IEEE Access
Multidisciplinary | Rapid Review | Open Access Journal

Received 24 July 2024, accepted 16 August 2024, date of publication 27 August 2024, date of current version 10 September 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3450690

RESEARCH ARTICLE

A Model-Based Approach to Enhance the Communication Between the Participants of Collaborative Business Processes

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ABSTRACT Business process modeling is used to model business processes using Business Process Modeling Notation (BPMN), which is a widely accepted standard for process modeling. BPMN elements are visually represented by the existing model, but the expressiveness of elements in terms of communication between the participants of the business process is a problem reported in modeling literature. Business processes use collaboration models to gain increasing importance in software development, describing their behavior and interaction. Recent years have seen the presentation of various approaches to ensure communication between business process pools. Despite the widespread adoption of BPMN for business process modeling, existing collaboration models often suffer from significant limitations in accurately capturing complex collaborative business processes. The existing approaches do not ensure proper structure and syntax for collaboration elements. The flow of information among multiple pools causes ambiguity in the developed business process. A Collaborative Business Process Model (CBPM) is proposed to address this issue, based on modeling rules that ensure proper syntax and structure of the models. The proposed CBPM also guarantees that the model is a better approach for participant interaction. This approach contributes to improving the communication mechanism between the participants of collaborative business processes. Moreover, we formally analyze and verify the working of CBPM by specifying the model in Z specification language. Performance evaluation regarding the flow of messages through test case coverage criteria indicates that the model is capable of ensuring successful communication among the multiple participants of business processes.

INDEX TERMS Business process modeling, collaborative business processes, syntactic, structural, participants.

I. INTRODUCTION

Business Process Modeling plays an effective role in the modeling of an organization's Information Systems (IS). It helps define standard and optimal organizational workflows. Companies now recognize process management value as the foundation for competitiveness, shifting from cost to achieving quality as the primary factors to model flexibility and responsiveness. Process management value is recognized as the premise of competitiveness that shifts from cost or attained quality to model flexibility and responsiveness [1]. The major need for change in business processes is due to the increasing demand for service quality and better productivity in organizations [2]. There are numerous approaches for modeling business processes. The Business Process Model and Notation, also known as BPMN, is a well-known and important modeling methodology.

A diverse class of audiences is used to communicate a wide variety of process configurations through the Business Process Modeling (BPM). Thus, BPMN was designed to

The associate editor coordinating the review of this manuscript and approving it for publication was Francisco J. Garcia-Penalvo.

cover many types of modeling and allow the creation of end-to-end business processes. Co-relation and communication are the main focus of business processes. BPMN uses business models to give a graphical representation of business processes to address the communication between multiple participants. This graphical representation facilitates the business process of communication, exploration, and management [3].

In BPMN, collaboration is a sub-model that mainly depicts the interaction among two or more business entities. Collaboration portrays the interactions of two or more business entities. Collaboration typically has two or more pools that reflect the Collaboration's Participant. A message flow connecting two pools depicts the message exchange between the participants (or the objects within the pools). Messages connected to the message flow can also be depicted graphically. Collaboration can be characterized by two or more public and/or private Processes communicating with one another [4]. There exist many issues in the communication and interaction between two or more participants.

In [5], the modeling elements of BPMN and the connection rules for the selected set of elements are briefly discussed.The description and the use of modeling elements in business process models are given. In Ref [6], a study listed the 12 most frequently used elements of BPMN that are generically enough to model a business process and address the issue of expressiveness in modeling the processes. The proposed model graphically depicts the connection between the most frequently used modeling elements. The meta-model describes the flow between the elements using the connection object.

The collaborative business process modeling approach is a major focus of research these days. The organizations are collaborating in different possible ways to meet their related goals. The integration of collaborative business processes is a complex activity. Since many pools are participating in a collaborative business process, communication is provided by an interplay that is message flow. Error-free communication is the only solution to the problem [7]. Further analysis is required to determine if the business process model described in the BPMN specifications is optimal and error-free. Message flow and sub-processes are among the factors that make the processes. The interaction of these elements hides subtle or unanticipated effects, making the design process error-prone, and perhaps resulting in the inclusion of inappropriate behavior [8].

A review of existing verification techniques reveals certain shortcomings in the proposed methodologies. According to the literature, when it comes to ensuring the syntax and structure correctness of process models, these methods do not address all areas. The model proposed in [6] is a sufficient contribution in terms of the research, but there are chances for improvement. In the existing literature, the contributed models lack representation of BPMN elements. Further, they did not address the issue of element interaction and communication between the elements following the connection rules. As message flow is a major element of collaboration, so its significance and interaction are highlighted in this research.An extended BPMN model proposed in this paper presents message flow as new elements and describes their interaction with flow elements. As in the collaboration definition, it is discussed that message flow is the major element in a collaborative business process. A message that is communicated between the participants of the collaborative business process is represented graphically in the proposed model. In the proposed model, interaction and collaboration using the message flow are clearly depicted to enhance communication among the number of collaborating participants. The interaction of message flow with the selected set of BPMN elements following the rules is graphically represented to address the issue of element connection. In the process model, message flow helps to indicate the business context of activities and events in a workflow regularly. The process model is checked syntactically against the defined rules, and structural checking is possible through proper handling of message flow among the connections. The use-case scenario is modeled using the proposed and existing models. The evaluation of the proposed model based on test case generation highlights the efficiency of the proposed model over the existing model.

