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SLAs, KPIs and BPMN Standard for the Digital Transformation of the Enterprises' IT Business Processes – The SLO Cases of Service Desk Response Time and Fault Detection

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KEYWORDS

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Human Resource Management (HRM)

Business Analytics

ABSTRACT

In order to better define and regulate their business process operations and management, enterprises can apply Business Process Model and Notation (BPMN) standard and Service Level Agreements (SLAs). The BPMN standard is considered to be the state-of-the-art business process modeling standard in enterprises while SLAs with their Service Level Objectives (SLOs) and Key Performance Indicators (KPIs), guarantee the service level of the enterprises' operations. In this extension paper of [1], the evolution of today's enterprises' business processes to the next generation SLA – aware business processes that are based on the BPMN standard continues in the light of the digital transformation. With reference to [1], the following two contributions / extensions are proposed: (i) *two new SLOs for the initial SLA*: The SLO cases of service desk response time (SLO C) and fault detection (SLO D) with the corresponding KPIs are reported, programmatically analyzed, added in the initial SLA of two SLOs (SLO A and B) of [1] and applied to the real enterprise's BPMN IT business process of [1]; and (ii) t*he MATLAB / Octave simulation methodology*: This methodology consists of two steps of innovation. During the first step of the methodology, the extended BPMN basic elements of [1] are further enriched with SLO and KPI attributes that are suitable for coping with the two new SLOs. In addition, the BPMN simulation equivalence table of [1] is further expanded so that each extended BPMN basic element is corresponded with its MATLAB / Octave code fragment. During the second step of the methodology, the proposed simulation module handles with the applied SLOs / KPIs of the BPMN IT business process SLA and integrates the MATLAB / Octave code development with the interdepartmental SLA definition framework of [1]. Simulation results are provided so that: (a) the performance of the two new SLOs is assessed and discussed; and (b) the synergy of the MATLAB / Octave simulation methodology and the interdepartmental SLA definition framework of [1] is highlighted. The MATLAB / Octave simulation code is freely distributed with the Supplementary Material file of the paper. Finally, new insights into the Human Resource Management (HRM) of the enterprises' IT personnel and the IT service outsourcing based on SLAs, SLOs and KPIs are given.

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1.0 INTRODUCTION

Already been recognized in [1], business processes stand at the heart of the operations and management of today's enterprises during their digital transformation [2]-[4]. A successful business process management strategy may promise in-depth knowledge through modeling, continuous improvement, easier change adaptation, higher automation and "intuitive" benchmarking of enterprises' business processes. Towards that direction, the next-generation SLA-aware business processes that have been proposed in [1] and are further elaborated in this extension paper can significantly help towards the required wiser business process management of the today's enterprises.

According to [1], the next-generation SLA-aware business processes are defined on the basis of the Service Level Agreement (SLA) concept and the Business Process Model and Notation (BPMN) standard. As the SLAs are concerned in this extension paper, these are contracts that are applied by the enterprises so that their own operations among the external and internal customers can be guaranteed in a business perspective [2]. An SLA consists of Service Level Objectives (SLOs) and Key Performance Indicators (KPIs); say, SLOs act as the SLA quantitative means to assess and benchmark the service levels of business processes while KPIs provide various measurements, which are suitable for the SLOs, during the operation of business processes [1], [5]-[14]. As the BPMN standard is concerned in this extension paper, this is the state-of-the-art business process modeling standard applied in enterprises while its graphical notations and diagrams allow the understanding of enterprises' business processes in an expressive and formal language but in a less verbal way [15], [16]. Except for the standardized graphical notations and diagrams described by the Object Management Group (OMG) and the International Organization for Standardization (ISO) / International Electrotechnical Commission (IEC) 19510:2013 standard, business process designers can extend the existing BPMN standard by exploiting the simplicity and the semantic richness of its kernel design [17]-[24]. By following the previous BPMN standard extension concept, the BPMN basic elements have been modified in [1], [15] so that BPMN diagrams can be notationally aligned with other business process modeling standards and programmatically cope with SLAs. On the basis of the interdepartmental SLA definition framework, which has been proposed in [1], the simultaneous application of SLAs with the BPMN diagrams may allow the enterprises to simulate, predict and optimize the service levels of their business processes without the exhaustive real-life in-situ service measurement trials or sophisticated frameworks and software. Also, the simultaneous application of SLAs with the BPMN diagrams can further regulate the cooperation of the enterprises' department / subdepartments with the external partners on the basis of the new SLA – SLO – KPI procedures [25], [26]. The SLA-aware IT business processes that are based on the BPMN standard are further elaborated in this extension paper.

With reference to [1], the two contributions of this extension paper are the proposals of: (i) the two new SLOs for the initial SLA; and (ii) the MATLAB / Octave simulation methodology. As the first contribution of this extension paper is concerned, a real enterprise's BPMN IT business process, which was regulated by an initial SLA of two main SLOs (SLO A: Availability and SLO B: Response Time) with the corresponding KPIs, has been simulated in [1] in order to validate the interdepartmental SLA definition framework and to benchmark the SLA regulation of the enterprise's BPMN IT business process itself, the initial SLA is here enriched with two new SLOs; say, the SLO C and D that stand for the service desk response time and fault detection, respectively. In the same way with [1], SLOs C and D are going to help towards the further validation of the interdepartmental SLA definition framework and the assessment of the new SLA regulation of the enterprise's BPMN IT business process. As the second contribution of this extension paper is concerned, the MATLAB / Octave simulation methodology that can accelerate the testing and preparation of SLAs for the enterprises' BPMN IT services is here proposed. In fact, the MATLAB / Octave simulation methodology exploits: (a) the awareness of BPMN diagrams of the enterprise's BPMN IT business processes that are going to be SLA guaranteed; and (b) the awareness of the statistical behavior of the KPIs that measure the performance of the basic elements of the enterprise's BPMN IT business processes by exploiting the big data from their operations as provided by the interdepartmental SLA definition framework. The contribution of the MATLAB / Octave simulation methodology can be further divided into two steps of innovation, namely: (1) the extended BPMN basic elements of [1] are further enriched with SLO and KPI attributes that are suitable for deploying the two new SLOs while a correspondence between the aforementioned extended BPMN basic elements and MATLAB / Octave code fragments is established in order to allow the straightforward MATLAB / Octave simulation code development; and (2) the simulation module of [1] is detailed in order to cope with the applied SLOs / KPIs and integrate the MATLAB / Octave code development with the interdepartmental SLA definition framework of [1]. Both contributions are going to be examined during the simulation where the cooperation between the MATLAB / Octave simulation methodology and the interdepartmental SLA definition framework of [1] is going to be verified and the performance of the two new SLOs is going to be assessed. Finally, Human Resource Management (HRM) issues regarding the internal KPI evaluation system for the enterprises' personnel and the IT service outsourcing based on SLAs, SLOs and KPIs are discussed across this extension paper.

The rest of this paper is organized as follows: In Section 2, a brief synopsis of the interdepartmental SLA definition framework is first given. Then, the two new SLOs with their corresponding KPIs for the BPMN IT business processes are analyzed. Section 3 first mentions the modifications of the extended BPMN basic elements of [1]. Then, the two new SLOs can be assessed during the simulation process. Furthermore, the BPMN simulation equivalence table that allows the straightforward correspondence between the extended BPMN basic elements and the respective MATLAB / Octave simulation code fragments is reported. Also, the MATLAB / Octave simulation code fragments of the simulation module that allow the synergy between the interdepartmental SLA definition framework and the MATLAB / Octave simulation methodology are presented. In Section 4, simulation results and discussion of the real IT business process, which has been presented in [1], are given in terms of the two new SLOs with reference to the interdepartmental SLA definition framework and the MATLAB / Octave simulation methodology. Section 5 concludes this extension paper.

2.0 THE INTERDEPARTMENTAL SLA DEFINITION FRAMEWORK AND NEW SLOs FOR BPMN IT BUSINESS PROCESSES

In this Section, a brief synopsis of the interdepartmental SLA definition framework for BPMN IT business processes is first given. Then, the initial SLA of [1] with its SLOs A and B is enriched with the proposed SLOs C and D defined for the BPMN IT business processes. Apart from the definition of SLOs C and D, suitable KPIs are also reported.

2.1 A Brief Synopsis of the Interdepartmental SLA Definition Framework

The interdepartmental SLA definition framework has been proposed in [1] with its architecture being illustrated in Figure 1. With reference to Figure 1, the interdepartmental SLA definition framework describes the transformation of a general BPMN IT business process in which various departments and external partners of the enterprises cooperate from the management decision phase for defining or improving an SLA till the final preparation and delivery of the SLA among the stakeholders of the examined BPMN IT business process. By exploiting the big data from the operation of the examined BPMN IT business process and the business analytics: (i) the desired SLOs and KPIs; (ii) the current SLOs and KPIs; (iii) the SLOs and KPIs proposals from those involved in the process; and (iv) the BPMN diagram with the extended BPMN basic elements with SLO and KPI attributes that are illustrated in green color in Figure 1, may be retrieved. In fact, the simulation module, which is shown in yellow color in the Decision Group of Figure 1 and allows the synergy between the interdepartmental SLA definition framework and the proposed MATLAB / Octave simulation methodology, can benchmark and test all the desired scenarios while the continuous negotiations among the stakeholders help towards the best SLO and KPI compromise. Therefore, the new SLA, which is shown in red color in Figure 1 and consists of the optimized SLOs, the optimized KPIs and the optimized extended BPMN diagram with SLO and KPI attributes, is defined, agreed, signed and can guarantee the performance of the entire BPMN IT business and the cooperation of the other departments and the external partners among them. After the new SLA that is agreed by all the stakeholders, the new BPMN IT business process enters in the execution phase.

Observing the BPMN diagram of Figure 1, the simulation module stands as the heart of the interdepartmental SLA definition framework but it is also the cornerstone and the final step of the proposed MATLAB / Octave simulation methodology. The way that the MATLAB / Octave simulation methodology handles the extended BPMN diagrams of the BPMN IT business processes, the statistical properties of the basic elements of the BPMN diagrams and the simulation module is discussed in Section 3.

2.2 SLO C, SLO D and Corresponding KPIs for BPMN IT Business Processes

To ensure the success of executing the SLA-aware BPMN IT business process lifecycle, the proper definition of the SLOs and the KPIs should be considered for the examined BPMN IT business processes. Towards that direction, a detailed dictionary of SLOs and KPIs for IT business processes that has been adopted in [1] and is also applied for the BPMN IT business process of this paper is reported in [27]. More specifically, 93 IT business process QoS requirement subcategories have been proposed in [27] while 2 out of 93, say, the availability (11) and response time (69), have been transformed into the SLOs A and B, respectively, in [1]. In fact, the SLOs A and B have been reported in Table 1 of [1] as well as their corresponding KPIs. In this extension paper, other 2 IT business process QoS requirement subcategories, say, the service desk response time (69) and the fault detection (36), are defined as SLOs C and D, respectively, and are reported in Table 1. In Table 1, apart from the title and the definition of the applied IT business process QoS requirement subcategory, case studies of suitable and popular SLOs of the literature for the enterprises are added in each subcategory as well as the required measurement period. Similarly to Table 1 of [1], the title, operation and type of the applied KPIs are reported for the corresponding SLO case studies.

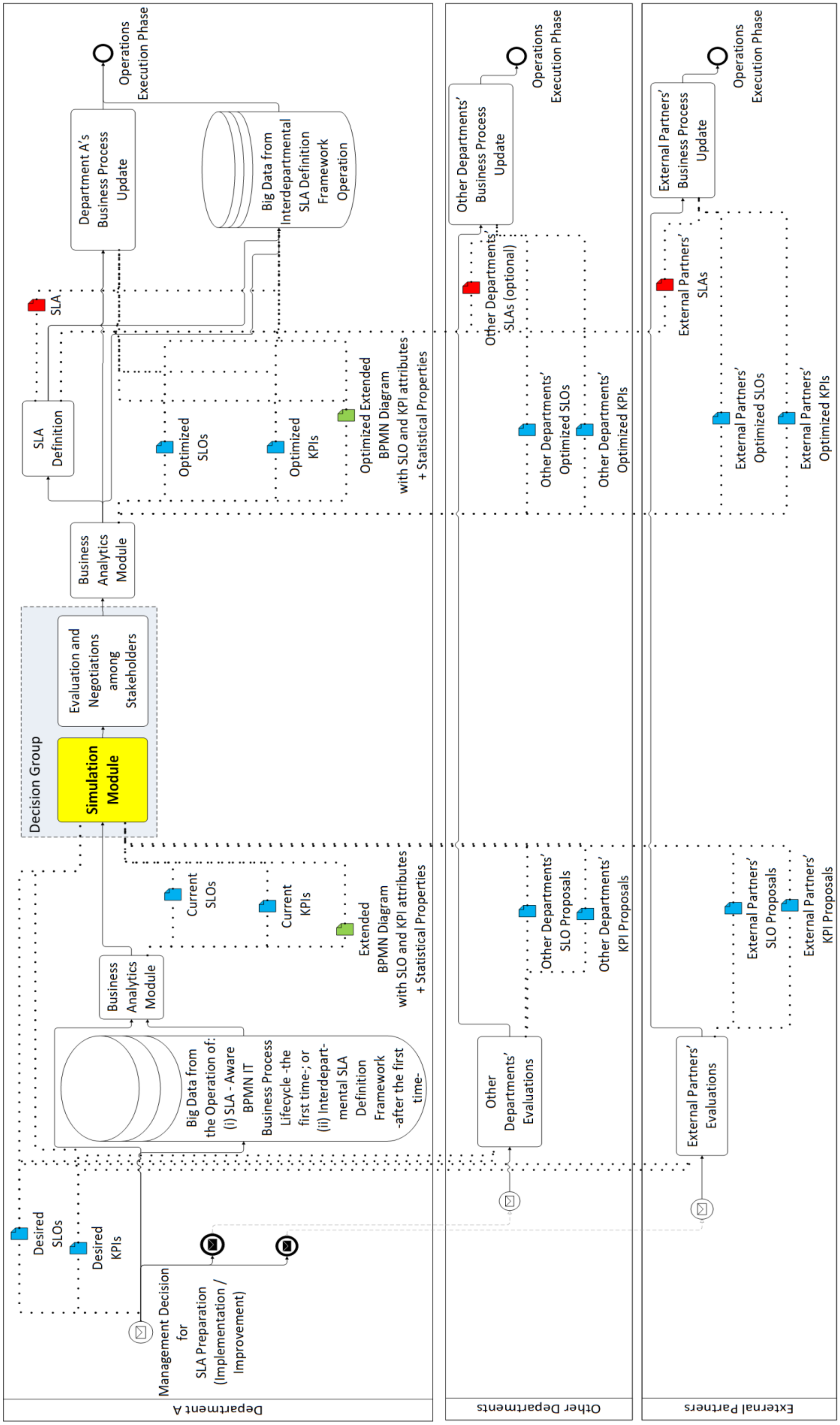


Figure 1. The interdepartmental SLA definition framework for a BPMN IT business process [1].

