Journal of Computer Science

Original Research Paper

Process Approach-Based Simulation Project Life Cycle: PAB-SPLC

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Article history
Received: 16-02-2023
Revised: 09-06-2023
Accepted: 19-06-2023

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Abstract: Simulation is one of the most effective decision support tools available to designers and managers of complex systems. In particular, discrete-event simulation is widely used in a wide variety of fields, such as industry and production, finance and economics, or even health and services. In addition, the conduct of a simulation project is of extreme importance, in order to carry out any simulation study. Our objective in this study is to propose a life cycle of a simulation project which is based on the process approach, the PAB-SPLC, as a "Process Approach Based Simulation Project Life Cycle". The choice of the process approach is justified by its agility and its inclusion in the quality approach of process management. The process approach will allow us to separate the managerial, operational, and support aspects, as well as to reach a certain level of detail on the sequence of sub-processes and tasks or activities of the simulation, while specifying the stakeholders concerned at each time, which will make our future simulation process PAB-SPLC a kind of roadmap for the development of a simulation project. Thus, we proceeded in this study to the modeling of the PAB-SPLC, based on the concepts of the process approach, then to its formalization according to the BPMN standard.

Keywords: Discrete Event Simulation, Simulation Process, Simulation Project, Life Cycle, Process Approach, BPMN

Introduction

The design and implementation of a simulation project, more exactly discrete event simulation (Camus, 2015; Zehrouni *et al.*, 2014) which we are interested in this study, are costly tasks in terms of time and human resources. In the traditional approach, the designer/developer of such projects must use his art and experience to produce an algorithmic description of the activities and events of a simulation project. This involves a great deal of effort, which despite everything, can sometimes lead to an unreliable or even unusable simulation program, for lack of recourse to the use of an organized and coherent approach for the management of the different phases in the construction of the simulation project.

Today and to guarantee the effectiveness of a simulation project, it is assumed that it is associated with a well-defined and formalized process. The objective is of course to structure the realization of the said project as well as possible. The objective is also and like the other processes of an organization, to define a precise framework for its management and the control of its sequence and its quality. However, the work carried out so far on simulation provides little explicit information on the approach or process followed and all the steps that make it up. A simulation project team still and most often, uses an intuitive and empirical approach.

This motivated us to review the literature on existing simulation processes and to highlight the steps constituting them, which are more or less numerous. The analysis of the most used simulation steps in the literature review led us to the development of a life cycle of a simulation project, which we named Simulation Project Life Cycle (SPLC) and which includes the simulation steps the most cited, explicitly or implicitly, in the literature (Ouazzani-Touhami and Souissi, 2020).

In this study, we propose to evolve the previously developed SPLC towards a representation based on the process approach. This will allow a finer, more precise, and more detailed breakdown of the simulation process into sub-processes and activities. The modeling according to the process approach of the new life cycle of a simulation project, named Process Approach Based Simulation Project Life Cycle (PAB-SPLC), as well as its formalization based on the Business Process Model and Notation (BPMN) 2.0, a standard of the Object Management Group (OMG) (OMG, 2011), made it possible to put in highlights many very important aspects in the management of the processes and which have been neglected until now, such as the non-separation between the managerial, operational and support aspects, the non-specification of the means of communication within the simulation process, as well as the non-specification of actors or stakeholders at each stage of the simulation process. This helps to ensure continuous improvement in performance and efficiency throughout the simulation process.

Related Works

In this section, we briefly review the existing simulation processes, which were the subject of a literature review that we conducted in our previous work (Ouazzani-Touhami and Souissi, 2020). We also present the SPLC that we developed following this literature review.

Simulation Process

The "Systems Engineering" approach is generally based on a chronology of stages, called the development cycle or life cycle (Foures, 2015). In the literature review we conducted on existing simulation processes (Ouazzani-Touhami and Souissi, 2020), we relied on more than ten papers, including (Arena and Bérard, 2011; Camus, 2015; Chalal, 2014; Foures, 2015; Frihat *et al*., 2015; Gangata *et al*., 2013; Marquès, 2010; Touhami *et al*., 2019; Vadeboncoeur and Baril, 2015; Zehrouni *et al*., 2014). Each of the reviewed papers presents a simulation process, or a development cycle of a simulation project, using more or less simulation steps. The steps most cited by the majority of proposals in the papers studied are:

1- Analysis and formulation of the problem
2- Definition of the system
3- Data collection
4- Modeling
5- Programming or implementing the model
6- Validation of the program
7- Validation of the model
8- Experimentation
9- Analysis of Results and Decision-making
10- Documentation

Nevertheless and according to this review of the literature, the different simulation processes examined do not always and explicitly use all these steps. Some steps are much more considered than others. Thus, steps 1 and 4 are used in almost all papers. Stages 3, 8, and 9, for their part, are considered by a majority of papers. Steps 5 and 6 are used a little less. Some other steps, in particular, steps 2 and 10 and despite their importance in a simulation process, are considered by very few papers. This disparate use of the different stages of the life cycle of a simulation project by the various papers dealing with the subject of simulation processes is due to the following facts:

- Some papers proceed by a fundamental solution of the problem and therefore do not consider all the steps concerning "programming" and "experimentation"
- In some papers, fewer steps are considered simply because some of these steps are sometimes grouped together. For example, "program validation" with "programming" and "model validation" with "modeling"
- Some steps are not always expressed explicitly in the different papers and are even sometimes neglected, such as the "definition of the system" or even the "documentation"

Simulation Process Life Cycle (SPLC)

The most cited simulation steps in the literature review led us to develop a simulation project life cycle that we named Simulation Project Life Cycle (SPLC) (Ouazzani-Touhami and Souissi, 2020). As shown in Fig. 1, the elaborated SPLC gathers, in a more or less exhaustive way, the most known and cited steps, to carry out a simulation process.

