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An agent-based profit allocation in supply chain management using Shapley value

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***Abstract*—The aim of this paper is to propose an approach that integrates multi-agent systems and game theory, enabling businesses to embed intelligent behavior in their activities and provide an efficiency at low cost. This specific combined approach has been rarely used in previous studies. Furthermore, a functional prototype is designed and implemented to illustrate the proposed approach's value and potential. The main characteristic of a supply chain is cooperation. The success and sustainability of cooperation depends on the stability as constituting component. In terms of cooperative game theory, the aspect of stability is closely related with the allocation of profits in cooperation. The proposed agent-based supply chain management allocates profit among cooperated companies by applying Shapley value that considered game theory solution for fair profit allocation. In this framework supply chain structural elements are represented by agents for decision-making, problem solving and better cooperation in a multi-agent environment.**

***Index Terms*—Agent technology, Profit allocation, Shapley value, Supply Chain Management (SCM)**

I. Introduction

A current business trend is embedding intelligent behavior in base activities, thereby achieving a competitive advantage and .improving efficiency while lowering costs. Intelligent behavior has several characteristics that combine thinking and learning as well as problem solving and decision-making [14].

Agent technology is one of most area used grown rapidly in recent years [2]. Intelligent agent in computer science is software agent considers an autonomous computer program that carries tasks on behalf of user. Economic capabilities of agent–based systems were recognized in the early 1990s, and a wide range of applications based on single- and multi-agent systems have been developed in various fields: decision support, e-commerce, supply chain management, resource sharing, production, industrial mechanism, cooperative work, mobile commerce, simulations, production, and inventory planning. The supply chain management (SCM) Supply chain management is one of the fields that have successfully applied agent technology [7]. Several architectures have been recently developed for SCM and are based on single- and multi-agent systems where each unit of supply chain management can be represented as an agent capable of interacting and connecting with other agents and with its environment to accomplish a specific task or activity.

Christopher describing a supply chain, states the "network involves set of organizations linked upstream and downstream, in the diverse processes and activities that produce goods in the form of products or services in the hands of the final customer" [16].

In the current global supply chain management environment, most companies do not fully control and manage their supply chain. Even when a company owns chief parts of the full supply chain, different components are likely to be controlled by other companies. This is due to that businesses having developed a greater understanding that efficiency and safety can be improved if they focus on primary capabilities and outsource peripheral tasks to other businesses that specialize in them.

The modern form of a supply chain system can be represented as a combination of independent firms with complementary abilities and integrated into an efficient flow of material, information, and assets working cooperatively to meet market demands. The firms are usually controlled by a channel master who owns the brand or product or has responsibilities such as selecting partners, controlling budgets, and distributing profits [21].

Supply chain profit allocation is considered an important strategic decision for industrial supply chain managers. Stability is closely associated with the allocation of profits, thus encouraging supply chain partners to remain in the partnership. This leads to a need for an effective method for allocating profit in a fair manner.

In the academic literature, a considerable amount of research has applied game theory in the area of profit allocation. Game theory is comprised of mathematical models providing a powerful framework for studying decision-making problems in business settings [10]. Game Theory has great potential in SCM applications. One of most appropriated game theory concepts is Shapley value, which is considered as a solution to the problem of determining profit allocation, assigns each cooperative partner with an exact allocation regarding its marginal contribution to the

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partnership's success.

Hence, this paper proposes agent-based supply chain management for profit allocation using Shapley value as common framework. The paper is organized as follows. Section 2 reviews the background and fundamental of three common fields: SCM, agent technology and game theory. Next, Section 3 summarizes some related works in two field's Multi-agent system in SCM and game theory in SCM. The proposed agent-based profit allocation framework and Shapley value algorithm, furthermore, details of an implemented prototype of a framework are presented in section 4. Result and discussion, conclusion is presented in two last sections.

II. BACHGROUND AND FOUNDMENTAL

A. *Supply chain management*

Supply chain management (SCM) is presented as a business practice providing solutions for some industrial challenges by introducing the idea of inter-company cooperation. Such cooperation allows scheduling and synchronizing tasks within a supply chain network to solve industrial problems. The goal of supply chain management in a network of companies is delivering products or services to end customers [5].

It manages and controls the flow between different stages in a supply chain network to achieve maximum profits [25]. Most definitions in the literature commonly agree that supply chain management depends on cooperation to create value. [31].

A supply chain is a grid containing many components such as the warehouse, supplier, factory, retailer and distribution center, which all deal with obtaining raw materials to perform processes, for example, modifying, generating and transmitting products and services to specific customers [26].

It is responsible for all activities related to manufacturing products, beginning with obtaining raw materials and ending when the customer receives the product, in addition to managing all data related to these activities [11].

Competitive pressures between businesses have increased over time, leading to a need for more cooperation which resulted in supply chains becoming more clever, agile, elastic, and able to react quickly and effectively [30].

Advances in information technology (IT) applications have provided opportunities for further developing supply chain management strategies, and companies who take advantage of these can be more successful by having a supply chain that efficiently provides a continuous stream of information and material.