Table 1. SLO C, SLO D and KPIs for the preparation of BPMN IT business process SLAs

IT Business Process QoS Requirement Subcategory in SLA		**SLO**				**Applied KPIs**		
Title (ID in [27])	**Definition**	**Title**	**Measurement Period**	**Scenario**	**ID**	**Title**	**Operation**	**Type**
Service Desk Response Time (69)	Time necessary to answer a desk call, from the moment it is dispatched until a response is received (Service A)	Service Desk Response Time (Generic case - prerequisite)			C	Counter_C_1	Counter at the input of Service A (Activity01) of the BPMN IT business process	atomic | multiple business process instances
						Counter_C_2	Counter at the output of Service A (Activity01) of the BPMN IT business process	atomic | multiple business process instances
						Duration_C_1	Time duration of Service A (Activity01) of the BPMN IT business process	atomic | multiple business process instances
		Service Desk Response 1	Over two weeks	85% of service desk calls (Service A) will be answered within 3.5h	C1	Flag_C1_1	1 if Duration_C_1 is equal or lower than 3.5h	composite | multiple business process instances
						Counter_C1_1	Counter at the output of Service A (Activity01) of BPMN IT business process if Flag_C1_1 is equal to 1	composite | multiple business process instances
						Mathematical Operator_C1_1	(Counter_C1_1 divided by Counter_C_1) times 100%	composite | one business process instance (every two weeks)
						Flag_C1_2	1 if MathematicalOperator_C1_1 is equal or greater than 85%	composite | one business process instance (every two weeks)
		Service Desk Response 2	Over two weeks	99.95% of service desk calls (Service A) will be answered within 7h	C2	Flag_C2_1	1 if Duration_C_1 is equal or lower than 7h	composite | multiple business process instances
						Counter_C2_1	Counter at the output of Service A (Activity01) of BPMN IT business process if Flag_C2_1 is equal to 1	composite | multiple business process instances
						Mathematical Operator_C2_1	(Counter_C2_1 divided by Counter_C_1) times 100%	composite | one business process instance (every two weeks)
						Flag_C2_2	1 if MathematicalOperator_C2_1 is equal or greater than 99.95%	composite | one business process instance (every two weeks)
Fault Detection (36)	Measurement of failures detected by a service in a certain period of time [23], [27]	Fault Detection - for the external partners and / or internal (sub)departments-	Over a month	Service B and C will be out of service due to failure less than 0.5% of the measurement time (or of the number of executions)	D	Counter_D_1	Counter at the input of Service B (Activity05) of the BPMN IT business process	atomic | multiple business process instances
						Counter_D_2s	Counters at the fault sections of Service B, C (Database01) and related objects (DataObject04) of the BPMN IT business process	atomic | multiple business process instances
						Mathematical Operator_D_1	(Counter_D_2 divided by Counter_D_1) times 100%	composite | one business process instance (every month)
						Flag_D_1	1 if MathematicalOperator_D_1 is equal or lower than 0.5%	composite | one business process instance (every month)

From Table 1, the definition and the operation of the SLOs C and D with their corresponding KPIs follow the pattern of SLOs A and B of Table 1 of [1]. Indeed, the operation of the SLOs C and D provides additional big data concerning the behavior of the BPMN IT business processes while the interdepartmental SLA definition framework may allow the optimization of SLOs C and D for the SLA preparation in terms of the respective desired values. These next-generation SLA-aware business processes that are based on the BPMN standard and KPIs imply that the enterprises, enterprise's departments and the external partners may have continuously and over time available their performance records in all the BPMN IT business processes thus allowing a KPI appraisal system either for the HRM of the enterprise itself or for the enterprise's departments and the external partners [1].

Already been mentioned, the simulation module stands as the heart of both the interdepartmental SLA definition framework and the proposed MATLAB / Octave simulation methodology. How the MATLAB / Octave simulation methodology handles the extended BPMN diagrams of the BPMN IT business processes, the statistical properties of the basic elements of the BPMN diagrams and the simulation module are discussed in the next Section.

3.0 THE MATLAB / OCTAVE SIMULATION METHODOLOGY (EXTENDED BPMN DIAGRAMS, BPMN SIMULATION EQUIVALENCE TABLE AND SIMULATION MODULE)

In this Section, the two steps of innovation of the MATLAB / Octave simulation methodology are analyzed. First, the modified BPMN basic elements of [1], [15] are further extended with SLO and KPI attributes so that SLOs C and D can be operational during the simulations. The BPMN simulation equivalence table is further expanded so that each extended BPMN basic element can corresponded to its respective MATLAB / Octave code fragment. Second, this Section concludes with the examination of the simulation module where additional MATLAB / Octave code fragments are given for the applied SLOs / KPIs and the general simulation operation.

3.1 Extended BPMN Basic Elements and BPMN Simulation Equivalence Table

In accordance with [15], [16], [19], [28], [29], the BPMN standard aims at quickly describing complex business processes via appropriate diagrams that can be easily and intuitively understandable in a flowchart way. According to [15], [30], a BPMN diagram consists of four element categories; say, the flow objects, the connecting objects, the swimlanes and the artifacts. Each of the four categories consists of subcategories with the corresponding BPMN basic elements. The four categories with their subcategories and the corresponding most popular BPMN basic elements have been reported in Table 2 of [1].

The already rich portfolio of BPMN diagram basic elements may further be modified by business process designers with internal markers so as to better satisfy the needs of the enterprises' BPMN IT business process. In fact, the basic BPMN elements have been modified in [1], [15] so that the BPMN diagrams can either cooperate with classic flowcharts, Gantt charts and Petri nets in a notational alignment concept or become operational during the simulations when SLOs A and B are benchmarked. The definition of the enterprise's BPMN IT business processes with appropriate extended BPMN basic elements is fundamental prerequisite so that the interdepartmental SLA definition framework can operate through the deployment of the MATLAB / Octave Simulation Methodology. Indeed, software platforms, such as MATLAB / Octave and Simulink software, may provide comprehensive state-of-the-art coverage of modeling and simulating by appropriately exploiting code principles and techniques [1], [31]-[33].

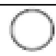
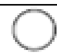
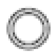
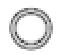
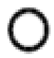
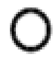
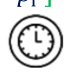
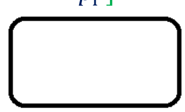
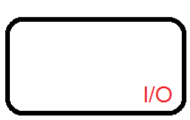
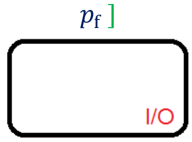
In this extension paper, the BPMN simulation equivalence table of [1] is further extended so that a straightforward and simplified process that corresponds each extended BPMN basic element with SLO and KPI attributes to respective MATLAB / Octave code fragment can occur. The MATLAB / Octave simulation code that runs in the simulation module of the interdepartmental SLA definition framework can be considered to be almost ready-to-take-off after the step of the BPMN simulation equivalence table (the final details are going to be added in the MATLAB / Octave simulation code in the following subsection of simulation module).

Prior to prepare the BPMN simulation equivalence table, the SLO and KPI attributes that are required for the extension of the BPMN basic elements so as to cope with SLOs C and D are going to be added to the already applied BPMN basic element modifications of [1], [15]. In accordance with [1], [15], the category, the name and the symbol of the modified BPMN basic elements are demonstrated in the first three columns of Table 2. The additions of the modified BPMN basic elements to the original ones are presented in red and green color for the modification made in [15] and [1], respectively. The following SLO and KPI attributes, which are suitable for SLOs C and D and are highlighted in dark blue color, should be taken into consideration during the preparation of the extended BPMN basic elements of this extension paper:

- *Service Desk Response Time (SLO C)*: By studying the service desk response time definition and the SLO C, C1 and C2 of Table 1, it is evident that this response time is required to be computed for a specific Service and for this reason the temporal characteristics of the extended BPMN basic elements that have to do with the Activity of Service Desk (let assume Activity01 in this paper) should be statistically computed and considered. Since the IT business process QoS requirement subcategory of Response Time preceded the one of Service Desk Response Time [1], the duration mean d_{μ} and the duration variance $d_{\sigma 2}$ for the Activity01 have already statistically been computed and are considered.
- *Fault Detection (SLO D)*: By studying the fault detection definition and the SLO D of Table 1, the availability and the fault detection subcategories have a general complementary relationship. But the term of reliability is the best complementary term for the fault detection since it refers to the probability of a service performing without failure under normal operating conditions over the examined measurement period. Hence, reliability may be treated as a subset of the availability. Similarly to the availability probability, the fault probability p_{f} expresses the possibility that the non-availability of a service is due to the service own fault and should be statistically computed and considered. The categories / subcategories of the extended BPMN basic elements that are affected by the extension of the fault probability are the same ones with the case of the availability of [1], say the Flow Objects, the Artifacts / Data Object and the Artifacts / Database. The fault probability can be ignored in all the remaining extended BPMN basic elements.

In accordance with [1], the SLO and KPI attributes that are taken into consideration during the preparation of the extended BPMN basic elements of the BPMN IT business processes depend on the big data and business analytics module of the interdepartmental SLA definition framework. Note that the SLO and KPI attributes for each of the extended BPMN basic element symbol follows the pattern of $[p_{\mathrm{av}} \quad d_{\mu} \quad d_{\sigma 2} \quad p_{\mathrm{f}}]$. In the sixth column, the IDentity (ID) of each of the extended BPMN basic element is given as in [1]. Note that the ID of the sixth column is going to be used for the correspondence of the extended BPMN basic elements to the respective MATLAB / Octave code fragments. The proposed

Table 2. The proposed BPMN simulation equivalence table

1st column **Category of Modified BPMN Basic Elements**	2nd column **Subcategory and Modified BPMN Basic Element Name**	3rd column **Modified BPMN Basic Element Symbol**	4th column **Extended BPMN Basic Element Symbol**	5th column **MATLAB / Octave Code Fragment**	6th column **Conversion Case ID**
Flow Objects	Event (Start)		 [p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]		ID01
	Event (Intermediate)		 [p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]		ID02
	Event (End)		 [p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]		ID03
	Event (Message Trigger)		 [p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]		ID04
	Event (Timer Trigger)		 [p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]		ID05
	Event (Business Rule)		 [p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]		ID06
	Activity (Generic Use)	 Activity start date/time, Activity duration and Activity end date/time inside the associated Activity	 Activity start date/time, Activity duration and Activity end date/time inside the associated Activity [p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]		ID07
	Activity (for Input / Output)	 Activity start date/time, Activity duration and Activity end date/time inside the associated Activity	 Activity start date/time, Activity duration and Activity end date/time inside the associated Activity		ID08

```
% Basic Object
% Basic Object MATLAB / Octave code fragment
    % Check if the simulation still runs
    % (SimulationIsActive==1)
    % and the basic element has permission
    % to run from the Basic Object 0 due
    % to the BPMN diagram flow
    % (Token_BasicObject0==1)
    if
    ((SimulationIsActive==1)&&(Token_BasicOb
    ject0==1))
        Token_BasicObject0=0;

        % SLO and KPI attributes of the
        % Basic Object
        p_av_BasicObject=■;
        d_mu_BasicObject=■;
        d_sigma2_BasicObject=■;
        p_f_BasicObject=■;

        % Check the availability through
        % random number generator with given
        % probability
        flag_operation_BasicObject(Simulation
        _Counter) = sum(rand >= cumsum([1-
        p_av_BasicObject,p_av_BasicObject]));
        SimulationIsActive =
        flag_operation_BasicObject(Simulation
        _Counter);

        if (SimulationIsActive==1)

            % Random Duration from normal
            % distribution with specific mean
            % and variance
            T_BasicObject(Simulation_Counter)=
            d_mu_BasicObject+(d_sigma2_BasicOb
            ject*randn);

            % Duration of the BPMN IT
            % business process until now.
            % If multiple flows come in
            % the Basic Object T is the
            % maximum
            % one (see also simulation module)
            T = T +
            T_BasicObject(Simulation_Counter);

            % The Token passes to the
            % next element; say, BasicObject2
            %Token_BasicObject2=1;


        % Since there is no availability,
        % the fault probability is checked
```

$[\, p_{av} \;\; d_{\mu} \;\; d_{\sigma 2} \;\; p_f \,]$

```
56          % via a random number generator
57          % with given probability
58          else
59
60             flag_fault_BasicObject(Simulation_
61             Counter) = sum(rand >= cumsum([1-
62             p_f_BasicObject,p_f_BasicObject]))
63             ;
64          end
65
66       % End of the Basic Object
67       end
```

Message Event (Send Message)

$[\, p_{av} \;\; d_{\mu} \;\; d_{\sigma 2} \;\; p_f \,]$

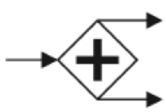
ID09

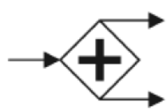
Message Event (Receive Message)

$[\, p_{av} \;\; d_{\mu} \;\; d_{\sigma 2} \;\; p_f \,]$

ID10

Gateway (Parallel Fork)