In the SPLC, the loop at the "Experiment" step offers two possibilities:

- Carry out other experiments for the same simulation scenario
- Consider another simulation scenario, which requires restarting the simulation process from the "data collection" step

The applicability of the elaborated SPLC to various fields has been demonstrated through its implementation in two simulation studies. The first relates to the field of road safety (Ouazzani-Touhami and Souissi, 2021), and the second to the field of voluntary retirement from the civil service in Morocco (Ouazzani-Touhami *et al*., 2022).

However, it should be noted that in the various simulation processes studied during our review of the literature, it is generally not specified, for each step of the simulation, the stakeholder concerned, the inputs, the outputs, etc. The same observation is also true for the SPLC developed following this literature review (Ouazzani-Touhami and Souissi, 2020). In other words, there is no separation between the managerial, operational, and support aspects of the simulation process. Our ambition in this study is to make the SPLC evolve towards a modeling based on a process approach that considers the mentioned aspects.

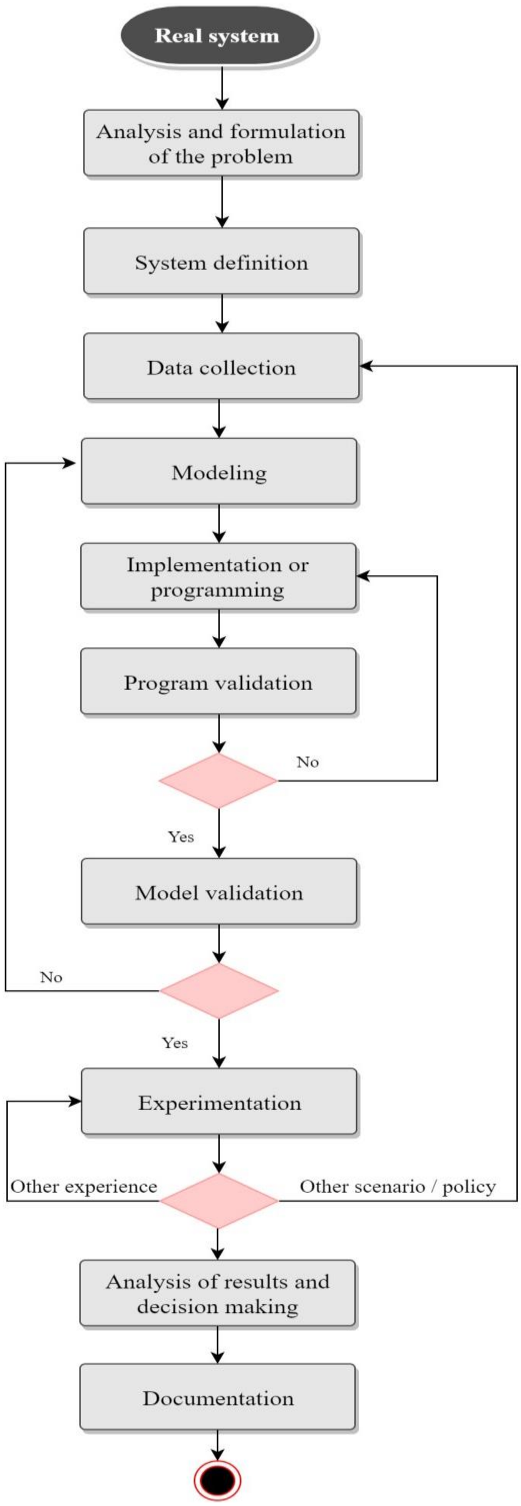

Fig. 1: Simulation project life cycle splc (Ouazzani-Touhami and Souissi, 2020)

We would like to point out that a first attempt at a representation of the SPLC in the form of a process map was presented by Ouazzani-Touhami *et al*. (2021), based on another process map representing a Data Life Cycle (DLC) in the big data context. The main motivation for this study was to demonstrate the applicability of this DLC to a simulation project.

In the rest of this study, we will attempt to formalize our SPLC, based on the process approach, with the BPMN standard.

Materials and Methods

This section is organized into three parts. The first part presents the process approach as well as the motivation for its use, the second defines the notion of process and the last part deals with the typology of processes in the context of a process approach.

Principle and Motivation

The process approach is one of the foundations of Quality approaches (Certification-QSE, 2017). It is part of the seven quality management principles ISO 9001 v2015 (ISO 9001, 2015). The process approach is based on the identification and management of processes and their interactions so as to obtain the planned results in accordance with a quality policy (ISO 9001, 2015).

The traditional mode of management based on a functional division of activities is not enough, in particular, because of the induced compartmentalization. Through more effective coordination of activities, the management mode by processes, also called "process approach", is better able to meet expectations, such as the identification and prioritization of activities, the identification of parties stakeholders, the specification and optimization of material and immaterial flows, the highlighting of interactions and correlations between activities and processes, as well as the consideration of processes in terms of added value and possibly the allocation of unity of place and time to actions. To this end, the process approach allows significant gains in terms of performance, deadlines, and costs, because it is based, among other things, on the priority given to added value, the detection, correction, and prevention of malfunctions, and also the optimal use of resources (Ange N'gadi, 2017).

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DOI: 10.3844/jcssp.2023.925.937

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The process approach introduces horizontal management, which lowers the barriers between the different functional units by unifying their focus on the main objectives of an organization (Serehane and Talbi, 2015). In addition, management by process often leads to better inter-organizational coordination, since it requires the reduction of silos and multidisciplinary work teams to promote collaboration (Toumi Amara and Djellali, 2020). According to Cattan M., the process approach leads to abandoning the primacy of a purely hierarchical logic based on trades and specialties in favor of a balance between hierarchical logic and transversal and systemic logic (Cattan, 2015).

