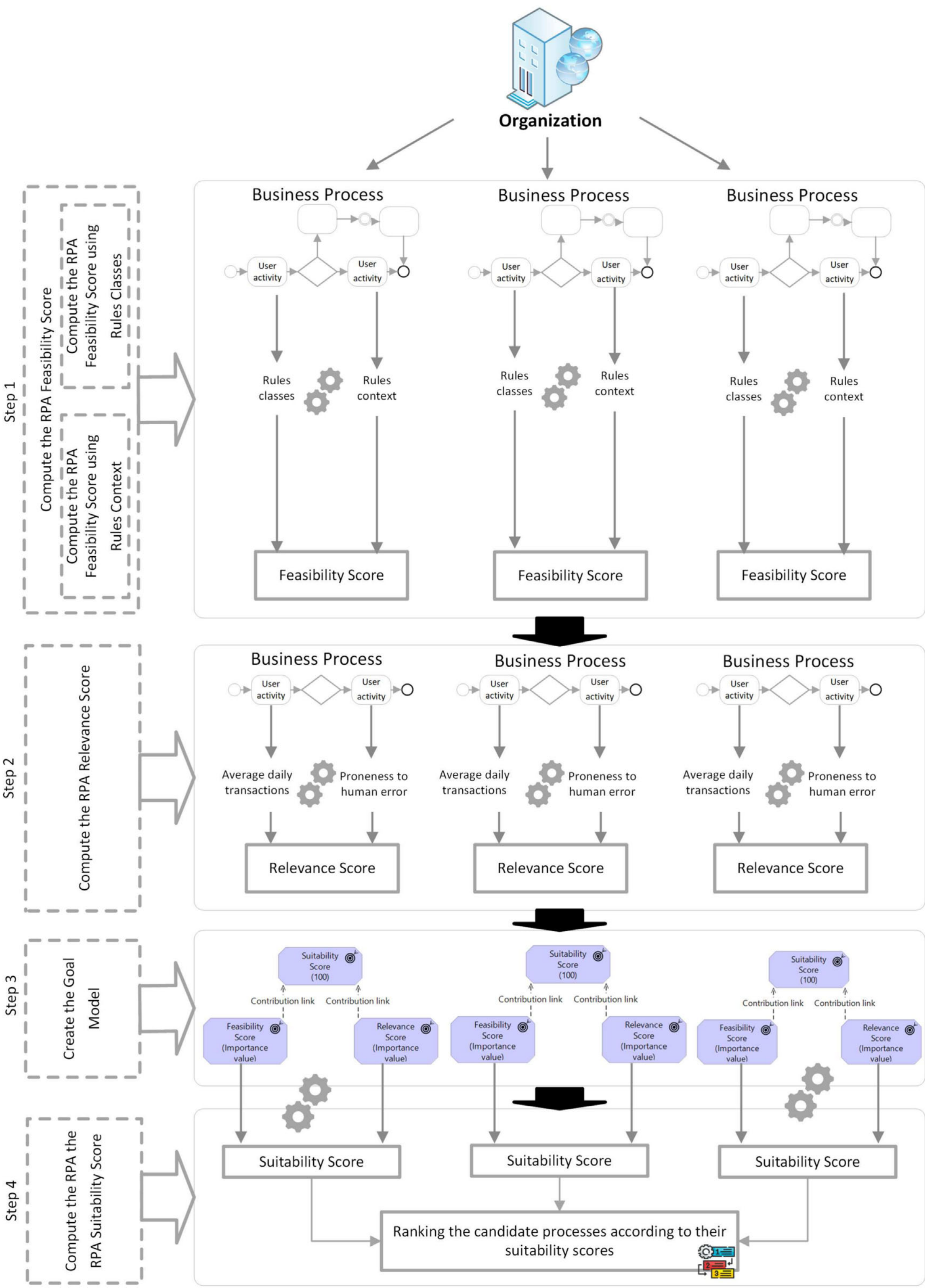

FIGURE 3 The detailed process of the rule-based robotic process analysis (RRPA) method.

- Question 4: Does the rule use structured data?
- Question 5: Does the rule have limited exceptions/alternatives[†]?

Each positive answer is worth 1/8. If the answer is negative, then the context feasibility score for the criterion is set to 0. Note that the method asks a question only if the class feasibility score of the rule (see Table 3) is equal to "PC," that is, depends on the process execution context. For

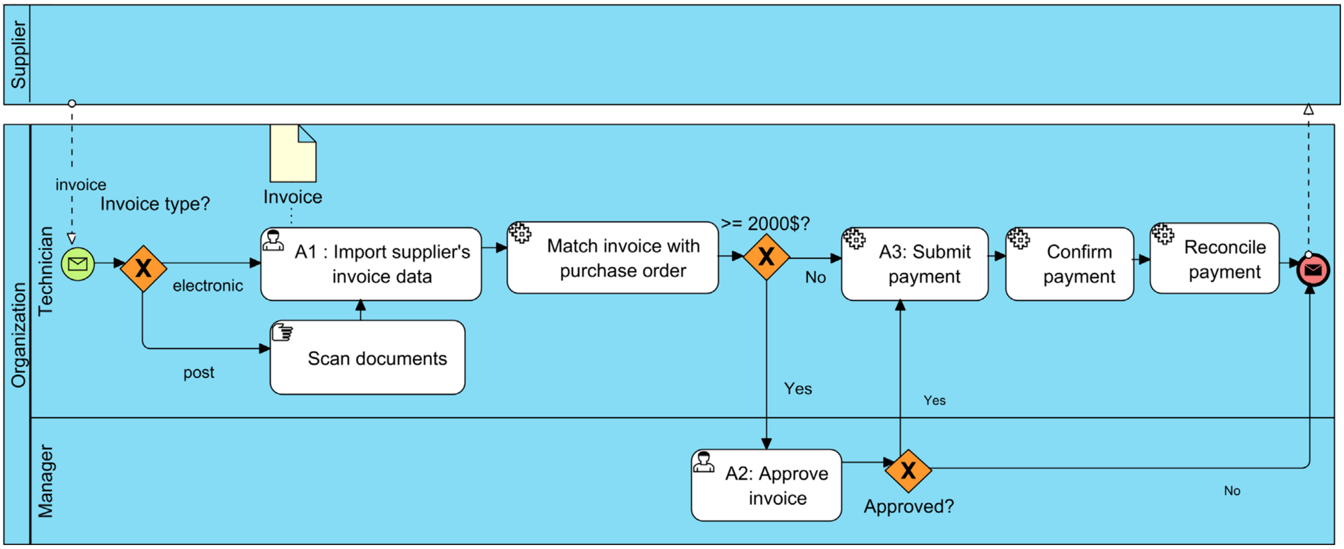

FIGURE 4 Generic account payable business process.

instance, RPA loader rules are already identified as rules with limited exceptions/alternatives (see Table 3). Thus, Question 5 does not apply to RPA loader rules.

