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Mathematical Modelling of Supply Chain under Current COVID'19 Business scenario with the Review Study on the Fuzzy Logic based Supply Chains

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Abstract: Organisation should focus on raw material flow, and process flow for the smooth running of supply chain. And the success of the supply chain depends on the demand aspects of the market too. Designing a supply chain does involve many challenges in all the flows mentioned above. This article is a review study of Fuzzy logic has been applied in modelling the supply chain. Besides the article also suggests briefly the initial requirements of evolving a mathematical model for an integrated supply chain.

Keywords: Supply Chain, Fuzzy, Mathematical Model.

1. INTRODUCTION

To influence demand volatility, seasonality, short life-cycle things, and lack of historic information, we should use Artificial Intelligence techniques—fuzzy logic and neural networks, beside data processing to supply reliable and sturdy results. By simulation technique, this system might cut off the bullwhip effect within the textile-apparel market [14]. A motivating finding was that including a downward substitution to a split market will reduce the Bullwhip. The timely sharing of relevant data on the Supply Chain will dramatically cut back the "bullwhip effect" [28]. A usual reaction of managers in response to challenges is to extend their order size. This reaction itself will increase the unreasonable demand and amplifies the bullwhip effect [19]. Visibility of demand across the Supply Chain minimizes the risks like bullwhip-effects, which might otherwise increase demand level out of proportion and eventually result in disruption in demand-side [33]. Lack of data / knowledge or distorted information responded to the Supply Chain will cause vital problems together with misguided capability plans, missed lost production schedules, abnormal inventory capital, improper transportation, poor client service and lost revenues. These don't seem to be deliberate to sabotage the performance of fellow Supply Chain members, however rather distorted data throughout the Supply Chain having a bullwhip effect [12]. Dynamic results of the availability supply chain have a big effect on production rates and bullwhip effect [19].

Price and demand management is additionally accustomed to take care of bullwhip effect in varied situations like direct and substitute product, seasonal demand, agent-based provide

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chain, discount, product life cycle and demand and supply elasticity are accustomed to predict the advanced nature of bullwhip effect [8].The optimum answer (i.e) fuzzy logic within the system reduces the order variability (bullwhip effect) and increasing the inventory responsiveness [16].The bullwhip effect caused by augmented uncertainty is lowered by information sharing among the members of supply chain [15]. George et al. (2004) indicated that fluctuations in client demands results in backlogging or shortages within the orders, designing flaws and bullwhip impact. Forrester briefed SDM with bullwhip effect in SCM to bring behavioural aspects into thought during management decision making [11]. The authors have showed that using possibility theory and fuzzy numbers for calculating demand and orders during supply chain process is beneficial, underneath conditions of demand uncertainty. They justify that despite the augmented quality of their model, the findings have improved with respect to the bullwhip impact and oscillations within the inventory.

Concept of Fuzzy

Fuzzy means “not clear” or “blurred”. It was proposed by A. Zadeh, professor in computing at the University of California in Berkeley. Fuzzy logic is nothing but a multi-valued decision making technique derived from fuzzy concept of set theory to address approximate reasoning. Fuzzy logic technique is computing with "degrees of truth" rather than the usual "true or false". In simple words fuzzy can be used when the decision is not just the matter of 0’s and 1’s or yes or no, the result often requires more degree for accuracy for decision making. Fuzzy numbers are used in fuzzy logic which can be defined as the set of possible values having their own weightage ranging from 0 to 1. Such weightage is known as membership function.The membership function fully defines the fuzzy set. There are different shapes of membership functions like triangular, trapezoidal, Gaussian etc. Recent decades has witnessed increasing popularity for Fuzzy Logic application in many sectors of industry both in technology and management, including in military and aerospace applications.

Fuzzy Logic Control (FLC)

Fuzzy logic controller is a common model with fuzzy linguistic variable, fuzzy set, and fuzzy reasoning module. FLC simulates the way people think [12], which benefits its coping mechanism within the complex system.