The process approach was born within quality management and it grew with Information Technologie.

Today, it is used for good governance in areas as varied as the supply chain, information systems, quality management, project management, etc. (Toumi Amara and Djellali, 2020). It is an approach that aims for a dynamic of permanent improvement. Its application can lead to considerable gains in terms of performance, time, and costs. The benefit can be obtained thanks to the priority given to the added value and to the detection and correction of dysfunctions, thanks to well-chosen indicators. In addition, the prevention of errors and the deployment of resources in an optimal way constitute one of the strengths of this approach (Tarraq *et al*., 2014).

According to D. Noyé, the application of the process approach considers the following points:

- Identification of major activities and activity streams
- Identification of support processes, which cover human and financial resources, information, and know-how
- Identification of the environment of the organization concerned
- Search for input and output data of each process
- Breakdown of processes into sub-processes
- Establishment of lists of the resources necessary for process control
- Establishment of evaluation criteria for these processes

The application of the process approach within the framework of a quality management system allows the understanding and the permanent satisfaction of the requirements, the consideration of the processes in terms of added value, the obtaining of performance effectiveness of processes, as well as the improvement of processes on the basis of an evaluation of data and information (Ange N'gadi, 2017).

Process

The concept of the process has been treated by several authors. According to C. Tempony, a process can be defined as a set of activities, considering a number of inputs to create a number of value-added outputs. According to the ISO standard, a process is a system of activities that uses resources to transform input elements into output elements.

A process is formed by a set of interdependent activities for the production of one or more appreciable deliverables by actors. A deliverable is subject to performance conditions in relation to well-defined criteria.

A process consists of a set of operations or activities carried out by actors using means, according to references with a view to a finality. As such, a process is always oriented towards a beneficiary or a beneficiary system, internal or external. Simply put, a process is an ordered sequence of actions intended to produce a result.

Any activity or set of activities that use resources to convert input elements into output elements can be considered a process (Tarraq *et al*., 2014). In absolute terms, a process is part of an organization's operating cycle. It is limited in time by a clearly defined beginning and end and characterized by an input (the resources) and an output (the service) (Toumi Amara and Djellali, 2020).

In the literature, several other definitions are attributed to the term process. AFNOR defines the process as a set of correlated, interactive, or interdependent activities which transform input elements into output elements. We mean by correlation here, the reciprocal dependence between two processes that can vary simultaneously depending on each other (Ange N'gadi, 2017). An output element of a process often constitutes the input element of another process (Certification-QSE, 2017).

A process can be composed of sub-processes, each being a succession of activities carried out using means such as personnel, equipment, materials, information, procedures, etc. The expected result is a product (Motaki *et al*., 2015). An activity is a set of interrelated tasks constituting a transformation step of the process. A task is a set of operations, generally contributing to a transformation of information (Ange N'gadi, 2017).

Typology of Processes

The process approach, as a requirement of the ISO 9001 version 2015 standard (ISO 9001, 2015), constitutes a roadmap that aims to control the processes, whether it is their implementation phase or restructuring, from the data preparation phase to the capitalization of the results. The progress promised by the process approach requires the establishment of a methodology that will promote exchanges and communication between all the actors involved and this by establishing a process-based approach and a reflection oriented towards total quality and satisfaction rather than immediate results. The process approach provides a mode of organization that promotes the creation of value for better satisfaction (Serehane and Talbi, 2015).

The ISO standard, as well as CIGREF, the repository of the network of large French companies and public administrations, distinguish between three types, families, or classes of processes (ISO 9001, 2015; CIGREF, 2009):

- Steering processes that define the general policy and strategy and which allow the supervision of operational processes (Curatolo *et al*., 2013). Their purpose is to organize the strategic objectives of a project (Motaki *et al*., 2015). They participate and contribute to the determination, the development of the policy, and the deployment of the objectives in the organization, they also serve as common threads between the two other types of processes, operational and support. They also have the role of controlling or coordinating the activity of other processes. They also ensure the consistency of the production and support processes, including the measurement and monitoring of the processing system and the exploitation of the results with a view to improving performance (AFNOR, 2017)
- Operational or Execution processes that correspond to products and/or services responding to stakeholder demands/needs (Curatolo *et al*., 2013). Their role is to accomplish a mission in a given area and uses several functions of the organization (Motaki *et al*., 2015). They contribute to the execution of a product or service, from the detection of the need to its satisfaction. They include the activities dedicated to the production cycle of the product or service in question (Ange N'gadi, 2017)
- Support processes that ensure proper functioning by providing the necessary resources (Curatolo *et al*., 2013). Their role is to support the achievement of a business objective (Motaki *et al*., 2015). They are essential for the proper functioning of all the other processes (Ange N'gadi, 2017). In fact, they concern the resources necessary for the proper functioning of other processes, whether these resources are human, linked to the management of skills within the project, or whether they are material or linked to infrastructure

Process Approach-Based Simulation Project Life Cycle: PAB-SPLC

In this section, we propose to evolve the SPLC previously developed in the form of a flowchart, based on the literature review conducted (Ouazzani-Touhami and Souissi, 2020), towards a modeling based on the process approach. The proposed life cycle will be named “Process Approach Based Simulation Project Life Cycle”, for (PAB-SPLC).

Modelization

The PAB-SPLC process was modeled, as already mentioned, according to the process approach and was represented by three types of sub-process:

(A): The “steering” type sub-processes

(B): The “execution” type sub-processes

(C): The “support” type sub-processes

Three different colors have been chosen to represent each of the three types of PAB-SPLC sub-processes, Steering, Execution, and Support, as well as their respective sub-processes and activities. And this, throughout this study.

