Reducing Bullwhip effect of Supply Chain by applying Multi-agent having Fuzzy thinking

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Abstract: The common focus of supply chain operations is delivering the precise product at the accurate place at the right time in spite of alteration in product supply and customer demand. The proposed model consists of a set of fuzzy agents that are working together to maintain supplying, manufacturing, inventory and distributing. The main operations of the fuzzy agents include: (1) receiving information from customer orders (2) check the inventory (3) make the production schedule (4) issue the order of raw materials from the suppliers (5) receive the raw materials (6) production (7) deliver products to the customer. In addition to the interface agents and communication protocols among agents.

With the help of the dyanmic reasoning capabilities, the proposed MAS system is capable of handing the uncertainty in the E-supply chain activities. This fact helps to reduce the impacts of the bullwhip effect.

Keywords: **MAS, Fuzzy thinking, Bullwhip effect, Demand forecasting.**

I. INTRODUCTION

The bullwhip effect is one of the majority imperative causes for inefficiencies in supply chain management system. Since Forrester exposed around 45 years ago that discrepancies of demand boost up the supply chain from consumer to merchant, the researchers seem for reasons and attempt to discover the countermeasures. Yet the responsibility that human being activities engage in recreation in the bullwhip effect is still unnoticed.

The capability to swiftly react to ecological changes has been renowned as a key constituent in the accomplishment and continued existence of corporations in today's marketplace. This dexterity includes a continuing monitoring of proceedings both indoors and exterior the conglomerate, rapid acknowledgment of the collision of exogenous actions, and hasty re-planning and reconfiguration to permit the activity to take benefit of opportunities and diminish deserved costs.

In a manufacturing attempt, the entire supply chain is area under conversation to unanticipated events for which reactions are obligatory. The supply chain flows from the client order taken by the sales dissection through scheduling, production, allotment, field overhaul, and reclamation. Exogenous events are copious and wide-ranging: renovate in the consumer order, unavailability of a fussy source, price alteration in a resource, belatedly deliverance of a resource, crash of a machine, an imperative order from a high-quality customer, and so on.

There are following disputes encountered in the supply chain management system as given below:

Globalization of manufacturing process

With the globalization of manufacturing functions, having a universal procurement organization that can continue and react to the supply chain needs is noteworthy. Opting for a strategic supplier provides computerized positions with unswerving comprehensive superiority and a unswerving restricted service which is a doubtful.

Protection and superiority products

The heaviness on manufacturers to fabricate high-quality products that are protected is an increasing challenge. The number of manufactured goods recall cases is mounting each day. It can damage a company's reputation and is expensive to its bottom line.

Shorter lead time, less inventory and better throughput

With shorter product life cycles and changing market demands, companies are forced to embark on a lean journey. It is important to note that the supply strategies in a lean environment support the operations strategy. The challenge is always to find not just a lean concept, but a working lean solution

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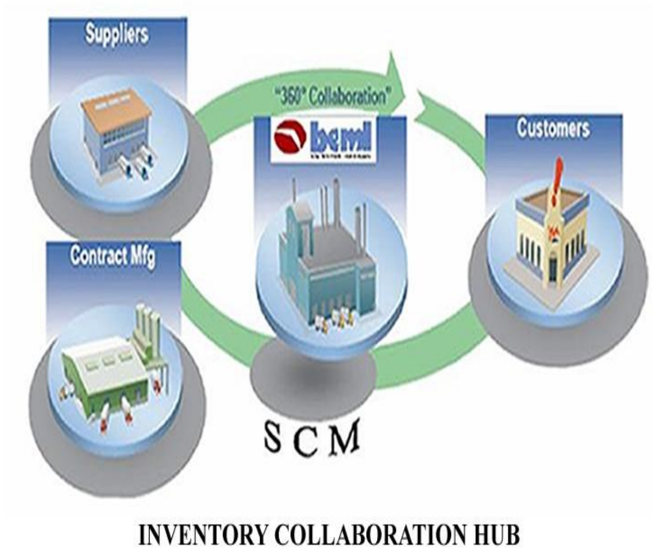

Figure 1: Conceptual Model

Not extended past, logistics administrative at Procter & Gamble (P&G) scrutinized the order prototypes for one of their best-selling products, Pampers. It's vending at retail stores were changeable, but the variability were undoubtedly not unnecessary. However, as they inspected the distributors' orders, the executives were stunned by the degree of variability. When they looked at P&G's orders of materials to their suppliers, such as 3M, they exposed that the swings were even superior.

