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THESE DE DOCTORAT

Managing adaptability in process based software using Q-Learning and web services

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Abstract

Over the past decades, there has been substantial interest and progress in research in both fields “the process approach” as a management strategy, and “machine learning” as an artificial intelligence discipline. Several problematic issues have been addressed in the literature, around these two themes.

In this thesis, we use reinforcement learning to improve the performance of business processes, and more precisely, to make it self-adaptive. To this end, a four-level referential is established tracing the concept of adaptability throughout the supply chain. At the three first supply chain levels, L-SCOR, the proposed reference extends SCOR processes and metrics by adding "sL Learn" process and the attribute "Adaptability", at the fourth supply chain level it proposes an implementation to sL process using web service and Q-Learning.

Within the framework of this thesis, and in order to prove the effectiveness of the proposed reference, three case studies were carried out, based on distinct supply chains: "the retirement supply chain", "the electricity supply chain" and "the drugs supply chain". The aforementioned case studies were established according to a three-step proposed methodology. The first step is the supply chain exploration through SCOR modeling. The second step is the supply chain evaluation using a combination of methods and technologies to respect "DMAIC" the six-sigma approach. The last step is the supply chain improvement based on the implementation of the proposed L-SCOR reference.

The results analysis provides composite evidence of the proposed reference effectiveness.

Keywords: Reinforcement learning, Q-Learning, Process adaptability, SCOR

Résumé

Au cours des dernières décennies, il y a eu un intérêt et des progrès considérables dans la recherche dans les deux domaines «l'approche processus» en tant que stratégie de gestion et «l'apprentissage automatique» en tant que discipline de l'intelligence artificielle. Plusieurs problématiques ont été abordées dans la littérature, autour de ces deux thèmes.

Dans cette thèse, nous utilisons l'apprentissage par renforcement pour améliorer la performance des processus métier, et plus précisément, pour le rendre auto-adaptatif. Pour ce faire, un référentiel à quatre niveaux est établi retraçant le concept d'adaptabilité tout au long de la chaîne d'approvisionnement. Aux trois premiers niveaux de la chaîne d'approvisionnement, L-SCOR, la référence proposée étend les processus et les métriques SCOR en ajoutant le processus «sL Learn» et l'attribut «Adaptabilité», au quatrième niveau de la chaîne d'approvisionnement, elle propose une implémentation au processus sL à l'aide du service Web et Q-Learning.

Dans le cadre de cette thèse, et afin de prouver l'efficacité de la référence proposée, trois études de cas ont été réalisées, basées sur des chaînes logistiques distinctes : «la chaîne logistique d'une pension de retraite», «la chaîne logistique de l'énergie électricité» et «la chaine logistique des médicaments au sein de l'hôpital». Les études de cas susmentionnées ont été établies selon une méthodologie proposée en trois étapes. La première étape est l'exploration de la chaîne logistique à travers la modélisation SCOR. La deuxième étape est l'évaluation de la chaîne logistique en utilisant une combinaison de méthodes et de technologies pour respecter «DMAIC» l'approche six-sigma. La dernière étape est l'amélioration de la chaîne logistique basée sur la mise en œuvre de la référence L-SCOR proposée.

L'analyse des résultats fournit une preuve composite de l'efficacité de référence proposée.

Mots clés : Apprentissage par renforcement, Q-Learning, Adaptabilité des processus, SCOR

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Introduction

Motivation and Contributions

On one hand, the process approach, which was first introduced in ISO 9001:2000, is now adopted in a huge number of organizations. Consequently, several references and models based on this approach have been developed and adopted in recent years. Among which, we cite SCOR that is a process reference models integrating the well-known concepts of business process engineering, benchmarking, process measurement and organizational design into a cross-functional framework. Several research works have been interested in the process improvement especially in a managerial way. The literature includes several issues that deal with the evaluation of process performance, its exploration, and its optimization. Within the framework of this thesis, it is its adaptability, which is investigated, having as objective building processes that offers and guaranteeing a continuity of the activity.

On the other hand, Machine learning "the science of getting computers to act without being explicitly programmed", has proven itself in a large number of areas. Especially in software engineer, where the ML has been used in several research works for different aims, among which we quote: "software defect prediction", "software quality improvement", "data classification", "software effort estimation", "code changes detection "," software process evaluation "," software testing improvement "," software verification "," software learning "," software maturity assessment "," software requirement specifications analysis "," software risk identification "and" software run-time prediction ".

The objective of this thesis is to be able to develop self-adaptive software based on the process approach. For this, an extension of the SCOR reference has been established integrating the concept of adaptability to these processes, with an implementation proposal taking advantage of Q-learning a reinforcement-learning algorithm. The proposed reference system and its implementation have been tested in three different supply chain cases.

Thesis outline

This thesis is composed of four chapters, which are:

- Chapter 1: L-SCOR: A 4-level reference for self-adaptive processes based on SCOR and integrating Q-Learning
- Chapter 2: The retirement supply chain: exploration, evaluation and improvement
- Chapter 3: The supply chain of hospital drugs: exploration, evaluation and improvement
- Chapter 4: The supply chain of electricity: exploration, evaluation and improvement

Chapter 1 starts with an introduction of the main technologies the proposed reference is based on. Then it gives an overall overview about the research works done around "the process adaptability" theme. The focus then shifts to the description of the proposed reference. Lastly, this chapter ends by explaining the methodology respected in the different case studies.

The three remaining chapters represent three different case studies in which three distinct supply chains (the retirement supply chain, the supply chain of hospital drugs and the supply chain of electricity) are explored, evaluated and improved. Each of the aforementioned chapters starts with a description of the studied supply chain, then its exploration is done using SCOR modeling, its evaluation respects a combination of methods and technologies to adopt "DMAIC" the six-sigma approach. The improvement step is based on the implementation of the proposed L-SCOR reference.

Chapter 1

1. L-SCOR: An extension of SCOR for a self-adaptive supply chain

This chapter is devoted to the description of the proposed reference for self-adaptive processes and its implementation.

1.1. Introduction

In order to improve a business process behavior, to guarantee the service continuity, to minimalize the waste of time automatic activities execution, a reference is proposed to analyze the self-adaptability of a business process and to improve this performance. The proposed approach is a combination of SCOR, Web services and Q-learning.

1.1.1. SCOR

SCOR is a reference to represent the flows of a company allowing modeling its different structures and processes; SCOR makes it possible to create for the supply chain actors a shared language and to harmonize their practices. It thus allows the improvement of the supply chain's performance and builds standardized indicators. Among the fields in which it has been used, we can cite : health [1,2], retirement [3-5] and electricity [6-8], in these works the authors have proposed approaches based on SCOR and integrated with other methods (BPM, DMAIC ...) to ameliorate their supply chains performance. The steps to follow in order to improve the supply chain performance according to SCOR are: "Describe the actual processes from various sources", "Quantify operational performance and compare results to derive benchmark performance levels", "Identify practices and tools that have achieved the best results" and "Propose a 'to-be' state of the evaluated processes”. This work focuses on this improvement approach. It proposes L-SCOR an extension to the SCOR model by adding to its six processes (sP "Plan", sS "Source", sM "Make", sD "Deliver", sR "Return", sE “Enable”) a seventh one sL "Learn" which relies on reinforcement learning principle, and triggers the self-adaptation of supply chain processes. L-SCOR also adds to the five SCOR performance attributes a sixth one “adaptability” with eight metrics.

1.1.2. Q-Learning

Q-Learning, a model-free algorithm of reinforcement learning, which is more in line with the self-learning mechanism of human society. Actually, it optimizes long-term benefits by rewarding positive behavior and punishing negative behavior. Watkins [9] proposes a typical description of Q-learning, the algorithm allows individuals to maintain a Q-value table for each strategy and to update the table in each round, and finally selects the strategy with the highest Q-value as the next round strategy [10]. Based on the foundation of Markov decision processes theory, Q-learning is a useful and meaningful method for solving problems of agent actions under different complicated conditions, it is very reliable because a discounted future reward is obtained when transiting from one state to another [11]. The literature offers a huge number of problematic issues that have been dealt with solutions based on Q-learning in various fields, among which we cite in the aeronautical field [12] that proposed a Q-learning based approach that stands on the experience quality of the served users, to plan the flight of stations of unmanned aerial vehicles-base. In the robotics field, [13] proposes an approach integrating Q-learning to plan the path of a robot arm. This approach has as objective to plan the path of the robot arm end-effector such that it can reach a fixed target position by getting over the minimum distance while dodging the obstacles present in the environment in an efficient manner. Within the same framework, [14] proposes an approach for the path planning of mobile robot in different environments with static obstacles in various shapes, sizes and layout. In this work, Q-learning is used in software engineer field, in order to allow process based software's to be self-adaptive, in fact the process activities will execute, when needed, the activity that implement Q-Learning algorithm, in order to obtain the optimal strategy for their operation. Q-learning is chosen as a reinforcement learning (RL) algorithm from a range of other RL algorithms. This choice is justified on one hand by its low computational footprint and being a 'model-free' algorithm, it combines learning and execution, simultaneously in any given environment having states and possible actions; Which is a very important point knowing that the proposed web-service would be used by different processes (different agents). On the other hand the proposed web-service learns by experience replay, so we need an off-policy learning method, that's why the on-policy methods have been discarded, like SARSA that expects that the actions in every state are chosen based on the current policy of the agent that usually tends to exploit rewards. So among the free-model algorithms based on off-policy learning we choose Q-Learning as a standard RL algorithm to first evaluate the proposed implementation of sL.

1.1.3. Web services

Web services are a platform-independent technology primarily designed to connect heterogeneous applications over a network. They are widely used in different domains and are based on standard protocols that enable communication between the providers, which offer the operations, and the consumers [15]. Reusing and composing third-party Web services has become a common practice in modern software systems engineering to provide high quality and feature rich systems. Several service ecosystems have emerged in recent years hosting a highly increasing number of published Web services by different providers on Internet [16]. The different roles involved are service provider, service registry and service requestor. The various communication/interaction between the roles are publish, discovery and bind operations. To describe a typical web service environment, we have to distinct between the service provider and service consumer roles. A service provider establishes network accessible software, and offers its description that explains the functional properties of the service and publishes it to a service repository. The service consumer utilizes the discovery operation to find the published service description from the registry, and uses the description to bind with the provider [17]. In this work web services are used to allow the communication between the implementation of a recommendation activity (that implement Q-learning algorithm) and the rest of a process activities.

This chapter describes and explains a 4-level reference from the overall supply chain to the finer activity of a business process, describing processes and allowing their self-adaptation. The 4-level proposed approach uses L-SCOR in the three first levels and BPMN integrating web service and Q-learning in the 4th level as shown in fig 1.

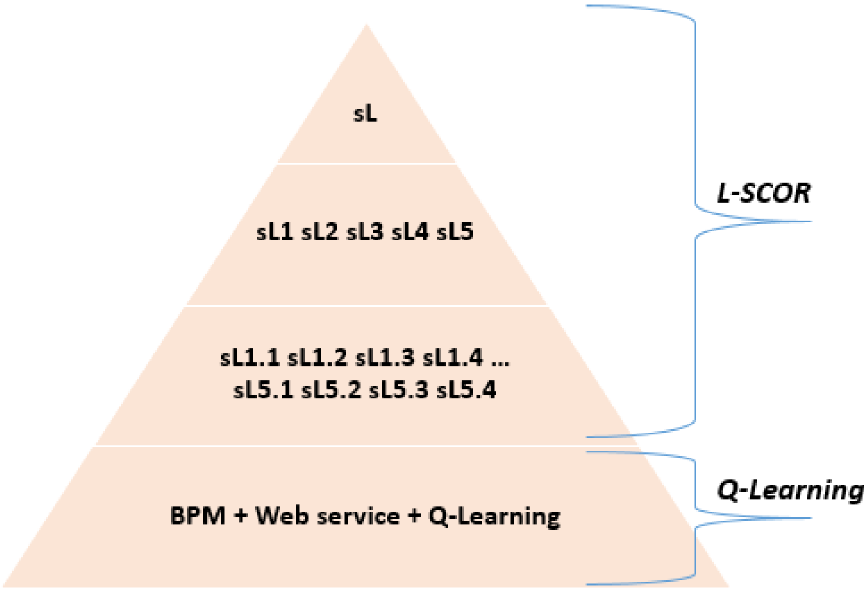

Figure 1.1 The proposed 4-level reference

This chapter's remainder is organized as follow: the next section traces the work related to process self-adaptation propositions grouped from literature. Section 3 details the process sL at the four levels of the proposed approach, it also explains the proposed performance attribute and its metrics, in addition to the details of the sL implementation. Section 4 sums up the content of the chapter.

1.2.Adaptive process

Several authors have faced the issue connected to process and software adaptability. Reference [18] highlights current research on methods and techniques for the design and engineering of adaptive software systems, it describes a goal-oriented framework for adaptive service composition by proposing adaptive feedback loops for applications deployed in cloud based on the MAPE-K architecture. While [19] focuses on the growth of adaptive software reliability. The authors demonstrate the reliability of a software as an action of the software operational use and incremental modifications, their model developed the reliability reliance of a software with environment, usage, and the processed data type. In [20], authors modified and evaluated extreme programming process model and suggested a new model for adaptive process; that is adjusted as stated in the software project requirements, and which eliminates the limitations of development of reusable components, large development teams,

documentation, quality, average and complex software development. For [21] they were interested in enhancing context specifications to have dependable adaptive systems. In order to extract a list of relevant contexts and their related variables, tasks, and/or goals, the authors proposed a process for design time analysis based on data mining algorithms. Reference [22], proposed an approach to develop and verify distributed adaptive software. The explained framework used choreography languages to obtain correctness by construction. Within the same framework, [23] proposed a framework that applies software cybernetics to lead the evolution of self-adaptive architecture, that is expressed as a feedback control process. Reference [24] proposed an adaptive Petri net to model a self-adaptive software, and which is an extension of hybrid Petri net by embedding a neural network algorithm into it. In the same context, [25] proposed a framework that extends UML and creates three types of modeling views: analysis, structure and behavior. The object is to identify modeling requirements of Fuzzy self-adaptive software. As for [26], in order to integrate model checking with lifecycle of an adaptive software, the authors proposed a framework that allows the adaptive software design through a limited state machine and the software adaptation during runtime. Reference [27], studied the application of control theory to realize self-adaptation and develop novel control-based adaptation mechanisms that guarantee desired system properties. Reference [28], proposed a rule model to extract scattered rules from different procedures, to enhance the self-adaptive ability of software. Finally yet importantly, [29] focused on a feasibility study in applying an architecture based approach to develop self-adaptive robotic systems, the authors also proved the approach through two case studies.
This brief literature overview show that adaptive systems in a general way is clearly a highly research issue of major importance nowadays. This work is distinguished by focusing on a way to push the process to behave in the most optimal and efficient way.

1.3.L-SCOR: a proposed extension of SCOR

The latest version of the SCOR (SCOR 12), considers that all supply chains are composed of the following six processes: Plan, Source, Make, Deliver, Return and Enable. This chapter suggests an extension to SCOR by adding to those processes a seventh one "sL Lean", in order to manage the adaptive aspect of a supply chain processes, and to its fifth performance attributes a sixth one “adaptability” with eight metrics. It also offers a sL management approach at the fourth level of a supply chain.

1.3.1. Processes:

1.3.1.1. Strategic level :

L-SCOR suggets in the supply chain strategic level to add the process sL. sL Learn process describes the activities associated with developing policies to be adopted in order to provide the ideal functioning of the process. The Learn processes include on one hand the gathering of each process states, the gathering of the possible actions for each process and of the rewards related to each action, on the other hand they also include the establishment of the optimal policy for the process execution. Fig. 2 shows the processes of L-SCOR at the top level.

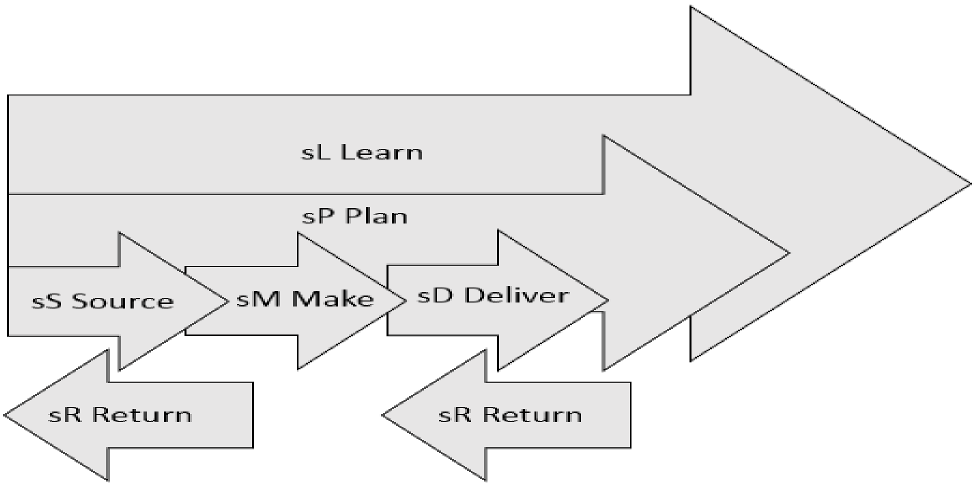

Figure 1.2 L-SCOR at the supply chain strategic level

1.3.1.2. Tactical level

In the configuration level, sL is divided into processes related to establishing the ideal policies for self-adaptive supply chains, which are "sL1 - Learn Plan", "sL2 - Learn Source", "sL3 - Learn Make", "sL4 - Learn Deliver" and "sL5 - Learn Return". Fig. 3 represents the process sL at the second level of a supply chain.

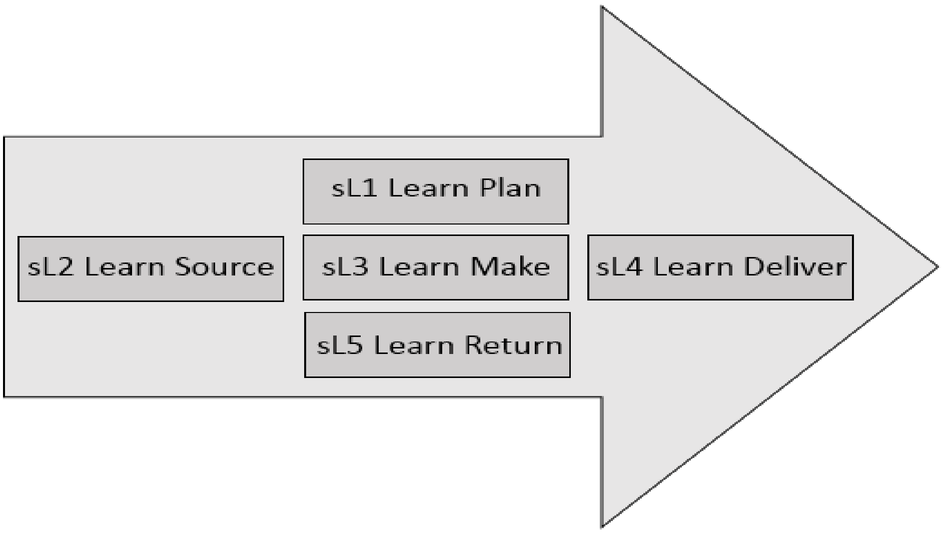

Figure 1.3 sL at the configuration level of L-SCOR

1.3.1.3. Operational level

Concerning the supply chain operational level, each of the second level processes are divided into sub-processes. sL1 - Learn Plan describes the process of development and establishment of optimal policy for the self-adaptive supply chain planning. It consists of the following sub-processes: "sL1.1 - Identify plan states", "sL1.2 - Identify plan actions", "sL1.3 - Identify rewards of planning actions" and "sL1.4 - Establish and communicate plan policy". It receives as input the supply chain requirements and resources from the planning processes to give the ideal supply chain planning policy as an output, as shown in Fig. 4.

Figure 1.4 sL1 at the process element level of L-SCOR

sL2 - Learn Source describes the process of development and establishment of optimal policy to meet the sourcing conditions of a self-adaptive supply chain. It's composed of the following activities : "sL2.1 - Identify sourcing states", "sL1.2 - Identify sourcing actions", "sL1.3 - Identify rewards of sourcing action" and "sL1.4 - Establish and communicate sourcing policy". It receives as input the products requirements and sources from the planning processes, to return as output the optimal supply chain sourcing policy, as shown in Fig. 5

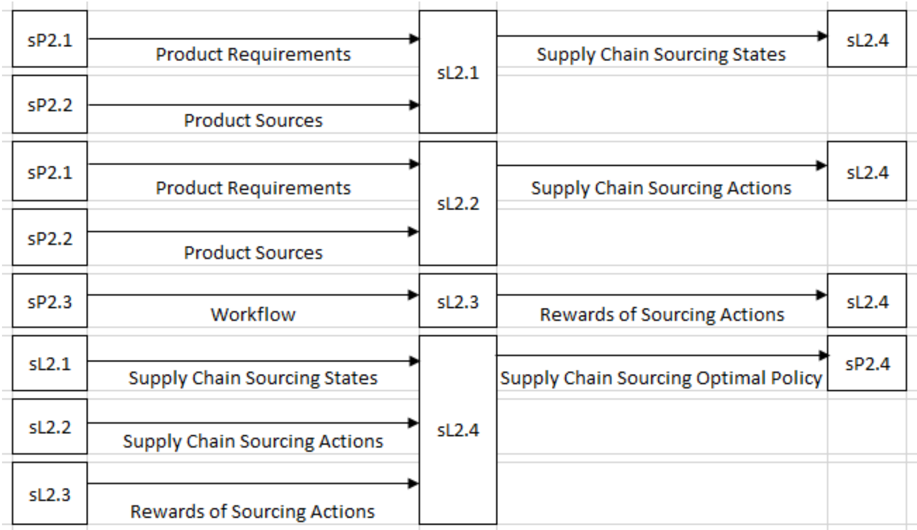

Figure 1.5 sL2 at the process element level of L-SCOR

sL3 - Learn Make describes the process of development and establishment of optimal policy to meet the production requirements of a self-adaptive supply chain. It's composed of the following activities : "sL3.1 - Identify production states", "sL3.2 - Identify production actions", "sL3.3 - Identify rewards of production actions" and "sL3.4 - Establish and communicate production policy". It gets from the planning processes, the production conditions and resources as input, to give as output the ideal supply chain production policy, as shown in Fig. 6.

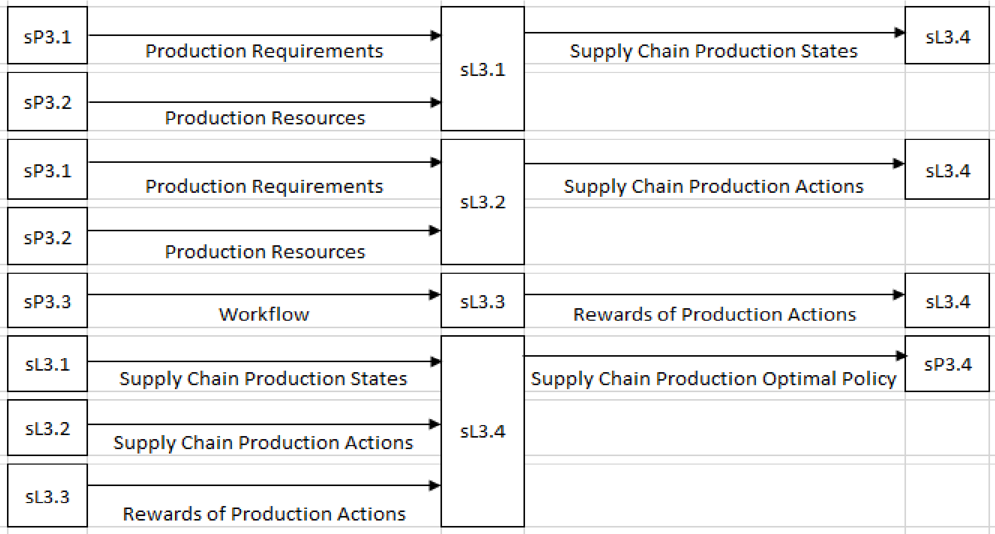

Figure 1.6 sL3 at the process element level of L-SCOR

sL4 - Learn Deliver outlines the development process of the optimal policy in order to meet the delivery requirements of a self-adaptive supply chain. It’s composed of the following activities : "sL4.1 - Identify delivery states", "sL4.2 - Identify delivery actions", "sL4.3 - Identify rewards of Delivery actions" and "sL4.4 - Establish and communicate delivery policy". It receives as input the delivery requirements, resources and capabilities from the planning processes, to return as output the optimal policy for supply chain delivery, as shown in Fig. 7.

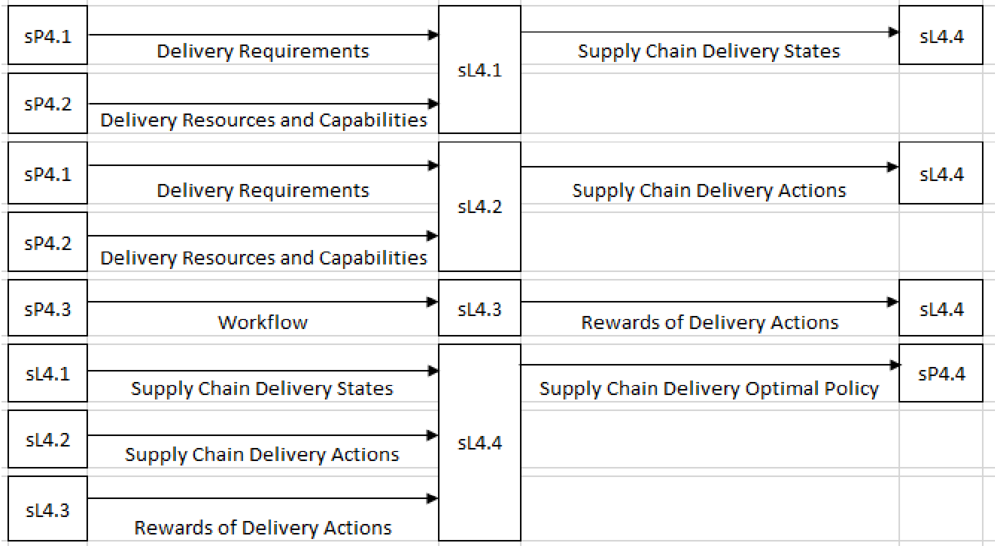

Figure 1.7 sL4 at the process element level of L-SCOR

sL5 - Learn Return describes the process of development and establishment of optimal policy to satisfy anticipated and unanticipated return conditions of a self-adaptive supply chain. It consists of the following sub-processes: "sL5.1 - Identify Return states", "sL5.2 - Identify Return actions", "sL5.3 - Identify rewards of return actions" and "sL5.4 - Establish and communicate return policy". It receives as input, the return requirements and resources from the planning processes, to give as output the ideal supply chain return policy, as shown in Fig. 8.

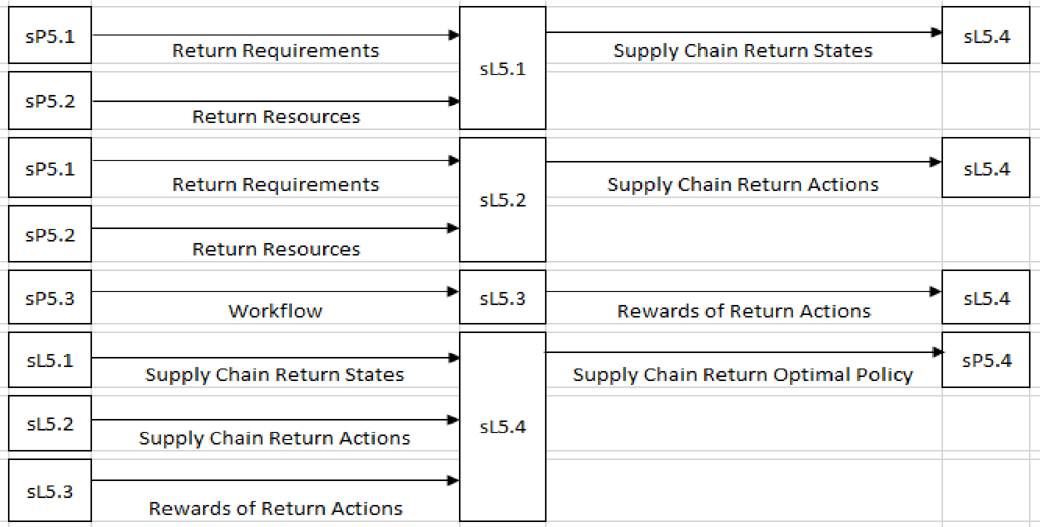

Figure 1.8 sL5 at the process element level of SCOR

1.3.1.4. Real-time Level

At the fourth level of the supply chain, the use of the BPMN as a descriptive language of an activity is proposed. With the integration of a control on the result of execution of each activity. In the event of a processing anomaly, the process calls a web-service that executes sL Learn process. This web service receives as input for the concerned activity, the execution data (as detailed in the previous levels), it reformulates the task of the activity in agent, states and actions, and it returns the optimal behavior to execute thanks to the Q-learning algorithm. The activity runs a second time with the data received, and if its behavior is normal, the process goes to the next activity, otherwise we call the web-service with the new data, as shown in Fig. 9.

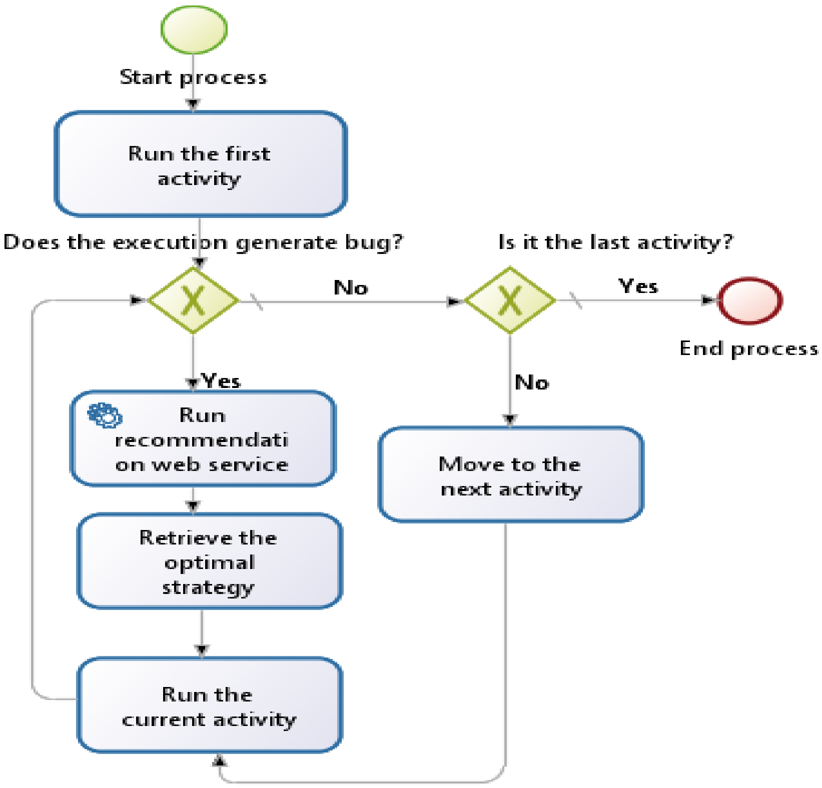

Figure 1.9 sL implemented at the fourth level of the supply chain

1.3.2. Metrics:

There are over two hundred and fifty SCOR metrics that are codified and structured in a hierarchical framework. Those metrics are grouped in five performance attributes, which are 'asset management efficiency', 'reliability', 'costs', 'responsiveness' and 'agility'. In addition to those five performance attributes, L-SCOR add a sixth one: “Adaptability”. The “Adaptability” performance attributes outlines the supply chain ability to deal with changes and unexpected malfunction. The tactical level metrics perform as diagnostics for the strategic level metrics. This implies that by examining the tactical level performances metrics, performance gaps or improvements for the strategic level metrics are explained. Likewise, operational level metrics perform as diagnostics for tactical level metrics. Table 1.1 presents the eight metrics related to the proposed performance attribute.