Table 1 presents a description of the PAB-SPLC in three types of sub-processes, Steering (A), Execution (B), and Support (C). Each type of sub-process with its subprocesses, as well as the activities composing it. It also sheds light on the stakeholders involved each time, each corresponding to a role that can be performed by the same or several individuals.

Table 1: Description of the PAB-SPLC

Type of sub-process	Sub-process	Activities	Stakeholders
A. Steering Planning and management of the different simulation processes	A.I. Planning	A.I.1. Define and analyze the studied system A.I.2. Define the scope of the study A.I.3. Define the different scenarios and policies to be simulated A.I.4. Set the parameters and hypotheses for each scenario to be simulated A.I.5. Develop the security policy (data confidentiality, access to data, etc.)	Steering team
	A.II. Management	A.II.1. Define the indicators to be measured during the simulation A.II.2. Determine the number of observations to be made A.II.3. Analyze and interpret the results and reports of the simulation, with a view to a decision-making	
B. Execution Execution of the operational processes of the simulation, whose mission generally consists, among other things, in transforming the data and parameters of the simulation into results, knowledge, and recommendations for decision-making support	B.I. Data collection	B.I.1. Fix the initial data of the simulation B.I.2. Locate and collect deterministic data from the simulation B.I.3. Identify the random variables, or stochastic data of the simulation B.I.4. Specify the random number generator to use to generate the stochastic data for the simulation B.I.5. Validate data collection	Modeling team
	B.II. Modeling	B.II.1. Build the logical and/or mathematical model B.II.2. Validate the model	
	B.III. Implementation	B.III.1. Build the simulation program according to the built model B.III.2. Run the simulation program B.III.3. View simulation results B.III.4. Validate the program	Development team
	B.IV. Quality control	B.IV.1. Control the quality of data collection B.IV.2. Control the quality of the model B.IV.3. Control the quality of the simulation program	Quality team
	B.V. Experimentation	B.V.1. Experiment the simulated scenario B.V.2. Simulate and experiment with another scenario	Experimentation team
	B.VI. Reporting	B.VI.1. Represent the results of the different simulated scenarios in different forms B.VI.2. Discuss the results of each scenario, as well as the cross-results of the different scenarios B.VI.3. Formulate the conclusions and recommendations B.VI.4. Edit simulation reports	Reporting team
C. Support Accompaniment and support for the proper functioning of the execution and steering processes	C.I. Documentation	C.I.1. Document the various deliverables of the simulation C.I.2. Document the various simulated scenarios	Documentation team
	C.II. Archiving	C.II.1. Document the various simulated scenarios C.II.2. Archive the various simulation documents	Technical team
	C.III. Security	C.III.1. Ensure compliance with and application of the security policy at the level of all simulation processes	

Stakeholders

The stakeholders involved in the three types of PAB-SPLC sub-processes, Steering, Execution, and Support, as well as their sub-processes and activities, are as follows:

- Steering team: The role of the actors of this team is the planning, as well as the management of the simulation process
- Modeling team: The role of this team is to collect the different types of data essential to the simulation project, as well as to build and validate the simulation models
- Development team: The role of this team is to implement the models, build and validate the simulation programs
- Quality control team: The role of this team is to control the quality of data collection, control the quality of the simulation models developed, as well as control the quality of the simulation program
- Experimentation team: The role of this team is to put the simulation program into action and to experiment with the different simulated scenarios
- Reporting team: The role of this team is to present and comment on the results of the various simulated scenarios, as well as to edit the simulation reports
- Technical Team: The role of this team is to ensure the application of the security policy at the level of the various simulation processes, as well as the archiving of the various simulation documents: Data, results, models, programs, etc.
- Documentation team: The role of this team is to document the various simulation deliverables and scenarios
- The stakeholders presented above generally correspond to roles and not to individuals, for better stability of the model

Formalization of the PAB-SPLC

In this section, we formalize the PAB-SPLC, presented in the previous section, based on the Business Process Model and Notation (BPMN) notation. This formalization is done in several stages, going through different levels of detail of the diagrams, going from the global to the detail. With this in mind, several diagrams are provided before presenting the final detailed diagram of the PAB-SPLC.

Choice of BPMN

The BPMN standard of the Object Management Group (OMG) is the notation standard used in the modeling of organizational processes and the automation of workflows in an organization (OMG, 2011).

BPMN is a standard for the description, analysis, and simulation of processes, in computer science and in many other fields of activity, such as the fields of agriculture, industry, and banking. BPMN supports different levels of abstraction, from high-level process models to detailed models (Correia and Abreu, 2012; Nordemann *et al*., 2020).

The BPMN standard makes it possible to represent processes graphically to make them clear and understandable. It makes it possible to simplify the representation of a process, facilitate the understanding of the flow of its sub-processes and their activities, as well as to specify the various participants or stakeholders and the means of communication between them. This by using different diagrams (Nordemann *et al*., 2020).

The BPMN standard is a language that makes it possible to represent processes, based on semantics, syntax, symbols, and usage rules (OMG, 2011).

In order to be able to formalize our simulation process, the PAB-SPLC, we chose BPMN, more precisely the BPMN 2.0 standard which is the latest version of BPMN, since its update in 2011 by the OMG (Correia and Abreu, 2012; Kurz *et al*., 2014).

Diagrams of the PAB-SPLC

After the semantic or textual modeling of the PABSPLC, given in Table 1, it was formalized through a set of diagrams allowing a visual representation of the different types of sub-processes that compose it, their subprocesses, and respective activities, as well as their sequence, the stakeholders involved and the input and/or output artifacts.

