Towards a cloud computing in the service of green logistics

Zineb Benotmane* and Ghalem Belalem
Department of Computer Science, Faculty of Exact Sciences and Applied, University of Oran 1, Ahmed Ben Bella, Oran, Algeria
Email: benotmane.dz@gmail.com
Email: ghalem1dz@gmail.com
*Corresponding author

Abdelkader Neki
QLIO Department, IUT de Cergy Pontoise, 95-97, rue Valère Collas, 95100 Argenteuil, France
Email: abdelkader.neki@u-cergy.fr

Abstract: The development of cloud computing solutions for logistics offers new benefits to companies, such as access to resources on demand, elasticity and usage billing. In this paper, we propose a multi-agent system based on a cloud computing platform called system agent cloud logistics (SACL), which aims to measure the economic, environmental and social performances of a logistic process and to help a company to make the right decision. For achieving this goal, our proposed system integrates: cloud computing technology, web services techniques, multi-agent approach, and simulation model. As a scenario, we’ve chosen the case of a virtual pharmaceutical wholesaler, and we have formulated the problem for command preparation process. The results show that our proposed system helps the decision maker to estimate the economic, environmental and social costs of a logistic process and to know the impact of a new strategic solution and its cost before retaining it.

Keywords: cloud computing; CC; green logistics; multi agent approach; simulation model; economic aspect; ecological aspect; social aspect; logistics process.


Biographical notes: Zineb Benotmane has graduated in the Department of Computer Science of the Faculty of Exact and Applied Sciences at the University of Oran 1, Ahmed Ben Bella in Algeria, where she received her Master thesis degree in Computer Science in 2014. Currently, she is a PhD student at University of Oran 1, Ahmed Ben Bella, Algeria. Her research interests include cloud computing, green logistics, economic, ecological and social aspect of a logistics process.
1 Introduction

Evolution of needs and expectations in logistics obliges companies to demonstrate sustained responsiveness and streamlined management of logistics chain. Today, the logistics costs increase to a significant fraction. In general, the companies focus on the logistics performance parameters such as economic cost, efficiency, carbon footprint and safety.

Many companies spend time, effort and money in building sustainable logistics systems friendly to the environment. This requires the measurement and improvement of parameters by making decisions, but how much this will cost?

The supply chain management is a complex task, which is associated to decision-making at all levels. Three decision levels could be distinguished on the basis of time horizon, i.e., strategic, tactical, and operational (Lièvre et al., 2015; Tjader et al., 2014). In this paper, we propose a system that measure logistics performance to reduce economic, environmental and social costs. Measuring costs helps to identify which decision should be made, so, to design our system, first, we have considered the logistics process as the entity to be measured, because logistics is a process-oriented business constituting different processes related together to perform different varied operations. Second, we have determined the relationship between the logistics process and the environment where it is taking place. Finally, we have formulated the problem to measure the functional parameters of this process and to evaluate which decision should be made. Our proposed system have to be simple and easy to understand in terms of measuring, calculating and interpreting, for that, we propose a multi-agent system based on cloud platform, to reach these three challenges:

1 collecting data related to the execution of the process
2 measuring a logistics process costs in economic, ecological and social terms
3 evaluating a decision-making cost.

The basic reasons why we have chose to use a cloud platform are: treating a large amount of collected daily data, achieving research by quickly accessing system information in cloud via internet and Outsourcing of IT. Subramanian et al. (2014) have developed and tested a conceptual model to examine the environmental and economic benefits of the
integration of ‘logistics service providers of small and medium enterprises (SMLSPs)’ and ‘cloud computing service providers’ in the same Chinese context, this model measures the need to adopt cloud computing (CC) by logistics service providers and results shows that they are ready to adopt it. Minjeong and Hongchul (2015) have proposed a design of the integrated logistics information system based on CC to optimise resources required to logistics management. This system is targeted at the small and medium sized third-party logistics (3PLs) companies which are difficult to establish IT system. Abhay Kumar (2013) describes the opportunities of CC in supply chain management.

Our proposed system integrates: CC technology, web services (WS) technique, multi-agent approach, and simulation model (Sim), and is called system agent cloud logistics (SACL).

To prove the effectiveness of this approach, we present a study scenario of a virtual pharmaceutical wholesaler (VPW). The rest of the page is structured as follows: in the Section 2, we present some related works. In Section 3, we describe the details of the proposed system which is based on CC al architecture. In Section 4, we present a comparative study to position our approach regarding the other works. In Section 5, we describe the scenario of study case and we present the different results. Finally, we conclude our work by some extensions which we will consider in the future.

2 Related work

Logistics is able to pilot physical flows through to information flows, and consequently, a set of tools and technology solutions for the informational management of products throughout the supply chain has been implemented and proposed by logistics service providers, we cite among these solutions some systems and software such as enterprise resource planning (ERP), warehouse management system (WMS), transportation management systems (TMS) reviewed in Nettstrater et al. (2014). ERP software packages are systems that aim to coordinate all the activities of a company around a common information system, the most important decisions are made in ERP they are then sent to other systems such as WMS or TMS. Nettstrater et al. (2014) have listed key functions and extended functions of each software package, and have proposed a task model encompassing all logistics activities with the IT support for supply chain management. Nowadays, many professionals in logistics sector see in the CC a new tool to optimise their processes. Sometimes as individual applications but also as complete software solutions all hosted in the cloud. However, despite advantages offered by the use of CC in logistics, opinions are still divided: is cloud a real promising concept, which allows better economising and responding to change and to limit restrictive investment? Or conversely, are security, performance and availability really guaranteed? to answer these questions, Subramanian et al. (2014) have developed and tested a conceptual model to examine the environmental and economic benefits of the integration of ‘SMLSPs’ and ‘CC service providers’ in the same Chinese context, this model measures the need to adopt CC by logistics service providers, by using statistical techniques such as factorial analysis. For this statistical study, employees from different departments of different companies were answered on questionnaires, the questions focused on the economic and environmental benefits of adopting CC, and the responses were evaluated on the scale
Likert basis of five points. Karakostas (2013) proposed a cloud-based data sharing architecture for dynamic virtual organisations in the domain of transport logistics; this architecture ensured that transport chain data are always available on demand to those that require them, while minimising unnecessary exposure of data and thus security risks.