Table 1-1 The "Adaptability" L-SCOR metrics

	Strategic metrics	Tactical metrics	Operational metrics
Adaptability	perfect change adaptation AD1.1 : [Total Perfect adapted	% changed activities AD2.1 : [total changed activities] /	# of activity requirements AD3.1 # of activity resources AD3.2 # of activity states AD3.3

	changes] / [Total Number of changes] x 100%	[total activities] x 100%	# of activity actions AD3.4
		% adapted activities AD2.2 : [total adapted activities] / [total changed activities] x 100%	% adapted activities use AD3.4 : [number of used optimal policies] / [number of adapted activities] x 100%

1.3.3. Recommendation web service implementation

The implementation of sL at the real-time level of a supply chain, is done using a RESTful Web service with python Flask that calls the Q-learning algorithm implemented with python language. In this section, a RESTful API service is presented which any user, programmer or program can access to take advantage of Q-learning algorithm.

1.3.3.1. RESTful Web service with python Flask

In recent years, REST (REpresentational State Transfer) has emerged as the standard architectural design for web services and web APIs, due to its ability of supporting simpler programmatic access through returning either using XML or JSON [30]. RESTful Web Service is a structural mode, where the data is outlined in the terms of Uniform Resource Identifier (URI) and the behaviors are outlined as methods. Since the performance, scalability, flexibility is improved in the RESTful systems when it is compared with SOAP service, REST hypnotize the end user due to the less consumption of resources [30]. REST services are robust, use minimal bandwidth and are suitable for connecting with cloud services. Sites such as Amazon, LinkedIn and Twitter use RESTful APIs [31]. The standard REST protocol is: the client or the applicant process generates a Uniform Resource Locator (URL) that is sent to the server using a simple HTTP GET request. The Get request is received at the server and processed by the API. The HTTP RESPONSE is formatted as eXtensible Markup Language (XML) or JavaScript Object Notation (JSON) [31]. The structure of the GET request includes the resource location that is being accessed, the output format, and the Q-learning parameters, separated by "&". For web development in Python, there are many frameworks available, the most known are Django and Flask, in this project research we use Flask.

1.3.3.2. Q-learning algorithm

Q-Learning is a learning method that can be applied to find a sequence of actions associated with states of any Markovian decision process. It works by learning a state value function that determines the potential benefit (reward) of taking some action in a certain state by following an optimal policy. The principle of Q-learning algorithm is as follows:

- For each agent state, we note the action that led to this state by strengthening our existing q-value. Arrived on the state s' from state s and action a, we note the q-value as following:

  $Q(s, a) = \lambda \times (r + \gamma \times \max a' (Q(s', a'))) + (1 - \lambda) \times Q(s, a)$

  $\lambda \in [0; 1]$ is the learning rate

  $\gamma \in [0; 1]$ is the discount factor

  r is the reward obtained for achieving state s' from state s with action a
- The agent carries out several research cycles of rewards, from initial state to goal state and reinforces with each passage the q-value of the action which leads to rewards or leading to states leading to rewards.
- Initially, the agent does not know the states where the rewards are, does not know the arrival state of an action, so he starts by choosing random actions he explores.
- After a certain time or when it reaches a goal state, the agent resumes a search for a solution from the state initial. At each cycle, the system exhibits a behavior of less and less exploratory, and increasingly guided by quality

The Q-learning algorithm is implemented in this work as following:

```
Function Q-Learning
        ∀s ∀a Q(s, a) ← 0
        for n ← 1, nbCycles do  #nbCycles is the number of learning cycles
           λ ← 1 ;
           α ← 1 ;
           currentState ← firstState
          for i ← 1, nbMaxActions do  #the max number of actions to execute
                s ← currentState
                nb ← random(0, 1)
                if (nb < α) then
                        a ← randomAction(s)
                else
                        a ← argMax a' (Q(s, a'))
                end if
                s'← a(s)
                Q(s, a) ← α × (r + γ × max a' (Q(s ' , a' ))) + (1 − α) × Q(s, a)
                 λ ← 0.99 × λ
                α ← 0.99 × α
                if (s' = finalState) then
                        exit loupe i
                end if
          end for
    end for
End Function
```

1.4.Case studies methodology

As part of this thesis, three different case studies were established according to a methodology that consists of three steps, which are "Supply Chain exploration" "the Supply Chain evaluation" and "the Supply Chain improvement" as shown in Fig 1. The exploration is done through the mapping of the first three levels of the SC using SCOR. Once the exploration is done we move on to the evaluation of the SC, this phase is done with a proposed approach based on the data-driven quality strategy "Define, Measure, Analyze, Improve, Control" (DMAIC) which is used to drive Six Sigma projects, the define step is the mapping of the 4th level of the SC using BPMN. In the measure phase, we applied the BPM simulation to the BPMN model, using Bonita soft for both modeling and simulation; in the Analyze step, we represent the results of simulation using the root cause analysis tree diagram. in the improve phase we took advantages of Smart supply chain characteristics to adapt our "as is" model, the last step we propose a set of SCOR KPIS to keep controlling the behavior of our system. The last phase is the improvement one, the improvement is done by the implementation of the process sL of the proposed reference L-SCOR, which consist in the implementation of the web service which uses the Q-learning algorithm for general anomalies during the simulation. This web service directs the activity to work by using its optimal policy thus avoiding the situations generating the anomaly.

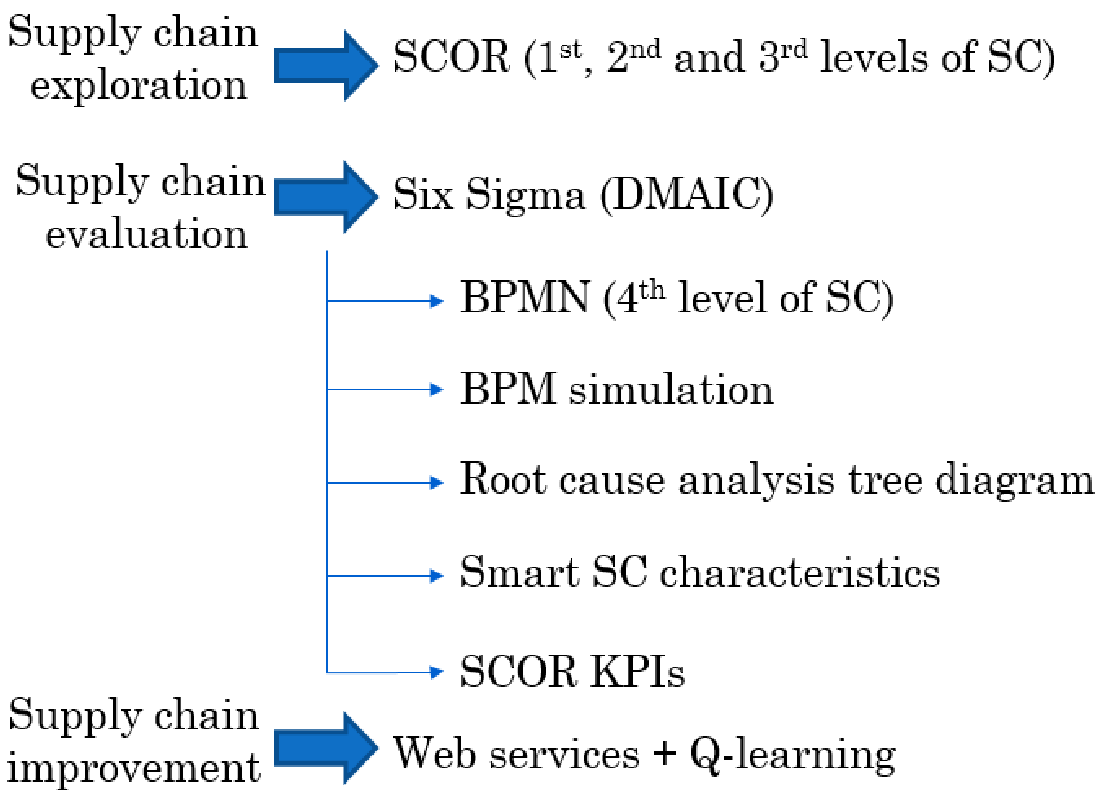

Figure 1.10 The case studies methodology

1.5.Conclusion

This chapter explains the 4-level proposed reference for self-adaptive business processes, its implementation and the case studies methodology.

The proposed reference is based on SCOR, which is adapted to the different supply chains; it extends SCOR by integrating the notion of adaptability on its both sections processes and metrics. That is, the proposed reference adds to SCOR another process "sL" describing all possible activities managing adaptability. It also adds the performance attribute "adaptability" with eight metrics. This chapter details the "sL" process on the three levels of a supply chain, and describes the performance attribute "adaptability" metrics. The fourth level of this reference is described using the BPMN (since SCOR does not provide process description for the fourth level of a supply chain), in a way to explain how this adaptability is supported. Indeed the fourth level details how an activity of a given process can call a web service implementing the algorithm Q-learning that will return for the calling process the optimal policy for its operation. This chapter also describes how the implementation of this proposition is carried out for the different case studies that will be detailed in the next chapters.

Chapter 2

2. The retirement supply chain: exploration, evaluation and improvement

This chapter is devoted to the analysis, evaluation and improvement of the retirement supply chain using the case study of the Moroccan retirement pension.

2.1. Introduction

2.1.1. The service supply chain: Retirement supply chain

With the expanding service sector priority in economies, the SSC has achieved a more important role in operations management, while many traditionally product based organizations like Pitney Bowes garner, Cisco and IBM are developing a percentage of their revenues from services [32]. Furthermore, considering the growing regard on SSC by both academics and practitioners, [33] describes the supply chain as the movement of products and services that affects raw materials supply, their storage, and the work for final products from point of origin to point of consumption". Moreover, [34] outlines it as "a sequence of activities consisted of a particular organization and all the other organizations interacting directly or indirectly, through its suppliers and customers, upstream and down-stream, for the effective consumption of products and/or services by end users". Within the same framework [35] give the following SSC definition: "a methodical competencies set that compose relational, proactive, coordinative technology and people dimensions needed to deliver particular service offerings". On one hand, several works are instead concerned in the difference between the traditional supply chain and the SSC, for [36] this divergence is due to the special IHIP characteristics of services (heterogeneity, perishability, inseparability, and intangibility) that need to be considered. Reference [37], determines that the traditional supply chain differs from the SSC in two aspects, the first one is the fact that the supplier can produce her products; while in the SSC supplier's capacity is fixed for service firms (e.g. in hotels); the other difference is the absence of operation cost in SSC while the operation cost cannot be neglected in the traditional supply chains. On the other hand, diverse research works were interested on evaluating the SSC performance, such as the study of [38] that established a measure of sustainable service supply chain management (SSSCM) performance by concentrating on the type of network hierarchical relations with quantitative and qualitative measures, the study established a hierarchical network for SSSCM in a closed-loop hierarchical structure, they also explained the practical implementation. While [39] suggested a grey based hybrid framework for evaluating the SSC environmental performance, by merging grey based method with VIKOR and ELECTRE approaches. The research work used two case studies, in order to understand the criteria effectiveness to evaluate SSC environmental performance in a developing country context. In a similar vein, [40] proposed a SSC framework for performance measurement, by underlining a methodology based on the fuzzy analytic hierarchy process. The attention is on performance measures redressing SSC processes such as service performance, technology management and SSC finance customer relationship management, capacity and resource management, supplier relationship management, information and demand management. The developed SSC framework for performance measurement was applied to the hotel supply chain. Along the same lines, [41] was interested on the performance assessment considering the presumed actors perception of the SSC, in this case it is the hospital (the actors are patients, medical staff and managers). The study used the AHP (Ana-lytic Hierarchy Process) method to choose the most suitable healthcare SSC design in a case study based on three decision criteria: accessibility to health quality and products, in addition to costs. Similarly, [42] analyzed the SSC performance under various logistics strategies affecting information and risk sharing between the application service provider and the application infrastructure provider. The study defined many key managerial insights from the proposed model. Most importantly, it defined an adequate decentralized mechanism to accomplish the aim of maximizing the overall SSC performance. Several fields were covered in the literature, for instance in the automobile industry where [43] investigated on the effectiveness coordination of automobile logistics SSC under buy-back contract. For automobile logistics service integrator and functional logistics service provider, they decide the optimal logistics effectiveness order quantities separately based on their maximum profits. When both the order quantities are equivalent, the automobile logistics SSC reaches an optimal coordination state. In addition, the numerical simulation confirmed the model correctness. Among the studies that focused on the after-sales SSC configuration, we cite [44] that investigated three configuration types: the decoupling of activities, the degree of vertical integration, and the degree of centralization. This research work carried out an investigative case study with seven organizations of durable consumer goods industries. The findings indicated that choices of configuration differ; proposing that no "one best way" exists. Within the same framework, and in order to investigate the call centers competition in the call center SSC, [45] built a theoretical model that use an index collecting various agreement parameters. The proposed model is used to split this SSC market and to determine the contract prices. The findings helped the call centers to detect and focalize on their market niches. Clients used it to determine the cost of their contracts and negotiate with the call centers for better deals. Concerning the energy field, [46] studied theoretically and empirically, the distinctiveness of the SSC configurations in the energy efficiency retrofitting services sector (EERS). Three perfect types of SSC configurations were discovered based on the scope and size of the energy efficiency-retrofitting project. In addition, the study have investigated the influence of these configurations on the SSC performance. Along the same lines, [47] established a review of UK current and past strategies, and gave a timeline of effects adjust strategies has had upon the EERS sector within the UK. These strategies evaluation, were focusing in the way how many strategy tools communicate and affect SSC and end users from various angles.

Regarding the retirement field, [48] proposed a model that focused on the pension scheme structure and communication, to find out how they affected the pension contribution and participation rates at the SSC levels. Reference [49], focused on the aged citizens retirement security, it interested in the opportunity of covering all inhabitants in a region; this study outlined and analyzed the possibilities of the actual pension conditions in the Czech Republic.

This work's outcome is composed by the description of the conditions for the public pension fund to perform, and a particular solution that expressed an actuarial model of the regional pension fund functioning. In the same vein, [50] focused on the link between the no-contribution in pension schemes and the financial optimism. The study concluded that the possibility of self-employed subscribing to private pensions schemes, or the possibility of employees subscribing employer run pension plans are reduced by the financial optimism. Their study proposed that both self-employed individuals and employed who are financially optimistic could confront the negative effects of pension shortfall and low pensions income when they retire. While [51] analyzed an extrapolate multi-period mean–variance portfolio selection problem within the game theoretic framework for a defined-participation pension plan member. Reference [52] focused in the impact of the new rural pension plans on the labor supply behavior of the elderly, it used pooled data from two waves of the China Retirement and Health Longitudinal Study and an analytical framework for regression discontinuity design combination and difference in various method, the outcomes explain that pension receipt from the new rural pension plan program does significantly induce the elderly to withdraw from the labor market. Furthermore, the authors of [53] focused on inspecting the movement from defined benefit to defined participation pension plans, and on this change interface with accounting, and using a critical perspective they reflected on this interface including how the change is accounted for in corporate reporting narrative. The authors of [54] investigated the link between the level of a return guarantee in an equity-linked pension plan, and the percentage of an investor’s contribution needed to finance this guarantee by considering three schemes types: surplus contribution, participation guarantee and investment guarantee. They found a negative (and for two contract specifications concave) relationship between the contribution in the surplus return of the investment strategy and the guarantee level in terms of a minimum rate of return. Besides, the introduction of the probability of early contract termination (e.g. due to the death of the investor) has no qualitative and very little quantitative effect on this relationship and as a last example of researches related to this field, [55] presented the first study that quantified the redistributive impacts of a rule change by a real world scheme (the Universities Superannuation Scheme, USS) where the sponsor covers the pension promise. They concluded that the pre-October 2011 scheme was not viable in the end, while the post-October 2011 scheme is probably viable in the end, but faces medium term problems.

In these different aforementioned works, and in order to deal with various problematic issues, the pension scheme is modelled in an actuarial mathematical way, whereas this chapter considers the SSC side of the retirement field, and using a methodology that combined different methods, this SSC is modelled and analyzed, considering the case study of the Moroccan retirement scheme.

2.1.2. The Moroccan retirement pension

Retirement in Morocco is provided by five general schemes. The National Social Security Fund (NSSF) manages a compulsory one, for employees in the private sector, and which. A compulsory scheme for the incumbents employers of the state (civilian and military) represented by the Moroccan Pension Fund (MPF). The Collective Retirement Allowance

Scheme (CRAS), which is compulsory for the staff of public establishments and temporary employees of local authorities. As well as a voluntary supplementary scheme for private sector employees managed by the Moroccan Inter-professional Fund of Retirement (MIFR). In addition, there are two internal funds, the National Office of Water and Electricity (NOE - EB), the water and electricity distribution Boards and the Bank Al-Maghreb. These funds are managed differently and their method of pension calculation is not the same.

In this chapter, the studied organism is the MPF. This fund manages the civil pensions scheme, the military pensions scheme, the supplementary pension scheme ATTAKMILI, and the non-contributory pension schemes. When treating the civil retirement scheme, the processing steps differ according to the budget type of the affiliate administration. Therefore, a distinction between "the general budget" and "the autonomous budget" is made. Actually, when one refers to the general budget of the State, reference is made to what would constitute nearly 85% of the budget law and which traces the needs of all the ministries and institutions of the country. On the other hand, as for public establishments for inter-municipal co-operation, they have a so-called autonomous budget, which is voted by the bodies responsible for the establishment, as is the case for the local authorities. In this work, the focus is on the civil retirement scheme and especially the general budget.

Among the challenges the retirement scheme faces on one hand there is the need to make this system last longer. Whiting this framework, in Morocco a reform was adopted at the end of 2016, which concerned only the civil retirement scheme. This reform has mainly affected three points: the contribution to the scheme, the retirement age, and the calculation of the pension. Another one that will aim at a merger between the different funds can follow it. The other main challenge is the difficulty of managing the continuity between the salary and the retirement pension, which means the difficulty of offering this service (the retirement pension) to the customer (the pensioner) at the right time (first month of his retirement). In this work, this challenge is approached from a service supply chain side, as an example of continuity issues in SSC, and which provide us an over-all analysis of this system, and consequently enable us to put strategies to address the root causes of this problem[4].

The remainder of this chapter is organized as follow: the next section traces the results of the studied supply chain exploration. Section 3 details the evaluation of the retirement supply chain. Section 4 presents the result of the improvement of the studied supply chain. This chapter is concluded in section 5.

2.2. Exploration of the retirement supply chain

2.2.1. Strategic level

At the strategic level, SCOR defines the supply chain contents and its context. As shown in Fig. 2.1 the studied organization is the MPF, its customer is the pensioner, and its supplier is the contributing affiliated. The affiliated manages the process Deliver (sD) that outlines the management rules for its contribution to the pension scheme. The MPF manages three processes, Source (sS) that outlines the management of the affiliation and the contribution; Make (sM) that outlines the management of the rights liquidation, Deliver (sD) that outlines the management of the pensioner's payment. The pensioner manages the Source (sS) process that outlines its benefits of a pension. The process Plan (sP) is the one that balance aggregate demand and supply to develop a course of action, which best meets sourcing, production, and delivery requirements.

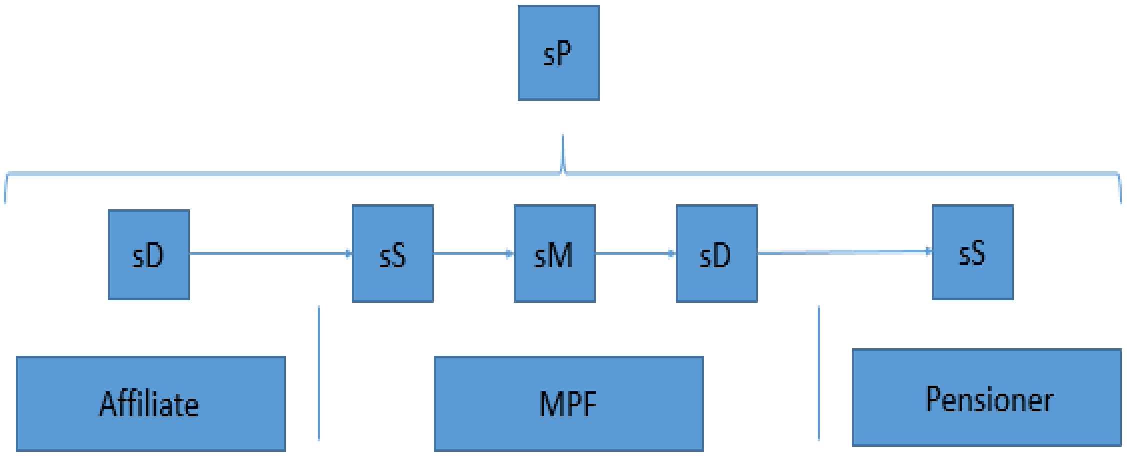

Figure 2.1 The Strategic level model of the Moroccan retirement SC

2.2.2. Tactical level

The tactical level is a reflection of the SC strategy adopted by the organization to conduct its operations, in this case there is neither a stocked product nor an engineer-to-order product, the studied product (the retirement pension) is a make-to-order product, so this level processes are: sS2 (Source Make-to-Order Product), sM2 (Make-to-Order), sD2 (Deliver Make-to-Order Product). We note that the processes Plan shown in Fig. 2.2 are sP1 (Plan Supply Chain), sP2 (Plan Source), sP3 (Plan Make), sP4 (Plan Deliver).

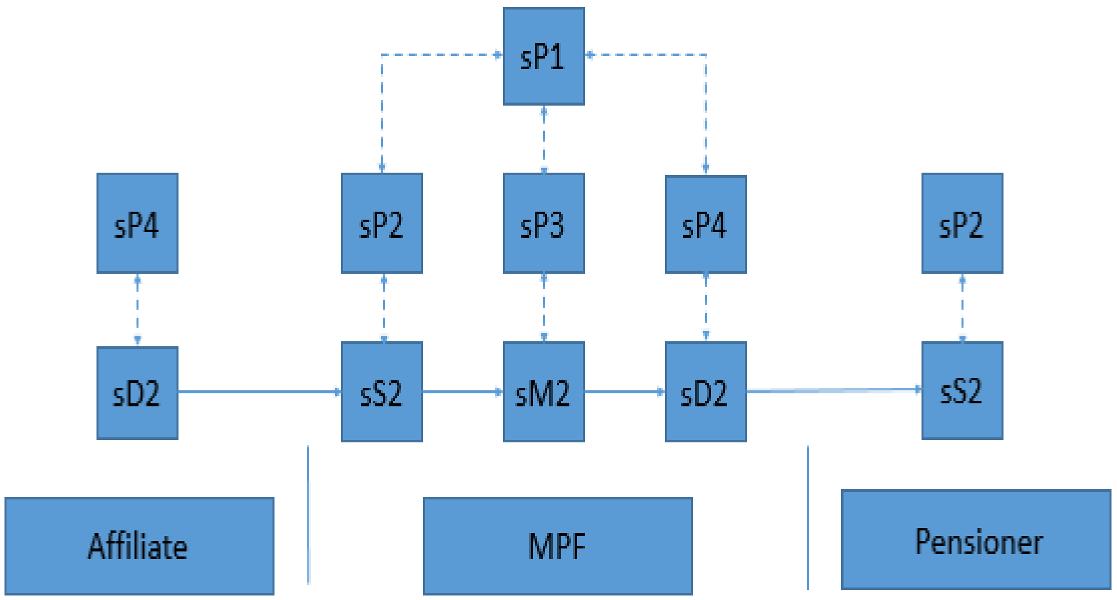

Figure 2.2 The Tactical level model of the Moroccan retirement SC

2.2.3. Operational Level

At the operational level, organizations can specify the activities of sub-processes, best practices, the functionality of the software and existing tools. For this case, the MPF is the studied company, so we detail at this level the process sM2, sS2, sD2.

2.2.3.1. sS2 Source Make-to-Order product:

The following figure (Fig. 2.3) describes the details of the process sS2 as defined at the third level of SCOR; and which corresponds in this case to the affiliation and the contribution management processes. This level of the SCOR model details the process sS2 into five process elements. In this studied case, the affiliation and contribution process consists of four elements. We therefore chose among the five elements the four ones that correspond functionally to this case, and which are sS2.1, sS2.2, sS2.3 and sS2.4. sS2.1 Schedule Product Deliveries corresponds to the reception and the allocation of the contributors' files, it receives as input information from the processes Sourcing Plans sP2.4 and Logistics Selection sES6. As output, sS2.1 executes the process sP2.2 Identify, Assess and Aggregate Product Resources. sS2.2 Process Element: Receive Product corresponds to the processing of the contributor's files. As output, sS2.2 requests the processing verification by executing the process sS2.3. sS2.3 Verify Product corresponds to the verification of the processed files, it receives as input the execution request from sS2.2. sS2.3 Transfer Product corresponds to the processed and verified files sending to the liquidation service. As output, sS2.3 executes the processes sED.4: Manage Finished Goods Inventories and sES.4 Manage Product Inventory the processes of establishing inventory information. For Services - as this case - this may include tracking the number of service providers (in our case contributors) and the financial resources committed (in our case contributions) at any given point in time.

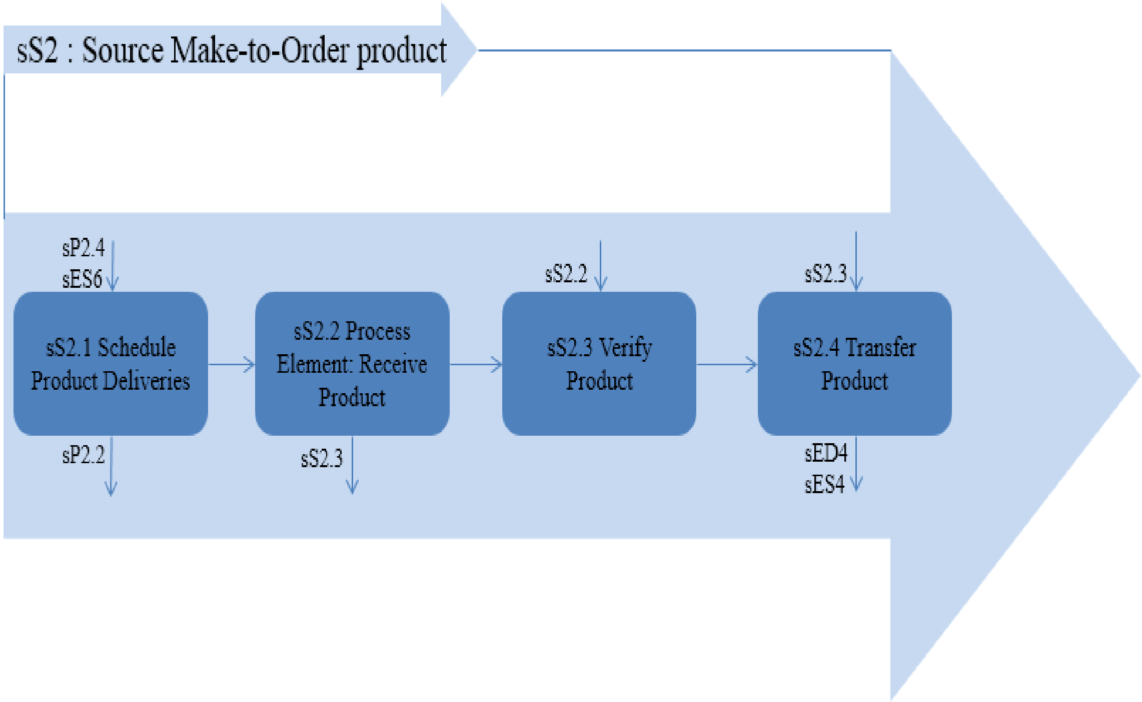

Figure 2.3 The Source Make-to-Order product model for the Moroccan retirement SC

2.2.3.2. sM2 Make-to-Order:

The following figure (Fig. 2.4) shows the details of the process sM2 as described at the third level of SCOR; and which corresponds in this case to the rights liquidation process. This level of the SCOR model details the process sM2 into seven process elements. In this case study, the rights liquidation process consists of five elements. We therefore chose among the seven elements the five ones that correspond functionally to this case, and which are sM2.1, sM2.2, sM2.3, sM2.5 and sM2.6. sM2.1 Schedule Production Activities corresponds to the reception and the allocation of the liquidation files, it receives as input information from the processes sP3.4 Establish Production Plans and sEM5Manage Make Equipment and Facilities. As output, sM2.1 executes the process sP3.2 Identify, Assess and Aggregate Production Resources. sM2.2 Issue Sourced/ In-Process Product corresponds to the rights constitutions. As input sM2.2 receives rules and calculation information from sM2.1. As output, sM2.2 gives feedback information to sM2.3. sM2.3 Produce and Test corresponds to the rights liquidation. sM2.5 Stage Finished Product corresponds to the rights concession, at this stage all the liquidated files are edited in a decision. As input, it receives data and files from the execution of sP3.4 Establish Production Plans. sM2.6 Release Finished Product to Deliver corresponds to the liquidated and conceded files sending to the Payment service. As output, it give the payment plan by executing the process sP4.4 Establish Delivery Plans.