As already mentioned, the formalization of the PABSPLC, namely the development of the various diagrams describing it, was done step by step, going from the global to the detail.
The formalization of the PAB-SPLC was made through the following diagrams:

- An overall diagram of the PAB-SPLC
- An overall diagram of the sub-processes
- Detailed diagram of “Steering” type subprocesses
- Detailed diagram of “Execution” type subprocesses
- Detailed diagram of “Support” type subprocesses

As for the stakeholders involved in the various subprocesses and activities of the PAB-SPLC, it should be noted that they have been indicated in the detailed diagrams relating to the sub-processes of the " Steering ", " Execution " and "Support" types, namely the following three diagrams:

- Detailed diagram of “Steering” type subprocesses
- Detailed diagram of “Execution” type subprocesses
- Detailed diagram of “Support” type subprocesses

Results

In this section, elaborate diagrams representing the PAB-SPLC are presented, ranging from the overall diagram to the detailed diagram of the PAB-SPLC. Going through the overall diagram of the PAB-SPLC subprocesses, as well as the respective detailed diagrams of the "steering", "execution" and "Support" type subprocesses.

Overall Diagram of the PAB-SPLC

The diagram presented in Fig. 2 represents the overall diagram of the PAB-SPLC process, with the three types of sub-processes that compose it: Steering, execution, and support. It also represents the sequence and communication between these sub-processes.

Overall Diagram of the PAB-SPLC Sub-Processes

Figure 3 presents the overall diagram of the PAB- SPLC sub-processes Steering, execution, and support, as well as all of their respective sub-processes. It also represents the sequence of their various sub-processes.

The simulation process begins and ends at the level of the “Steering” sub-process. It begins with the planning and management of the various simulations to be carried out, in accordance with the tasks specified in Table 1. It ends at the "management" level with the reception of the simulation reports for analysis, interpretation, and decision-making.

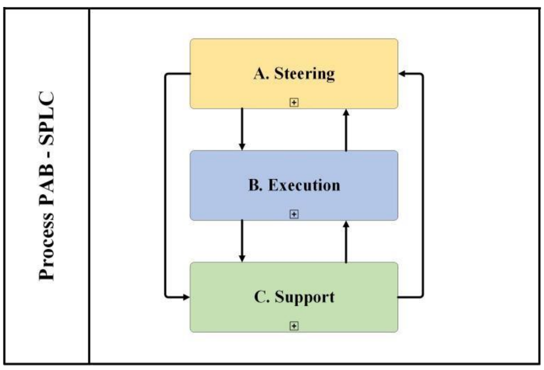

Fig. 2: Overall diagram of the PAB-SPLC

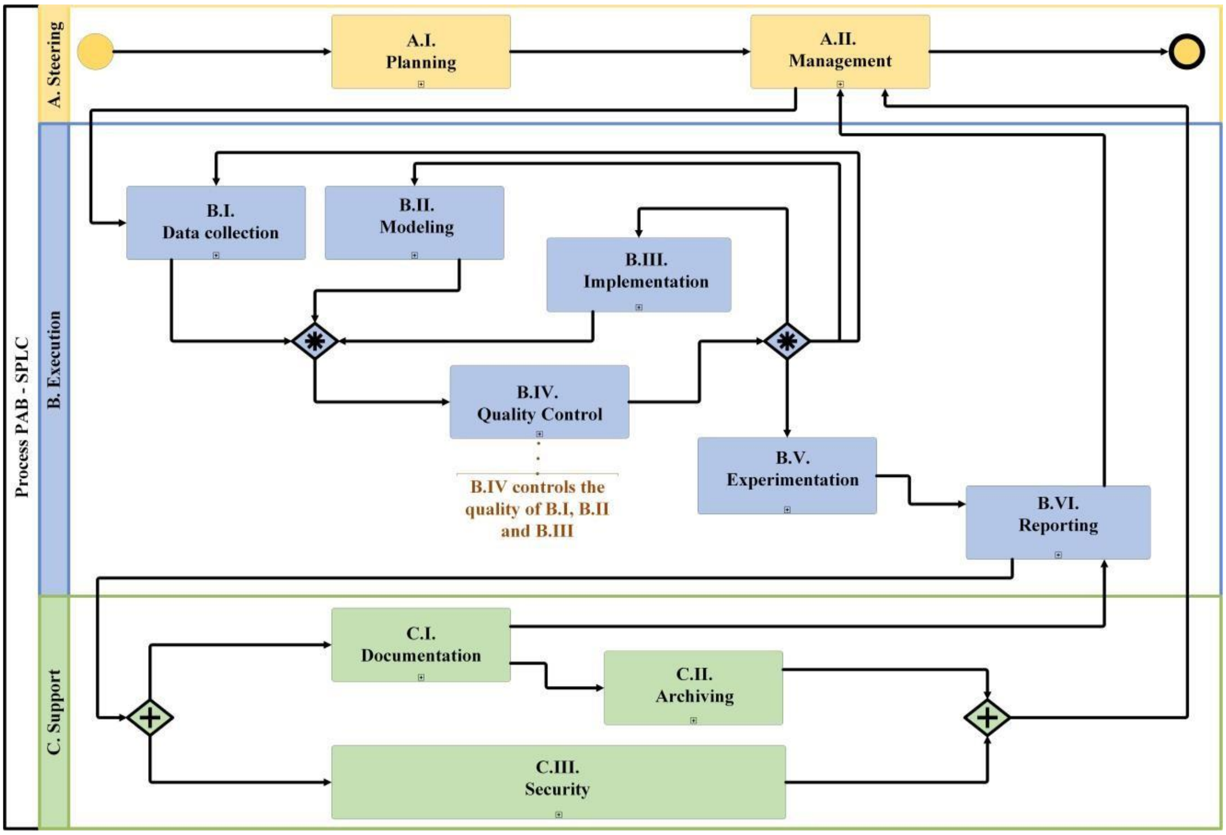

Fig. 3: Overall diagram of the PAB-SPLC sub-processes; Legend: Parallel gateway**:** Used to synchronize parallel streams. It makes it possible to create parallel paths each corresponding to a sequence flow leaving the gateway. Complex Gateway: Used to model complex synchronization behavior. It can correspond to a complex condition or situation, with several outgoing flows, three or more, each corresponding to a considered situation

The outputs of the "planning" and "management" subprocesses of the "management" sub-process are routed to the entry of the "execution" sub-process, more precisely the "data collection" sub-process.