The Fraunhofer Institutes for Material Flow and Logistics (IML) and for Software and System Technology (ISST) created in 2012 the logistics mall, which is a kind of online application supermarket, these new platforms were described in Daniluk and Holtkamp (2014) and Holtkamp (2014). The principle of the logistics mall is to combine several logistics applications, such as warehouse management applications with inventory applications connected at customs for the needs of a particular client company, each of these applications is offered by a provider logistics application and hosted in the logistics centre. Li et al. (2012) present a cold chain logistics system based on CC which functions are: real-time monitoring of cold chain logistics, data calculation, logbook recording, query, generating reports and so on. Authors take the distribution model of the cloud calculating system as an example. In Chow et al. (2007), an intelligent system called logistics process knowledge-based system is presented, the aims of which are: to describe the real-time status of process environments through diagnosing multiple real-time data/information sources, to address potential problems within logistic processes, to deliver logistic process procedures (explicit knowledge) and logistic process logic (tacit knowledge) to staff members who are orchestrating and performing various logistics processes satisfactorily in real time, and, to provide information of real-time logistics process progress status, thereby helping logisticians systematically to manage logistics processes and resources effectively.

Formerly, strategic decisions in logistics were taken to reduce costs and provide better service, considering only the economic aspect (eco). At present, these decisions are taking a green curve by considering, in addition to eco, the ecological aspect.

Inspired by research on performance measurement, Boukherroub et al. (2015) designed a method that links sustainability performance to supply chain decisions, and allows setting coherent performance measures, then they transposed this method to a multi-objective mathematical programming to optimise the supply chain planning while the economic, environmental and social performances are all coherently integrated into the model. To illustrate their approach, they applied it to a Canadian lumber industry case.

Still in the context of a green logistics, authors defined in Muttingi (2014) the impact of reverse logistics in green supply chain management by identifying key performance measures for green supply chains (SC), the causal linkages between important variables in a typical supply chain, and by developing a dynamic Sim for developing appropriate green policies and strategies when translating from reverse logistics to green supply chain.

In Shaharudin et al. (2015), the objective of authors was to propose a conceptual framework to study the strategic orientations of 3PLs relating to the reverse logistics service offerings.

Tao et al. (2015) designed a two stage algorithm for the green traffic flow allocation problem on logistics network. In the first stage, alternative paths are generated for each origin-destination flow by iterating the k-shortest path algorithm. In the second stage, the solution of traffic allocation with best green utility is chosen from candidate solutions.

Pochampally et al. (2009) discuss about integrating environmental considerations into purchasing decisions which is called eco-procurement. The advantages of this practice
include cost savings, conservation of natural resources and energy, and compliance with environmental laws and regulations. In their paper, they address the following two crucial issues, and propose a quantitative decision-making strategy for each of them:

1. Which products must be chosen from a set of candidate-used products containing recyclable content?
2. Which suppliers, viz. companies that collect and sell the chosen used products, must be selected for eco-procurement?

Dubey et al. (2014) propose to investigate the impact of green supply chain practices on organisational performance in Indian rubber industry. Their study has adopted two prolong strategies that includes critical literature review published in reputed journals to identify research gaps and identify variables and survey methodology using structured questionnaire. The multiple regression analysis suggested that ‘supplier relationship management’ and ‘waste reduction through collaboration’ are found to be positive determinants of ‘business performance’.

Luthra et al. (2014) have proposed a study which aims to identify critical success factors to achieve high Green supply chain management performances from three perspectives i.e., environmental, social and economic performance. The critical success factors to achieve high Green supply chain management performances relevant to Indian automobile industry have been identified and categorised according to the three perspectives and a conceptual models also have been put forward.

Mangla et al. (2014) provides thought their paper an interpretive structural modelling-based approach to implement and initiate green activities in SC. Variables such as supplier and stakeholder commitment, cost benefits, environmental issue, and customer redundancy, etc., have been identified and categorised under enablers; green and sustainable products, processing time and green productivity and efficiency, etc., under results.

Abduaziz et al. (2014) tried to assess green logistics practices in automotive industry by using simulation method. The proposed model will assist decision makers acquire an in-depth understanding of environmental impacts and costs associated.

In this paper, we propose a multi-agent system based on CC, in service of a green logistics called SACL including: CC technology, WS technique, multi-agent approach, and Sim which aims to improve economic, environmental and social performances of supply chain by measuring different costs related to a logistic process. In the next section, we describe the details of the proposed system.

3 Presentation of SACL

Nowadays, the supply chain aims to ensure the economic, environmental and social development by reducing related costs and pollution while increasing profits and assuring safety. Several decisions must be made to improve the chain. It is in the context of optimisation and decision support for supply chain management that this paper is taking part. The supply chain management is a complex task that is associated to decision-making at all levels: from the chain design stage to its operational functioning. All these decisions will have an impact within a defined period of time. For this, three
time levels with which decisions are associated are defined, i.e., strategic, tactical and operational that will have an effect in the long, medium and short-term respectively.