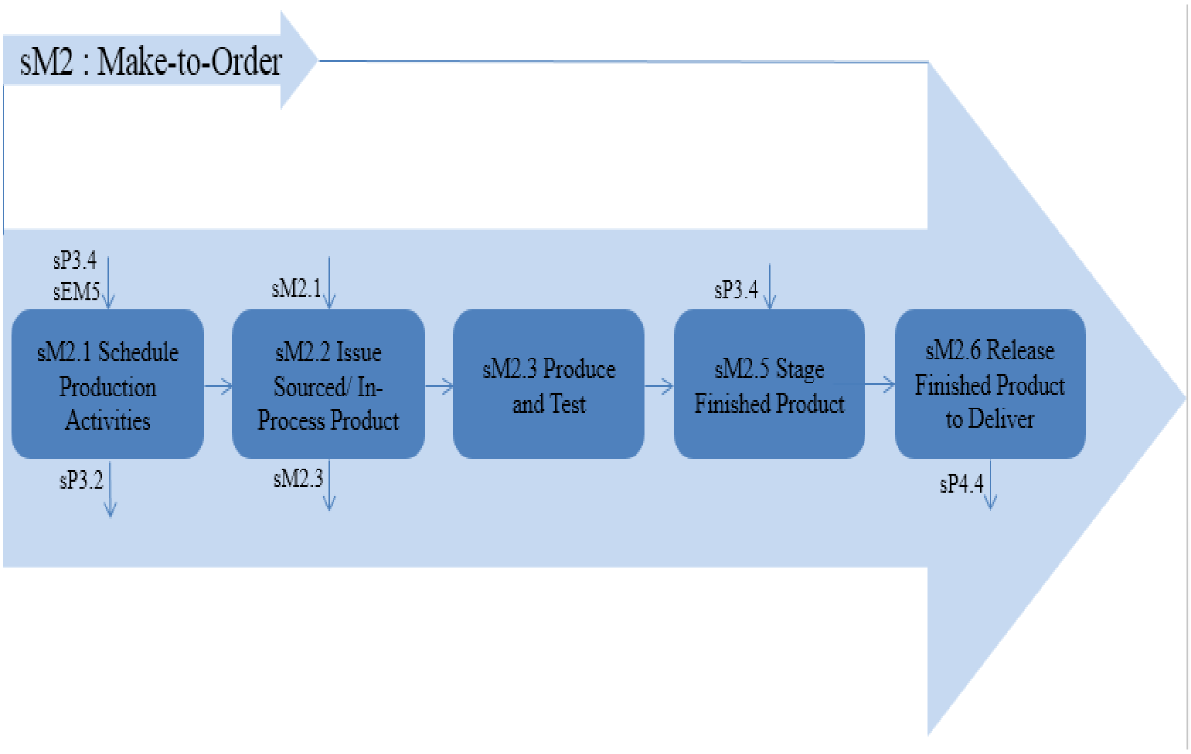

Figure 2.4 The Make-to-Order model for the Moroccan retirement SC

2.2.3.3. sD2 Deliver Make-to-Order product:

The following figure (Fig. 2.5) shows the details of the process sD2 as described at the third level of SCOR; and which corresponds in our case to the payment process. This level of the SCOR model details the process sD2 into fifteen process elements. In our case study, the payment process consists of six elements. We therefore chose among the seven elements the six ones that correspond functionally to our case, and which are sD2.2, sD2.4, sD2.10, sD2.11, sD2.13 and sD2.15. sD2.2 Receive, Configure, Enter and Validate Order corresponds to the reception, control and integration processes, it receives as input the necessary order rules and information (for our case it receives information such as account numbers) by executing the process sED1 Manage Deliver Business Rules. sD2.4 Consolidate Orders corresponds to the decree of the day and the closing of the deadline process this process execution prevents the data updates at the level of the liquidation to impact the payment processing. Only data loaded before the deadline end is supported. sD2.10 Pack Product corresponds to the edition of decisions process. sD2.11 Load Product & Generate Shipping Docs corresponds to the validation and sending to accountants process. As input, sD2.11 receives the bank transfer parameters and documentation from the execution of the processes sED6 Manage Transportation and sED8 Manage Import/Export Requirements. As output, it gives the bank transfer history for the sED8 process. sD2.13 Receive and Verify Product by Customer corresponds to the commitments control process. sD2.15 Invoice corresponds to the accounting process.

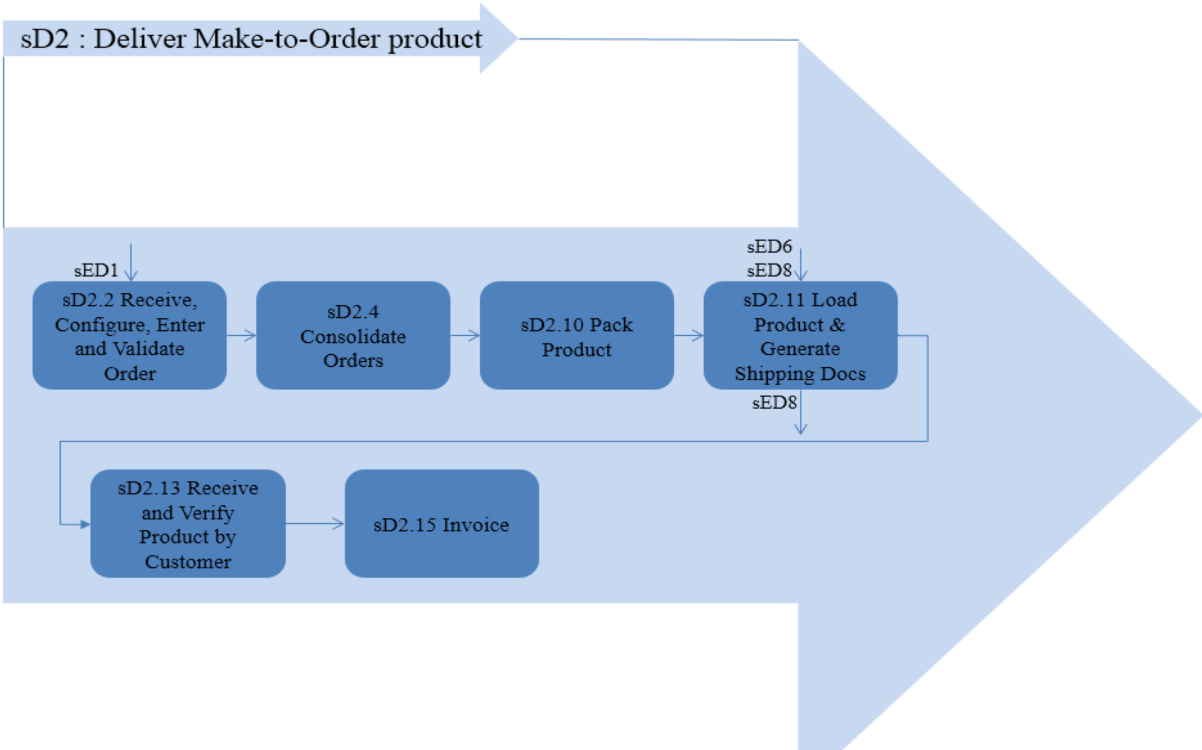

Figure 2.5 The Deliver Make-to-Order product model for the Moroccan retirement SC

2.3.Evaluation of the retirement supply chain

2.3.1. Define phase

At the real-time level, the focus is on the operational study of the retirement records circulation processes within the MPF, so the itinerary of each file from its reception by the department concerned until its final archiving is traced. This study also concerns the intermediate stages of the each file processing as well as the interveners in each step, which allowed to define the number of intervening in the processing of files and to stop all the documents generated following the liquidation of records. Among the pension two types (civil and military), this study is based on ‘the management of civil pension rights’. According to figure 2.6, ‘the management of civil pension rights’ process is composed of six lanes: “head of career tracking service”, “Dispatching”, “Affiliation”, “Contribution”, “Liquidation”, and “Concession”. The process is initiated by the start event "receive folders", and it ends by the execution of one of the three end events: "folder sent to the organization", "Non-compliant folder", or "conceded folder". Once the folders are received from the different affiliate's administrations, the head of career service assign these folders to the affiliation officers, and then he designates a monitoring agent who will be responsible for the follow-up of the processing of folders, he starts by dispatching the folders to the assigned officers. The affiliation officer studies the folder, if the folder is not complete (all papers are received) he rejects it, if not he validates it, and then he certifies the affiliation data before printing the certification sheet. Then he sends the certified folder with its certification sheet to the concerned contribution officer and a copy of it to the monitoring agent. Once the contribution officer receives the folder, he verifies the affiliation certification, if it is valid, he certifies the contribution, if not he rejects the certification. The liquidator studies the certified folder (affiliation and contribution), if it is not valid he reject the folder. If a folder is Rejected before the certification and / or before the liquidation, the monitoring agent establishes a rejection letter that describes the rejection causes; this letter is signed by the head of career service before being send to the concerned organization. For each rejected folder, once it is sent to the organization, the management of civil pension rights ends by executing the error end event "folder sent to the organization". For the valid certified folder, the liquidator verifies the compliance with the rights, if this compliance is not valid he rejects the folder, in this case the management of civil pension rights ends by executing the error end event “Non-compliant folder”. For the folders with valid rights compliance, the liquidator validates the legal conditions, and then he runs the liquidation via the system (which will calculate the pension amount and generate a pension number) before printing the liquidation report, then he sends the folder for verification to the verifier. In case the verifier rejects the liquidation, the liquidator reviews the folder and repeats the verifier validates the liquidation operation until it. Once the verifier validates the liquidation, he concedes the folder (which will generate a decision number) and finally generates the decision. In this case, the management of civil pension rights ends by executing the end event “conceded folder”.

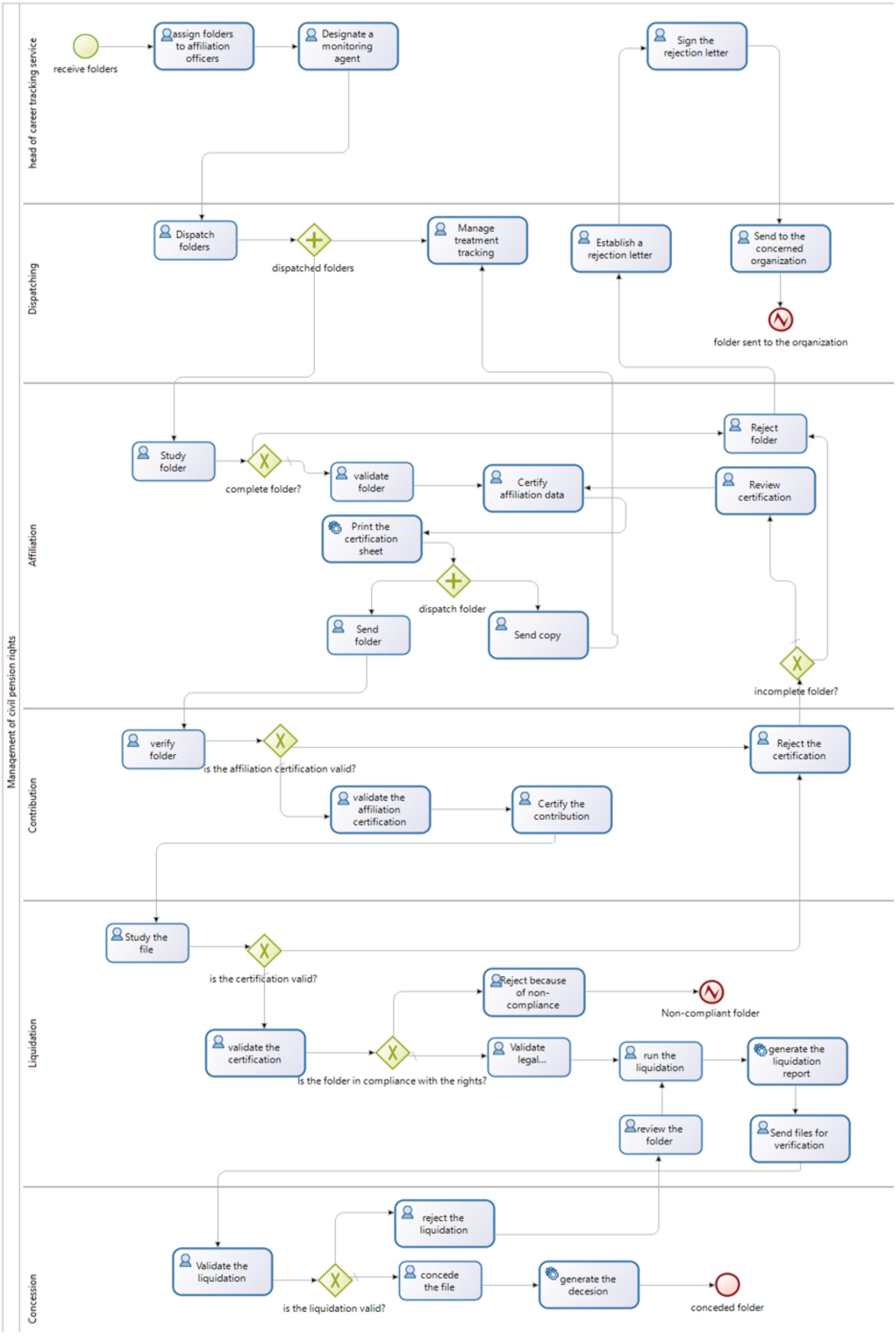

Figure 2.6 The 'management of civil pension rights' business process model

2.3.2. Measure phase

In this step, we take advantage of BPM, which is both a management discipline, and a set of technologies aimed at automating organizations' key business processes, as defined in [56], to execute the simulation. Simulation can be applied for different purposes, namely prediction, performance, entertainment, training, education, confirmation and discovery [2]. In this phase, it is applied to determine how the process currently performs. When a simulation is run, a specified number of iterations over a specified period are run either with simulated data or with assigned probabilities. The load profile used in this work is composed of the start date 01-06-2018 at 08:30 am, the end date 31-12-2018 at 04:30 and 100 instances. The objective is to simulate the case of affiliates who are going to retire in the end of the year 2018. Giving that the affiliate's administrations have to send their folders six months before their retirement, we choose the start date on June 2018. It is considered that a folder is received late if the reception date is greater than the retirement date minus 3 months, in our case, a folder is late if it is received after September 30, 2018. A received folder may be complete or incomplete (lack of a files), and during its processing, a folder may not be subject to a revision, or it may be subject to more than one revision. In this study, we choose five as a maximum possible number of revisions. Therefore, to characterize a folder, we create the business object 'dossierState' (LONG bonitaBPMid; DATE receptionDate; BOOLEAN complete; INTAGER revisionNbr;). Six scenarios are considered, as shown in Table 1. In keeping with our profile, we considered a date that meets the deadlines, and one that represents a late reception, we also considered whether the file is complete or not, and the case of a treatment without revision and the other with maximum number of revisions.

Table 2-1 The 'management of civil pension rights' simulation scenarios

Scenario	Reception date	Complete	Revision number
Scenario 1	01/06/2018	Yes	0
Scenario 2	01/06/2018	Yes	5
Scenario 3	01/06/2018	No	-
Scenario 4	01/11/2018	Yes	0
Scenario 5	01/11/2018	Yes	5
Scenario 6	01/11/2018	No	-

The simulation is based on a reception of 1000 folders (the average number of received folders in 6 months). The reception respects the period of our simulation profile. The following table (Table 2) presents the minimum, the average and the maximum execution time (by hours) of the main activities of our process, and which are: Certify affiliation, certify contribution, Run the liquidation, Review the folder, Concede the file. (Sc: Scenario, Mi: minimum, A: average, Ma: maximum).

Table 2-2 The activities execution time per scenario

Scenario	Certify affiliation data			Certify the contribution			Run the liquidation			Review the folder			Concede the file		
	Mi	A	Ma	Mi	A	Ma	Mi	A	Ma	Mi	A	Ma	Mi	A	Ma
Sc 1	293.667	250	450	722.083	1239	1499	314.5	539	630	0	0	0	165.1	201	320
Sc 2	293.667	250	450	722.083	1239	1499	375.8	596	697.12	38.5	93	185.88	199.12	241.4	385
Sc 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sc 4	293.667	250	450	722.083	1239	1499	314.5	539	630	0	0	0	165.12	201	320
Sc 5	293.667	250	450	722.083	1239	1499	375.8	596	697.12	38.5	93	185.88	199.12	241.4	385
Sc 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2.3.3. Analyze phase

This phase allows to closely examining the process based on the result of the previous phases. So, according to the BPMN model simulation, we conclude that:

- The reception date does not affect the duration of processing, but it does affect the date on which the pensioner receives his first pension. A folder received late, given the duration of the processing, may be paid late (reception on 01/11/2018 in a lot of 1000 folders: 3000 hours on average).
- The scenarios that take more time are 2 and 5, and therefore the revision impact the duration of processing, knowing that 5 was considered as the maximum number of revisions.
- When an incomplete folder is received, the activities presented in the table are not executed, and therefore an incomplete folder is not conceded.

Based on these results, we note that the two parameters to be considered in the development of our dashboard are "incomplete folder reception" and "folder revision". So apart from not receiving the affiliate's folder, the cause tree below presents Figure 2.7, the reasons behind the discontinuity between the salary and the pension.

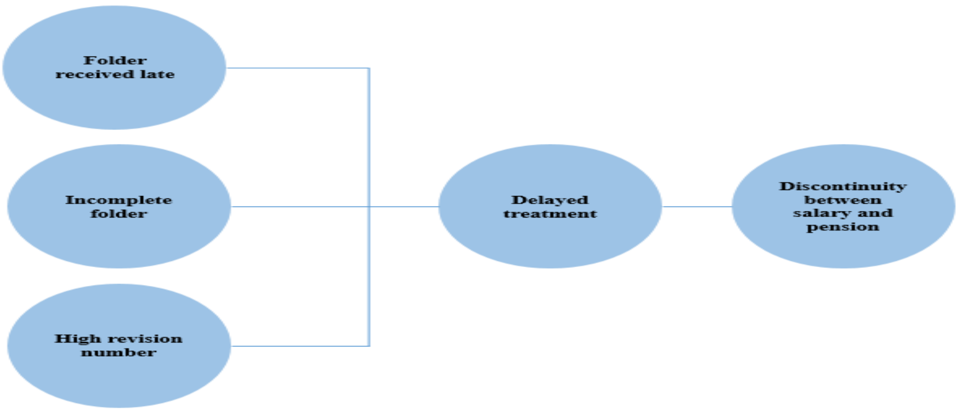

Figure 2.7 The cause tree diagram for delayed treatment

2.3.4. Improve phase

This phase is about mitigating the root causes of the problem. For this, we chose to integrate one of the characteristics of the smart supply chain explained in [7]. According to [7], the smart supply chain has three core characteristics: Interconnected, Instrumented, Intelligent. In this work, the focus is on the interconnectivity characteristic. Besides creating a more holistic view of the supply chain, this extensive interconnectivity will also facilitate collaboration on a massive scale [7]. For this, information flows will be created between the different actors of this SSC, namely: MPF, the affiliate's administration, pensioner. Which will leads us to the second level model (SCOR) presented in Figure 2.8.

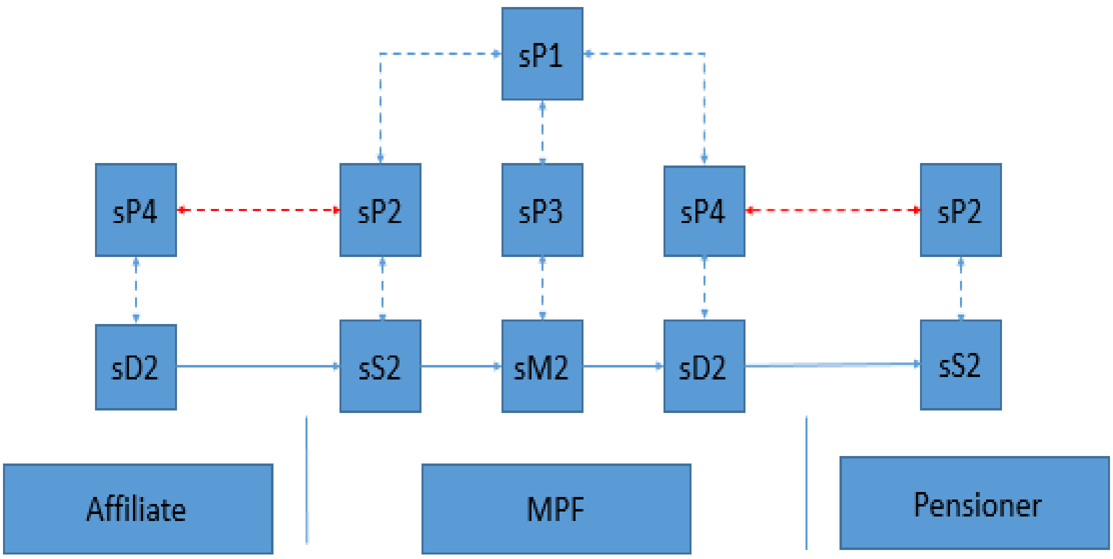

Figure 2.8 The Tactical level model of the smart Moroccan retirement SC

Concerning the business process 'the management of civil pension rights' of the SSC real-time level, this change is reflected on the BPMN model by the addition of the lane ‘Control’ which groups the activities related to this interconnectivity as shown in Figure 2.9. At the beginning of each month, the agent of control elaborates a list of affiliates who will be retired in 6 months, and then he compares the folders contained in this list with the folders sent by the different administrations. For the received ones, he verifies the content; if no files is missing, he sends the folder for processing, if the folders is not complete, he elaborate and send a list per administration that contains missing files per affiliate. Concerning the files not received, as long as the duration of the delay does not exceed 3 months, he elaborates and sends reminders letters to administrations, containing the list of the not received folders. For affiliates who will be retired in less than 3 months and whose files are not received, he sends letters to affiliates informing them of the files list to provide.

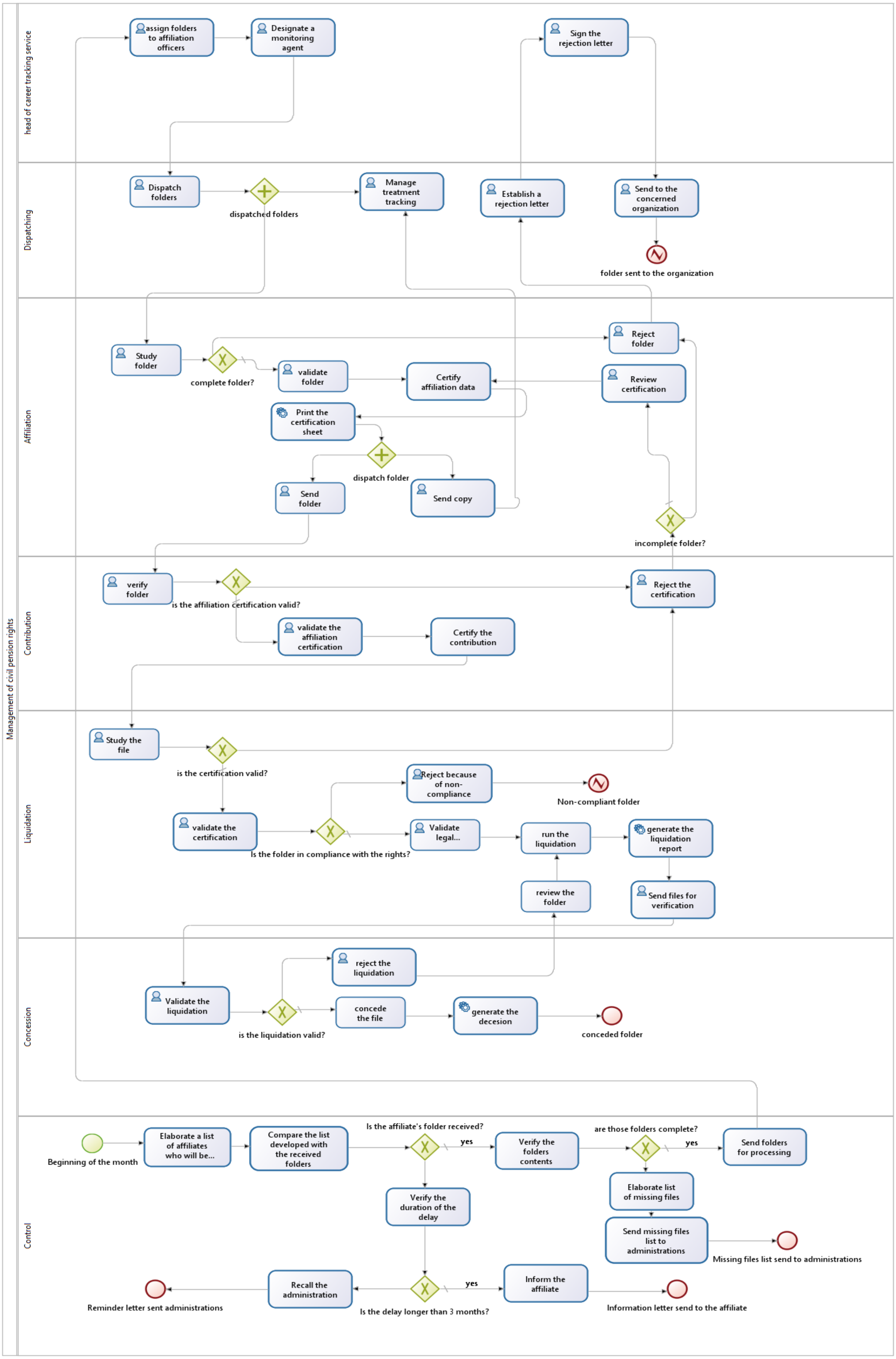

Figure 2.9 The improved 'management of civil pension rights' business process model

2.3.5. Control phase

The last phase of Six Sigma's DMAIC model is the Control phase. This phase allows us to continually verify if the actions created in the previous phase are well maintained. For this, a dashboard composed of Steering and Performance indicator was elaborated to be checked monthly. As a part of our goal to evaluate the continuity between the salary and the pension, we are interested in the responsiveness attributes, which means in a general way the speed at which tasks are performed, the speed at which a SSC provides services to the customer. SCOR manage performance using two major elements: Performance Attributes and Metrics [1]. To express a strategy, the performance attribute is used as a grouping of metrics. Among those proposed, this work focuses on 'Responsiveness' (The speed at which tasks are performed) and 'Reliability' (The ability to perform tasks as expected). The chosen metric for responsiveness is 'Order Fulfillment Cycle Time'. It represents the time passed between the moment a customer places the order (in our case: the moment of receiving a folder) to the moment the order is fulfilled (in our case: the moment the folder is conceded). To calculate the 'Order Fulfillment Cycle Time' SCOR specifies: [Sum Actual Cycle Times for All Orders Delivered] / [Total Number of Orders Delivered] [57]. 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 pensions conceded before the 25th of the first month of retirement' and which can be calculated for each trimester as follow: [the number of folders conceded before the 25th of the first month of retirement since the beginning of the period] / [the total number of folders received before the end of the period], for example, for the A trimester 'January , February , March' the indicator will be [the number of folders conceded before the 25th of the first month of retirement since the 1st January] / [the total number of folders received before the 31th March].

Reliability focuses on the predictability of the outcome of a process. The chosen metric is 'Perfect Order Fulfillment'. To calculate the 'Perfect Order Fulfillment' SCOR specifies [Total Perfect Orders] / [Total Number of Orders] [58]. The indicator that corresponds functionally to the 'Perfect Order Fulfillment' is:

- 'Rate of processed folders' and which can be calculated for each trimester as follow: [the number of folders processed] / [the number of folders that must be processed].

And based on the simulation results we propose:

- 'Late folders rates' and which can be calculated for each trimester as follow: [Number of folders received after retirement] / [the total number of folders received before the end of the period]
- 'Revised folders rates' and which can be calculated for each trimester as follow: [Number of revised folders] / [the total number of folders received before the end of the period].

And to recapitulate Table 2.3 presents the dashboard that sum up these indicators.

Table 2-3 The Moroccan retirement SC control Dashboard

The indicator source	The indicator title	The calculation formula	The indicator type	The calculation periodicity
SCOR - 'Perfect Order Fulfillment'	Rate of processed folders	[the number of folders processed] / [the number of folders that must be processed]	Steering indicator	A trimester
SCOR - 'Order Fulfillment Cycle Time'	Rate of pensions conceded before the 25th of the first month of retirement	[the number of folders conceded before the 25th of the first month of retirement since the beginning of the period] / [the total number of folders received before the end of the period]	Steering indicator	A trimester
Simulation	Late folders rates	[Number of folders received after retirement] / [the total number of folders received before the end of the period]	Performance indicator	A trimester
	Revised folders rates	[Number of revised folders] / [the total number of folders received before the end of the period]	Performance indicator	A trimester

2.4. Improvement of the retirement supply chain

2.4.1. Supply chain modelling with L-SCOR

At the second level of L-SCOR, Figure 2.10 presents the retirement SSC modelling. We note that the planning processes interact with the learning process sL3 "Learn Make" that describes the management of adaptability for rights liquidation.

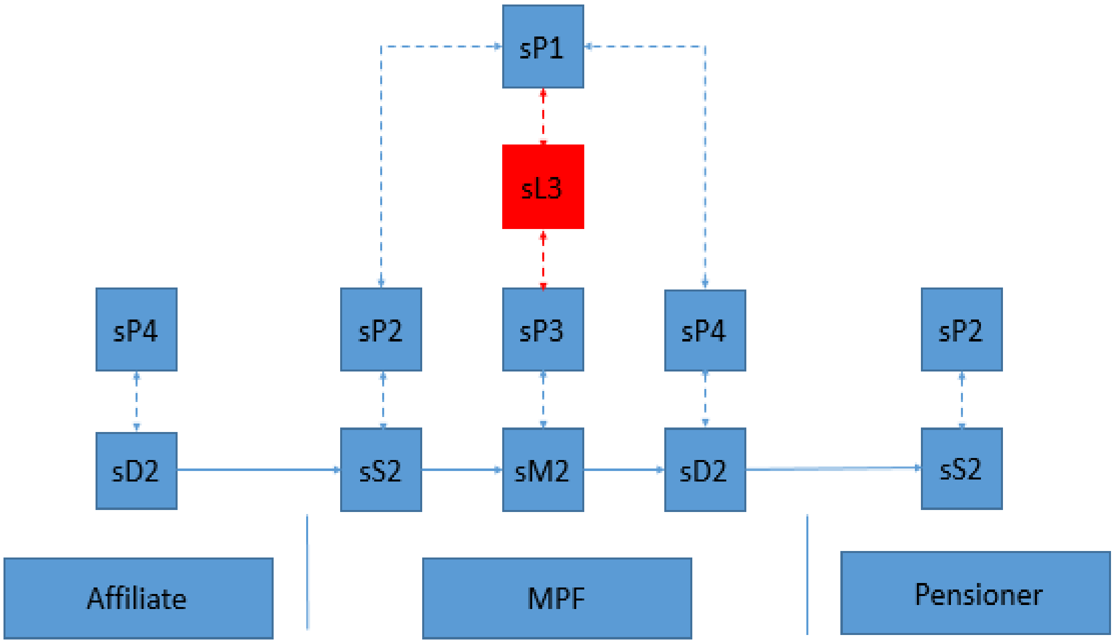

Figure 2.10 The Tactical level model of the self-adaptive Moroccan retirement SC

Concerning the studied business process, which is in this case “the civil pension rights management" of the self-adaptive retirement SC presented by Figure 2.11, we notice on the BPMN model the addition of the script activity “Execute recommendation system". This one applies the Q-learning algorithm, and gets the necessary data for its execution from the activity "Study the file", returning thus the optimal combination (state, action) for the treatment of the current pension file.

