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Linking the Production Planning and Supply Chain using Fuzzy Logic: an Integrated Model for FMCG Products

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Abstract:- A supply chain is a system which organizes the internal and external resources of an economic enterprise. This research paper identifies the linking or integration of production planning system to the supply chain by using the fuzzy logic methodology for FMCG products. In present market the information associated with a product is fast especially in fast moving consumer goods (FMCG) industry there is more fierce competition and unable requirement. The study focus on SCM under fuzzy and production planning, which has a great significance.

Keywords:- Fuzzy Theory, Supply Chain Management (SCM), Matlab, Production Planning.

I. INTRODUCTION

A supply chain (SC) is a system of facilities and activities that functions to procure, produce,and distribute goods to the customers. Basically, supply chain management (SCM) is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs (or maximize profits) while satisfying service level requirements (Simchi-Levi , Kaminsky&Simchi-Levi, 2000). The best companies around the world are discovering a powerful new source of competitive advantage. It's called supply-chain management and it encompasses all of those integrated activities that bring product to market and create satisfied customers. The Supply Chain Management Program integrates topics from manufacturing operations, purchasing, transportation, and physical distribution into a unified program. Successful supply chain management, then, coordinates and integrates all of these activities into a seamless process.

Nowadays, market competition is fierce, especially in fast moving consumer goods industry. Specific properties of fast moving consumer goods industry lead to forecast requirement becoming more important. Firstly, in a fast moving customer goods company, the products are diversified. At the same time it means the inventory of raw materials and products carry a lot of cost. Secondly, consumers have many choices in the market; the level of customer satisfaction becomes a very important Key Performance Index (KPI) for a company. Delivering on time, correct demand and good quality are the main parameters for this KPI. It becomes an important element for the company's existence.

Supply chain managers often adapt new optimisation techniques to address these complexities and risks that also lead to new set of supply chain risks (Ostby, 2009). Also, the concern lies with the performance indicators the supply chain managers use to manage and monitor the supply chains (Mishra, 2008), resulting in using inappropriate measures to tackle the supply chain issues.

A further reason for conducting this research was to address those discouraging questions that many FMCG supply chains face, particularly in the light of the recent (year 2008/9) economic crisis (Bitran, Gurumurthi& Sam, 2006; Desai, 2008; Lofstock&Foucher, 2009; Resse, 2009; Blackstone, 2010; Bala, Prakash& Kumar, 2010):

- What is an appropriate operating framework for FMCG supply chains?
- What learning can we draw from the experiences of similar (developing) countries?

The first component of a SC system is Material flow. Previous analyses of this component have mainly been studied in fields of inventory, cost, price, and quality considerations [12]; Chandra and Fisher, 1994[13]; Lui,1999[16]). Petrovicet. al (1999)[17] examine uncertainties in SC by focusing on "decentralized control of each inventory" and "partial coordination of the inventory control". Petrovicet. Al (1998)[17] tried to identify the stock level and order quantities for inventories in a SC, with a consideration of two sources of uncertainty in a SC system: "customer demand" and "external supply of raw materials". Gerchak (2000)[14] investigates cost reduction in manufacturing processes and supply chain, by considering the uncertainties in projects. He Qi-Ming and Jewkes (2000)[15] also investigate inventory costs in a SC by presenting two algorithms for computing average total cost per product.

The second component of a SC is information flow. Companies' Information Technology (IT) strategies in their SC, role of the IT in cost reduction of SCM, and IT-SC inter-relationships are some of the main aspects of information flow in SC (Lancioni and Smith, 2000[29])