Let us take the rule inherent in the user activity A2 (Figure 4). We asked the process specialist within a Canadian company the Questions 2, 3, 4, and 5 (Question 1 does not apply because it is a production rule). The answers are as follows. "Yes" for Question 2 and Question 3 because the rules and the systems are stable. "No" for Question 4 because some suppliers' source data include unstructured data such as, text and multimedia contents. "Yes" for Question 5 because both production rules have limited exceptions. As a result, three questions have been answered positively. For each positive answer, 1/8 is added to the RPA context feasibility score of the activity. Therefore, the context feasibility score of the activity A2 is $\frac{3}{8}$.

The RPA feasibility score of an activity A, denoted *A.feasibilityScore* is computed as follows:

$$A.feasibilityScore = A.classScore + A.contextScore$$

where *A.classScore* and *A.contextScore* represent the class feasibility score and the context feasibility score of the activity A, respectively.

Thus, the RPA feasibility score of the user activity A2 (see Figure 4) is computed as

$$\frac{4}{8}+\frac{3}{8}=\frac{7}{8}$$

4.5 | Step 2: Compute the RPA relevance score

The objective of RPA relevance is to assess whether it is viable to replace humans with software robots for a particular activity. According to previous works,[6,15,17] RPA is relevant when a business process (i) has a high volume of transactions involving manual operations and (ii) its activities are prone to human-specific errors, not typical of software robots (e.g., matching numbers, extracting, and reformatting data into reports). Therefore, to assess whether a process activity is worth automating using RPA, the method proposes to compute the number of times (NOT) the activity is performed per day and its proneness to human errors (PHE). The latter is based on the average number of manual operations, such as matching numbers and reformatting data that the activity requires on each process transaction.[9] As illustrated in Figure 5, the RPA relevance score of a process activity is based on a 5-point Likert scale[36] (0, 25, 50, 75, and 100).

4.6 | Step 3: Create the goal model

The goal of this step is to build a goal model that links process activities to the RPA suitability goal, which is the high-level goal, through the feasibility and relevance sub-goals. Indeed, RRPA views the RPA suitability as a high-level goal that depends on two sub-goals: RPA feasibility (i.e., the

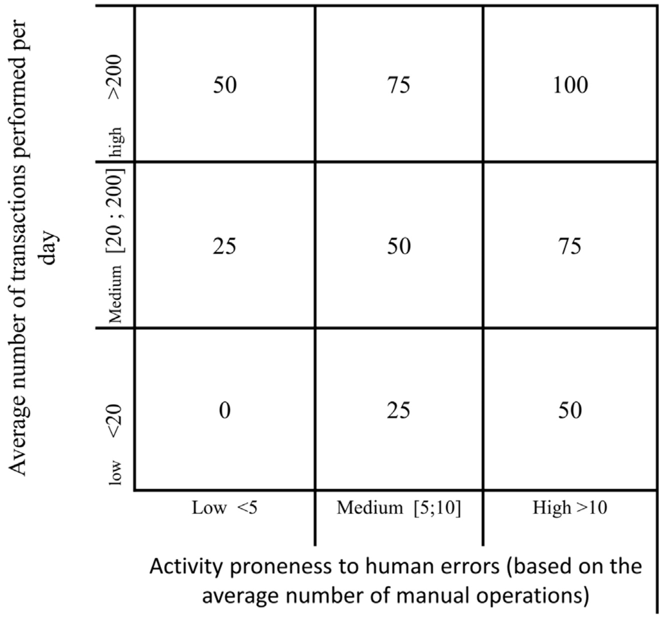

FIGURE 5 RPA relevance quadrant (*Source*: adapted from previous works[9]).

activity must lend itself to automation with RPA) and RPA relevance (i.e., RPA automation must be relevant for the user activity). Thus, we needed a goal language that is easy to use; that links each process activity to the RPA goals; and that allows computing a satisfaction score for each activity based on its contribution to satisfy the RPA goals of feasibility and relevance. Among various available goal-oriented languages, including *Keep All Objects Satisfied* (KAOS),[37] *i**,[38] and the NFR Framework,[39] we argue that the GRL[33] is the most suitable language for our needs as it is (i) a lightweight goal language, (ii) easy to implement, and (iii) allows to compute satisfaction scores using qualitative, quantitative and hybrid approaches (as proposed in previous works[40]).

GRL is part of the *User Requirements Notation* (URN) standard and offers a lightweight graphical language that allows modeling the goals, requirements, and their relationships.[33] Figure 6 shows the subset of GRL concepts used by our method. A goal is a quantifiable element that is used to model process activities. Soft-goal refers to qualitative aspects that cannot be measured directly.[40] Soft-goals are used to model RPA objectives/goals (i.e., RPA feasibility and RPA relevance). A GRL task is a solution, which achieves goals or satisfies soft-goals.[40] GRL links (Section b of Figure 6) are used by our approach to connect process activities (GRL goals) to RPA goals in the GRL model. *Means-End* links describe how goals (i.e., process activities) are achieved (i.e., automated) using GRL tasks (e.g., web services, EJB components). *Contribution* links specify desired impacts of one element on another element.[40] A contribution link can have a qualitative contribution type and/or a quantitative contribution (integer values between −100 and 100).[40]

Recall that the goal of this step is to create a GRL model in order to compute a satisfaction score that serves as an RPA suitability score. For that, the RRPA user must proceed as follows:

1. Link each user activity to the high-level goal (*RPA Suitability*): A process activity represents a GRL hard-goal (or simply GRL goal) to automate. The *RPA Suitability* is a GRL soft-goal to satisfy. In GRL, hard-goals can only be connected to soft-goals through the solutions (GRL tasks) that automate the hard-goals. Thus, RRPA proposes to following steps:
   a. Connect the high-level RPA goal (GRL soft-goal), *RPA Suitability* to its sub-goals *RPA Feasibility* and *RPA Relevance* using the contribution link.
   b. Link the solution (e.g., web service) to the user activity (e.g., Approve Invoice) using the means-end link.
   c. Link the solution to the RPA sub-goals *RPA Feasibility* and *RPA Relevance* using two contribution links.
2. Quantify the goal model: RRPA uses quantitative values from 0 to 100 to quantify the GRL-based goal model as follows.
   d. Assign the feasibility score computed in Step 1 to the contribution link that connects the solution to the *RPA Feasibility* sub-goal. The feasibility score is a value between 0 and 8 while RRPA proposes to use values between 0 and 100. Thus, the feasibility score, which serves as a contribution value, must be normalized between 0 and 100. The normalized value corresponding to a value x, denoted by `Nx`, between 0 and 8, is computed as follows:

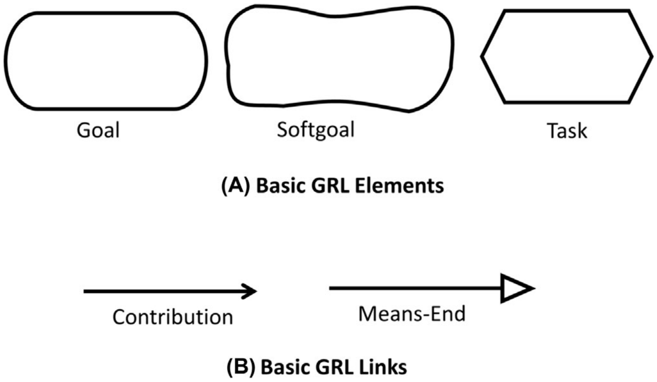

FIGURE 6 Basic GRL concepts (*Source*: adapted from previous works[40]).

$$Nx = \frac{x \times 100}{8}$$

b. Assign the relevance score computed in Step 2 to the contribution link that connects the solution to the *RPA Relevance* sub-goal. The relevance score is already normalized between 0 and 100.

c. Assign quantitative values to the contribution links that connect the sub-goals RPA Feasibility and RPA Relevance to the RPA Suitability high-level goal. By default, the RRPA method assigns the same contribution value (100) to both links. Thus, the feasibility and the relevance are weighted equally. The user of the method (e.g., business analyst and business architect) can adapt the method by changing the default contribution values to weigh each goal according to its specific needs.

d. Quantify the importance values of the intentional elements. Importance values are shown between brackets inside the intentional elements (i.e., user activities, RPA goals, and solutions) in the goal model. For that, the RRPA method proposes to assign a default quantitative value of 100, which is the higher importance value. This value serves as a baseline against which other values can be compared and adjusted based on the specific needs and priorities of the organization using the method. As for contribution links that connect the RPA goals (Feasibility and RPA Relevance, and RPA Suitability), the user can modify these default values according to the specific need of the organization. For example, the user can assign different values if he/she wants to prioritize the automation of certain tasks. Note that the importance values of the sub-goals *RPA Feasibility* and *RPA Relevance* are propagated down from the high-level goal (*RPA Feasibility*) to its sub-goals (*RPA Suitability*, *RPA Relevance*) using the following formula (see previous works[41]):

$$\frac{parentGoal.iValue \times subGoal.cValue}{100}$$

where *parentGoal.iValue* is the importance value of the parent goal and *subGoal.cValue* is the value of the contribution link that connects the sub-goal to the parent goal.

To automate this step, RRPA uses an Archimate-based GRL model. Archimate is a language for modeling enterprise architecture that has been adopted as a standard by the Open Group. Archimate is composed of five layers, namely, Strategy, Business, Application, Technology, Implementation, and Migration and four aspects, namely, Passive structure, Behavior, Active Structure, and Motivation.[42]

To create the GRL goal model with the archimate language, we mapped the (i) GRL soft-goal to the Archimate goal aspect, (ii) GRL hard-goal to the Archimate requirement aspect, (iii) GRL contribution link to the Archimate influence relation, and (iv) GRL means-end link to the realization relation. Figure 7 shows an example of a GRL model for the activity "A2: Approve invoice" of the generic account payable process of Figure 4. The values 87.5 and 50 represent the feasibility score and the relevance score, respectively.

4.7 | Step 4: Evaluate the GRL goal model

Amyot et al. propose in previous works[40] three algorithms (quantitative, qualitative, and hybrid) to evaluate GRL models. GRL evaluation consists of computing satisfaction scores that measure how goals are satisfied. A satisfaction score is a quantitative measure that assesses the degree to which a certain goal or soft-goal is satisfied within a given context. Satisfaction scores in GRL typically range from 0 to 100, where 0 indicates complete dissatisfaction or nonachievement of the goal and 100 represents complete satisfaction or full achievement of the goal. To compute the

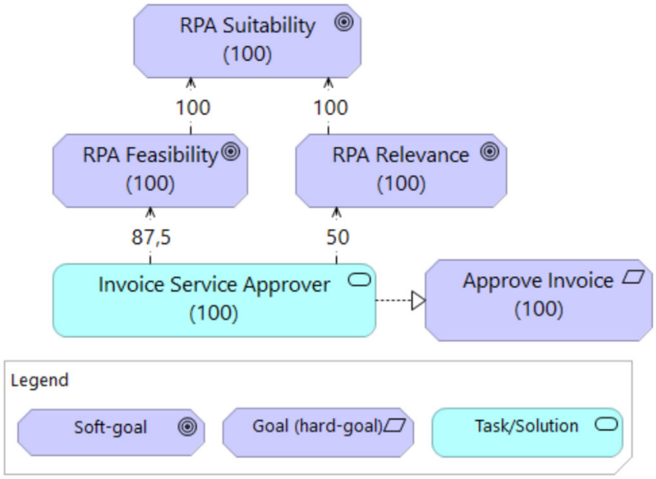

FIGURE 7 The goal model for the user activity "approve invoice."

