Improving Reverse Logistics Process Using Multi-Agents System and Semantic Web

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***Abstract*—Nowadays increasing global and competitive marketplace requires more agile firm to survive and succeed. Therefore, the importance of integration for reverse logistics is growing for companies. Reverse logistical activities include return, remanufacture, disassemble and dispose of products can be quite complex to manage. In addition, demand can be difficult to predict and information flows quite challenging to process. These complexities have amplified the need for reengineering of existing reverse system. The purpose of this work is to propose an approach based on multi-agents system and semantic web technologies to efficiently integrate data and information in reverse logistics(RL) activities, and to reduce the uncertainty in the decision making process. Each agent execute different tasks in each step in reverse logistics Process, and each of them is able to take the best decisions, estimating benefits in cost and time, analyzing and managing uncertain information about return, using Bayesian decision network .**

***Index Terms*—reverse logistics, multi-agents system, semantic-Web, decision-making, bayesian decision network**

I. Introduction

Due to the growing environmental legislation, more attention is given to reverse logistics in this decade, as a process of planning, implementing and controlling the efficient cost effective flow of raw material, in process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value, or proper disposal [1]. In other words, reverse logistics (RL) is the management of any type of returns from any customer with lower costs and greatest profits even it is very complicated and quite difficult to manage.

One of the most serious problem facing enterprise in the execution of the operation of reverse logistics is uncertainty in information and decision, these uncertainties are inherent in such Process due to lack of perfect knowledge or conflicting information.

To deal with this problem, we propose a novel approach combines between semantic web technologies to efficiently integrate data and information in RL system, and multi-agents system where each agent execute different tasks in each step in reverse logistics process, the brain of agent is composed of a Bayesian decision network (BDN), this option allows the agent for taking best decision, estimating benefits in cost and time, analyzing and managing uncertain information about return.

The remaining parts of this paper are organized as follows: In next section we introduce some key literatures relevant to this study, problems in reverse logistics process are stated in Section 3, the proposed architecture is shown in Section 4, and Section 5 concludes the paper with some remarks and perspectives.

II. Related Literature

In recent years, many researches about how to efficiently optimize and to improve reverse logistics process have been proposed. Some present a mathematical model. Others deal with virtual problems that are so far from reality.

Actually, there are some studies focuses on applying artificial intelligent to solving problem of managing the reverse logistics processes. Table I introduces some related works.

TABLE I. RELATED WORKS IN REVERSE LOGISTICS PROCESS.

Researchers	Issues for related works
Heng-Li Yang and Chen-Shu Wang [2]	They developed framework using Multi-agents system, to solve the problem of prediction in context of reverse logistics
S. Wadhwa and J. Madaan, 2007 [3]	They proposed framework for management information system in RL
S.Lambert, D.Riopel and W.Abdul kader.2011 [4]	They developed conceptual framework for decision making dedicate to reverse logistics process
A. Mihi-Ramírez , H. Bodaghi K. Noubar and V.Fernández Bendito, 2011 [5]	They proposed a theoretical approach describe the relationship between knowledge management and reverse supply chain

Most of the above approaches, however usually consider multi-agents to improve the RL process, beside they did not consider using semantics web to allows flexible information query. In 2001 Reference [6] proposed architecture for semantic web is shown in Fig. 1 where the content in documents are stored in xml and

Manuscript received December 1, 2013; revised April 3, 2014.

doi: 10.12720/jtle.2.3.206-210

RDF formats which can easily represent the document structures, there are modules for rules, logic and other inference methods to support the semantics introduction.