The strategic level considers the decisions that have a long-term impact on the organisation. This includes decisions on the number, location and capacity of warehouses, the production facilities, the choice of partners, the organisation of flows within the logistics network, etc.

The tactical level includes decisions that are reconsidered periodically, with periods ranging from a few months to a year, for example: procurement decisions and production planning, storage policies and transportation strategies.

The operational level focuses on everyday decisions, such as scheduling, resource allocation, identification of delivery, routing, truck loading, etc.

Sundarakani et al. (2014) analyse the environmental implications of the rapidly growing construction industry in UAE using system dynamics approach. The paper has addressed in detail the various drivers and inhibitors of carbon emission in the construction industry supply chain and ways to evaluate the carbon savings. The paper provided an analytical decision framework to assess emissions of all stages applicable to the construction industry supply chain.

Considering the operational decision-making level, the objective of this article is to design a multi-agent system based on CC called SACL, for the sustainability of supply chain, including: CC technology, WS technique, multi-agent approach, and simulation methods which aims to measure and improve economic, environmental and social performances and to help a company to make a right decision.

In this section, we present our proposed system; first, we explain our motivation, then, we justify our integration of different techniques (CC, multi-agent approach, web service and Sim), finally, we describe the system and its functional architecture.

### 3.1 Motivation

Nowadays, companies focus on the logistics performance parameters such as economic, ecological and social costs, however, decision makers can not easily estimate that costs, in addition, when they propose a new strategic solution, it will difficult to know its impact and cost. From this point, our idea is first, to break up the problem into smaller and manageable pieces, for this, we consider the logistics process as the entity to be measured; second, to evaluate the impact of a decision and its cost.

In the next section, we describe our motivation for the using of different techniques that we have combined to design our proposed system.

#### 3.1.1 Why cloud?

Procurement, warehouse and TMS optimise the supply chain, while, several challenges appear for logistics service providers since their customers require individual services with flexibility, transparency cost and performance, massive demand for resources, resource variation, a claim for calculation and short-term contracts. These requirements lead many logistics service providers to the following problems:
• lack of investment funds for the extension of IT
• lack of IT expertise
• insufficient human resources to operate necessary IT
• difficulty of developing new IT components and their integration into the existing.

Nowadays, many professionals in logistics sector see the CC as a new tool to optimise their processes, sometimes as individual applications besides as completed software solutions hosted in the cloud. This is a concept where IT resources are virtualised and dynamically elastic; these resources are provided as a service over the internet and transparently to users. The concept includes infrastructure as a service (IaaS), platform as a service (PaaS) and software as a service (SaaS). The use of specific logistic cloud services is therefore regarded as a viable solution that is based on the paradigm ‘everything is service’, and here are some reasons for which it would be interesting to apply the CC to manage the supply chain:

• software in cloud included free versions
• companies invest in a monthly/yearly charge relatively low, moreover, they can have access to the latest hardware platforms and better solutions without the need to consider the cost of assessing the hardware and software for the reason that in cloud ‘we pay what we use’
• the CC enable small and medium enterprise to have access to professional solutions with less IT investments
• through applications as services offered by a cloud, companies can significantly reduce the number of IT professionals and technical personnel
• internal IT professionals could place more energy and time in the development of critical applications in the heart of the trade
• logistics systems based on CC also allow better collaboration, better monitoring of the supply chain and provide better services for customers.

3.1.2 Multi-agent approach advantages

Multi-agent approaches implement resolution strategies based on the behaviour of a set of autonomous agents. A multi-agent approach can be seen as a weakly interconnected set of agents that work together in order to solve a problem based on the abilities and knowledge of each individual entity. The interest in the use of multi-agent approaches is based on their ability: to provide robustness and efficiency and to allow interoperability of existing systems.

3.1.3 Web service benefits

WS offer many benefits as the use of standards-based communication methods, code reuse, application and data integration. In addition, they are deployed over standard internet technologies and are virtually platform-independent.
3.2 Platform for SACL

A logistics process is executed following a set of procedures and rules predefined by decision makers and performed by employees; its execution is related to several parameters and the use of equipment; if the decision maker puts into action a new solution, these procedures are updated.

To understand more, we address the following functionalities of our proposed system:

1. collect daily data required for measures
2. Measure a logistics process costs in economic, ecological and social terms
3. evaluate a decision-making cost
4. update the procedures of the process by validating or not the decision.

In Figure 1, we illustrate a CC platform for our proposed system.

Figure 1  CC platform for SACL

In Figure 1, the left part represents the different processes of logistics, and the right part represents the cloud platform on which are implemented the different operations of our proposed system.

3.3 Organisation of SACL

To support business processes, two main stakeholders are distinguished in our proposed system: the employee and the decision-maker; in addition, the customer can intervene for an eventual claim.

The employee’s role is to execute the process and to communicate with the system, for this he consults the predefined procedures and rules of the process and reports any problems registered. This will allow the system to: collect process information on real-time, assist the employee to follow the process steps to the predefined rules and procedures, record the various problems and then measure and save economic, ecological and social costs of the process.
The decision maker’s role is to consult overall economic ecological and social costs in regular (daily, weekly, monthly, yearly), through periodic reports provided by the system, he can query the system to evaluate the cost of strategic solution by running simulation, once the solution is retained, the system will update the procedures, redefine the rules of the process and enrich the knowledge base.