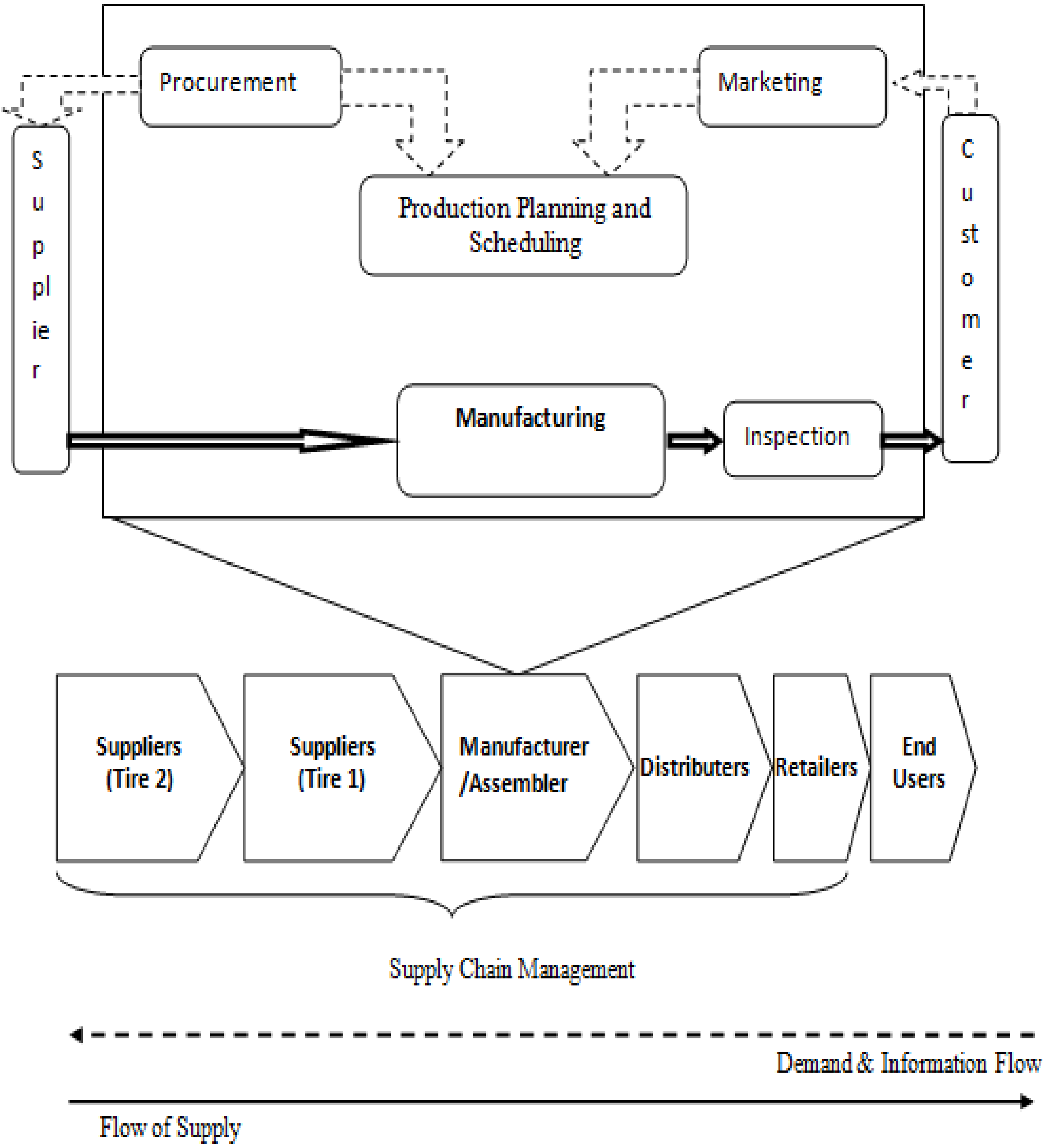


Fig. 1. Conceptual process model of SCM

Typology of FMCG supply chains

Stadtler and Kilger (eds.) (2007) characterise the FMCG industry by functional attributes applicable to each partner, entity, member or location of supply chain and also structural attributes describing the structure of relations among its entities, for example, topography and integration. This is explained in Table 1.

Table 1: Typology for FMCG supply chain (Kumar, 2009)

Functional attributes	
Attributes	**Contents**
Products procured	**Standard (raw material) and specific (packaging material)**
Sourcing type	**Multiple (raw material); Single/double (packaging materials)**
Organisation of the production process	**Flow line**
Repetition of operations	**Batch production**
Distribution structure	**Three to four stages**
Pattern of delivery	**Dynamic**
Deployment of transportation	**Unlimited routes (third stage)**
Loading restrictions	**Chilled and frozen transports**
Relation to customers	**Stable**
Availability of future demands	**Forecasted**
Products life cycle	**Several years**
Products sold	**Standard**
Portion of service operations	**Tangible goods**
Structural attributes	
Attributes	**Contents**
Network structure	**Mixture**
Degree of globalisation	**World wide**
Location of decoupling points	**Deliver-to-order**
Legal position	**Intra-organisational**
Direction of co-ordination	**Mixture**
Type of information exchanged	**Forecasts and orders**

Table 1 also confirms that FMCG supply chains use complex distribution networks. Furthermore, it was established that FMCG organisations could use many different combinations for the buying function, but that this freedom could raise concerns among supply chain executives. Another two important aspects identified are the types of products involved (including their life cycle and shelf life) and the sharing of information among the various supply chain entities.

