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Case-Based Reasoning and Multi-Agents for Cost Collaborative Management in Supply Chain

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Abstract

The cost collaborative management of supply chain is a new topic which integrates three fields: cost management, intelligent application, supply chain management, and develops one of the most important tools on how to apply multi-agents and case-based reasoning to the improvement of cost collaborative management. This study has two objectives: one is to develop the multi-agents system for CCM; the other is to construct a novel framework model of cost collaborative management in supply chain based on the application of case-based reasoning. More specifically, this paper develops a new method—the four steps for CCM, in order to improve the competitive capacity and to solve some current problems in the cost management of supply chain.

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Key words: Cost collaborative management (CCM); Multi-agents; case-based reasoning(CBR); supply chain

Nomenclature and abbreviation

CCM Cost Collaborative Management in supply chain

CBR Case-based reasoning

MAS Multi-Agents System

MAS-MCC Multi-Agents System for Cost Collaborative Management in supply chain

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1. Introduction

With economy globalization and fiercer competition environment, it is very important that companies collaborate with their network partners to reach their goal. However, due to uncertainties from demand, manufacturing, and supply sides [1], traditional supply chains, in which companies operate based on the push model with traditional media to interact with each other, are unable to agilely respond to these uncertainties. Furthermore, more general inter-organization cost management will be discussed, which is a new pattern ([2], [3] and [4]) of organization between the traditional firm and the market model. Dubois et al.(2004)[5] argue that by evaluating performance within different boundaries, what is and is not included in different benchmarks is also highlighted and thus can be a platform for increasing awareness of interdependence existing across borders.

Generally, the alliance organization is set up a connected mechanism and operational mechanism by serious contracts (including agreements, corporate institutions and legal contracts) among those members of the supply chain [6]. The key goal of established inter-organization is putting the higher related firm into the supply chain firm, so that it can create more return of capital by synergic effect [7]. In recent years, agent technology has successfully been used for managing business processes ([8], [9], [10], [11] and [12]) and supply chain ([12] and [13]). The model proposed here, which called an ‘intelligent agent-based system’, solves problems related to cost synergy management by viewing the process as a cost synergy agent.

This study introduces another approach CBR which is available to interactively construct dynamic and collaborative situations. Intelligent agents with learning ability are able to construct adaptive negotiation strategies depending on their knowledge, experience and information available from the use of case-based reasoning (CBR) [14] in association with CCM. Loo et al. (2011) [15] conducted that the proposed solution stems from arborescent (various) case bases, which enable the similarity between a target situation and all the cases in the base to be calculated at any time. Our framework is more focused on showing the benefits of having multi-agent and CBR simultaneously.

The purpose of this paper is to propose a multi-agent system, which is adaptable to the cost collaborative management in supply chain; and to apply case-based reasoning in MAS-CCM and to propose the method of four steps for CCM. For this purpose, this paper specifically suggests a flexible cost collaborative model for multi-agent systems, because cost synergy of agent systems is determined by transaction methods [16]. The system consists of an interpretable and exchangeable cost collaborative policy model, a procedure for four steps for CCM, and a mechanism about how actual transactions can be performed using new cost collaborative policies [17].

The remainder of this paper is organized as follows: Section 2, a brief review on the Multi-Agents System approach will be given. Supply chain cost synergy management framework based on Multi-agent system will be described along with CBR application in section 3. Section 4 discusses the integrated system and processes for CCM. And finally, a conclusion will be presented.

2. The multi-agent approach for CCM

The main goal of the MAS approach consisted in providing a framework that would allow integration of any type of resource provider exposing their capabilities over the network firms, in order to make synergy effect that meets specific business needs and goals. The framework makes extensive use of multi-agent standards so as to allow common uptake from both larger and smaller companies, respectively individuals. In network firm, each member firm must have a sub-strategic cost goal in order to manage cost collaboratively for realizing the whole goal of cost synergy management goal. This study maps the

whole cost synergy management onto MAS system and maps each member firm sub- cost synergy management onto each agent.