The outputs of the "data collection" sub-process are subject to the "quality control" process for quality validation and:

- As long as the "quality control" sub-process does not validate the quality of the "data collection", rerun this one and take the necessary improvement actions
- Once the quality of the “data collection” subprocess is validated, move on to the “modeling” sub-process

After modeling, the outputs of the “modeling” subprocess are submitted to the “quality control” subprocess for quality validation and:

- As long as the "quality control" sub-process does not validate the quality of the models developed by the "modeling" sub-process, rerun this one, or even rerun the "data collection" sub-process, each time integrating the actions of improvement required
- Once the quality of the “modeling” sub-process is validated, move on to the “Implementation” subprocess

The outputs of the “implementation” sub-process are then submitted to the “quality CONTROL” sub-process for validation and:

- As long as the "quality control" sub-process does not validate the quality of the simulation programs developed by the "Implementation" sub-process, rerun this one, or even rerun the "modeling" subprocess, each time integrating the actions of improvement required
- Once the quality of the "Implementation" subprocess is validated, move on to the "experimentation" sub-process

The "Support" sub-process is a transversal process that accompanies the other two, " steering " and "execution", through the parallelism between its "documentation" and "Archiving" sub-processes on the one hand and its "security" process on the other hand.

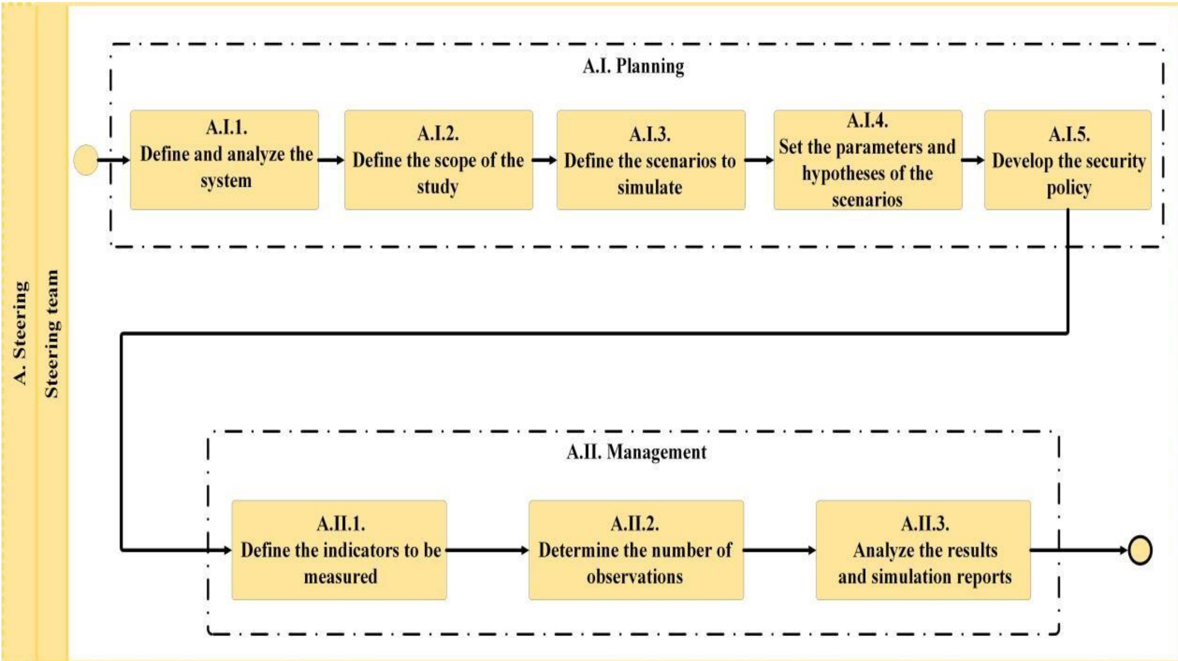

Fig. 4: Detailed diagram of "steering" type sub-processes

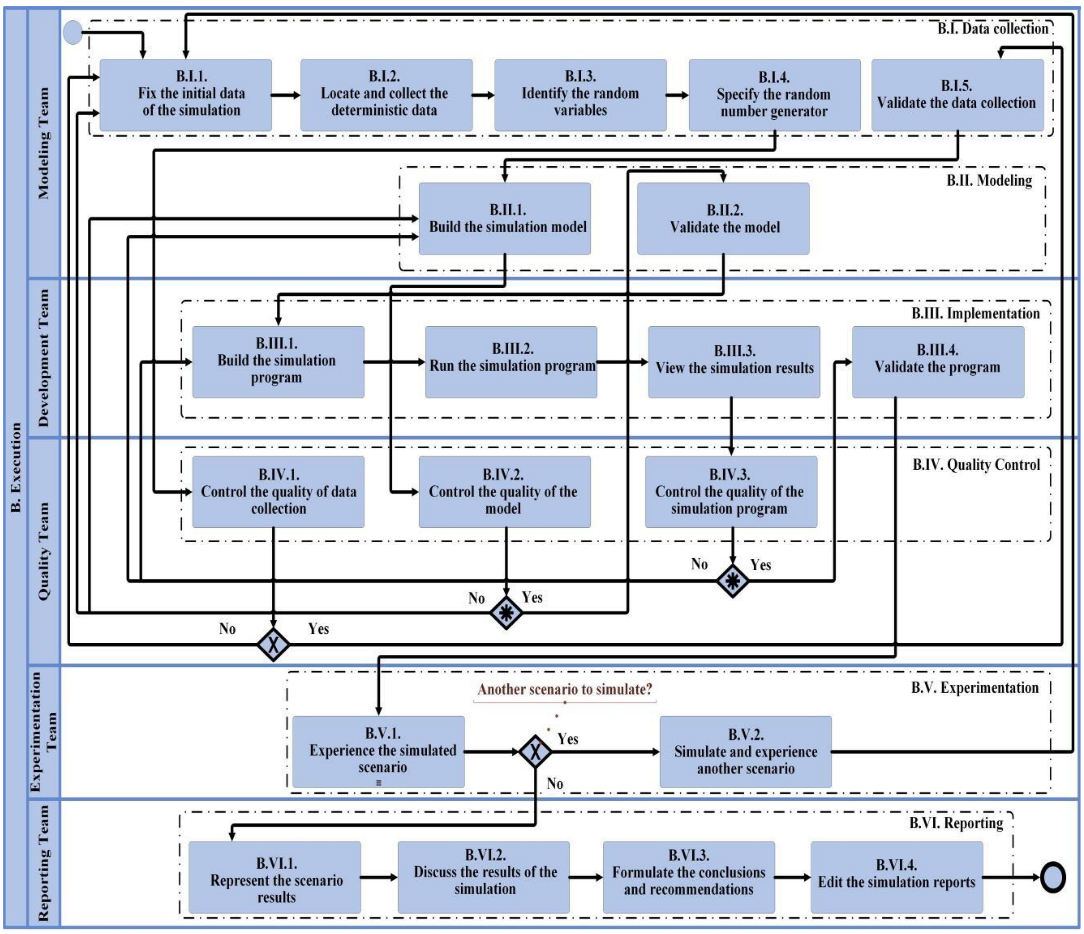

Fig. 5: Detailed diagram of "execution" type sub-processes

The outputs of the "Experimentation" and "documentation" sub-processes are used at the entry of the "Reporting" sub-process to generate simulation reports, which will be analyzed for decision-making at the level of the "Management" sub-process, something by which the simulation process ends at the level of the "Steering" sub-process.

