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PREVENTING OR DECREASING BULLWHIP EFFECT IN A BIOMASS SUPPLY CHAIN

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Abstract— **The bullwhip effect that occurs in supply chain leads to inefficiencies such as excessive inventory and back orders. This study investigates supply chain of a biomass. A simulation model using system dynamics approach is proposed to study behaviors and relationships within the supply chain and to determine variation of supply chain members demand related to end customer demand which has known as Bullwhip Effect. The purpose of this study is to represent the bullwhip effect in biomass supply chain by developing a system dynamics model and then presenting an improvement policy for preventing or decreasing bullwhip effect for supply chain members. We find that information sharing across the supply chain vanishes bullwhip effect for retailer and supplier also decreases this effect for distributor and manufacturer.**

I. INTRODUCTION

It is anticipated that prime energy sources (oil, coal, natural gas) will be depleted within next 40-50 years. Moreover, growing energy demand and related environmental concerns such as global warming, acid rain and urban smog which cause due to the production of emissions from these sources have shifted researchers towards finding alternative ways of energy production (Halil Ibrahim Cobuloglu, 2014) (Saidur, 2011).Researchers suggested bio-mass liquid transportation fuels and energy products as an impressive solution which can help us to control climate change and lower our dependency on fossil fuels, mainly because the bio-mass feedstock can be produced renewably from different domestic sources. Furthermore, utilizing and use of bioenergy/biofuel products decrease environmental impacts comparing their petroleum counterparts (Wilhelm&Searcy, 2011) (Gold&Seuring, 2011) (Marquardt, 2010)

Any organic matter derived from living organisms is named biomass. It is one of the most noticeable sources of renewable energy. Biomass is made up of plant and animal materials, also residues such as wood from forests, crops, seaweed, material left over from agricultural and forestry processes, and organic industrial, human and animal wastes (Saidur, 2011) (Mafakheri, 2013).

II. LITERATURE REVIEW

This section presents the current research in biofuels supply chains, as well as, bullwhip effect and system dynamics modeling

A. biofeuls supply chains

Supply chain management plays a critical role in the management of bioenergy production processes (Gold&Seuring, 2011).Biomass supply chain management has been considered as integrated management of bioenergy production from harvesting biomaterials to energy conversion facilities (Gold&Seuring, 2011) (annevelink&demol, 2007). (Adams, 2011) mentioned biomass energy supply chain members: the supplier of biomass, transportation and distribution entities, energy production facility developers and operators, the government and utility firms who provide the incentives and the end-users. Typically, a biofuel production comprised of members such as agriculture (energy crops, raw materials production), biofuel production (modification and adoption of already existing plants or/and infrastructure development for new plants) and surely includes distribution and trade network also end-users (papapostolou, 2011).the present study also considers a four-echelon supply chain involves agriculture(biofuel supplier), biofuel manufacturer, distribution network and distributor . Several studies have applied mathematical modeling techniques to optimize biofuel supply chain performance indicators. In particular, (Halil Ibrahim Cobuloglu, 2014) provide a mixed integer optimization model for the economic and environmental analysis of biomass production.

B. bullwhip effect

Most supply chains suffer from the effects of demand uncertainty, demand amplification, and information distortion from their immediate downstream order placement which known as bullwhip effect (Lee, 1997) (Jones&Towill, 2000).such phenomenon arises when a downstream member in a supply chain place orders including large compared to its actual sales(demand distortion),and this demand distortion propagates to its upstream member causing the demand amplification (Lee w. , 2004) (Kahn, 1987) (Metters, 1997)

(Baganha&Cohen, 1998).Most of studies regarding the bullwhip effect emphasize the existence of bullwhip effect, the reasons of its occurrence and possible ways to lower it. (Sterman, 1989) proved existence of the bullwhip effect via the study of Beer distribution game. (Lee, 1997) mentioned four major reasons of bullwhip effect as(1) demand forecast updating(2)order batching(3)price fluctuation and(4)rationing and shortage gaming. (chen, 2000) presented a model which quantified the bullwhip effect for a simple supply chain. Later on, (Kim, 2006)developed a model for stochastic lead time also a model for stochastic lead time and demand were developed by (Fioriolli&Fogliatto, 2008).