Generally speaking, these agents will exhibit the characteristics of rational agents [14] and [15], such as: (1) Autonomy. Agents perform their tasks without the explicit guidance of humans or other agents. They will control their own actions and internal states. (2) Sociability. Agents cooperate with the others in order to carry out their own tasks or to help other agents. (3) Responsiveness. Agents perceive the needs for planning and executing tasks and for working with other agents. (4) Pro-activeness. Agents proactively bid for sub-tasks to perform and learn how to improve their bidding or cooperation decisions.

2.1. Firm agents in supply chain

The node firm member level defines the architectures for each individual agent in a multi-agent system. This level considers the definition, the flow of control, and the intelligence of an agent together with how the intelligence can be captured. In the cost synergy framework, all member agents have the same architecture for their internal control in network firm.

The set of member agents includes: the supplier (S), the producer or manufacturer (M), the customer (C). The definitions of the agents are specified as follows for the proposed model.

A supplier is an entity (or an individual) that provides product for manufacturer. In this model, for a given product industry, a list of suppliers can be defined: $S = \{S_i\}$, $i = 1, 2, \dots, n$. Each supplier S_i is characterized by a set of static attributes SS_k^i , $k = 1, 2, \dots, k_i$, a set of dynamic attributes $SD_{\alpha,t}^i$, $\alpha = 1, 2, \dots, \alpha_i$, $t = 1, 2, \dots, t_i$, and a set of specific capabilities SK_i . Thus, it can be written as $S_i = \langle SS_k^i, SD_{\alpha,t}^i, SK_i \rangle$

A manufacturer is an entity that owns one or several plants and produces some products for sale. It sells the product to the spot market and/or the multilateral market through the wholesalers. For a given product supply industry, a list of producers can be defined: $M = \{M_j\}$, $j = 1, 2, \dots, m$. Each producer M_j is characterized by a set of static attributes MS_k^j , $k = 1, 2, \dots, k_j$, a set of dynamic attributes $MD_{\alpha,t}^j$, $\alpha = 1, 2, \dots, \alpha_j$, $t = 1, 2, \dots, t_j$, and a set of specific capabilities CK_j . Thus, it can be written as $M_j = \langle MS_k^j, MD_{\alpha,t}^j, CK_j \rangle$

A customer is an entity (or an individual) that purchases product for self-use. Customer may purchase product on the spot market and/or the multilateral market through the wholesalers or the retailers. In this model, a basic consumer purchases product from the retailers. For a given product industry, a list of consumers also can be defined: $C = \{C_m\}$, $m = 1, 2, \dots, N$. Each consumer C_m is characterized by a set of static attributes CS_k^m , $k = 1, 2, \dots, k_i$, a set of dynamic attributes $CD_{\alpha,t}^m$, $\alpha = 1, 2, \dots, \alpha_i$, $t = 1, 2, \dots, t_i$, and a set of specific capabilities CK_m . Thus, it also can be written as $C_m = \langle CS_k^m, CD_{\alpha,t}^m, CK_m \rangle$

2.2. Cost collaboration management agents (CCM-agent)

In order to take into account the situations where a participant in a market cumulates more than one basic roles (e.g.: an entity that is simultaneously a distributor and a retailer, etc.), the concept of synthetic agent will be introduced, which service for cost collaboration management in supply chain. A synthetic agent is composed of basic agents and coordinates the actions of its components related to a specified goal (cost collaboration) and accordingly to some strategies. Nevertheless, these basic agents stay intrinsically autonomous in regard of their specificities and abilities.

The cost collaboration management agents only interact with their component basic agents or with other agents. Therefore, they do not directly interact with other basic agents. Association of agents belonging to a same class is a particular synthetic agent that is represented by a singleton. This responsibility is delegated to the control at the inter-organization level. The inter-organization level defines the interaction, coordination, and organization between agents and their environment. In the proposed control framework, the inter-organization level is mainly established by self-regulation and self-organization strategies, which mainly depend on the cost collaborative management presented in this paper.

