

Proposal for an approach to evaluate continuity in service supply chains: case of the Moroccan electricity supply chain

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ABSTRACT

The purpose of this paper is to develop an approach to analyse and evaluate continuity in Service Supply Chain (SSC), through a case study. This approach is based on the data-driven quality strategy "Define, Measure, Analyze, Improve, Control" (DMAIC) which is used to drive Six Sigma projects, and on the characteristics of Smart Supply Chain. It combines Business process management (BPM), Supply Chain Operations Reference (SCOR), and the Root cause analysis tree diagram. The chosen case study is the electricity SCC, especially the business process 'management of electricity for residential buildings' of the Moroccan electricity SSC. The paper shows that the suggested approach identifies the discontinuity causes for the studied SSC, improves the business process behavior and manages its control by providing a dashboard that encompasses KPIs for periodically controlling of the SSC "to-be" state.

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1. INTRODUCTION

Nowadays, the world economy has grown progressively service oriented and an increasing attention on SSC by both practitioners and academics is noticed. Actually, in a supply chain, there is a product created by the points of origin and delivered at the points of consumption. When the product is not a physical product, we talk about a SSC [1, 2]. Despite this difference of product nature, in the manufacturing supply chain as in SSC, the objective of achieving efficiency and responsiveness is equally important and relevant. Moreover, maintaining SSC operations, can be a major challenge for organizations. Part of what makes continuity such a challenge for SSC in a general way, and particularly for the electrical SSC which is characterised by the stochastic nature of electricity production and the time varying load demand. And since the majority of the performance works in electricity field are interested in only one process (example: electricity generation) without taking into account the impact on the whole SSC, or they are interested to a performance at the operational level by studying a single device (example: smart meter) without considering the whole process [3-8], it makes this service (electricity) a good case study for a global SSC analysis approach.

Apart from its capacity to guide actions, a holistic view of SSC has an explanation and description capacity, in this context, [9-13] proposed modelling methodologies for SSC analysis which combines different methods and tools, aiming to provide a capture of the "as-is" state of the SSC, as credible as possible. In addition to describe the current SSC, this work propose an approach able to determine the causes of the service discontinuity, to correct the discontinuity and to control periodically the updated SSC. This approach is based on the data-driven quality strategy DMAIC of Six Sigma projects, and on

the characteristics of Smart Supply Chain. It combines BPMN, BPM simulation, SCOR, and the Root cause analysis tree diagram. And it's proven by the case study of the Moroccan electricity SSC. The application of the proposed approach to the Moroccan electricity SSC, allowed us to analyze this SSC, to identify the discontinuity causes for the chosen business process, to propose a process improvement for the SSC, and to develop a dashboard for periodic control of the continuity management of this SSC. The reminder of this paper is organized as follows. Section 2 explains the proposed approach, used in this work to evaluate the performance of the studied SSC. The obtained results and analysis are explained in Section 3. Finally, Section 4 is a conclusion that synthesizes the achieved work.

2. PROPOSED APPROACH

The research was developed based on the case study of the business process 'the management of electricity for residential buildings' of the Moroccan electricity SSC. The performance methodology used is based on Six Sigma, this methodology brings structure to process improvement by providing the user with a more detailed outline of Deming's PDCA cycle by guiding the initiative through a five stage cycle known as DMAIC [14], which actually stands for the phases of the improvement projects Define, Measure, Analyze, Improve and Control [15]. The Table 1 explains the detail of the DMAIC adaptation to this paper purpose.

Table 1. DMAIC phases

Phase	Detail
Define	This phase is done in [16] according to a methodology in fourth levels organized in a descending order (that is, from the overall system, to decompose the latter into finer granularity subsystems), the three first levels are done with SCOR and the last one is done with the BPMN. In this work we focus on the fourth level, and especially the business process 'the management of electricity for residential buildings'.
Measure	The second phase represents the results of the aforementioned model simulation using Bonita BPM.
Analyze	In this phase the results of the simulation are analyzed and presented in a root cause analysis tree diagram.
Improve	In the fourth phase we take advantage of the principles of Smart Supply Chain presented in [17] to improve the process of the first phase.
Control	Based on the simulations' results analysis and the SCOR KPIs, a dashboard is elaborated to control the performance of this SSC in this phase

The following research questions are formulated as a basis for respecting our methodology:

RQ1: what is "the management of electricity for residential buildings" process of the current Moroccan supply chain of electricity?