RPA suitability score of process activities, RRPA uses the quantitative algorithm. The RPA suitability score is, thus, based on (i) the contribution values and (ii) the importance value of the intentional elements (activities, RPA goals, and solutions).

The algorithm starts by initializing the evaluation values of the solutions using the neutral default value of 100. Then, the algorithm propagates the values through GRL links to obtain *evaluation values* for the intentional elements. Evaluation values are displayed next to the intentional elements in Figure 8. The evaluation value of an RPA goal (*goal.evValue*) reached by *n* contribution links is computed as follows:

$$goal.evValue = \frac{\sum_{i=1}^{N} srcElt_i.evValue \times elt_i.cnValue}{n \times 100}$$

where $srcElt_i.evValue$ is a source element of the RPA goal and $elt_i.cnValue$ is the contribution value of the source element to the RPA goal.

For example, the evaluation value of the soft-goal *RPA Feasibilty* is computed by (i) multiplying the evaluation value of the solution *Invoice Service Approver* (i.e., 100) by the value of the contribution link that connects them (i.e., 87.5, which is obtained by assessing the business rules classes and the context of the process user activity as detailed in Sections 4.4.1 and 4.4.2) and (ii) then, dividing the result by 100 (i.e., [100 × 87.5]/100). The algorithm ensures that the evaluation value of each goal will not go above the maximum value of 100.

The RPA suitability score is computed using the quantitative evaluations for actors proposed in previous works.[40] Thus, the RPA suitability score of a user activity a, denoted by `a.rpaScore`, is computed using the importance and the evaluation values of the *n* intentional elements bound to the user activity. Therefore,

$$a.rpaScore = \frac{\sum_{i=1}^{n} ie_i.impValue \times ie_i.evValue_i}{\sum_{i=1}^{n} ie_i.impValue}$$

where *ie.impValue* and *ie.evValue* are the importance value and the evaluation value of the intentional element *ie* respectively.

The RPA suitability score of a business process *P* composed of *n* user activities, denoted by `a.rpaScore`, is calculated using the result obtained in the previous step. It is defined as the average of the RPA suitability score attributed to each of the user activities that compose the business process. Therefore,

$$p.rpaScore = \frac{\sum_{i=1}^{n} a_i.rpaScore}{n}$$

Figure 8 illustrates the evaluation of the Archimate-based goal model after applying the GRL evaluation algorithm to the example shown in Figure 7. Thus, the RPA suitability score of the user activity "Approve Invoice" is 68.75.

To assess the RPA suitability of a business process, RRPA uses the satisfaction model illustrated in Figure 9. This simple linear model is based on the RPA classification quadrant designed in previous works.[6] The latter is based on the automatable band proposed in previous works.[4] Thus,

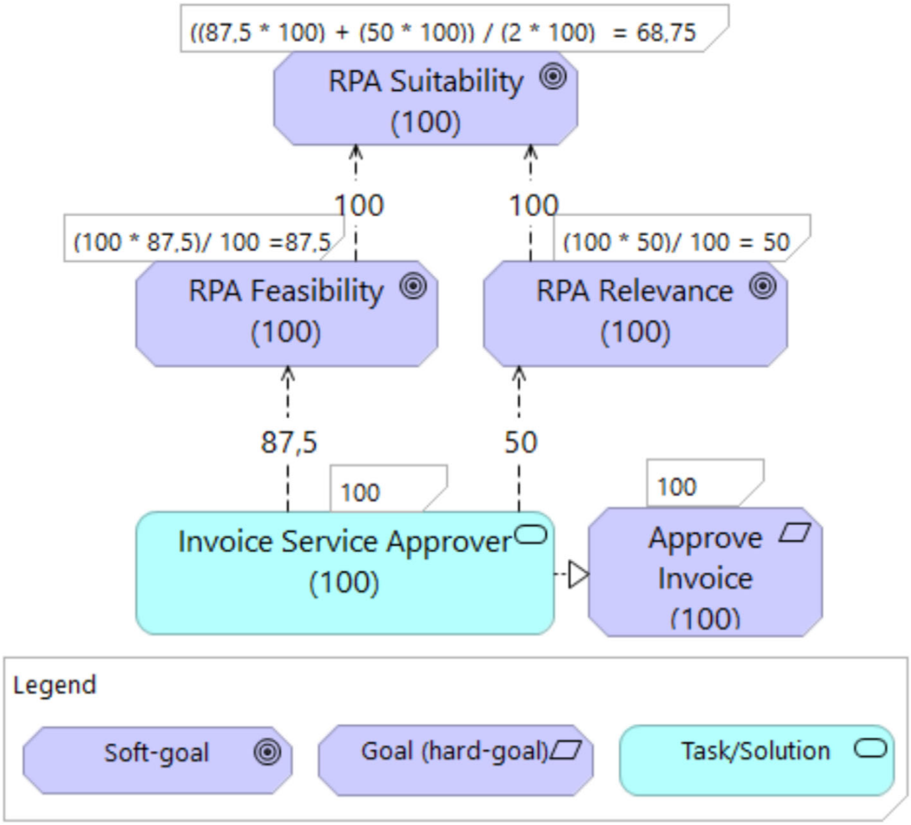

FIGURE 8 Evaluation of the goal model for the user activity "approve invoice."

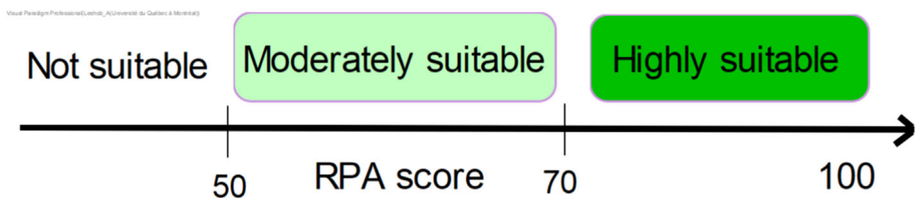

FIGURE 9 Proposed RPA satisfaction model.