3. The multi-agents system for CCM based on case-based reasoning

Multi-agents system for CCM extends main strategic management processes to external node companies beyond core company boundary [7] in order to seek the approaches of reducing the cost of the entire supply chain. The core company and node firms can utilize sufficiently the synergic opportunity and synergic effect among partners of the network firms by means of coordinating the cost management projects among manufacturers and suppliers and customers. In this paper, the architecture model focuses mainly on the cost collaboration multi-agent. The architecture of the system is composed of four essential elements (see fig.1): a group of agents, a set of tasks to be carried out and a set of resources. Each agent in the conceptual market model is represented by an agent in the multi-agent system, and its name is derived from the role that it plays in the market. As shown in fig.1, the agents are the suppliers, the manufacturers, the customers, the cost collaboration management. Each agent is autonomous and should be responsible for own decision making.

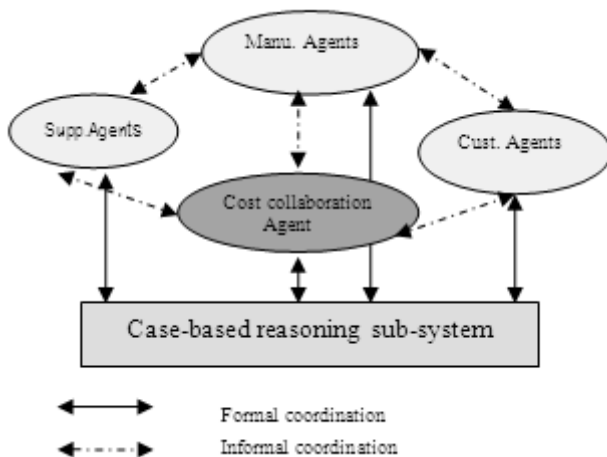


Fig.1. Multi-agent architecture for cost collaboration management base on case-based reasoning

3.1. Multi-agent system for collaborative cost management (MAS-CCM)

Communication and cooperation are two most important capabilities of the multi-agents system. The term cooperation is assumed to include both collaboration and competition [13]. In Multi-agent architecture for cost collaborative management, the agents are designed to have the capability to collaborate or compete. Collaboration is the basic characteristic of the CCM agents, and synergic effect the goal of MAS for collaborative management.

Each firm node agent represents a kind of end-user and its goal is mainly to meet its own profitable and cost management. CCM-agent end-user is a kind of core firm user including sets of basic end-users that may be bound by alliance relationships, i.e., union of sets of consumers located in different geographic areas but purchasing product from the some wholesalers and suppliers whose asset is shared amongst them. Once this kind of core firm of CCM-agent is instantiated, its knowledge about the product market is organized in its information and knowledge base. As the trading process progresses, this information and knowledge base changes and is enriched with new knowledge obtained from other agents and from its own reasoning [20].

Since the software agent has both social ability and reactivity, it can easily adjust its goals as a new uncertainty emerges. The detailed roles of each agent are described as follows:

S-Agent: Produces components or materials. It receives raw materials from outside the supply chain and supplies the components or processed materials to the manufacturer (M-Agent). Its goal is to maximize profits by maximizing revenue and minimizing costs in purchasing, inventory, backlog, and setup. It determines the production quantity.

M-Agent: Manufactures products by assembling components. It receives orders from the customer (C-Agent) and places component orders to the supplier (S-Agent). Its goal is to maximize profits by maximizing revenue and minimizing costs in inventory, backlog, ordering and setup. The main decisions are order and production quantities. It must also decide whether to expand its supplier base if it faces supply uncertainties.