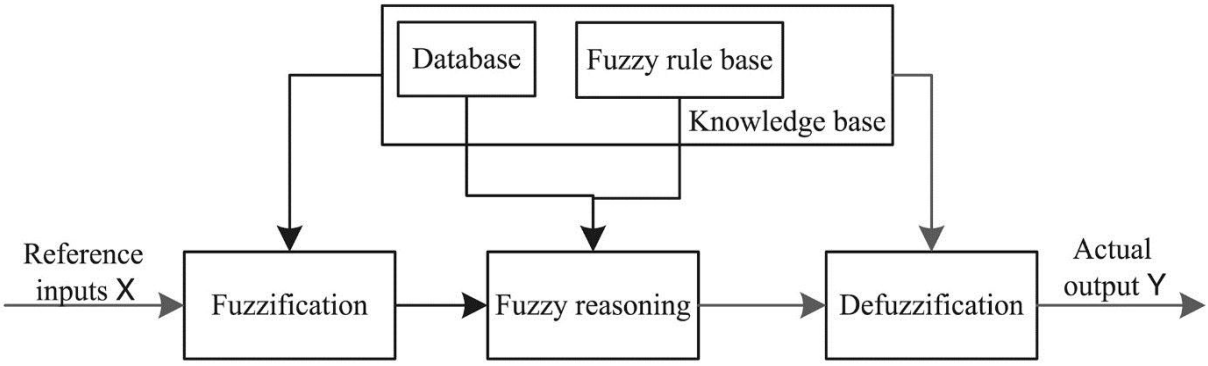

Figure 1: Structure of Fuzzy Logic Controller [15]

There are three process in fuzzy system they are fuzzification, inference and defuzzification. Fuzzification transforms input value into a fuzzy value with the help of information in the knowledge base. Inference or fuzzy reasoning is the middle stage where the results are obtained by qualifying the certain rules assigned and the output will be in the

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form of fuzzy. Defuzzification yields feasible result in Crisp logic, given fuzzy sets and corresponding membership degrees. Based on the type and size of problem the corresponding number of membership functions can be finalized. The right selection of membership functions is required in the fuzzification process which leads to the success of fuzzy expert system.The most commonly used fuzzy inference technique is Mamdani method. Identified the accuracy of the fuzzy output is based on the defuzzification methods, which is applied to convert the fuzzy output values into the crisp output. Most familiar defuzzification method is centroid method that is considering centre of gravity.

How Fuzzy is Used for Supply Chain Modelling?

A supply chain is the network of all the individuals, organizations, resources, activities, and technology involved in creating a product and selling the product to the customer. It involves procurement of raw materials from the suppliers, manufacturing the product and delivering the product to the end user. Organisational should concentrate on all areas of the organization to make more profit. Successful Supply chain management (SCM) deals with professionally coordinating and d efficient decision making with the available options. This can be generally done under fuzzy environment. Fuzzy decision-making helps in making accurate decision using the fuzzy sets whose boundaries are not sharply defined.

Fuzzy in Inbound Management

Recently, with the presence of the concept of supply chain management, researchers have found that choosing the appropriate supplier and managing it is an approach that can be used to increase the supply chain competitiveness (Stadtler, 2015; Yan, 2009). Vendors play an important role in accomplishing the key supply chain performance goals. Choosing the correct supplier is critical for both the purchasing manager and the operational manager. Supplier's analysis and assessment must consider both tangible and intangible criteria. Thus a multi-objective decision-making model is often employed for selecting proper suppliers.