The customer may report a problem after receipt of the product, and the decision maker can later associate his claim to one process.

The explanation of the system operation will be discussed in detail below.

3.4 Functional architecture of SACL

As it is mentioned in Section 3.2, our proposed system offers many functions. To provide an abstraction of implementation details and divide the problem into smaller manageable pieces, we’ve proposed a multilayer architecture of this system. Modelisation with layers provides the level abstraction; each layer performs a different set of functions and is independent as possible from all the others; in addition, information is used from one layer to the other. Figure 2 shows the functional architecture of the proposed system, SACL comprises two subsystems: collect subsystem, and decision-making subsystem, both of them consist of four main layers which will be described later.

To understand the relationship between its parts, we describe a brief example of how the system operates:

An employee executes a given process, he loads through his web browser, rules of conduct and the steps for the execution of this process; at each step, problems can be recorded and entered into the system via the interface. In addition, employee mentioned if he has used a special equipment or not. So, the Collect subsystem calculates the cost of the process execution and records it in a database.

After a given period, the decision maker would know how much the process has cost during then, so, he launches his request to the decision-making subsystem, and receives a periodic report recapping cumulative process costs. The decision maker proposes a strategic solution by modifying a procedure, the system launches a simulation and displays the consequent cost of this solution; the decision maker will decide to accept it or not. Once retained, the system updates the procedures related to the process and designs a new rule as a new knowledge.

3.4.1 Collect subsystem

This subsystem operates in real time, it collects and analyses various information related to a process execution, through agents: collect agent, checking agent, and calculating agent, with the assistance of WS.

The main functions of this subsystem are:

- collect basic information about the process
- allow the employee to follow the process procedures and consider recorded problems during execution
- calculate and save the economic, ecological and social information of processes.

The intervener using this system is the employee and the customer for any claim. The collect subsystem consists of four main layers:
3.4.1.1 Action layer

This layer represents the material with which the employee is equipped, as a PDA or a RFID chip, to enable him to communicate with the system and to store information. Several equipment and information systems are interconnected through the internet to form a larger and smarter grid. These materials are used to fill the system with the needed data to perform its tasks. Information is entered and displayed through a web browser.

*Figure 2* Functional architecture of SACL system

3.4.1.2 Service layer

Given the technological development in distributed infrastructures, it became possible to virtualise computing, processing and storage in the cloud. WS provide quick access to information in the cloud via the internet. This layer provides a proposed web service catalogue to access the databases, to enter and transmit information and to achieve communication between the different agents. For the definition of our WS catalogue, we have based on the proposal in Yang (2012), in which the author presents an energy saving multi-agent system with web service technique. The different WS used and their functions are shown in Table 1.
Table 1  Services description

<table>
<thead>
<tr>
<th>Service</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW_Retrieve_Data</td>
<td>Retrieves data from interfaces</td>
</tr>
<tr>
<td>SW_Intro_Data</td>
<td>Enters the data in the database</td>
</tr>
<tr>
<td>SW_Passive_Data</td>
<td>Retrieves data from internal and external databases</td>
</tr>
<tr>
<td>SW_CA_ChA</td>
<td>Retrieves data from the collect agent and transmits them to the checking agent</td>
</tr>
<tr>
<td>SW_ChA_CA</td>
<td>Retrieves data from the checking agent and transmits them to the collect agent</td>
</tr>
<tr>
<td>SW_CA_CalA</td>
<td>Retrieves data from the collect agent and transmits them to the calculating agent</td>
</tr>
<tr>
<td>SW_Out_Data</td>
<td>Retrieves data from database and transmits them to the report agent</td>
</tr>
<tr>
<td>SW_Sim</td>
<td>Enters parameters for simulating agent</td>
</tr>
</tbody>
</table>

3.4.1.3 Application layer

In this layer three different agents are assisted by WS to perform their respective tasks:

- **Collect agent**: It aims to collect information related to a process, it is the mediator between the user interface and the system. At the launch of a process, the Collect Agent assisted by SW_Retrieve_Data and SW_Passive_Data services, collects the necessary data for calculations of the system. Then, the collected data is transmitted to both Checking Agent through SW_CA_ChA and Calculating Agent via SW_CA_CalA.

- **Checking agent**: It retrieves procedures and predefined rules from database of rules (BDD_Rules), and transmits them to the Collect Agent via SW_ChA_CA for displaying to the employee. The employee confirms the end of each step and signals when there is a problem such as: accidents, breakage, failure, etc., from this, the Checking Agent saves these information in the database of economy, ecology, social aspects (BDD_EES) via SW_Intro_Data service. These recorded data are the active data.

- **Calculating agent**: This agent retrieves active and passive data related to the process from the database; then he calculates how much the process has cost to the company during the period of its execution, in economic, ecological and social terms. The calculations are presented in Section 5.

3.4.1.4 Data layer

Data is accessed by agents to perform various treatments such as a process measurement or solution evaluation. Two types of data are distinguished: passive data and active data. Passive data is input during the design of the system or from the internet using the web service SW_Passive_Data. Active data is that entered during the process execution or calculated by the Calculation Agent. There are two databases in our system: BDD_rules and BDD_EES; the first contains rules and procedures of a logistics process; the second contains daily cost of process in economic, ecological and social terms.
3.4.2 Decision-making subsystem

This subsystem operates periodically, which is used by the decision maker. Through its three agents, it allows the decision maker to have knowledge on the economic, environmental and social cost related to a process during a selected period. It also proposes evaluating strategic solutions by running simulations; it creates a knowledge base too, to establish a base case reasoning in future decisions. The decision-making subsystem consists of four layers:

3.4.2.1 Action layer

The layer of material used by the decision maker, it is generally a personal computer.