Most supply chain networks are composed of independent components that have individual favorites. Each component looks forward and attempts to improve his own preference [21]. The modern form of supply chain management can be represented as managing a combination of independent firms, owning complementary abilities, and having an efficient flow of material, information, and assets which work cooperatively to meet market demands. The supply chain paradigm has changed in recent years to include global-nonlinear networks that allow efficient interactions between multiple layers of suppliers, manufacturers, and other partners. Interaction among supply chain entities can be achieved regardless of their size, position, or number of provided services and products [31].

Profit allocation in supply chain is regarded as an important component in any supply chain management (SCM) system, which requires that it operate efficiently and efficiency. However, creating a rational allocation mechanism is challenging since it is influenced by many uncertain factors in the supply chain, for example, the partners' stability, transferable contribution, and risk behavior. Consequently, these uncertain factors must be considered broadly. Supply chain profit allocation has the following features [12]:

1) It exists in various forms and can be a long- or short-term commitment that is shared or unshared.

2) Profit allocation in a supply chain usually depends on all the partners' contributions and common cooperation; therefore, it cannot be simply briefed an autonomous profit of each partner.

3) In a global supply chain management environment, the associated companies are allocated diverse responsibilities, but may receive more profit or less profit than expected considering their level of contribution and expended effort.

4) In a global supply chain, the associated companies may have a diverse experience with or diverse understanding of profits.

Traditionally, the market mechanism method has been perceived as one of most effective ways to determine profit allocation in general. However, when applied to supply chains, several problems related to profit allocation are confronted such as mutual ownership, cooperation in product development, and cooperation in investment; hence, there is a need for a variety of effective solutions. Regarding price schemes, one of the most effective approaches is a type of game theory that treats these problems as a collection of players where profit is allocated among them. Therefore, each player's percentage of the profit and overall benefit must be considered equitably. The cooperation approach has three basic types of profit allocation [22]:

1) Distributer profit type - partners are paid from total profits based on percentages.

2) Static allocation type – partners receive a static payment amount which is agreed upon among partners and the supply chain planner.

3) Shared profits and risks type - mixed use of the two mentioned types.

Profit allocation in a supply chain must ensure all the partners can earn more profit from cooperation than acting individually; otherwise, they are unlikely to remain in the partnership.

B. *Agent Technology*

Agent technology is a vital and encouraging tool for developing industrial distributed systems and enterprise cooperation [20].

The word agent has been broadly used in several areas of technologies, for instance, artificial intelligence, operating systems and databases, the e-marketplace. Although agent technology has no distinctive definition, several researchers in various fields agree that an agent has independence [9].

The most common definitions of agent are provided by

[18-27]; they view an agent as an important special software element capable of autonomous operation and its interoperable interface can be used to create independent systems or incorporate humanlike features.

Agents have several typical features [6-17]:

1) Autonomous: they have their own aims and goals to achieve.

2) Adaptability: they are capable of adapting to the surrounding environment, including other agents or human users; they can also learn from experience and improve their performance in other environments.

3) Reactivity: they are reactive because they can observe the surrounding environment and respond rapidly to changes in ways that are consistent with preprogrammed objectives.

4) Proactivity: they can initiate action rather than simply responding to the environment to achieve their design aims.

5) Collaboration: they can cooperate with other agents, which is the most important feature.

6) Robustness: they can tolerate failure, meaning if one or more other agents fail in the system, they can still function normally.

7) Scalability: means it's easier to add one or more new agents to the system and achieve a homogenous system.

C. Game Theory

Cooperative and non-cooperative are two concepts related to game theory. The term non-cooperative, as it relates to game theory, represents the general idea of Nash's equilibrium, where the goal of players is to maximize their own payoff regardless of the possible overall benefit of the global game. However, in supply chain management (SCM), the multiple players involved attempt to collectively maximize the global benefit. For this goal to be met, there is an essential need for a different type of game theory, which is termed cooperative game theory [21].

Cooperative game theory is differentiated from non-cooperative game theory by the agent seeking to cooperate with each other based on making arrangements to create a stable common benefit [13].

Cooperation is usually considered a required component in supply chain management to create a common benefit. Cooperative game theory is related to coalition theory, which can be defined as individual subsets of players wherein two or more players cooperate in sub-coalitions to reach their goals. Cooperative Game theory has great potential in SCM applications since cooperation to improve SC performance is the key issue in many SC applications [21].

Game theory includes a set of techniques for use in business and SCM. Shapely value is a solution concept in cooperative game theory applied to analyzing cooperation among supply chain networks and provides a fair and satisfactory method for addressing the profit allocation issue; it has a direct impact on the chronicity and stability of the coalition and cooperation among networks [13].

1) Shapley Value concept

The Shapley value concept was developed as a mathematics method and proposed by L.S. Shapley in 1953. It is a concept related to cooperative game theory founded on axiomatic bases that are also referred to as fairness axioms. It is used to provide solutions in cooperative game problems. Shapley value considered a fair method, especially when applied to the profit allocation issue. It assigns each player a portion of the total profit produced by a group of players according to the marginal contribution of each player of the related coalitions, ensuring fairness so the coalition remains stable.

In the context of applying the Shapley value method in supply chain management, there are four basic axioms, and these will be discussed in the following paragraph. [22].

The Pareto axiom guarantees the value generated by coalition matches the totality of all payments the individual players accept. The Shapley value never exceeds the core, meaning the distributions according to Shapley's approach are not affected by the rebound of sub-coalitions.