C. .System dynamics modeling

Most of studies on system dynamics modeling in supply chain management focuses on information sharing, bullwhip effect, inventory planning/management, supply chain integration, system performance, planning and forecasting demand and production planning and scheduling (Tako&Robinson, 2012). (Nilsson&Hansson, 2001)studied use of intermediate storage locations between biomass fields and the power plant using a dynamic discrete event simulation. (Connolly, 2010)used system dynamics to evaluate physical structure of energy systems. Some studies developed a system dynamics model to asses environmental effects in energy systems (Feng, 2013) (Trappey, 2012) (Anand, 2005) (Jin, 2009) (Han, 2008).there are some other researches which implemented system dynamics for analyzing substitution of renewable energy resources with oil and non-renewable fuels (Aslani, 2012) (Hsu, 2012) (Bennett, 2012).There is a need on how to address and prevent bullwhip effect in biomass supply chains (Mafakheri, 2013).this work attempts to develop a simulation model using system dynamics approach either prevent or decrease bullwhip effect in biofuels supply chain.

III. METHODS ANAD MATERIALS

A. Problem characteristics

(Altiok, 2007) presented several reasons for using a simulation model rather than analytical model when a system is complex; excessive required time for solving, incapability in capturing systems behavioral aspects can be considered as disadvantages of analytical model. In contrast, simulation model is able to capture behavioral aspects, subject to any assumption. That is why simulation was used for modeling proposed problem. Our problem is a four-echelon supply chain problem.Fig1 shows the structure of supply chain which has been made up of agriculture (biofuel supplier), biofuel manufacturer, distribution network and distributor. we started with modeling different levels of supply chain whereas considered in transit inventory, storage inventory, preparation time and backlog order. as well ordering policy, desired order rate and desired shipment rate were determined for all members. As our product is a exclusive product missed sales has not been considered while inventory cost and backlog cost were took into account.in this four level supply chain manufacturer is aware loss will be face if can not respond to distribution center demand so manufacturer should estimate demand based on former periods demands and current orders. totally, there is a time lag between shipping biofuel by manufacturer and receiving by distribution network. in this case every member of supply chain is able to be aware of lower level order and do his/her anticipation according this order. anticipation which is done by members includes error in comparison with end-user demand. when there is volatility in end-user order, mentioned error will increase and leads to bullwhip effect over supply chain. In this research firstly bullwhip effect in biofuel supply chain is shown then actions for lowering it are proposed.

B. simulation model

Applying existing logic in supply chain stock management and models presented by (Strman, 2000) a system dynamics model is developed. Various stages of the supply chain (shown in fig1) are translated into corresponding stock and flow variables. Stock-flow diagram of problem has made up of three parts. Part one that is order-shipment also backlog. Part two includes variables which are used for determining desired order and section three quantifies bullwhip effect using order quantity variance and demand variance. As it is obvious cited sectors are integrated. For the reason that stock-flow diagram is large scale different sections of diagram are depicted separately. Figure 2 represents system dynamics simulation model designed for order-shipment and backlog part in vensim software. In system dynamics models, stock variables accumulate their flow variables and net flow into the stock is the rate of change for the stock variable. This structure is represented as

$$Stock(t) = \int_{t0}^{t}[inflow(s) - outflow(s)]ds + stock(t0) \quad (1)$$

Where inflow(s) and outflow(s) represent the value of inflow and outflow between initial time (t0) and current time t.