Issues faced by FMCG supply chains

The focus of FMCG supply chains is on reducing costs (lean strategy) and improving fficiencies within the buying, distribution and selling functions (Stadtler&Kilger [eds], 2007). Also, retailers govern the selling function in this industry. Kumar and Bala (2009) and Bala et al. (2010) ighlight the issues faced by the FMCG supply chains:

- Supply chains own various production plants, including co-manufacturers and copackers, which increases complexities in the supply chain.
- Distribution is handled by specialised firms, which increases the pressure on relationships.Transport hauliers, logistics firms and warehouse service providers are typically involved.
- The retail sector is pressurising the industry to manufacture and supply at the lowest possible price and to decrease the response time. The other concern with the retail sector is the ‘dealer-owned brands’, which makes them not only the FMCG organisations’ customers, but also their competitors.

Hence, there is a need to identify performance attributes for the FMCG supply chains that could manage holistically the above risks and the supply chain performance.

Product categories in the FMCG industry

Not all FMCG organisations handle the entire range of product segments. A Deloitte report (2009) found that among the leading 250 global consumer goods firms, six of the top 20 FMCG organisations (Nestle, Procter & Gamble, Unilever, Pepsico, Kraft Foods and Coca- Cola) – based on net sales in financial year 2007 – are involved with only two product segments in common, i.e. ‘dairy’ and ‘packaged food’. In addition, these two product segments have been identified as universal product segments and the challenges faced by these product segments are independent of natural and geographic conditions (CII, 2005; Parthasarathy, 2009).

Planning and Scheduling in Supply Chains

The main objective in a supply chain or production distribution network is to produce and deliver finished products to end consumers in the most cost effective and timely manner. Of course, this overall objective forces each one of the individual stages to formulate its own objectives. Since planning and scheduling in a global supply chain requires the coordination of operations in all stages of the chain, the models and solution techniques described in the previous section have to be integrated within a single framework. Different models that represent successive stages have to exchange information and interact with one another in various ways. A continuous model for one stage may have to interact with a discrete model for the next stage. Planning and scheduling procedures in a supply chain are typically used in various phases: a first phase involves a multi-stage medium term planning process (using aggregate data), and a subsequent phase performs a short term detailed scheduling at each one of those stages separately. Typically, whenever a planning procedure has been applied and the results have become available, each facility can apply its scheduling procedures. However, scheduling procedures are usually applied more frequently than planning procedures. Each facility in every one of these stages has its own detailed scheduling issues to deal with; see Figure 1. If successive stages in a supply chain belong to the same company, then it is usually the case that these stages are incorporated into a single planning model. The medium term planning process attempts to minimize the total cost over all the stages. The costs that have to be minimized in this optimization process include production costs, storage costs, transportation costs, tardiness costs, non-delivery costs, handling costs, costs for increases in resource capacities (e.g., scheduling third shifts), and costs for increases in storage capacities. In this medium term optimization process, many input data are only considered in an aggregate form.

For example, time is often measured in weeks or months rather than days. Distinctions are usually only made between major product families, and no distinctions are made between different products within one family. A setup cost may be taken into account, but it may only be considered as a function of the product itself and not as a function of the sequence.

The results of this optimization process are daily or weekly production quantities for all product families at each location or facility as well as the amounts scheduled for transport every week between the locations. The production of the orders requires a certain amount of the capacities of the resources at the various facilities, but no detailed scheduling takes place in the medium term optimization. The output consists of the allocations of resources to the various product families, the assignment of products to the various facilities in each time period, and the inventory levels of the finished goods at the various locations. As stated before, in this phase of the optimization process, a distinction may be made between different product families, but not between different products within the same family. The model is typically formulated as a Mixed Integer Program. Variables that represent quantities that have to be produced are often continuous variables. The integer (discrete) variables are often 0-1 variables; they are, for example, needed in the formulation when a decision has to be made whether or not a particular product family will be produced at a certain facility during a given time period.

The output of the medium term planning process is an input to the detailed (short term) scheduling process. The detailed scheduling problems typically attempt to optimize each stage and each facility separately. So, in the scheduling phase of the optimization process, the process is partitioned according to:

(i) The different stages and facilities, and

(ii) The different time periods.