RQ2: how can the characteristics of the Smart Supply Chain emphasize the intelligence of the studied business process?

RQ3: how can the reliability and reactivity of the proposed supply chain be evaluated?

3. RESULTS AND ANALYSIS

This section presents the five phase's results, done accordingly to the aforementioned approach, while responding to the research questions elaborated in the previous section. The first question is addressed by the first three phases, the second question by the fourth phase, and the last question by the last phase.

RQ1: what is "the management of electricity for residential buildings" process of the current Moroccan supply chain of electricity?

3.1. Define phase

The first phase consists of analyzing the studied business process and make it clear while offering a global view of the studied SSC. The business process 'the management of electricity for residential buildings' of the Moroccan supply chain of electricity is shown in Figure 1. The aim of this business process is to satisfy the end users' needs of electricity. At least one of the three start events shown in Figure 1 triggers the production of electricity: "producers' activity management", "sends the consumer profile" and "production plan". Electricity producers presented by the lane "private producer" are organizations whom the activity management generates electricity. These consume a generated electricity share and they sell a share of it to ONEE. For areas whose distribution is managed by private distributors (e.g. Redal), these distributors periodically sends to the ONEE the area consumption profile, if not for areas whose distribution is managed by the ONEE, it respects its production plan. Thus, to produce electricity, ONEE refers to data provided by the distributors or to its data (and not to both data sources, for the same area). The electricity supply is based on the production made by ONEE, import of electricity, or purchase of electricity (activities of the ONEE lane), once the electricity is generated, ONEE ensures its transport, and then depending on

the area it manages the distribution, or it sells it to distributors. The distributors buy electricity from ONEE and distribute it. The end user consumes electricity. These processes are managed by contracts between producers and ONEE, ONEE and distributors and between the user and the distributor. These contracts include various clauses specific to different situations. Other support processes are not shown in the figure, such as the management of transmission and distribution networks and the billing.