C-Agent: Receives the customer's order and then sells the product if it is in inventory. If the agent cannot fill the order, it places an order for the product to the manufacturer (M-Agent) and the order is backlogged. The R-Agent's goal is to maximize profits by maximizing revenue and minimizing costs in inventory, backlog, and ordering. It decides how much to order from the manufacturer.

CC-Agent (Cost Collaboration Agent): Facilitates additional levels of coordination and information sharing for cost collaborative management. Its main priorities are to maximize the overall supply chain profits by coordinating with the other agents. It may or may not rely on a case base while working with the other agents. This agent utilizes a case base only when the relationships among the firms are strategic. When the CC-Agent relies on a case base, it is expected to increase the overall performance of the supply chain compared to when it does not. The following expression displays the objective function of the CC-Agent. Multi-agents highly effective in dealing with coordination and conflicts among firms and improving that they do not share strategic information or cooperate to achieve optimal solutions when the firms have transactional relationships.

3.2. To apply case-based reasoning (CBR)

Basically, the CBR (case-based reasoning) mechanism used in this study plays the role of recommending a proper collaborative management method for cost of supply chain in each agent based on its share information. A case base is composed of customer profile, manufacturer profile, supplier profile, relationship type, and product characteristics, with cost data on firms in the supply chain. Accordingly, supply chain strategies are determined using case base. Case retrieval mechanism is based on a conventional similarity measure.

CBR is a problem-solving paradigm in the field of Artificial Intelligence, in which previous similar situations are retrieved and used to resolve new problems. An important argument for CBR is that situations recur with regularity. It is likely that the decision made for one case is applicable to another, similar case. CBR allows businesses to treat past cases as a corporate resource and reuse them in future decision-making [14, 15] (Loor et al., 2011, Fang et al., 2010). This motivated us to use CBR as a key method for storing and reusing retailer profiles, manufacturer profiles, supplier profiles, relationship types,

product characteristics, and associated market data for an Enhanced Integration mechanism. Applying CBR to multi-agent SCM systems is rather unique, though there exist several works applying CBR to electronic commerce and negotiation problems [19,21]. There are several advantages of using CBR for multi-agent SCM:

(1) CBR allows agents to propose new offers quickly without deriving them from scratch. This provides organizational memory-based intuition for a given SCM problem to avoid an inconsistent problem-solving process.

(2) CBR alerts agents to avoid repeating past mistakes because those mistakes are already captured in CBR.

(3) CBR helps agents to analyze the importance of features and issues of supply chain management, thus leading to better deals in future.

(4) CBR is flexible in handling inter-firms cost management uncertainty, and changes in relationships and strategies (e.g., the introduction of a new supplier).

The case base keeps track of all of the supply chain dynamics. If the partners (S-agent, C-agent, M-agent) change their relationships from transactional to strategic, the case base is updated to reflect this new relationship. Moreover, the subsequent supply chain strategies will be based on the new relationship. Similarly, if the manufacturer experiences uncertainty from the suppliers, it may add another supplier, or pool the production capacities or inventories of its existing suppliers for risk pooling. The case base also records this new case.

The multi-agent system controls and maintains the case base. This case base is not available to the Autonomy and Integration levels. In this case, the MAS-CCM just facilitates the sharing of public information across the agents. To more closely investigate CBR's effectiveness, the experimental design will be used, in which CBR provides additional market information that facilitates better decision making at the enhanced integration level, while information being shared across the agents includes the number of competitors, price, order quantity, and production quantity, at the other levels. Market data suggested by CBR is limited to price level and its corresponding demand quantity.

4. Integrated System and processes for CCM

In supply chain, because of the connection of company internal, company to company, and company to customer with computer network, keeping synchronously reflecting information flows, fund flows and goods flows, the cost collaborative management system defined in this paper could provide more helpful information for management of synergic effect. How to build a cost collaborative management process model, which could realize the goal of this paper, is a hard nut, but is key important research issue in this section.