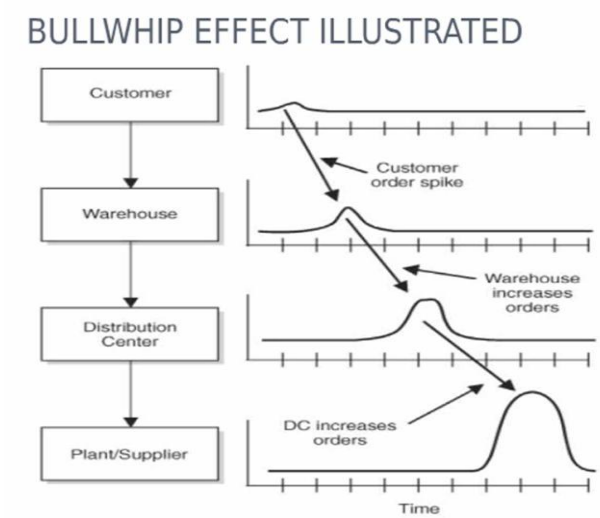

Figure 2 BWE illustrated

In the past few years, the Efficient Consumer Response (ECR) inventiveness has tried to redefine how the grocery supply chain should labor. One encouragement for the inventiveness was the excessive quantity of stock in the supply chain. Various industry studies found that the entirety supply chain, from when products depart the manufacturers' production lines to when they disembark on the retailers' shelve, has supplementary than 100 days of inventory supply.

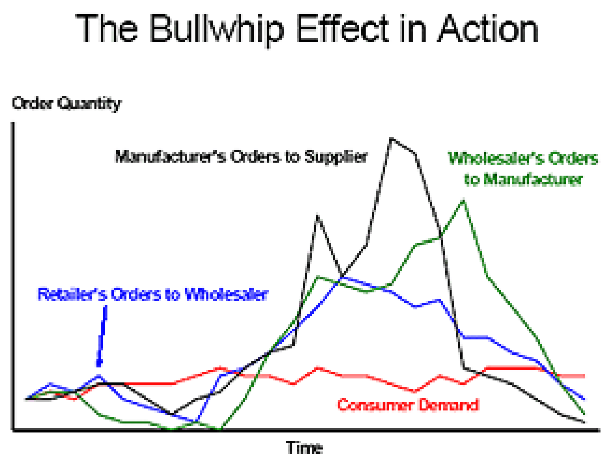

Figure 3 BWE stages

The imprecise information has led every entity in the supply chain – the plant warehouse, a manufacturer's shuttle warehouse, a manufacturer's market warehouse, a distributor's central warehouse, the distributor's regional warehouses, and the retail store's storage space – to accumulation because of the sky-scraping quantity of demand uncertainties and variability. It's no conjecture that the ECR reports estimated a potential $30 billion opportunity from reorganization the inefficiencies of the grocery supply chain [3].

The inconsistency mentioned above can be described in 6 stages (see fig. 3).

1. This is the factual client demand
2. Supply cannot meet requirement, authentic deficiency subsists.
3. Channel intermediaries over-order to convene demand and congregate their stockpile levels.
4. Supply catches up with demand. Intermediaries stop ordering or cancel orders.
5. Planning is not aligned with real demand, therefore production continues
6. Demands declines. Intermediaries try to drain inventory to reduce handling costs and to prevent write downs (spoiled goods)

The causes can be divided into behavioral and operational causes. Behavioral causes are:

- Misuse of basic stock policies
- Misperceptions of feedback and time delays
- Panic ordering reactions after unmet demand
- Perceived risk of other players‟ bounded rationality

Operational causes are:

- Forecast errors
- Lead time variability
- Lot sizing/order synchronization
- Trade promotion and forward buying
- Anticipation of shortages

Lee defines four categories for these causes:

1. Demand forecast updating (forecast errors, stock policies, lead times)
2. Order batching (Lot sizing)

3. Price fluctuations (trade promotion and forward buying)
4. Rationing and shortage gaming (misperceptions, panic ordering, bounded rationality.