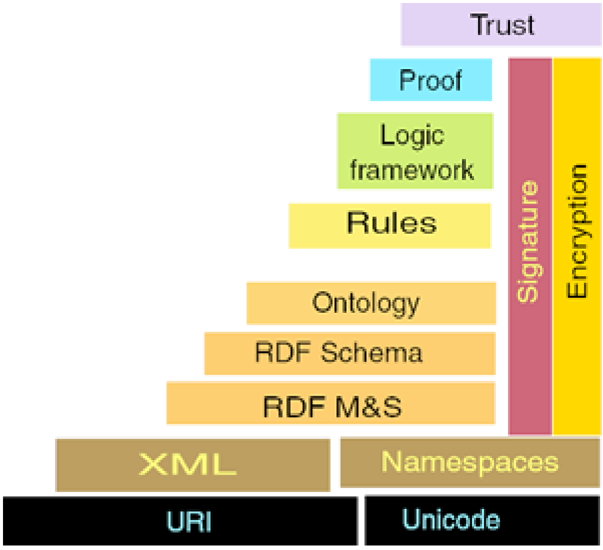

Figure 1. The architecture of semantics web presented by [6].

Furthermore, they did not consider the problem of uncertainty in knowledge. To deal with this problem we are proposing a Bayesian decision network as a model of representing uncertain knowledge and also as a network to minimize decision making process in time and cost. According to References [7], [8] the Belief networks are used to determine new beliefs (in the form of probabilities) as observation are made or facts are gathered. They are composed only of so-called nature nodes. A decision network (also called influence diagram) is formed by adding decision nodes and utility nodes (also called value node) to a belief network. A Bayesian decision network allows probabilistic reasoning based on beliefs under conditions of uncertainty.

In this paper, we propose architecture based on multi-agents paradigm which combines ontology and Bayesian decision network to solve the above Problems.

III. Problem Description

In the literature, most of the authors including [1]-[4]-[9], have defined a reverse logistics system with four main steps: Gate keeping (entry), collection, sorting and disposal. The first step is the recognition of product return, this is very critical to succeed in managing the system. Reference [1] defines it as deciding which products are allowed to enter the system. The second step is the collection permits the retrieval of products from internal or external customers; here the collection may be made in several ways. Detailed sorting (or the third step) decides the fate of each returned item. At that moment, the company may decide what to do with the product, be it subject to inspection, tests, or other manipulations. The last step involves the choice of disposal, the destination of the product.

These RL activities need two other important elements to be integrated as is mentioned by Reference [4], and as is shown in Fig. 2: an information system to keep track of what's happening and coordinating system which is responsible of the overall performance and management of the RL system. The communication among different elements plays a major role in the successful implementation of these steps.

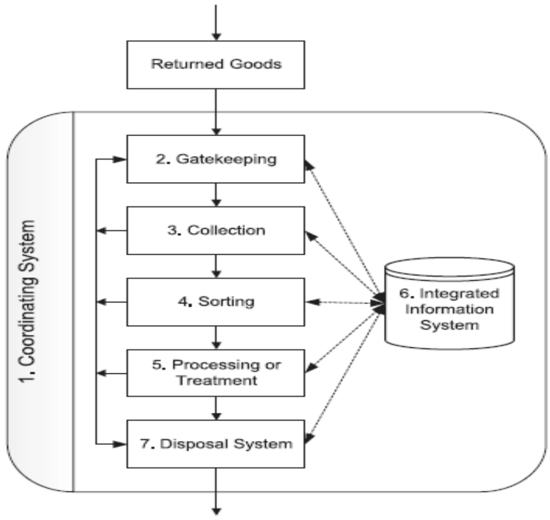

Figure 2. Reverse logistics system elements [4].

In particular, companies need to choose how to collect recoverable products from their former users, where to inspect collected products in order to separate recoverable resources from worthless, scrap, where to reprocess collected products to render them remarketable and how to distribute recovered products to future costumers, as is noted by Fleischmann *et al* [10] that are the critical decisions facing producers.

TABLE II. Phases of Integration of Knowledge in Reverse Logistics [3].