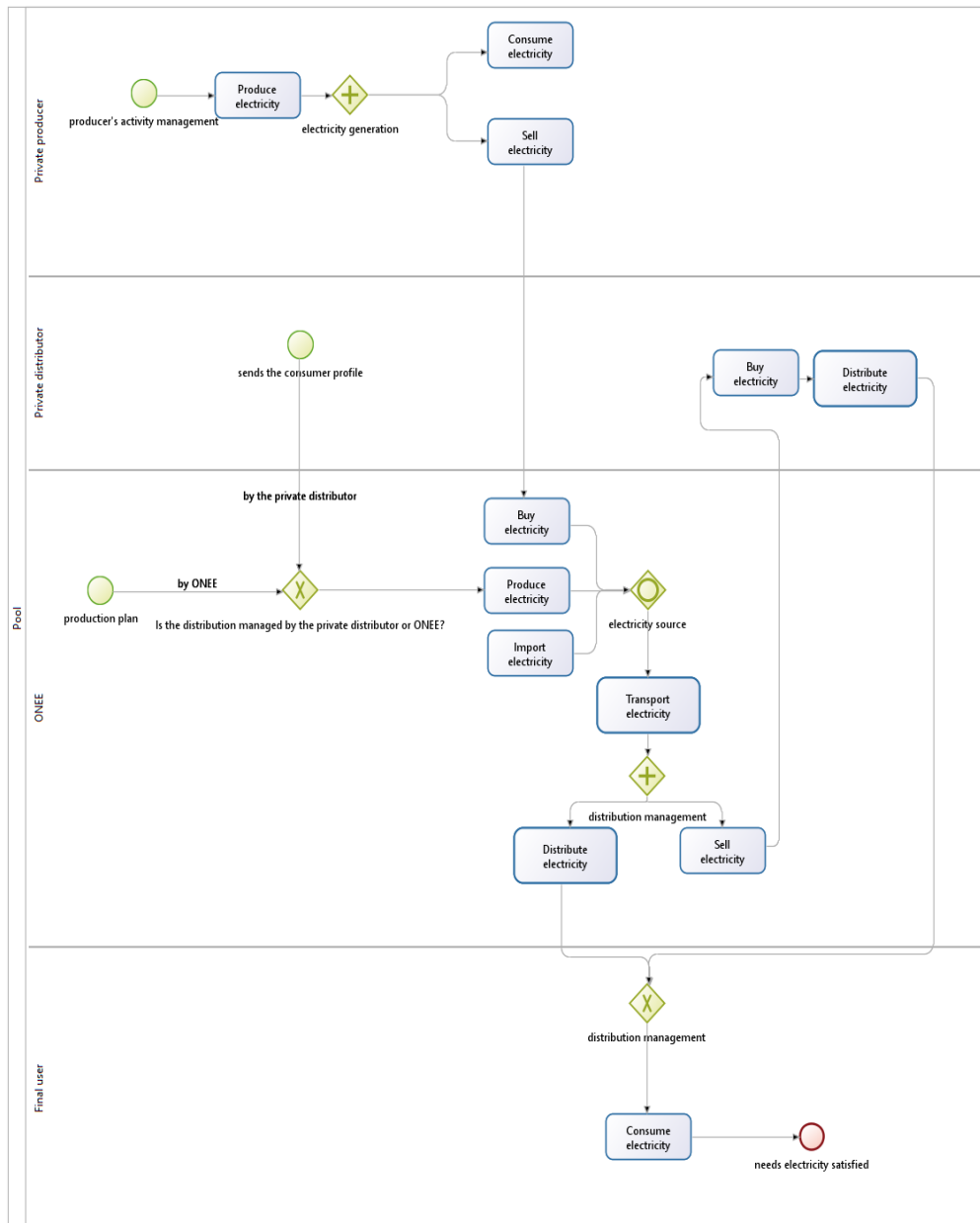


Figure 1. The business process ‘management of electricity for residential buildings’

3.2. Measure phase

The second phase clarify the way the business process currently perform, for this phase the business process simulation is done using the same tool chosen for the modelling, with applying probabilities for the flow paths. Simulation can be applied for different purposes, namely prediction, performance, entertainment, training, education, confirmation and discovery. When a simulation is run, a specified number of iterations over a specified period of time are run either with simulated data or with assigned probabilities. In order to specify the scenarios to simulate, the form shown in Figure 2 is created, to feed our objects before launching the simulation.



Management of electricity for residential buildings parameters

Generation Plant Distribution line Distribution substation
 Transmission line Transmission substation Peak demand

Figure 2. The business process form

This phase of our study considers six possible scenarios related to the resources specific to each task and to the various cases of this business process management. Table 2 shows the scenarios to simulate, in order to deduce the elements that impact the service continuity.

Table 2. The simulation scenarios

	Generation plant failure	Distribution line failure	Distribution substation failure	Transmission line failure	Transmission substation failure	Peak demand
Scenario 1	True	False	False	False	False	False
Scenario 2	False	True	False	False	False	False
Scenario 3	False	False	True	False	False	False
Scenario 4	False	False	False	True	False	False
Scenario 5	False	False	False	False	True	False
Scenario 6	False	False	False	False	False	True

The Table 3 presents the minimum, the average and the maximum execution time (by hours) of the main tasks of the lanes ONEE and Final user, and which are: produce electricity, transport electricity, distribute electricity, and consume electricity. (Sc: Scenario, Mi: minimum, A: average, Ma: maximum). The load profile used in this work is composed of the start date 01-07-2018 at 00:00 am, the end date 31-07-2018 at 00:01 and 100 instances. The simulation is runned six times, and in each time, we have entered the parameters specific to each scenario.

Table 3. The execution time by activity

Scenario	Produce electricity			Transport electricity			Distribute electricity			consume electricity		
	Mi	A	Ma	Mi	A	Ma	Mi	A	Ma	Mi	A	Ma
Sc 1	0	125	450	0	0	0	0	0	0	0	0	0
Sc 2	103.667	250	697.21	0	293	561.08	0	0	0	0	0	0
Sc 3	103.597	244	690.67	0	67	240.9	0	0	0	0	0	0
Sc 4	103.43	249	697.09	232.78	339	722.083	0	439	530	0	0	0
Sc 5	111.09	250	690.821	199	267	673.98	0	102	295.12	0	0	0
Sc 6	109	259	729.68	299	378	651.88	287.08	390	721.51	369.245	411	712

The discontinuity of the service is marked by the non-execution of the final event, and therefore according to our business process by the non-execution of the task “consume electricity”, which corresponds to the scenarios sc1 sc2 sc3 sc4 and sc5.