The symmetry axiom requires that distributions depend on the value the players can create for the coalition and are not determined by the identities of players. For example, if two companies, A and B, create the same value for a coalition S, then they must accept the same payments.

The unnecessary partner's axiom requires that players who do not add value to a coalition will not be considered when the coalition's total profits are distributed; and these noncontributing players are also referred to as dummy partners.

In the additively axiom, a payment received by a player from a cooperative game equals the sum of payments the player would receive from non-cooperative sub games. This axiom states a company must acquire as much out of one specific coalition as it obtains from two sub coalitions of that coalition.

2) Shapely value model for profit allocation

Formal model of cooperative game theory and the Shapley value method are explained as follow:

Assume $N = \{i, j, \ldots, n\}$ players among whom profit must be distributed. Players may conjoin to a coalition where there are subsets called S of N. Let the number of players in each coalition or subset S is denoted s. The function $v\ (S)$ determines the value of each player's contribution. The question to be answered: How is the profit divided between the players?

To answer the question; assume the players conjoined to a sub-coalition where there are subsets S of N; for example: the two separated sub-coalitions X and Z, must achieve the following two conditions:

$$v(X \cup Z) \geq v(Z) + v(X) \quad (1)$$

$$v(z) = v(x) = 0; \; but \quad v(X \cup Z) \geq 0 \quad (2)$$

Generally, cooperation between two or more linked companies is more valuable and efficient in a supply chain than cooperation in any other area (e.g., just-in-time linkage can occur between a manufacturer and the first level supplier).

The Shapley value Φi refers to the value of expression: $[v(S) - v\{S\text{-}\{i\}\}]$ as a contribution value accepted by player i to all possible sub-coalitions. The following formula is used to calculate the Shapley value of player$i$:

$$\Phi_i = \sum_{\substack{S \in N \\ s \in (0, n-1)}} \left(\frac{s!(n-s-1)!}{n!}(v(S \cup \{i\}) - v(S)\right) \quad (3)$$

Where

The term $\frac{s!(n-s-1)!}{n!}$ is a binomial coefficient of elements in *N*, the term $(v(S\bigcup\{i\})-v(s))$ represents the marginal contribution value that generated by player *i*.

The Shapley value method is considered a fair approach to profit allocation because it allocates profits based on each cooperative partner's individual contribution.

III. RELATED WORK

Supply chain management is one field that has successfully applied agent technology, possibly because its automation requires a distributed point-to-point architecture. The trend in modern supply chain networks is to seek cooperative partnerships that improve efficiency in the face of increasing globalization and outsourcing.

One major related problem raised is how to allocate profit fairly among the partners in such a supply chain network. Game theory is considered a powerful framework for studying decision-making problems in business and has potential in supply chain networks. It also provided Shapley value as a solution to fair profit allocation in cooperative environments.

Utilizing multi-agent systems in the design of supply chain management could lead to more cooperative, autonomous, faster, and lower cost systems and also provides a dynamic adaptation of the individual. Several researchers have applied intelligent agent technology to SCM. Table 1 summarizes some of the different frameworks and application systems which are supported by agent technology and use various approaches to facilitate SCM.

Game theory is considered and influential framework for studying and analyzing decision-making problems in different fields. One of them is supply chain networks. There are many researches in game theory area, most of them dealing with the use of Shapley value in analysis and solving the profit allocation issue as seen in Table 2.

Table 1:Multi-agent systems applications in SCM

Field	Contribution	result
A negotiation-based multi-agent system for supply chain management [23]	Developed framework consists of functional agents that can join, remain in, or leave the system. Cooperation between agents is achieved by using negotiation per formatives to build third-party and pair-wise protocols. Provided explanatory example for a virtual supply chain in context of customer satisfaction. The virtual supply chain started by receiving order through automated or semi-automated negotiation between agents.	The proposed framework integrates multi-agent systems and supply chain management for automated-negotiation. The negotiation protocol used can provide more formal confirmation. Limitations include: communication between negotiating functional agents remain a challenge.
Overview of supply chain management and multi-agent systems [28]	Proposed model of cooperation in supply chain management using a multi-agent system. The methodology to build a model is a matchmaking process that uses clustering and is rule-based with a neural network. Produced and overview the problems encountered in supply chains and the techniques to address these problems by multi-agent system. For example, The Bullwhip effect problem (amplification of the order variability)	Summarized some advantages of multi-agent systems such as being easier to understand and implement, allowing more flexibility when considering the modularity of the real supply chain system, its distribution may propose new algorithms to solve problems, high-level interactions of agents, Summarized some projects applying agents to supply chains such as an agent-based genetic algorithm , agent-based auction protocol under constraints for partner selection and so on.
Real-time coordination of a typical supply chain [3]	Proposed Framework for real-time coordination in supply chain via the intelligent wireless web (IWW), the framework is modeled and designed based on JADE to investigate the system architecture and its performance. Explanatory simulation achieved to evaluate the value of framework.	Smart web-based supply chain coordination software.
Logistics supply chain coordination [32]	Studied the problems of logistics and SCM coordination based on the multi-agent system to efficiently develop distributed big-rule data.	Agent-based logistics in supply chain coordination can increase the level of flexibility in the supply chain and enables supply chain members to be more responsive.
Real-time business intelligence in supply chain management [1]	Using case base reasoning agents for developing real-time agent-based software system for business intelligence in SCM	Framework of a multi-agent system consisting of three intelligent agent-based subsystems (extracting and uploading data management sub-system, data mining subsystem, and case base reasoning based decision analysis subsystem. It emphasizes the benefits of an agent- oriented solution

Communication and negotiation in supply chain Management[24]	Design and implementation of web services based SCM is modeled using multi-agent modeling, consists of the supplier, manufacturer, inventory, seller, and customer. These entities negotiate with each other in order to achieve their goals.	A multi-agent system provides a natural solution for SCM because various entities involved in SCM can be represented as intelligent agents. Proposed approach can be apply to a complex supply chain system because agents are capable of making complex decisions and are able to communicate seamlessly.