1. When *p.rpaScore* < = 50, the process *p* is considered "not suitable" for RPA automation.
2. When 50 < *p.rpaScore* < 70, the process *p* is considered "suitable" for RPA automation.
3. When *p.rpaScore* > = 70, the process *p* is considered "highly suitable" for RPA automation.

5 | EVALUATION

This section corresponds to the evaluation stage of the DSR methodology. It presents the results of an empirical study conducted to assess the usability of the RRPA method. According to the ISO 9241-11 standard,[43] the usability is "the extent to which a system, product or service can be used by specified users to achieve specified goals with *effectiveness*, *efficiency* and *satisfaction* in a specified context of use." The *effectiveness* designates the accuracy of achieving specific goals by the users. The *efficiency* is about resources needed to achieve the goal, including time and scarce (advanced) technical skills. *Satisfaction* measures the physical, cognitive, and emotional responses of the users after using the system. The study evaluated the effectiveness and the efficiency of the RRPA method. It also validated the applicability and relevance of the techniques and metrics used to assess the feasibility and the relevance aspects. Specifically, the goal of the experiment was to answer the following questions:

1. Are the techniques used by the RRPA method to assess the suitability (feasibility and relevance) of business processes for RPA automation, applicable, and relevant? The technique is applicable when it can be instantiated. For example, the technique used to assess the feasibility of RPA is applicable if it allows to: (i) classify the business rules that are inherent in each user activity and (ii) compute a feasibility score. This technique is relevant means that it provides a relevant measure of the automation potential with RPA technology.
2. Is the RRPA method *effective* in assessing the suitability of business processes for RPA automation?
3. Is the RRPA method *efficient*, in the sense of *not* requiring scarce advanced technical skills, in assessing the suitability of business processes for RPA automation?

To carry out the experiment, we used the Goal-Question Metric (GQM) approach.[44] The GQM approach defines three levels[44]: (i) the goal of the experiment, (ii) the questions used to characterize the way to attain the defined goals, and (iii) the metrics used to answer the questions. The experiment needed human participants with sufficient expertise that allows them to walk through the method and evaluate each aspect to validate.

The rest of this section is organized as follows. Section 5.1 describes the experimental setup. It presents the participants selection, and the selected business processes used as experimental objects. Section 5.2 presents the design of the study. Section 5.3 presents the experimental operation and execution. The results of the evaluation are presented in Section 5.4. Finally, Section 5.5 discusses the threats to the validity of the results of the experiment.

5.1 | Experimental processes and subjects

5.1.1 | Experimental business processes

To carry out the empirical studies, we analyzed 22 business processes mainly from the ERP literature and the manufacturing domain. We selected 13 processes each having sufficient user-type activities (at least two activities per process are performed by human actors with the use of software applications). Table 4 lists the selected business processes.

5.1.2 | Participant selection

To conduct the empirical studies, we approached three RPA experts from the banking, insurance, and manufacturing sectors who volunteered to participate. In addition to their experience with RPA, all experts have a solid expertise in business process management and automation. Specifically:

- Participant 1 is a senior RPA specialist. He has more than 15 years of experience in business process automation for a major Canadian financial institution. Over the past 5 years, he has led the implementation and governance of RPA within a major Canadian financial institution. Expert 1 has already worked on the evaluation of the process analysis approach to adopt RPA proposed in previous works.[6]

TABLE 4 Experimental business processes.

Process ID	Business process
BP1	Expense claim management
BP2	Exchange rate management
BP3	Invoice processing
BP4	Transactions monitoring
BP5	Insurance claim management
BP6	Shipping
BP7	Payroll processing
BP8	Cash management
BP9	Daily bank checks verification
BP10	Employee/partner integration
BP11	Invoice reception
BP12	Procurement
BP13	Transport fees reconciliation

- Participant 2 is a senior solution architect with more than 20 years of experience in various IT projects in the banking and insurance industry. Over the past 2 years, he has been involved in various RPA projects.
- Participant 3 is an experienced consultant in enterprise architecture who has led six large projects in BPM and RPA during the last 4 years. She has also conducted key business process reengineering (BPR) projects in a government institution. She also has a strong experience with SOA and ERP.

5.2 | Experimental design

To evaluate the *usability* of the RRPA method from the expert point of view, the following questions were encoded:

1. *RQ1*: Are the techniques used by the RRPA method to assess the feasibility of RPA automation applicable and relevant?
2. *RQ2*: Are the metrics used by the RRPA method to assess the relevance of RPA applicable and relevant?
3. *RQ3*: Does the RRPA method effectively assess the suitability of business processes for RPA?
4. *RQ4*: Does the RRPA method require advanced technical skills in RPA and process automation?

To conduct the experiment, we presented the 13 processes of Table 4 to the experts and asked them to answer the questions in the context of each process. For RQ1 and RQ2, we asked the experts to judge whether the techniques and the metrics used by the RRPA method, as instantiated for a particular process, were perceived as applicable and relevant. For RQ3 and RQ4, we asked the experts to assess whether the RRPA method, as instantiated for a particular process, was perceived as effective (RQ3) and efficient (RQ4). For each question, an additional space was available to allow the participants to add comments in order to explain their answers.

To assess the *effectiveness* and *efficiency* of the RPA method, we needed to evaluate the following *variables* for each process in Table 4:

- The variable that measures the applicability and the relevance of the techniques used by the RRPA method to assess the feasibility aspect has a value between 0 and 1. This value represents the ratio of the process user activities for which the experts found the proposed techniques applicable and relevant out of all process user activities. Thus, the resulting value is presented in the form of a fraction $\left(\frac{A}{B}\right)$. The denominator B designates the total number of user activities in the process. The numerator denotes the number of user activities within the process for which the expert found the techniques applicable and relevant. For example, the value 2/3 means that the techniques are applicable and relevant for two user activities out of the three user activities of the process.
- The variable that measures the applicability and the relevance of the metrics used by the RRPA method to assess the RPA relevance aspect has a value of 0 or 1. The value 1 means that the metric was found to be applicable and relevant. The value 0 means that the metrics were found as not applicable or irrelevant.
- To assess the *effectiveness* of the RRPA method, we need to compare the RPA suitability assessment made by the experts, to that made by RRPA. Thus, we need a variable that represents the experts RPA suitability assessment, which can take three values: 0, means that the process at hand is deemed “not suitable” for RPA automation; 2, means that the process is deemed “highly suitable” for RPA automation; and 1 means that the process was deemed to be suitable for RPA automation but should not be prioritized.
- To assess the *efficiency* of the RRPA method, we used a variable representing the Single Ease Question (SEQ) metric to assess how difficult users find the RRPA method. SEQ is a 7-point rating scale, from *Very difficult* to *Very easy*.