The lack of supply chain coordination leads to a phenomenon known as bullwhip effect (BWE), in which fluctuation increases as we move up the supply chain from retailers to wholesalers to manufacturers to suppliers. The bullwhip effect distorts demand information within the supply chain, with each stage having a different estimate of what demand looks like. Common practical effects of this variance amplification were found in cases of companies Procter & Gamble **(**dealing with mainly diapers) and Hewlett-Packard **(**dealing with mainly computers and its components), and are presented to students worldwide through the business game **"**Beer Game**"** developed at MIT. Since then, worldwide researches have been carried out by various authors to study different aspects of SCM causing the bullwhip effect and suggested a number of methods to reduce its effect

II. MULTI-AGENT THEORY

Agent is a software entity which functions are proactive and autonomous in a particular environment. Multi-agent system (MAS) is a kind of intelligent system that interconnects separately developed agents, thus enabling the ensemble to function beyond the capabilities of any singular agent in the set-up [3].

There are two fundamental approaches used in modeling multi-agent systems: qualitative (some form of logic, e.g. BDI) and quantitative (e.g. Bayesian). Utility theory is a quantitative one to model MAS. Utility function is a mapping from states of the world to real numbers, indicating the agent's level of happiness with that state of the world. Agents in the competitive MAS potentially have different utility function.

In MAS, as to bounded resources and capability, agent does not stand alone. In accordance with behavior in reality, agent must take action based on certain strategy or rationality. Traditionally, designers have sought to make their agents rational so that they can "do the right thing". Rationality is how the rational decision is made among multiple strategies in the interaction of multi-agent [4].

The predominant theory of rational decision making in agents is that of the economic principle of maximizing the expected gain of actions [5]. Decision theoretic rationality dictates that the agent should choose an action which will maximize the expected utility of performing that action given the probability of reaching a desired state in the world and the desirability of that state [6]. The action that maximizes individual utility may conflict with overall interest (social utility), or redundant actions could be taken due to local utility preference. Hence rationality needs to be considered not only from the individual's point of view, but also from the social perspective. Jennings and Campos proposed the principle of social rationality [7] as follows:

If a member of a respective society can perform an action whose joint benefit is greater than its joint loss, then it may select that action. Here, joint benefit is defined as the benefit provided to the individual plus the benefit afforded to society as a result of an action

Where $Ui(aj)$ is the individual utility of agent i when it takes an action aj,λi is the weighting given to the individual utility of agent i; $\Sigma Uk'(aj)$ is the sum of utilities of other agents in the system when action aj is taken by agent i , λsoc is the weighting given to the social utility part of the function.

At a coarse level, equation (1) can be rewritten as:

$U(i,j)=k1*selfUtility(ps)+k2*publicUtility(pp)$. (2)

Where $U(i, j)$ is the utility of agent i when it takes action j; $k1$, $k2$ are the weighting given to individual utility and public utility respectively. ps and pp are the key influence parameters for individual utility function and public utility function, e.g. activity's duration, waiting time, priority. The values of $k1$, $k2$ can be altered to implement a wide range of decision making strategies [8].

The proposal of social rationality is to ensure the proceeding of task planning when resource competition appears [9]. Social rationality can be used to guide an agent's decisions. In process simulation, when different activity instances could not share limited resources, competition appears. Thus agent social rationality can be introduced into process simulation to represent the decision making strategies of organizations/departments. Related organization will prefer the activity instances which maximize their predefined rationality utility functions.

III. PRIOR WORK

Wang et al. (2011) stated that demand variability increased when it moved downstream to upstream in a supply chain, this was called the 'Bullwhip effect'. This effect caused unnecessary inventory built up along the nodes of the supply chain and hence reductions of this play a vital role. In this paper the causes of bullwhip effect were analyzed and the reducing measure was discussed, such as: Establishing the information sharing mechanism, Coordinating the information sharing's benefit allocation model, establishing the strategic alliance, strengthening the trust cooperation, Strengthened the stock management and reduces the supply chain lead time.