Table 2: Shapley Value Potentials in Profit Allocation

Issues	Contribution	Result
Profit allocation mechanism among partners [13]	Analysis of Supply Chain Management in the light of Game Theory. Apply The Shapley-Value as algorithm to allocate the profit among the cooperating partners	The cooperative game theory has a great potential to explore cooperation within supply chain management. The Shapley value axiomatic framework can be the most appropriated framework to analyze the linkage within a supply chain.
Profit allocation issue [12]	Study the profit allocation among partners in Supply Chain Alliance Based on shapely value. Propose new strategy to profit allocation.	The strategy is on basis of non-reductive profit and can enhance the rationality of the additional profit and safeguard the interests of special members who bring additional revenue members that achieve the optimization and keep the stability.
Knowledge management in supply chain[8]	Proposed framework integrates qualitative and quantitative research and provided the profit allocation process to efficient cooperation between enterprises, universities and institutes. Experimental analysis of cooperation profits allocation methods are carried out with the numerical example of Shapley value application in profit allocation.	The Shapley value provides cooperation with fair and reasonable method of profit allocation which facilitates cooperation of partners. Design of profits allocation system should pay more attention to first line personnel and cut down intermediate mediums, avoiding profits preserved in different levels.
Profit Allocation of Multi-Suppliers [11]	Using Shapley value method to realize the distribution of interests be- tween enterprises. With the same average cost of suppliers, the interests of the whole supply chain is the same, has nothing to do with the number of suppliers.	Shapley Value can achieve the benefit allocation of four-level supply chain based on multiple suppliers. It can consider distribution weight of different enterprises and avoid the average distribution. So all enterprises will be pleased with the fair distribution and promote the stability of cooperation.
budget allocation in random inventory models[15]	Proposed two strategies of cooperation : First, the firms cooperatively residence an order if their combined inventory position extents a certain stock level, Second, the firms reorder before reaching their inventory stock level.. Applied numerical investigation between proposed strategies:	Result showed that the second strategy provide conjoint with low cost This strategy, based on game theory solution that is Shapley value and the allocation rule of a cost in shared the procurement cost and each pays its own holding cost.

IV. FRAME WORK DESIGN AND IMPLEMENTATION

In this paper, the proposed framework is agent-based supply chain management system designed by Shapley value for profit allocation. It can generate a flexible, reconfigurable, and automated method for profit allocation among the multiple partners.

The Shapley value technique is very suitable for profit allocation in supply chains because different agents may exist in cooperative supply chain environments with a primary objective to fair and rational allocation of profit according to each partner's contributions. As illustrated in Fig.1 the proposed framework consists of two agents: a CDA agent and service-type agent with multiple service providers.

Each type of service agent represents different components in a supply chain, ranging from manufacturing and production to logistics and transportation. This agent gathers information about contribution value by the cooperative partners and sends it to the CDA agent. Each service type agent has multiple service provider's information, including name, identification number, and contribution value.

A CDA agent represents the channel master or planner for a supply chain network. This agent uses the information provided by service type agents to form a coalition and the compute Shapley value, which represents an allocated value of profit for each cooperated partners.