The key contributions of the proposed work are as below:

- We present the meta-model following the connection rules to improve the collaboration among the participants of business processes.
- Using the formal method, we check the syntax and structure correctness of modeling elements in the proposed model.
- Following the proposed model, we model a use-case scenario and generate test cases against it to check the requirements coverage of the proposed framework in comparison to existing approaches.
- To identify the set of objects from BPMN elements that enhance the communication between the elements of collaborative business processes when multiple pools are interacting to achieve a significant goal.

The rest of the paper is organized as follows. Section II presents related work of collaborative business processes. The proposed methodology is discussed in Section III. To evaluate our proposed approach, sample process models are syntactically and structurally checked, and different coverage criteria applied to the case studies are discussed in Section IV. Finally, a conclusion is provided in Section V.

II. PRELIMINARIES

There have been several studies in which business processes are proposed using modeling languages. It is important to mention that many of the developed processes have employed the BPMN, a modeling language, to define the business process models. A detailed study into the modeling and customization of process families based on BPMN standards is conducted [1]. It highlighted the limitations in existing approaches, such as insufficient element coverage for the business process [2], [3]. In addition to this, limited attention is given to the communication of elements in a business process. An open issue that needs to be considered is the definition of better error messages, and the support for collaborative processes (i.e., many pools), among others [2], [6]. Existing approaches are limited in the context of ensuring the element's connection and the syntactic and structural correctness of process elements [6], [9]. In collaboration with other business entities, the existing approaches are inefficient to model a better design for the business [7].

Researchers have contributed to the field of business process modeling and re-engineering by identifying frequently used modeling elements. Previously discovered subsets of BPMN elements have a shortcoming: They do not highlight association connection rules and lack a visual representation of how to use these elements in connection with one another. In [6], the selected elements in terms of their connection rules are specified, but the approach is not effective enough for communication among the participants of the business processes. In collaborative business processes, communication occurs between the elements of two or more pools/participants. Moreover, the connection between the elements should be clear, so that correctness is ensured at the initial step in the process modeling [4], [10].

Process model creation requires more and more potential distributors as well as stakeholders to overcome the quality issues and to help create the process's collaboration. The understandability and maintainability of these business processes have remained a major area of research for the past few years. In [11], the authors proposed a tool to support the creation of collaborative processes and, subsequently, analyzed the process modeling within the modeling environment. With the help of the tool, the data is evaluated by highlighting the metrics. This approach has limitations when it comes to usability for a larger number of participants. Also, the approach is limited in the context of usability for a greater number of participants. The second major problem associated with collaboration is the improper depiction of behavior and interaction among the processes. In effect, the communication using message flow makes the design activities error-prone and causes incorrectness in behavior. A framework is proposed for checking the correctness after modeling collaborative business processes with a major focus on message flow and sub-processes [9]. The soundness property is ensured as a quality criterion and addresses the issues that occur with asynchronous messages [12]. A framework is implemented that is latterly integrated with the Camunda modeling environment [13]. This approach is applied only to private processes or processes communicating between two pools or participants.

With the increasing complexity in the environment of collaborative business processes, organizations have to compete with large systems and also need to share their resources. Collaborative Business Process (CBP) is a good source to describe the collaboration requirements of different organizations, as many enterprises are coordinating to ensure effective collaboration, and also achieve significant goals [14]. Several business process modeling tools are proposed, based on the standard BPMN for centralized deployment and execution of business processes. These tools are compared without focusing on distributed deployment and execution. In [15], the authors summarize the comparison by stating that none of the CBP tools covers all the elements and attributes of BPMN, the execution engine (that runs on each server that deals with incoming requests) of these tools is in the same situation. Storage for business processes is preferably done in a Database Management System (DBMS). These tools only support centralized deployment but are inefficient in covering distributed deployments.

The third problem is the poor business process verification to ensure that the represented process is both syntactically and structurally valid. According to reports, the standard specification of BPMN covers syntactic principles fairly well enough but misses the formal semantics. A review of the literature is conducted to identify available options for process verification [16]. In BPMN, collaboration models lack formal verification properties that hinder fully adopting the BPMN standard as it makes it impossible to check the fulfillment of behavioral criteria exactly, and it has a negative influence on software quality. A Web-based tool-chain is proposed that allows for successful modeling, verification, and result exploration [17]. Validation approaches are available for business processes, but business process collaboration is given the least importance. Collaboration among business processes is playing its part in many fields such as e-commerce, logistics, outsourcing, and many other online platforms. Collaborative business processes are created and distributed daily among the employees and trainees of the organizations. The collaborative business processes are difficult to handle by other collaborators. This issue results in the occurrence of uncertainty among the processes. In some cases, informal descriptions of activities and processes within the meetings and organizations make the process description language inappropriate. To overcome this issue, trust is the major factor that is needed. The trust layer is introduced and uncertainties among the processes are identified in the model's presentation to address the issue. The trust layer behaves as an analytical tool to improve process transparency and reduce the impact of uncertainty [18], [19]. The proposed approach describes the type of uncertainties that occur in different types of modeling elements. However, it did not address the issue of uncertainties that will occur when two different modeling elements interact with each other.