Zhang et al. (2011) applied H∞ robust control method to operate closed-loop supply chains. Compare ability of H∞ method to reduce bullwhip effect under two forecasting methods of market demand: Moving average and exponential smoothing. Numeric examples showed H∞ control could reduce bullwhip effect effectively in single period and whole periods.

Zhigang et al. (2011) provided a quantitative analysis of the reduction in the bullwhip effect, and the potential benefits thanked to real-time visibility of production flows provided by the Radio Frequency Identification (RFID) technology and other technologies. This paper was based on a Fast Moving Consumer Goods (FMCG) supply chain; the supply chain is composed of there echelons, namely manufacturers, distributors and retailers of FMCG, the RFID-based intra-SC system was implemented for the enterprise's warehouse in JiangSu province, china. The result showed that RFID application could dramatically improve the efficiency of FMCG supply chain, And real-time visibility of supply chain could markedly reduce the bullwhip effect, and substantially affecting the economical profitability of the whole FMCG supply chain.

Barlas et al. (2011) investigated some of the structural sources of the bullwhip effect, and explored the effectiveness of information sharing to eliminate the undesirable fluctuations. Extensive simulation analysis was carried out on parameters of some standard ordering policies, as well as external demand and lead-time parameters. Simulation results showed that (i) a major structural cause of the bullwhip effect was isolated demand forecasting performed at each echelon of the supply chain, and (ii) demand and forecast sharing strategies could significantly reduce the bullwhip effect, even though they could not completely eliminate it. They specifically showed how each policy was improved by demand and forecast sharing. Future research involved more advanced ordering and forecasting methods, modelling of other well-known sources of bullwhip, and more complex supply network structures.

Shoar et al. (2011) considered Bullwhip Effect (BE) as one of the most important issues in supply chain management. Although it was well established that demand signal processing, order batching, gaming and pricing were the main sources that led to the BE, but sometimes they were facing problems in qualifying it. One reason for that could be the incomplete, inconsistent, uncertain or unclear data. In that situation, the BE quantification was the most significant activities which could be performed by us. Therefore, the aim of this paper was to create a methodology which used a fuzzy inference system (FIS) based on the experience of experts to quantify the BE to reducing its negative impacts.

Xiang-zhi et al. (2012) stated that bullwhip effect was the phenomenon of increasing demand variability in the supply chain as one moves from downstream echelons (retail) to upstream echelons (manufacturing). That was the volatility of the supplier's order (variance) was greater than the customer's demand (variance). Based on the data from Wind, from the perspective of the industry, they tried to document the intensity and trend of the bullwhip effect in the manufacturing industry of China by empirical study method. They found that the bullwhip effect was not often observed in industry level data. This was indeed good news for firms and their suppliers.

Chen et al. (2012) developed a simple set of formulas that described the traditional bullwhip measure as a combined outcome of several important drivers, such as finite capacity, batch-ordering, and seasonality. Their modeling framework was descriptive in nature as it features certain plausible approximations that were commonly employed in practical inventory systems. The results were nonetheless compelling and could be used to explain various conflicting observations in previous empirical studies. Building on the theoretical framework, they discussed the managerial implications of the bullwhip measurement. They showed that the measurement could be completely noninformative about the underlying supply chain cost performance if it was not linked to the operational details (such as decision intervals and leadtimes). Specifically, they showed that an aggregated measurement over relatively long time periods could mask the operational-level bullwhip. In addition, they showed that masking also exists under product or location aggregation in some illustrative cases.

Zhang et al. (2012) applied the state-space method used in modern control theory to study the stability/instability of a two-stage supply chain controlled by the order policy called Automatic Pipeline, Variable Inventory and Order Based Production Control System (APVIOBPCS). Because product returns were not permitted, the supply chain might turn out to be an autonomous switched system according to the retailer's order pattern. The stability of each subsystem was examined by analytic method and numerical analysis. The relationship between the supply chain stability/instability and bullwhip effect at different values of input parameters was then examined through simulation. Finally, the impacts of the decision variables on the relationship between the supply chain stability and the chain-wide total cost were analyzed, and the implications for demand forecasting, inventory control, and supply process for improving the supply chain operations were identified.