So, in each detailed scheduling problem the scope is considerably narrower (with regard to time as well as space), but the level of detail taken into consideration is considerably higher; see Figure. This level of detail is increased in the following dimensions:

(i) The time is measured in a smaller unit (e.g., days or hours); the process may be even time continuous,

(ii) The horizon is shorter,

(iii) The product demand is more precisely defined, and

(iv) The facility is not a single entity, but a collection of resources or machines.

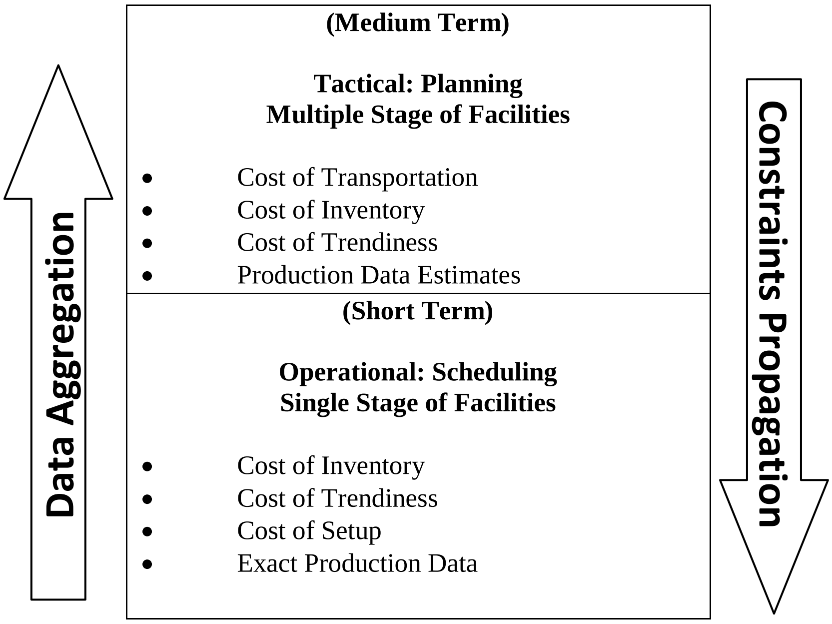


Fig.2 Data Aggregation and Constraint Propagation

The product demand now does not consist, as in the medium term planning process, of aggregate demands for entire product families. In the detailed scheduling process, the demand for each individual product within a family is taken into account. The minor setup times and setup costs in between different products from the same family are taken into account as well as the sequence dependency.

The factory is now not a single entity; each product has to undergo a number of operations on different machines. Each product has a given route and given processing requirements on the various machines. The detailed scheduling problem can be analyzed as a job shop problem and various techniques can be used, including:

(i) dispatching rules,
(ii) shifting bottleneck techniques,
(iii) local search procedures (e.g., genetic algorithms), or
(iv) integer programming techniques.

The objective takes into account the individual due dates of the orders, sequence-dependent setup times, sequence-dependent setup costs, lead times, as well as the costs of the resources. However, if two successive facilities (or stages) are tightly coupled with one another (i.e., the two facilities operate according to the jit principle), then the short term scheduling process may optimize the two facilities jointly. It actually may consider them as a single facility with the transportation in between the two facilities as another operation.

II. METHODOLOGY

A. Fuzzy Concept for Supply Chain

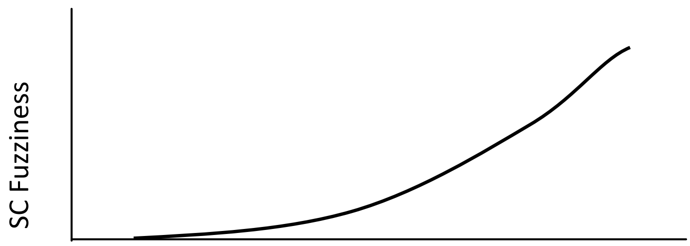
Real world production management, planning, and control problems are usually imprecise, complex, and critically depend on human activities. However managers are to interact in an intelligent way with this environment. Thus, they have to reach out for new kind of reasoning based on such situation. (Turksen and FazelZarandi, 1999)[27]. A SC system usually contains several sub-systems with unlimited relations and interfaces. Each subsystem and its interfaces with others in the context of Material Flow, Information Flow, and Suppler-Buyer relations naturally contain a lot of uncertainties. It is a challenge to model a SC with an integrated approach and to capture relations between different elements of such a chain. Petrovic et al. (1999)[19] demonstrate the uncertainties in SC systems as follows:

"· · · A real SC operates in an uncertain environment. Different sources and types of uncertainty exist along the SC. There are possible events, uncertainties in judgment, some lack of evidence, as well as a lack of certainty in available evidence. They appear in customer demand, production processes and supply sources. Each facility in the SC must deal with uncertain demand imposed by succeeding facilities and uncertain delivery of the preceding facilities in the SC · · · " (Petrovic et al., 1999)[19].