Analysts define business processes in BPMN, while some collaborative business processes are not defined using these languages. In some cases, informal descriptions of activities and processes within meetings and organizations make the process description language inappropriate. In [20], the authors extended the existing language with new notations to model the complex processes. The approach highlights the problem and suggests the aspects that are the root of the problem in modeling the new complex system [21]. Humans involved in large numbers contribute to the complexity of collaborative business processes. Related researchers have thoroughly discussed numerous models closely related to our work in the related work section. The message flow between the participants and the collaboration among organizations using different techniques are discussed in the literature review. In addition, modeling rules and their connections are also discussed in this research, as the execution of activities between the modeling elements and flow of information take place following the defined rules. The main relevance of this research is collaboration among various participants by adhering to message flow principles and the most commonly used BPMN standard.

III. THE PROPOSED CBPM METHODOLOGY

In this paper, we proposed a solution based on formal methods to solve the identified problems of modeling and visualizing the connection among the flow and connecting objects. The proposed solution is based on Z specification and test coverage, in which well-formed rules have been formally defined to ensure the syntactic and structural correctness of process models. The requirements coverage of the proposed model is evaluated based on test-case generation. Moreover, formally defined process models are compared based on pools and message flow to identify gaps.

The proposed methodology is composed of the following steps.

- Identification of frequently used modeling elements and associated well-formed rules for collaboration.
- The proposed model represents the connection between the selected modeling elements based on identified rules.
- Formally specifying schema in Z specification language.
- Evaluation of proposed model in comparison to existing based on requirements covered by process models.

Using formal methods, a solution based on Z specification is proposed. The proposed solution is composed of six different steps, which are shown in Figure 1. The subsequent sections of the proposed methodology provide a detailed elaboration of each step, offering a comprehensive guide through the process.

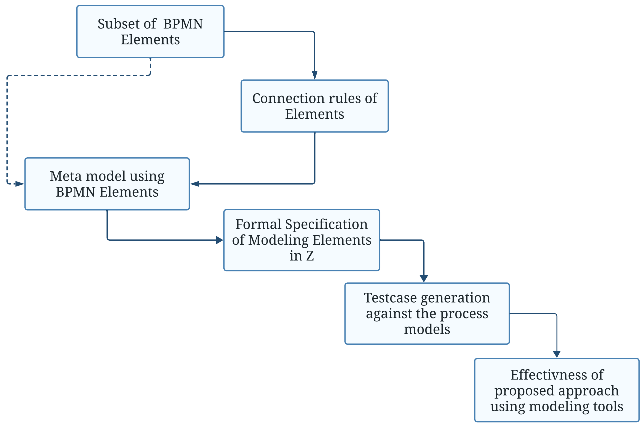

FIGURE 1. Collaboration plan.

A. WELL-FORMED RULES

Well formed rules for selected modeling elements are extracted from the standard specification of BPMN [5]. Rules related to relationship types and the way elements of collaboration will connect are part of syntactic rules. Structural rules cover aspects, such as the flow of information between modeling elements.

- **Syntactic Rules (Connection Rules)**

R1: A task can connect to another task using message flow.

R2: A task can connect to a start event using message flow.

R3: An end event can connect to a task using message flow.

R4: Message flow can be used to communicate to different pools.

R5: Message flow cannot connect to the elements that are within the same pool.

R6: A task may be a target for a message flow. Zero or more incoming message flow can target a single task.

R7: Targeted tasks have multiple incoming message flows.

R8: A task may be a source for message flow. Zero or more outgoing message flow can target a single task.

R9: A start event can never be a source for message flow.

R10: A start event can be a target for message flow having zero or more incoming message flows.

R11: An end event can never be a target for message flow.

R12: An end event can be a source for message flow having one or more outgoing message flows.

R13: A start event in a process requires at least one end event.

R14: An artifact can never be a part of message flow as a source or destination.

B. META-MODEL OF BPMN SUBSET

In this section, we define the meta-model for the BPMN subset. Figure 2 visually shows the selected modeling elements and the relationships between them. The figure also represents the proposed CBP Model. Sequence flow defines the execution order of the activities within a process while message flow indicates a flow of messages between pools to send and receive them. The meta-model uses these connecting objects to describe their usage in the processes. ‘‘Pool’’ and ‘‘Lanes’’ are subtypes of ‘‘Swimlanes’’. ‘‘Text annotation’’ comes under the category of ‘‘Artifacts’’. All these subsets collectively make Business Processes.

The proposed model for collaboration is shown in Figure 2. The model is proposed following the selected set of modeling elements and the rules defined in Well-formed rules section A.

The relation among modeling elements is represented using connecting elements. Figure 3 show the selected

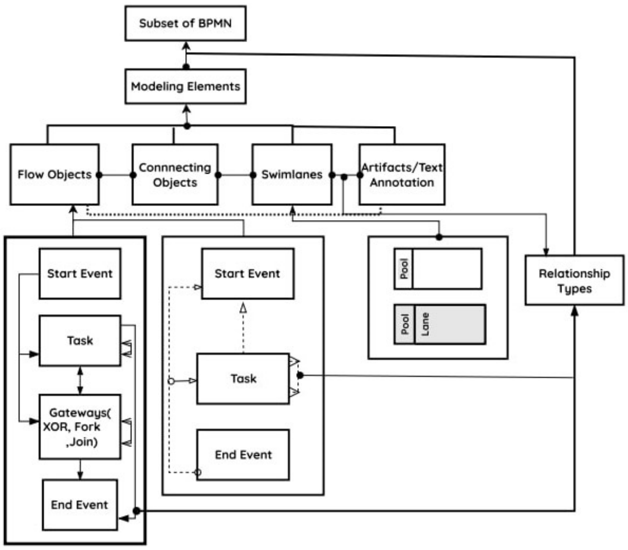

FIGURE 2. Meta-model of proposed CBPM methodology.

connecting elements along with their symbols. Each relationship type is briefly described to enhance understanding and ensure its appropriate application.

