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A Fuzzy Goal Programming Approach for Collaborative Supply Chain Master Planning

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1. Introduction

Supply chain management (SCM) can be defined as the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain (SC), for the purposes of improving the long term performance of the individual companies and the SC as a whole (Mentzer et al. 2001). One important way to achieve coordination in an inter-organizational SC is the alignment of the future activities of SC members, hence the coordination of plans. It is often proposed that operations planning in supply chains can be organized in terms of a hierarchical planning system (Dudek & Stadtler 2005). This approach assumes a single decision maker with total visibility of system details who makes centralized decisions for the entire SC. However, if partners are reluctant to reveal all of their information or it is too costly to keep the information of the entire supply chain up-to-date, the hierarchical planning approach is unsuitable or infeasible (Stadtler 2005). Hence, the question arises of how to link, coordinate and optimize production planning of independent partners in the SC without intruding their decision authorities and private information (Nie et al. 2006).

Stadtler (2009) defines collaborative planning (CP) as a joint decision making process for aligning plans of individual SC members with the aim of achieving coordination in light of information asymmetry. Then, to generate a good production-distribution plan in a SC, it is necessary to resolve conflicts between several decentralised functional units, because each unit tries to locally optimise its own objectives, rather than the overall SC objectives. Because of this, in the last few years, the visions that cover a CP process such as a distributed decision-making process are getting more important (Hernández et al. 2009).

Selim et al. (2008) assert that fuzzy goal programming (FGP) approaches can effectively be used in handling the collaborative production and distribution planning problems in both centralized and decentralized SC structures. The reasons of using FGP approaches in this type of problems are explained by Selim et al. (2008) as follows:

1. Collaborative planning is the more preferred mode of operation by today's companies operated in SCs. These companies may consent to sacrifice the aspiration levels for their goals to some extent in the short run to provide the loyalty of their partners or to strengthen their partners' competitive position in the long term. In this way, they can facilitate providing a long-term collaboration with their partners and subsequently gaining a sustainable competitive advantage.

2. Due to the impreciseness of the decision makers' aspiration levels associated with each goal, conventional deterministic goal programming (GP) approach cannot fully reflect such complexity.

3. Collaborative planning problems in SCs are complex and mostly multiple objective problems, and often include incommensurable goals. Incommensurability problem in goal programming occurs when deviational variables measured in different units are summed up directly. In goal programming technique, a normalization constant is needed to overcome this difficulty. However, in FGP, incommensurable goals can be treated in a reasonable and practical way.

Therefore, it may be appropriate to use FGP approaches in production and distribution planning problems existing in real-world supply chains.

We arrange the rest of this work as follows. Section 2 presents a literature review about integrated production and distribution planning models, as well as collaborative. Section 3 describes the FGP approaches to deal with supply chain planning problem in centralized and decentralized SC structures. Section 4 presents a multi-objective, multi-product and multi-period model for the master planning problem in a ceramic tile SC. Then, in Section 5, the solution methodology and the FGP approaches for different SC structures (i.e. centralized and decentralized) are described. Section 6 validates and evaluates our proposal by using an example based on a real-world problem. Finally, Section 7 provides conclusions and directions for further research.

2. Literature review

The considered ceramic supply chain master planning (CSCMP) problem deals with a medium term production and distribution planning problem in a four-echelon ceramic tile supply chain involving one manufacturer, multiple warehouses, multiple logistic centres and multiple shops. The integration of production and distribution planning decisions is crucial to ensure the overall performance of the SC, and has attracted attention both from practitioners and academics for many years (Vidal & Goetschalckx 1997; Erengüç et al. 1999; Bilgen & I. Ozkarahan 2004; Mula et al. 2010). According to Liang & Cheng (2009), in production and distribution planning problems, the decision maker (DM) attempts to: (1) set overall production levels for each product category for each source (manufacturer) to meet fluctuating or uncertain demand for various destinations (distributors) over the intermediate planning horizon and (2) make suitable strategies regarding regular and overtime production, subcontracting, inventory, and distribution levels, and thus determining appropriate resources to be used.