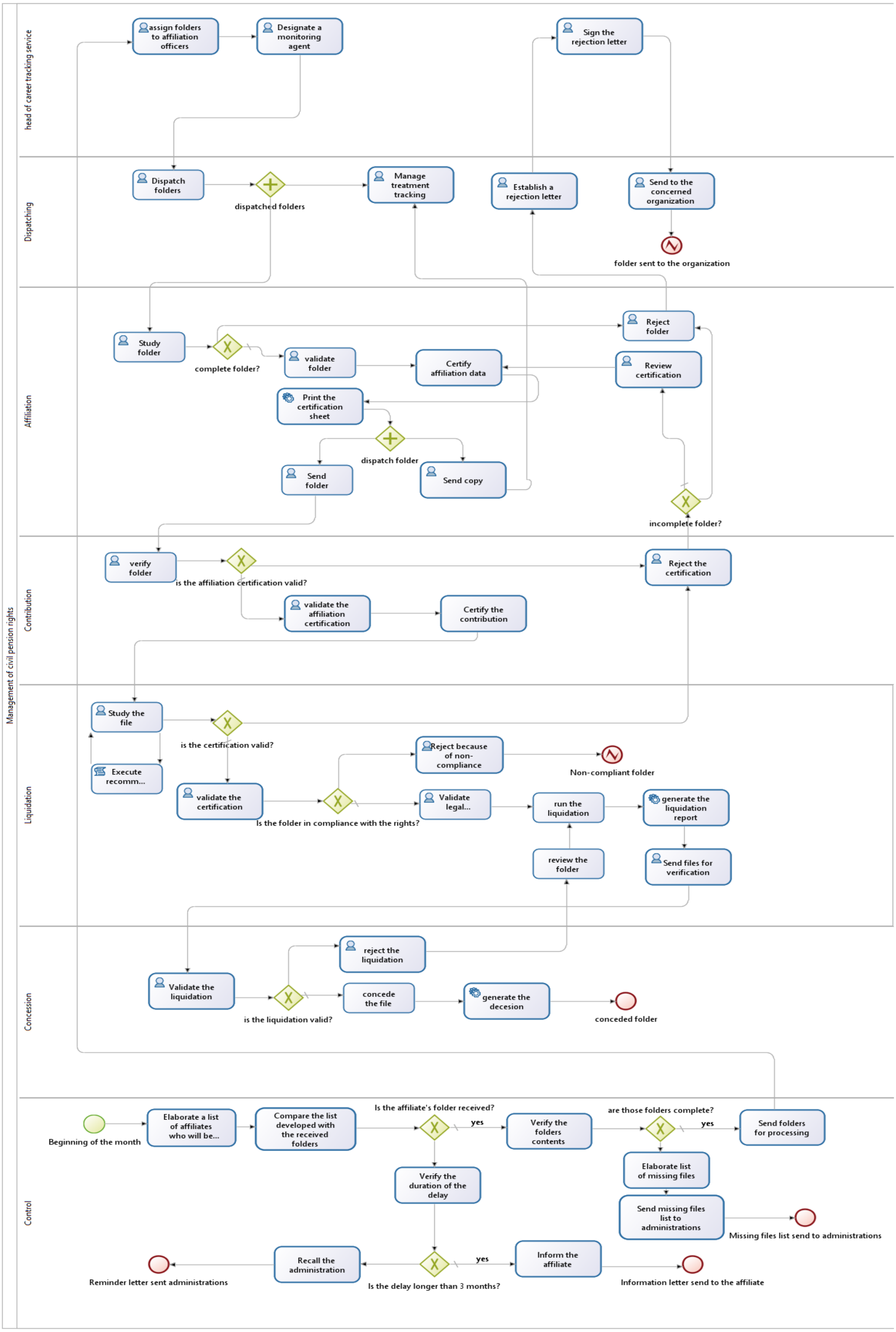

Figure 2.11 The self-adaptive 'management of civil pension rights' business process model

2.4.2. Implementation and results analysis

2.4.2.1. State Space and Actions

The first step to apply Q-Learning algorithm is defining the state space. In real cases, we are focusing to obtain results in a limited period. If the state space is very large, the algorithm will take too long to converge. The treatment steps through which a retirement folder passes, trace all the possible states for this agent. The possible states of a retirement folder are as follows: 'Received', 'Certified affiliation', 'Certified contribution', 'Liquidated', 'Revised', 'Conceded', 'Rejected', and 'Incomplete'. An identifier is associated with each state respectively as follows: ‘S0: Received', ‘S1: Certified affiliation', ‘S2: Certified contribution', ‘S3: Liquidated', ‘S4: Revised', ‘S5: Conceded', ‘S6: Rejected', ‘S7: Incomplete', ‘S8: Stuck in a state’, ‘S9: Returned to a previous state’, and ‘S10: Skipped a treatment step’. S the space of states is the set of these identifiers, S = {S0, S1, S2, S3, S4, S5, S6, S7, S8, S9, S10}. The possible operations on the retirement folder treatment present all the agent actions as follows: 'Reject', 'Certify Affiliation of received folder', 'Certify contribution for certified affiliation folder', 'Review certified contribution folder', 'Liquidate certified contribution folder', 'Concede liquidated folder', ‘Stay in the same folder state’ and ‘Return to a previous state’. An identifier is associated with each action respectively as follows: 'A0: Reject', 'A1: Certify Affiliation of received folder', 'A2: Certify contribution for certified affiliation folder', 'A3: Review certified contribution folder', 'A4: Liquidate certified contribution folder', and 'A5: Concede liquidated folder'. The actions space A is the set of these identifiers A= {A0, A1, A2, A3, A4, A5}.

2.4.2.2. The Reward Function

The purpose of choosing an action transitioning to some state is illustrated by the reward function that plays a key role in learning speed. The reward value can be negative or positive. A negative reward value is used to express a penalty for an undesirable action. The rewards that are generated after a state transition are a short-term outcome. Because of including future rewards in the evaluation of algorithm actions, it may return a low immediate reword for an action linked to a high Q-value. A fixed reward function is implemented generating static rewards. Table 2-4 describes the used reward function.

Table 2-4 Reward function for the 'retirement folder' agent

State	Reward
S0: Received	0
S1: Certified affiliation	10
S2: Certified contribution	10
S3: Liquidated	10
S4: Revised	1
S5: Conceded	50
S6: Rejected	0
S7: Incomplete	0
S8: Stuck in a state	0

S9: Returned to a previous state	-1
S10: Skipped a treatment step	0

2.4.2.3. The Value Functions

The Q values of state-action pairs is stored in Q-table. All values stored in the table are initially set to zero. The rows in the table represent the retirement folder's states, and the columns represent the action corresponding to the given state. During training, each entry in the table is populated by updating the Q values. After sufficient training, the Q values converges. The updating equation is shown below:

$$Q(s, a) \leftarrow \alpha \times (r + \gamma \times \max a' (Q(s', a'))) + (1 - \alpha) \times Q(s, a)$$

Where 's' is the current joint state, and 'a' is the selecting action. 's'' is the next state that the retirement folder transfers to from the current state after performed by the action 'a'. 'α' is the learning rate, it specifies to what extent recently learned information supersedes old information. 'γ' is the discount factor, it determines the importance of future rewards. After training, the retirement folder is able to execute the best action for each state.

2.4.2.4. The Results

The search table where the agent determines the maximum anticipated future rewards for action at each state is called a Q-table. This table will lead the agent to the best action at each state. In the Q-table, the columns represent the available actions and the rows represent the states. Every Q-table outcome represents the utmost envisaged a future reward that the agent will obtain if it executes that action at that state. In order to learn and improve each value of the Q-table in every repetition of the iterative process, the algorithm "Q-learning" is executed. Before exploring the environment by the agent, the Q-table accords identical arbitrarily fixed values. While the agent still in the exploring step, the Q-table attributes a better and better estimation by repeatedly updating Q(s, a). Exploration and exploitation are the two strategies of the training process. Exploration is finding more information about the environment and exploitation is exploiting known information to maximize the reward. The agent aim is to maximize the expected cumulative reward. However, the agent may trap in local optimum and fail to find a feasible solution. That being the case, Q-learning uses what is called "the epsilon greedy strategy". An exploration rate ϵ is specified as the rate of steps that the agent takes actions randomly. At the beginning of the mission, ϵ rate have to be at its maximum value, since the agent ignores the Q-table values, it needs to do a lot of exploration by arbitrarily choosing its actions. Therefore, a random number N is generated. If $N > \epsilon$, the agent will then do the exploitation, meaning that the agent uses what is already known to select the best action in each step. Else, the agent will do the explorations. The idea is that the agent must have a big ϵ rate at the beginning of the Q-function training. As the agent explores the environment, the ϵ rate reduces and the agent begins the environment exploitation. Then, reduce ϵ rate gradually since the agent starts being more confident at estimated Q-values. The Q-Learning used parameters are defined in table 2.5 as follow.

Table 2-5 Q-Learning used parameters for "the retirement folder" agent

Parameter	Value
Learning rate	0.05
Discount factor	0.7
Initial Q-value	0
Initial value of ϵ	0.6
ϵ Decay rate	0.005

The Q-table returned by the recommendation web service for the 'retirement folder' agent is shown in table 2.6.

Table 2-6 The returned Q-Table for "the retirement folder" agent

	A0	A1	A2	A3	A4	A5
S0	0	9.745	0	0	0	0
S1	0	0	9.745	0	0	0
S2	0	-1.345	0	1.859	9.745	0
S3	0	-1.354	-1.354	1.859	0	49.99
S4	0	-1.354	-1.354	1.859	9.745	49.99
S5	-1	-1.354	-1.354	-1.354	-1.354	0
S6	0	0	0	1.859	0	0
S7	0	0	0	1.859	0	0
S8	0	0	0	1.859	0	0
S9	0	0	0	1.859	0	0
S10	0	0	0	1.859	0	0

The optimal strategy imposed by the recommendation web service for the "retirement folder" agent according to the returned Q-Table is as follows:
OS = {(S0, A1), (S1, A2), (S2, A4), (S3, A5), (S4, A5), (S5,A5), (S6, A3), (S7, A3), (S8, A3), (S9, A3), (S10, A3)}
By comparing the optimal strategy with the results of applying the 'Evaluation of the retirement supply chain' approach, we conclude that the recommendation web service requires our agent to behave in a manner avoiding the service discontinuity causes.

2.5.Conclusion

This chapter is devoted to the case study of the Moroccan retirement SC. The exploration of this SC is done using SCOR at the three first levels of the supply chain, defining the main stakeholders, activities and flows. The SC evaluation is based on the five-phase DMAIC method. The "Define" phase projects sM2 Make-to-Order process that describes the management of rights liquidation, at the fourth level of the SC using BPMN. At the second phase "Measure", we used the BPM simulation according to a defined load profile and six different scenarios. Based on the results of the aforementioned phases, the "Analyze" phase, traces a cause tree diagram that presents the causes behind discontinuity between the salary and the pension. At the "Improve" phase, and in order to mitigate the discontinuity root causes, we took advantage of “Interconnectivity”, the smart SC characteristic as defined in literature. The made modifications concerning flows are presented using SCOR 2nd level model, and those concerning the business process activities are presented using the 4-th level BPMN model. In the last phase "Control”, a dashboard is established, composed of both steering and performance KPIs based on both SCOR metrics and simulation results. Regarding the improvement of the Moroccan retirement SC, the proposed reference L-SCOR is adopted. We started by expressing the SC at the second level of L-SCOR, in order to clarify the flows between the planning processes and sL3 "Learn Make" that describes the management of adaptability for rights liquidation. Then we established at the fourth level of L-SCOR the business process "the management of civil pension rights", thus explaining, how the recommendation web service will be used for this business process. Last and not least, we explain, the communication protocol between the calling activity and the recommendation web service, the prerequisites for the implementation of the Q-Learning algorithm, by defining the environment adapted to this case agent, the action space, the state space, and the reward table. Finally, we discuss the returning Q-table and the adopted strategy used by the called activity.

Chapter 3

3. The supply chain of hospital drugs: exploration, evaluation and improvement

This chapter is devoted to the analysis, evaluation and improvement of the drugs supply chain within the hospital.

3.1. Introduction

3.1.1. The hospital supply chain

The hospital settings have the same characteristics as industrial environments with much greater complexity and a very uncertain process of care. The entrance of a patient in the hospital triggers a therapeutic management process in which the drug is an essential component [1]. In a general way various research works have concerned the pharmaceutical supply chain, [59] have developed a two-echelon pharmaceutical supply chain inventory model under realistic problems in pharmaceutical company and hospital such as effective inventory policies and decisions, constraints, maintaining customer satisfaction, permissible delay in payments, inventory lead time, and minimize total inventory cost. As for [60], they construct a generalized network oligopoly model with arc multipliers for supply chains of pharmaceutical products using variation inequality theory. The model captures the Cournot competition among the manufacturers who seek to determine their profit-maximizing product flows, which can be perishable, with the consumers differentiating among the products of the firms, whether branded or generic, and the firms taking into consideration the discarding costs. In addition, [61] developed simple yet powerful MILP model for multi-period enterprise-wide planning. They represented the entire enterprise in a seamless fashion with a granularity of individual task campaigns on each production line. Their model integrates procurement, production, and distribution along with the effects of international tax differentials, inventory holding costs, material shelf lives, waste treatment / disposal, and other real-life factors on the after-tax profit of the company. Rui, T.S. et al. [62] addressed a dynamic allocation/planning problem that optimizes the global supply chain planning of a pharmaceutical company, from production stages to product distribution to markets. The model explores different production and distribution costs and tax rates at different locations in order to maximize the company's net profit value (NPV). The model explores different production and distribution costs and tax rates at different locations in order to maximize the company's net profit value (NPV). In their work, [63] discussed the pharmacy supply chain and current managerial practices in a case hospital, examine the often-conflicting goals in decision making amongst the various stakeholders, and explore the managerial tradeoffs present at the operational, tactical, and strategic levels of decision-making. They focused on the inventory management at a local storage unit within an individual Care Unit (CU). Other authors have faced the issues connected with the hospital supply chain. We see through literature, that there are two aspects to the definition of hospital logistics. One aspect is based on the logistics activity and a second is based on the logistics flow. By focusing on the overlap of the different activities of hospital logistics, [64] identified two approaches for the hospital supply chain analysis. One related to internal activities such as inventory control, receiving and internal distribution. The other one concern relations with external partners (supplier and distributors) which focuses more on the procurement process, contract negotiations, supplier selection and storage strategies. Mousazadeh et al. [65] defined the hospital supply chain by a complex system of processes, operations, activities and organizations involved in the discovery, development and manufacturing of medications and drugs. According to Fanny, A. and Marie-France B. [66], the drug circuit in a health facility covers prescription, analysis and validation of the prescribing, dispensing, delivery, distribution and administration of the drug, pharmacy orders. There is the circuit called "physical", which includes such delivery, receiving, repackaging, preparation and transportation of the drug, and a second circuit called "information" on medication management, which affects more the order and transmission of information on the drug between members of the healthcare team. Vedpal et al. [67], discusses the nature of healthcare supply chains particularly focusing on dental implant. The authors have characterized the dental supply chain and the basic process flow of the supply chain specifically for dental implants, they show the lacking areas which actually differentiate between the high technology supply chain and a conventional supply chain. Securing the medicine circuit in the hospital is a public health priority that involves a collective approach. In this context, [68] operates an inventory of the different possible approaches to risk reduction in hospital, illustrated by the experience of Grenoble University Hospital in this area. Within this framework, the authors confirm that computerization of the medication circuit represents a major advance in terms of organization and security. Similarly, the contribution of new technologies enables the automation of the overall distribution at the central pharmacy and deployment of drug distribution automata care units. In the same context, care quality and safety, the authors of [69] propose to come to the main approaches to business process improvements that have been used in hospitals focusing specifically on one of the newest and most used today: Lean. Ygal, B. and Harold, B. [70], presents radio-frequency identification (RFID)-enabled traceability system for the management of consignment and high value products requiring item level traceability in a hospital environment. According to the authors, when the health care supply chain members are included in the replenishment process with EDI, many other benefits can be derived. Various other research works were interested in a holistic hospital logistics chain, which links the hospital to its suppliers, [71] for their part investigated the influence of hospital-supplier integration on its supply chain performance and the influence of relational assets (interorganizational IT integration, trust, and knowledge exchange) on hospital-supplier integration. The results show that a hospital that has a high level of logistical integration with its suppliers will yield greater performance within its supply chain. Uthayakumar, R. and Priyan, S. [72], described the decision-making process in French public hospitals, using qualitative interviews that were conducted with 14 pharmacists in 14 hospitals in various regions of France. The study showed that few structures used detailed guidelines on request for adding a new drug, preparation of the evaluation report and decision-making, to establish transparency in drug selection. The authors concluded that the complexity of the process of drug selection imposes the development in all the structures of a formal approach for the management of such a process. In order to understand the current operations of healthcare industries, the authors of [73] developed the procedure for determining the optimal solutions of inventory lot-size, lead-time and total number of deliveries with the objective of achieving target customer service level of the hospital at minimum pharmaceutical company-hospital supply chain total cost.

3.1.2. Drug management cycle: case of Moroccan public hospitals

The hospital pharmacy organization and development, has been an important concern of the Health Ministry for several years. The priority objective is to ensure the availability and accessibility of quality health products in all public hospitals within a general framework of good use, combined with a control of health expenditure. Since health products are the main budget item for hospitals, it is essential to organize and operate optimally hospital pharmacies with the aim of improving efficiency. The hospital pharmacy only manages and delivers pharmaceutical products intended for inpatient patients.

Depending on the health products and their destination, depending on the pharmaceutical needs and the technical level of the hospital and its organization, certain activities are defined as "base activities", generally considered mandatory, some optional, that is to say carried out conditionally, and finally other activities are complementary and transversal, these are the "support activities".

Whatever the type of activity and their operational management, the responsibilities incumbent on it are conceived only according to the operationally of a number of criteria in terms of human resources, premises, equipment and information systems.

The drug circuit in health facility covers two circuits, the first one, clinic, is that of the patient's drug therapy hospitalized since its entry, when its treatment is considered, until discharged when a prescription is made. The second circuit, logistics, concerns the drug as a product, from purchase to its delivery in the care unit [1].

The drug management within Moroccan public hospitals is composed of a series of successive steps, performed by different professionals. These steps are selection, acquisition, reception and storage, dispensation.

- The selection is made from the national list of essential and vital pharmaceuticals. This list take into consideration the following criteria:
  - Adapted for epidemiological
  - Adapted to the pathology encountered (infectious diseases ....)
  - Cover all categories of Patients (age, sex, pregnancy ...)
  - Take into account the cost of products (affordability)
- The acquisition is the responsibility of the Supply Division (SD) of the health ministry; for the essential hospital pharmaceutical needs, the SD collects annually individual needs of public hospitals (excluding CHU). Hospitals can make decentralized purchases (purchases by purchase order or tender) for needs not provided by joint buying of SD (e.g., vital missing product-specific out-nomenclature). The purchase is done through open tenders based on orders of delegations and hospitals.

- Although it is a frequent event, the drugs reception for the pharmacy should never be considered a trivial event. We must pay great attention to it and execute the related tasks methodically, because most of the hospital's activities are based on an adequate supply. This stage of the drug management cycle is the responsibility of the pharmacist. The reception operation is performed under the supervision of the reception committee. The stock should help regularize the flow of pharmaceutical products in the procurement cycle, through two essential functions; the first one is to ensure continuity of deliveries between two supply deadlines (rolling stock), the second one is to protect against uncertainties: epidemic, disaster, supplier failures and seasonal variations (safety stock). Therefore, inventory management must seek an optimal balance to avoid both stock-outs, overstocks, deterioration of stored products and the expiration. It is based on a good needs assessment, good storage conditions, complete and infallible management software, and a mastered planning receptions and deliveries.
- The role of hospital pharmacy in the drug circuit is central and it has set the goal of providing the necessary pharmaceutical care of hospitalized patients. This cycle includes optimizing inventory of the pharmacy and those held by care units. If the dispensation, whether global or registered, is under the supervision of the pharmacy, the transport is performed under the responsibility of the care units [2].

The remainder of this chapter is organized as follow: the next section traces the results of the hospital drugs supply chain exploration. Section 3 details the evaluation of the drugs supply chain within the hospital. Section 4 presents the result of the improvement of the studied supply chain. This chapter is concluded in section 5.

3.2. Exploration of the drugs supply chain within the hospital

3.2.1. Strategic level

At this level, the company makes the basic strategic decisions, in our case we analyze the drugs supply chain within the hospital. As shown in Fig. 2 the supplier has two processes Deliver (D) describes the drugs delivery from the supplier to the hospital, and Return (R) describes the return permission of rugs from the hospital to the supplier. The hospital pharmacy has three processes, Source (S) describes drug procurement, Deliver (D) describes the drugs delivery from the hospital pharmacy to the patient, and Return (R) describes the drug return from the hospital to the supplier. The patient has the process Source (S) that describes in our case, receiving drugs by the patient. The process Plan (P) is the one that balance aggregate demand and supply to develop a course of action, which best meets sourcing, production, and delivery requirements.

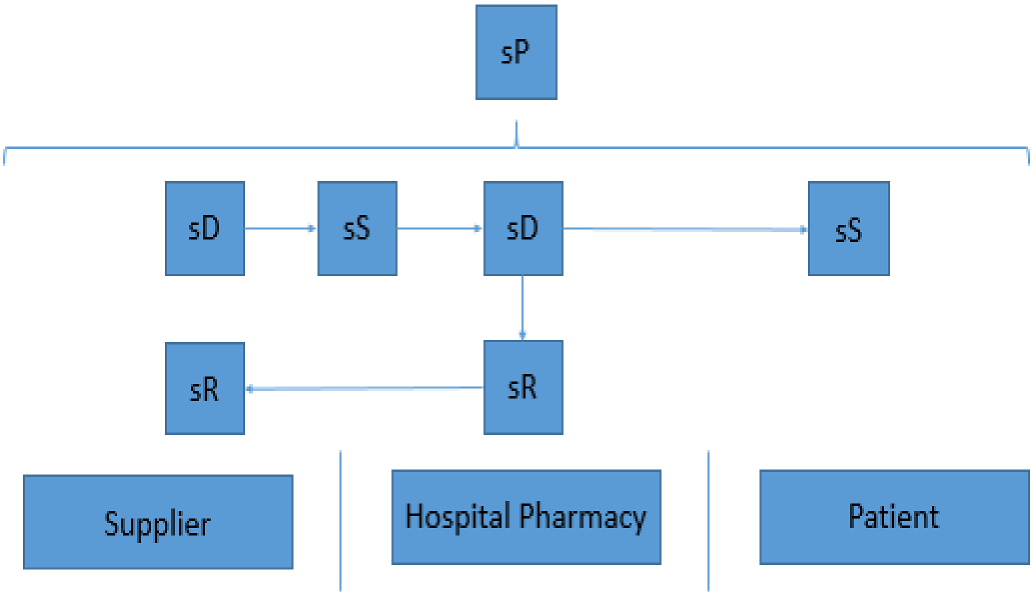

Figure 3.1 The Strategic level model of the drugs SC within the hospital

3.2.2. Tactical level

This level splits domains according to the configuration of the supply flow, and the results are Source Stocked Product (S1), and Deliver Stocked Products (D1). In our case, the return is concerning any drug of which the end user cannot benefit, the processes describe this return in SCOR are Source Return Defective Product (SR1) and Deliver Return Defective Product (DR1). We note that the Plan processes are Plan Supply Chain (P1), Plan Source (P2), Plan Deliver (P4), and Plan Return (P5). The modeling of this level is shown in Fig. 3.

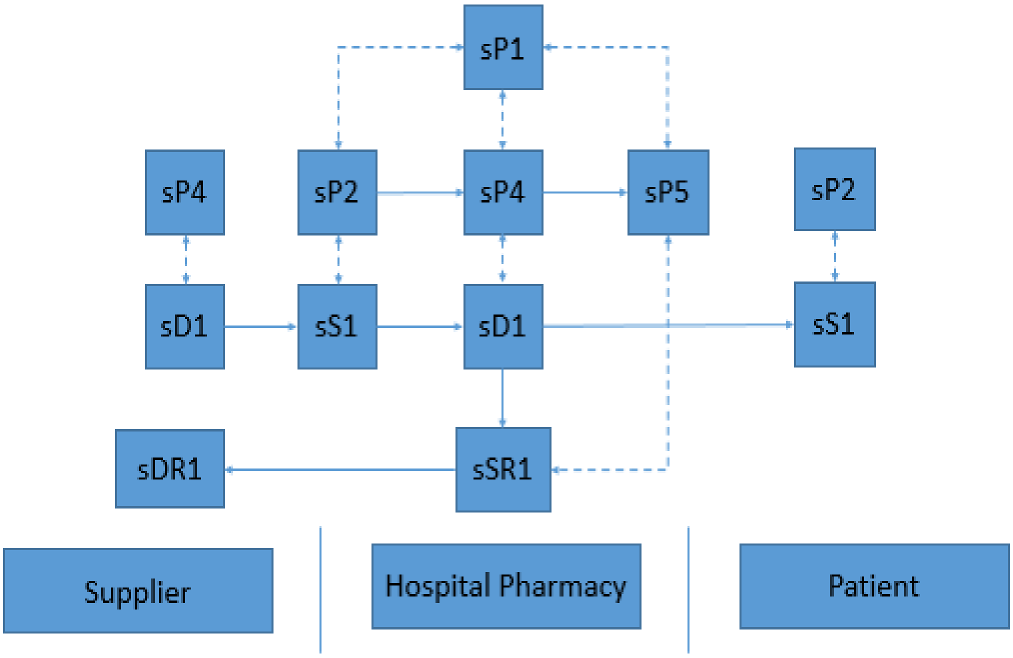

Figure 3.2 The Tactical level model of the drugs SC within the hospital

3.2.3. Operational level

3.2.3.1. Source Stocked Product

As shown in Fig. 4, S1 is composed of five process elements, Schedule Product Deliveries (S1.1), Receive Product (S1.2), Verify Product (S1.3), Transfer Product (S1.4) and Authorize Supplier payment (ES1.5). S1.1 allows scheduling the drugs delivery; it receives in input the procurement plan from the process Establish Sourcing Plan (P2.4), and the management data of the upstream logistics from the process Manage Incoming Product (ES.6). As output, it gives the drug list to order to the process Identify, Prioritize and Aggregate Product Resources (P2.2). S1.2 allows the drugs reception; it receives in input receipt order from the process Identify, Prioritize and Aggregate Production Requirements (P3.1), and the return plan from the process Establish and Communicate Return Plans (P5.4). As output, it gives the receipt verification data to the process S1.3. S1.3 allows the drugs verification; it receives in input the receipt verification data from S1.2. S1.4 allows drugs delivery; it receives in input the drugs location data in stock from the process Manage Product Inventory ES.4. As output it gives the actual data of drugs stock to the process Manage Finished Goods Inventories (ED.4). S1.5 allows the supplier payment; it receives in input the payment conditions data from the process Manage Supplier Agreements (ES.10).

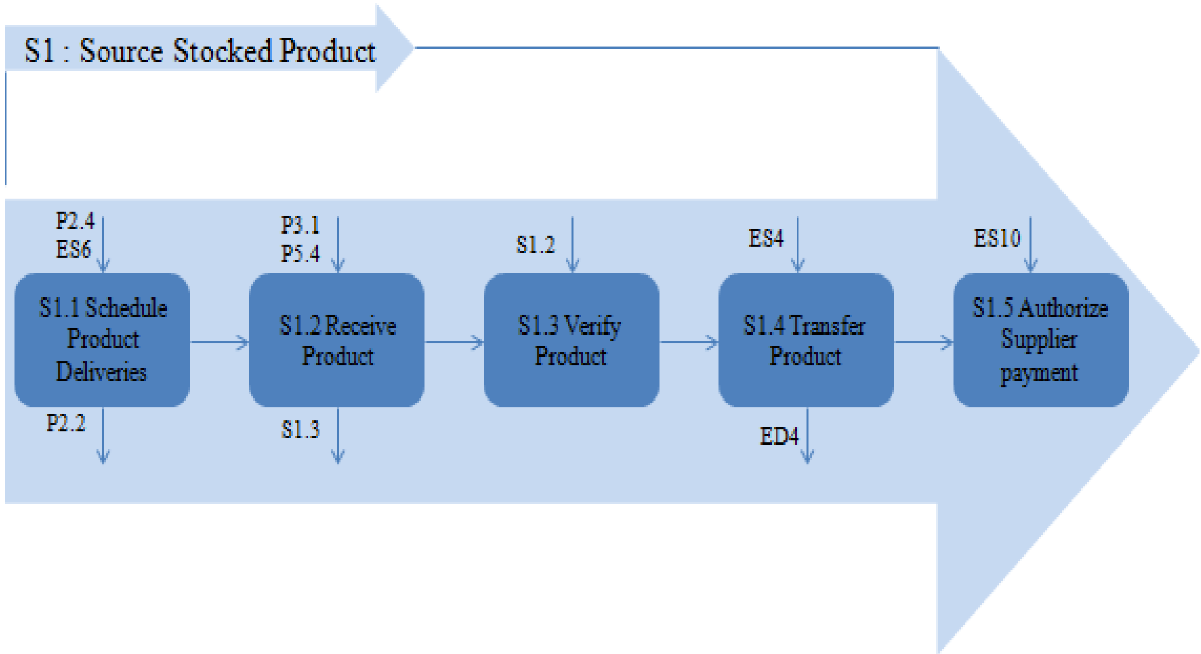

Figure 3.3 The Source Stocked product model for the drugs SC within the hospital

3.2.3.2. Deliver Stocked Product

In our case, the distribution of drugs within the hospital is done through five steps, so we choose five process elements which fit most to the hospital management, and which are Process Inquiry and Quote (D1.1), Reserve Inventory and Determine Delivery Date (D1.3), Receive Product from Source or Make (D1.8), Ship Product (D1.12), Receive and Verify Product by Customer (D1.13). D1.1 is the process of answering the information request. D1.3

allows the booking stock and determines the delivery date; it receives in input the data stock availability from the process Manage Deliver Business Rules (ED.1). As output, it gives the delivery date and the stock information to the process Manage Deliver Information (ED.3). D1.8 allows the drugs purchased receipt. As output, it gives the actual data of drugs stock to the processes ES.4 and ED.4. D1.12 allows the drugs delivery. D1.13 allows the receipt and verification of drugs by the patient. The D1 modeling at this level is shown in Fig. 5.

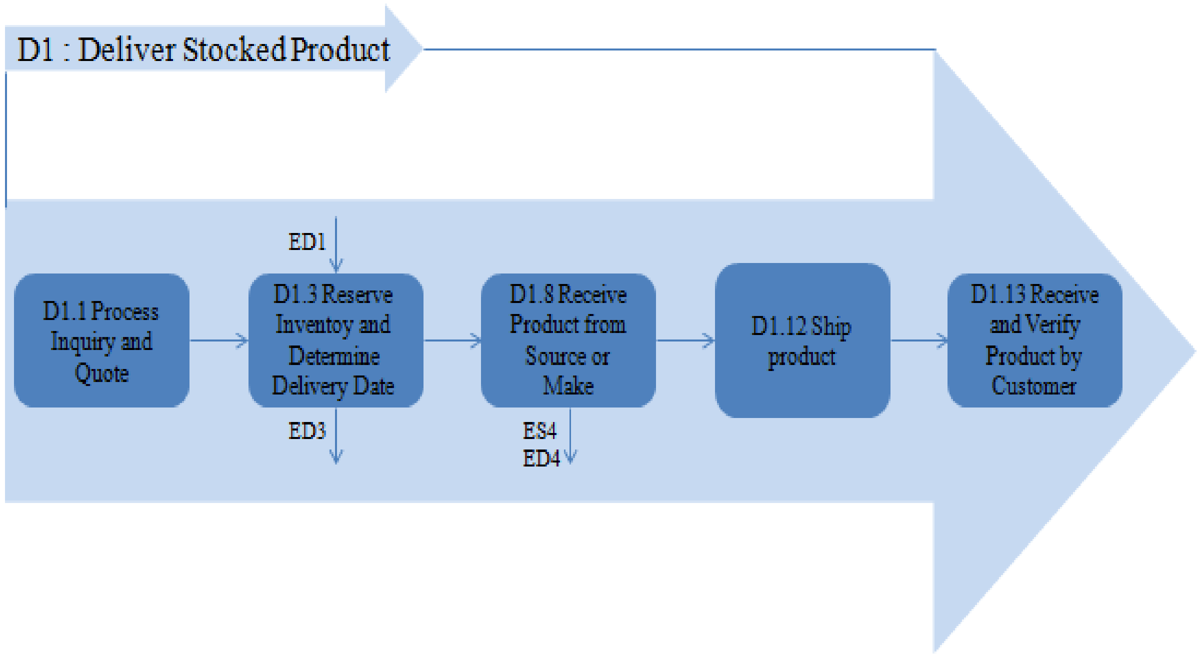

Figure 3.4 The Deliver Stocked product model for the drugs SC within the hospital

3.2.3.3. Source Return Defective Product

As shown in Fig. 6, SR1 is composed of five process elements, Identify Defensive Product Condition (SR1.1), Disposition Defective Product (SR1.2), Request Defective Product Return Authorization (SR1.3), Schedule Defective Product Shipment (SR1.4) and Return Defective Product (SR1.5). SR1.1 allows identifying management conditions for defective drugs; it receives in input the return process business rules from the processes Manage Sourcing Business Rules (ES.1) and Manage Business Rules for Return Processes (ER.1). SR1.2 allows the defective drug assignment to the supplier concerned; it receives the return plan from the process Establish and Communicate Return Plans (P5.4). As output, it gives the return authorization to the process D1.8. SR1.3 allows the drug return authorization request; it receives in input the request authorization response from the process Authorize Defective Product Return (DR1.1). As output, it gives the returns rate history to the process Assess and Aggregate Return Requirements (P5.1). SR1.4 allows the scheduling of the defective drugs shipment; it receives in input the stock availability of returns from the process Manage Return Inventory (ER.4). SR1.5 allows the defective drugs return.