Relationship Type	Description	Notation
Sequence Flow	To express relation between Flow Objects within a Pool or Lanes of a Pool.	———→
Message Flow	To express relation between elements of different Pools.	o- - - - - - -▷
Association	To attach Artifacts with Flow Object	······················
Generalization	To express relation of subcategory or subtype	●———→

FIGURE 3. Relationship types in CBP model.

C. FORMAL SPECIFICATION OF THE MODEL

In this section, the proposed schema is formally specified in Z notation. In comparison to other formal methods, the decision to use Z as the formal method for this model was based on several key factors that make it particularly well-suited to the needs of this research. Z is a formal specification language known for its strong mathematical foundation, which is crucial for ensuring the precision and rigor required in modeling complex business processes. This is particularly important for the Collaborative Business Process Model (CBPM), which requires an accurate representation of dynamic interactions among multiple stakeholders. Z is best suited for model checking, verification and validation.

The purpose of formally specifying the schema is to provide a generic approach in which any modeled process can be specified to check its syntactic and structural correctness. Correctly specified process models according to this schema will also have compliance with collaboration modeling and collaborative business processes. Modeling elements of identified subsets and well formed-rules are formally defined in Z specification. Formal specifications of modeling elements and well formed-rules are presented in the state space schema of Z notation. state space schema (often called a ''state schema'') is used to define the state of a system, encapsulating all the variables (state components) that describe the system at a particular point in time. In the context of a state space schema in Z notation, a type is used to define the kinds of values that a state variable can hold.

The general definitions of a task, start event, and end event are defined as Types in the state space. Message flows are considered functions, and their associated syntactic and structural rules are also defined in state-space as in-variants. Pools and Lanes within a pool are treated as operational schemas. The purpose of generally defining elements and rules in state space is to ensure compliance of the operational schema with this state space.

Pools and lanes are presented as operational schemas to formally specify any business process model. Tasks, start events, and end events will be specified in the operational schema as members of generally declared types of these elements in the state space. An operational schema is used to specify how the state of a system changes in response to certain operations or events. Message flow values will be updated as part of the functions declared in the state space. Other in-variants declared in the state space ensure the syntactic and structural correctness of the process model specified in the operational schema.

In contrast, other formal methods, while valuable in their own right, either lacked the expressiveness needed for this project or were less suited to the modular and reusable design approach required. For example, while Petri nets are effective for certain types of process modeling, they do not offer the same level of mathematical precision and modularity as Z. Similarly, methods like VDM (Vienna Development Method) are powerful but may not provide the same balance of expressiveness and readability.

D. VERIFICATION OF PROPOSED MODEL USING A CASE STUDY

The sample process model of an airline collaboration is selected from [22]. The collaboration combines private and public entities such as customers, travel agents, and airlines. The collaboration represents the interaction of participants communicating to complete a transaction related to the booking of travel. At first, the customer has to travel and call the travel agent, and ask for the latest offers, the travel agent proposes the offer to the customer by sending an 'Offer' message. After receiving the offer, the customer has to make a decision; that is represented by XOR gateway symbol. As per the decision shown in figure 5, the XOR gateway is activated. If the decision is NO, the customer rejects the offer, a rejected message is sent to the travel agent, and the entire execution process terminates. The travel agency also terminated the

─ [task1, task2, task3, startevent1, startevent2, startevent3, endevent1, endevent2, endevent3, pool, lane] └

Declaration

task: ℙ task
pool: ℙ pool
startevent: ℙ startevent
endevent: ℙ endevent
p1_s: startevent1
p2_s: startevent2
p3_s: startevent3
p1_e: endevent1
p2_e: endevent2
p3_e: endevent3
p1_t: task1
p2_t: task2
p3_t: task3
messageflow1: task1→ task2
messageflow2: task1 → task3
messageflow3: task2→ task3
messageflow4: task3 → task2
messageflow5: task3 → task1
messageflow6: task2 → task1
messageflow7: task1 → startevent2
messageflow8:task1 → startevent3
messageflow9: task2 → startevent3
messageflow10: task2 → startevent1
messageflow11: task3 → startevent2
messageflow12: task3 → startevent1
messageflow13: endevent1 → task2
messageflow14: endevent1 → task3
messageflow15: endevent2 → task3
messageflow16: endevent2 →task1
messageflow17: endevent3 → task2
messageflow18: endevent3 → task1
sequenceflow1: startevent → task
sequenceflow2: task → task
sequenceflow3: task → gateway
sequenceflow4: task → endevent
sequenceflow5:startevent → gateway
sequenceflow6: gateway → gateway
sequenceflow7: gateway → task
sequenceflow8: gateway→endevent

FIGURE 4. **Formal Specification of selected modeling elements.**

execution of the process. If the decision is Yes, the booking for the travel part is activated. If the customer accepts the offer, a message to book for travel is sent to the travel agency as the customer is ready to travel, and customer waits for the confirmation message. After receiving the confirmation for booking, the customer pays for the travel, and a confirmation message is sent to the travel agent. Finally, the customer waits for the confirmation message regarding the payment.