Thus, we had 52 (13×4) variables. From these variables, we derived 52 hypotheses:

$H1i_0$: The techniques used by the RRPA method to assess the RPA feasibility were found not applicable or irrelevant/ $H1i_a = \neg H1i_0$; For i = 1 to 13.
$H2i_0$: The metrics, used by the RRPA method to assess the RPA relevance, were found not applicable or irrelevant/ $H2i_a = \neg H2i_0$; For i = 1 to 13.
$H3i_0$: The RRPA method was found to be ineffective/ $H3i_a = \neg H3i_0$; For i = 1 to 13.
$H4i_0$: The RRPA method was found to be inefficient/ $H4i_a = \neg H4i_0$; For i = 1 to 13.

5.3 | Experiment operation and execution

The experiment was carried out using the Zoom platform. The researcher who conducted the experiment used tutorial material to introduce the experts to the RRPA method. All the instrumentation materials used in this experiment is available at https://tinyurl.com/2xjw58xr. It includes

1. BPMN models of each process in Table 4,
2. Detailed description of each business process, including, for each process activity, (i) the rules that govern it, (ii) its RPA context, (iii) the average number of the times it is performed per day, and (iv) its PHE (low, medium, or high),
3. Training slides with an overview of the RRPA method,
4. Detailed results obtained after applying the RRPA method to the experimental process. The results contain the RPA suitability score of each activity and each process after applying the RRPA method to the processes of Table 4,
5. A questionnaire for gathering the data.

The experiment was conducted in a single session of approximately 4 h. The experiment conductor presented the material and answered the questions raised by the participants. Then, the participants performed the evaluation in separated virtual classrooms of the Zoom platform and submitted the results. The experiment conductor joined the classrooms if requested by the participants.

5.4 | Results

5.4.1 | Analysis of the feasibility and relevance assessment

Table 5 depicts the evaluation of the applicability and the relevance of the techniques and the metrics used by the RRPA method to assess the suitability of RPA technology in the context of the experimental processes of Table 4.

The results show that the experts found the metrics used to assess the *relevance* aspect, which assesses whether the RPA automation is worthwhile applicable and relevant (column *Relevance* of the Table 5). For the participants 1 and 2, the use of the NOT, the user activities are performed per day, and their PHE metrics are applicable and measure correctly the relevance to apply RPA. While all experts agreed that the use of the NOT metric allows to assess the relevance of RPA (value 1 in Table 5), participant 3 found that the RRPA method should consider the Average Execution Time (AET) metric to assess the relevance of implementing RPA (column Relevance with gray background). Thus, the expert proposed to use three metrics (NOT, PHE, and AET) instead of two metrics used by the RRPA method (i.e., NOT and PHE). The expert agreed that the PHE metric is relevant to measure the complexity of the activities, but this is not sufficient as it should be combined with the AET metric. More precisely, participant 3 argued that the time has often served as a proxy for assessing process/activity complexity in BPM and RPA ([4]). She also pointed that the AET metric is often available from logs and monitoring tools. We agree with the expert to combine PHE and AET metrics to measure process tasks complexity.

To assess the feasibility aspect, the experts used the detailed description of each business process, that is, the description of each process activity and the rules that govern it, and annotated BPMN model obtained after applying the RRPA method. Figure 10 shows an example of an annotated process model. Recall that the method computes the feasibility scores using the business rules classes that govern the process activities and the business rules contexts. Consider the example of the shipping process of Figure 10. The activity A1 that decides on the shipping option is

TABLE 5 Assessment of the feasibility techniques and relevance metrics.

	Participant 1		Participant 2		Participant 3	
Process ID	Feasibility	Relevance	Feasibility	Relevance	Feasibility	Relevance
BP1	2/2	1	2/2	1	1/2	1
BP2	3/3	1	3/3	1	2/3	1
BP3	5/5	1	5/5	1	4/5	1
BP4	4/5	1	4/5	1	4/5	1
BP5	2/2	1	2/2	1	1/2	1
BP6	3/3	1	3/3	1	3/3	1
BP7	4/4	1	4/4	1	3/4	1
BP8	5/5	1	5/5	1	3/5	1
BP9	4/4	1	4/4	1	4/4	1
BP10	3/3	1	3/3	1	3/3	1
BP11	6/7	1	7/7	1	5/7	1
BP12	7/7	1	7/7	1	5/7	1
BP13	4/5	1	5/5	1	4/5	1

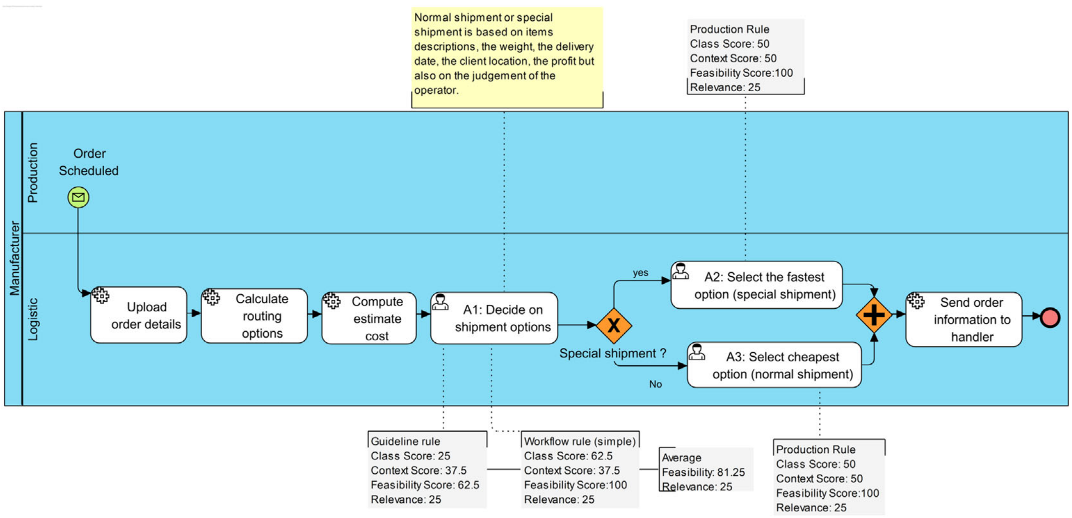

FIGURE 10 Example of an annotated process model.