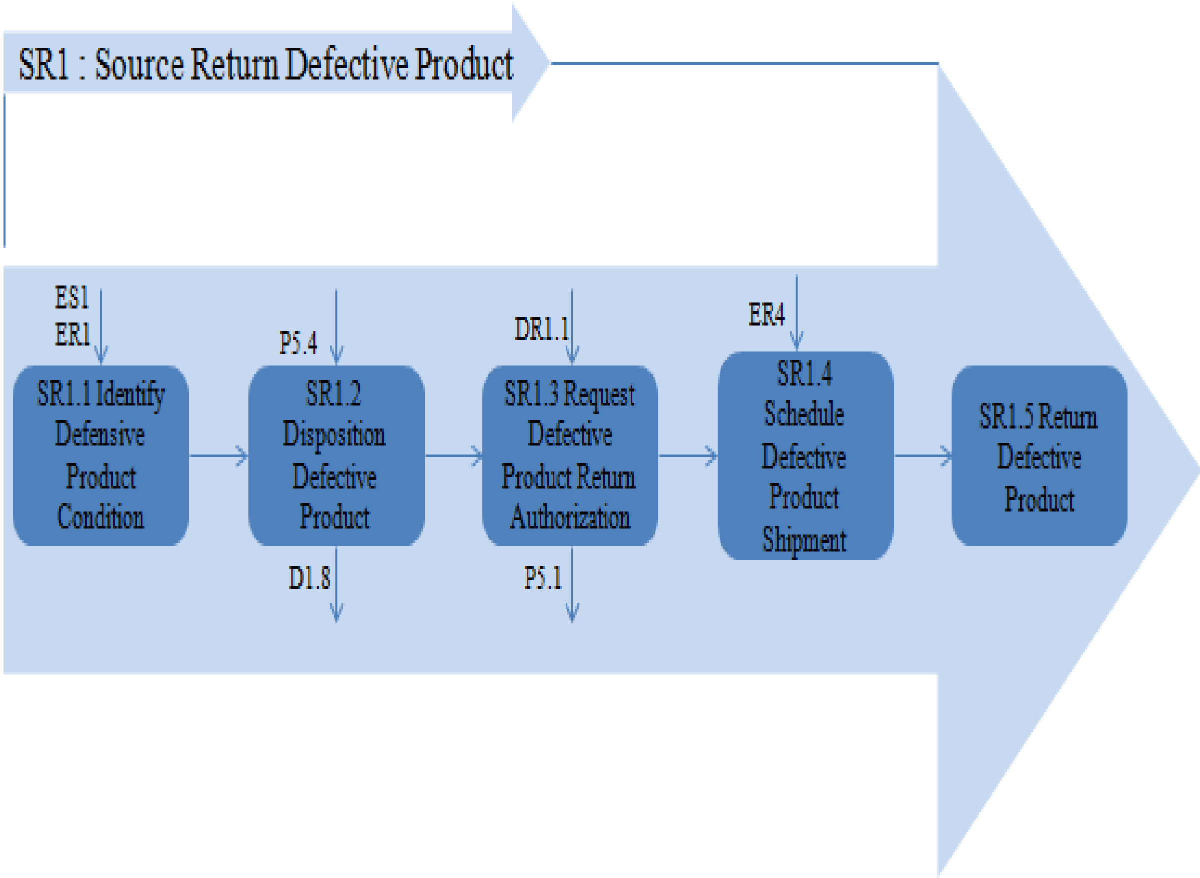

Figure 3.5 The Source return defective product model for the drugs SC within the hospital

3.3. Evaluation of the drugs supply chain within the hospital

3.3.1. Define phase

3.3.1.1. The acquisition business process model

The acquisition includes the procurement procedures (procurement and placing orders), the selection of suppliers and the quality and quantity controls, and monitoring management. This process is primarily managed centrally (SD of the Ministry of Health).The process of acquiring pharmaceutical products for Moroccan public hospitals is summarized in Figure 1.

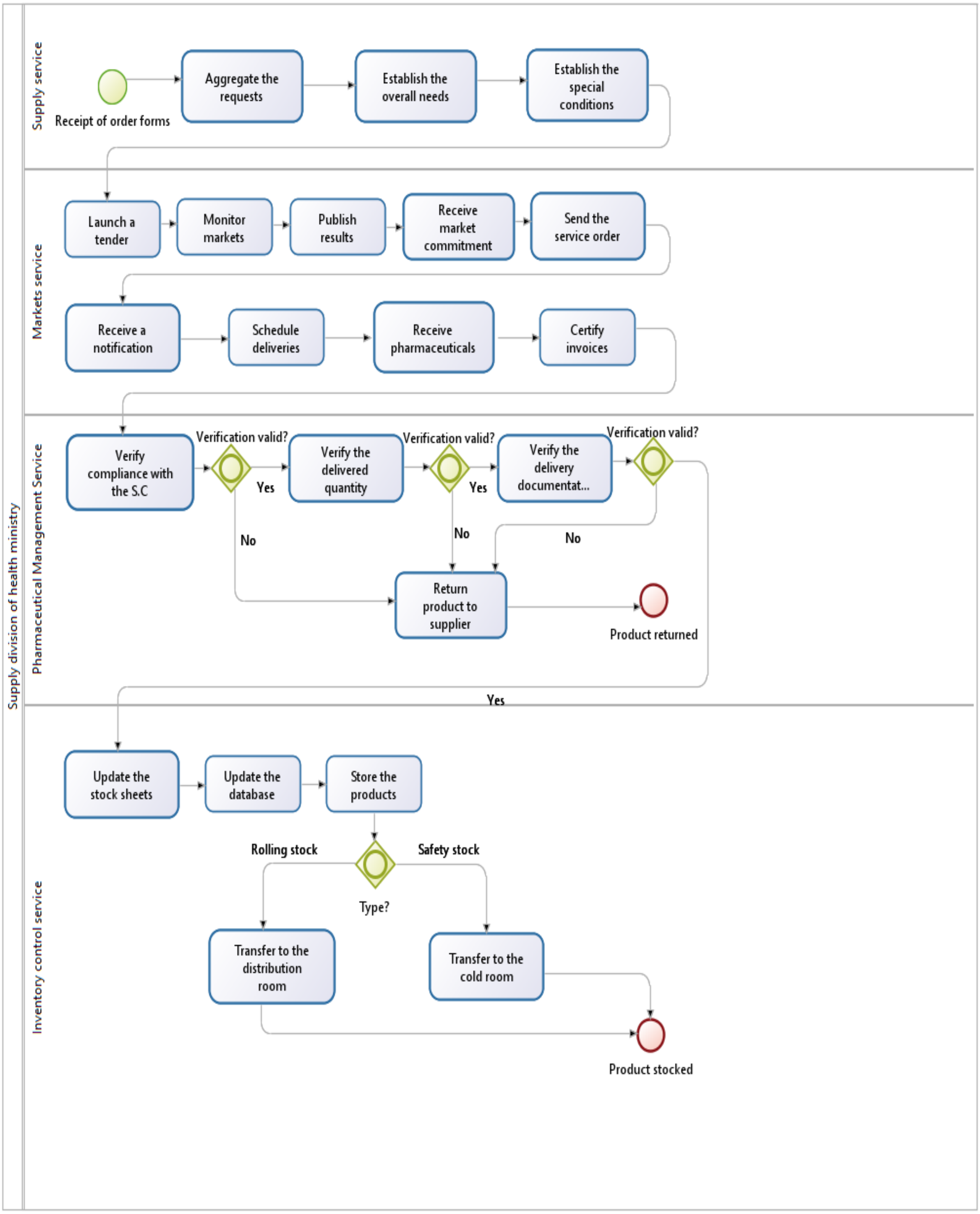

Figure 3.6 The acquisition business process model

3.3.1.2. The reception business process model

Receiving drugs requires prior organization of the receipt by the customer (hospital pharmacy) and therefore planning of shipments by the supplier (SD). Figure 2 shows the steps constituents the reception process from the carrier arrival until the drugs classification and storage.

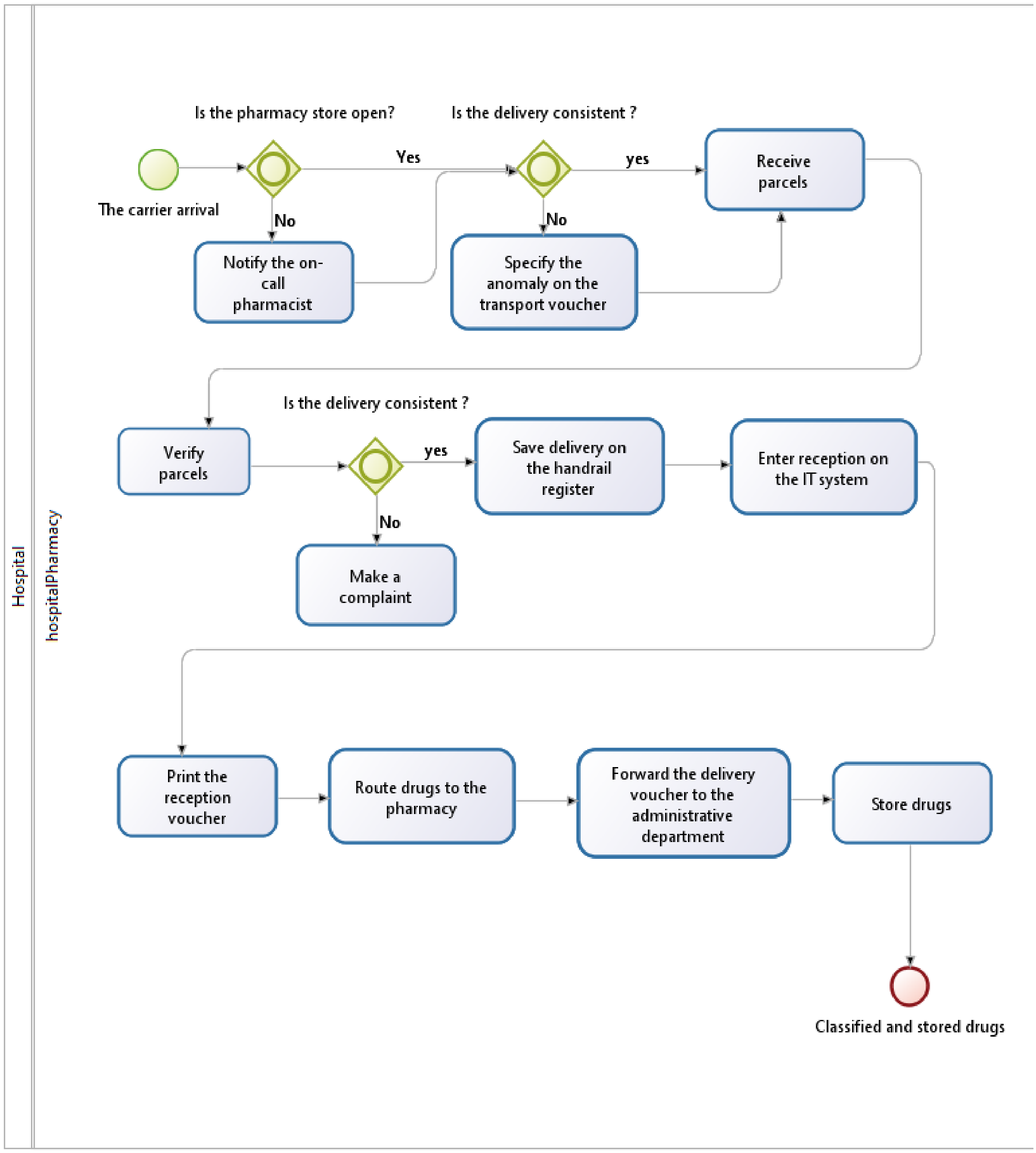

Figure 3.7 The reception business process model

3.3.1.3. The dispensation business process model

Depending on the type of care units, the type of product and the resources of the institution, dispensing drugs to care units obeys two key terms "Global" or "Nominative». The circuit of the global dispensation is based on a global list products delivered by the pharmacy, although simpler to set up, overall a dispensation more risk because the drug control is minimal. Nominative dispensation can be daily or not, it is safer in terms of safety (Risk minimizing dispensing errors by a pharmaceutical ante control), it requires by against a robust organization and a significant pharmaceutical investment in human resources. Figure 3 shows the steps of the hospital pharmacy dispensing process to the care unit.

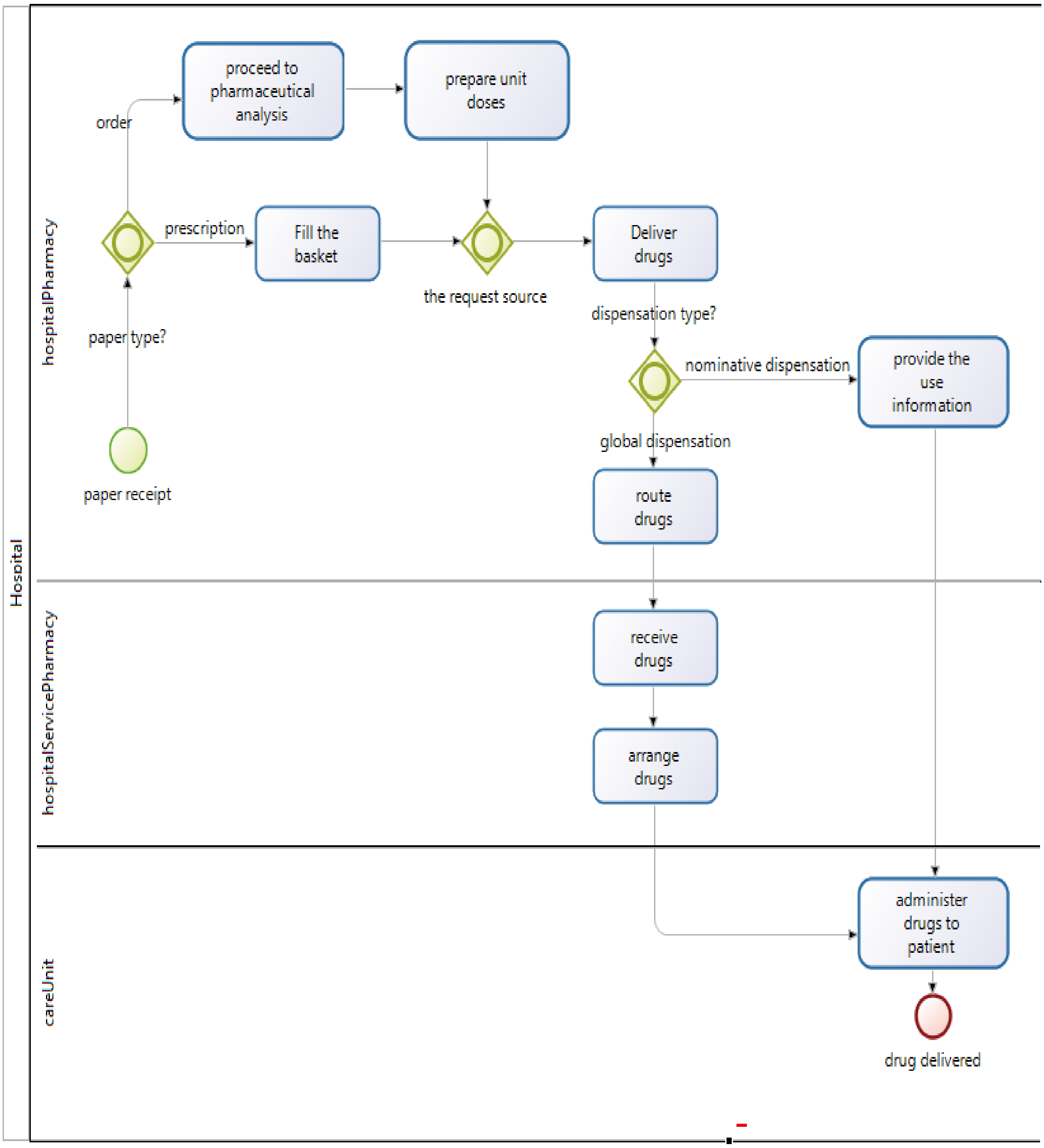

Figure 3.8 The dispensation business process model

3.3.1.4. The return business process model

The hospital_pharmacy pool consists of one lane: pharmacist. The process begins with the start event 'returned drugs' and ends with one of the three end events : 'destroyed drugs', 'sent drugs' and 'returned drugs'. After receiving the returned drugs list, the pharmacist proceeded to the drugs collection, and the elaboration of the necessary documents. Depending on the return type, either the pharmacist proceeds to 'drugs destruction' or 'donations to other hospitals' or 'supplier return request' .The return business process model is shown by Fig. 9.

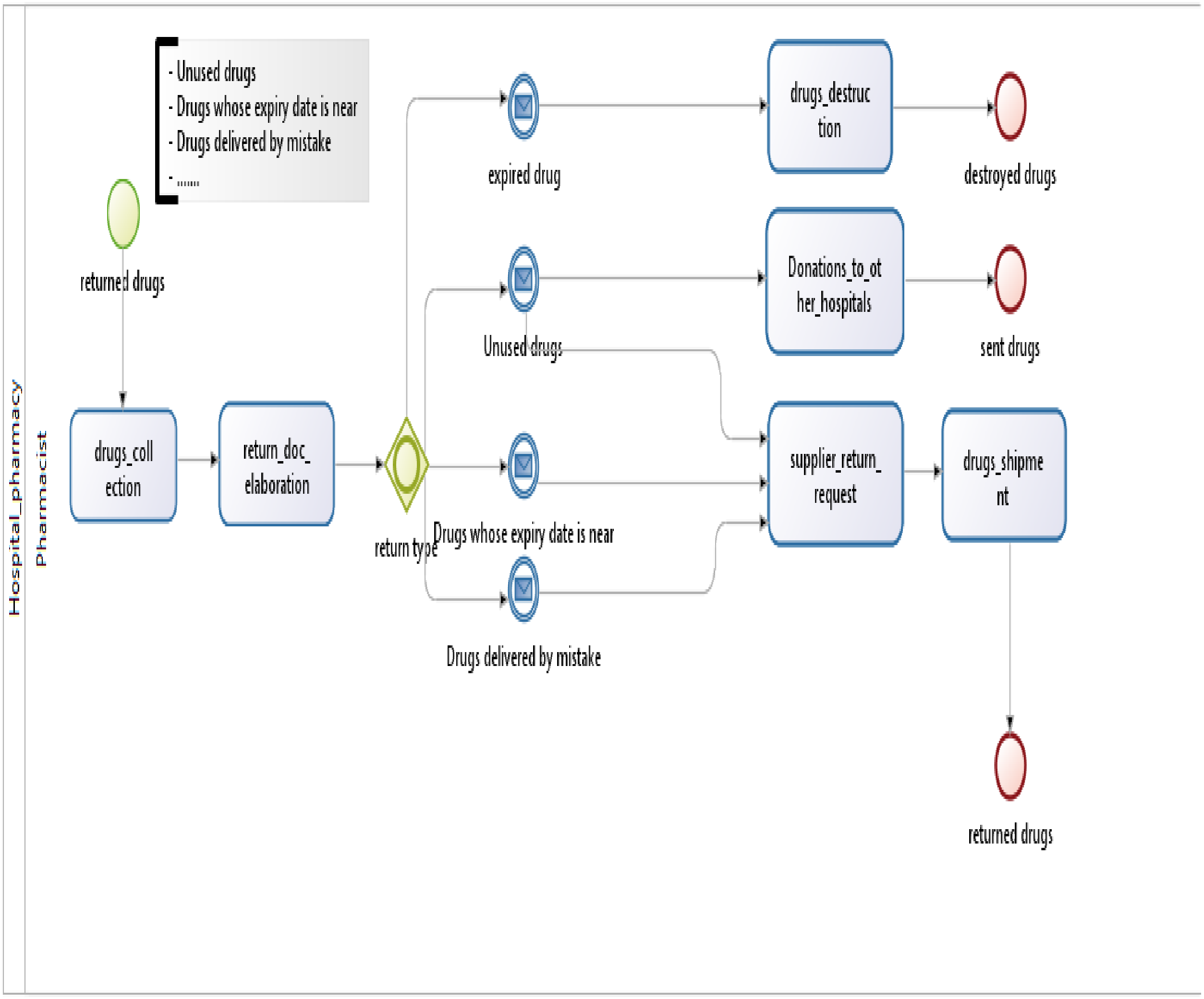

Figure 3.9 The return business process model

3.3.2. Measure phase

This simulation aims to compare the human resources qualification of the two scenarios of drugs dispensation (nominative dispensation and global dispensation) in a Moroccan public hospital. The simulation is based on the following information:

- The necessary human resources to manage this process are the pharmacist, the delivery agent and the nurse.
- The hospital consists of a single hospital pharmacy and of thirty-six services.
- In the case of nominative dispensation, prescriptions reception follow an exponential distribution, the estimated time for the reception of a single prescription varies from one to four minutes. In addition, in case of global dispensation, reception is monthly, and the estimated time for the orders reception varies from eighteen to twenty minutes.
- The hospital contains 36 nurses.

We also note that the simulation start date is 28/07/2016 09:52:38 and its end date is 19/11/2016 12:52:38, the simulation Duration is 113 days 16 hours, the execution time is 11 seconds, and the number of simulated instances is 100

3.3.2.1. The nominative dispensation

According to Figure 4 the percentage of the pharmacist commitment in the management process of the nominative dispensation is maximum and reaches 100%.

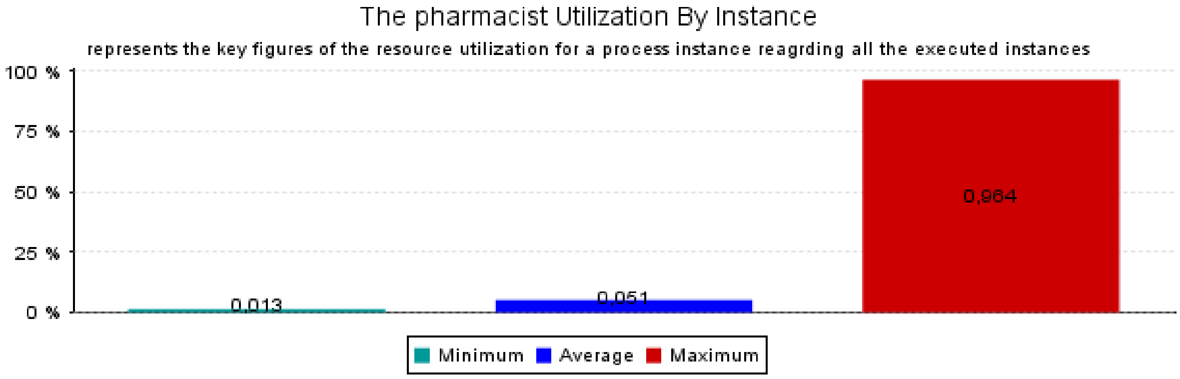

Figure 3.10 The pharmacist utilization by instance for the nominative dispensation

And according to Figure 5, 4% of the 36 of this hospital nurses are involved in managing the nominative dispensation process.

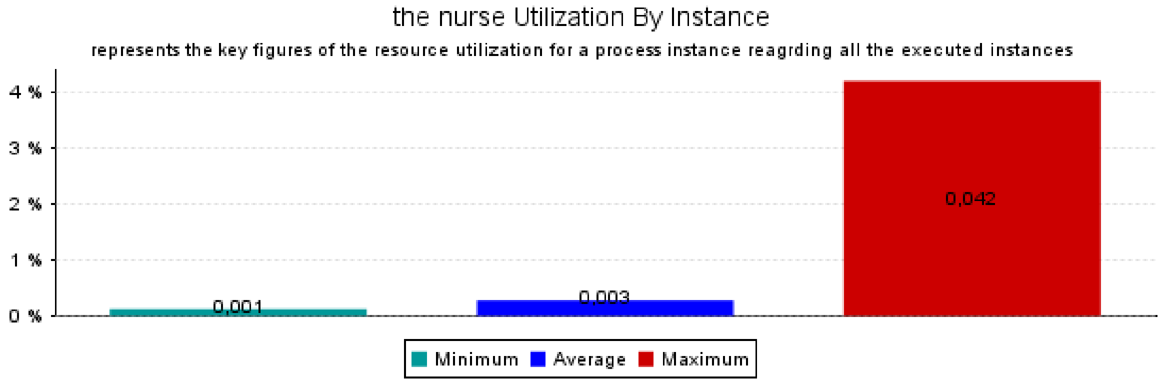

Figure 3.11 The nurse utilization by instance for the nominative dispensation

And for the last resource, the percentage of the delivery agent commitment in the management process of the nominative dispensation is 7,5%.

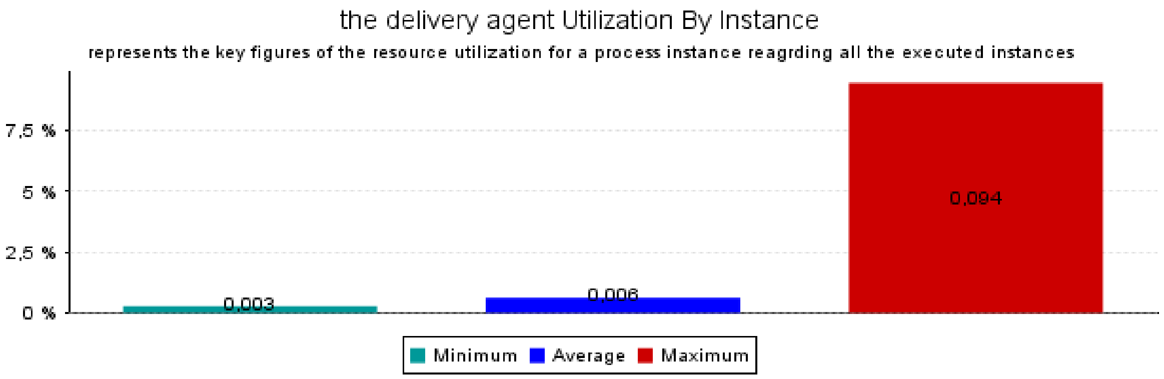

Figure 3.12 The delivery agent utilization by instance for the nominative dispensation

3.3.2.2. The global dispensation

Unlike the nominative dispensation, for the global one, Figure 7 shows that the pharmacist's commitment to the dispensation management is minimal at 0.75%.

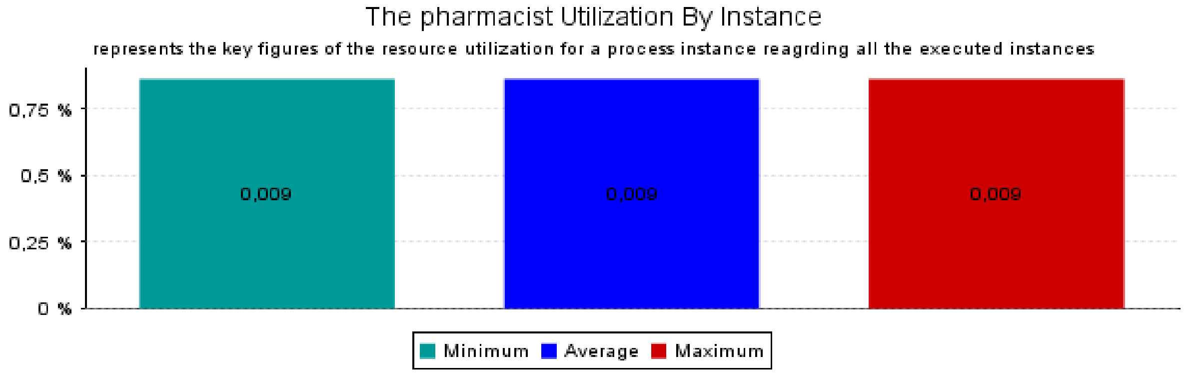

Figure 3.13 The pharmacist utilization by instance for the global dispensation

We also note that for this method of dispensation the nurse's commitment decreases to 2.5% (see Figure 8).

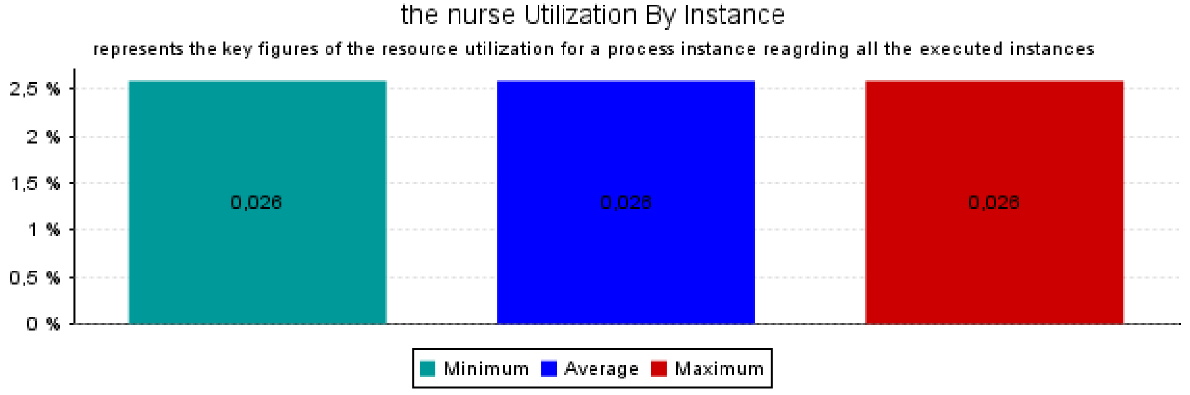

Figure 3.14 The nurse utilization by instance for the global dispensation

While for this method, the delivery agent's commitment rises to 25% (see Figure 9).