On the other hand, the communication starts between the travel agent and the Airline. In particular, the travel agent after sending the offer, waits for booking confirmation from the customer. If the customer rejects the offer, the travel agent cancels the booking as soon as the message is received. If the customer accepts the offer, the travel agent receives the travel message and the booking is confirmed by sending a confirmation message. The travel agent immediately after receiving the payment, orders a ticket by sending an order message. The Airline continues the process by handling the payment and activating the XOR gateway. The upper part is activated, if the payment is confirmed, a payment confirmation message is sent to the customer and the process terminates after it is successful. The lower part is activated in case the payment is not made and the airline refuses to assign the ticket.

In the existing model, the case study is modeled using Event-based gateways and intermediate events which are not part of the selected BPMN subset for the proposed model. While redesigning this process with the proposed model, the intermediate event is replaced by a task and is working well using the selected element. The selected use-case is modeled using the most used modeling elements as well as the modeling rules that are lacking in the existing approaches and are building blocks for modeling the collaborative business processes. The message flow following the rules is highlighted in the modeled use-case to better understand the collaboration among multiple pools and participants.

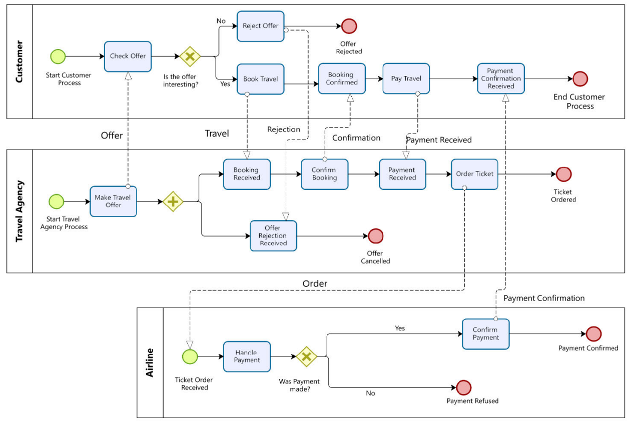

FIGURE 5. **Flight reservation system (proposed model).**

E. ANALYSIS AND MODELING

After finalizing the selected use-case using the Bizagi modeler, we imported the model design to the Testmodeller.io tool that inputs the use-case in the BPMN modeling standard as well as allowing us to model the use-case. We introduced the Swimlanes for imported models to show the pools and the flow of elements forming a business process.

After importing the model into the tool, the tool provides support to re-layout the model according to a sequence in which the model represents the flow and connections. It also validates that all the nodes and edges are connected. After that, the next step is to automate the inputs and generate the test cases. We have modeled the usecase according to the existing model and the proposed model. In the existing model, the message always flows to the start event that is communicated by the collaborating participants and it flows from pool to lanes and vice versa. However, in the proposed model, the use-case visualizes the message flow and its connection with other selected modeling elements.

After importing the test data and sorting it, the next step is to generate the test cases against the inputs. As the models are flow charts and have nodes and edges, therefore, the test coverage criteria that best suit these models are mentioned below. Testmodeller is an efficient tool and the coverage criteria evaluate the elements and control flows in all possible ways. It covers all the possible paths and then categorizes the test cases into positive and negative paths. Moreover, the tool categorizes the path based on completing a flow from the starting node to the end node.

F. COVERAGE CRITERIA'S

The three coverage criteria evaluate the performance and execution of activities and transfer of flow for the existing model as well as the proposed model. The test coverage criteria were determined based on standard practices in software engineering and systems modeling, where the goal is to ensure that all possible paths, branches, and nodes within a process or system are adequately tested. The criteria were also chosen to address the specific complexities inherent in business process models, such as the need to handle various decision points (branches), sequential operations (paths), and individual actions or tasks (statements). For instance, in a hospital management system, it's crucial to test every decision point to ensure patient care processes function smoothly. In the context of the airline collaboration model, path coverage ensures that all potential routes a customer might take from booking a flight to changing reservations are tested.

1) Statement or Node Coverage.
2) Path Coverage.
3) Branch Coverage.

1) STATEMENT OR NODE COVERAGE

Statement coverage or node coverage is a testing technique in which all the executable statements in the model are executed at least once. The main purpose of statement coverage is to cover all the possible paths, nodes, and statements in a control flow model.

$$Statementcoverage = (statementscovered/Totalnumberofstatements) * 100$$

Testmodeller generates the number of nodes covered by a model and the total number of nodes against the test cases. Figure 6 represents the node coverage against the existing model.

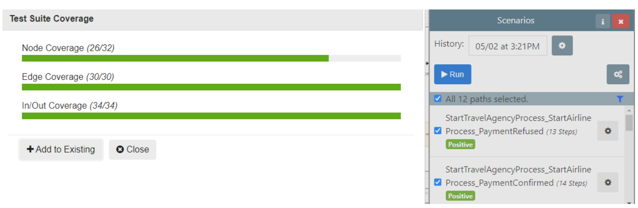

FIGURE 6. Node coverage (existing model).