On supply chain planning, most prior studies have concentrated on formulating a sophisticated supply chain planning model and devising an efficient algorithm to solve it under a centralized supply chain environment where all supply chain participants are grouped as one organization or company and all functions of a supply chain are fully integrated by an independent planning department or supervisor (Jung et al. 2008). According to Mula et al. (2010), the vast majority of works that deal with the production and distribution integration opt for the linear-programming based approach, particulary mixed integer linear programming models. Chen & Wang (1997) proposed a linear programming model to solve integrated supply, production and distribution planning in a supply chain of the steel sector. McDonald & Karimi (1997) presented a mixed deterministic integer linear programming model to solve a production and transport planning problem in the chemical

industry in a multi-plant, multi-product and multi-period environment. Timpe & Kallrath (2000) and Kallrath (2002) presented a couple of models for production, distribution and sales planning with different time scales for business and production aspects. Dhaenens-Flipo & Finke (2001) modelled a multi-facility, multi-item, multi-period production and distribution model in the form of a network flow. Park (2005) suggested an integrated transport and production planning model in a multi-site, multi-retailer, multi-product and multi-period environment. Likewise, the author also presented a production planning submodel whose outputs act as the input in another submodel with a transport planning purpose and an overall objective of maximizing overall profits with the same technique. Ekş{}ioğ{}lu et al. (2006) showed an integrated transport and production planning model in a multi-period, multi-site, monoproduct environment as a flow or graph network to which the authors added a mixed integer linear programming formulation. Later, Ekşioğlu et al. (2007) extended this model to become a multi-product model solved by Lagrangian decomposition. Ouhimmou et al. (2008) developed a mixed integer linear programming (MIP) model for tactical planning in a furniture supply chain related to production and logistics decisions. Fahimnia et al. (2009) proposed a model for the optimization of the complex two-echelon supply networks based on the integration of aggregate production plan and distribution plan.

According to Dudek & Stadtler (2005) the relevant literature on linking and coordinating the planning process in a decentralized manner, distinguishes three main approaches: coordination by contracts, multi-agent systems and mathematical programming models. The largest number of references reviewed in Stadtler (2009) employs mathematical decomposition (exact mathematical decomposition, heuristic mathematic decomposition and meta-heuristics). Originally developed for solving large-scale linear programming, mathematical decomposition methods seem to be an attractive alternative for solving distributed decision-making problems. Barbarosoglu & Özgür (1999) developed a model which is solved by Lagrangian and heuristic relaxation techniques to become a decentralized two-stage model: one for production planning and another for transport planning. It generates a final plan level by level, where one stage determines both its own plan and supply requirements and passes the requirements to the next stage. Luh et al. (2003) presented a framework combining mathematical optimization and the contract communication protocol for make-to-order supply network coordination based in this relaxation method. Nie et al. (2006) developed a collaborative planning framework combining the Lagrangian relaxation method and genetic algorithms to coordinate and optimize the production planning of the independent partners linked by material flows in multiple tier supply chains. Moreover, Walther et al. (2008) applied a relaxation approach for distributed planning in a product recovery network.

However, these examples require the presence of a central coordinator with a complete control over the entire supply chain, otherwise there is no guarantee for convergence of the final solution without extra modification procedure or acceptance functions because of the duality gap or the oscillation of mathematical decomposition methods (Jung et al. 2008). In this context, FGP can be a valid alternative to the previous drawbacks.

Fuzzy mathematical programming, especially the fuzzy goal programming (FGP) method, has widely been applied for solving various multi-objective supply chain planning problems. Among them, Kumar et al. (2004) and Lee et al. (2009) presented FGP approaches for supplier selection problems with multiple objectives. Liang (2006) presented a FGP approach for solving integrated production and distribution planning problems with fuzzy

multiple goals in uncertain environments. The proposed model aims to simultaneously minimize the total distribution and production costs, the total number of rejected items, and the total delivery time. Torabi & Hassini (2009) proposed a multi-objective, multi-site production planning FGP model integrating procurement and distribution plans in a multi-echelon automotive supply chain network.