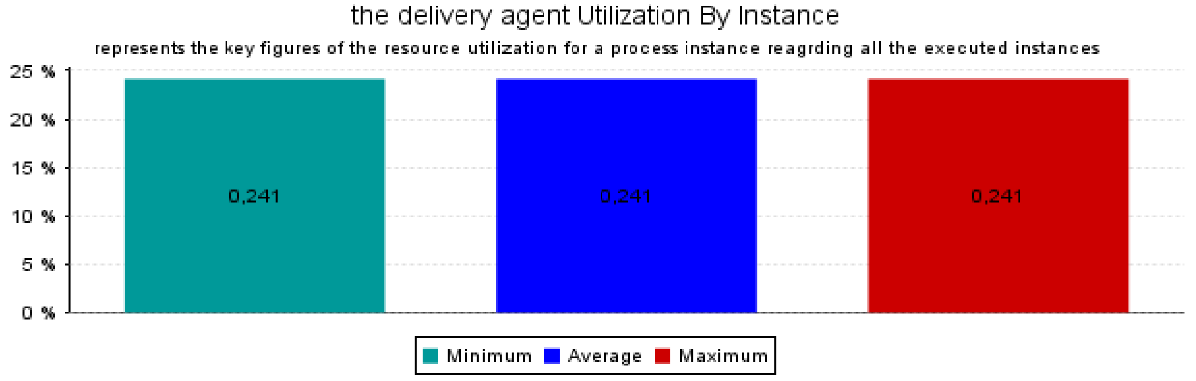

Figure 3.15 The delivery agent utilization by instance for the global dispensation

3.3.3. Analyze phase

Based on the simulation, we conclude that the nominative dispensation has fewer risks in terms of safety (minimization of the risks of dispensing errors by a priori pharmaceutical control), but it requires a robust organization and a significant investment in pharmaceutical human resources. Conversely, although simpler to put in place, the global one, with a minimal pharmaceutical control, it presents more risks.

The balance to be found between the two dispensing methods is done according to an "advantages / disadvantages" analysis for each of the products and / or classes of products. For stable and tagged prescription drugs and devices (e.g., massive solutes), those with no critical benefit / risk ratio and / or risk of misuse we have to opt for a global dispensation.

Conversely, for drugs and devices with a critical benefit / risk ratio, those with a risk of misuse (e.g. antibiotics, anticancer drugs) or those for which traceability or economic monitoring is desired, we have to opt for a nominative dispensation. This will also be the case for all products subject to regulation (e.g. narcotics), or local or national normative recommendations (e.g., prescription-controlled drugs and Implantable Medical Devices). The cause tree below presents, the causes of the discontinuity for this business process.

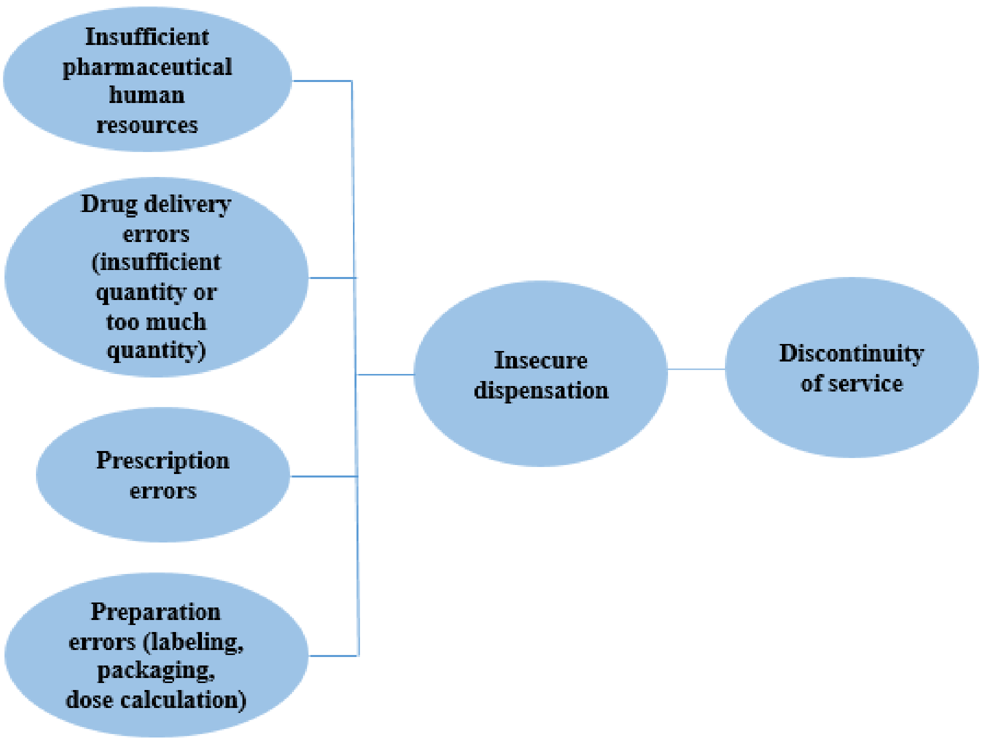

Figure 3.16 The cause tree diagram for insecure dispensation

3.3.4. Improve phase

This phase is about mitigating the root causes of the problem. For this, we chose to integrate one of the characteristics of the smart supply chain explained in [7]. According to [7], the smart supply chain has three core characteristics: Interconnected, Instrumented, Intelligent. In this work, the focus is on the interconnectivity characteristic. Besides creating a more holistic view of the supply chain, this extensive interconnectivity will also facilitate collaboration on a massive scale [7]. For this, information flows will be created between the different business processes managed in the hospital pharmacy. Which will leads us to the second level model (SCOR) presented in Figure 3.

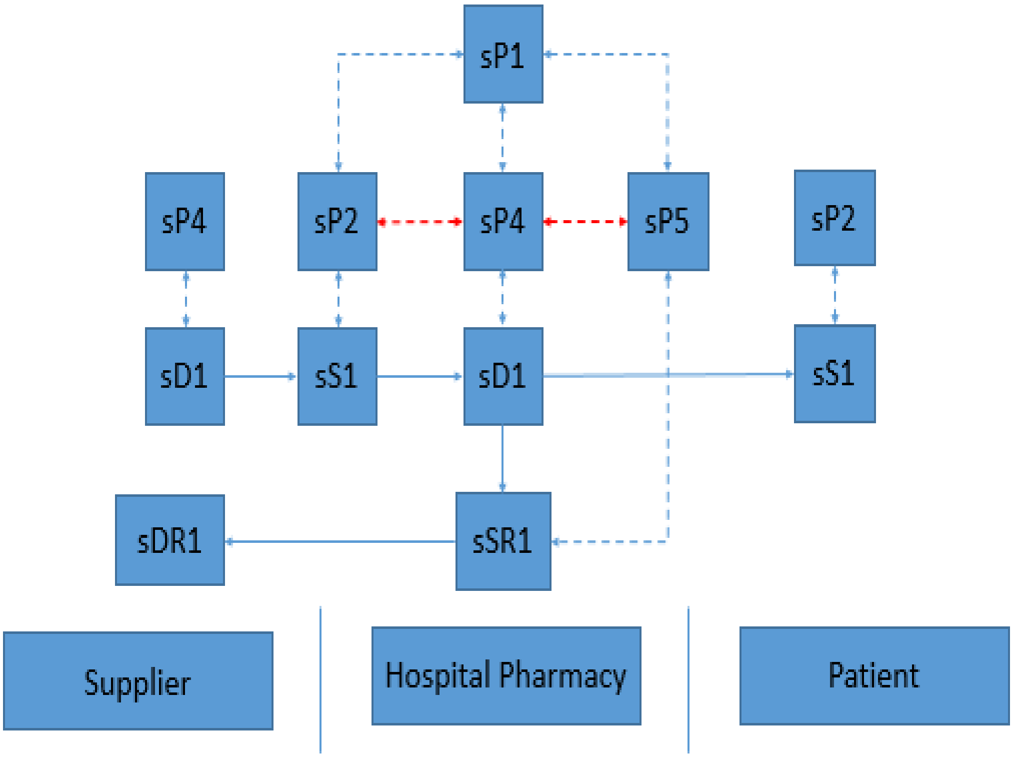

Figure 3.17 The Tactical level model of the smart drugs SC within the hospital

Concerning the dispensation business process model of the SC real-time level, this change is reflected on the BPMN model by the addition of three activities which are "enter received paper information", "enter received drugs information" and "enter administered drugs" and which represents the activities related to this interconnectivity as shown in Figure 4. These activities enable the dispensing data to be supported throughout the process, by feeding a shared database every step of the way.

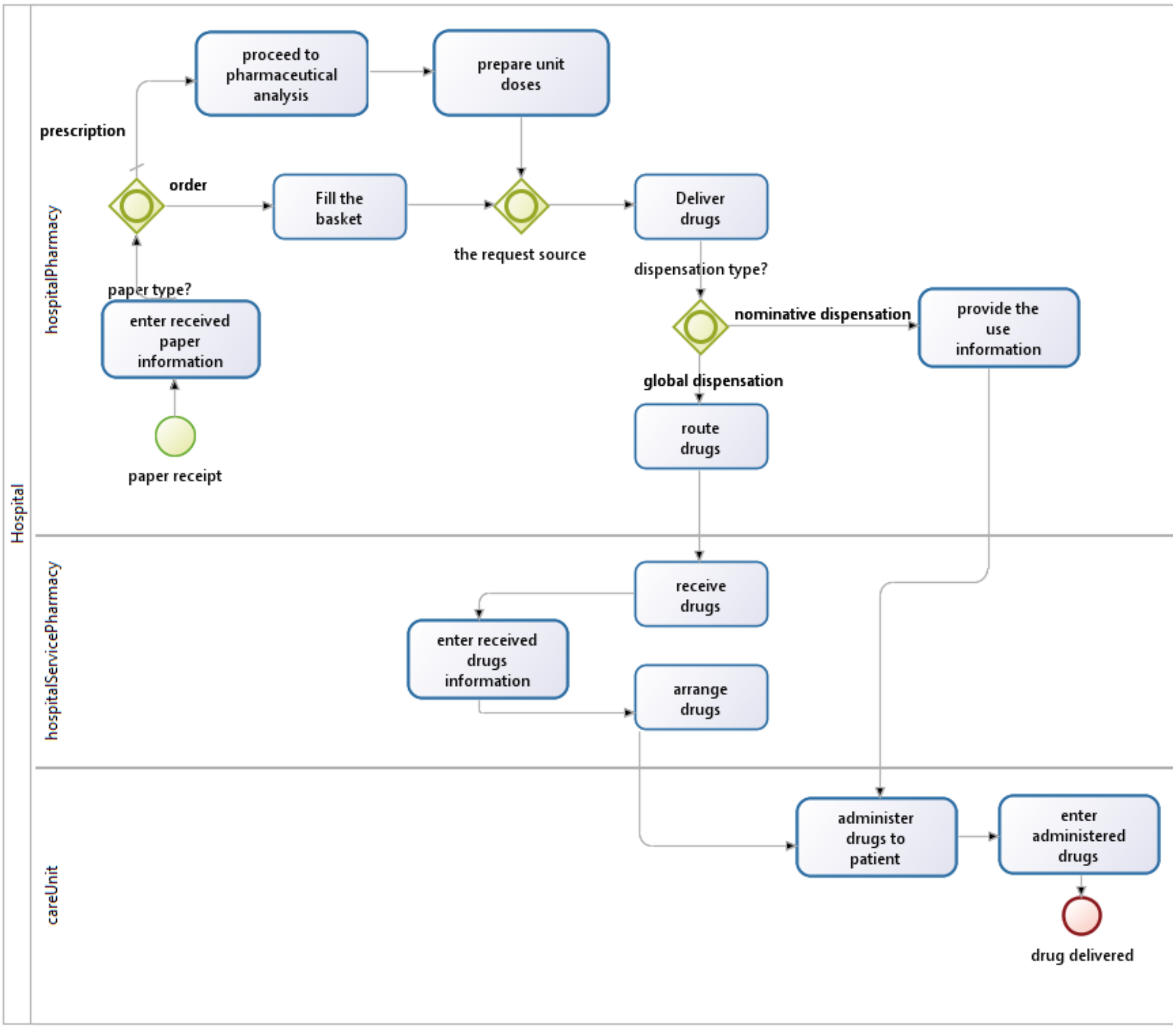

Figure 3.18 The improved dispensation business process model

3.3.5. Control phase

The last phase of Six Sigma's DMAIC model is the Control phase. This phase allows us to continually verify if the actions created in the previous phase are well maintained. For this, a dashboard composed of Steering and Performance indicator was elaborated to be checked monthly. As a part of our goal to evaluate the effectiveness of the dispensation process, we are interested in the responsiveness attributes that means in a general way the speed at which tasks are performed, the speed at which a SSC provides services to the customer. SCOR manage performance using two major elements: Performance Attributes and Metrics [1]. To express a strategy, the performance attribute is used as a grouping of metrics. Among those proposed, this work focuses on 'Responsiveness' (The speed at which tasks are performed). The chosen metric for responsiveness is 'Order Fulfillment Cycle Time'. It represents the time passed between the moment a customer places the order (in our case: the moment of the drug prescription) to the moment the order is fulfilled (in our case: the moment the drug is delivered to the patient). To calculate the 'Order Fulfillment Cycle Time' SCOR specifies:

[Sum Actual Cycle Times for All Orders Delivered] / [Total Number of Orders Delivered] [57]. 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 delivered drugs to patient' and which can be calculated for each trimester as follow: [the total number of delivered drugs at time] / [the total number of prescribed drugs].

Moreover, based on the simulation results we propose:

- 'Global dispensation rate' and which can be calculated for each trimester as follow: [Number of drugs in global dispensation] / [the total number of drugs]
- 'Nominative dispensation rate' and which can be calculated for each trimester as follow: [Number of drugs in nominative dispensation] / [the total number of drugs]
- 'Out of stock rate for a drug' and which can be calculated for each trimester as follow: [Number of days a drug is out of stock] / [90 days]

In addition, to recapitulate Table 3 presents the dashboard that sum up these indicators.

Table 3-1 The control dashboard for the drugs SC within hospital

The indicator source	The indicator title	The calculation formula	The indicator type	The calculation periodicity
SCOR - 'Order Fulfillment Cycle Time'	Rate of delivered drugs to patient	[the total number of delivered drugs at time] / [the total number of prescribed drugs]	Steering indicator	A trimester
Simulation	Global dispensation rate	[Number of drugs in global dispensation] / [the total number of drugs]	Performance indicator	A trimester
	Nominative dispensation rate	[Number of drugs in nominative dispensation] / [the total number of drugs]	Performance indicator	
	Out of stock rate for a drug	[Number of days a drug is out of stock] / [90 days]	Performance indicator	

3.4. Improvement of the drugs supply chain within the hospital

3.4.1. Supply chain modelling with L-SCOR

At the second level of L-SCOR, Fig 3 presents the modelling of the drugs supply chain within the hospital. We note that the planning processes interact with the learning process sL4 "Learn Deliver" that describes the management of adaptability for drugs dispensation in a hospital.

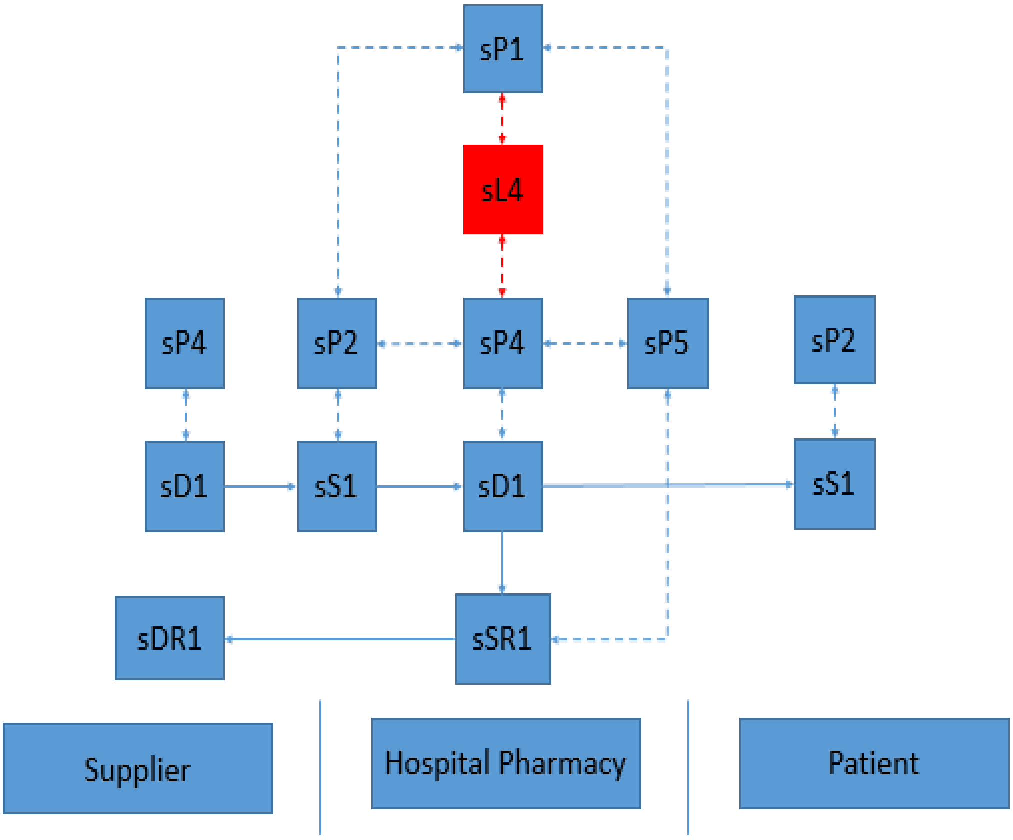

Figure 3.19 The Tactical level model of the self-adaptive drugs SC within the hospital

Concerning the dispensation business process of the drugs self-adaptive SC presented by Fig 4, we notice on the BPMN model the addition of the script activity “Execute recommendation system" which implements the Q-learning algorithm, and receives from the activity "Deliver drugs" the necessary data for its execution, returning thus the optimal combination (state, action) for the current drug dispensation.

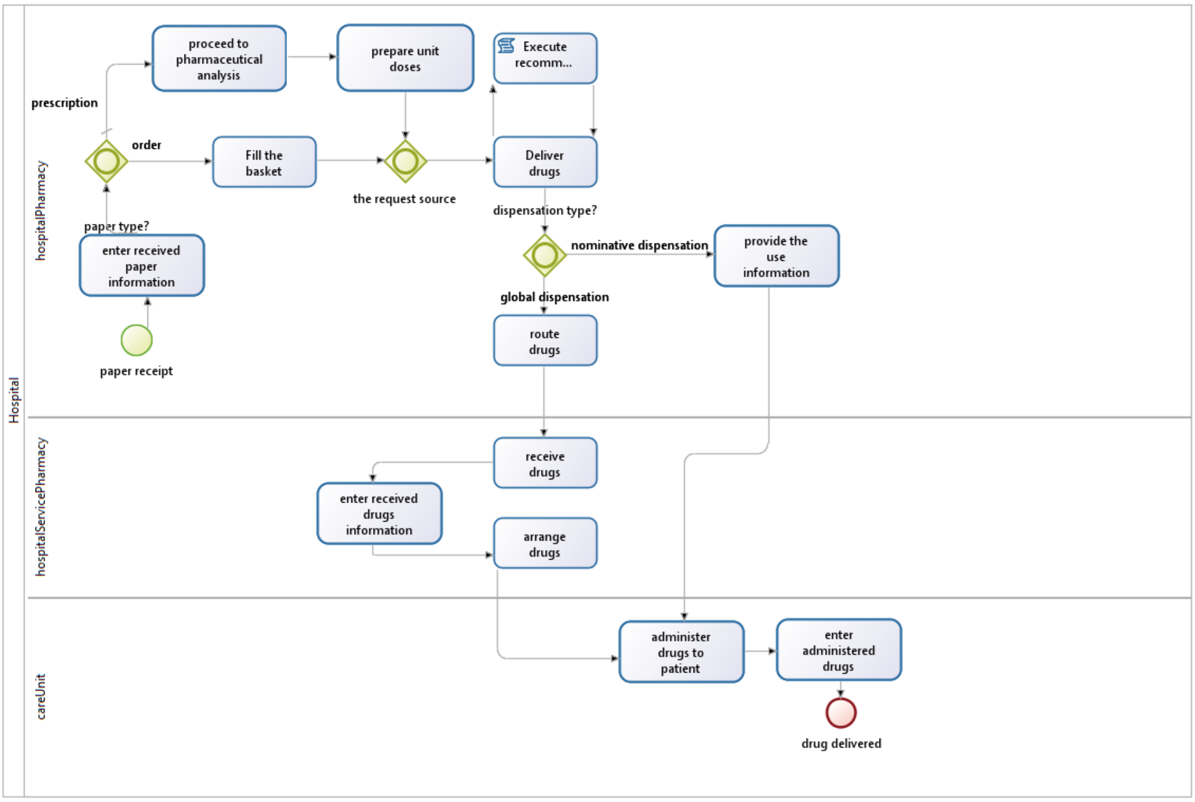

Figure 3.20 The self-adaptive dispensation business process model

3.4.2. Implementation and results analysis

3.4.2.1. State Space and Actions

The first step to apply Q-Learning algorithm is defining the state space. In practical applications, we are looking to obtain results in a limited time frame. If the state space is very large, the algorithm will take too long to converge. The steps through which a drug within hospital passes, trace all the possible states for this agent. The possible states of a drug within the hospital are as follows: 'Prescribed drug', 'Drug ordered from the hospital pharmacy', 'Stable and tagged drug dispensed by a GD', 'Drug of no critical risk of misuse dispensed by a GD', 'Drug for which traceability is desired dispensed by a ND', 'Drug with a critical benefit / risk ratio dispensed by a ND', 'Drug present in the care unit', 'Drug administered to patient', 'Drug dispensation revised', 'Drug stuck in a state', 'Drug returned to a previous state' and 'Drug skipped a treatment step'. An identifier is associated with each state respectively as follows: 'S0: Prescribed drug', 'S1: Drug ordered from the hospital pharmacy', 'S2: Stable and tagged drug dispensed by a GD', 'S3: Drug of no critical risk of misuse dispensed by a GD', 'S4: Drug for which traceability is desired dispensed by a ND', 'S5: Drug with a critical benefit / risk ratio dispensed by a ND', 'S6: Drug present in the care unit', 'S7: Drug administered to patient', 'S8: Drug dispensation revised', 'S9: Drug stuck in a state', 'S10: Drug returned to a previous state' and 'S11: Drug skipped a treatment step'.. The states space S is the set of these identifiers S = {S0, S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11}. The possible operations on drugs within hospital present all the agent actions as follows: 'Order from the hospital pharmacy', 'Check drug's type for the ordered or revised drug', 'Dispense as a global dispensation', 'Dispense as a nominative dispensation', 'Administer to patient', 'Return result' and 'Revise dispensation'. An identifier is associated with each action respectively as follows: 'A0: Order from the hospital pharmacy', 'A1: Check drug's type for the ordered or revised drug', 'A2: Dispense as a global dispensation', 'A3: Dispense as a nominative dispensation', 'A4: Administer to patient', 'A5: Return result' and 'A6: Revise dispensation'. The actions space A is the set of these identifiers A= {A0, A1, A2, A3, A4, A5, A6}.

3.4.2.2. The Reward Functions

The purpose of choosing an action transitioning to some state is illustrated by the reward function that plays a key role in learning speed. The reward value can be negative or positive. A negative reward value is used to express a penalty for an undesirable action. The rewards that are generated after a state transition are a short-term outcome. Because of including future rewards in the evaluation of algorithm actions, it may return a low immediate reword for an action linked to a high Q-value. A fixed reward function is implemented generating static rewards. This function is described in Table 3 - 2.

Table 3-2 Reward function for the 'drug within hospital' agent

State	Reward
S0: Prescribed drug	0
S1: Drug ordered from the hospital pharmacy	10
S2: Stable and tagged drug dispensed by a GD	10
S3: Drug of no critical risk of misuse dispensed by a GD	10
S4: Drug for which traceability is desired dispensed by a ND	10
S5: Drug with a critical benefit / risk ratio dispensed by a ND	10
S6: Drug present in the care unit	10
S7: Drug administered to patient	50
S8: Drug dispensation revised	1
S9: Drug stuck in a state	0
S10: Drug returned to a previous state	-1
S11: Drug skipped a treatment step	0

3.4.2.3. The Value Functions

The Q values of state-action pairs is stored in Q-table. All values stored in the table are initially set to zero. The rows in the table represent the retirement folder's states, and the columns represent the action corresponding to the given state. During training, each entry in the table is populated by updating the Q values. After sufficient training, the Q values converges. The updating equation is shown below:

$$Q(s, a) \leftarrow \alpha \times (r + \gamma \times \max a' (Q(s', a'))) + (1 - \alpha) \times Q(s, a)$$

Where 's' is the current joint state, and 'a' is the selecting action. 's'' is the next state that the retirement folder transfers to from the current state after performed by the action 'a'. 'α' is the learning rate, it specifies to what extent recently learned information supersedes old information. ‘γ’ is the discount factor, it determines the importance of future rewards. After training, the retirement folder is able to execute the best action for each state.

3.4.2.4. The Results

As explained in section 2.4.2.4 the Q-table is a lookup table where the agent calculates the maximum expected future rewards for action at each state, and which will guide the agent to the best action at each state. In the Q-table, the columns will be the available actions and the rows will be the states. For the ‘drug within hospital’ agent Q-learning algorithm is executed according to the parameters presented in table 3.3 as follow.

Table 3-3 : Q-learning used parameters for the ‘drug within hospital’ agent

Parameter	Value
Learning rate	0.05
Discount factor	0.7
Initial Q-value	0
Initial value of ϵ	0.6
ϵ Decay rate	0.005

The Q-table returned by the recommendation web service for the 'drug within hospital' agent is shown in table 3.4.

Table 3-4 The returned Q-Table for the ‘drug within hospital’ agent

	A0	A1	A2	A3	A4	A5	A6
S0	9.745	0	0	0	0	0	0
S1	-1.354	9.745	0	0	0	0	0
S2	-1.354	-1.354	9.745	0	0	0	0
S3	-1.354	-1.354	9.745	0	0	0	0
S4	-1.354	-1.354	0	9.745	0	0	0
S5	-1.354	-1.354	0	9.745	0	0	0
S6	-1.354	-1.354	-1.354	-1.354	49.99	0	0
S7	-1.354	-1.354	-1.354	-1.354	-1.354	49.99	0
S8	-1.354	9.745	0	0	0	0	0
S9	0	0	0	0	0	0	1.859
S10	0	0	0	0	0	0	1.859
S11	0	0	0	0	0	0	1.859

The optimal strategy imposed by the recommendation web service for the "drug within hospital" agent according to the returned Q-Table is as follows:

OS = {(S0,A0), (S1,A1), (S2,A2), (S3, A2), (S4,A3), (S5,A3), (S6,A4), (S7,A5), (S8, A1), (S9,A6), (S10, A6), (S11,A6)}

By comparing the optimal strategy with the results of applying the 'Evaluation of the drugs supply chain within the hospital' approach, we conclude that the recommendation web service requires our agent to behave in a manner avoiding the service discontinuity causes.

3.5.Conclusion

This chapter is devoted to the case study of the drugs SC within the hospital. The exploration of this SC is done using SCOR at the three first levels of the supply chain, defining the main stakeholders, activities and flows. The SC evaluation is based on the five-phase DMAIC method. The "Define" phase projects sD1 Deliver Stocked Product process that describes the management of drugs dispensation within the hospital, at the fourth level of the SC using BPMN. At the second phase "Measure", we used the BPM simulation according to a defined load profile to compare the human resources qualification of the two scenarios of drugs dispensation (nominative dispensation and global dispensation) in a Moroccan public hospital. Based on the results of the aforementioned phases, the "Analyze" phase, traces a cause tree diagram that presents the causes behind an insecure dispensation. At the "Improve" phase, and in order to improve the dispensation business process functioning, we took advantage of “Interconnectivity”, the smart SC characteristic as defined in literature. The made modifications concerning flows are presented using SCOR 2nd level model, and those concerning the business process activities are presented using the 4-th level BPMN model. In the last phase "Control”, a dashboard is established, composed of both steering and performance KPIs based on both SCOR metrics and simulation results. Regarding the improvement of the drugs SC within the hospital, the proposed reference L-SCOR is adopted. We started by expressing the SC at the second level of L-SCOR, in order to clarify the flows between the planning processes and sL4 "Learn Deliver" that describes the management of adaptability for drugs dispensation in a hospital. Then we established at the fourth level of L-SCOR the dispensation business process, thus explaining, how the recommendation web service will be used for this business process. Last and not least, we explain, the communication protocol between the calling activity and the recommendation web service, the prerequisites for the implementation of the Q-Learning algorithm, by defining the environment adapted to this case agent, the action space, the state space, and the reward table. Finally, we discuss the returning Q-table and the adopted strategy used by the called activity.

Chapter 4

4. The supply chain of electricity: exploration, evaluation and improvement

This chapter is devoted to the analysis, evaluation and improvement of the electricity supply chain.

4.1. Introduction

4.1.1. The electricity supply chain

The electrical energy supply chain is a system of resources involved in moving electricity from supplier to customer; it is divided into three sectors: generation, transmission and distribution.

Generation is the production of electricity, from fossil fuels, nuclear or renewable energy sources. Transmission is the electrical energy transport in a very high voltages from generation points to bulk distribution points. Whilst, the local region supply of electrical energy to end-users is the distribution. [7].