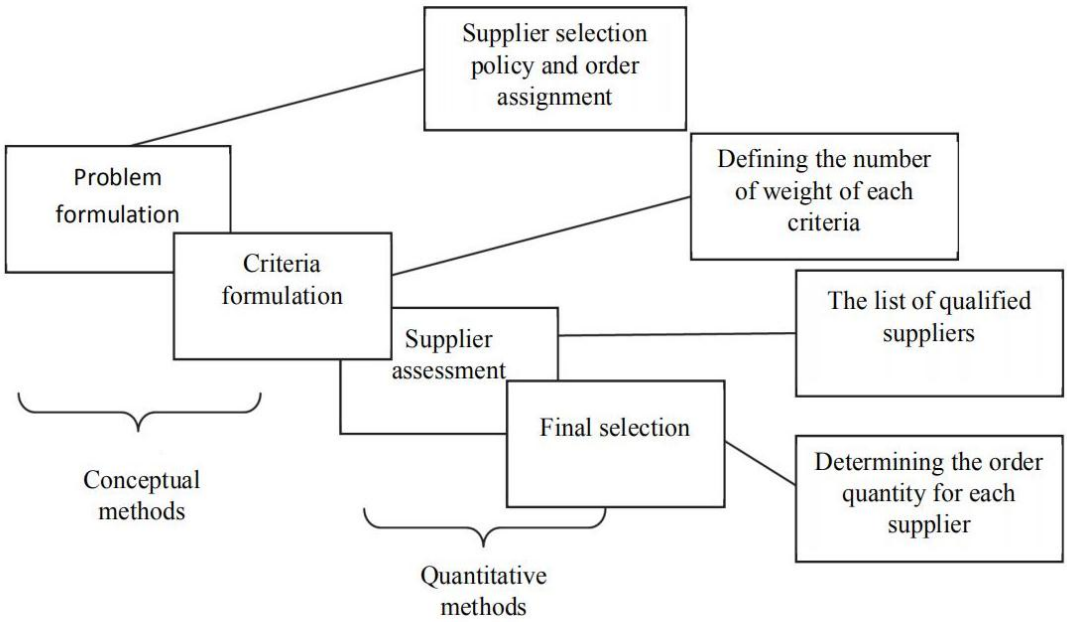

Figure 2: A Framework for Supplier Selection and Order Assignment

As uninterrupted supply of items is required, more vendors must be available for all raw materials and spare parts. Periodic assessment of vendor's performance is mandatory to

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ensure that they fulfil the required quality norms for the receiving materials. Other criteria for vendor evaluation are quality, cost, delivery, flexibility, and response. Because of the diversified nature of vendor parameters, all must be categorized before future assessment for which an executive team must evaluate the vendor criteria.

Due to the imprecise nature of linguistic vendor attributes, irregularity or improper handling of parameters To overcome inconsistency, a fuzzy-based method is required to transform the supplier's linguistic criteria into fuzzy numbers that gives accurate evaluation of vendors [7].

An important consideration in creating a fuzzy system is by generating the fuzzy rules and the membership function for each fuzzy set. When considering the input, the assessment team is usually engaged in formulating the fuzzy rules for several performance attributes. Fewer rules are more than enough to design fuzzy rule [20].

In VMI

Vendor-managed inventory (VMI) is a strategy executed by the supplier of consignment, optimizes the stock held by a distributor or retailer. In traditional practice, a retailer is a decision maker with respect to the order size. As far as the VMI is considered, the decision making is executed by the vendor. This could reduce stocking undesired inventories and help in overall cost reduction. Moreover, the bullwhip effect is also diminished by employing the VMI approach [5].

A fuzzy model of a VMI supply chain can be used in order to face demand uncertainty which could arise from volatile demand or inaccurate forecasts based on historical data. VMI supply chain model is suitable where the demand is varying. In such case inventory input information is considered as crisp values, the manufacturer utilizes fuzzy estimations for releasing production orders. Thus the fuzzy estimations for manufacturing orders are modelled by fuzzy numbers. The fuzzy based VMI supply chain models, can help in generating manufacturing orders and reduce the bullwhip effect [14].

Fuzzy in in house Management

Efficient inventory control activity is a crucial one to any organization. The inventory consumes an outsized a part of budget, space, overheads and maintenance. EOQ is the basic technique in formulating inventory policies. It is very much essential the operations executive must be able to assess quantity of ordering along with the period in order to minimize the total inventory costs carrying, order, production and shortage costs. Fuzzy based approach has been always precise and accurate [25]

In Forecasting

Forecasting is a core business process as it influences all other actions. Error in forecasts could not help the production planning. Demand forecasting is the basis of all supply chain planning processes either a push type or a pull type. Many problems in real world deal with uncertainty and imprecise data. So conventional approaches are not helpful for the best solution. To help these type of ambiguous situation, the fuzzy set theory evolved by (Zadeh 1965) is very efficient. Since fuzzy linguistic models allow the translation of verbal expressions into numerical ones, fuzzy method is most performing whenever decision making involves confusing and conflicting criteria with vagueness [22].

Fuzzy Forecasting Methods

- Fuzzy Times Series:
  Time-series models make use of discrete and equal time increments.
- Fuzzy Regression:

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Regression analysis, a statistical technique to investigate and model the correlation among the variables.

- Fuzzy Rule Based Systems:

Fuzzy rule based systems (FRBS) is a computing technique that employs fuzzy set theory.