In this context, the modelling progress following the steps (Efstathiou 1990) (Figure 1):
List the input variables that affect the decision of production plan:

• Determine the fuzzy membership values associated with the input variables
• Determine the rules, which are to be fired in the rule base
• Use FIS (Fuzzy Inference System) to determine appropriate output fuzzy
• Choose method to determine the crisp value for the output variable
• Defizzifier for the result

Concerning above characteristics of SC system, applying fuzzy concepts and theory seems appropriate in SCM. In mathematical foundations of the fuzzy theory, there exists enough flexibility subject to certain axioms. In fuzzy systems, it is not difficult to merge hard and soft constraints. Moreover, the main source of difficulty for constructing reasonable production planning and scheduling stems from conflicting nature of the criteria and goals. Fuzzy approach provides tools to satisfy constraints to certain degree and to take into account the relative importance in a format easily understood by human experts (Turksen, 1992[28]).



Rate of Material and Information Flow

Fig. 3 Relation between Supply Chain Fuzziness and Rate of Material and Information Flow

Our hypothesis is that SC is a complex system with imprecise parameters and conditions and it can be analyzed and modeled by using fuzzy set theory, more appropriately. In sum, the fuzzy systems approach demonstrates many advantages in real world applications like SC systems that could be summarized as follows (Turksen and FazelZarandi, 1999)[27].

(1) Fuzzy systems are conceptually easy to understand.
(2) Fuzzy systems are flexible, and with any given system, it is easy to mange it or layer more functionality on top of it without staring again from scratch.
(3) Fuzzy systems can model most nonlinear functions of arbitrary complexity.
(4) Fuzzy systems are tolerant of imprecise data.
(5) Fuzzy systems can be built on top of the experience of experts.
(6) Fuzzy systems can be blended with conventional control techniques.
(7) Fuzzy systems are based on natural language.
(8) Fuzzy systems provide better communication between the experts and the managers.

B. Steps of the Problem Solution

When solving the evaluation problem of the manufacturing process quality using fuzzy logic, we realize three basic steps -
Fuzzification,
Fuzzy inference,
Defuzzification.

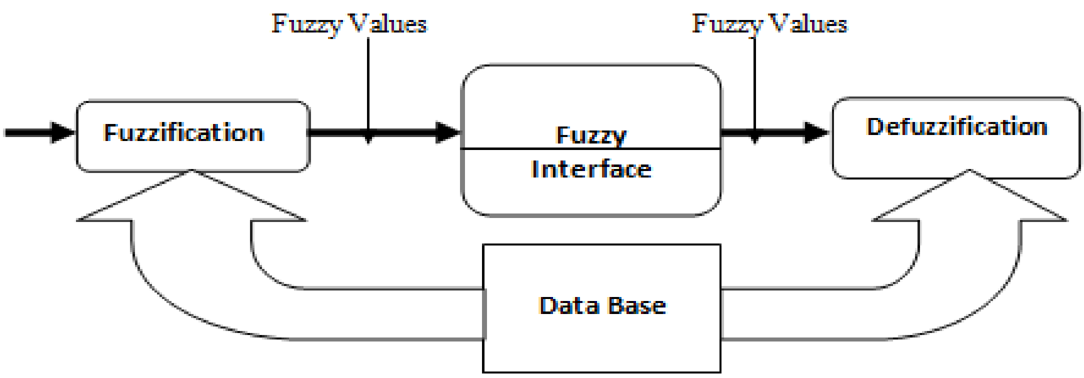


Fig. 4. Fuzzy System

Fuzzification is the assignment process of the measure values of the input variables to fuzzy sets by means of the membership functions. Thus, to individual input variables the membership functions are assigned and the weight of the rule for each if-part of the rule (truth degree of the rule) is calculated. The principal application use of fuzzy sets consists in the fact that by their help we are able to interpret the meaning of vague linguistic statements, to quantify this statement and to formalize their relations [30].