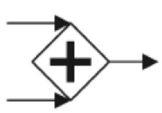


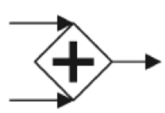
$[\, p_{av} \;\; d_{\mu} \;\; d_{\sigma 2} \;\; p_f \,]$

```
A01  % The Basic Object MATLAB / Octave
A02  % code fragment
A03  % is used as the basis
A04
A05  % The following changes are made in
A06  % the Basic Object MATLAB / Octave
A07  % code fragment:
A08
A09         % Line 51: Two Tokens pass to
A10         % the next elements
A11         %(BasicObject2 and BasicObject3)
A12         %Token_BasicObject2=1;
A13         %Token_BasicObject3=1;
```

ID11

Gateway (Parallel Join)





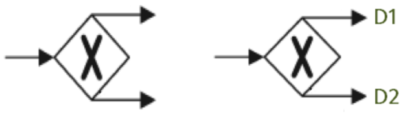
$[\, p_{av} \;\; d_{\mu} \;\; d_{\sigma 2} \;\; p_f \,]$

```
B01  % The Basic Object MATLAB / Octave
B02  % code fragment
B03  % is used as the basis
B04
B05  % The following changes are made in
B06  % the Basic Object MATLAB / Octave
B07  % code fragment:
B08
B09         % Lines 9-12: Two Tokens come
B10         % from Basic Object 0a and
B11         % Basic Object 0b that are
B12         % both checked and if valid
B13         % deactivated
B14         if
B15         ((SimulationIsActive==1)&&(Token_Ba
B16         sicObject0a==1)
B17         &&(Token_BasicObject0b==1))
B18            Token_BasicObject0a=0;
B19            Token_BasicObject0b=0;
B20
B21         % Lines 46-47: The duration of
B22         % the BPMN IT business process
B23         % comes from the maximum
B24         % duration among the incoming
B25         % flows
B26
```

ID12

```
T = max(T_0a,T_0b) + T_BasicObject(Simulation_Counter);
```

Gateway (Data-based XOR Decision)

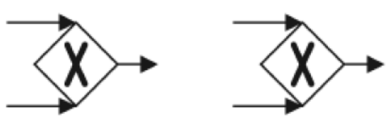


[p_{av} d_{μ} $d_{\sigma 2}$ p_f p_{D1} p_{D2}]

```
% The Basic Object MATLAB / Octave code fragment
% is used as the basis

% The following changes are made:

        % Line 20: The appearance
        % probabilities of decisions
        % D1 and D2 should be added
        p_D1_BasicObject=█;
        p_D2_BasicObject=█;
        %p_D3_BasicObject=█;    % D3

        % Line 50: Check the
        % decision
        % through
        % a random number generator
        % with the given appearance
        % probabilities
        decision_BasicObject(Simulation_Counter) = sum(rand >= cumsum([0,p_D1_BasicObject,p_D2_BasicObject]));
        %decision_BasicObject(Simulation_Counter) = sum(rand >= cumsum([0,p_D1_BasicObject,p_D2_BasicObject,p_D3_BasicObject]));   % D3


        % Line 51: The Token passes to the
        % next element depending on the
        % decision; say, D1 or D2
        if
        (decision_BasicObject(Simulation_Counter)==1)
           Token_BasicObjectD1=1;
           Token_BasicObjectD2=0;
           %Token_BasicObjectD3=0;    % D3
        elseif
        (decision_BasicObject(Simulation_Counter)==2)
           Token_BasicObjectD1=0;
           Token_BasicObjectD2=1;
           %Token_BasicObjectD3=0;    % D3
        %else    % D3
           %Token_BasicObjectD1=0;    % D3
           %Token_BasicObjectD2=0;    % D3
           %Token_BasicObjectD3=1;    % D3
        end
```

ID13

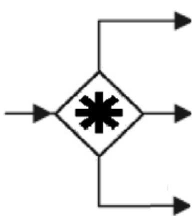
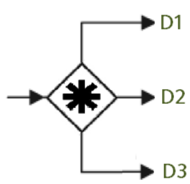
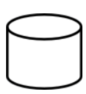
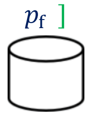
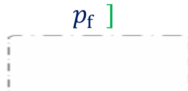
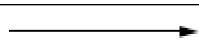
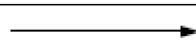
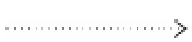
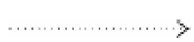
Gateway (XOR Merge)



[p_{av} d_{μ} $d_{\sigma 2}$ p_f]

```
% The Basic Object MATLAB / Octave
% code fragment
% is used as the basis

% The following changes are made in
% the Basic Object MATLAB / Octave
% code fragment:

        % Lines 9-12: Two Tokens come
        % from Basic Object 0a and
        % Basic Object 0b. Only one
```

ID14

<table>
<tr><td></td><td></td><td></td><td></td><td>D12 % Basic Object 0 each time
D13 % can activate the gateway
D14 % thus affecting the deactivation
D15 if
D16 ((SimulationIsActive==1)&&((Token_B
D17 asicObject0a==1)&&(Token_BasicObjec
D18 t0b==0))|
D19 ((Token_BasicObject0a==0)&&(Token_B
D20 asicObject0b==1)))
D21 if (Token_BasicObject0a==1)
D22 Token_BasicObject0a=0;
D23 else
D24 Token_BasicObject0b=0;
D25 end
D26
D27 % Lines 46-47: The duration of
D28 % the BPMN IT business process
D29 % comes from the incoming flow that
D30 % has the maxim duration
D31 T = max(T_BasicObject0a,
D32 T_BasicObject0b)+T_BasicObject(Simu
D33 lation_Counter);</td><td></td></tr>
<tr><td></td><td>Gateway (Event-based XOR Decision)</td><td></td><td>
[p_{av} d_{μ} $d_{\sigma 2}$ p_{f} p_{D1} p_{D2} p_{D3}]</td><td>% Similar to the MATLAB / Octave code fragment
% of the Gateway (Data-based XOR Decision).
% Uncheck the comments about D3 in ID 13</td><td>ID15</td></tr>
<tr><td>Swimlanes</td><td>Pool</td><td></td><td></td><td>-</td><td>ID16</td></tr>
<tr><td></td><td>Lane</td><td></td><td></td><td>% Department / Subdepartment</td><td>ID17</td></tr>
<tr><td>Artifacts</td><td>Data Object</td><td></td><td>
[p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]</td><td>% Same with the MATLAB / Octave code fragment
% of the Basic Object case</td><td>ID18</td></tr>
<tr><td></td><td>Database</td><td></td><td>
[p_{av} d_{μ} $d_{\sigma 2}$ p_{f}]</td><td></td><td>ID19</td></tr>
<tr><td></td><td>Group</td><td></td><td></td><td>-</td><td>ID20</td></tr>
<tr><td></td><td>Text Annotation</td><td></td><td></td><td>-</td><td>ID21</td></tr>
<tr><td>Connecting Objects</td><td>Sequence Flow Line</td><td></td><td></td><td>-</td><td>ID22</td></tr>
<tr><td></td><td>Message Flow Line</td><td></td><td></td><td>-</td><td>ID23</td></tr>
<tr><td></td><td>Associatio n Line</td><td></td><td></td><td>-</td><td>ID24</td></tr>
</table>

BPMN simulation equivalence table is completed with the fifth column of the MATLAB / Octave code fragments for each of the extended BPMN basic elements of the fourth column. To explain the fifth column of MATLAB / Octave code fragments, the following guidance is provided:

- With reference to the discussed SLO and KPI attributes, the proposed MATLAB / Octave code fragments act as the basis for each BPMN element of the BPMN diagram. Comments are added so that each area of the code fragment can become more easily comprehensible by the business process designers and developers. Small and targeted changes, which are further analyzed in the following subsection of the simulation module, are required so that the occurred MATLAB / Octave code fragments of the BPMN elements of the BPMN diagram can be integrated and: (i) describe the overall flow in the BPMN diagram during the simulations; and (ii) activate the measurements described in SLOs and KPIs of Table 1 during the simulations.
- Already been mentioned in [1], a common MATLAB / Octave code fragment can act as the MATLAB / Octave code fragment basis thus meaning that, the handling of the extended BPMN basic element symbols can remain the same to a certain extent. Actually, the basic object MATLAB / Octave code fragment is sufficient for the operation description of ID01-ID11 and ID18-ID19 extended BPMN basic element symbols. As the basic object MATLAB / Octave code fragment is concerned, the following remarks can be pointed out:
    - In the first line, a comment is added that refers to the name of the examined extended BPMN basic element. Since the basic object MATLAB / Octave code fragment deals with the generic case, the name of the Basic Object is given hereafter.
    - From the line 9 to the line 12, two checks that should be both satisfied (boolean AND) are done; first, the simulation is still running (i.e., the simulation has not been interrupted due to the unavailability of any previous basic element of the examined BPMN diagram) and, second, the token from the previous basic element across the flow of the examined BPMN diagram has successfully delivered to the basic object that is now ready to run. In the inverse procedure, the token from the basic object passes to the basic element that follows the flow of the examined BPMN diagram in the line 51.
    - From the line 16 to the line 19; the SLO and KPI attributes that have been added in the extended BPMN basic elements are initialized. More specifically, the corresponding values for the SLO and KPI attributes should be added in the orange boxes depending on the operations of the extended BPMN basic element.
    - From the line 24 to the line 29, a random number generator is applied so that the availability of the basic object can be simulated. By taking into consideration the availability probability of the basic object operation, 1 and 0 describe the availability and the unavailability of the basic object operation; respectively.
    - In the line 31, it is obvious that this availability operation check of the basic object may not only stop the further run of the basic object but of the entire simulation as well (see lines 9-12). From the line 32 to the line 51, the availability case of the basic object is examined whereas from the line 59 to the line 63, the required commands for the unavailability of the basic object are going to be reported below.
    - From the line 36 to the line 38, the duration of the basic object operation is simulated. Since the operation duration is assumed to follow the normal distribution with mean and variance already defined in the lines 16-19, a random number generator returns the duration of the basic object. From the line 46 to the line 47, the duration of the basic object is added to the total

duration of the simulation unless multiple flows occur where the total duration is determined by the flow of the examined BPMN diagram with the maximum duration among the separate flows to be selected.

- As already been mentioned, from the line 59 to the line 63, the unavailability case of the basic object is examined. The simulation stops being active in the line 59 while the probability of a fault is examined in the lines 60-63. Note that the fault probability of the basic object is calculated in this paper given its unavailability through a random number generator.
- To obtain a clear image of the multiple simulations that are required in order to have a high population of samples, all the variables that are used in the MATLAB / Octave code fragment and affect the operation of the entire simulation are in array format. The counter of the array that is used is the number of the simulation case that is performed thus allowing to have a clear monitoring of the simulation operation; similarly to a flight recorder ("black box").

- In accordance with [15] and Table 2, the Gateways define the decision points of the BPMN IT business processes thus controlling the Sequence Flow lines through forking, merging and joining in the BPMN diagram. In [1], details concerning the definition, internal markers and operation of the 5 specialized Gateways are given and are not mentioned here. In this extension paper, these 5 specialized Gateways are analysed in the context of their respective MATLAB / Octave code fragments. More specifically, since the extended BPMN basic element symbols of Gateways initially comprise same SLO and KPI attributes with the ID1-ID11 and ID18-ID19 ones, the basic object code fragment also remains valid. The additional special attributes concerning the respective MATLAB / Octave code fragments of the 5 specialized Gateways are given as follows:
  - *Gateway (Parallel Fork)*: By taking into account the definition of the Gateway (Parallel Fork) of [1], the following extensions are required: (i) No additional special attributes are required to be added in the extended BPMN basic element symbol; and (ii) Multiple Tokens are required for the outgoing sequence flows (e.g., two Tokens pass to the Basic Objects 2 and 3 as shown in the lines A12 and A13 that replace the line 51 of the basic object code fragment).
  - *Gateway (Parallel Join)*: By taking into account the definition of the Gateway (Parallel Join) of [1], the following extensions are required: (i) No additional special attributes are required to be added in the extended BPMN basic element symbol; (ii) Multiple Tokens come from the incoming sequence flows while the basic object starts to run when all the incoming Tokens are activated. For example, two Tokens come from the Basic Objects 0a and 0b. The check and the deactivation of the incoming Token of the lines 9-12 of the basic object code fragment is replaced by the lines B14-B19; and (iii) The duration of the BPMN IT business process comes from the maximum of the computed durations of the incoming sequence flows (e.g., for two incoming flows the lines 46-47 of the basic object code fragment are replaced by the lines B26 and B27).
  - *Gateway (Data-based XOR Decision) and Gateway (Event-based XOR Decision)*: Already been identified in [1], the operation of these two gateway types remains the same during the simulations. By taking into account the definition of the Gateway (Data-based XOR Decision) of [1], the following extensions are required: (i) For the sake of the simulation, each decision has its appearance probability (e.g., p_{D1} and p_{D2} for decisions D1 and D2, respectively). The aforementioned appearance probabilities follow the new pattern of $[p_{\mathrm{av}} \quad d_{\mu} \quad d_{\sigma 2} \quad p_{\mathrm{f}} \quad p_{\mathrm{D1}} \quad p_{\mathrm{D2}}]$ in this extension paper. Orange boxes are waiting for their values. In the line 20 of the basic object code fragment, the code fragment of lines C10-C12 should be added. Note that a

command that copes with a third decision is appearing as a comment; (ii) The random number generator, which is mentioned in [1] and concerns the simulated decision, takes into account the decision appearance probabilities p_{D1} and p_{D2}. As the basic object code fragment is regarded, its line 50 is replaced by the lines C20-C28. Again, a suitable extension of the random number generator concerning the decision is given as a comment in order to deal with a third decision; and (iii) As the output of the decision random number generator is concerned, the token may pass either to decision D1 or to decision D2. Again, an extension that is applied in the case of a third decision is given as a comment. Hence, line 51 of the basic object code fragment is replaced by the lines C35-C50. Already been discussed in [1], similar object code applies in the case of the Gateway (Event-based XOR Decision) that is the ID15 extended BPMN basic element of the Table 3; the previous described comments concerning the decision D3 should be uncommented to deal with the third decision of the Gateway (Event-based XOR Decision). In a similar way, more than three decisions can be programmatically considered.