Furthermore, it should be noted that the simulation process, PAB-SPLC based on the process approach, is agile and iterative and therefore, its sequence should in no way be interpreted as being strictly sequential. Return transitions can be expected at all stages. Thus, it is understood that at the level of each sub-process, there is an implicitly:

- A transition from the sub-process to itself
- A return transition from the sub-process to the sub-process which precedes it in the sequence of the simulation

This is with the aim of continuous improvement in the search for the solution to the simulation project in question.

These transitions are not all represented in our diagram, so as not to overload it. The same would be true for the activities of the PABSPLC.

Detailed Diagram of "Steering" Type Sub-Processes

Figure 4 presents the detailed diagram of the "Steering" type sub-processes. This diagram represents the "Planning" and "Management" sub-processes with all of their respective activities, as well as the sequence between them. It also represents the stakeholders concerned by the various activities, namely the Steering team.

It should also be noted that, as indicated above with the sub-processes, it is understood that at the level of each activity, there is an implicitly:

- A transition from activity to itself
- A return transition from the activity to the activity that precedes it in the sequence of the simulation

This is with the aim of agility and continuous improvement in the search for the solution to the simulation project in question.

These transitions are not always represented in our diagram, so as not to overload it.

The same would be true for the PAB-SPLC diagrams that follow.

Detailed Diagram of "Execution" Type Sub-Processes

Figure 5 presents the detailed diagram of the "Execution" type sub-processes. This diagram represents the different sub-processes of this type with all of their respective activities, as well as the sequence between them. It also represents the stakeholders involved in the various activities, namely the five teams: Modelling, development, quality, experimentation, and reporting.