Initial Requirements for a New Mathematical Model of Supply Chain

Production planning and scheduling are two important topics that serve to increase efficiency in manufacturing and improve effectiveness in customer service. Production planning determines what, when, and how much to produce to meet the customers' needs, without excessive inventory or back order costs The model to be introduced in this article is about Production planning(PP), that is carried out to evaluate production lots or batches and the time of production or production horizon, to meet out the demand which is generated by Make to Stock environment(MTS) or Make to Order(MTO) environment via customers and it is obvious there remains works to be done on both model enhancements with solution algorithms that are practically and industrially aiding and supporting the manufacturers who are always longing for evolving a feasible and economic production plans considering important and influencing factors like availability of all resources like materials, machineries, man power keeping focus on the production quantity to be manufactured within production horizon to meet the supply and dispatch for the demand horizon. Therefore, the production planning models must claim the feasibility considering many criteria like production cost, inventory cost, set up cost, backorder cost, demand, number of machineries, size of man power and various overheads etc,. The planning model of an organization is often formulated to maximize the revenue keeping in view of the demand period or demand horizon considering the criteria like price and transportation modalities. Therefore, an Integrated Production Revenue management Model (IPRM) might be evolved with the above said criteria either to minimize the cost or maximize the profit.

With respect to supply chain network, IPRM deals with all the three components namely Inbound, In house and Outbound. The proposed model in this paper excludes inbound and is associated with In house and outbound components of the supply chain considering this current business scenario of the COVID 19's impact on the operational features of the organizations which portray a serious threat to revenue generation aspects. The model description is presented with the following features:

- Objects cum indices
- Data
- Variables
- Constraints
- Objective Equation

Objects/Indices

Sales is zero initially for a few months as lockdown is due to curfew imposed by the government to prevent pandemic spread. The show rooms are closed. Sales activity is nil. After lock down for a few months, demand is uncertain and is assumed to fluctuate every month.	
Objects/Indices	Mathematical Notations
One Manufacturer One Product.	Assumed Lockdown months: m Demand period: t months

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Monthly time periods. Production and in house resources are ignored.	$t = 1,2,\ldots 12$

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Data

Objects/Indices	Mathematical Notations
Production Set up cost	s given
Production Unit Cost	p given
Inventory(holding) Cost	h given
Backorder cost	b
Initial stock	s_ini_t
Final Stock	s_final_t
Demand forecasts (every month's closing stock becomes opening stock for subsequent month; closing stock may occur as uncertainty exists for demand and sales for any month)	d_t

Variables	Mathematical Notations
Production Quantity	x, x_t Greater than or Equal to 0
Production period	yy_t Greater than or Equal to 0
Demand	d_t d_t Greater than or Equal to 0
Price	s

Objective Equation

Total Cost consists of cost of {Inventory, Production, Setup, backorder}

Here the back order cost is for the demand period $t = f(x) = \sum_{t=1}^{T}(dt - pt)$ where q is selling price (q,dt and pt are optimal)

Production Cost= $\sum_{t=1}^{T}(p+s)pt$ where p and s are unit production and unit set up cost respectively and pt = production quantity(optimal)

Total Holding Cost = average inventory x holding cost per unit

$$\text{Holding Cost= } \sum_{t=1}^{T}(s_{ini} + s_{fina})\frac{1}{2}h$$

$$\text{Total value of Sales= } \sum_{t=1}^{T}(s_{ini} + dt - s_{fina})q$$

Revenue = Sales value – Total cost i.e back order cost, holding cost and production cost

Z= $\sum_{t=1}^{T}(s_{ini} + dt - s_{fina})q$ --

$\sum_{t=1}^{T}\left((dt - pt)q + (s_{ini} + s_{fina})\frac{1}{2}h\right)$ --

$\sum_{t=1}^{T}\sum_{t=1}^{y}\left(\frac{s+p}{y}\right)pt$

The Objective equation is Maximize Z

The Decision variables are dt, p t, q and production period "y"

we need to include production period too which we are going to find.

2. CONCLUSION

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The advantage of using fuzzy is the incorporation of uncertainty of demand, and holding and back-ordering costs for production plan. The optimal production quantity, stock to be kept on-hand at the end of each period, backlogging amounts and the workforce policy can be estimated for different fuzziness levels [23]Fuzzy logic supports production executives to know the value of membership degree of development plan in the optimum set. In fact, for specific uncertainty, the planner could get an idea about the optimum planning costs. The fuzzy models use fuzzy numbers based on the possibility theory to represent demand and orders. Departments such as marketing, finance, operations, and purchasing directly use forecasts in their processes. Forecasting highly significant for a supply chain as it has impact over all the activies [26]. Fuzzy could be applied wherever uncertainty is there. As the future scope of this article, a full fledges mathematical model might be evolved and resolved using Fuzzy Logic after setting the various constraints by considering all types of uncertainty with respect to demand and others.

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