- *Gateway (XOR Merge)*: Already been identified in [1], the following extensions are required for the operation of the Gateway (XOR Merge): (i) Multiple Tokens come from the incoming sequence flows. When only one (boolean XOR) of the incoming Tokens is activated the basic object starts to run. For example, two Tokens come from the Basic Objects 0a and 0b. The check and the deactivation of the incoming Token of the lines 9-12 of the basic object code fragment is replaced by the lines D15-D25; and (ii) Depending on the incoming sequence flow, the duration of the BPMN IT business process comes from the maximum duration of the incoming sequence flow in a similar way to the duration computation of the Gateway (Parallel Join) (e.g., for two incoming flows the lines 46-47 of the basic object code fragment are replaced by the lines D31-D33).

The operation of the remaining extended BPMN basic elements, say, ID16-17 and ID20-24 ones, does not directly affect the simulation operation and results. Therefore, there are no code fragments for these elements in the fifth column of Table 3 except for the ID17 BPMN basic element where a comment refers to the departments and / or subdepartments presented in the Lane basic element.

The proposed BPMN simulation equivalence table of Table 2, which is the extended version of Table 3 of [1], corresponds the extended BPMN basic elements with the respective MATLAB / Octave code fragments. In the following Section, the MATLAB / Octave code fragments of the simulation module are going to be presented so that the integrator role of the simulation module is revealed.

3.2 Simulation Module

In this subsection, the simulation module, which is the third step of the proposed MATLAB / Octave simulation methodology and the connecting link with the interdepartmental SLA definition framework, is here analyzed, namely: (i) additional MATLAB / Octave code fragments are given for the applied SLOs and KPIs of the Table 1; (ii) additional MATLAB / Octave code fragments of general purpose are presented so that the simulation is able to run; and (iii) certain aspects are touched upon that have to do with the simulation module role as the integrator and the simulation module interaction with the enterprise's business analytics and the interdepartmental SLA definition framework.

With reference to the SLO and KPI case study of Table 1 of [1], the SLO and KPI case study of Table 1 and the semiotics of Table 2, the SLO title, SLO ID and the applied KPIs are reported in Table 3 with the respective MATLAB / Octave code fragments. In the interests of the integrity of the SLO and KPI case study presentation, the SLO title, SLO ID and the applied KPIs are reported in Table 3 with the respective MATLAB / Octave code fragments for all the SLOs (say, SLOs A-D) of the examined SLA. For each applied KPI, the exact location where the respective MATLAB / Octave code fragment should be added with respect to the Basic Object MATLAB / Octave code fragment of Table 2 is mentioned as well as explanatory comments about the KPI operation and cooperation with the other MATLAB / Octave code fragments.

According to [1], the simulation module acts as the integrator of the MATLAB / Octave simulation methodology for the connection of the aforementioned code fragments into the complete MATLAB / Octave code of the simulation. Towards that direction, the simulation module is responsible for regulating the following MATLAB / Octave code issues [1]: (i) Counter declaration and initialization; (ii) Start of the simulation process; (iii) Token management; (iv) Duration timer management; and (v) Gateway counter deployment and initialization. As an application example of the token management and the duration timer management is concerned, their handling by the simulation module is reported in Table 4 of [1] for the real BPMN IT business process that is also of interest in this extension paper. Anyway, the simulation module that is the cornerstone of the MATLAB / Octave simulation methodology and the interdepartmental SLA definition framework cannot operate without the operation of a robust and efficient business analytics module that provides the input data for the simulation module but also the output results of the decision group through procedures that involve statistics, domain expertise and result visualization [34]-[37].

In the following Section where the simulation results are given, the operation and the simulation results of the real BPMN IT business process of [1], [15] are further assessed in the context of the two proposed SLOs, the MATLAB / Octave simulation methodology and the interdepartmental SLA definition framework. It should be reminded that the real enterprise's BPMN IT business process of interest in this extension paper is a daily IT business process where two Departments of the same enterprise cooperate while two Subdepartments of the same Department complete the daily process.

Table 3. SLOs A-D and KPIs with the corresponding MATLAB / Octave code fragments

SLO Title	ID	Applied KPIs Title	Applied KPIs Operation	MATLAB / Octave Code Fragment Line	MATLAB / Octave Code Fragment Code
Availability	A	Counter_A_1	Counter at the Start Event (Timer Trigger) of the BPMN IT business process	E01	% The Basic Object MATLAB / Octave
				E02	% code fragment
				E03	% is used as the basis for the Start Event
				E04	% (Timer Trigger) -ID05 of Table 3-
				E05	
				E06	% Prior to the start of
				E07	% the Basic Object MATLAB / Octave
				E08	% code fragment of
				E09	% the Start Event
				E10	% (Timer Trigger), the following code
				E11	% insertion
				E12	% is made:
				E13	Counter_A_1= Counter_A_1 + 1;
				E14	T_Counter_A_1(Simulation_Counter)=Counter_A_1;
		Counter_A_2	Counter at the End Event of the BPMN IT business process	F01	% The Basic Object MATLAB / Octave
				F02	% code fragment
				F03	% is used as the basis for the Event (End)
				F04	% -ID03 of Table 3-
				F05	%
				F06	
				F07	% In line 52 of
				F08	% the Basic Object MATLAB / Octave
				F09	% code fragment of
				F10	% the Event
				F11	% (End), the following code
				F12	% insertion
				F13	% is made:
				F14	Counter_A_2 = Counter_A_2+1;
				F15	T_Counter_A_2(Counter_A_1)=Counter_A_2;
		MathematicalOperator_A_1	(Counter_A_2 divided by Counter_A_1) times 100%	G01	% After the end of
				G02	% the Basic Object MATLAB / Octave
				G03	% code fragment of
		Flag_A_1	1 if MathematicalOperator_A_1 is equal or greater than 95%	G04	% the Event
				G05	% (End), the following code insertion
				G06	% is made:
				G07	
				G08	% MathematicalOperator_A_1
				G09	MathematicalOperator_A_1=100*Counter_A_2/Count
				G10	er_A_1;
				G11	T_MathematicalOperator_A_1(Counter_A_2)=Mathem
				G12	aticalOperator_A_1;
				G13	
				G14	% Flag_A_1 comes right after the
				G15	% MathematicalOperator_A_1
				G16	if (MathematicalOperator_A_1>=95)
				G17	Flag_A_1=1;
				G18	else
				G19	Flag_A_1=0;
				G20	end
				G21	T_Flag_A_1(Counter_A_2)=Flag_A_1;
Response Time (Generic case - prerequisite)	B	Counter_B_1	Counter at the Start Event (Timer Trigger) of the BPMN IT business process		% The same Basic Object MATLAB / Octave
					% code fragments
					% with the ones of Counter_A_1 and Counter_A_2,
		Counter_B_2	Counter at the End Event of the BPMN IT business process		% respectively
		Duration_B_1	Time duration from the Start Event to the End Event of the BPMN IT business process	H01	% The Basic Object MATLAB / Octave
				H02	% code fragment
				H03	% is used as the basis for the Event (End)
				H04	% -ID03 of Table 3-

				H05 % H06 % In line 53 of H07 % the Basic Object MATLAB / Octave H08 % code fragment of H09 % the Event H10 % (End), after the insertion of Counter_B_2, H11 % the following code H12 % insertion H13 % is made: H14 Duration_B_1 = T; H15 T_Duration_B_1(Counter_B_2) = Duration_B_1;
Response Time 1	B1	Flag_B1_1 Counter_B1_1 MathematicalOperator_B1_1 Flag_B1_2	1 if Duration_B_1 is equal or lower than 11h Counter at the End Event of the BPMN IT business process if Flag_B1_1 is equal to 1 (Counter_B1_1 divided by Counter_B_1) times 100% 1 if MathematicalOperator_B1_1 is equal or greater than 85%	I01 % After the end of I02 % the Basic Object MATLAB / Octave I03 % code fragment of I04 % the Event I05 % (End), the following code insertion I06 % is made: I07 I08 % Flag_B1_1 I09 if (Duration_B_1<=11) I10 Flag_B1_1=1; I11 else I12 Flag_B1_1=0; I13 end I14 T_Flag_B1_1(Counter_B_2)= Flag_B1_1; I15 I16 % Counter_B1_1 I17 if (Flag_B1_1==1) I18 Counter_B1_1= Counter_B1_1+1; I19 end I20 T_Counter_B1_1(Counter_B_2)= Counter_B1_1; I21 I22 % MathematicalOperator_B1_1 I23 MathematicalOperator_B1_1=100* I24 Counter_B1_1/Counter_B_2; I25 T_MathematicalOperator_B1_1(Counter_B_2)=Mathe I26 maticalOperator_B1_1; I27 I28 % Flag_B1_2 comes right after the I29 % MathematicalOperator_B1_1 I30 if (MathematicalOperator_B1_1>=85) I31 Flag_B1_2=1; I32 else I33 Flag_B1_2=0; I34 end I35 T_Flag_B1_2(Counter_B_2)=Flag_B1_2;
Response Time 2	B2	Flag_B2_1 Counter_B2_1 MathematicalOperator_B2_1 Flag_B2_2	1 if Duration_B_1 is equal or lower than 23h Counter at the end Event of the BPMN IT business process if Flag_B2_1 is equal to 1 (Counter_B2_1 divided by Counter_B_1) times 100% 1 if MathematicalOperator_B2_1 is equal or greater than 99.5%	% The same Basic Object MATLAB / Octave % code fragment % with the one of Response Time 1 SLO but for 23h (instead of 11h) and 99.5% (instead of 85%)
Service Desk Response Time (Generic case -	C	Counter_C_1	Counter at the input of Service A (Activity01) of the BPMN IT business process	J01 % The Basic Object MATLAB / Octave J02 % code fragment J03 % is used as the basis for the Activity01 J04 % -ID07 of Table 3- J05 J06 % After the SLO and KPI attributes of J07 % the Basic Object MATLAB / Octave

prerequisite)				J08 % code fragment of J09 % the Activity01, J11 % the following code J12 % insertion J13 % is made: J14 Counter_C_1= Counter_C_1 + 1; J15 T_Counter_C_1(Simulation_Counter)=Counter_C_1;
		Counter_C_2	Counter at the output of Service A (Activity01) of the BPMN IT business process	K01 % The Basic Object MATLAB / Octave K02 % code fragment K03 % is used as the basis for the Activity01 K04 % -ID07 of Table 3- K05 K06 % In line 52 of K07 % the Basic Object MATLAB / Octave K08 % code fragment of K09 % the Activity01, K11 % the following code K12 % insertion K13 % is made: K14 Counter_C_2 = Counter_C_2+1; K15 T_Counter_C_2(Counter_C_1)=Counter_C_2;
		Duration_C_1	Time duration of Service A (Activity01) of the BPMN IT business process	L01 % After the precious code fragment of L02 % Counter_C_2, the following code fragment L03 % is added: L04 Duration_C_1 = L05 T_Activity01(Simulation_Counter); L06 T_Duration_C_1(Counter_C_2) = Duration_C_1;
Service Desk Response 1	C1	Flag_C1_1	1 if Duration_C_1 is equal or lower than 3.5h	M01 % After the end of M02 % the code fragment of M03 % the Duration_C_1 KPI, the following M04 % code insertion M05 % is made: M06 M07 % Flag_C1_1 M08 if (Duration_C_1<=3.5) M09 Flag_C1_1=1; M11 else M12 Flag_C1_1=0; M13 end M14 T_Flag_C1_1(Counter_C_2)= Flag_C1_1; M15 M16 % Counter_C1_1 M17 if (Flag_C1_1==1) M18 Counter_C1_1= Counter_C1_1+1; M19 end M20 T_Counter_C1_1(Counter_C_2)= Counter_C1_1; M21 M22 % MathematicalOperator_C1_1 M23 MathematicalOperator_C1_1=100* M24 Counter_C1_1/Counter_C_2; M25 T_MathematicalOperator_C1_1(Counter_C_2)=Mathe M26 maticalOperator_C1_1; M27 M28 % Flag_C1_2 comes right after the M29 % MathematicalOperator_C1_1 M30 if (MathematicalOperator_C1_1>=85) M31 Flag_C1_2=1; M32 else M33 Flag_C1_2=0; M34 end M35 T_Flag_C1_2(Counter_C_2)=Flag_C1_2;
		Counter_C1_1	Counter at the output of Service A (Activity01) of BPMN IT business process if Flag_C1_1 is equal to 1	
		MathematicalOperator_C1_1	(Counter_C1_1 divided by Counter_C_1) times 100%	
		Flag_C1_2	1 if MathematicalOperator_C1_1 is equal or greater than 85%	
	C2	Flag_C2_1	1 if Duration_C_1 is equal or lower than 7h	% The same Basic Object MATLAB / Octave % code fragment

Service Desk Response 2		Counter_C2_1	Counter at the output of Service A (Activity01) of BPMN IT business process if Flag_C2_1 is equal to 1	% with the one of Service Desk Response 1 SLO but for % 7h (instead of 3.5h) and 99.95% (instead % of 85%)
		MathematicalOperator_C2_1	(Counter_C2_1 divided by Counter_C_1) times 100%	
		Flag_C2_2	1 if MathematicalOperator_C2_1 is equal or greater than 99.95%	
Fault Detection - for the external partners and / or internal (sub)departments-	D	Counter_D_1	Counter at the input of Service B (Activity05) of the BPMN IT business process	% The Basic Object MATLAB / Octave % code fragment % is used as the basis for the Activity05 % -ID07 of Table 3- % After the SLO and KPI attributes of % the Basic Object MATLAB / Octave % code fragment of % the Activity05, % the following code % insertion % is made: Counter_D_1= Counter_D_1 + 1; T_Counter_D_1(Simulation_Counter)=Counter_D_1;

		Counter_D_2s	Counters at the fault sections of Service B, C (Database01) and related objects (DataObject04) of the BPMN IT business process	% The Basic Object MATLAB / Octave
				% code fragment
				% is used as the basis for the Activity05,
				% Database01 and DataObject04
				% -ID07 of Table 3-
				