3. Modelling approaches for centralized and decentralized planning in SC structures

3.1 Planning in centralized supply chain structure

According to their basic structures, SCs can be categorized as centralized and decentralized. A supply chain is called centralized if a single dominant firm has all the information and tries to, in the short run, simply optimize its own operational decisions regardless of the impact of such decisions on the other stages of the chain (Erengüç et al. 1999). According to Selim et al. (2008), FGP approaches can be used in handling collaborative master planning problems in both centralized and decentralized SC structures. In order to handle the problem in centralized SC, Selim et al. (2008) propose to use Tiwari et al. (1987) weighted additive approach defined as follows:

$$
\begin{aligned}
& Maximize \sum_{k} w_k \mu_k (x) \\
& subject\ to\ \mu_k \in [0,1] \quad \forall k \\
& \qquad\qquad x \geq 0
\end{aligned}
\tag{1}
$$

In this approach, w_k and μ_k denotes the weight and the satisfaction degree of the kth goal respectively. Therefore, the weighted additive approach allows the dominant partner in the SC to assign different weights to the individual goals in the simple additive fuzzy achievement function to reflect their relative importance levels.

3.2 Planning in decentralized supply chain structure

A SC is called decentralized when various decisions are made in different companies that try to optimize their own objectives. Selim et al. (2008) state that the methods that take account of min operator are suitable in modelling the collaborative planning problems in decentralized SC structures. Among these methods, Selim et al. (2008) propose to use Werners (1988) fuzzy and operator to address the SC collaborative planning problems in decentralized SC structures. By adopting min operator into Werners' approach the following linear programming problem can be obtained:

$$
\begin{aligned}
& Maximize\ \gamma \lambda + (1 - \gamma)(1/K) \sum_{k} \lambda_k \\
& subject\ to\ \mu_k (x) \geq \lambda + \lambda_k \quad \forall k \in K, \forall x \in X \\
& \qquad\qquad \lambda, \lambda_k, \gamma \in [0,1]
\end{aligned}
\tag{2}
$$

where K is the total number of objectives, μ_k is the membership function of goal k, and γ is the coefficient of compensation defined within the interval [0,1]. In this approach, the coefficient of compensation can be treated as the degree of willingness of the SC partners to sacrifice the aspiration levels for their goals to some extent in the short run to provide the loyalty of their partners and/or to strengthen their competitive position in the long run.

To explore the viability of the proposed fuzzy modelling approaches for the collaborative SC planning in centralized and decentralized SC structures, we consider a supply chain master planning problem related to a ceramic tile supply chain in the next section.

4. Model formulation

We adopt the ceramic supply chain master planning problem presented in Alemany et al. (2010). Figure 1 shows the structure of a typical SC of the ceramic sector. The authors describe the peculiarities related to these SCs and consider several assumptions. First, the flow of parts, components, raw materials (RMs) and finished goods (FGs) that might circulate between the nodes is known beforehand. The existence of several production plants situated in various geographical locations is also assumed. These production plants are supplied with various RMs provided by different suppliers with a limited supply capacity.
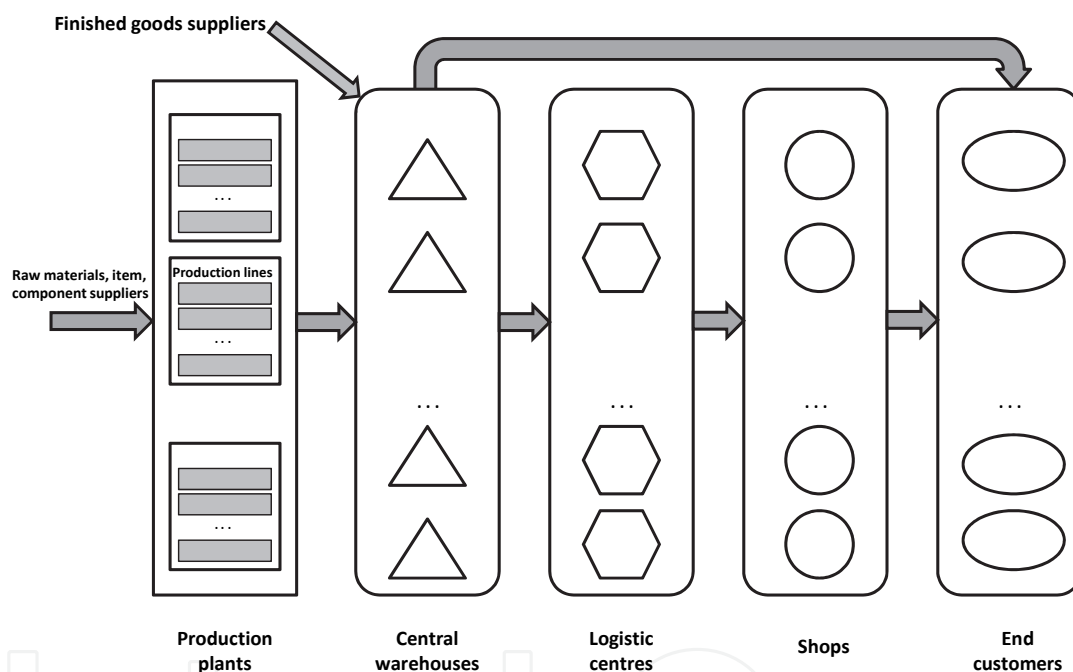