Figure 7 represents the node coverage against the proposed model. The test cases generated against the model show the number of total statements and the executed statements. The proposed model executes all the statements at least once and 100% statements are covered by the proposed model.

Table 1 presents the comparison of the results between the existing and the proposed model. The statement coverage was executed as part of a case study of airline collaboration. The existing model covers 83% of the statements. However, the proposed model is executing all the statements at least once and 100% statements are covered by the proposed model.

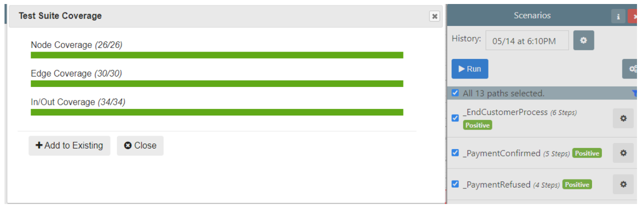

FIGURE 7. Node coverage (proposed model).

TABLE 1. Statement coverage results.

Sr.Name	Statements covered	Total number of Statements	Results
Existing Model	26	32	83
Proposed Model	26	26	100

2) PATH COVERAGE

In path coverage, test cases are executed in such a way that every path is executed at least once. Path coverage ensures that all paths are covered from start node to end. In our model, we applied path testing to every pool within the model. The model is traversed from the start node to the end node. The execution is performed on the use-case of the existing and the proposed model.

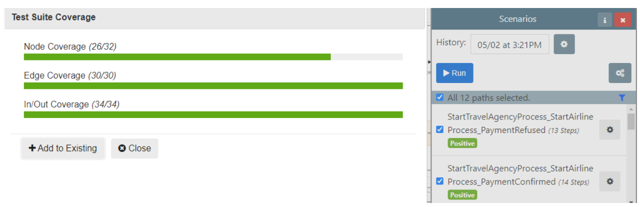

FIGURE 8. Path coverage (proposed model).

In path coverage, the path of a participating entity is traversed from the start event to the end event, and counts the number of steps taken to fully cover the requirement. The proposed model helps to design the business process in such a way that the requirements are completed in less possible time.

TABLE 2. Customer pool.

Sr. Name	Starting node	Ending node	No of test cases	No of steps executed
Proposed Model	Start Customer Process	Offer Rejected	1	5
Existing Model	Start Customer Process	Offer Rejected	5	89
Proposed Model	Start Customer Process	End Customer Process	3	38
Existing Model	Start Customer Process	End Customer Process	2	67

Table 2 presents the results of the customer pool. In the customer pool, there is one starting node and two end nodes. Both the end nodes are covered by test cases, and the results highlight a number of test cases created against the path and the total steps taken to traverse the model.

TABLE 3. Travel agency pool.

Sr. Name	Starting node	Ending node	No of test cases	No of steps executed
Proposed Model	Start Travel Agency Process	Ticket Ordered	3	30
Existing Model	Start Travel Agency Process	Ticket Ordered	5	96
Proposed Model	Start Travel Agency Process	Offer Cancelled	2	12
Existing Model	Start Travel Agency Process	Offer Cancelled	5	81

Table 3 presents the results of the travel agency pool. In a travel agency, there is one starting node and two ending nodes. Both the end nodes are covered by test cases, and the results highlight the number of test cases created against the path and the total steps taken to traverse the model.

Table 4 presents the results of the Airline pool. In this, there is one starting node and two ending nodes. Both the end nodes are covered in test cases, and the results highlight a number of test cases created against the path and the total steps taken to traverse the model.

TABLE 4. Airline pool.

Sr. Name	Starting node	Ending node	No of test cases	No of steps executed
Proposed Model	Start Airline Process	Payment Confirmed	1	5
Existing Model	Start Airline Process	Payment Confirmed	5	336
Proposed Model	Start Airline Process	Payment Refused	1	4
Existing Model	Start Airline Process	Payment Refused	6	155

3) BRANCH OR DECISION COVERAGE

Branch coverage is a testing criterion in which a decision must be tested at least once, and each point of entry to a program or subroutine must be invoked at least once, according to test coverage criteria. In every branch (choice) decision is made either true or false. It aids in validating all branches of the model to ensure that no branch leads to anomalous application behavior. In branch coverage, the process model is executed against the Yes or No decisions of a conditional statement. Testmodeller allows selecting the start and end node. After selection, the number of generated test cases shows the number of steps taken to cover a branch.

TABLE 5. BC customer pool.

Sr. Name	Case	Branches covered	Covered paths	Branches covered
Proposed Model	Yes	Start customer process - End customer process	3	4
	No	start Customer Process - Offer Rejected	1	
Existing Model	Yes	Start customer process - End customer process	5	6
	No	start Customer Process - Offer Rejected	11	

TABLE 6. BC airline pool.