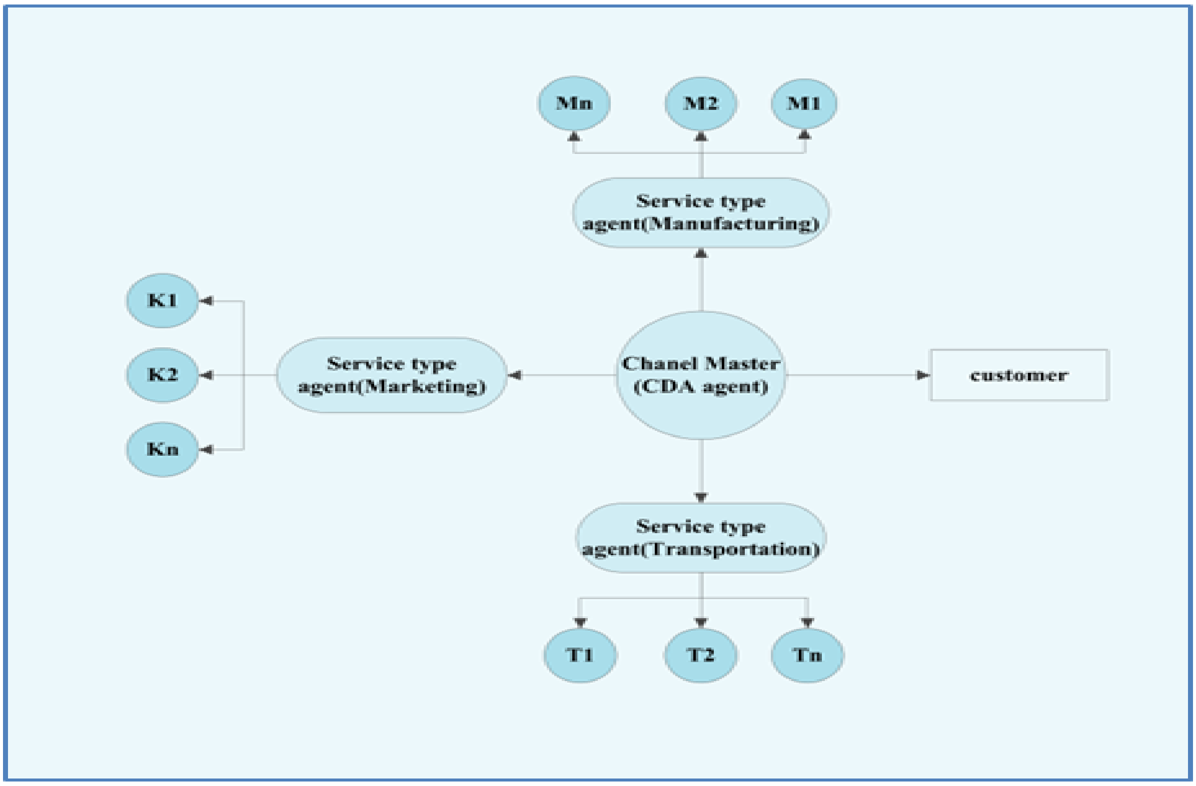

Figure 1: A proposed framework (agent-based SCM using Game theory)

A. Profit allocation mechanism

Profit allocation process as illustrated in Fig.2;

1) The process is started by a service type agent when it gathers the contribution value of each partner from details accepted by service providers.

2) Service type agent sends the gathered information to CDA agent

3) CDA agent forms sub-coalitions based on the number of partners and displays them as total costs.

4) CDA agent computes Shapley value and displays the results.