3.3. Analyze phase

This phase allows to closely examine the process based on the results of the Measure phase. So, according to the BPMN model simulation, we conclude that "Generation plant failure", "Distribution line failure", "Distribution substation failure", "Transmission line failure", "Transmission substation failure" are events that prevent the execution of the activity "consume electricity", which prevents the execution of the final event of our BPMN model and consequently causes a discontinuity in the SSC. Figure 3 shows the causes of the discontinuity for this business process.

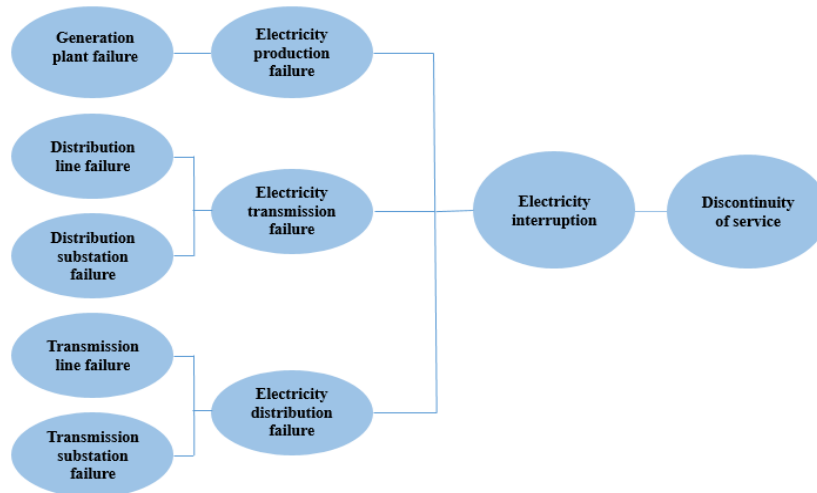


Figure 3. Root cause analysis tree diagram

Responding to RQ1, and making clear the way the business process perform, the resources and elements that could cause the discontinuity of the service, leads us to answer the second research question (RQ2).

RQ2: how can the characteristics of the Smart Supply Chain emphasize the intelligence of the studied business process?

3.4. Improve phase

As the world begins to work differently, we see a different kind of supply chain emerging a smarter supply chain with three core characteristics: Interconnected, Instrumented, Intelligent.

- ‘Interconnected’: Smarter supply chains will take advantage of a new levels of interaction with all objects of the supply chain. In addition to creating a global view of the supply chain, this interconnectivity will facilitate collaboration on a large scale [18].
- ‘Instrumented’: Sensors, Radio frequency identification (RFID) tags, meters, actuators, GPS and other devices and systems, will increasingly generate supply chain information that was previously created by people. The smarter supply chain will witness events as they occur [19].
- ‘Intelligent’: A smarter supply chain is able of learning and making decisions by itself, without human involvement. This intelligence will be used not only to make real-time decisions, but also to predict the future. Equipped with sophisticated modelling and simulation capabilities, the smarter supply chain will move past sense and-respond to predict-and-act [18].

The characteristic of the Smart Supply Chain that interests us in this work is "Interconnected". To meet the challenges of the current Supply Chain, we aim to make it more interconnected by integrating the end user as an actor in this chain. The end users are either major customers (factories, business ...) or individuals, and the predictions are based mainly on historical consumption which is almost unchanged for major customers, the forecast error is typically caused by individuals whose consumption is unpredictable. By integrating these individuals into this system we move from a traditional supply chain to an interconnected supply chain, where the final consumer participates by generating power at the point of consumption. In this case, individuals will consume electricity they produce, still linked to the national grid, they can (if needed) consume electricity provided by the network.

The proposed business process model is presented in Figure 2. This model is similar to the previous one, with the same start events, end event, and the three first lanes' activities namely: Private producer, Private distributor, and ONEE. The reconfiguration is made as an adding of two activities at the lane "Final user", and of a flow between "ONEE" and "Final user". These added activities reflect the fact that the end user (individual) can generate the electricity he needs. From a managerial side the implementation of this business rule is based on the management of some constraints such as electricity production prices by the individual must be less than or equal to that of its purchase of ONEE. This means that the management of the decentralized electricity production will add other support activities to the lane "ONEE" not shown in Figure 2 as encouraging individuals to follow this new policy as shown in Figure 4.