Sr. Name	Case	Branches covered	Covered paths	Branches covered
Proposed Model	Yes	Start Airline Process - payment confirmed	3	4
	No	Start Airline Process - payment refused	1	
Existing Model	Yes	Start Airline Process - payment confirmed	5	6
	No	Start Airline Process - payment refused	11	

IV. RESULTS AND DISCUSSION

We used different criteria to check the efficiency of the proposed CBP model. We compare the results of each criterion with a recent existing model [6] that improves business process modeling using BPMN elements, such as task and sequence flow. It identifies the gap by modeling as-is and to-be process models. We proposed an approach in which we will compare the models on the basis of different test case coverage criteria. The models are compared with respect to the number of execution steps, test cases, path coverage, and branch coverage.

The results demonstrate that our extended CBP model is effective and generates better results in the context of communication improvement than the existing models. The findings are based on 3 use-cases modeled using the selected subset of modeling elements. The use-cases are selected from different combinations following basic communication elements. Use-case airline collaboration has multiple pools and demonstrates communication between multiple participants of the organization. The order management use-case has pools and lanes covering the communication between participants and sub-participants within an organization. The hospital management system represents the behavior of the proposed model in the context of complexity.

Figure 9 shows the statement coverage of the three selected use-cases in comparison to the existing model. This metric likely represents the percentage of statements or nodes (such as decision points, actions, or processes) covered or handled

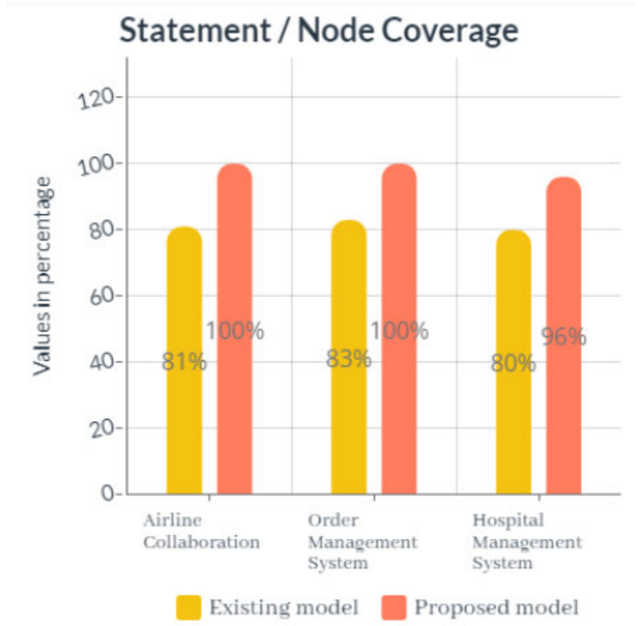

FIGURE 9. Statement Coverage of Selected use-cases in comparison to existing model.

by each model within a given system. The proposed model significantly improves coverage of statements and nodes within the system, ensuring all relevant aspects are included. Compared to the existing model, which covers 81% of statements or nodes, the proposed model covers 100%. This improvement is similar to the airline collaboration system, where the existing model leaves out 17% of statements. The proposed model consistently outperforms the existing model in all three systems, demonstrating its ability to handle a wider range of statements. The improvement is particularly noticeable in the Airline Collaboration and Order Management System and the Hospital Management System.

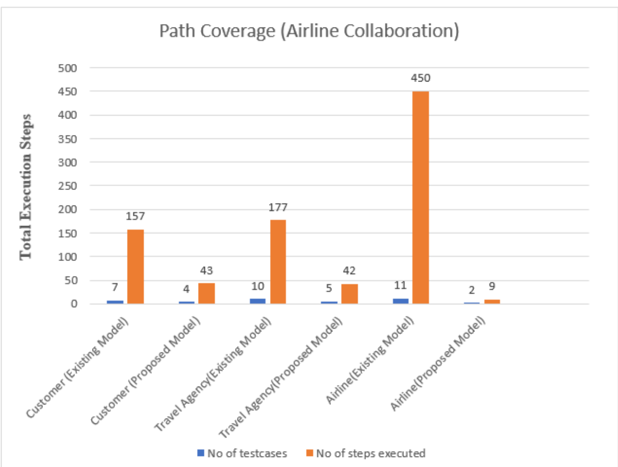

FIGURE 10. Path Coverage of airline collaboration UC in comparison to existing model.

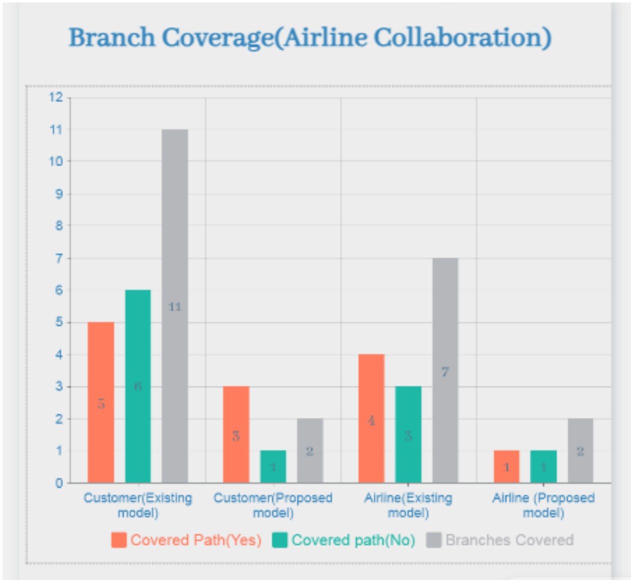

FIGURE 11. Branch Coverage of airline collaboration UC in comparison to existing model.