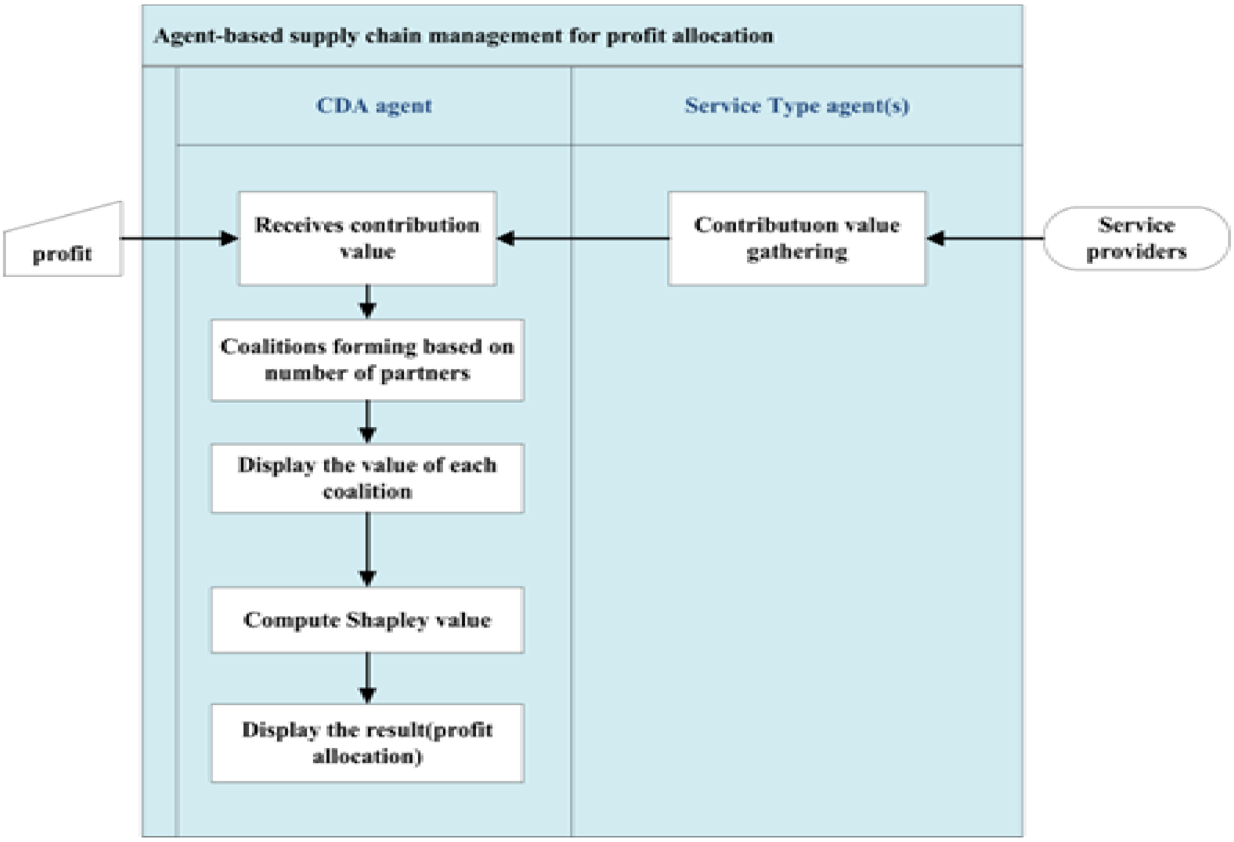

Figure 2: Profit allocation process

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B. *Compute shapely value*

Shapely value computation starts by forming coalitions of involved agents and then requires calculating a value of every possible sub-coalition. The question is: How can value be distributed among members of a possible sub-coalition if it was formed? If the number of is agents viewed as set *A*, and then every non-empty subset of *A* is a possible coalition (i.e. the total number of these subsets is $(2^{|A|} - 1)$

The coalition formation process includes three main steps:

1) Generate the coalition's structure: dividing the set of agents into complete and split coalitions. Such a division is called a coalition structure (i.e. For number of agents n , there are 2^n possible sub-coalitions (i.e. given a set of agents *A*={*a*-1, *a*-2, *a*-3}, there exist seven possible sub-coalitions: {*a*-1}, {*a*-2}, {*a*-3}, {*a*-1, *a*-2}, {*a*-1, *a*-3}, {*a*-2, *a*-3}, {*a*-1, *a*-2, *a*-3}, and five possible coalition structures {{*a*-1}, {*a*-2}, {*a*-3}}, {{*a*-1}, {*a*-2, *a*-3}}, {{*a*-2}, {*a*-1, *a*-3}},{{*a*-3}, {*a*-1, *a*-2}}, {{*a*-1, *a*-2, *a*-3}})

2) Optimize the value of each coalition: combining the value of the agents in every coalition into the coalition structure to maximize the coalition value.

3) Payoff distribution: dividing the value of each coalition among its members.

C. *Shapley value algorithm*

1) Constructing a basic Shapley matrix

In this matrix each row has distinct subsets S_l of factors and the number of factors in each row referred as s_l ,$l \in \{1,2,..,2^n\}$, and the number of column is n. Each line l views the factors involved in subsets S_l to compute the v (S_l). The following steps provide more details to explain Shapley value algorithm:

- Let $pi = 2n - i$(i referred to factors)
- Set $n = 3$

1.1 constructing the first column of matrix

- initialize the first column to value 1 in position from 1 to p_1, i.e. for $n = 3$,set value 1 from level 1 to 4
- initialize the first column to value 2 from position $p_1 + 1$ to $p_1 + p_2$
- initialize first column to value i from $\sum_{j=1}^{i-1} p_j + 1$ to $\sum_{j=1}^{i} p_j$
- continue until $i = n$

1.2 constructing the second column c2 of Shapley matrix

- copy values from first column to second column according to the following table 4:

Table 3: The Pattern For Constructing Second Column Of Shapley Matrix

Copy from first column in position:			to second column in position:		
p_1+1	o	p_0	2	o	p_1+1
p_1+p_2+1	o	p_0	p_1+2	o	p_1+p_2+1
$\sum_{j=1}^{i-1} p_j + 1$	o	p_0	$\sum_{j=1}^{i-1} p_j + 2$	o	$\sum_{j=1}^{i} p_j + 1$

- Continue until $i = n$.

1.3 Constructing the other columns in matrix

- Use the same a mentioned table to copy values from second column to third column
- Continue until last column.

1.4 The resulted matrix showed as Table 2, its first raw $S_1 = \{1\}$ says that $v\{S_1\}$ must computed with the first factor only. Second raw means that $v\{S_2\}$ must be computed with the first and second factors, and so on.

Table 4: Basic Shapley Matrix

Level (l)	Column 1	Column 2	Column 3
1	1		
2	1	2	
3	1	2	3
4	1		3
5	2		
6	2		3
7	3		
8	.	.	.

2) Constructing the Shapley matrix of coefficients

- Indicate the number of factors that appear in each raw l by f_l ,and set value as f'_l
- Create two $2^n * 1$vectors $\sum$ and $\sum'$,set vectors with value determined by $sl = \max(0, f_l - 1)$ And $sl' = \max(0, f'_l - 1)$ at position l, see the table 5;

Table 5: Size of Coalitions without Potential Factor

$\sum$	0	1	2	1	0	1	0	0
$\sum'$	1	0	0	0	1	0	1	3

- let the indicator as $d_{l,i} = 1$ if $i \in S_l$,otherwise set to 0.let indicator $d'_{l,i} = d_{l,i} - 1$

The elements of coefficients matrix in table 6 are defined by following formula:

$$m_{l,i} = \frac{d_{l,i} s_l!(n-s_l-1)! + d'_{l,i} s'_l!(n-s'_l-1)!}{n!} \quad (4)$$

Table 6: coefficient matrix

Level(*l*)	Column1	Column2	Column3
1	0.1666	0.0000	0.0000
2	0.5000	0. 5000	0. 5000
3	0.6666	0.6666	-0. 1666
4	0.5000	0.6666	0. 5000
5	0.1666	-0.5000	0. 1666
6	-0.5000	0.5000	0.5000
7	-0.666	0.1666	0.5000
8	0.1666	-0.1666	0. 1666