3.4.2.2 Service layer

Has the same principle as the service layer of the collect subsystem.

3.4.2.3 Application layer

In this layer, the three agents (Report Agent, Decision Agent, Update Agent) operate together to achieve the main objective, i.e., allow a decision maker to make the right decision with knowledge of its impact and cost.

- **Report agent:** It receives daily data using SW_Out_Data service and establishes a periodic report describing how much the process has cost to the company over a defined period, in economic, ecological and social terms.

- **Decision agent:** This agent uses a Sim to evaluate the cost of a strategic decision; the data for simulation is entered through SW_Sim; the proposed model will be described in the process definition of the study scenario. Another characteristic of this agent is the construction of a knowledge base.

- **Update agent:** Once a solution is retained and a decision is made, procedures and rules should be modified and then the BDD_rules updated.

3.4.2.4 Data layer

The collect subsystem and the decision-making subsystem use the same data layer to access to the databases.

4 Comparative study

Several studies have proposed and discussed the integration of CC and logistics in the same context (Subramanian et al., 2014; Daniluk and Holtkamp, 2014; Holtkamp, 2014); the approach we proposed is also based on CC in service of logistics. Our system SACL combines several techniques:
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- Multi-agent approach: Based on proposals in Chow et al. (2007) and Yang (2012), our system proposes to make a collaboration between many agents for the sustainability of supply chain by considering the logistics process in economic, ecological and social terms, these three dimensions were considered in Boukherroub et al. (2015) and Luthra et al. (2014).

- Sim: Taking inspiration of the proposed model in Abduaziz et al. (2014), we present a model based on the stock and flow diagram, which is used by our proposed system (SACL) to evaluate different decisions.

- Measure of performance: Several studies have proposed calculating costs in the supply chain (Li et al., 2012; Boukherroub et al., 2015; Hsu et al., 2007; David et al., 2015; Bulsara et al., 2016); our system also calculates several costs and considers the process as the basic unit.

In Table 2, we try to position our proposal to the other approaches. The first line contains techniques as CC, WS, Sim, knowledge bases (KB), and discussed points as SC, eco, environmental aspect (env) and social aspect (soc). The presence of a cross indicates that the technique was used or the point was discussed in a work, for example, Li et al. (2012) use technology of CC and treat only the eco of logistics.

<table>
<thead>
<tr>
<th>Papers</th>
<th>Techniques and discussed points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CC</td>
</tr>
<tr>
<td>Holtkamp (2014)</td>
<td>X</td>
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<tr>
<td>Li et al. (2012)</td>
<td>X</td>
</tr>
<tr>
<td>Chow et al. (2007)</td>
<td>X</td>
</tr>
<tr>
<td>Boukherroub et al. (2015)</td>
<td>X</td>
</tr>
<tr>
<td>Abduaziz et al. (2014)</td>
<td>X</td>
</tr>
<tr>
<td>Yang (2012)</td>
<td>X</td>
</tr>
<tr>
<td>SACL</td>
<td>X</td>
</tr>
</tbody>
</table>

5 Study scenario: VPW

For the study scenario, we have chose the case of a VPW, his role is to buy from pharmaceutical laboratories, manage and store medicines in his repository, and then deliver within a specified period. Our proposed system is designed to support wholesalers in their activities for maintaining the quality of service and efficient management of the supply chain.

To modelise our approach, the following hypotheses are proposed:

- VPW has competent and trained staff to perform various tasks.
- VPW has suitable and sufficient premises, facilities and equipment to ensure good conservation and good delivery of medicines. In particular, the repository must be clean, dry and maintained within acceptable temperature limits. In our approach, we establish a mapping for VPW, this is to divide the company into several areas, in
each area, a set of processes are performing, we mention: shipping, receiving, storage and business area.

- Medicines are stored in a repository, separately and alphabetically; access is limited to authorised staff. It should be also noted that special attention should be given to products requiring special storage conditions.
- The storage conditions must be maintained during the transport.
- A medicine has several presentations: syrup, tablet, ampoule, capsule, suppository, cream, sachets solution for local application, eye drops, these are called pharmaceutical forms.
- The VPW has many installed equipment, such as coolers, surveillance cameras, shelves, and other mobile equipments such as forklift trucks, cadis, stepladders and different means of transport...

5.1 Problem formulation

As we mentioned before, in our approach the basic entity to measure is the process, and as illustrative example, we consider especially the process of ‘command preparation’, Figure 3 shows the process activity diagram. The system uses passive and active data for calculations of different costs associated to one execution of the process in economic, environmental and social terms. Each cost is constituted by many parameters, which will be described later. After getting an order from a customer, the employee prepares the listed products, ‘command preparation’ process runs in a defined area and uses mobile equipment, once it starts, the system retrieves passive data and start calculating. In Figure 4 we illustrate the relationship of the process, the description of data is presented in Table 3; this table contains passive and active data.