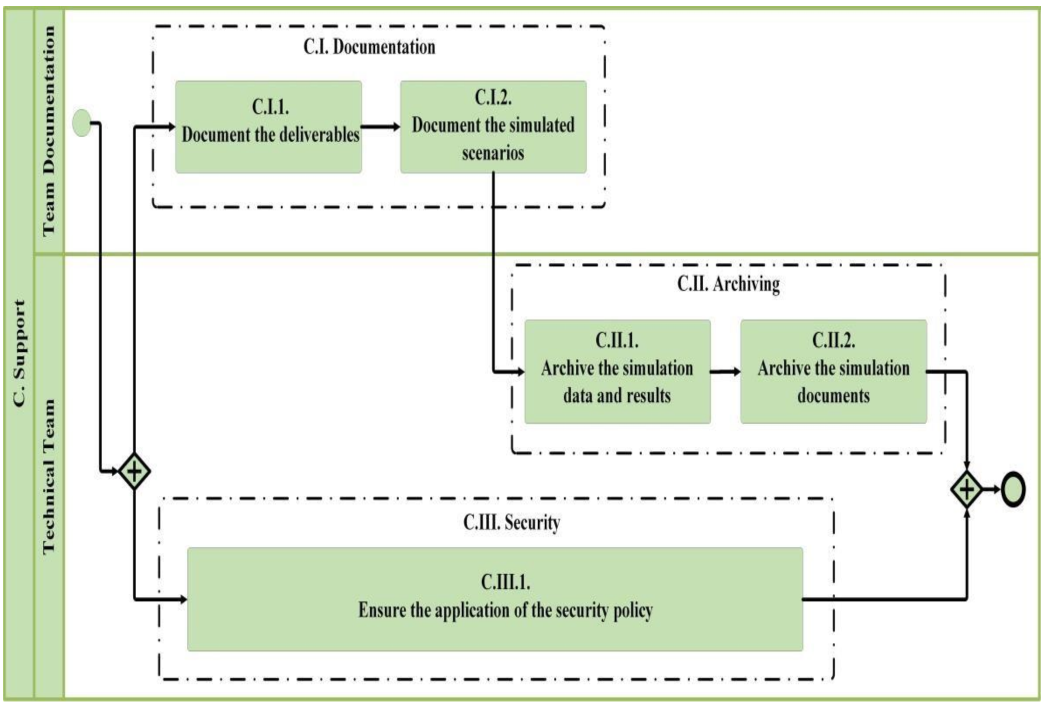

Fig. 6: Detailed diagram of "Support" type sub-processes

Detailed Diagram of "Support" Type Sub-Processes

Figure 6 presents the detailed diagram of the "Support" type sub-processes. This diagram represents the different sub-processes of this type with all of their respective activities, as well as the sequence between them. It also represents the stakeholders involved in the various activities, namely the two teams: Documentation and technical.

Discussion

The literature review conducted on existing simulation processes (Ouazzani-Touhami and Souissi, 2020) showed that the number of steps is very disparate from one simulation process to another. This ranges from two or three steps to ten or more. And, whatever the number, these steps are not necessarily the same from one process to another. A step that we find in one simulation process is missing in the other and vice versa.

In Ouazzani-Touhami again, we have tried to identify the most important and most cited simulation steps in the various existing simulation processes and to bring them together in a more or less exhaustive manner. This led us to develop the life cycle of a simulation project that we named SPLC. The SPLC thus constitutes a kind of synthesis of the existing simulation processes.

The observation is that both the existing simulation processes and even the developed SPLC have a number of limitations, the main ones being:

- The detail of the tasks to be carried out in each step of the simulation is not given. The content of each step remains imprecise and subject to uncontrolled interpretations
- The sequence of simulation tasks in each step and the communication between them also remain imprecise
- The non-separation of managerial, operational, and support aspects in the simulation process
- The non-specification of the stakeholders concerned by each simulation task

In order to meet these limits, we opted to upgrade our SPLC to the PAB-SPLC modeled according to the process approach and formalized according to the BPMN 2.0 standard. The process approach makes it possible to detail the simulation process in sub-processes, activities, and tasks, while separating the managerial from the operational and the support, as well as specifying the stakeholders concerned. BPMN diagrams emphasize the flow or sequencing of different simulation tasks and their communication. The PAB-SPLC will thus be able to constitute a real roadmap for the development of a simulation project.

Conclusion

In this study, we started by recalling the problems linked to the development cycle of a simulation project, as well as the literature review that we conducted on the simulation processes and their stages, which led us to elaborate on the SPLC (Ouazzani-Touhami and Souissi, 2020).

After emphasizing some limitations noted on the existing simulation processes, including the elaborate SPLC, we expressed our ambition to evolve the SPLC towards a PAB-SPLC based on the process approach. Following this, we presented the general principles of the process approach, as well as our motivation for using this approach.

Then, we proceeded to model the PAB-SPLC in three types of sub-processes, " Steering ", " Execution " and "Support", each with its sub-processes, their activities, as well as the stakeholders. A descriptive table has been drawn up to summarize the essentials of this modeling.

Finally, we used the BPMN 2.0 standard for the formalization of the PAB-SPLC. This formalization was done at different levels, from global to detailed, and gave five BPMN diagrams. The diagrams elaborated shed light in turn on some very important aspects in the management of a simulation process, thus showing the contributions of the PAB-SPLC, in particular:

- The separation between the managerial, operational, and support aspects
- The introduction of new aspects, such as steering, security, and archiving
- The transversality of "Steering" and "Support"
- The detailed flows between the activities or tasks of each sub-process of the simulation process
- Communication within the simulation process
- The agility and the iterative aspect of the different sub-processes and tasks, for continuous improvement during the simulation process
- The inputs/outputs of the various sub-processes and activities of the PAB-SPLC
- The stakeholders involved in each of the simulation tasks

In the end, we can conclude that the developed PABSPLC which is the subject of our contribution in this study, with its various diagrams, can be perceived as a set of guidelines for the realization of a simulation project and can thus constitute a real "Guideline" for conducting a simulation project.

We have already conducted a simulation study in the field of road safety based on the SPLC (Ouazzani-Touhami and Souissi, 2021). We are currently conducting the same simulation study according to the PAB-SPLC. In our future work, we plan to make a comparison of the SPLC and PAB-SPLC via this same simulation study, in order to demonstrate the importance of the contributions of the PAB-SPLC, in an applicative and experimental way.

Acknowledgment

Our sincere thanks go to Professor Saliha Assoul for her invaluable collaboration.

Funding Information

The authors have not received any financial support or funding to report.

Author's Contributions

Khadija Ouazzani-Touhami: Worked on the development and written of the entire paper**.**

Kawtar Tikito: Participated in the BPMN formalization of the life cycle developed in the paper and in the design of the diagrams that represent it.

Nissrine Souissi: Contributed to the supervision, revision, and validation of all the work carried out in the paper.

Ethics

This study is original and contains unpublished material. The authors have perused and endorsed the manuscript and no ethical issues involved or conflicts of interest to release.

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