4.1. Integrating case-based reasoning into MAS-CCM

Cost collaborative management (CCM) is an important philosophy, an attitude and a set of techniques to create more value at lower cost. The critical success factors for cost collaborative management not only encompass financial factors, such as costs and revenues, but also encompass non-financial factors, for instance new product development, product quality, customer satisfaction. Therefore, the definition for cost collaborative management in supply chain is an integrated cost management, which integrates information management system into cost collaborative management system (see Figure 2). It provides non-financial information, traditional financial information, and external information for decision maker in order to get the goal and the competitive advantage of the core firm and node firms in the supply chain. Thus it builds a future new framework with three functions:

(1)Planning and decision-making in static cost collaborative management and dynamic cost collaborative management like managing cash flow, budgeting, purchase of raw materials, production scheduling, pricing, inter-firms designing and inter-firm cost management.

(2) Real time collaborative control beyond the firm boundary. Controlling and monitoring in the cost collaborative management implementation could be extended to upstream and lower stream by multi-agent system and CBR, and could be emphasized on matching with the company’s strategic position.

(3)To make optimal cost collaborative management not only for collaborative effect but also for multi-win requirements.

In this paper, we will focus on mentioned above three functions in CCM, and emphasize that internet and supply chain firms have a very important effect on CCM.

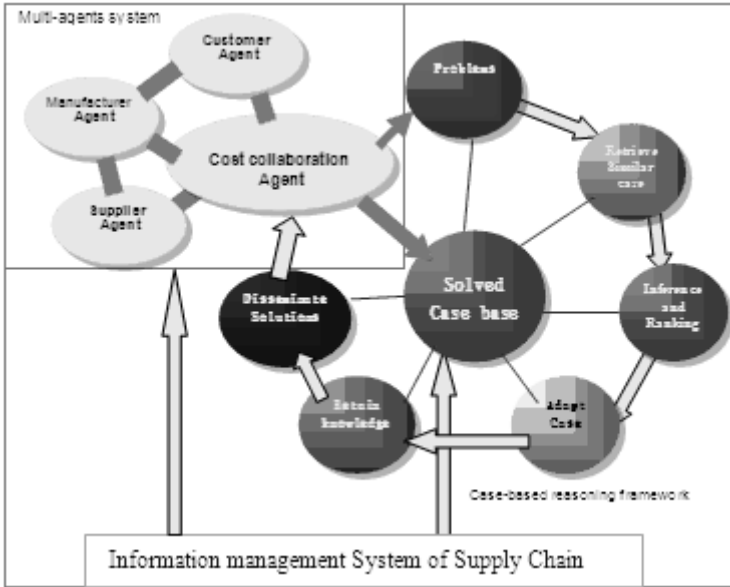


Fig.2. Integrating case-based reasoning into MAS-CCM

In this paper, the research of the cost collaborative management in supply chain is beyond the traditional cost management research. Is there a suitable model from those current models of cost collaborative management to satisfy the need in this paper? The answer is no. But, there are some models from current models and extend these specific chosen models. Of course, it is fine to choose the model—multi-agents system for cost collaborative management based on case-based reasoning—which extends it to the integrated system (see fig.2).

The description of the framework model (fig.2): based on the network (supply chain) coordinating mechanism[12], taking the strategic objectives and financial objectives as basic goals of the system, taking the strategic cost plans as the action guidance of cost collaborative management, and integrating multi-agents system and case-based reasoning into an integrated cost collaborative management system, which are utilizing all resources (tangible assets, intellectual assets, information etc.) effectively and efficiently in supply chain to create value for a specific firm. The system is emphasized that inter-firms cost collaborative management and it should match with strategic position of the specific firm.