based on two types of business rules, a *guideline rule* to determine the shipping method, and a *workflow rule* that controls the process flow. The RPA feasibility scores (class score and context score) are shown in the BPMN annotations. The activity A1 involves more than one rule. Thus, the feasibility score is computed using the average of the RPA feasibility scores of each rule. The column *Feasibility* of Table 5 shows the evaluation of the applicability and the relevance of the techniques used by the RRPA method to assess the RPA feasibility. As explained in the experimental design section (Section 5.2), the results are presented in the form of a fraction $\left(\frac{A}{B}\right)$ where the denominator B represents the total number of *user activities* of the process at hand and the numerator represents the number of, those among such user activities, for which the expert found the techniques to be applicable and relevant. Overall, the results show that the experts found the techniques that assess the feasibility of RPA (automation potential) applicable and relevant at:

$$\frac{148}{55\times3}\times100=89.70\%$$

where 148 is the total number of user activities for which the experts found the techniques to be applicable and relevant and 55 is the total number of the user activities of the experimental processes.

The evaluation raised the following questions:

1. All experts noted that the feasibility score of a workflow rules that depend on the execution of a user-type activity must be computed only if the rules that govern it have not been taken into account when computing the score of a previous gateway (simple or complex). Recall that the method computes a feasibility score for a gateway only if its rule depends on the execution of at least a user-type activity.
2. All experts proposed to add new rules classes for simple exchange-type operations such as sending emails and notifications.
3. For Experts 1 and 3, send and receive activities, such as `Send Purchase Order` and `Communicate Security Policies`, should be given the same weight as "RPA Loader Rule" class as opposed to "Generic Rule."
4. Expert 3 proposed to separate send-type activities (*Send Task* in BPMN) from compound activities in order to assess more accurately the feasibility of RPA. For example, in the expense management process, the expert proposed to break down the activity where the user completes and validates the report and then sends it, into two activities/tasks: "Complete the expense report" and "Send the report." The rules validation is only applied for the "Complete the expense report" activity. The "Submit the report" activity should have the same feasibility score as the activities governed by "RPA Loader Rules."

5.5 | Analysis of the effectiveness and efficiency assessment

To assess the effectiveness aspect, we first applied the RRPA method to the experimental processes to compute the RPA suitability scores and then, classified the processes according to the satisfaction model illustrated in Figure 9. Then, we asked the participants to assess the RPA suitability of each process from their point of view using the detailed description of each process. We asked them to identify the processes that are not suitable for RPA (value = 0) and the processes that are highly suitable for RPA (value = 2). The processes that are good candidates for RPA automation but should not be prioritized (i.e., are not highly suitable) were given the value 1.

Table 6 shows the RPA suitability scores obtained for each process after applying the RRPA method. The column *RPA suitability* is based on the default satisfaction model illustrated in Figure 9. Table 7 shows the evaluation of the effectiveness aspect of the RRPA method from the point of view of the experts.

The results show that, overall, the experts identified the same highly suitable processes (the four processes among 13 identified as highly suitable by the RRPA method have also been identified as highly suitable by all experts). The results also show that all the processes classified as "not suitable" by the RRPA method were found "not suitable" by the experts. Overall, participants 1, 2, and 3 found the RRPA method effective at 92.31%, 84.62%, and 69.23%, respectively, which gives an average effectiveness of 82.05%.

For the efficiency aspect, we wanted to assess if the RRPA method is easy to use. For that, we used the SEQ metric with 7-point rating scale (from *Very difficult* to *Very easy*). Overall, participants 2 and 3 gave a rating of 5 out of 7 for the RRPA method, while participant 1 rated it at 6 out of 7, giving an average efficiency score of 76.19%. Overall, the participants 2 and 3 found that the feasibility aspect is relatively difficult to compute as it requires the users to manually assign the rules and its context to the process activities. On the other hand, participants

TABLE 6 RPA suitability scores after applying rule-based robotic process analysis (RRPA).

Process ID	Feasibility score	Relevance score	RPA suitability score	RPA suitability
BP1	90.6	25	57.8	Moderately
BP2	100	50	75	Highly
BP3	95	75	85	Highly
BP4	98.1	90	94.1	Highly
BP5	100	75	87.5	Highly
BP6	93.8	25	59.4	Moderately
BP7	100	37.5	68.8	Moderately
BP8	92.5	5	48.8	Not suitable
BP9	100	25	62.5	Moderately
BP10	95.8	33.3	64.6	Moderately
BP11	96.4	0	48.2	Not suitable
BP12	100	7.1	53.6	Moderately
BP13	100	30	65	Moderately

TABLE 7 Effectiveness assessment.

	0: Not suitable 1: Moderately suitable 2: Highly suitable			
Process ID	Participant 1	Participant 2	Participant 3	RRPA
BP1	1	1	0	1
BP2	2	2	2	2
BP3	2	2	2	2
BP4	2	2	2	2
BP5	2	2	2	2
BP6	1	1	1	1
BP7	0	1	0	1
BP8	0	0	0	0
BP9	1	1	1	1
BP10	1	1	1	1
BP11	0	0	0	0
BP12	1	0	0	1
BP13	1	0	0	1

Abbreviation: RRPA, rule-based robotic process analysis.