Table 3   Data description

<table>
<thead>
<tr>
<th>Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process_ID</td>
<td>Process Identifier</td>
</tr>
<tr>
<td>Name</td>
<td>Process name</td>
</tr>
<tr>
<td>T_start</td>
<td>Process time start</td>
</tr>
<tr>
<td>T_end</td>
<td>Process time end</td>
</tr>
<tr>
<td>Employee_ID</td>
<td>Identifier of employee</td>
</tr>
<tr>
<td>Nbr</td>
<td>Number of employee performing a process</td>
</tr>
<tr>
<td>Area_ID</td>
<td>Area identifier</td>
</tr>
<tr>
<td>Surface</td>
<td>Surface of area</td>
</tr>
<tr>
<td>Equip_ID</td>
<td>Equipment identifier (installed of mobile)</td>
</tr>
<tr>
<td>Model</td>
<td>Equipment model</td>
</tr>
<tr>
<td>FuelCons</td>
<td>Fuel consumption rate by equipment (L/h)</td>
</tr>
<tr>
<td>ElecCons</td>
<td>Electricity consumption rate by equipment (kW/h)</td>
</tr>
<tr>
<td>CO2_Pord</td>
<td>Production rate of CO₂ (kg)</td>
</tr>
</tbody>
</table>
Figure 3  Diagram activity of ‘command preparation process’

Figure 4  Class diagram of ‘command preparation’ process
Corresponding procedures and predefined rules of 'command preparation' process are loaded from BDD rules, and displayed for the employee. Each time, he confirms the completed step and indicates when there is a problem.

The system uses passive and active data for calculations of different costs associated to one execution of the process in economic, environmental and social terms. Each cost is constituted by many parameters, which will be described later.

A process runs over a duration $T_p$ [see formula (1)] estimated by hour:

$$T_p = T_{\text{end}} - T_{\text{start}}$$

For define our measures, we associate to each process three vectors: economic vector $V_{\text{eco}}^i$, ecological vector $V_{\text{env}}^i$, and social vector $V_{\text{soc}}^i$, where each input vector represents the cost associated to a parameter during execution $i$.

In next sections, we try to define each parameter.

### 5.1.1 Economic cost of the process

We suppose that economic cost of a process includes various parameters as the salary of the employee, the energy cost and other costs defined below.

#### 5.1.1.1 Employee salary

An employee is paid for accomplished tasks; let $Sal_H$ the hourly rate of the employee. Several employees can perform the same process, $Nbr$ is the number of employees running the process, and therefore the overall salary for a given process during one execution is calculated by formula (2).

$$C_1 = Nbr * T_p * Sal_H$$

#### 5.1.1.2 Energy cost

From Figure 4, a process is executed within an area in which several devices are installed. Therefore, for one execution of the process, corresponding energy consumption includes:

- electricity that was used to illuminate the area during $T_p$
- electricity used for cooling
- energy consumed by equipment that has been used in the execution of the process.

So, the correspond parameter is done by formula (3).

$$C_2 = \sum_{e1} E_{\text{Con}} E_{\text{elec}} T_p + \sum_{e2} F_{\text{Con}} F_{\text{Fuel}} T_p$$

With $E_{\text{elec}}$ electricity cost per hour, $F_{\text{Fuel}}$ Fuel cost per hour, $e1$ is Installed Equipment and $e2$ is Mobile Equipment, $T_p$ is the time during which the Mobile Equipment has been used.
5.1.1.3 Packaging cost
The order can concern large quantities (complete cartons or pallets) or detail quantities (boxes of medicines), in the second case, it requires additional packaging cartons and the cost is estimated in formula (4).

\[ C_3 = \alpha \cdot Q_{Cart} \cdot Price_{kg} \]  

(4)

With \( Q_{Cart} \) the amount of carton in kilogram, \( Price_{kg} \) is cost of 1 kilogram of carton, and \( \alpha \) is a Boolean variable that is equal to 1 if there was a use of additional cartons and 0 otherwise.

5.1.1.4 Damage cost
This cost concerns the damage of medicines during the process, it is estimated according to the pharmaceutical form and by unit [see formula (5)].

\[ C_4 = \beta \sum_{PF} Q_{dam} \cdot Price_{unit} \]  

(5)

With \( PF \) the pharmaceutical form, \( Q_{dam} \) the amount of damaged units by form and \( Price_{unit} \) the damaged unit price, \( \beta \) is Boolean variable that is equal to 1 if there was damaged product 0 otherwise.

So, economic costs associated to the process execution \( i \), represents the inputs of the Economic Vector: \( V_{eco}^i = (C_1, C_2, C_3, C_4) \), and therefore an objective function \( F_{eco} \) can be deduced which represents the cost of one execution \( i \) of a process [see formulas (6) and (7)].

\[ F_{eco} = C_1 + C_2 + C_3 + C_4 \]  

(6)

\[ F_{eco} = \text{Nbr} \cdot T_P \cdot Sal_{ht} + \text{Elec}_{ht} \cdot T_P + \text{Cool}_{ht} \cdot T_P + \text{Fuel}_{ht} \cdot T_P' + \alpha \cdot Q_{Cart} \cdot Price_{kg} + \beta \sum_{PF} Q_{dam} \cdot Price_{unit} \]  

(7)

5.1.2 Environmental cost of process
We consider for environmental cost process, the amount of \( \text{CO}_2(C'_3 = Q_{CO_2}) \) generated by equipment that the process has used (Mobile_Equipment) and by the installed equipment in the area. The amount of solid \( (C'_3 = Q_{Sol}) \), semi-solid \( (C'_3 = Q_{SSI}) \) and liquid \( (C'_4 = Q_{Liq}) \) matter resulting from its execution [see formula (8)]. Environmental vector associated to execution \( i \) of the process is defined by \( V_{env}^i = (C_1, C_2, C'_3, C'_4) \).

\[ V_{env}^i = (Q_{CO_2} \cdot T_P', Q_{Sol} \cdot T_P, Q_{SSI} \cdot T_P, Q_{Liq} \cdot T_P) \]  

(8)

\( Q_{Sol} \) includes any solid matter as the amount of delivered carton because the client will discard the shipping carton and causes pollution to the environment. In addition, we consider emptied cartons during the execution and which will be discarded.
5.1.3 Social cost of the process

We consider for the social cost in our approach, the following social parameters: working conditions, health, safety and customer satisfaction, social vector is noted $V_{soc}^i$.