In this study, we use Matlab,Short for Matrix Laboratory MATLAB is a high level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, we can solve technical computing problems faster than with traditional programming languages. software to apply the method. Matlab is a menu driven software that allows the implementation of fuzzy constructs like membership functions and database of decision rules.

1. Fuzzification of the Input

Firstly, it is important to define which factors are effective on the result as profit of production plan as the fuzzy set's inputs:

Normally, in FMCG industry, there are four main elements have to be considered when make a mid-term production plan:

- Net requirement workload
- Available production capacity operating factor
- Inventory cost rate
- Company's special strategies

The second step is to define the inputs' possibility distribution membership functions and the weight of each one. In fuzzy set theory, trapezoidal functions were recommend as easily be applied on the obtained quantities.

In the end, the boundaries of each input levels are base on the membership functions, such as low, medium, high different levels.

Starting from the value of the gross requirement GR(P,T) and taking into account the inventory level of product P at Period T, Inv(P,T), the net requirement.

$$NR(P,T) = GR(P,T) - Inv(P,T)$$

……..(01)

The following calculations will be used as the basic operations on trapezoidal fuzzy set. Because it is easy to be apply. They were defined in Dubois and Prade (1989).

$$A_i + A_j = (a,b,c,d,h) with h = \min(h_i, h_j)$$

$$c = h\left(\frac{c_i}{h_i} + \frac{c_j}{h_j}\right), \quad d = h\left(\frac{d_i}{h_i} + \frac{d_j}{h_j}\right)$$

……..(02)

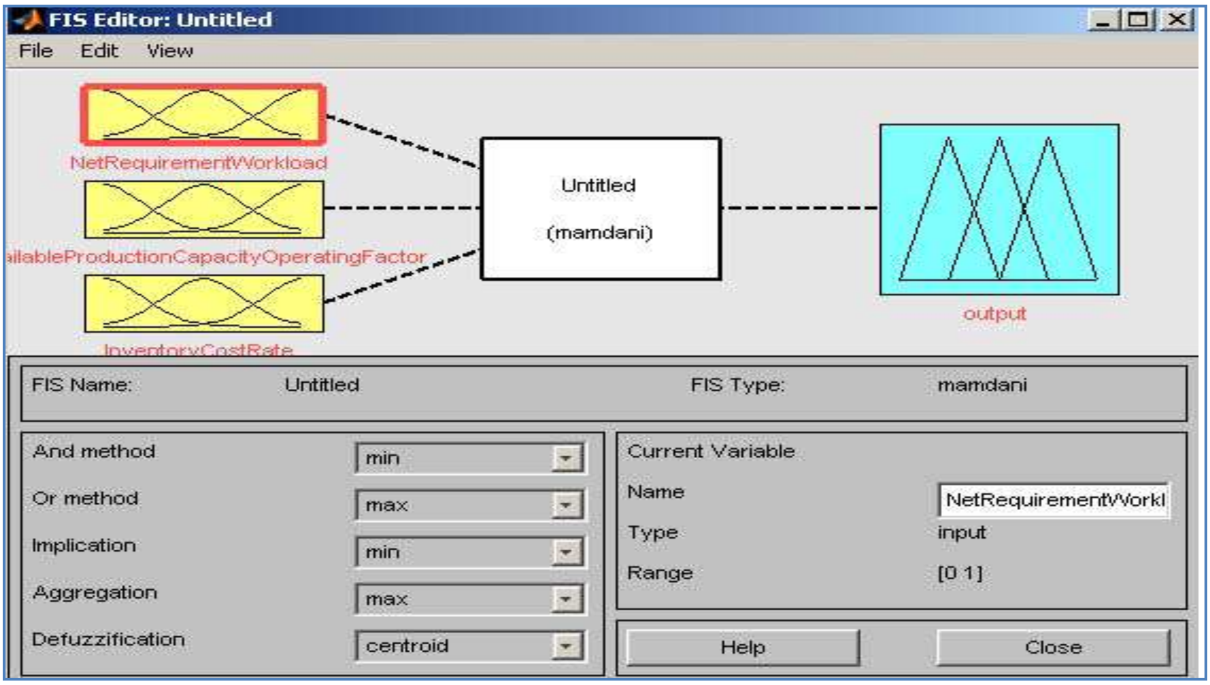
$$A_i - A_j = (a,b,c,d,h) with h = \max(h_i, h_j)$$

$$c = h\left(\frac{c_i}{c_j} + \frac{d_j}{h_j}\right), \quad d = h\left(\frac{d_i}{h_i} + \frac{d_j}{h_j}\right)$$