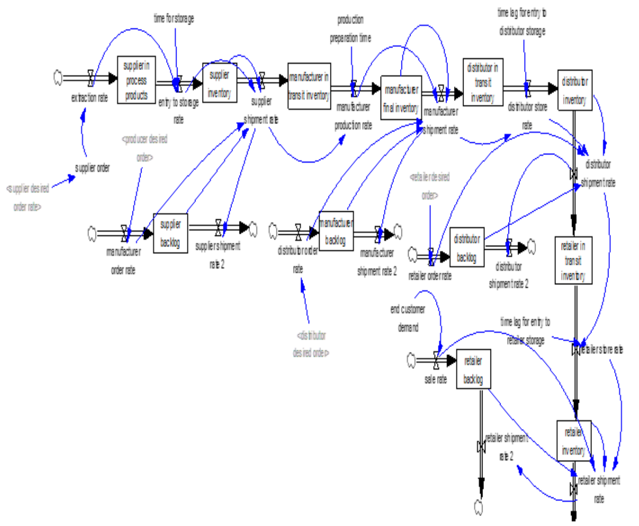

Fig2.Stock and flow diagram for order-shipment system of four-echelon supply chain

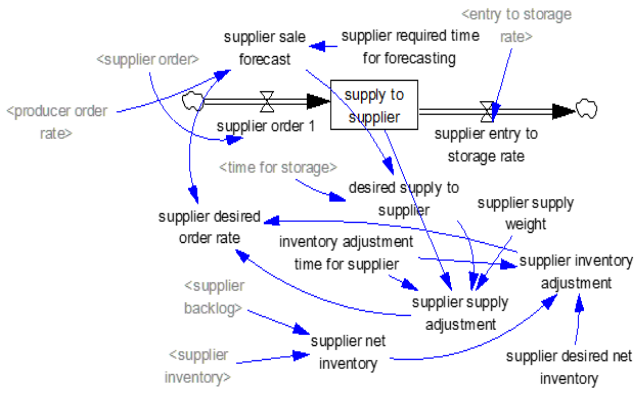

Fig3.Stock and flow diagram for desired order of supplier

Figure4 represents stock-flow diagram for quantifying bullwhip effect. Mathematical formulation applied for calculating bullwhip effect is

$$\text{Bullwhip effect}=\frac{\text{supplier order quantity } variance}{\text{demand variance}} \qquad (2)$$

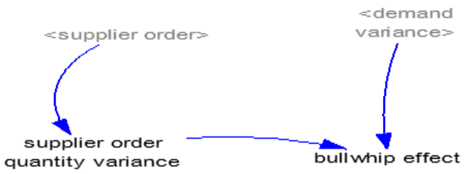

Fig4.Stock and flow diagram for bullwhip effect

Method of calculating bullwhip effect for other members of supply chain is same as supplier

IV. Results Based on Primary Supply Chain

As it was pointed out, aforementioned supply chain is managed commonly. In other words members forecast order comes from lower level and determine desired order level separately. According to equation (2) presented in section 3 bullwhip effect is calculated for levels of supply chain and is represented in fig5.