5.1.3.1 Condition of work

The employee can feel discomfort resulting from sound pressure level forklifts for example or other equipment used by the process, his claim should be considered to improve working conditions. Let $C_1 = C_{inc}$ the claim of employee which is equal to 1 in the case where an employee has complain a discomfort during an execution of the process, 0 otherwise.

5.1.3.2 Health and security

The employee may face some hazards such as falls from heights or injuries resulting from the mechanical action of an equipment or a work tool. $C_2 = Dan$ is variable that is equal to 1 if this problem was recorded during an execution of the process, 0 otherwise.

5.1.3.3 Customer satisfaction

A client cannot be satisfied by the quality after receipt of the medicines, this may result from the quality of packaging or bed stacking of medicines… Let $C_3 = Rec$ the variable which is 1 for any claim related to the process, 0 otherwise.

So, after defining social parameters, social vector $V_{soc}^i = (C_{inc}, C_1, C_2, C_3)$ associated to one process execution is defined in formula (9).

$$V_{soc}^i = (C_{inc}, Dan, Rec)$$ (9)

5.1.4 Global calculation

The decision maker assisted by our proposed system can adopt a strategic decision and know its economic, ecological and social cost. Based on the daily data calculated at each execution of the process and stored in BDD_EES, the system calculates overall parameters and makes a global report to the decision maker, who becomes aware on how much costs a process during a given period. $n$ is the number of process executions during the given period.

$$Mat_{eco} = \sum_{i=1}^{n} V_{eco}^i$$ (10)

$$Mat_{env} = \sum_{i=1}^{n} V_{env}^i$$ (11)

$$Mat_{soc} = \sum_{i=1}^{n} V_{soc}^i$$ (12)
The proposed system allows, using the Sim and based on ‘stock and flow diagrams’ (see Figure 5), to know the impact of adopting a new solution on different costs associated to the process, for example, from Figure 5, we can see that the ‘command content’ affects the consumption of diesel, because if the command concerns products ranging in height, the use of forklift is necessary; causing an energy cost included in
process economic cost and emission of CO\textsubscript{2} included in process environmental cost; in addition ‘command content’ also affects packaging, in fact, when it is a command concerning details, additional cartons are required, the costs of their acquisition influences the eco, and their discarding affects the ecological aspect of the process by producing a bad solid waste for the environment.

5.2 Scenario description

We consider the following data:

- P03 is the Process_ID of ‘command preparation’ which runs in area Z01.
- Procedures of P03 are illustrated in its activity diagram (see Figure 3).
- The rules associated to this process are: wearing a special clothing with boots for protection, the employee must begin also by the pharmaceutical forms heavier in weight.
- Active data collected at the launch of the process are: Process_ID = P03, T\textsubscript{start} = 8:30 am, Employee_ID = E0125, Nbr = 1, Area_ID = Z01.
- Data collected at the end of the process execution is: T\textsubscript{end} = 10:30 am, the forklift remained in operation during T\textsuperscript{f} = 1 h, during performing P03, the employee has used four additional cartons having as average weight 200g each one, and has discarded one empty carton. After delivery, a complaint was registered by a customer who has received four damaged tablets priced at 2.80 $/unit. The command included eight cartons in whole, all these represent the active data...

The system has the following passive data: \( Sal_{H} = 15 \$, Surface\ of\ Z01 = 450\ m^{2},\ it\ is\ equipped\ with\ 450\ fluorescent\ tubes\ type\ T12\ with\ length\ of\ 60\ cm\ and\ estimated\ power\ at\ 20\ W\ each\ one,\ this\ will\ ensure\ a\ illumination\ power\ of\ 20\ W\ per\ m^{2},\ so\ we\ can\ deduce\ that\ the\ power\ installed\ is\ 9kWh.\ The\ area\ Z01\ is\ also\ equipped\ with\ five\ cooler\ with\ 30,000\ BTU\ each\ one,\ knowing\ that\ cooler\ consumes\ 8.79\ kWh,\ total\ consumption\ is\ 43.95\ kWh.\ Forklifts\ used\ are\ diesel\ type,\ with\ load\ capacity\ of\ 4,000\ kg\ and\ consumes\ 4.1\ L/h.\ The\ cost\ of\ 1\ kW\ is\ valued\ at\ 0.12\ $/kWh.\ The\ cost\ of\ 1\ litre\ of\ diesel\ is\ 0.97\ $/L,\ in\ addition,\ 1\ litre\ of\ diesel\ generates\ 2.6\ kg\ of\ CO\textsubscript{2}.\ The\ cost\ of\ 1\ kg\ of\ carton\ is\ 2\$.\ For\ corresponding\ units\ see\ Table\ 4.