……(03)

An uncertain order can be represented with a union of trapezoids:

$$A = (a,b,c,d,h') \cup (0,0,0,0,h'')$$



Let's consider an illustrative example:
NR(P,T) = (120 ,160 ,10 ,20 ,0 .8) ∪ (152 , 210 ,10 ,15 ,1) ∪ (240 , 260 ,0 ,15 ,0 .6) ,
with a product P being manufactured by lots of 50 parts (Figure.3.).
A workload includes set-up time and processing time:
WL (P,T)=set-up time ⊕LR(P,T)* process time (4) Let's suppose that these products are manufactured on the same machine or production line M, with respective set-up times of 10min and respective processing time per part of 20min. The result can be seen in Figure 4.

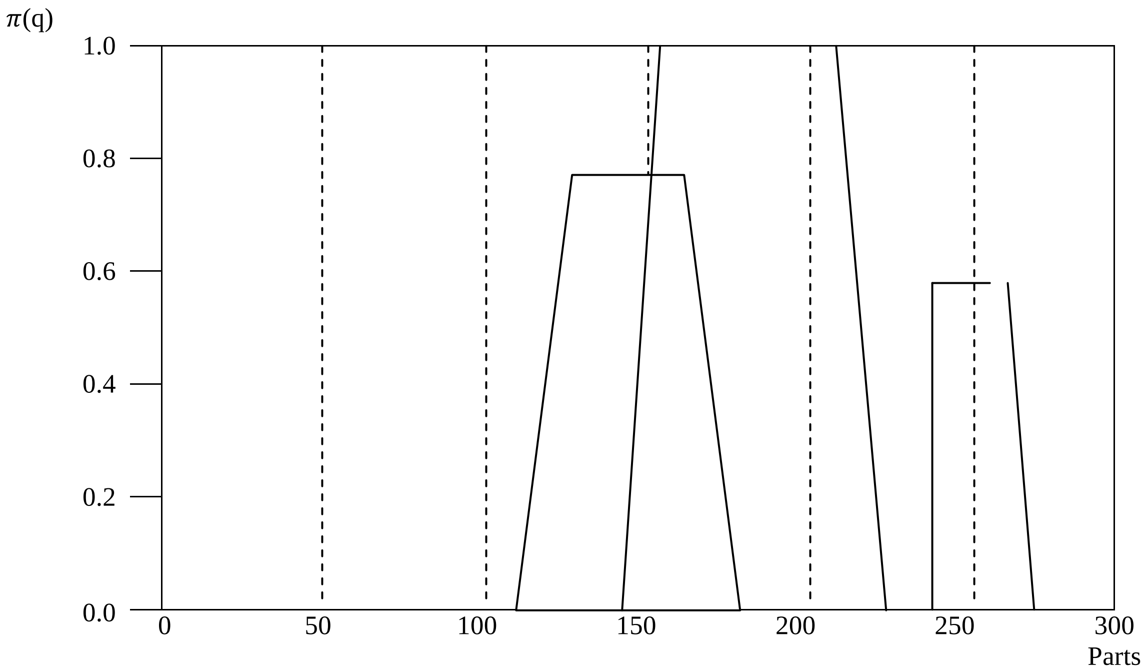


Fig.5. Determination of the number of lots

WL(M) = 10⊕(20 * (152 ,210 ,10 ,15 ,1) ∪(240 ,260 ,0 ,15 ,0 .6) ∪ (120 ,160 ,10 ,20 ,0 .8)
= (2410, 3210 ,200 ,400 ,0 .8)∪ (4810 ,5210 , 0 ,300 ,0 .6) ∪ (3050 ,4210 ,200 ,300 ,1)