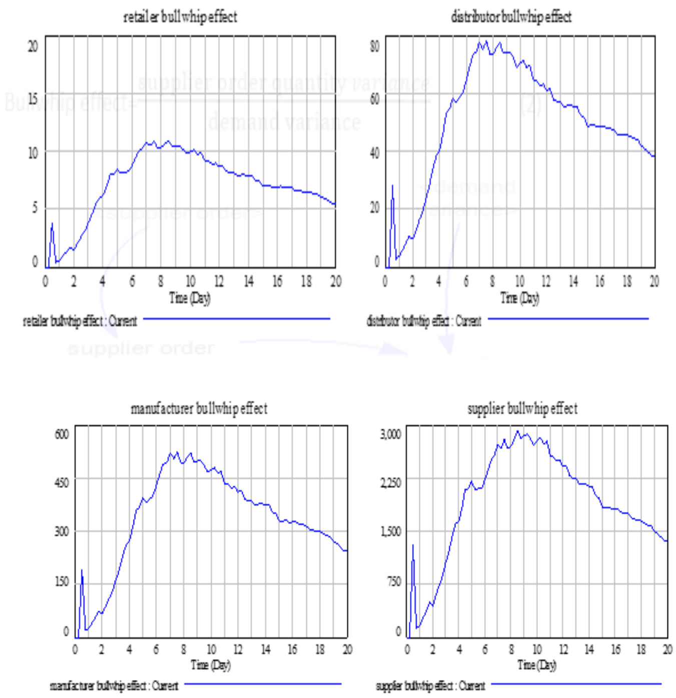

Fig5.bullwhip effect for members of supply chain

As it is obvious, bullwhip effect is amplified from retailer to supplier. In next section two scenarios are presented to decrease or prevent bullwhip effect in biofuel supply chain.

V. Scenario-Based Analysis

A. Scenario1.Information sharing

After information sharing, retailer timely shares biofuel sale information and market demand information. The order rate of retailer and distributor, manufacturer production rate and supplier extraction rate no longer depend on their own sale forecasting, but depend on market sales rate delivered from retailers. Now effect of information sharing on bullwhip effect over the supply chain is investigated.Fig6 represents bullwhip effect before and after information sharing for members of supply chain.

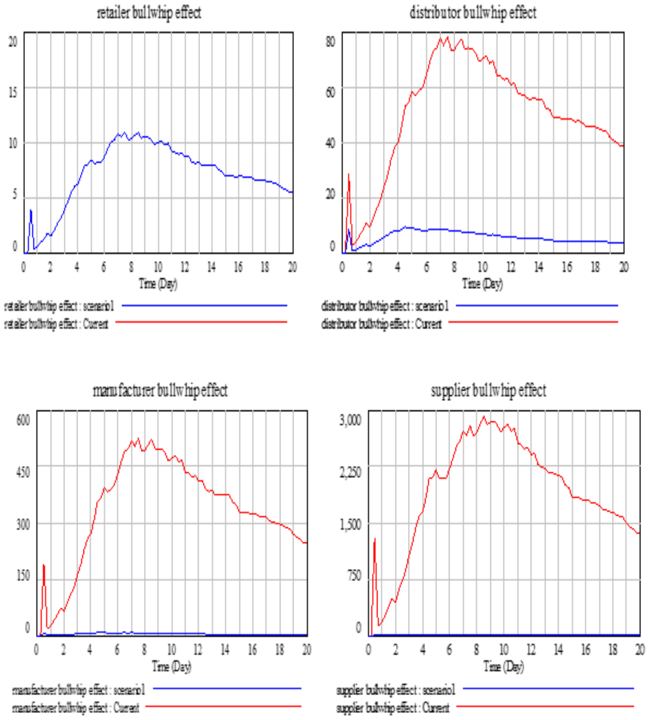

Fig6.Effect of information sharing on bullwhip effect over supply chain

According to figure6 it is clear that bullwhip effect did not change for retailer because of having information before and after information sharing .Distributor bullwhip effect had a considerable decrease while it can be claim that bullwhip effect has been vanished for manufacturer and supplier.

VI. Conclusion

In summary, bullwhip effect has been considered as one of the most common problems in supply chain management which has tremendous influences on supply chain efficiencies. In this study, we particularly focus on modeling and analyzing the bullwhip effect in biofuel supply chain. Increase in variance of order quantity results in the rise in the bullwhip effect, leading to increase in the variance of inventory eventually. In addition, the impact of bullwhip effect becomes more severe for upstream members of supply chain so that supplier encounters highest bullwhip effect amongst members. After identifying bullwhip effect in biofuel supply chain information sharing proposed as a influential action for controlling bullwhip effect. We showed that although information sharing declined bullwhip effect for distributor, destroyed it for manufacturer and supplier.

The Future work can take other corrective actions for lowering bullwhip effect in biofuel supply chain.

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