The above model does pay attention not only to the cost drivers of a stand-alone company but also to the cost drivers of other node companies in supply chain and macro-economic policies, so that it make up the deficiency which the earlier model of cost management only consider those factors of single company. The system emphasizes that to set up an system connection between strategic objective (such as lower

product cost strategy and product technique differentiation) and suppliers, company purchasing, design, manufacturing, sale, distribution and logistic, furthermore, to integrate financial management, accounting, risk management, information system and human resource management into the system of cost collaborative management in supply chain. Moreover, traditional standard cost, overall budgeting, pricing and cost analysis have become ones of the basic parts which are integrated into the system (including the real time control and management of logistic and fund flow, financial report and other decision information report, performance evaluation and incentive, strategy management decision support subsystem, and so on).

4.2. Cost collaborative management processes

The cost collaborative management process is executed in four stages: cost driver identification, cost driver impact assessment, decision and implementation of cost collaborative management actions and optimization. The process involves collaboration amongst supply chain partners through exchange of information and allocation of specific roles, in order to get the goal of collaborative cost management in the supply chain.

4.2.1. Key cost driver and problem identification

This is the fundamental stage of the entire cost collaborative management process, where cost problems and cost drivers are identified through the use of qualitative and quantitative analysis. The backbone of this process is based up on the monitoring of various key performance indicators (KPIs) related to the performance of supply chain partners (e.g. suppliers and manufacturers). The product research and development, product cost, product quality, delivery lead times and the level of an in-stock inventory, production throughput, utilization of capacity are some of the KPIs that can be used to identify an abnormal situation that may involve a potential opportunity cost. The actual values of those KPIs are monitored within a specific time frame and compared with predefined values from S-Agent, M-Agent and C-Agent that are described either in an agreement among partners (agents). This sub-section includes the problem identification of CBR and getting cost driver from multi-agents for CCM.

4.2.2. Cost driver impact assessment and ranking

This stage is necessary for the selection of suitable corrective management actions for the key cost drivers identified in retrieve similar case from case base. The impact analysis takes into consideration a wide range of criteria such as the probability of occurrence of the loss event, the loss level and risk impact, and it prioritizes the according to the outcome of this process. In conjunction with the outcome of cost driver assessment, a description for the level of the impact using ordinal scales(e.g. no impact, minor impact, medium impact or serious impact)and the level of probability for the occurrence of the loss event(e.g.very unlikely, improbable event, moderate event, probable event, very probable)can be given. This process is executed by a root cause identifier software, which is incorporated in the learning module of the cost collaborative management agent. Through the monitoring of crucial KPI's(e.g. delivery time, product quality), the potential causes of the triggered alarm can be identified. For example, in case of a significant delivery delay, the root cause identifier will initiate a process to trace the cause of this delay. In the inference and ranking of CBR, the root cause identifier will "label" this incident as probable delays risk. Subsequently, each of the potential remedies for any identified cause (that is about to become a loss risk), is evaluated using a built-in simulator. The success of a past decision applied to a specific cost driver is taken into consideration during the evaluation process. The best similar case responses to cost drivers are selected, through the multi agents of cost collaborative management improving the quality of supply chain management.

For example, in case an alarm is triggered at the side of a supplier due to the identification of an abnormal KPI, all the potential loss cost that arise (e.g. potential delays) are identified by the root identifier in the field “type of loss cost”. This sub-section integrates the retrieve similar case, inference and ranking of CBR into cost driver assessment from multi-agents for CCM. Potential remedies are then evaluated by the built-in simulator initially in terms of their feasibility and based on specific constraints (e.g. contractual agreements). To get customer’s local optimal policy by invoking C-Agent; and get manufacturer’s local optimal policy by invoking M-Agent using retailer’s local optimal policy; and get supplier’s local optimal policy by invoking S-Agent using retailer’s and manufacturer’s local optimal policies. Then, the expected costs of those feasible local optimal policies are calculated, generating a list of remedies for the risk that emerges along with the associated costs. The following calculations are conducted hierarchically: (a) the probability $P(y)$ for the disruption to become reality is estimated through the use of failure mode and effect analysis and/or formal mathematical models that can utilize linear regression, time series regression models; (b) the amount of financial loss $L(y)$ for the specific disruption to become reality; (c) the investment cost y to mitigate the probability $P(y)$, in order to lessen the specific disruption risk; (d) an optimal y^* investment cost for the mitigation of the risk, in order to minimize the expected cost $EC(y) = y + L(y)P(y)$, that is to arise in case the risk becomes a reality.