The generation sector represents the process of producing electrical energy from other primary energy sources. Electrical energy production is done through the turbines turning. In several electricity generation stations, these turbines are turned by pressurized steam. The coal burning or any other fossil fuels in huge boilers make this steam. Concerning hydroelectricity, the turbines are turned due to the rushing water force. Approximately, the fossil fuels represents 80% of the world's primary energy, its combustion for electrical energy production is one of the main sources of global carbon dioxide emissions, and electricity generation stations participate to over 37% of the worldwide CO2 emissions [74]. A various research works were interested in electricity generation. In order to substitute coal or oil and to gain a partial energy independence, [75] analyzed the economic and technical possibility of the natural gas introduction for electrical energy production in no interconnected insular systems in Crete. Within the same framework, in Algeria also, the electricity production stations were the most important CO2 emission sources, so [74] proposed to use carbon dioxide capture and storage (CCS) to produce electrical energy with the geothermal heat extraction processes, in order to reduce CO2 emissions. In order to achieve this objective, [74] examined the spatial distribution of dioxide carbon emission sources, the authors also determined the most appropriate locations to use the proposed technology, for these appropriate locations, CO2 emissions were quantified in order to evaluate the potential for electrical energy generation and to determine its cost. Along the same lines, [76] proposed for reaching a low-carbon society, to utilize renewable energy sources to a considerably Greater extent. The study outlined the state of the art, goals and challenges of electrical energy generation from renewable energy sources in Slovenia. With the purpose of participating to the assessment of the possible effects of various electricity generation stations in terms of sustainable

development, [77] proposed a logic models as a decision-aid supporting tool, that is a beneficial tool to give a precious starting approach for an Impact Assessment of the ongoing change that power systems have been going through.
As soon as the turbines produce the electrical energy, its voltage is remarkably increased by passing it via step-up transformers. Therefore, the electrical energy is routed toward a network of high-voltage transmission lines capable to successfully transport electrical energy over long distances. Basically, there are two systems by which electrical energy transition is possible: the high voltage direct current (DC) electrical transmission system, and the high voltage alternating current (AC) electrical transmission system. AC power is today the most used technology to transport high and very high voltage electricity. That said, in three very specific situations, it might be technically more advantageous to use DC. This is the case for some interconnections and for overhead lines, underground or underwater beyond a certain length. Various research works was interested in this process, Reference [78], suggested a new deterministic approach that aims to support the planning system of the electrical energy transmission, which is a market characterized by high levels of uncertainties. The authors applied their approach on two distinct test systems in order to prove the approach efficacy in transmission system planning applications. In their study [79] investigates the replacement of traditional materials (steel, wood and concrete) in electricity transmission lines by fiberglass pultruded members. Design equations available in Fiber reinforced polymers FRP design manuals and analytical methods proposed in the literature are used to predict the critical buckling load and compared to the experimental results. Reference [80]; focus on the ability of European Transmission System Operators (TSOs) to meet the demand for substantial investments in the electricity transmission grid over the next two decades. They employ quantitative analysis to assess the impact of the required capital expenditures under a set of alternative financing strategies. They consider a best-case scenario of full cooperation between the European TSOs. It appears that under current trends in the evolution of transmission tariffs, only half the volumes of investment currently planned could be funded. A highly significant increase in transmission tariffs will be required to ensure the whole-scale investments can be delivered. Reference [81] present a particle swarm optimization (PSO) based approach to solve the multi-stage transmission expansion planning problem in a competitive pool-based electricity market. It is a large-scale non-linear combinatorial problem. They have considered some aspects in their modeling including a multi-year time horizon, a number of scenarios based on the future demands of system, investment and operating costs, and the continuous non-linear functions of market-driven generator offers and demand bids.
At the electric distribution substation that serves your home, the electricity is removed from the transmission system and passed through step-down transformers that lower the voltage. The electricity is then transferred onto your local electric network of distribution lines and delivered to your home. There, the electricity's voltage is lowered again by a distribution transformer and passed through your electric meter into your home's network of electric wires and outlets. A vast number of the literature is related to this process. Reference [82] present simulation results for future electricity grids using an agent-based model developed with MODAM (MODular Agent-based Model), the simulations were run over many years, for two areas in Townsville, Australia, capturing variability in space of the technology uptake, and for

two charging methods for EV, capturing people's behaviors and their impact on the time of the peak load. Impact analyses of these technologies were performed over the areas, down to the distribution transformer level, where greater variability of their contribution to the assets peak load was observed. In their study, [83] present a novel approach for performance assessment of electricity distribution units with stochastic outputs and identify the most important factor through accurate mathematical modeling. Their approach is applied for assessment of Iranian distribution units from 2001 to 2011. Different Iranian distribution units are considered as decision-making units (DMUs). Network length, transport capacity and the number of employees are chosen as inputs while number of customers and total electricity sales are chosen as stochastic outputs. Then, the best electricity distributions units are selected with respect to efficiency scores in stochastic environment. In addition, stochastic data envelopment analysis
(SDEA) model is performed for each input, separately to identify the most important input indicators by comparing the results of associated efficiencies with SDEA model. The empirical results show that network length is the most important and influential input factor in this particular case study. Reference [84] presents a benchmarking study for the maintenance and outage repair activity carried out by a Portuguese electricity distribution company, EDP Distribuição (EDP-D), using the Value-Based DEA method, which builds on links between Data Envelopment Analysis (DEA) and Multiple Criteria Decision Analysis (MCDA). Their study illustrates the impact of the incorporation of managerial preferences in the classification and ranking of 40 network areas served by EDP-D. In order to deal with the underlying uncertainty, the Value-Based DEA method for performance evaluation is adapted to include the concept of super efficiency. Besides identifying best practices, sources of inefficiency, gaps relatively to best practices and opportunities for improvement, their analysis supports the introduction of corrective measures and informs decisions about future goals. In their research, [85] analyze the efficiency performances of 21 Turkish electricity distribution companies during the period of 2002–2009. For this aim, the authors employ a two-stage analysis in order to take into account the business environment variables that are beyond the control of distribution companies. They determine the efficiency performances of the electricity distribution companies by help of DataEnvelopment Analysis (DEA) in the first stage. Then, in the second stage, using these calculated efficiency scores as dependent variable, they utilize Tobit model to determine the business environment variables that may explain the efficiency scores. According to the results, customer density of the region and the private ownership affect the efficiencies positively. Thus, the best strategy to improve efficiency in the market is privatizing the public distribution companies.

4.1.2. The Moroccan electricity supply chain

At the national level, the National Office of Electricity Electrical branch (NOE -EB) is the main operator of electricity. It’s an institution established in 1963 and among its core missions is to satisfy electricity demands in Morocco at the lowest cost and highest quality of service [6]. In order to maintain a balance between the demand and the supply, the NOE -EB operates at all the levels of the supply chain: the production, the transportation, and the distribution of the electricity. The contribution of the NOE -EB in the electricity production has recorded a significant decrease between 1998 and 2003, from 55.4% to 32.3% because of the increasing reliance on dealers and imports to satisfy the expanding demands for electricity. Besides, certain industries that used to contribute in their self-sufficiency of electricity such as (OCP, national sweets, cellulose Morocco) etc. have reduced their contribution to 0.3% in 2003. Compared to 0.5% in 1998. Being the monopoly of electricity transmission in Morocco, NOE -EB takes all the responsibility of its centralized and coordinated management through its headquarters based in Casablanca. The total length of its network infrastructure for transmission and distribution of electricity in 2002 was 128,633 km: 16338 km of very high and high voltage, 33120 km of medium voltage and 79175 km of low voltage network. The NOE -EB is in charge of the distribution of electricity especially in rural areas and in large urban centers by dint of municipal or inter utilities. Since 1999, the NOE -EB distributes by only 49% of the electricity, handing over 51 % to delegates in large cities (Lydec, Redal, Radeema ...). A distributed management of its supply chain currently characterizes the field of electrical energy in Morocco, each party has to make its own local decisions, but the orchestration of the entire chain is supervised by NOE -EB, being the main producer, transporter and distributor [86]. The production of electricity in Morocco is partly provided by the National Electricity Office (NOE -EB), and two major private producers: Jorf Lasfar Energy Company and electric power Tahaddart. The rest of the production is handled by third-party producers (1 %) and supplemented by imports. In Morocco, and during the period 1999-2012, a power generation capacity of 2400 MW has been achieved, including 487 MW in wind energy, 20 MW in solar, 598.4 MW in hydraulic and in nearly 1,300 MW thermal [87].

The transmission network carries electricity from the place of production to the distribution network, and provides interconnection with the networks of neighboring countries. In Morocco, the length of this transport network is 22,995 km in 2013 and it is interconnected to the Spanish and Algerian electrical networks, with the aim of enhance the reliability and security of supply, benefit from the potential savings on the cost per kWh, and integrate the national electricity market in a vast EuroMaghreb market [88]. In Morocco, the NOE -EB is the largest electricity distributor with a market share of 55%; it has ten regional offices throughout the country, and more than 4.9 million customers across the rural world. The rest of the customers is managed by boards of public distribution or private distributors who are themselves major accounts of the NOE -EB. The NOE -EB has a sales network of 25 provincial offices and 192 service agencies including 66 provincial agencies service [89].

The remainder of this chapter is organized as follow: the next section traces the results of the exploration of the Moroccan supply chain of electricity. Section 3 details the evaluation of the Moroccan supply chain of electricity. Section 4 presents the result of the improvement of the studied supply chain. This chapter is concluded in section 5.

4.2.Exploration of the supply chain of electricity

4.2.1. Strategic level

Concerning the studied SC, we have three actors: Supplier (as TAQA/JLEC), NOE -EB and the Distribution agency (as REDAL). As shown in Fig 5, Supplier must produce the electrical energy (presented by the SCOR process sM) to sell it to NOE -EB (presented by the SCOR process sD). The NOE -EB buys (presented by the SCOR process sS) and produces the energy (presented by the SCOR process sM) he also provides its transport, and then he ensures distribution, either by doing it himself, or by selling the electricity to the distribution agencies (presented by the SCOR process sD). As for the agencies, they must buy the electricity from NOE -EB (presented by the SCOR process sS) to distribute it (presented by the SCOR process sD) [6].

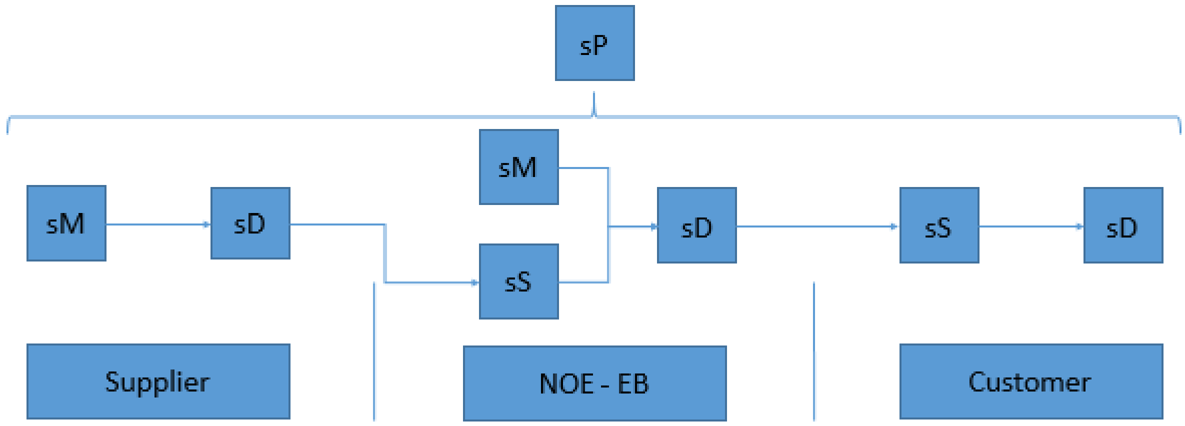

Figure 4.1 The Strategic level model of the Moroccan electricity SC

4.2.2. Tactical level

The second level is a reflection of the strategy adopted by the organization to conduct its operations, in our system there is neither a stocked product nor an engineer-to-order product, our product (the electric energy) is a make-to-order product, so the processes that we have at this level are: sS2 (Source Make-to-Order Product), sM2 (Make-to-Order), sD2 (Deliver Make-to-Order Product). We note that the processes Plan shown in Fig. 6 are sP2 (Plan Source), sP3 (Plan Make), sP4 (Plan Deliver) [6].

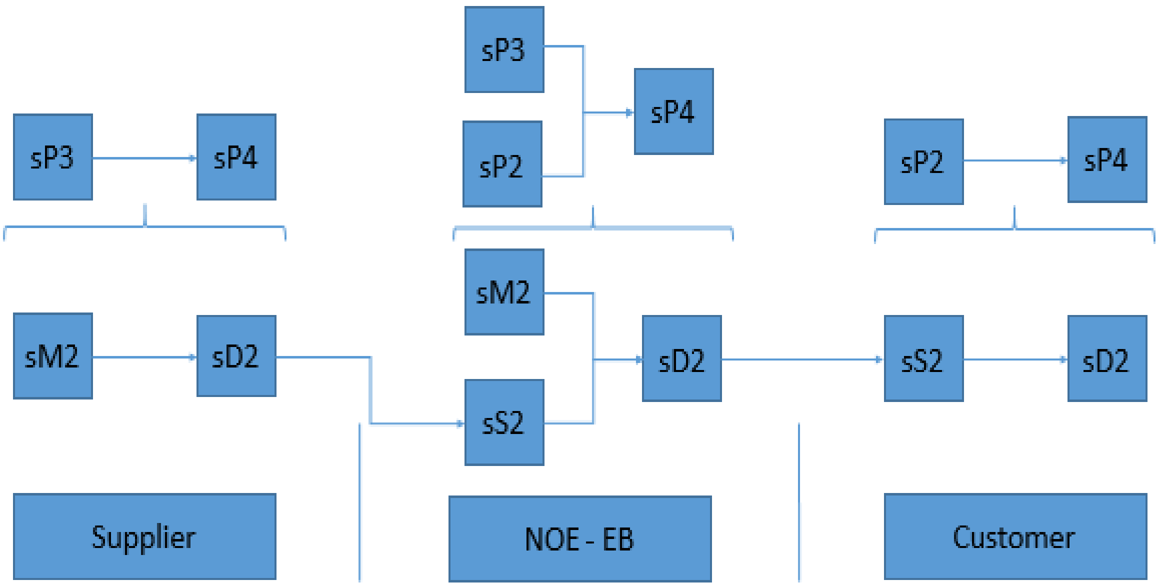

Figure 4.2 The Tactical level model of the Moroccan electricity SC

4.2.3. Operational level

4.2.3.1. sM2 Make-to-Order:

The process of producing electric energy by NOE - EB is detailed at this level by Fig.7. The process sM2.l allows to schedule production, it receives in input the necessary data issued by the processes sEM4 (Manage In-Process Products) and sEMS (Manage Make Equipment and Facilities), and it gives in output the necessary data for the execution of the process sP3.2 (Identify, Assess and Aggregate Production Resources). The process sM2.2 provides the raw materials, it receives in input the necessary data issued by the processes sEM7 (Manage Production Network) and sEM8 (Manage Make Regulatory Environment), and it gives in output the necessary data for the execution of the process sS2.1 (Schedule Product Deliveries). The process sM2.3 checks the production resources received by the process sP3.4 (Establish Production Plans), and it takes into consideration data received by sEM9 (Manage Supply Chain Make Risk) to produce the energy. The process sM2.S puts the finished product in the distribution area, it receives in input the necessary data issued by the processes sP4.4 (Establish Delivery Plans).

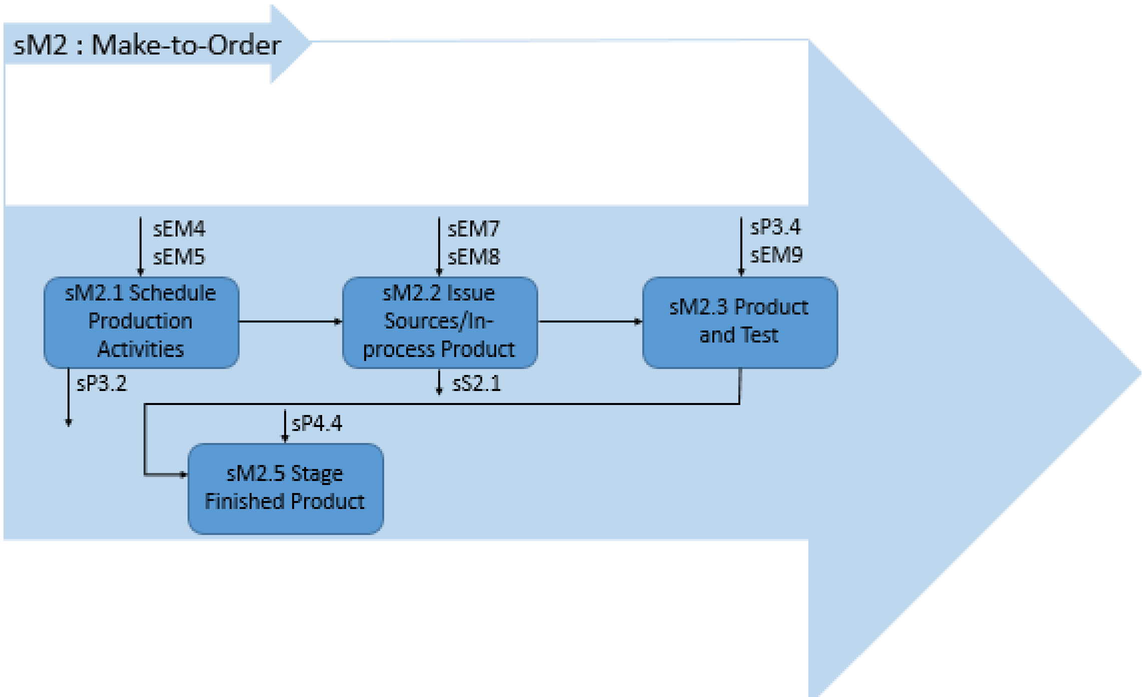

Figure 4.3 The Make-to-Order model for the Moroccan electricity SC

4.2.3.2. sS2 Source Make-to-Order Product

The process of buying electric energy is detailed by Fig.8. The process sS2.1 allows planning delivery, it receives in input the necessary data issued by the processes sP 1.4 (Establish & Communicate Supply-Chain Plans) and sP2.4 (Establish Sourcing Plans), and it gives in output the necessary data for the execution of the processes sP2.2 (Identify, Assess and Aggregate Product Resources) and sES9 (Manage Supply Chain Source Risk). The process sS2.2 manages the reception of the product, it receives in input the necessary data issued by the process sD2.13 (Receive and Verify Product by Customer), and it gives in output the necessary data for the execution of the processes sESI (Manage Sourcing Business Rules), sES2 (Assess Supplier Performance), sES6 (Manage Incoming Product), and sES8 (Manage Import/Export Requirements). The process sS2.3 allows the verification of the receipt of the energy. The process sS2.4 allows the transfer of energy to the distribution network of NOE - EB. The process sS2.S manages the payment of suppliers; it receives in input the necessary data issued.

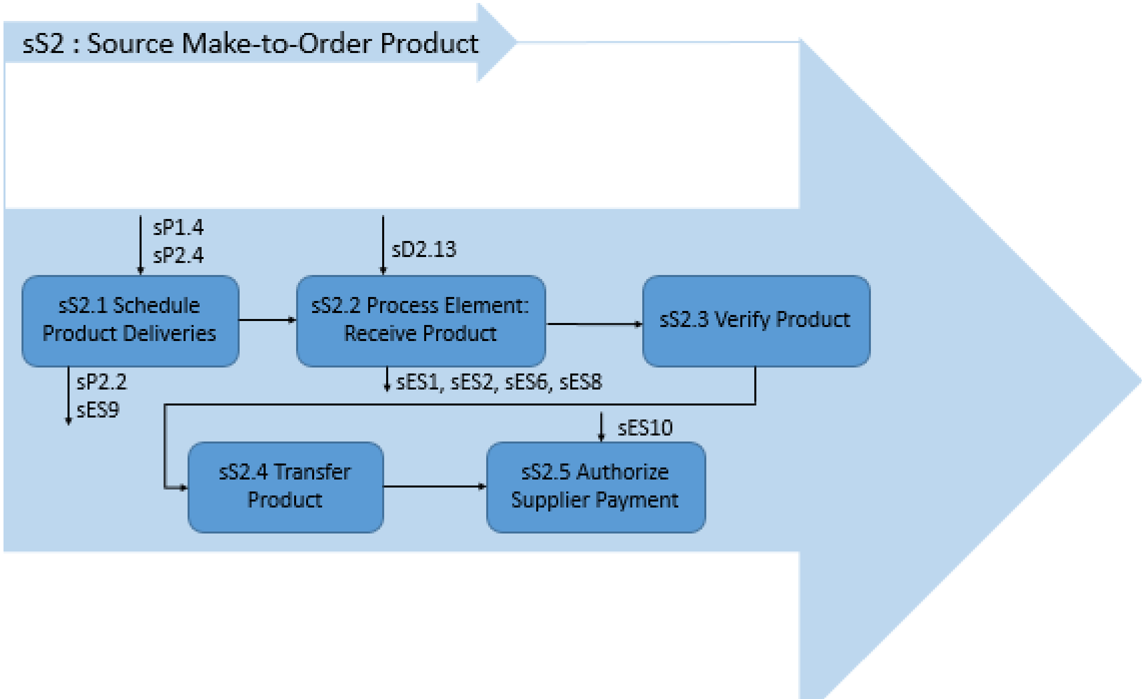

Figure 4.4 The Source Make-to-Order product model for the Moroccan electricity SC

4.2.3.3. sD2 Deliver Make-to-Order Product

The process according to which the NOE - EB distributes purchased electrical energy and the produced one is detailed by Fig.9. The process sD2.1 constitutes the response to the request for information and for quotation. The process sD2.2 manages the receipt and validation of orders, it receives in input the necessary data issued by the process sEDI (Manage Deliver Business Rules), and it gives in output the necessary data for the execution of the processes sED7 (Manage Product Life Cycle), sED3 (Manage Deliver Information), and sED6 (Manage Transportation). The process sD2.4 groups the orders of the different agencies. The process sD2.7 schedules the transmission of energy and evaluates shipping costs. The process sD2.8 ensures the transfer of purchased and produced energy. The process sD2.9 ensures product collection. The process sD2.11 allows charging energy and generates the shipping documents, it receives in input the necessary data issued by the processes sED6 (Manage Transportation) and sED8 (Manage Import/Export Requirements). The process sD2.12 ensures the shipment of energy. The process sD2.13 manages the reception and control of energy. The process sD2.14 ensures the dispatch of energy in the network of distribution agencies. The process sD2.l 5 manages billing.

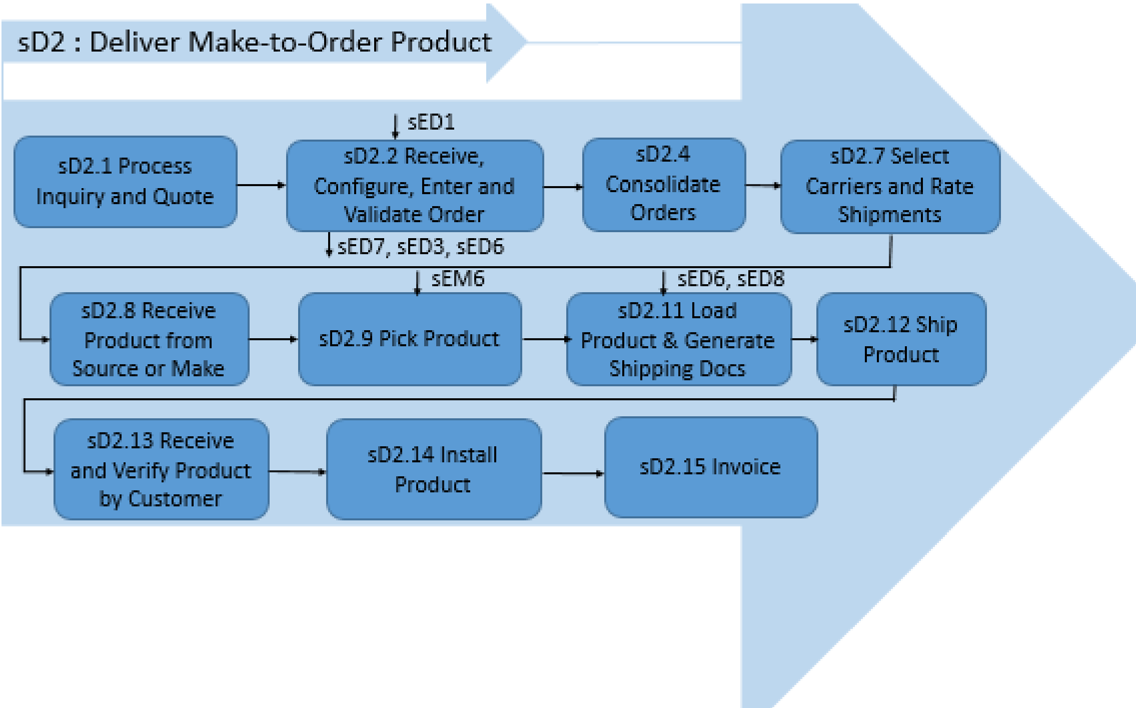

Figure 4.5 The Deliver Make-to-Order product model for the Moroccan electricity SC

4.3.Evaluation of the supply chain of electricity

4.3.1. Define phase

The first phase consists of analyzing the studied business process and make it clear. The business process ‘the management of electricity for residential buildings’ of the Moroccan supply chain of electricity is shown in Fig 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 Fig.4 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 whose the activity management generates electricity. They consume a generated electricity share and they sell a share of it to NOE - EB. For areas whose distribution is managed by private distributors (e.g. Redal), these distributors periodically sends to the NOE - EB the area consumption profile, if not for areas whose distribution is managed by the NOE - EB, it respects its production plan. Thus, to produce electricity, NOE - EB 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 NOE - EB, import of electricity, or purchase of electricity (activities of the NOE - EB lane), once the electricity is generated, NOE - EB ensures its transport, and then depending on the area it manages the distribution, or it sells it to distributors. The distributors buy electricity from NOE - EB and distribute it. The end user consumes electricity. These processes are managed by contracts between producers and NOE - EB, NOE - EB 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, the billing.

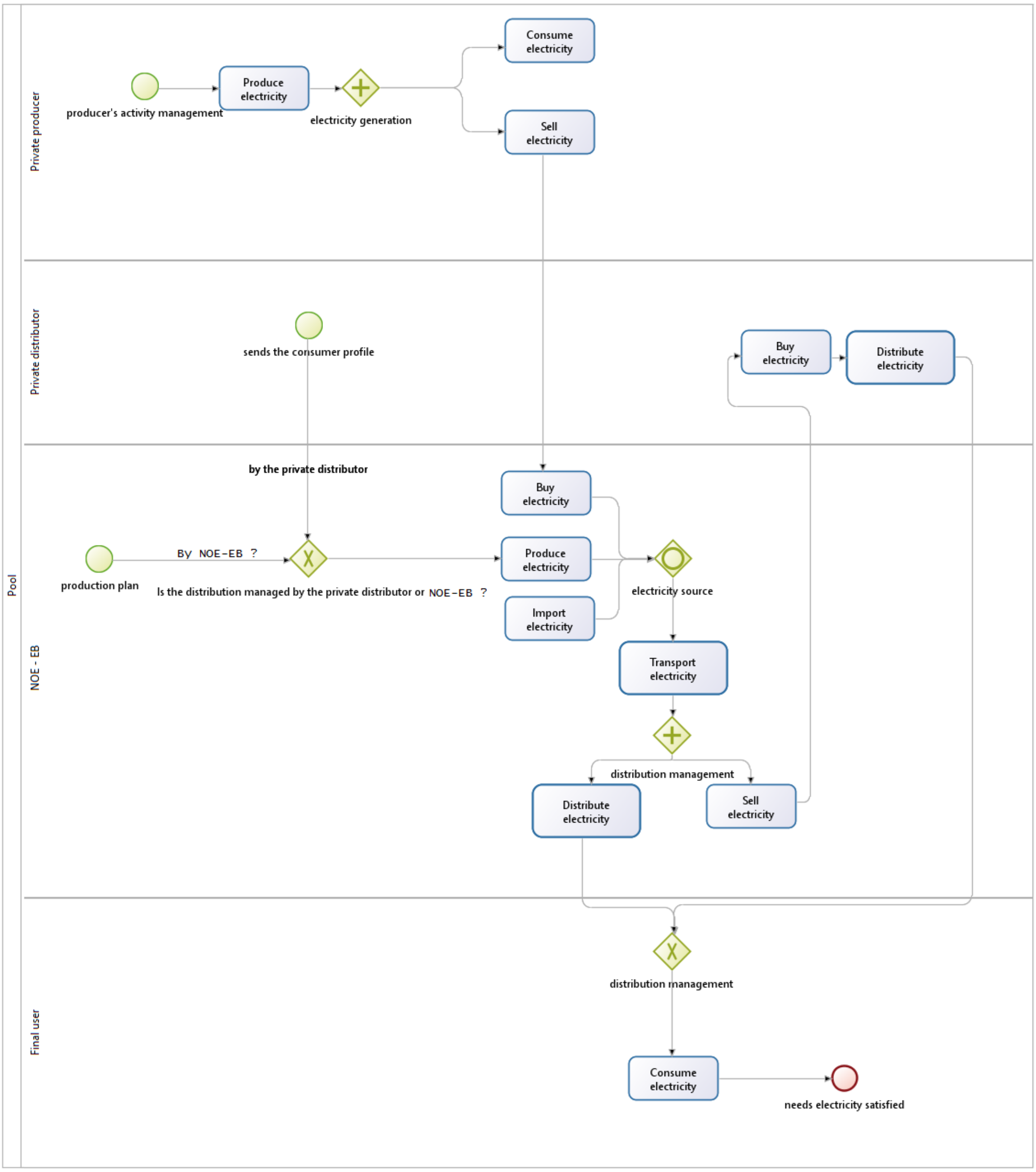

Figure 4.6 The 'electricity management for residential buildings' business process model

4.3.2. 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, and 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 are run either with simulated data or with assigned probabilities. In order to specify the scenarios to simulate, the form shown in Fig. 2 is created, to feed our objects before launching the simulation.

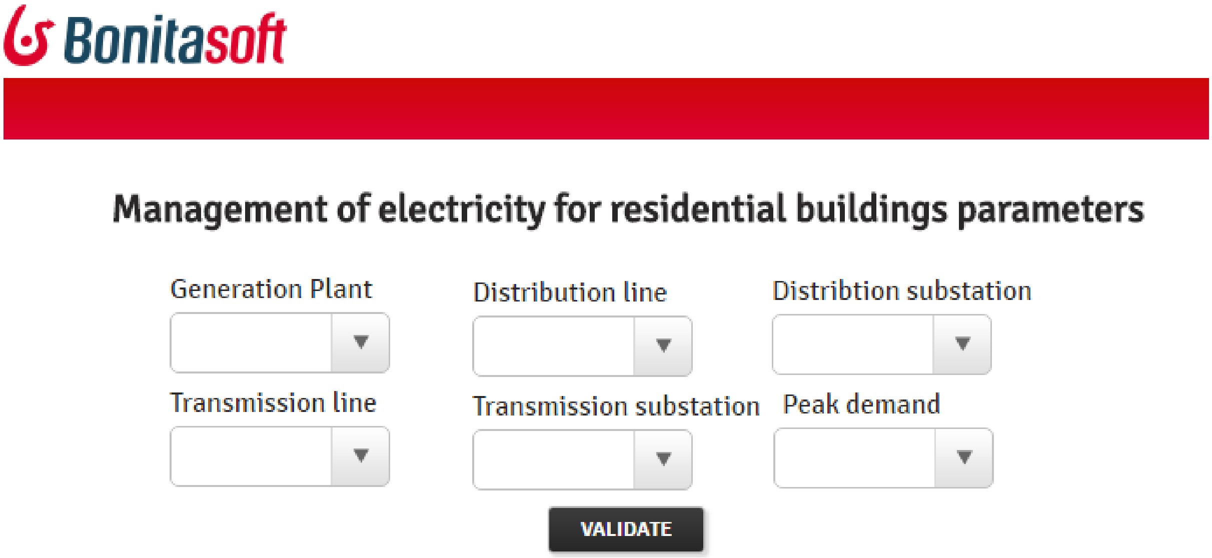

Figure 4.7 The simulation scenarios Form

Table 1 shows the scenarios to simulate to detect the elements that affect the service continuity.

Table 4-1 The 'electricity management for residential buildings' 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 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 executed six times, and in each time, we have entered the parameters specific to each scenario. The following table (table 2) presents the minimum, the average and the maximum execution time (by hours) of the main tasks of the lanes: NOE - EB and Final user that are ‘produce electricity’, ‘transport electricity’, ‘distribute electricity’, and ‘consume electricity’. (Sc: Scenario, Mi: minimum, A: average, Ma: maximum).

Table 4-2 The activities execution time per scenario

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.

4.3.3. Analyze phase

This phase allows to closely examining 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.
The cause tree below presents, the causes of the discontinuity for this business process.

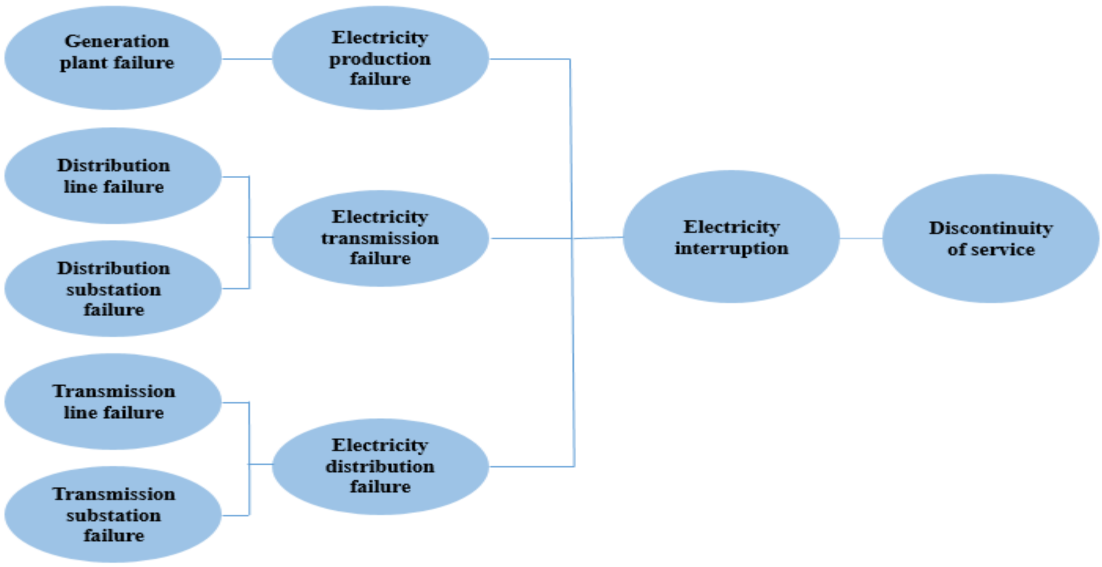

Figure 4.8 The cause tree diagram for electricity interruption

4.3.4. 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 level 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. [90].