3) Estimating the contribution value of each factor

3.1 Estimating the value of factor i according to the level of its introduction

- Let 2^n*1 vector referred as $l_{i,x}$.this vector Generated to estimate the contribution value of i according to its introduction level $x \in [1,..,n]$,e.g. $l_{1,2}$ use to estimate the value contribution of factor 1 at second level i.e. founded when factor 1 introduced to compute the contribution value of coalition after another factor.
  - ➢ If $d_{l,i}$ =1 and f_l=x or $d'_{l,i}$=1 and f'_l=x-1
  - ➢ Let the elements of $l_{i,x}$ equal $m_{l,i}$ at position $p \in [1, 2^n]$

- Otherwise ,Set to 0
- Then, The contribution value of factor i at level x equal to $l'_{i,x}$ **V**

3.2 Estimate the elements of the Shapley decomposition

- Let $V = (v_1, \dots, v_{2^n})$, V is vector of type $1 * n$ and can be given by the function $v(S_l)$. V Viewed as following table

Table 7: Value of Vector V

Level(l)	V
1	v(1)
2	v(1,2)
3	v(1,2,3)
4	v(1,3)
5	v(2)
6	v(2,3)
7	v(3)
8	v(θ)

- The marginal contribution is given by $1*n$ vector E, which $E=VM$; the elements of E represent the Shapley value of each factor i.

V. Prototype Design and Implementation

A. System description

A simple supply chain management consists of two main entities designed as agents. The first called a service agent type(s) that represent several independent stages, each has its own core capabilities and cooperated together to achieve benefits (manufacturing, marketing, and transportation). Each stage has multiple outsourcing service providers. Second, the called CDA agent that represents the channel master and applying Shapley value and allocate profit.

B. System interfaces

As Fig.3, showed the system interfaces that include:

- CDA agent that enable user to input profit
- Agent service type(s) to create service providers details (stage Name, ID, and contribution value
- Supply chain management is main interface and have tow button Create CDA to forming coalition and transfer to CDA page
- CDA page has two labels displaying the stage name and coalition value, also include create service agent type(s) to compute Shapley value and displays result.