4.2.3. Decision of cost collaborative management actions

In the third stage, the rectification proposer selects the optimal corrective strategy for the cost driver identified at the end of the cost driver impact assessment process. Specifically, the rectification proposer is informed by the coordination agent about the feasible corrective scenarios for the emerging losses. This initiates a process that intends either to eliminate or reduce the prominent loss risk, or to further dichotomize it, in order to be shared to the supply network. The selected corrective actions are transferred again to the built-in simulator, where the optimization process begins (towards improving performance for the entire supply chain). This stage can be characterized as the backbone of the database, where successful strategies are also constructed using case-based reasoning (see fig. 2), in order to form the whole data into a database legible to the system—so that past successful decisions are transformed as knowledge for future use.

This sub-section integrates the adapt case and retain knowledge of CBR into decision of cost collaborative management agent in supply chain.

4.2.4. Optimization and solution

In the final stage of the cost collaborative management process, the supply chain profit is calculated initially through a formula that quantifies global supply chain profit for decentralized supply chains under disruptions regimes that is proposed by Huang et al. (2006). Then, through the application of “what-if” scenarios by the built-in simulator, the loss risk is managed in order to: (i) achieve a higher global supply chain cost effective. In this manner, the global supply chain profit is increased and the risk (cost) is decreased, or (ii) to retain global supply chain efficiency in the same level, decreasing in this manner both the cost and the risk. The output of this process is the selection of the rectification strategy that is considered as beneficial for all the members of the supply chain.

The internal structure of the cost collaborative management agent, and the management process is illustrated in Fig.2. It can be seen in the figure that learning takes place when the cause for an alarm is identified and a rectification strategy is proposed. In the entire process, a static and a dynamic case-base are utilized (situated within the CCM-agent). In the static case-base data that remain unchanged in the short run are situated (e.g. the location of the manufacturing plants, the number of the manufacturing machines). The dynamic case-base stores data that are continuously updated such as the status of manufacturers, supplier and customers.

This sub-section integrates the solution dissemination of CBR into optimization of cost collaborative management in supply chain.

The integrated system ensures that all transactions within the node member agents (three basic agents) are efficient and effective so that members must keep win-win collaborative cost management by case-based reasoning.

5. Conclusions

In recent years, inter-organization cost management has become more common in supply chains, due to the increasing supply chain complexity. In this study, the proposed agent based model builds a novel framework for effective cost collaborative basis, through the facilitation of software agents and through the utilization of CBR which choose previous successful corrective actions as cases for future decisions. There are certainly many benefits from the utilization of MAS-CCM initiatives. Moreover, this study develops a new method, which includes the four key steps: cost driver and problem identification, cost driver impact assessment and ranking, decision of cost collaborative management actions, optimization and solution, integrates CBR into MAS-CCM. This integrated system, at the operational level, can deal with cost drivers associated with supplier choice, customer service planning, order planning and so on concerning synergic effect of collaborative source management. At the tactical level, it can significantly facilitate order fulfillment, providing substantial information for CCM by the method of CBR. And it offers opportunities to effectively support the management of supply chain activities, to communicate and share information in a speedy and reliable way, to reduce information asymmetries across the supply chain.

This paper expects that the results of research paper in cost collaborative management of supply chain will increase significantly in the coming years, given the increased interest in this research field by academicians and practitioners. Some directions for further research that this paper has identified are: (1) to study further theory on cost collaborative management in supply chain; (2) to conduct empirical studies about the synergic effect on cost collaborative management; (3) to develop some intelligent agent based simulation models for cost management in supply chain.

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