Thompson et al. (2015) used the context of a popular management simulator that taught students about the bullwhip effect (i.e., the beer distribution game) to explore an integrated decision analytic, control theory, and system dynamics approach to the game that recognized the value of available (imperfect) information and considers the value of perfect information to provide the optimal strategy. Using a discrete event simulation, they characterized optimal decisions and overall team scores for the situation of actual available information and perfect information. They describe their implementation of the strategy in the field to win the 2007 beer game world championship played at the 25th conference of the International System Dynamics Society. This paper seek to demonstrate that better understanding of the system and use of available information leads to significantly lower expected costs than identified in prior studies. Understanding complex systems and using information optimally might increase system stability and significantly improve performance, in some cases even without better information than already available.

IV. FUZZY MULTI-AGENT

Multi-Agent Based Simulation Systems (MABS) have provided new perspectives on modeling and simulating complex problems. While traditional simulation systems have been limited to a certain class of applications, MABS have employed the powerful concepts of adaptation, emergence and self-organization to model complex, real-world problems. Many domain specific MABS have been developed over the past two decades. Even though these systems have addressed important issues in domains such as social or traffic simulations they are not reusable outside of their application area. On the other hand, the multi-agent system community has spent effort developing generic frameworks for MABS.

These frameworks provide the basic building blocks, i.e., architectures, software components and libraries for the development of a variety of agent-based simulation systems.

Unfortunately, none supports the development of MABS where the environment is *open* (i.e., inaccessible, non-deterministic, dynamic and continuous). This represents a major weakness since realistic simulations require the modeling of dynamic environments that can only be partially perceived by the agents.

Over the past several years we have developed a framework for the development of large scale multi-agent based simulation systems for complex domains. The framework called DIVAs (Dynamic Information Visualization of Agent systems) offers reusable architectures, abstract classes, software components and libraries to support the development of enterprisescale simulation systems. DIVAs is based on the premise that agents and environment play an equally important role in MABS. Agents are situated in an open environment that is partially perceived, and the environment is totally decoupled from agents. Such a clear separation of duties leads naturally to extensible, reusable architectures. In addition, DIVAs offers means to dynamically access and modify agent and environment properties at run-time, a unique feature that none of the existing frameworks offers.

As shown in Figure 3, in DIVAs, an agent consists of four main modules [15]. The Interaction Module handles an agent's interaction with external entities and separates environment interaction from agent interaction. An agent communicates with other agents through the Agent Communication Module. It receives environmental data (e.g., agent states, environment object states, external event information) from the Environment Perception Module. The Knowledge Module is partitioned into External Knowledge Module (EKM) and Internal Knowledge Module (IKM). The EKM serves as the portion of the agent's memory dedicated to maintaining knowledge about entities external to the agent, i.e., acquaintances, environment objects situated in the environment. The IKM serves as the portion of the agent's memory dedicated for keeping information that the agent knows about itself (i.e., current state, physical constraints, social limitations). The Task Module manages the specification of the atomic tasks that the agent can perform (e.g., walk, run). The Planning and Control Module serves as the brain of the agent; it uses information provided by the other modules to react to critical situations, plan, initiate tasks, make decisions, and achieve the agent's goals.

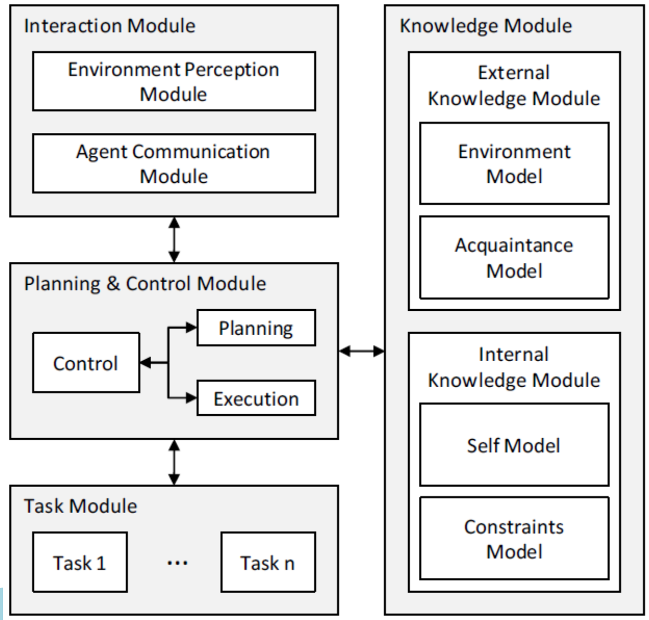

Fig. 3. Agent architecture showing the agent's main components.