Table 4

<table>
<thead>
<tr>
<th>Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>L</td>
<td>Litre</td>
</tr>
<tr>
<td>kWh</td>
<td>kilowatt/hour</td>
</tr>
<tr>
<td>g</td>
<td>gram</td>
</tr>
<tr>
<td>BTU</td>
<td>British thermal unit</td>
</tr>
<tr>
<td>h</td>
<td>Hour</td>
</tr>
<tr>
<td>W</td>
<td>Watt</td>
</tr>
</tbody>
</table>
5.2.1 Results and discussion

The proposed system measures costs associated to the process using formulas of Section 5.1, and the results are presented in Table 5. In this table, the first row represents economic, ecological and social vectors; each vector has its parameters (row two) and the last row presents the obtained values of each parameter. The results show that for one execution from 8:30 am to 10:30 am, command preparation process has cost: 21$ of employee salary, 16.6$ of energy, 1.6$ of additional cartons and 72$ of damage; so, the economic cost of this process in one execution is estimated at 111.2$. Ecological cost is estimated at 12.4$ which comprise 10.6 kg of CO₂ and 1.8 kg of discarded carton. Finally, one claim was registered from a client. These results were obtained by application of formulas defined in Section 5.1.

Table 5 Costs associated to one execution of command preparation process

<table>
<thead>
<tr>
<th>Vector</th>
<th>$V_{eco}$</th>
<th>$V_{ecr}$</th>
<th>$V_{soc}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>$C_1$</td>
<td>$C_2$</td>
<td>$C_3$</td>
</tr>
<tr>
<td>Value</td>
<td>21$</td>
<td>16.6$</td>
<td>1.6$</td>
</tr>
</tbody>
</table>

After approximately one month, the decision maker wants to know what P03 has cost in economic, ecological and social terms; the system makes the overall calculation and displays the results to the decision maker. Assuming that there have been 360 ‘command preparation’ in one month, let $n = 360$ executions, results are presented in Table 6.

Table 6 Global results

<table>
<thead>
<tr>
<th>Vector</th>
<th>$Mat_{eco}$</th>
<th>$Mat_{ecr}$</th>
<th>$Mat_{soc}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>$C_1$</td>
<td>$C_2$</td>
<td>$C_3$</td>
</tr>
<tr>
<td>Value</td>
<td>8,211$</td>
<td>4,313.2$</td>
<td>361.6$</td>
</tr>
</tbody>
</table>

After displaying these results, the decision maker noted that this process has cost 361.6$ of cartons and caused 416.8 kg of solid polluting for the environment, this quantity of cartons might result from the high number of detailed boxes commanded by customers; another observation related to the uses of cartons, is that 34 claims were registered from customers which caused the back of damaged medicines boxes at cost of 10,366$. The decision maker would like to evaluate the following decisions:

- D1: Use plastic pallets with marketing stickers, and recover the plastic boxes at the next delivery.
- D2: Establish a contract and sell the surplus to a cardboard carton factory.

The decision maker can launch the simulations with the model in Figure 5 to reflect the impact of these decisions. Table 7 presents the influence of decisions on economic, ecological and social variables, the presence of a cross means that a decision influence on a variable; for example, if the decision D1 is made, the amount of carton $Q_{Cart}$ will be reduced.
Table 7 Influences of decisions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>QCart</th>
<th>Qdam</th>
<th>QSol</th>
<th>Rec</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>D2</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The proposed system evaluates the economic, ecological and social costs and associated gains if decisions D1 and D2 will be made, results of different simulations are shown in Figures 6 to 9. These simulations illustrate daily costs of the process in the left part and the costs that may be obtained if decisions D1 and D2 are made.

In Figure 6, for the daily costs, we can see that a number of additional carton is used to packing the medicines, these carton are bought for additional use; if decisions D1 and D2 are made the cost of purchased carton will be null because the company stops investing in buying additional carton and it uses recoverable plastic pallet, this is demonstrated in the curve of the right part.

Stop buying additional carton by making D1 and D2 decisions, implies a reduced quantity of solid polluting for the environment (see Figure 7) because the client has not a carton to discard when he removes the medicines and the company will use plastic pallets recovered at the next delivery, so, the amount of carton in the right part of Figure 7 is associated to the cartons that the company has emptied during the preparation command process; and so, the amount of discarded carton has fell by 83%.

In Figure 8 the use of plastic pallets reduces the cost of damaged boxes by 85%, because the plastic is more solid then carton and this prevents the crushing of medicines. In Figure 9, the rate of customer claims is reduced by 86%, in general, the claims are related to the client insatisfaction. Before decisions D1 and D2 are made, the customer received damaged medicines boxes due to bad stacking of cartons; if decisions D1 and D2 are made, fewer complaints are recorded, in addition, the marketing side provides more satisfaction.

Figure 6 Carton associated cost before and after made decision
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6 Conclusions

In this paper, we presented a multi-agent system based on CC for sustainable supply chain, our system combines several techniques. The integration of CC services for logistics offers new benefits for companies such as access to resources on demand, elasticity and usage billing. The system proposed in this paper uses a multi-agent
approach to achieve the goal of reducing economic, ecological and social cost of logistics; by considering the process as a principal entity, it allows through its agents that are assisted by WS, to assess the economic, environmental and social cost of a logistic process and provides a decision-support system for evaluating a new solution before its application. As scenario, we have chosen the case of a VPW, and we’ve formulated the problem for command preparation process.

Thanks to our proposed system, the decision maker can easily estimate a process cost and when he proposes a solution, he can know its impact before retain it. In fact, we’ve calculated the different costs before and after decision, and the system has demonstrated the gains if decisions are made.

For future work, we will try to integrate a data mining agent for the proposed decisions, we also propose generalising the work for other logistic processes, and in the near future we propose performing our tests on a real cloud platform.

References


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