				% In line 63 of
				% the Basic Object MATLAB / Octave
				% code fragments of
				% the Activity01, Database01 and DataObject04
				% the following code
				% insertion
				% is made:
				if flag_fault_BasicObject(Simulation_Counter)
				== 1
				Counter_D_2 = Counter_D_2+1;
				T_Counter_D_2(Counter_D_1)=Counter_D_2;
				
				% Note that the same Counter_D_2 name is
				% used in all the involved Services
				
				% MathematicalOperator_D_1
				MathematicalOperator_D_1=100*
				Counter_D_2/Counter_D_1;
				T_MathematicalOperator_D_1(Counter_D_2)=Mat
				hematicalOperator_D_1;
				
				% Flag_D_1 comes right after the
				% MathematicalOperator_D_1
				if (MathematicalOperator_D_1<=0.005)
				Flag_D_1=1;
				else
				Flag_D_1=0;
				end
				T_Flag_D_1(Counter_D_2)=Flag_D_1;
				end

		MathematicalOperator_D_1	(Counter_D_2 divided by Counter_D_1) times 100%	
		Flag_D_1	1 if MathematicalOperator_D_2 is equal or lower than 0.5%	

4.0 SLA – AWARE BUSINESS PROCESS BASED ON BPMN STANDARD AND KPIs – SIMULATION RESULTS FOR THE SLOs C AND D

In this Section, the simulation results of the combined operation of the interdepartmental SLA definition framework and the MATLAB / Octave simulation methodology are demonstrated with reference to the representative real BPMN IT business process of [1]. First, the BPMN diagram of the IT business process is going to be further upgraded with the extended BPMN basic elements of SLO and KPI attributes that are suitable for coping with SLOs C and D. Since the default operation settings of the simulation process and the role of the simulation module remain the same with [1], a brief synopsis is given. Second, the progress of the examined SLA is evaluated in relation with SLOs C and D; under the aegis of the simulation module and business analytic modules, the values of the applied SLOs C and D with their corresponding KPIs are assessed after the simulation of the representative real BPMN IT business process. Similarly to [1]. SLO / KPI improvement actions that may be implemented towards the mitigation of the problematic SLO and KPI values are proposed while issues such as the internal KPI evaluation system for the enterprises' personnel, the IT service outsourcing based on SLAs, SLOs and KPIs and the dynamics of the digital transformation are discussed in a practical basis.

4.1 The Real BPMN IT Business Process (Case Study) – Extended BPMN Diagram, Default Operation Settings of the Simulation Process and Simulation Module

In Figure 2, the extended BPMN diagram of the real enterprise's IT business process, which acts as the case study of the original paper and this extension paper, is shown. As the history of the real BPMN IT business process is regarded, the initial BPMN IT business process has been presented and modified in [15] with the modifications shown in red color. Then, the extended BPMN basic elements of [1] have been added in green color as well as the values of the SLO and KPI attributes per BPMN basic element based on the big data processing by the interdepartmental SLA definition framework. In this extension paper, the SLO and KPI attributes, which are suitable for SLOs C and D, are highlighted in dark blue color as well as their values derived from the interdepartmental SLA definition framework processing of big data.

With reference to Figure 2, the real BPMN IT business process consists of the following modified BPMN basic elements: 1 Start Event (Timer Trigger), 5 Activities (Activity01-05), 4 Data Objects (DataObject01-04), 6 Messages (Message01-06), 1 Database (Database01), 1 Gateway XOR Merge (Gateway01), 1 Gateway Event-based XOR Decision (Gateway02) and

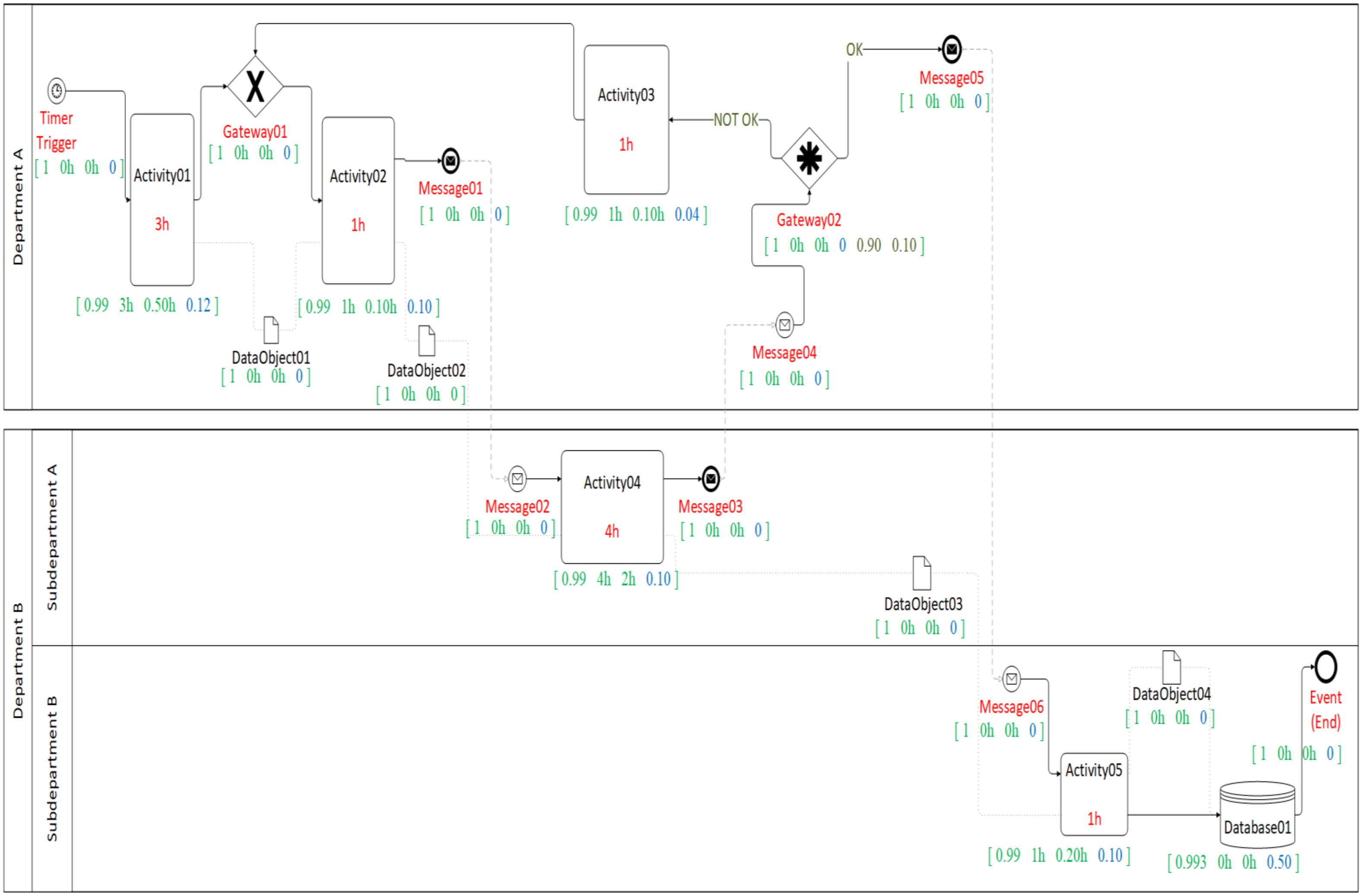


Figure 2. The extended BPMN diagram of the real enterprise's IT business process with the SLO and KPI attributes appropriate for SLOs A-D.

1 End Event (Event End); say, 20 BPMN basic elements of interest. More details concerning the inner and Quality of Service (QoS) operation of this the real BPMN IT business process among the Departments and the Subdepartments are given in [1]. It should be reminded that the today's average duration of the BPMN IT business process is approximately 9.5h and the business process must be completed within the working day (say, daily IT business process). Note that the SQL database (Database01) is on-premises and is characterized by a high fault probability (p_f=0.50).

As the operation settings for the simulations of this extension paper are assumed, details are given in [1] concerning: (i) The number of simulations (say, 100,000 simulations); (ii) The assumption of zero duration mean and zero duration variance for the start event, end event, gateways, message exchange and data object exchange of Figure 2; (iii) The assumption of normal distributed durations for all the extended BPMN basic elements of Figure 2 except for the aforementioned ones in (ii); (iv) the behavior of Gateway02 NOT OK flow; and (v) the token management and the duration management by the simulation module -see also Table 4 of [1]-. In addition to the previous operation settings that are assumed for both the original paper and this extension one, the following operation settings are only assumed for this extension paper since they have to do with the assessment of SLOs C and D, namely:

1. For the sake of simplicity, the start event, end event, gateways, message exchange and data object exchange are assumed to be always available without failures or faults.
2. As the value range of the operation settings of Figure 2 is concerned, the duration mean, the duration variance, the availability probability and the fault probability of the extended BPMN basic elements are calculated by exploiting the big data pool of Figure 1 from the operation of the interdepartmental SLA definition framework.
3. As the value range of the SLOs C and D is discussed, their target values are reported in Table 1 and come from the corresponding literature in each SLO case.

Similarly to the MATLAB / Octave simulation code of the original paper of [1], the entire MATLAB / Octave simulation code of this extension paper is provided in the Supplementary Material. The researcher and the potential reader can freely experiment with the code in [38].

In the following subsections, the progress of achieving the SLA that contains the SLOs C and D with their corresponding KPIs, which have been reported in Table 1, is analytically examined by exploiting the simulation code of the Supplementary Material of this paper.

4.2 Simulation Results Concerning the Progress of the Paper SLA

With reference to Table 1, the initial SLA of two IT business process QoS requirement subcategories (say, availability and response time) is here enriched with two main SLOs with their three SLO variances (i.e., SLO C1, C2 and D). SLOs C and D (say, service desk response time and fault detection, respectively) are going to be monitored and benchmarked. For each SLO, corresponding KPIs have already been deployed across the simulation code. For assessing the progress of this paper SLA, two sub-subsections that separately treat the two SLOs are demonstrated.

4.2.1 Service Desk Response Time – SLO C

With reference to Table 1, the service desk response time is the duration time that is necessary for answering a desk call, from the moment that it is dispatched until a response is received. In this paper, let assume that Activity01 of Figure 2 may act as the service desk where the first daily call is made by the Timer Trigger and one of the token of the received response is the DataObject01 of Figure 2. Judging by the time duration of Activity01 (i.e., the duration mean of Activity01 is equal to 3h), the decisive answer of the Activity01 remains a complex multi-hour activity that involves processing and sending of a deliverable (DataOject01). SLO C that deals with the service desk response time of the Activity01 examines two objectives: SLO C1 and SLO C2. Quantitatively and in accordance with SLO C1, the Activity01 of Figure 2 is expected to finish within 3.5h in the 85% of the successful answers. Similarly to SLO C1, SLO C2 demands that the Activity01 finishes within 7h in the 99.95% of the successful answers. Actually, SLO C2 ensures that the Activity01 will last at most 8h so that no new employee shift is needed. By reviewing the available applied KPIs of SLOs C and C1, Duration_C_1 KPI, which is a general purpose KPI for the SLO C, can count the time duration of the Activity01, MathematicalOperator_C1_1 computes the percentage of the successful Activity01 executions whose time duration is equal or lower than 3.5h and Flag_C1_2 KPI examines whether the average time duration is equal or lower than 3.5h in equal or greater than 85% of the successful Activity01 executions. In a similar way to the KPIs of SLO C1, Duration_C_1 KPI, MathematicalOperator_C2_1 KPI and Flag_C2_2 KPI are deployed by the SLO C2; MathematicalOperator_C2_1 KPI computes the percentage of the successful Activity01 executions whose time duration is equal or lower than 7h while Flag_C2_2 KPI examines whether the average time duration is equal or lower than 7h in equal or greater than 99.95% of the successful Activity01 executions. Similarly to the response time, the business analytics module may further provide statistical properties of the service desk response time, such as histograms.

In Figure 3, the percentage of the successful Activity01 executions whose time duration is equal or lower than 3.5h, which is computed by the MathematicalOperator_C1_1 KPI of SLO C1, is plotted with respect to the number of the successful Activity01 executions when the default operation settings are assumed. In the same Figure, the accomplishment progress of the SLO C1, which is computed by the Flag_C1_2 KPI of SLO C1, is also shown when the target value is equal to 85%. Figure 4 is the same with Figure 3, but for time duration threshold and target value that are equal to 7h and 99.95%, respectively.

From Figures 3 and 4, it is shown that the Activity01 of Figure 2 marginally fails to satisfy the SLO C1, which aims at keeping the Activity in strict time schedule while the performance of Activity01 satisfies the SLO C2 with flying colors, which aims at securing the 8h employee shift (one hour safety margin is given in SLO C2). Indeed, the percentages of the successful Activity01 executions whose time duration is equal or lower than 3.5h (SLO C1) and 7h (SLO C2) are equal to 84.27% and 100%, respectively, after the completion of the simulation process. Anyway, the result of the failure of SLO C1 for a while was expected since the theoretical 84.1% of the executions of the Activity01 could not last more than 3h + 0.5h = 3.5h in accordance with the normal distribution theory. Since SLO C1 is not satisfied, suitable SLO / KPI improvement actions are required for the improvement of the statistical properties of the Activity01 (e.g., SLO / KPI scenarios for Activity01). Anyway, the SLO / KPI improvement actions that are required for achieving SLO C1 can also beneficially act for SLO C2.

Similarly to [1], the SLO / KPI improvement actions may be applied for reducing the duration mean (SLO / KPI scenario C.A) and duration variance (SLO / KPI scenario C.B) of the Activity01. In order to assess the previous two SLO / KPI scenarios, the cumulative density functions (cdfs) and the histograms that are the output metrics of the business analytics module of Figure 1 are going to be exploited in this sub-subsection. More specifically, in Figure 5(a), the desk response time cdf is plotted when the duration mean of Activity01 is equal to 2h, 2.5h, 3h (default), 4h and 7h. In Figure 6(a), same plots with Figure 5(a) are demonstrated but for different values of the duration variance -i.e., 0h, 0.25h, 0.5h (default), 1h and 2h–. In Figures 5(b) and 6(b), same plots with the respective Figures 5(a) and 6(a) are given as histograms cdfs with the following classes-bins: (0h 1h], (1h 2h], (2h 2.5h], (2.5h 3h], (3h -3.5h], (3.5h 4h], (4h 5h], (5h 6h], (6h 7h] and (7h 8h]. Labels that indicate the percentages of the successful Activity01 executions whose time duration is equal or lower than 3.5h (SLO C1) and 7h (SLO C2) in each of the examined cases in Figures 5(a) and 6(a) are added on the plots.