V. EXPERIMENTAL IMPLEMENTATION

Aiming to illustrate the applicability of MAS platforms, a washing machine production line will be used as case study to accommodate an agent-based control system that will be modelled and simulated in the Multi-agent simulation environment. The use of simulation in this work has supported the task of specification of an agent-based control system for the process control, adjusting the definition of the autonomous agents' behaviour and the interaction among them.

A. Description of the Case Study

The case study used in this work is a part of a washing machine production line, following a product-driven control approach. This simplified production line is composed by 11 machines that are linked together by conveyors, as illustrated in Fig. 1, including two particularities:

- The first one is centred on a workstation (WS) where a marriage operation occurs, consisting in joining two different components (i.e. Rear Tub and Drum) that arrive from two independent conveyors.
- The other is the existence of an operation that can be performed in one of two available and similar machines (i.e. tub welding machines).

All other operations are single machine operations that are placed on a sequential order, each one having a processing time, according to the type of product to be processed. The production line also comprises a station (WS9, functional tests), where a quality control check is made to all produced products. This station is in charge to run a proper quality check program and the product is labelled with the inspection results for posterior analysis.

The products enter the line with a process plan that must be fulfilled. The process plan is set to the product taking into consideration the variables (e.g. type of the rear tub) and operation parameters (e.g. thickness of welding process) according to the type of washing machine to be manufactured.

B. Implementation Details

The agent-based model to control this production line was developed in NetLogo. The agent-based system is composed by 3 types of agents: Product Agents (PA), Quality Control Agents (QCA) and Resource Agents (RA). The Rear Tub and Drum are examples of PA agents, the machines and conveyors are examples of RA agents and WS9 is a QCA. The behaviour of the PA agent is very simple. Basically the PA is created with a process plan containing the details and sequence of operations that must be fulfilled. During its lifecycle the PA agent will interact with the RA agents in order to guarantee the execution of the product according to the process plan. The results of the operations' execution are stored for posterior analysis and to support traceability..

VII. CONCLUSION

In this case, and since the line is not well balanced and only one tub welding machine is available, a congestion in the upstream sequence of the production line appears, and consequently the MLT is significantly increased due to the time spent by the pallets stocked in the line. Also the WIP parameter is increased.

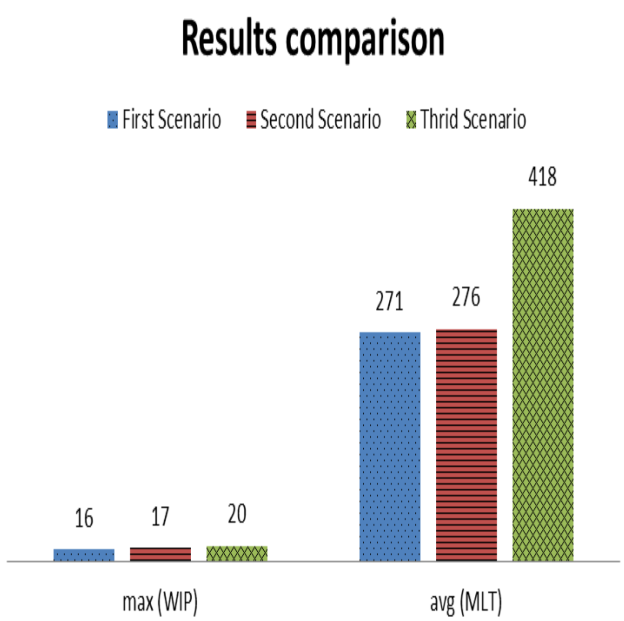

Fig. 5 summarizes the WIP (maximum value) and MLT parameters for the three scenarios simulated..

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