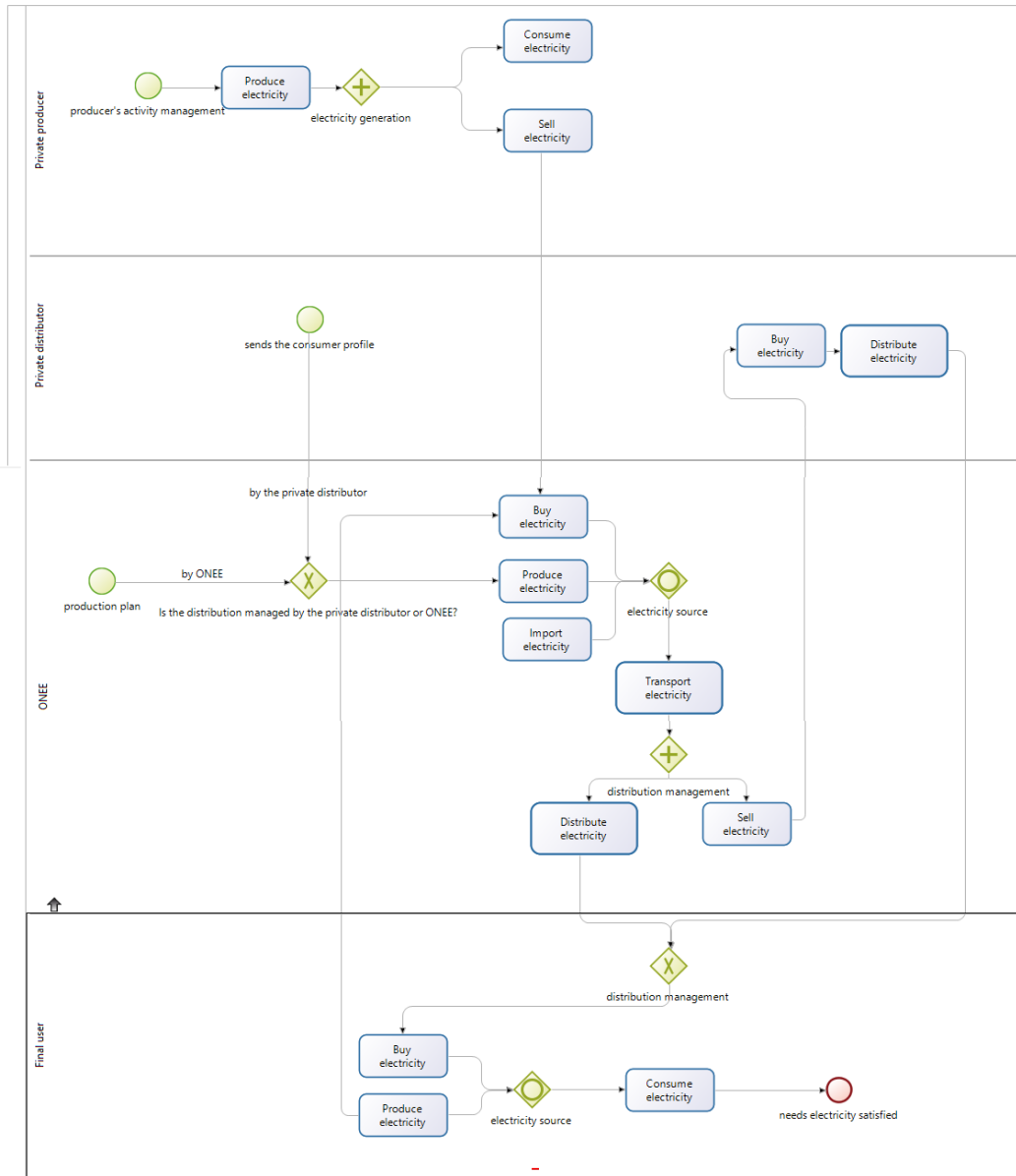


Figure 4. The proposed business process ‘management of electricity for residential buildings’

Once we clarified the way the characteristics of the Smart supply chain would improve the studied business process and emphasize the intelligence of our SSC, we go to RQ3, whose answer will clarify the way the changes made in the previous phase will be controlled.