From Figures 5 and 6, the impact of the duration mean and the duration variance of Activity01 on its service desk response time has been assessed. As the SLO / KPI scenario C.A is concerned, when the default operation setting of the Activity01 duration mean (i.e., 3h) is applied in Figures 5(a) and 5(b), SLO C1 fails whereas SLO C2 succeeds, being already known from Figures 3 and 4. Let assume that the duration mean of the Activity01 is reduced by 1h by adopting SLO / KPI improvement actions (i.e., 2h instead of 3h). In the case of the 2h duration mean of Activity01, SLO C1 and SLO C2 succeed with 99.87% (with target value 85%) and 100% (with target value 99.95%), respectively. In contrast, when the duration mean of the Activity01 increases by 1h to 4h, SLO C1 still fails with 15.89% (with target value 99.95%) while SLO C2 succeeds. Therefore, the decrease of the duration mean of the Activity01 by at least 1h is crucial for the achievement of SLO C1 and SLO C2. As the SLO / KPI scenario C.B is concerned, in Figures 6(a) and 6(b), when the default operation setting of the duration variance is applied (i.e., 0.5h), SLO C1 fails whereas SLO C2 succeeds, that is already known from Figures 3 and 4. Let assume that the duration variance of the Activity01

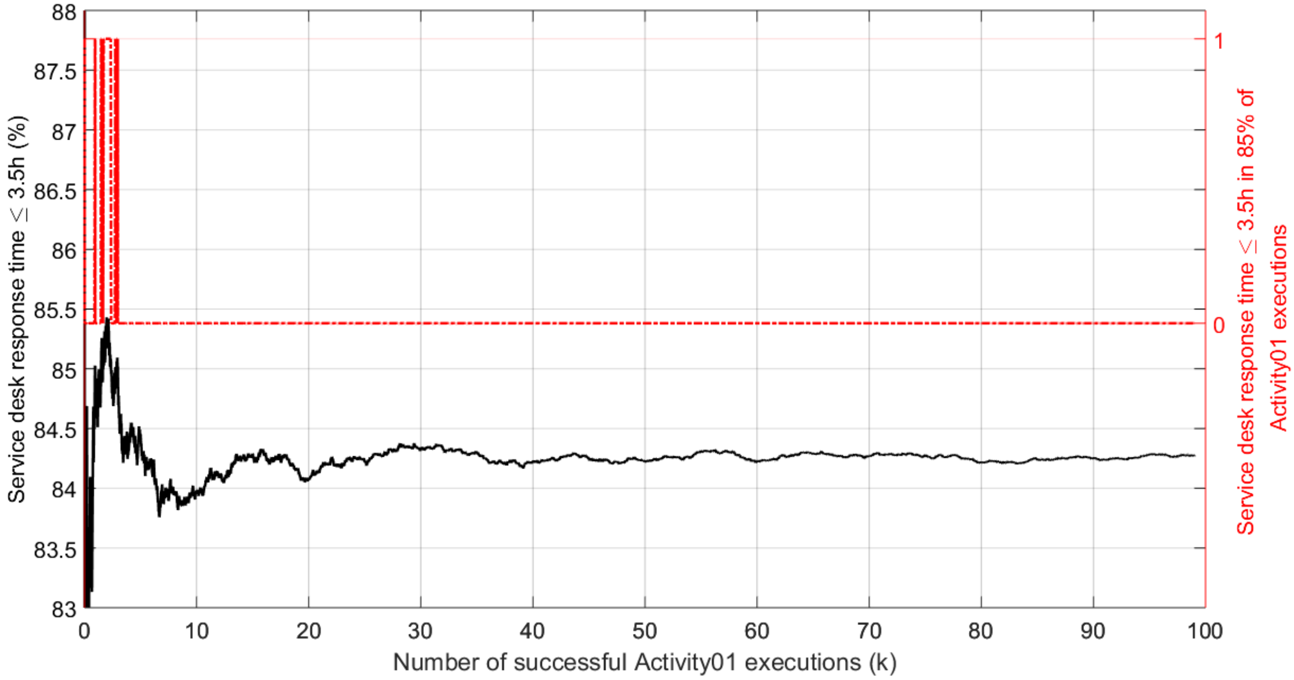


Figure 3. The percentage of the successful Activity01 executions whose time duration is equal or lower than 3.5h (▬) and the progress of the SLO C1 (╍) (SLO C1 target value: ≥85%).

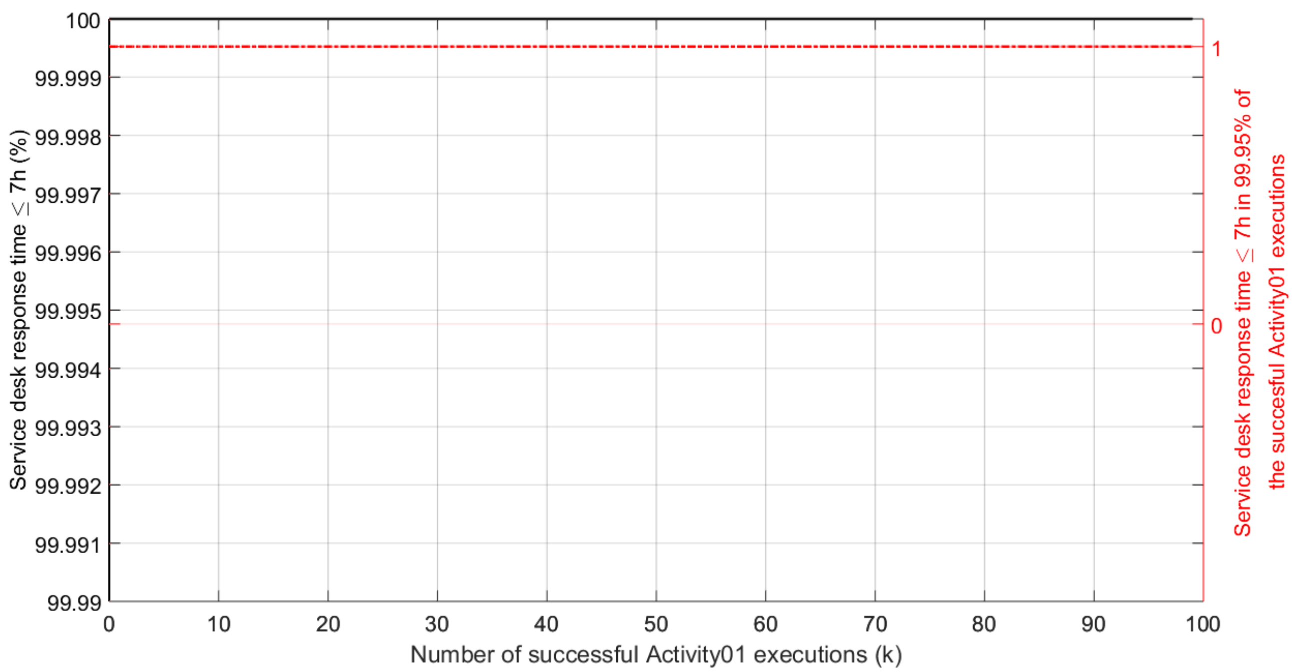


Figure 4. The percentage of the successful Activity01 executions whose time duration is equal or lower than 7h (▬) and the progress of the SLO C2 (╍)(SLO C2 target value: ≥99.95%).

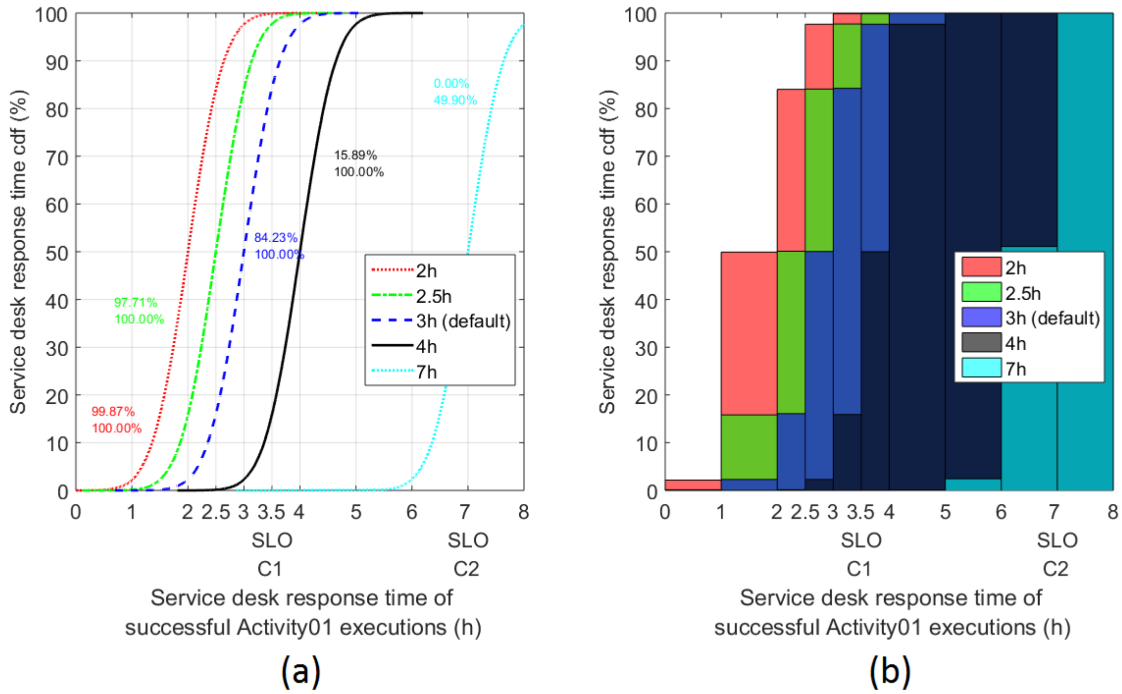


Figure 5. The service desk response time cdfs of the successful Activity01 executions for different values of Activity01 duration mean with labels of progress achievement of SLO C1 and SLO C2. (a) cdf. (b) cdf histogram.

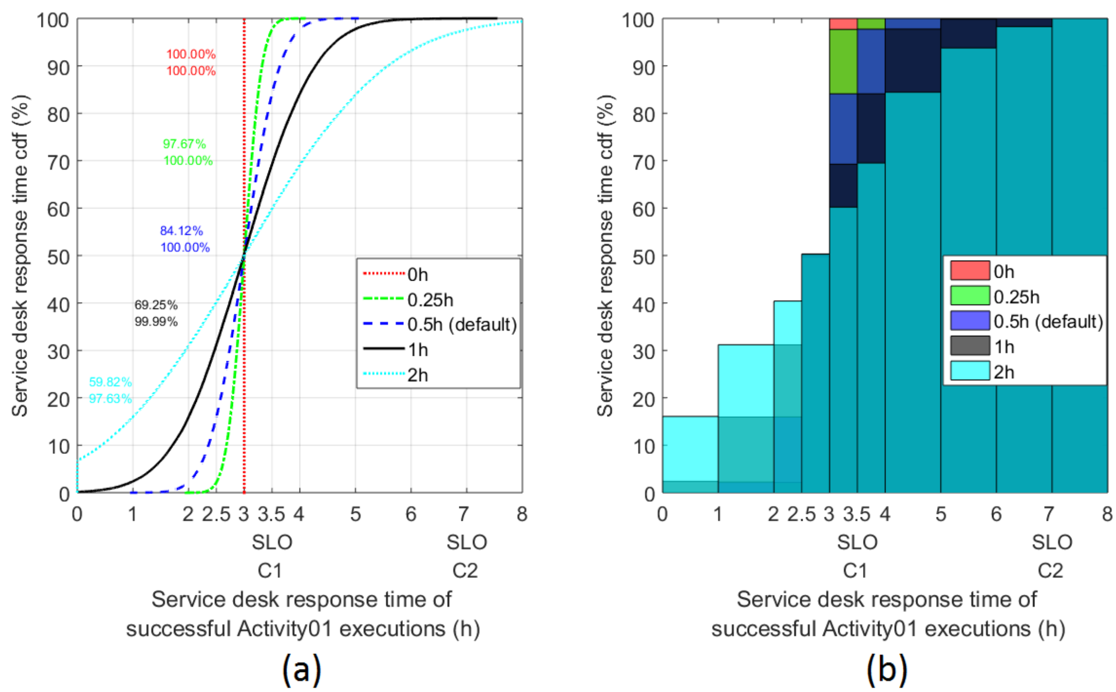


Figure 6. The same curves with Figure 5 but for different values of Activity01 duration variance.

is reduced by 50% to 0.25h by adopting SLO / KPI improvement actions. In the case of the 0.25h duration variance of Activity01, both SLO Cs succeed. The SLO C1 and C2 achievement progress becomes even more improved when the duration variance is further reduced to 0h; the percentages of the successful Activity01 executions whose time duration is equal or lower than 3.5h (SLO C1) and 7h (SLO C2) are equal to 100% (with target value 85%) and 100% (with target value 99.5%), respectively, after the completion of the simulation process. In contrast, when the duration variance of the Activity01 increases from 0.5h to 2h, both SLO Cs fail. Therefore, the decrease of the duration mean of the Activity04 by at least 50% to 0.25h is crucial for the achievement of both SLO Cs. Figures 5(b) and 6(b) reveal the stepwise IT service nature of the service desk while the achievement progress of SLO Cs for the different scenarios can also be verified by the cdf histograms.