Origin of knowledge	Type of knowledge	Application of knowledge
Collection Phase	Availability of the collection Center Transport distance Transit time Transport cost Product categories	Inspection/ separation specialized
Recovery phase	Inventory Inspection/separation Product design knowledge and expertise Cost of remanufacturing Knowledge of the availability	Product design and development Production planning and control of collection and distribution phase
Distribution	Distribution cost and time Customer feedback and awareness of the availability of orders	Retail customers Phase of recovery and collection

Here, is the importance of knowledge management, it can play a key role to reduce uncertainty in decision making in time and cost. Knowledge Management in Reverse Logistics integrates information from external and internal elements of the management process of the product returned, aid to allies in Reverse Logistics to make appropriate choices, support the process. According to Reference [3] the knowledge needed to be efficiently integrated and used in different steps of reverse logistics activities is shown in Table II.

Therefore, to improve the decision making process in reverse logistics and to deal with the uncertainty in information we need to develop new capabilities to produce and to efficiently manage information in reverse logistics system.

IV. PROPOSED APPROACH

Faced with the complexity of information management in RL system, and with uncertainty in making decision in reverse process, we propose a novel approach which combines between semantic-web technologies and multi-agents paradigm to design a collaborative knowledge management system. It will be a way to communicate and coordinate between the different stakeholders and a way to improve decision making process.

The proposed system consists of four layers. Which are decision-making layer, coordinating system layer, Ontology (semantic web) layer and Database layer, the relation among the four layers are shown in Fig. 3 .the major function of these layers are listed As follows:

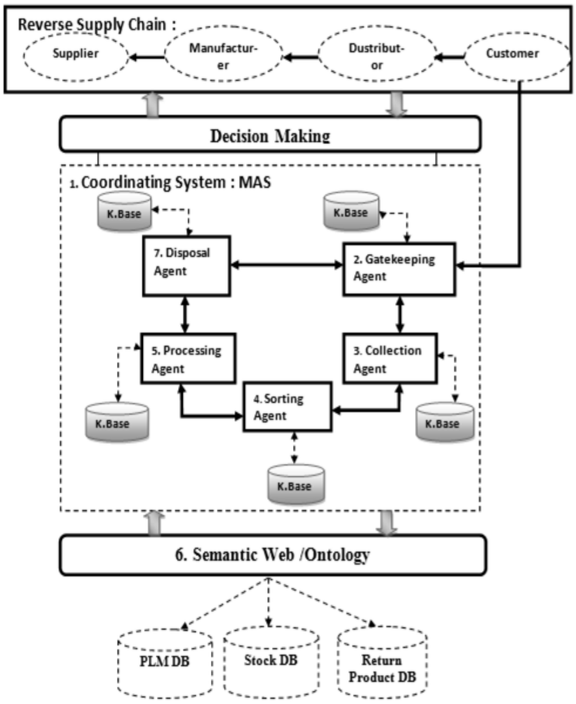

Figure 3. The proposed architecture

1) Decision making layer: Decision making is quite difficult process in reverse logistics process leading to the analysis of several variable of characterized by uncertainty, for this reason, the brain of each agent using in the coordinating system is composed of Bayesian decision network, this allows the agent to take best decision

2) Coordinating system layer : It is a multi-agents System composed of 5 agents who act respectively during the 5 steps of reverse process: Gate keeping Agent, Collection Agent, Sorting Agent, Processing Agent and Disposal Agent, each agent has its own knowledge base that contains knowledge about the system environment (as is shown in Fig. 3). Furthermore, each of those is characterized by learning capability to improve its own behavior. These agents communicate with internal resources (local databases) and external (partners of the supply chain).