RQ3: how can the reliability and reactivity of the proposed supply chain be evaluated?

3.5. Control phase

The last phase of Six Sigma’s DMAIC model is the Control phase. The aim of this phase is to maintain the changes created in the previous phase. For this a dashboard composed of Steering and Performance indicator was elaborated. As a part of our goal to evaluate the continuity between the electricity production and its consumption, and obviously to evaluate how much the smart electrical supply chain is interconnected we are interested in the two attribute: ‘Supply Chain Reliability’ and ‘Supply Chain Responsiveness’ as defined in the first level of SCOR.

The chosen SCOR metric for ‘Reliability’ is ‘Perfect Order Fulfillment’. The formula given by the model for it is : $[Total\ Perfect\ Orders] / [Total\ Number\ of\ Orders]$. Based on this indicator, and given the context of our case study, the indicator that corresponds functionally to the ‘Perfect Order Fulfillment’ is ‘Rate of electricity supply’: $[electricity\ production\ expressed\ in\ Twh/an] / [electricity\ consumption: expressed\ in\ primary\ energy\ kWhep/m2/year, the\ area\ is\ considered\ the\ living\ area]$.

'Responsiveness' is the speed at which tasks are performed. The chosen metric for this attribute is 'Order Fulfillment Cycle Time'. It represents the time passed between the moments a customer places the order to the moment the order is fulfilled. To calculate the 'Order Fulfillment Cycle Time' SCOR specifies: $[\text{Sum Actual Cycle Times for All Orders Delivered}]/[\text{Total Number of Orders Delivered}]$. Based on this indicator, and given the context of our case study, the indicator that corresponds functionally to the 'Order Fulfillment Cycle Time' is 'Rate of Electricity access'; $[\text{consumption duration} - \text{outages duration}]/[\text{consumption duration}]$.

And based on [16, 19, 20] which tackled the same supply chain in the three levels of SCOR with the same objective of evaluation the continuity in this SSC, we regrouped the following performance indicators related to the attributes 'Accessibility' and 'Availability':

Accessibility:

- Population with access to power (% of pop. in utility service area).
- Number of residential Subscribers per 100 Households in the Concession Area (Residential Coverage).

Availability:

- Energy losses in Distribution per Year (%).
- Average duration of interruptions per subscriber (Hours/year).
- Average frequency of interruptions per subscriber (Interruptions/year).

And to recapitulate the Table 4 presents the dashboard that sum up these indicators.

Table 4. Dashborad

Attribute	Indicator	Indicator type	Calculation periodicity
Reliability	[electricity production expressed in Twh/an]/[electricity consumption: expressed in primary energy kWh/m ² / year, the area is considered the living area]	Steering indicator	A trimester
Responsiveness	$[\text{consumption duration} - \text{outages duration}] / [\text{consumption duration}]$	Steering indicator	A trimester
Accessibility	Population with access to power (% of pop. in utility service area)	Performance indicator	A year
	Number of residential Subscribers per 100 Households in the Concession Area (Residential Coverage)	Performance indicator	A year
Availability	Energy losses in Distribution per Year (%)	Performance indicator	A year
	Average duration of interruptions per subscriber (Hours/year)	Performance indicator	A year
	Average frequency of interruptions per subscriber (Interruptions/year)	Performance indicator	A year

To implement these indicators, several methodological steps are necessary:

- Define the scope to study to calibrate the type of data to be collected.
- Define energy-consuming activities to consider in identifying technology solutions to mobilize to collect data.

Set the type of energy and the collection of scale (spatial, temporal ...) to calibrate the choice of indicators.

4. CONCLUSION

This work presents a new approach to evaluate SCC performance. The proposed approach is based on DMAIC method of Six Sigma, and combined BPM, SCOR, Smart supply chain, and Root cause analysis tree diagram. It's proven by the case study of evaluating the continuity in the Moroccan electricity SSC. By applying the aforementioned approach, the results and analysis gives us an overall overview of the studied SSC, establishes the causes behind the service discontinuity, proposed an improved version of the chosen business process, elaborates a dashboard to evaluate the chosen metric for this case (continuity). More case studies can be used to more thoroughly evaluate the presented approach, that can be improved by generalizing it to all SSC business processes.

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