From the previous analysis concerning the SLO and KPI attributes of Activity01, SLO / KPI improvement actions are required so that both SLO Cs can be completed. More specifically, the following two SLO / KPI improvement actions that are suitable for the IT service desk of Activity01 are available to the enterprise's management:

1. An SLO / KPI improvement action that can be applied in-house is the improvement of the time durations and QoS of IT operations through the adoption of Information Technology Service Management (ITSM), which is anyway a set of process guidelines for the enterprises. Standardized frameworks, such as Information Technology Infrastructure Library (ITIL), Capability Maturity Model Integration for Services (CMMI-SVC) and Control Objectives for Information and Related Technologies (COBIT), assist the enterprises to easier define and monitor their KPIs across their business processes with the IT service desk being among the major components of their implementations [39]-[42]. By analyzing and digitally transforming the IT business processes across the enterprise's operations, the objective of ITSM is to offer high QoS and direct communication with its IT service users, employees, business partners and customers. The ITSM automated system ensures that all the requests of IT service users and customers are received by the enterprise and can optimize the duration time and the QoS of the delivered IT services. In accordance with [43], the optimization of the duration time and the QoS of the delivered IT services can be achieved through a three-fold analysis of the service desk IT services, namely: (i) analysis of the existing enterprise's service desk system; (ii) the investigation of the existing service desk processes; and (iii) the investigation of alternative service desk systems that may provide better duration times and QoS. The duration mean and duration variance of Activity01 can significantly be improved by the adoption of ITSM so as to catch the aforementioned desired SLO and KPI target values.
2. Looking at the mode of IT service desk sourcing, there are two archetypical IT sourcing modes: (i) *Insourcing*: The operations of the service desk of Activity01 can be performed by the enterprise itself, as done by Department A in Figure 2 now; or (ii) *Outsourcing*: The IT service desk of Activity01 can be transferred and provided by one or more external partners, that is anyway an HRM issue [44]. During the outsourcing implementation, the Activity01 could be transferred into the responsibility of the external partners as dictated by: (a) the interdepartmental SLA definition framework concerning the SLA responsibilities of the external partners of the BPMN IT business processes; (b) The SLA terms including the aforementioned desired SLO and KPI target values that come from the simulation process; and (c) Possible further improvements of the aforementioned desired SLO and KPI target values can be suggested by the external partners during the Evaluation and Negotiations among Stakeholders module of Figure 1 towards the optimized SLOs and KPIs. Apart from the optimized SLOs and KPIs, other benefits that are expected from the outsourcing of the Activity01 are: (1) Reduction of various service-desk-

related costs; (2) Instant hire of trained, experienced, qualified and certified personnel; (3) Increase of the efficiency and the competitiveness; (4) Quick implementation of a new technology; (5) Compliance and security; and (6) The IT department stays focused on its core business [45].

A service desk may serve as the communications hub and the single point of contact among IT service users, employees, business partners and customers. The customer- and business-centric model starts from the enterprise's IT services highlighting the availability and response time as critical SLO and KPI parameters for the enterprise's digital transformation.

In the next sub-subsection, the fault detection SLO, which can be treated as a subcategory of the availability, is studied.

4.2.2 Fault Detection – SLO D

With reference to Table 1, the fault detection is the measurement of failures detected by a service in a certain period of time [23], [27]. Quantitatively and in accordance with SLO D, Activity05, DataObject04 and Database01 must be out of service due to failure less than 0.5% of the number of their execution. In accordance with the default settings of this extension paper, it is assumed that DataObject04 is always available, has zero duration time and does not present any fault behavior. Hence, DataObject04 contribution can be ignored without affecting the fault detection computations of this sub-subsection. The fault probabilities of Activity05 and Database01 express the possibility that the non-availability of a service is due to their own respective faults and should be statistically computed. However, in this sub-subsection, the fault probability of the combined operation of Activity05 and Database01, operating as a database service and treated as BPMN IT database service fault probability hereafter, is investigated when the availability probabilities of Activity05 and Database01 remain different. By studying the available applied KPIs of SLO D, MathematicalOperator_D_1 KPI may compute the fault probability of the BPMN IT database service while Flag_D_1 KPIs examines whether the fault probability of the BPMN IT database service remains equal or lower than 0.5%, which is the target value of the SLO D. Furthermore, the simulation results of the MathematicalOperator_D_1 and Flag_D_1 KPIs are stored in T_MathematicalOperator_D_1 and T_Flag_D_1 KPI arrays, respectively, so that the achievement progress of SLO D can be examined during the simulation process.

In Figure 7, the fault probability of the BPMN IT database service is plotted with respect to the number of the faults of the BPMN IT database service when the default operation settings are assumed. In the same Figure, the accomplishment progress of the SLO D is plotted.

From Figure 7, it is clear that the BPMN IT database service of Figure 2 (say, the concatenation of Activity05, DataObject01 and Database01) easily satisfies the SLO D. Indeed, the fault probability of the BPMN IT database service is equal to 0.457% after the completion of the simulation process when the SLO D target value is 0.50%. In contrast with Figures 3 and 4 where the x-axes deal with the number of the successful activity executions, the x-axis of Figure 7 presents the number of faults of the BPMN IT database service. On the basis of the system theory, the approximately 457 faults of the BPMN IT database service out of the 100,000 simulations may be explained as follows: With reference to the sub-subsection 4.2.1 of [1], the 95.111% availability of the BPMN IT business process of Figure 2 implies that approximately 95,111 successful simulations run. A fault occurs during the BPMN IT database service, when either Activity05 or DataObject01 or Database01 are unavailable and, at the same time, a fault should come from the respective random number fault generator. In mathematical terms, the number of faults can be approximated by the following system theory rule of thumb, namely:

$$100{,}000 \times 95.111\% \times \left\{ \underbrace{\left(100\% - \overbrace{99\%}^{\substack{\text{Availability}\\ \text{probability}}}\right) \times \overbrace{10\%}^{\substack{\text{Fault}\\ \text{probability}}}}_{\text{Activity05}} + \underbrace{\left(100\% - \overbrace{100\%}^{\substack{\text{Availability}\\ \text{probability}}}\right) \times \overbrace{0\%}^{\substack{\text{Fault}\\ \text{probability}}}}_{\text{DataObject01}} + \underbrace{\left(100\% - \overbrace{99.3\%}^{\substack{\text{Availability}\\ \text{probability}}}\right) \times \overbrace{50\%}^{\substack{\text{Fault}\\ \text{probability}}}}_{\text{Database01}} \right\} =$$

$$= 95{,}111 \times \left\{ \underbrace{1\% \times 10\%}_{\text{Activity05}} + \underbrace{0\% \times 0\%}_{\text{DataObject01}} + \underbrace{0.7\% \times 50\%}_{\text{Database01}} \right\} = 95{,}111 \times \left(\underbrace{0.001}_{\text{Activity05}} + \underbrace{0}_{\text{DataObject01}} + \underbrace{0.0035}_{\text{Database01}} \right) =$$

$$= 95{,}111 \times \left(\underbrace{0.0045}_{\substack{\text{Fault probability of}\\ \text{BPMN IT database service}\\ \text{(system theory rule of thumb)}}} \right) = 428 \text{ faults} \qquad (1)$$

From eq. (1), the fault probability of BPMN IT database service depends on: (i) the availability probabilities of Activity05 and Database01; and (ii) the fault probabilities of Activity05 and Database01; in a concatenated way as described by the system theory rule of thumb.

The impact of the availability and fault probabilities of Activity05 and Database01 on the fault probability of BPMN IT database service is further investigated as well as the achievement progress of SLO D and the validation of the system theory rule of thumb. In order to assess the aforementioned impact, the fault probability of BPMN IT database service is plotted in Figure 8(a) for different values of the availability probabilities (SLO / KPI scenario D.A); say, when the availability probability of Activity05 takes the values 97%, 98%, 99% (Activity05 default value), 99.5% (approximate Database01 default value) and 100%. In the same Figure, the system theory rule of thumb as described by eq.(1) but for the applied values of the Activity05 availability probability is also plotted. In Figure 8(b), same curves with Figure 8(a) are given but for the availability probability of Database01. To assess the impact of the different values of the fault probabilities (SLO / KPI scenario D.B),

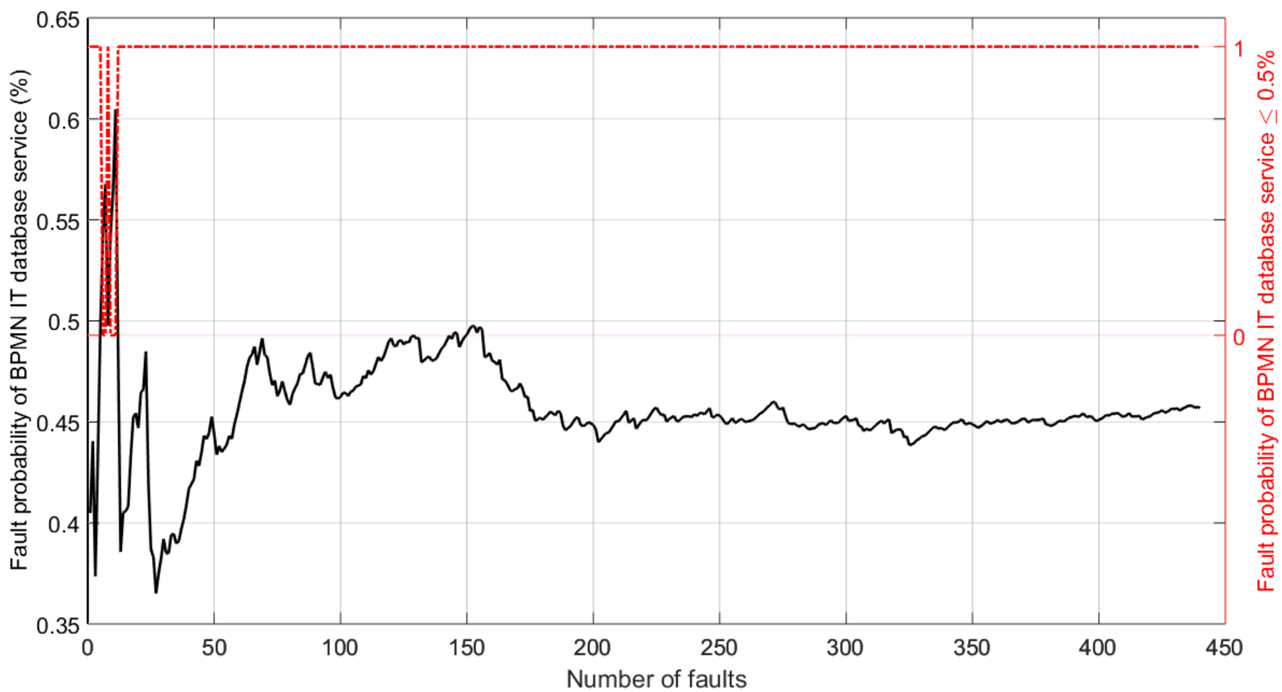


Figure 7. The fault probability of the BPMN IT database service (▬) and the progress of the SLO D (- -)(SLO D target value: ≤0.50%).

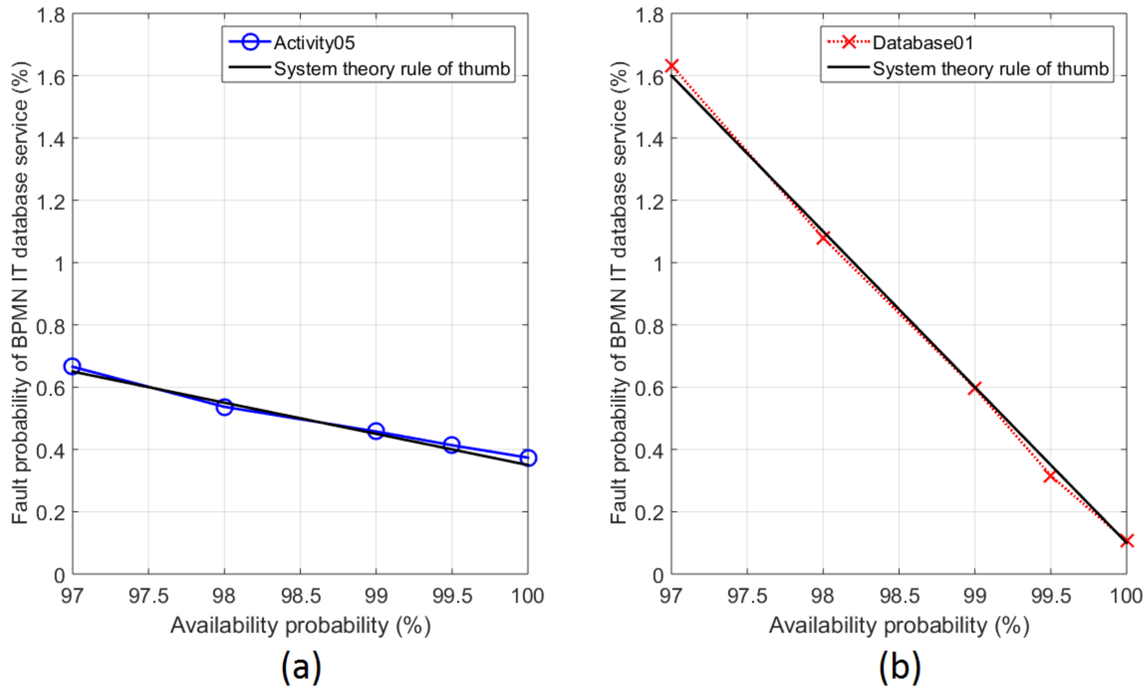


Figure 8. The fault probability of the BPMN IT database service for different values of activity availability probabilities and the system theory rule of thumb. (a) Activity05. (b) Database01.