The role of each agent is described in the following section:

- The Gate keeping agent: receives request from the customer, to authorize the returned products, based on its knowledge base it takes decision, the fact that his brain is composed of Bayesian decision network allows it to take the best choices.
- The Collection agent: after receiving a message from the gate keeping agent, the collection agent check its knowledge base which contains rules and information related to transportation mode and cost.
- The Sorting agent: it receives the returned product, and then it should decide how to treat it based on the information stored in its knowledge base. The next task is to undertake across-verification of the returned product with the return authorization given by gate keeping agent.
- The Processing agent: its knowledge base contains information about treatment options such as repair recycle, remanufacturing, upgrade and repackaging of returned products. The Bayesian network allows this agent to take the best decision about every option cited above and respecting certain criteria. After that the product may be subjected to the chosen treatment (recycling, reusing…)
- The Disposal agent: At the exit of reverse logistics system as is shown in figure 2 and after recapturing the product value, this agent is allowed to take decision about shipping cost and also using its knowledge base and its belief should think about how to minimize the redistribution process in cost and time.

3) Ontology layer: It uses semantics-web technology to improve the flexibility of access in different terms, different system may have their own terms, this layer used to resolve the semantic conflicts arising from the cooperation between different and heterogeneous systems used in reverse logistics process.

4) Database layer: Many database exist in this layer, for example there may be database respectively for Return Product, inventory, costumer, and among others. The database are mainly used for query, maintenance, they can effectively utilized by the different actors through the ontology layer.

V. AN EXAMPLE

In this section, we have provided an example to demonstrate that our proposed architecture can solve problems of uncertainty and complexity in reverse logistics network. Assume an end-user (costumer) wants to return a quantity of electronic damage products. The global processing for this situation is shown in Fig. 4. Which consist of following steps:

Step 1: Customer connect via user interface to place his return order of quantity Q of laptop at time T.

Step 2: The system loads the gate keeping programs after its decision; it sends the authorization to both the costumer and the collection agent.

Step 3: System loads the collection agent programs and asks it to make decision about the transportation mode also this agent must check the collection site availability and if it’s possible to collect at that time T within that quantity Q of returned laptop. The collection agent is able to estimate cost of transportation using probabilistic method based on Bayesian decision network in case if some variables aren’t determinate.

Step 4: After analyzing the returned products quality, the sorting agent checks the capacity of refurbishing and disassembling site and other knowledge. If different terms are used, then the ontology layer will first transform into the used one in the databases. To complete its task the sorting agent may send information about the sort of treatment.

Step 5: At this stage the system loads the processing agent program is responsible of the recycling, or reusing the product or part of this product. For example in case of laptop we can reuse just a battery of this product to create new one, this sort of process will help saving time and cost.

Step 6: The last process is concerned with the shipping of product; at this stage the disposal agent must give information about the shipping and purchasing cost.

The proposed system is able to forecast if there are any cases of a similar return order from the end user.

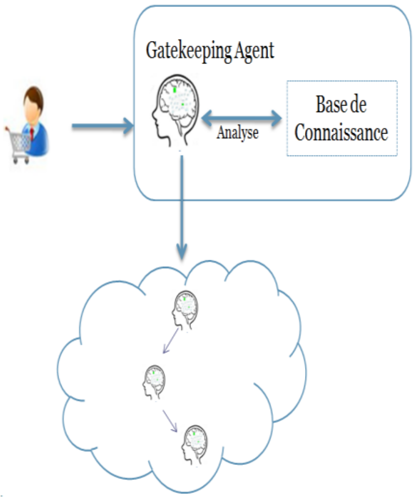

Figure 4. A set of agents collaborate to fulfill the customer’s order, the gate keeping agent receiving the order and then after his decision using BDN the process is developed hierarchically within the other agents in the coordinating system.

VI. Conclusion

In this paper we presented a design of collaborative and smart knowledge management system, dedicated to efficiently manage uncertain information in reverse logistics process. We have proposed the architecture of the system based on semantics-web technologies and Multi-agents paradigm. There are four main layers in the system, including decision-making layer, coordinating system layer, Ontology (semantic web) layer and Database layer, these layers are linked together to achieve the purpose of integration of RL activities and communication with less human intervention.

As a perspective we are proposing a model of Bayesian decision network in reverse logistics context. And we are developing an example of this system.

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