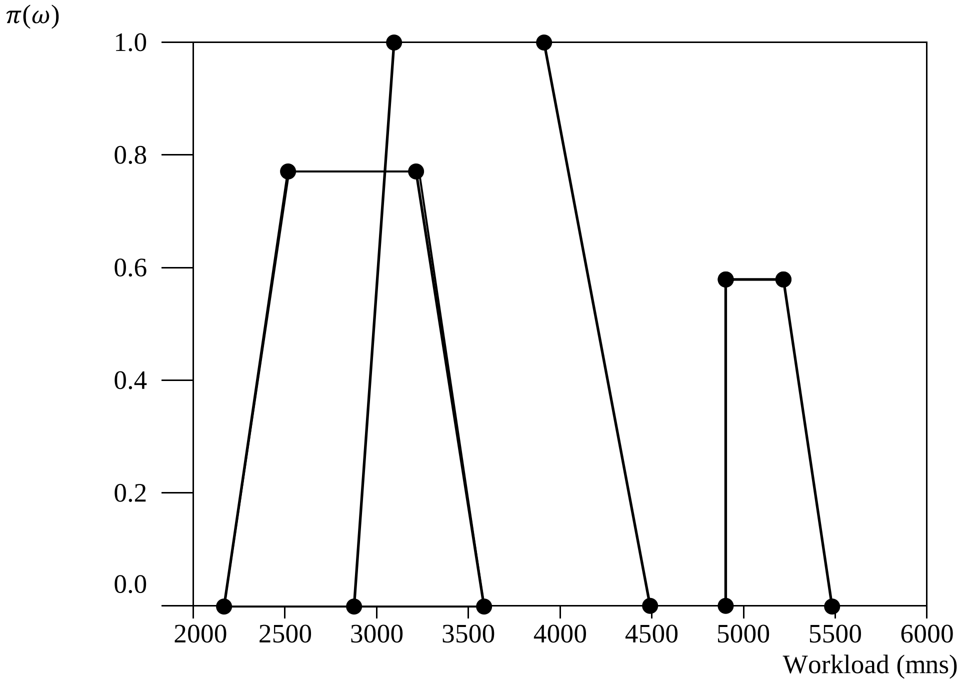


Fig. 6. Workload distribution

As a matter of fact, Figure (4) shows the possibility distribution π (w) of the workload. Let S be thesuccessive possible values of the load. We can calculate

$$\pi (R \geq S) = \sup \pi (w) \text{ for} w \geq S \tag{5}$$

At the same time, the necessity that

$$q \geq 0, N(q \geq 0) = \inf(1-\pi (q)) \text{ for } q \leq 0 \tag{6}$$

This is only the right part of the possibilitydistribution has been exploited. In order to get morecomprehensive information (Grabot et al. 2005)

From Figure 5, we can see three different levels of workload, the first level called fully necessary load, the second one is fully possible load, and the last one is maximum load. This is the first input of FIS (Fuzzy Inference System).

The second input is available production capacity operating factor. We define three different levels: machine idle; normal; overtime.

The third input is Inventory cost rate. We also can define three different levels as different prices in market: low; medium; high.

2. Fuzzy Inference

An inference step (the evaluation of a rule) consists of three steps as follow:

- Aggregation: aggregation is the calculation of the fulfillment of the whole rule, base on the fulfillments of the individual premises. This process is the computing of "IF" part, generally corresponds to the logical AND operator of the individual premise expressions.
- Implication: Implication based on the certainty factors of the premises, calculates the corresponding degree of certainty for the conclusion. This is called the degree of fulfillment. This step represents the conclusion of the logic statement "IF…Then…"
- Accumulation: The classical operators for these functions are: AND =min, OR = max, and NOT
- = additive complement. (Kahraman 2007)

Base on the three inputs in this case, we can give rules to inference system.

3. Defuzzification

Defuzzification methods can be divided into:

- Center of gravity methods – the calculation is more complicated but we consider the shape of the membership function
- Maximum methods – the calculation is rather simple but we are not considering the shape of the function when calculating.

Defuzzification in Fuzzy theory means translation of the results of the inference process of a knowledge basedSystem (linguistic variables) into values, and recommendation to take action (Rondeau et al. 1997).

III. CONCLUSIONS

The main purpose of this research is to develop the most appropriate fuzzy model for supply chain in FMCG industry. This approach is an integrated management of production planning and supply chain for FMCG products. There are lot of uncertainties in FMCG manufacturing industry. For decision makers the fuzzy set model can produce better results. The fuzzy logic for set membership values to arrange between 0 (zero) and 1 (one) and its linguistic form so, it is easy to understand.

The aim of such approach is to highlight the possibility of creating expert system that would show the more accurate results. The awareness of the importance of such assessment gives companies a competitive edge and achieving the targets. It is found that the problems with in the FMCG supply chain could be manages if the decision makes use the measuring criteria that are specific to the FMCG industry.

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