Figure 10 shows the path coverage for the Airline Collaboration System, comparing the performance of the existing model against the proposed model across three entities: Customer, Travel Agency, and Airline. The proposed model is more efficient in handling customer-related paths, requiring fewer test cases and execution steps. In a customer entity, it reduces execution steps by over 70%, making it more streamlined and effective. For a Travel Agency entity, the model also significantly reduces the number of test cases and steps by over 75%, indicating an optimized approach. However, in Travel Agency 98% reduction in steps suggests the model is more efficient, possibly by eliminating redundant paths or simplifying decision-making processes within the airline system. The starting and ending node represents the pools and number of paths within the pool of a process. In the airline collaboration use-case, the proposed model traversed from start to end node in a smaller number of steps. However, the existing model is taking a greater number of steps to traverse from start to end node. Both the execution time and the cost grow as the number of steps to cover the process from start to end event increases.

Figure 11 compares the ''Branch Coverage'' in the Airline Collaboration system between the existing model and the proposed model across two entities: Customer and Airline. The selected use-case pools are evaluated for both cases (Yes/No). The results show that the existing model covers the branch in a greater number of steps, and the sum of both cases represents the total number of branch coverage. However, using the proposed model, we have covered the case more efficiently with a minimum number of steps. The proposed model, covering fewer branches but effectively, may be beneficial for situations requiring quality and reliability over quantity. However, its reduced scope and lower coverage effectiveness may not be as robust as the existing model in handling airline entity complexities.

However, the literature demonstrates just like sequence flow is used between elements of BPMN for the transfer of operation from one element to another. Similarly, the symbol message flow is used for communication among the participants of collaboration following some rules. The results show that the existing model is repeatedly covering the same nodes, which results in a greater number of execution steps. If we flow the message according to the existing model, we have seen from results that ambiguity increases within the business processes.

The proposed model covers 100% nodes, which means that all the nodes or statements within a business process are executed once. However, the existing model covers 81% to 83% of statements, which means that the model lacks a few statements and that not all the nodes are executed once. The path coverage is concerned with the branch coverage which means that the existing model is taking more time to traverse all the nodes and cover the path from the start to the end node. After deep analysis and comparison of results, the proposed model achieved high scores in terms of requirements coverage and was more accurate in the context of modeling.

V. CONCLUSION

Organizations are collaborating to evolve and grow their systems, and as a result, their business processes become more complicated, and modeling them becomes challenging. Process models are used to reason about difficulties discovered in present practices and the benefits of implementing new methods, and analysis will aid in identifying changes required during implementation. In this paper, we attempt to address the issue by developing a meta-model for collaborative business process modeling. The proposed solution defines the modeling rules and the elements to check the process model for its syntax and structural aspects. To deal with the modeling rules and constructs, the modeling rules and the process model were formally specified using formal Z specification language. The proposed model is designed following the connection rules and overcomes the issue of modeling the organization's collaboration.

We validated the model using case studies related to different domains and different organizations, collaborating to enhance the organization's processes. The case studies were analyzed and modeled following the selected set of modeling elements, and the connections were made using the defined modeling rules. As the modeling consists of flow elements and connecting elements, the flow elements are considered nodes, and the control flows are edges in the testing criteria. The path coverage was evaluated against all the edges and nodes in the use-case model. The number of steps and paths are used to evaluate the information flow from a node to an end node.

The key findings underscore the CBP model's capability to manage the complexities inherent in business process modeling. The 100% statement coverage across different systems reflects the model's robustness in ensuring that all potential actions and decisions within a business process are accounted for, reducing the risk of process failures. The reduction in test cases and execution steps without compromising on path coverage highlights the model's efficiency. This efficiency not only lowers operational costs but also makes the model highly scalable, suitable for both small-scale and large-scale business processes. The varying branch coverage results reveal the CBP model's strength in optimizing simpler, linear processes while indicating the need for further refinement in more complex operations. The model successfully highlights the error in the connection of nodes and enhances communication among the participants.

The proposed CBPM, while effective in many cases, faced challenges in scenarios involving dynamic and highly complex processes. For instance, in the branch coverage evaluation of the airline collaboration system, the model showed some variability, indicating that it struggled to cover all branches, especially in intricate operations that involved multiple decision points and interactions. The effectiveness of CBP model is highly dependent on the accuracy of the initial business process modeling. Any inaccuracies or incomplete information in the initial model can lead to sub-optimal results. In the future, we will include more events related to communication and events that are related to message flow. Future work will include both synchronous and asynchronous communication events to better model the real-time and delayed interactions that occur in complex business processes. The proposed system will be able to model complex event patterns and manage aggregated messages, which will improve decision-making processes by providing more comprehensive insights into the flow of communication within an organization.The proposed model will be evaluated using large case studies that include a greater number of participants. The proposed Collaborative Business Process (CBP) model offers significant practical benefits for organizations seeking to improve their business processes. By integrating the CBP model into existing Business Process Modeling (BPM) systems, organizations can streamline communication across various departments and workflows, ensuring that all stakeholders are aligned and informed in real-time. Organizations can anticipate improved efficiency through faster decision-making and response times, enhanced accuracy by reducing communication errors, and better collaboration across teams and departments.

ACKNOWLEDGMENT

The authors would like to thank who participated in this research work.

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