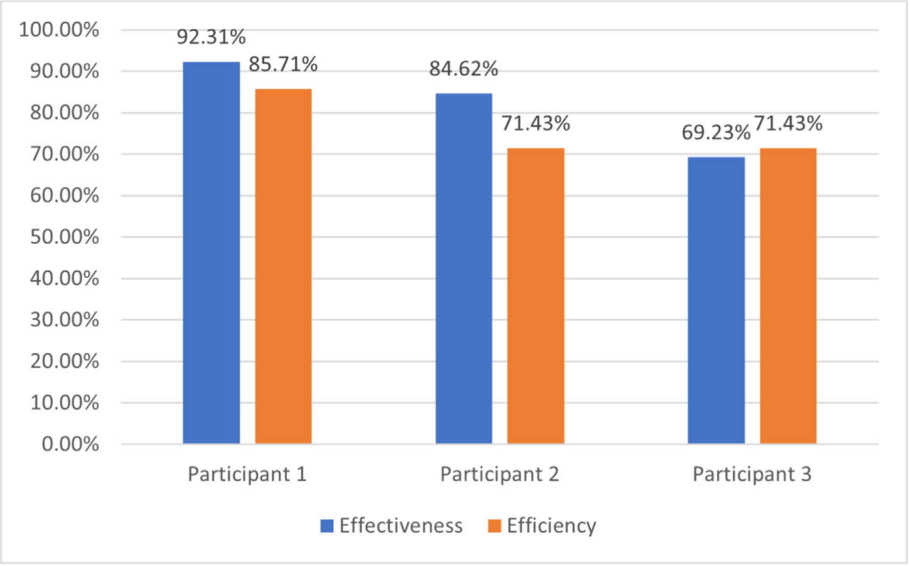

FIGURE 11 Evaluation of the effectiveness and the efficiency aspects per expert.

pointed out that the computation of the relevance metrics and the satisfaction scores are efficient. Figure 11 shows the evaluation of the effectiveness and efficiency aspects per experts.

5.6 | Threats to the validity

This section explores the main issues that may have threatened the validity of the experiment. We consider threats to internal and external validity as discussed in previous works.[45]

5.6.1 | Internal validity

The threats to internal validity compromise the confidence to confirm a relationship between the independent and dependent variables. This is relevant when the goal of the study is to establish a causal relationship between variables. In the context of the experiment, threats to internal validity were related to the experience of the participants, which might impact their evaluation of (i) the techniques used to assess the feasibility of RPA, (ii) the metrics that assess the relevance of RPA, and (iii) the effectiveness of the RRPA method. To mitigate the threat related to the profile of the experts, we defined a minimum skill set to be met by the participants. The selection of experts was based on their strong professional experience and knowledge background of BPM, RPA and business process automation. Another internal threat comes from the impact of learning effects that may affect the results of the experimental study because the participants may learn from/use the obtained RPA scores. To mitigate this threat, the experiment was designed to minimize the impact of learning effects on the results as the instrumentation materials did not provide detailed steps to obtain RPA scores. We also note that no expert use computed scores on their experience to classify processes for RPA adoption.

Finally, we note that information exchange between participants represents another threat to internal validity. On the particular context of the experiment, we eliminated this threat by assigning participants to separate classrooms within the Zoom platform.

5.6.2 | External validity

Threats to external validity might compromise the generalization of the experiment results. The primary external threat arises from the possibility that the selected business processes (Table 4) might not be representative of other kinds of business processes. To address this issue, we analyzed more than 20 business processes and selected 13 processes covering different business domains with sufficient user-type activities to allow us to assess the RPA suitability. It is worth noting that we validated the statistical representative of the experimental data with an expert statistician specialized in the empirical experimentation field. Nonetheless, our results might be valid only for the experimental processes, and further replications are needed to improve the generalizability of the results.

6 | CONCLUSION AND FUTURE WORK

RPA is a software technology that automates manual and repetitive tasks in business processes. RPA uses software robots that mimic human behavior when performing process tasks to interact with existing systems through the UI.[1] The goal of RPA is to relieve employees from repetitive and tedious tasks, increase productivity, reduced time, and improve accuracy.[9]

This paper proposed a rule-based method, called RRPA, to guide practitioners to evaluate the suitability of business processes for RPA automation. RRPA assists process automation practitioners to classify business processes according to their suitability for RPA. RRPA extends the method proposed in previous works[9] allowing organizations to compute the RPA suitability score using not only the business rule classes but also the specific PC. The novelty of this work is fourfold: (i) it uses an extensible business rule-based classification model to assess the *decisioning* aspect, (ii) it is flexible and adaptable according to the specific needs of the organizations (e.g., users can adapt the relevance model to set new metrics that better reflect the average number of transactions or the PHE), (iii) it is easy to implement by users, such as business analysts without having to become RPA specialists, and (iv) it automatically computes the RPA suitability score using a goal model.

While the results showed that the method is effective and efficient, we acknowledge mainly three limitations. First, the proposed method does not support cognitive activities that require creativity or complex interpretation. The second limitation is related to the relatively limited number of RPA experts who evaluated the method. It is worth noting that the selection of experts was based on their strong experience and knowledge of business process automation approaches. Third, the experimental processes might not be representative of business processes from other business domains.

This paper sets the basis of a long-term research project that aims to design and develop methods and tools to help organizations to adopt and implement effectively the RPA approach. To refine and improve the method, we plan to carry out the following research works in the future. First, we plan to use the Decision Management and Notation (DMN)[46] to describe and model the business rules that underlie user activities. DMN is an OMG modeling language for modeling business decisions and business rules. This enables RPA practitioners to effectively collaborate in defining the business rules underlying process activities. Second, we intend to support complex and cognitive tasks and work alongside BPMN and Case Management Model and Notation (CMMN) ([47]). Finally, we plan to conduct a replication study to improve the generalizability of the results.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

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ENDNOTES

* In BPMN terms, a *user activity* is an activity performed by human actors with the assistance of a software application.

† The user (e.g., process analyst) is asked to answer positively if the number of alternatives is less or equal to 10. This value is based on the cyclomatic complexity measure proposed by Mccabe.[35]

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