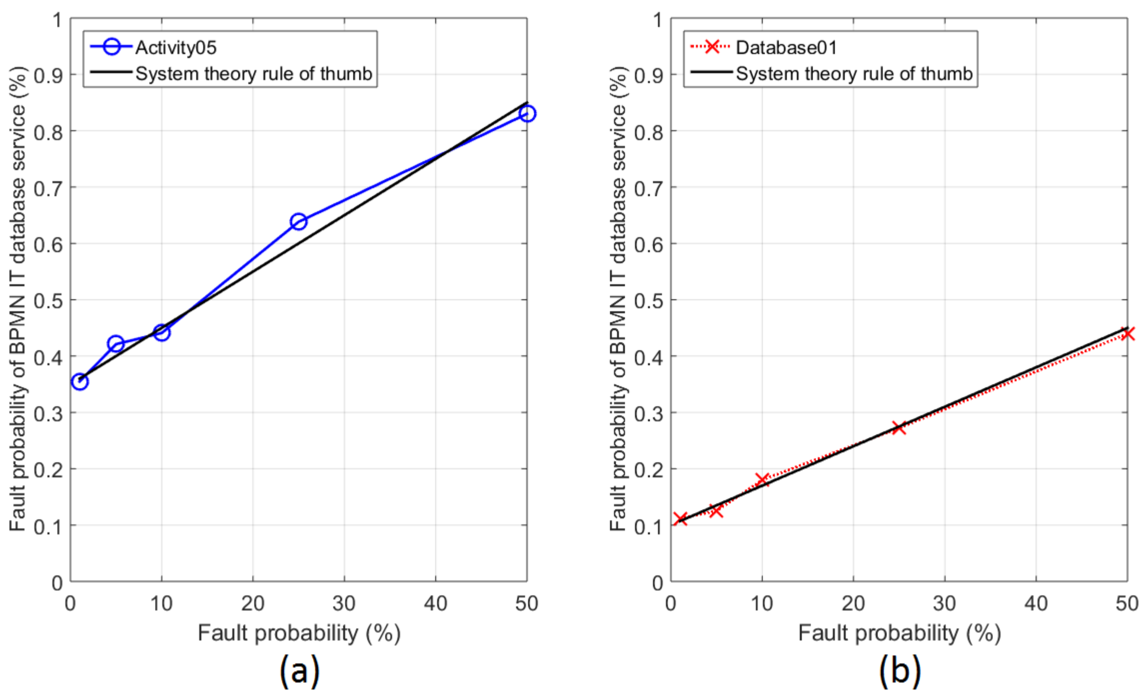


Figure 9. The same curves with Figure 8 but for different values of activity fault probabilities.

in Figures 9(a) and 9(b), same plots with the respective Figures 8(a) and 8(b) are given but for the activity fault probabilities that take the values 1%, 5%, 10% (Activity05 default), 25% and 50% (Database01 default).

From Figures 8 and 9, the impact of the different activity availability and fault probabilities of the Activity05 and Database 01 on the overall fault probability of the BPMN IT database service is examined as follows:

- As the SLO / KPI scenario D.A is concerned, the impact of the availability probability of Activity05 on the overall fault probability of the BPMN IT database service remains weak due to its low fault probability (10%). To assess the impact on the overall fault probability, when the Activity05 availability probability increases from 99% (default value) to 99.5%, the overall fault probability of the BPMN IT database service decreases from 0.4575% to 0.4135% (i.e., the probability decrease is equal to 0.044%). Conversely, the availability probability of Database01 presents a strong impact on the overall fault probability of the BPMN IT database service due to the high fault probability of Database01 (50%). To assess the impact on the overall fault probability, when the Database01 availability probability increases from 99% to 99.5%, the overall fault probability of the BPMN IT database service decreases from 0.5966% to 0.3155% (i.e., the probability decrease is equal to 0.2811% that is significantly greater than the probability decrease due to the Activity05 availability probability increase).
- As the SLO / KPI scenario D.B is concerned, the impact of the fault probability of Activity05 on the overall fault probability of the BPMN IT database service is comparable to the one of Database01 and this is due to almost the same default values of the availability probability of Activity05 (i.e., 99%) and Database01 (i.e., 99.3%). To assess the impact on the overall fault probability, when the Activity05 fault probability decreases from 10% (default value) to 1%, the overall fault probability of the BPMN IT database service decreases from 0.4409% to 0.3547% (i.e., the probability decrease is equal to 0.0862%). Similarly, when the fault probability of Database01 decreases from 10% to 1%, the overall fault probability of the BPMN IT database service decreases from 0.1801% to 0.1117% (i.e., the probability decrease is equal to 0.0684% that is almost equal to the one due to the Activity05 fault probability decrease). Anyway, any significant decrease of the default value of the fault probability of Database01, which is high and equal to 50%, may have significant effect on the overall fault probability of the BPMN IT database service.

With reference to the previous findings for the Figures 8 and 9, the combined impact of the availability probabilities of Activity05 and Database01 on the fault probability of the BPMN IT database service is illustrated in Figure 10 as well as the SLO D target value of 0.5%. Furthermore, the combined impact of the fault probabilities of Activity05 and Database01 on the fault probability of the BPMN IT database service is illustrated in Figure 11 as well as the SLO D target value of 0.5%. Observing Figures 10 and 11, the following remarks can be pointed out that the dependence of the fault probability of the BPMN IT database service on the concatenation of the Activity05 and Database01 availability probabilities may be verified in Figure 10 by: (i) the system theory rule of thumb lines in Figures 8(a) and 8(b) and their accurate approximation to the simulation results; and (ii) the quasi-linear contour lines of Figure 10. Also, the dependence of the fault probability of the BPMN IT database service on the concatenation of the Activity05 and Database01 fault probabilities is verified in Figure 11 by: (i) the system theory rule of thumb lines in Figures 9(a) and 9(b) and their accurate approximation to the simulation results; and (ii) the almost linear contour lines of Figure 11. In addition, the significant combined role of the availability and fault probabilities has been demonstrated towards the achievement of the SLO D.

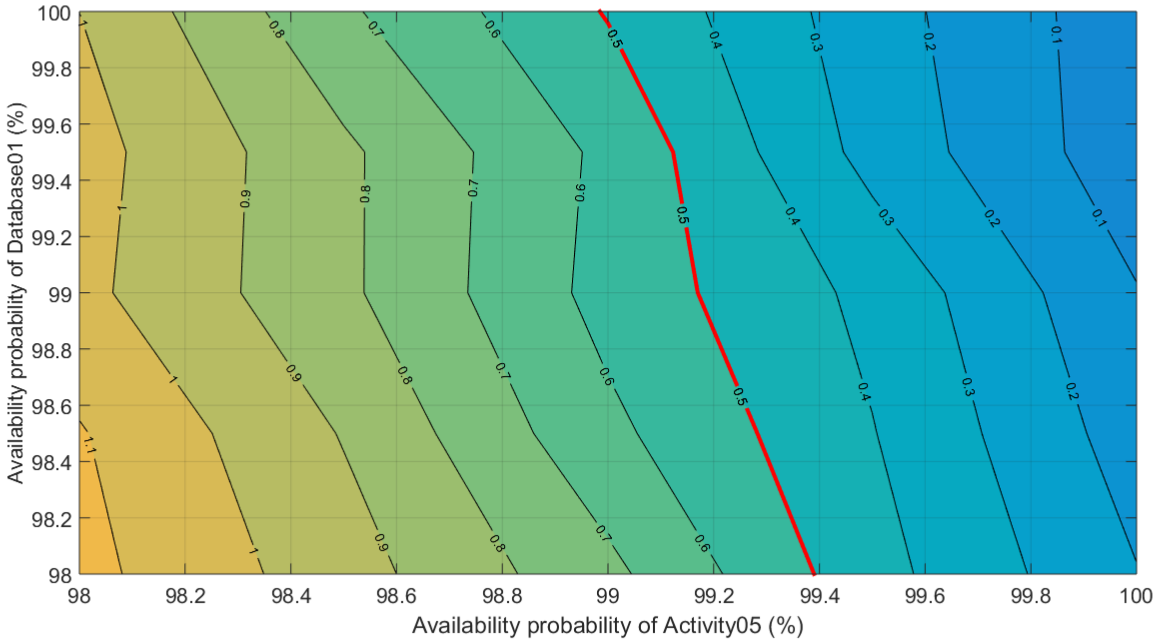


Figure 10. The fault probability of the BPMN IT database service for different combination values of availability probabilities for the Activity05 and the Database01 (the SLO D target value of 0.5% is highlighted in red color).

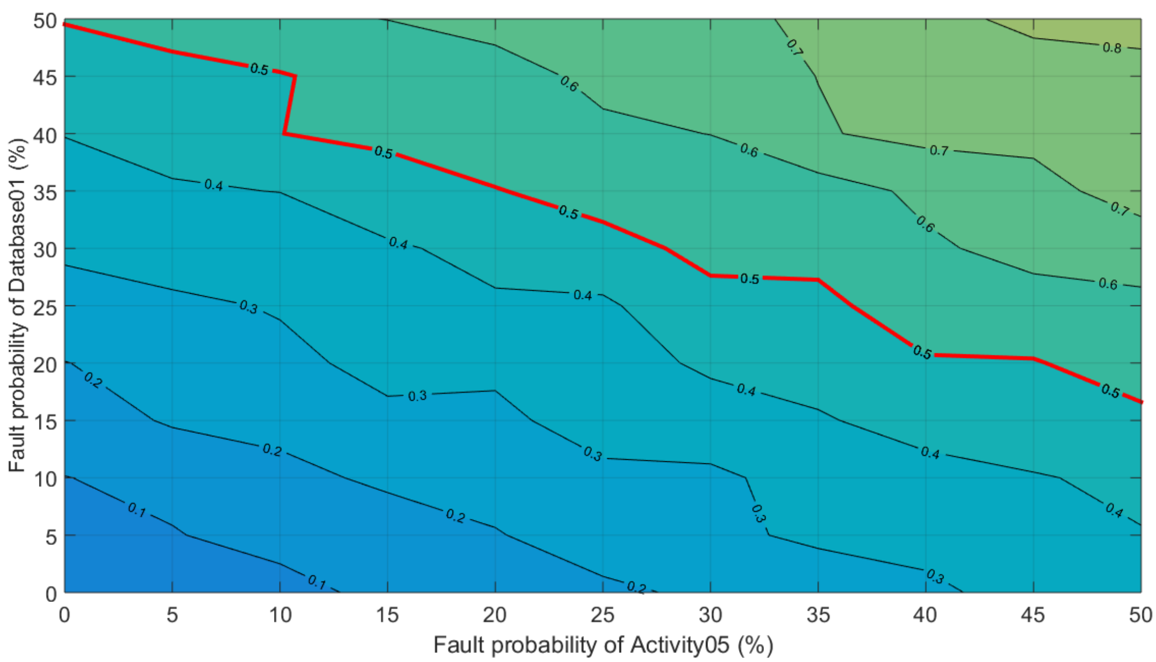


Figure 11. The same curves with Figure 10 but for different values of activity fault probabilities.

Since the SLO D equilibrium between fail and success for different combinations of availability and fault probabilities is fragile, SLO / KPI improvement actions should be applied so that the availability and fault probabilities of the activities of the BPMN IT business process of Figure 2 get improved.

The main SLO / KPI improvement action for the BPMN IT database service is the adoption of the cloud computing solutions, which are among the hottest trends of the today's enterprise's digital transformation. Already been mentioned, the SQL database of Database01 remains on-premises and is characterized by high availability probability while, at the same time, it suffers from high fault probability. Although big data and large data storage capacity become available at low costs with high availability probabilities and low fault probabilities, cloud computing technology and cloud storage platforms promise significantly lower operation, maintenance and upgrade costs with even better availability and fault probabilities than on-premise database server systems [46]. In fact, depending on the desired QoS performance of BPMN IT database services, enterprises may benchmark and adopt one of the following three types of cloud computing services, say: (i) IaaS: IaaS offers essential cloud-based computing, storage and networking resources that are available on-demand. Top IaaS providers for the BPMN IT database service of the BPMN IT business process of Figure 2 are: AWS, Microsoft Azure, Alibaba Elastic Compute Service, Google Cloud and IBM Cloud; (ii) PaaS: PaaS offers a complete development and deployment cloud environment with cloud-based apps and cloud-enabled enterprise platforms. Top PaaS providers for the BPMN IT database service of the BPMN IT business process of Figure 2 are: AWS Elastic Beanstalk, Google Cloud, Engine Yard, IBM Cloud, Heroku, Microsoft Azure Pipelines and Red Hat OpenShift; and (iii) SaaS: SaaS delivers applications over the internet as a service freeing from software and hardware installation and maintenance. Top SaaS providers for the BPMN IT database service of the BPMN IT business process of Figure 2 are: Salesforce CRM, Microsoft, Adobe Creative Cloud, Joyent and Google Workspace [47], [48]. Finally, except for the type of the cloud computing services, the deployment models of the cloud computing solutions, which can be studied by the enterprise for the BPMN IT database service of the BPMN IT business process of Figure 2, could be either a private cloud or a community cloud or a public cloud or a hybrid cloud [47], [49].

5.0 CONCLUSIONS

In this extension paper, the concept of the SLA – aware business processes based on BPMN standard and KPIs for the enterprises' IT services has been further enriched. With reference to the interdepartmental SLA definition framework of [1], two contributions have been presented, namely: (i) Two new SLOs (SLOs C and D) have been added in the initial SLA of two SLOs (SLOs A and B); and (ii) The MATLAB / Octave simulation methodology has been proposed with its two steps of innovation: (iia) new extended BPMN basic elements with SLO and KPI attributes and the BPMN simulation equivalence table; and (iib) the programmatically detailed simulation module. On the basis of the real enterprise's BPMN IT business process of [1], the SLA of the two new SLOs with the corresponding KPIs has been examined while the MATLAB / Octave code of the simulation process, which had been developed in accordance with the MATLAB / Octave simulation methodology, is freely distributed with the Supplementary Material file of the paper. During the simulation process, SLO / KPI improvement actions have been applied so that SLOs of the service desk response time (SLO C) and fault detection (SLO D) of the enterprise's BPMN IT business process SLA may succeed in all the examined scenarios. Towards the target of successful SLOs, a set of SLO / KPI improvement actions have been presented while operations and management issues, such as the HRM of the enterprises' IT personnel and the IT service outsourcing based on SLAs, SLOs and KPIs, have been addressed in theoretical and practical bases. Concluding this extension paper, the next generation SLA – aware BPMN IT business processes have been further investigated so that higher and guaranteed QoS performance for the enterprises' BPMN IT business processes by taking into account more focused SLOs and KPIs, better SLA-based professional relationships among the enterprises' departments and external partners can be established and more accurate management decisions can be taken.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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