- ‘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. [90].
- ‘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 [90].

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, individuals whose consumption is unpredictable typically cause the forecast error. 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 Fig 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 NOE - EB. The reconfiguration is made as an adding of two activities at the lane "Final user", and of a flow between "NOE - EB" 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 NOE - EB. This means that the management of the decentralized electricity production will add other support activities to the lane "NOE - EB"(not shown in Fig 2) as encouraging individuals to follow this new policy.

Figure 4.9 The improved 'electricity management for residential buildings' business process model

4.3.5. 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: [Sum Actual Cycle Times for All Orders Delivered] / [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'; [consumption duration – outages duration] / [consumption duration].

And based on [91] 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 (percentage 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 (percentage).
- Average duration of interruptions per subscriber (Hours/year).
- Average frequency of interruptions per subscriber (Interruptions/year).

In addition, to recapitulate the following Table presents the dashboard that sum up these indicators.

Table 4-3 The control dashboard for the Moroccan electricity SC

Attribute	Indicator	Indicator type	Calculation periodicity
Reliability	[electricity production expressed in Twh/an]/[electricity consumption: expressed in primary energy kWhep/m2 / year, the area is considered the living area]	Steering indicator	A trimester
Responsiveness	[consumption duration – outages duration] / [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	Performance indicator	A year

	Households in the Concession Area (Residential Coverage)		
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.

4.4. Improvement of the supply chain of electricity

4.4.1. Supply chain modelling with L-SCOR

At the second level of L-SCOR, Fig 3 presents the modelling of the supply chain of electricity. We note that the planning processes interact with the learning process sL3 "Learn Make" that describes the management of adaptability for electricity production.

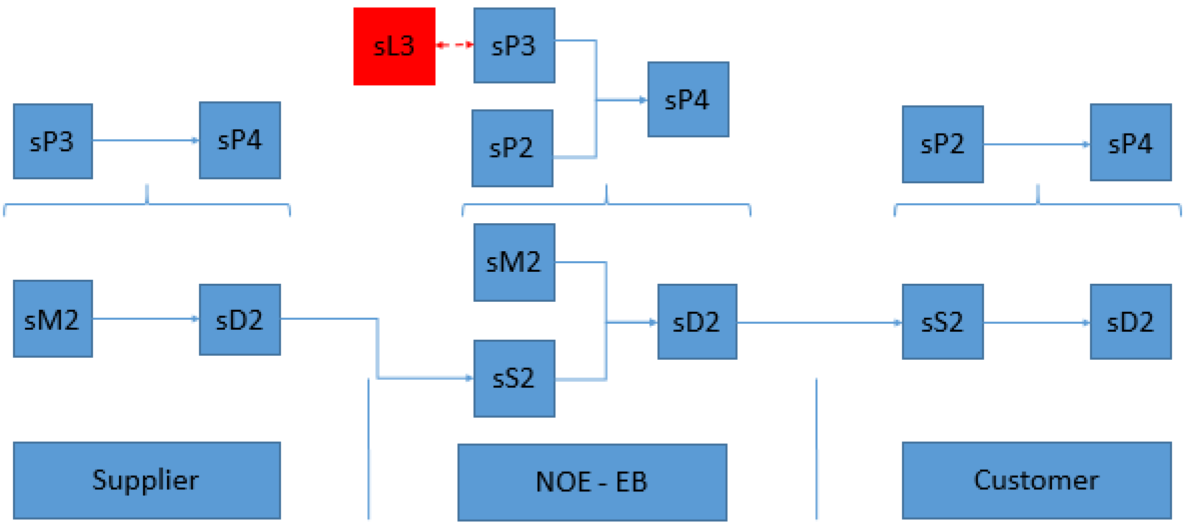

Figure 4.10 The Tactical level model of the self-adaptive Moroccan electricity SC

Concerning the real-time level, Fig 4 presents "the management of electricity for residential buildings" business process of the self-adaptive SC of electricity. We notice on the BPMN model the addition of the "Study electricity supply" activity and the script activity “Execute recommendation system". The added script activity implements the Q-learning algorithm, and receives the necessary data for its execution, returning thus the optimal combination (state, action) for the electricity supply.

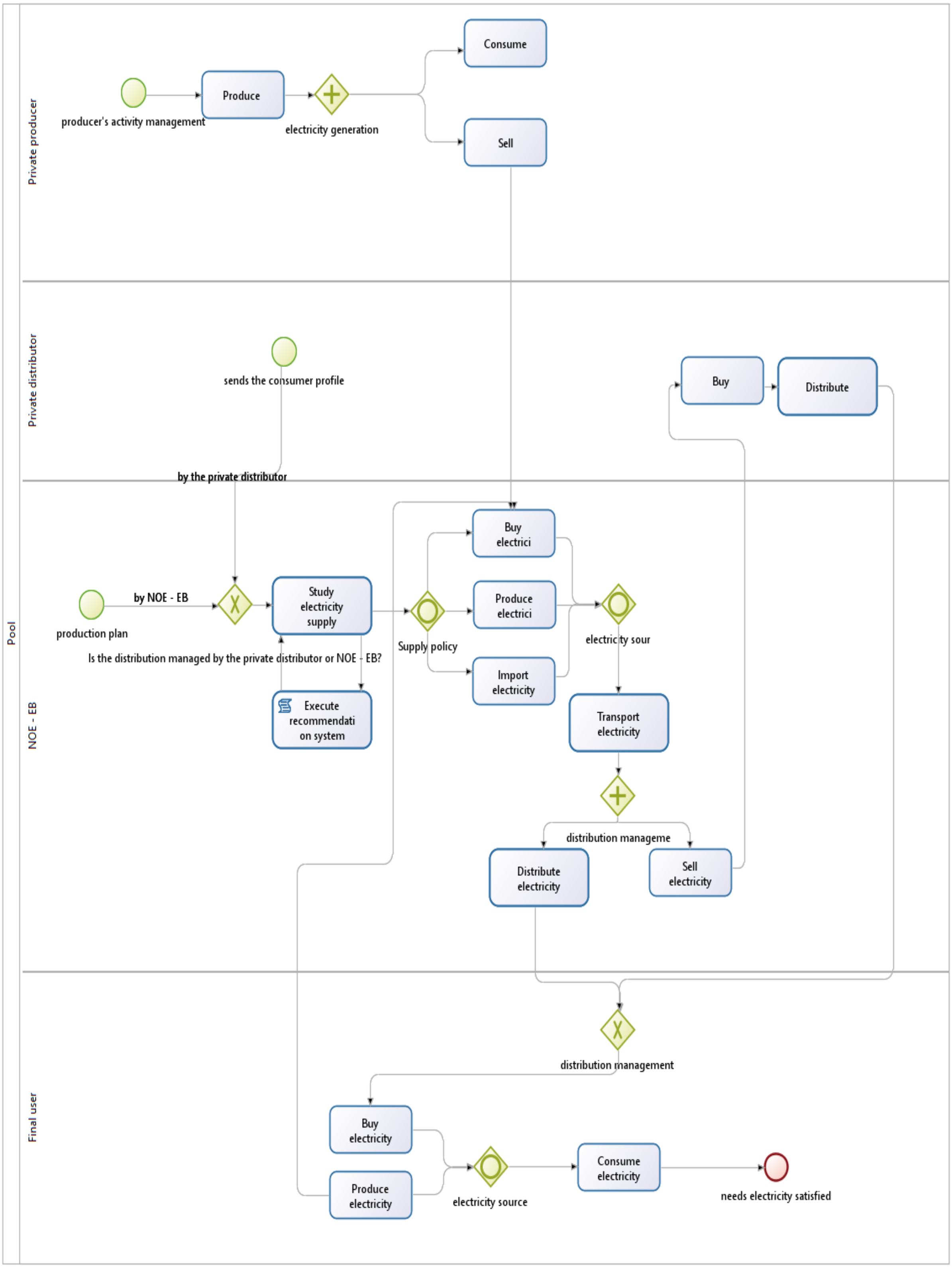

Figure 4.11 The self-adaptive ‘electricity management for residential buildings' business process model

4.4.2. Implementation and results analysis

4.4.2.1. State Space and Actions

The first step to apply Q-Learning algorithm is defining the state space. In practical applications, we are looking to obtain results in a limited time frame. If the state space is very large, the algorithm will take too long to converge. The possible states of the components of an electrical grid for managing electricity in residential buildings, trace the possible states for this agent. Those states are as follows: 'Electricity are need defined', 'Electricity supplied', 'Generation plant failure', 'Transmission line failure', 'Transmission substation failure', 'Distribution line failure', 'Distribution substation failure', 'Generation problem resolved', 'Transmission problem resolved', 'Distribution problem resolved', 'Electricity transported', 'Electricity distributed', 'Electricity consumed', 'Agent stuck in a state', 'Agent returned to a previous state', 'Agent skipped a processing step'. An identifier is associated with each state respectively as follows: 'S0: Electricity are need defined', 'S1: Electricity supplied', 'S2: Generation plant failure', 'S3: Transmission line failure', 'S4: Transmission substation failure', 'S5: Distribution line failure', 'S6: Distribution substation failure', 'S7: Generation problem resolved', 'S8: Transmission problem resolved', 'S9: Distribution problem resolved', 'S10: Electricity transported', 'S11: Electricity distributed', 'S12: Electricity consumed', 'S13: Agent stuck in a state', 'S14: Agent returned to a previous state', 'S15: Agent skipped a processing step'. The states space S is the set of these identifiers S = {S0, S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15}. The possible operations on electricity in residential buildings present all the agent actions as follows: 'Supply electricity', 'Transport electricity', 'Distribute electricity', 'Resolve electrical grid problem', 'Consume electricity' and 'Return result'. An identifier is associated with each action respectively as follows: 'A0: Supply electricity', 'A1: Transport electricity', 'A2: Distribute electricity', 'A3: Resolve electrical grid problem', 'A4: Consume electricity' and 'A5: Return result'. The actions space A is the set of these identifiers A= {A0, A1, A2, A3, A4, A5}.

4.4.2.2. The Reward Functions

The purpose of choosing an action transitioning to some state is illustrated by the reward function that plays a key role in learning speed. The reward value can be negative or positive. A negative reward value is used to express a penalty for an undesirable action. The rewards that are generated after a state transition are a short-term outcome. Because of including future rewards in the evaluation of algorithm actions, it may return a low immediate reword for an action linked to a high Q-value. A fixed reward function is implemented generating static rewards. This function is described in Table 4 - 4.

Table 4-4 Reward function for the 'electrical grid' agent

State	Reward
S0: Electricity are need defined	0
S1: Electricity supplied	20
S2: Generation plant failure	-1
S3: Transmission line failure	-1
S4: Transmission substation failure	-1

S5: Distribution line failure	-1
S6: Distribution substation failure	-1
S7: Generation problem resolved	20
S8: Transmission problem resolved	20
S9: Distribution problem resolved	20
10: Electricity transported	20
S11: Electricity distributed	20
S12: Electricity consumed	50
S13: Agent stuck in a state	0
S14: Agent returned to a previous state	-1
S15: Agent skipped a processing step	0

4.4.2.3. The Value Functions

The Q values of state-action pairs is stored in Q-table. All values stored in the table are initially set to zero. The rows in the table represent the retirement folder's states, and the columns represent the action corresponding to the given state. During training, each entry in the table is populated by updating the Q values. After sufficient training, the Q values converges. The updating equation is shown below:

$$Q(s, a) \leftarrow \alpha \times (r + \gamma \times \max a' (Q(s', a'))) + (1 - \alpha) \times Q(s, a)$$

Where 's' is the current joint state, and 'a' is the selecting action. 's'' is the next state that the retirement folder transfers to from the current state after performed by the action 'a'. 'α' is the learning rate, it specifies to what extent recently learned information supersedes old information. 'γ' is the discount factor, it determines the importance of future rewards. After training, the retirement folder is able to execute the best action for each state.

4.4.2.4. The Results

As explained in section 2.4.2.4 and 3.4.2.4 the Q-table is a lookup table where the agent calculates the maximum expected future rewards for action at each state, and which will guide the agent to the best action at each state. In the Q-table, the columns will be the available actions and the rows will be the states. For the 'electrical grid' agent, Q-learning algorithm is executed according to the parameters presented in table 4.5 as follow.

Table 4-5 Q-learning used parameters for the 'electrical grid' agent

Parameter	Value
Learning rate	0.05
Discount factor	0.7
Initial Q-value	0
Initial value of ϵ	0.6
ϵ Decay rate	0.005

The Q-table returned by the recommendation web service for the 'electrical grid' agent is shown in table 4.6.

Table 4-6 The returned Q-Table for the ‘drug within hospital’ agent

	A0	A1	A2	A3	A4	A5
S0	19.996	0	0	0	0	0
S1	0	19.996	0	0	0	0
S2	-1.345	-1.345	-1.345	19.996	0	0
S3	-1.345	-1.345	-1.345	19.996	0	0
S4	-1.345	-1.345	-1.345	19.996	0	0
S5	-1.345	-1.345	-1.345	19.996	0	0
S6	-1.345	-1.345	-1.345	19.996	0	0
S7	19.996	0	0	0	0	0
S8	-1.345	19.996	0	0	0	0
S9	-1.345	-1.345	19.996	0	0	0
S10	-1.345	0	19.996	0	0	0
S11	-1.345	-1.345	0	0	49.99	0
S12	-1.345	-1.345	-1.345	-1.345	0	49.99
S13	0	0	0	19.996	0	0
S14	-1.345	-1.345	-1.345	19.996	-1.345	-1.345
S15	0	0	0	19.996	0	0

The optimal strategy imposed by the recommendation web service for the "electrical grid" agent according to the returned Q-Table is as follows:
OS = {(S0,A0), (S1,A1), (S2,A3), (S3, A3), (S4,A3), (S5,A3), (S6,A3), (S7,A0), (S8, A1), (S9,A2), (S10, A2, (S11,A4), (S12,A5), (S13,A3), (S14,A3), (S15,A3)}
By comparing the optimal strategy with the results of applying the 'Evaluation of the supply chain of electricity' approach, we conclude that the recommendation web service requires our agent to behave in a manner avoiding the service discontinuity causes.

4.5. Conclusion

This chapter is devoted to the case study of the Moroccan electricity SC. The exploration of this SC is done using SCOR at the three first levels of the supply chain, defining the main stakeholders, activities and flows. The SC evaluation is based on the five-phase DMAIC method. The "Define" phase projects sM2 Make-to-Order process that describes the management of the electric energy production, at the fourth level of the SC using BPMN. At the second phase "Measure", we used the BPM simulation according to a defined load profile and six different scenarios. Based on the results of the aforementioned phases, the "Analyze" phase, traces a cause tree diagram that presents the causes behind the electricity interruption. At the "Improve" phase, we took advantage of “Interconnectivity”, the smart SC characteristic as defined in literature. The made modifications concerning flows are presented using SCOR 2nd level model, and those concerning the business process activities are presented using the 4-th level BPMN model. In the last phase "Control”, a dashboard is established, composed of both steering and performance KPIs based on both SCOR metrics and simulation results. Regarding the improvement of the Moroccan electricity SC, the proposed reference L-SCOR is adopted. We started by expressing the SC at the second level of L-SCOR, in order to clarify the flows between the planning processes and sL3 "Learn Make" that describes the management of adaptability for electricity production. Then we established at the fourth level of L-SCOR “the management of electricity for residential buildings” business process, thus explaining, how the recommendation web service will be used for this business process. Last and not least, we explain, the communication protocol between the calling activity and the recommendation web service, the prerequisites for the implementation of the Q-Learning algorithm, by defining the environment adapted to this case agent, the action space, the state space, and the reward table. Finally, we discuss the returning Q-table and the adopted strategy used by the called activity.

Conclusion

This chapter briefly summarizes the findings of this thesis and presents some directions for future research.

Summary

This thesis investigated adaptability of supply chain processes, in order to develop a framework for self-adaptability management of process approach based systems.

Chapter 1 proposes L-SCOR a 4-level reference for self-adaptive business processes based on SCOR and adapted to the various supply chain types. L-SCOR extends SCOR by integrating the notion of adaptability on its both sections "Process" and "Metric". Regarding "Process" section, and in addition to the five SCOR core processes, L-SCOR proposes the process sL "Learn", which is divided in the second level of a SC into five sub-processes: "sL1 - Learn Plan", "sL2 - Learn Source", "sL3 - Learn Make", "sL4 - Learn Deliver" and "sL5 - Learn Return". Moreover, concerning "Metric" section, L-SCOR adds the performance attribute "adaptability" that describes the SC ability to cope with changes or unexpected malfunction, and which is composed of eight metrics distributed between the three SC levels.
This chapter proposes also an implementation for the process sL, which is explained at the fourth level of the SC using BPMN. Indeed the fourth level details how an activity of a given process can call a web service implementing the algorithm Q-learning that will return for the calling process the optimal policy for its operation. This chapter also describes the adopted methodology for case studies, which is a three-steep method that goes from the exploration of a SC to its improvement.

Chapter 2 investigates the retirement supply chain, by first exploring the Moroccan retirement SC using SCOR at its three first levels. At the end of this step, the content and context of the studied supply chain are established; the main stakeholders (Affiliate, MPF, and Pensioner), activities and flows are defined. The second part of this chapter focuses on the evaluation of the Moroccan retirement SC, using a five-phase method. The first phase "Define" is a continuation of the SC exploration, it projects sM2 Make-to-Order process - that describes the management of rights liquidation - at the SC fourth level using BPMN. At the "Measure" phase, we used the BPM simulation according to a defined load profile and six different scenarios, in order to determine how the chosen business process currently performs. Based on the results of the aforementioned phases, the "Analyze" phase, traces a cause tree diagram that presents the causes behind discontinuity between the salary and the pension. At the "Improve" phase, we took advantage of the Smart SC characteristic "Interconnectivity" as defined in literature, in order to mitigate the discontinuity root causes, then we present the made modifications concerning flows using SCOR 2nd level model, and those concerning the business process activities using the 4-th level BPMN model. The last phase of this chapter second part is "Control", and it aims to continually verify if the actions created in the previous phase are well maintained, by establishing a dashboard composed of both steering and performance KPIs based on both SCOR metrics and simulation results. The third part of this chapter focuses on the improvement of the Moroccan retirement SC in order to move on from a classic SC to a self-adaptive one. To this end, the proposed reference L-SCOR is adopted. We started by expressing the Moroccan retirement SC at the second level of L-SCOR, in order to clarify the flows between the planning processes and sL3 "Learn Make" that describes the management of adaptability for rights liquidation. Then we established at the fourth level of L-SCOR the business process "the management of civil pension rights", which explains the way recommendation web service will be used for this business process. Once the modeling of the adaptive business process is developed. We explain, the communication protocol between the calling activity and the recommendation web service, the prerequisites for the implementation of the Q-Learning algorithm, the environment adapted to this case study agent, the action space, the state space, and the reward table. Finally, we discuss the returning Q-table and the adopted strategy used by the called activity. To conclude in this chapter we studied and analyzed an example of service SC using SCOR and a methodology based on six sigma, while taking advantage of a smart SC characteristic, then we established a self-adaptive version of this service SC that is based on the proposed reference L-SCOR.

Chapter 3 focuses rather on a classic SC with a physical product, it explores the drugs supply chain within the hospital, using SCOR at its three first levels. Which allows us to clarify the content and context of the studied SC, and to identify its main stakeholders (Supplier, Hospital pharmacy, and Patient), activities and flows. The evaluation of the drugs SC within hospital, is done with the same 5-phase method used in chapter 2. The first phase "Define" is a continuation of the SC exploration, it projects sD1 Deliver Stocked Product process that describes the management of drugs dispensation within the hospital, at the SC fourth level using BPMN. At the second phase "Measure", and in order to compare the human resources qualification of the two scenarios of drugs dispensation (nominative dispensation and global dispensation) in a Moroccan public hospital, we used the BPM simulation. The "Analyze" phase, traces a cause tree diagram explaining the causes behind an insecure dispensation. At the "Improve" phase, we took advantage of the Smart supply chain characteristic "Interconnectivity" in order to improve the dispensation business process functioning, then we present the made modifications concerning flows using SCOR 2nd level model, and those concerning the business process activities using the 4-th level BPMN model. The "Control" phase proposes a dashboard composed of both steering and performance KPIs based on both SCOR metrics and simulation results. The third part of this chapter uses the proposed reference L-SCOR to improve the drugs SC within the hospital, making it more self-adaptive. We started by expressing the studied SC at the second level of L-SCOR, in order to clarify the flows between the planning processes and sL4 "Learn Deliver" that describes the management of adaptability for drugs dispensation in a hospital. Then we established at the fourth level of L-SCOR the dispensation business process that explains the way recommendation web service will be used for this business process. Once the modeling of the adaptive business process is developed. We explain, the communication protocol between the calling activity and the recommendation web service, the prerequisites for the implementation of the Q-Learning algorithm, the environment adapted to this case study agent, the action space, the state space, and the reward table. Finally, we discuss the returning Q-table and the adopted strategy used by the called activity. To conclude in this chapter we studied and analyzed a classic SC with a physical product using SCOR and a methodology based on six sigma, while taking advantage of smart SC characteristic, then we proposed and explained a self-adaptive version of this classic SC that is based on the proposed reference L-SCOR.

The last case study is presented in chapter 4. This chapter addresses a different type of SC whose product is energy. It explors the Moroccan electricity SC using SCOR at its three first levels. Thus, establishing the content and context of this SC; and defining the main stakeholders (Supplier, NOE- EB, and Customer), activities and flows. The second part of this chapter focuses on the evaluation of the Moroccan electricity SC, using the same methodology used in the previous case studies. The first phase "Define" is a continuation of the SC exploration, it projects sM2 Make-to-Order process that describes the management of the electric energy production, at the fourth level using BPMN. At the second phase "Measure", and in order to determine how the chosen business process currently performs, we used the BPM simulation according to a defined load profile and six different scenarios. Based on the results of the aforementioned phases, the "Analyze" phase, traces a cause tree diagram to present the causes behind the electricity interruption. At the "Improve" phase, "interconnectivity" is integrated as a smart SC characteristic, in order to mitigate the discontinuity root causes. We present the made modifications concerning flows using SCOR 2nd level model, and those concerning the business process ‘the management of electricity for residential buildings’ using the 4-th level BPMN model. The last phase of this chapter second part is "Control", and it aims to continually verify if the actions created in the previous phase are well maintained, by establishing a dashboard composed of both steering and performance KPIs based on both SCOR metrics and simulation results. The third part of this chapter focuses on the improvement of the Moroccan electricity SC in order to move on from a classic supply chain to a self-adaptive one. To this end, the proposed reference L-SCOR is adopted. We started by expressing the Moroccan electricity supply chain at the second level of L-SCOR, in order to clarify the flows between the planning processes and sL3 "Learn Make" that describes the management of adaptability for electricity production. Then we established at the fourth level of L-SCOR the business process "the management of electricity for residential buildings", to explain the way recommendation web service will be used for this business process. Once the modeling of the adaptive business process is developed. We explain, the communication protocol between the calling activity and the recommendation web service, the prerequisites for the implementation of the Q-Learning algorithm, by defining the environment adapted to this case study agent, the action space, the state space, and the reward table. Finally, we discuss the returning Q-table and the adopted strategy used by the called activity. To conclude in this chapter the last case study is investigated using the same methodology used for the previous ones. And then a self-adaptive version of the studied SC is established based on the proposed reference L-SCOR.

Future research

Throughout this thesis a number new directions for future research presented themselves. Some ideas are briefly summarized below.

Regarding the proposed reference, it extends two of SCOR sections, future research should attempt to extend the two remained sections "practices" and "people". Making L-SCOR nearly a new version of the SCOR integrating the "adaptability" concept in all its sections.

The implementation of sL proposed and tested in this thesis is based on the basic version of the Q-learning algorithm. Future research should attempt to compare the results of other RL algorithms used in the same context, or to propose another algorithm more suitable to self-adaptive processes.

All the Python libraries offered for RL environments are rather robotics and games oriented. Future research should attempt to study the possibility of developing a flexible library that can be used to facilitate the application of RL algorithms for agents from everyday cases (retirement file, medication in the hospital, network of electricity ...).

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Appendix

Thesis publications

Book Chapters

1. Mezouar H., El Afia A. (2018) “A Retirement Pension from a Supply Chain Side: Case of the Moroccan Retirement Pension”. In: Ezziyyani M., Bahaj M., Khoukhi F. (eds) Advanced Information Technology, Services and Systems. AIT2S 2017. Lecture Notes in Networks and Systems, vol 25. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-69137-4_11

Journals

2. Mezouar H., El Afia A. (2019) “Proposal for an approach to evaluate continuity in service supply chains: case of the Moroccan electricity supply chain”. In: International Journal of Electrical and Computer Engineering (IJECE), Vol 9 (6) pp. 5552-5559. DOI: http://doi.org/10.11591/ijece.v9i6.pp5552-5559
3. Mezouar H., El Afia A. (2019) “Proposal of an approach to improve business processes of a service supply chain”. In: International Journal of Mechanical Engineering and Technology (IJMET), Vol 10 (03) pp. 978-989. DOI : http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=10&IType=3
4. Mezouar H., El Afia A. (2018) "Performance analysis model for service supply chains: Case of the retirement supply chain". In: International Journal of Engineering & Technology (IJET), Vol 7 (3) pp. 1429-1438. DOI: 10.14419/ijet.v7i3.13929

Conferences

5. Mezouar H., El Afia A. (2019) “A 4-level reference for self-adaptive processes based on SCOR and integrating Q-Learnin”. In: The 4th International Conference On Big Data and Internet of Things (BDIoT'19), October 23 & 24, 2019 - Tangier-Tetuan, Morocco, ACM, 2019. DOI: https://doi.org/10.1145/3372938.3372953 (in press)
6. Mezouar H., EL Afia A. (2017) “A process simulation model for a proposed Moroccan supply chain of electricity”. In: International Renewable and Sustainable Energy Conference (IRSEC), November 14-17, 2016 - Marrakech, Morocco, IEEE, 2017. DOI: 10.1109/IRSEC.2016.7983999
7. El Afia A., Mezouar H. (2017) “A global mapping of the Moroccan supply chain of hospital drugs and a simulation of the dispensation process”. In: the 2nd international Conference on Big Data, Cloud and Applications (BDCA'17), March 29-30, 2017 – Tetouan, Morocco, ACM, 2017. DOI: 10.1145/3090354.3090465

8. Mezouar, H., El afia, A., Chiheb, R., Ouzayd, F. (2016) “Proposal of a modeling approach and a set of KPI to the drug supply chain within the hospital”. In: The 3rd International Conference on Logistics Operations Management (GOL), May 23-25, 2016 – Fez, Morocco, IEEE, 2016.DOI: 10.1109/GOL.2016.7731691
9. Mezouar, H., El Afia, A., Chiheb, R. (2016) "A new concept of intelligence in the electric power management". In: The 2nd International Conference on Electrical and Information Technologies (ICEIT 16), May 4-7, 2016 - Tangier, Morocco, IEEE, 2016. DOI: 10.1109/EITech.2016.7519596
10. Mezouar, H., El Afia, A., Chiheb, R., Ouzayd, F. (2015) "Toward a process model of Moroccan electric supply chain". In: The International Conference on Electrical and Information Technologies (ICEIT 15), March 25-27, 2015 - Marrakech, Morocco, IEEE, 2015. DOI: 10.1109/EITech.2015.7162990

Managing adaptability in process based software using Q-Learning and web services

Résumé : Au cours des dernières décennies, il y a eu un intérêt et des progrès considérables dans la recherche dans les deux domaines «l'approche processus» en tant que stratégie de gestion et «l'apprentissage automatique» en tant que discipline de l'intelligence artificielle. Plusieurs problématiques ont été abordées dans la littérature, autour de ces deux thèmes. Dans cette thèse, nous utilisons l'apprentissage par renforcement pour améliorer la performance des processus métier, et plus précisément, pour le rendre auto-adaptatif. Pour ce faire, un référentiel à quatre niveaux est établi retraçant le concept d'adaptabilité tout au long de la chaîne d'approvisionnement. Aux trois premiers niveaux de la chaîne d'approvisionnement, L-SCOR, la référence proposée étend les processus et les métriques SCOR en ajoutant le processus «sL Learn» et l'attribut «Adaptabilité», au quatrième niveau de la chaîne d'approvisionnement, elle propose une implémentation au processus sL à l'aide du service Web et Q-Learning. Dans le cadre de cette thèse, et afin de prouver l'efficacité de la référence proposée, trois études de cas ont été réalisées, basées sur des chaînes logistiques distinctes : «la chaîne logistique d'une pension de retraite», «la chaîne logistique de l'énergie électricité» et «la chaine logistique des médicaments au sein de l'hôpital». Les études de cas susmentionnées ont été établies selon une méthodologie proposée en trois étapes. La première étape est l'exploration de la chaîne logistique à travers la modélisation SCOR. La deuxième étape est l'évaluation de la chaîne logistique en utilisant une combinaison de méthodes et de technologies pour respecter «DMAIC» l'approche six-sigma. La dernière étape est l'amélioration de la chaîne logistique basée sur la mise en œuvre de la référence L-SCOR proposée. L'analyse des résultats fournit une preuve composite de l'efficacité de référence proposée.

Mots clés : Apprentissage par renforcement, Q-Learning, Adaptabilité des processus, SCOR

Abstract: Over the past decades, there has been substantial interest and progress in research in both fields “the process approach” as a management strategy, and “machine learning” as an artificial intelligence discipline. Several problematic issues have been addressed in the literature, around these two themes. In this thesis, we use reinforcement learning to improve the performance of business processes, and more precisely, to make it self-adaptive. To this end, a four-level referential is established tracing the concept of adaptability throughout the supply chain. At the three first supply chain levels, L-SCOR, the proposed reference extends SCOR processes and metrics by adding "sL Learn" process and the attribute "Adaptability", at the fourth supply chain level it proposes an implementation to sL process using web service and Q-Learning. Within the framework of this thesis, and in order to prove the effectiveness of the proposed reference, three case studies were carried out, based on distinct supply chains: "the retirement supply chain", "the electricity supply chain" and "the drugs supply chain". The aforementioned case studies were established according to a three-step proposed methodology. The first step is the supply chain exploration through SCOR modeling. The second step is the supply chain evaluation using a combination of methods and technologies to respect "DMAIC" the six-sigma approach. The last step is the supply chain improvement based on the implementation of the proposed L-SCOR reference. The results analysis provides composite evidence of the proposed reference effectiveness.

Keywords: Reinforcement learning, Q-Learning, Process adaptability, SCOR