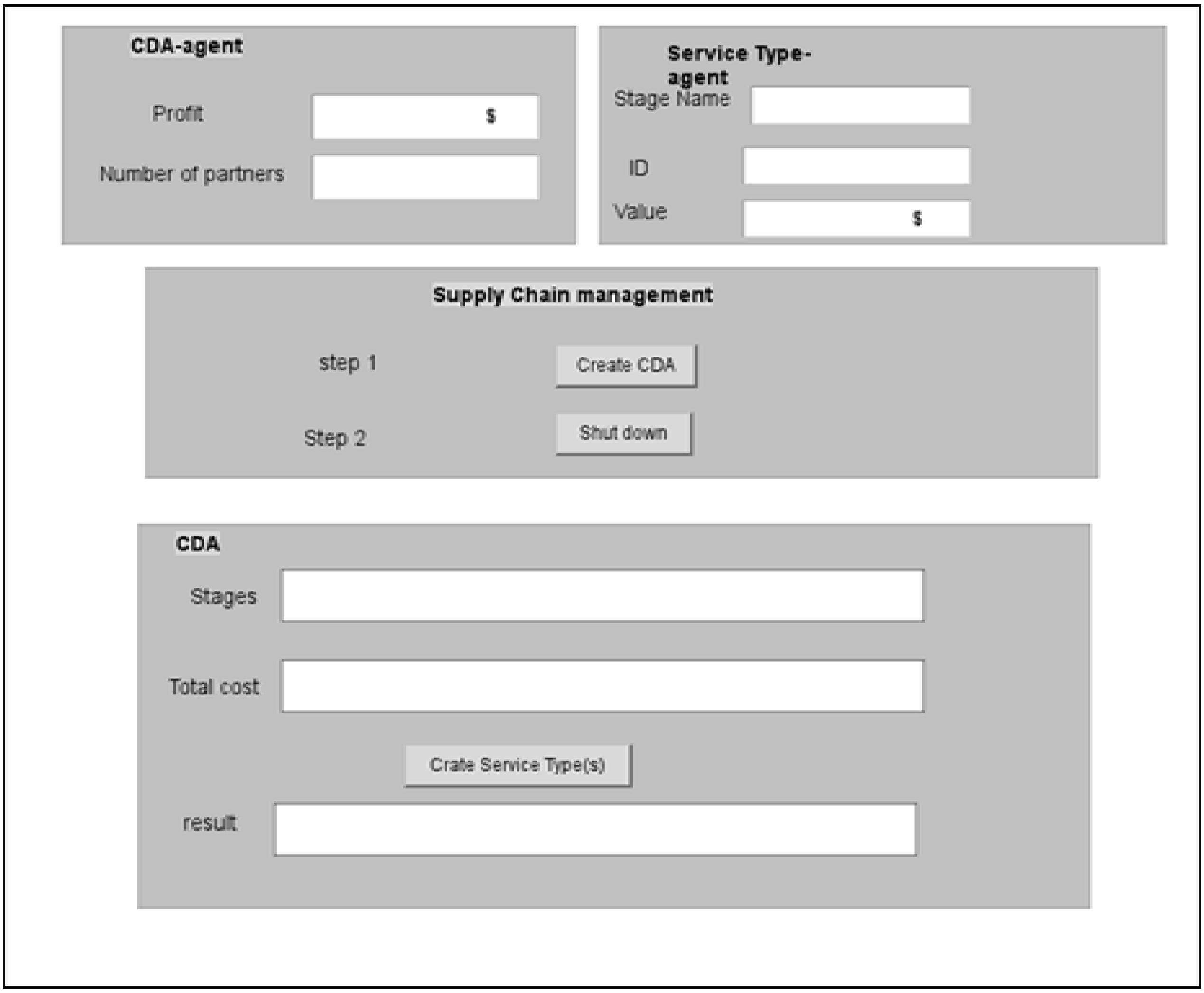

Figure 3: System interface flowchart

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VI. RESULT and DISCUSSION

The main goal of a supply chain is to achieve total values; at the maximum level, the value can be represented as profitability, delivery performance, or as customer satisfaction. Profitability means the total profit will be distributed among all participating companies and is considered one of most important parts in any supply chain, which has a direct effect on stability (i.e. thus no inducements exist that let supply chain partners abandon cooperation).

Now, “supply chain network” statement increased usable in the global supply chain management environment the companies represent as a part of whole supply chain network which all shared by their competences core to achieve the goal of business (i.e. deliver the goods service or product to customer).

Usually, a supply chain of this type needs to be controlled by a channel master who own the brand of new product and select other manufacturing and logistics partners in supply chain networks based on characteristic such as the requirement of the partner, and the total cost of order fulfillment.

A design agent-based supply chain can provide environments for cooperation that enhance the interaction and facilities communication at a low-cost. In any cooperative environment, the multiple partners seek to maximize their profit and guarantee a fair allocation of profit.

The research literature reflects that the profit allocation issue in supply chain management has benefited from game theory solutions such as the Shapley value method. The contribution of this thesis is developing an intelligent agent designed by Shapely value to automate profit allocation among the partners. A prototype was designed and implemented to evaluate the proposed system’s value and potential. We provide a test case to suggest that the proposed prototype of a profit allocation system is feasible and viable.

The test case:

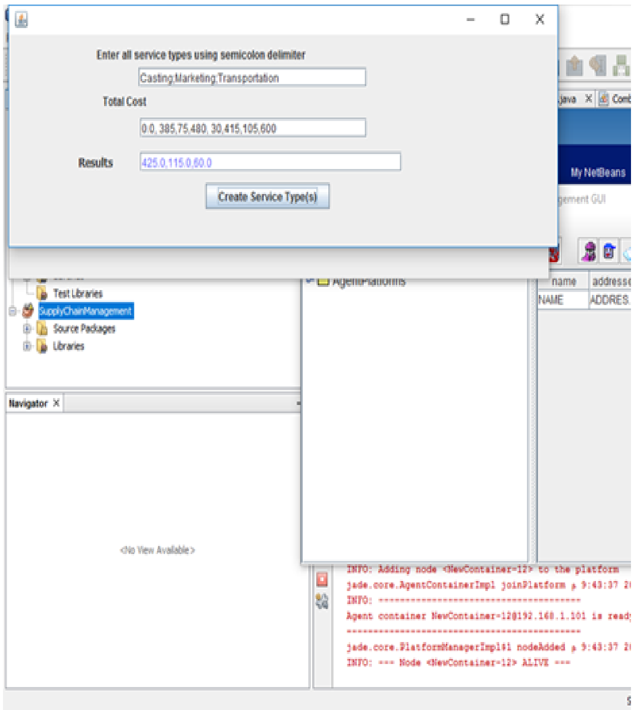
Assume the CDA have a total profit of about 600, and there are three participating companies that provide the services as listed with the following information in Table 8;

Table 8: Details about a test case

Service type	ID	Contribution value	Shapley Value
Production	P1	385	425
Marketing	M1	74	115
Transportation	T3	30	60

The result:

According to the mentioned numerical example, CDA agent allocates profit and assigned transportation stage with greatest part of profit, Where its contribution more than others; this prove the fair allocation See Fig.4 for an example of applying the prototype:



VII. CONCLUSION

This paper documents research regarding a new approach that integrates a multi-agent system with game theory in SCM. The motivation behind this research is a literature review that identified some “issues” raised in the modern supply chain paradigm which has changed to become global-nonlinear networks that allow efficient interactions between multiple layers of suppliers, manufacturers, and other partners. The interaction among supply chain entities can be achieved regardless of their size, positions, or number of provided services and products.

The most common issue is the stability of the cooperation that can be affected by profit allocation, meaning a fair profit allocation makes the cooperation more stable and discourages partners from leaving.

To better align agent-based supply chain management (SCM) with this issue, this paper introduced method of designing an intelligent agent in SCM applying the Shapley value in the context of profit allocation. A simple prototype is implemented using I multi-agent system. Entities related to a simple supply chain, such as the CDA agent and service type agent with multi-agent service providers. These agents are designed with their own specific goals to achieve the required task.

In order to keep things less complex and to demonstrate agent based- profit allocation effectively, entities of the supply chain are kept very simple. In real life, a supply chain is a very complex; this framework can be extended very easily to accommodate other issues in cooperative supply chain network such as partner’s selection and supply chain formation.

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