Fig. 1. Ceramic tile SC considered in Alemany et al. (2010)

In the SC under study, each production plant has one or several parallel production lines, which process different FGs, with a limited capacity. Moreover, there are FGs with high added values that are manufactured only in production plants; others may be partly subcontracted, while some may be totally subcontracted to external suppliers. FGs are grouped into product families to minimize setup times and costs. A product family is defined as a group of FGs with identical physical characteristics and whose preparation on product lines is similar. Given the important setup times between product families on production lines, minimum run lengths for product families are specified. Item setups among the products belonging to the same product family also exist. Because of technological factors involved in the production process itself, each product should be produced in an equal or greater amount than the minimum lot size defined, when it's manufactured on a specific line.

The distribution of FGs from production plants to end customers is carried out in various stages by different types of distribution centres, such as central warehouses, logistic centres and shops. Neither manufactured nor subcontracted FGs can be stored in manufacturing plants. They are sent to the first distribution level which is composed of several central warehouses with a limited storage capacity. The demand of end customers and logistics centres is covered by the outgoing FGs from central warehouses. Besides, logistics centres only supply FGs to shops that have been previously assigned to them. Finally, shops only attend end costumers' demand. Although a maximum service level is pursued in this SC, limited backorders are permitted in both central warehouses and shops.

4.1 Nomenclature

The nomenclature defines the indices, sets of indices, parameters and decision variables (Table 1).

Indices			
c	RMs, items, and components (*c*=1…*C*)	*q*	Logistic centres (q=1…*Q*)
i	FGs (*i*=1…*I*)	*w*	Shops (*w*=1…*W*)
f	Product families (f=1…*F*)	*r*	Suppliers of RMs, items, and components (r=1…*R*)
l	Production lines (*l*=1…*L*)		
p	Production plants (p=1…*P)*	*b*	Suppliers of finished products (b=1…*B)*
a	Warehouses (*a*=1…*A*)	*t*	Periods of time (*t*=1…*T*)
Sets of Indices			
Il(l)	Set of FGs that can be manufactured on manufacturing line *l*	*Lp(p)*	Set of manufacturing lines that belong to production plant *p*
Fl(l)	Set of product families that can be manufactured on manufacturing line *l*	*Pa(a)*	Set of production plants that can send FGs to warehouse *a*
If(f)	Set of FGs that belong to product family *f*	*Aq(q)*	Set of warehouses that can supply logistics centre *q*
Ip(p)	Set of FGs that can be produced in production plant *p*	*Rc(c)*	Set of suppliers that can supply RM *c*
Ia(a)	Set of FGs that can be stored in warehouse *a*	*Rp(p)*	Set of suppliers of RMs that can supply production plant *p*
Ic(c)	Set of FGs of that RM *c* form part	*Cr(r)*	Set of RMs that can be supplied by supplier *r*
PFNS	Set of FGs that cannot be subcontracted	*Qa(a)*	Set of logistics centres that can be supplied by warehouse *a*
PFSP	Set of FGs that can be subcontracted either partially or completely	*Wq(q)*	Set of shops that can be supplied by logistics centres *q*

$PFST$	Set of FGs that are compulsorily subcontracted completely	$Qw(w)$	Set of logistics centres capable of supplying shop w
$Iq(q)$	Set of FGs that can be sent to logistics centre q	$Bi(i)$	Set of suppliers of FGs i to which the FG may be subcontracted
$Iw(w)$	Set of FGs that can be sent to shop w	$Ba(a)$	Set of suppliers of FGs that can supply warehouse a
$Lf(f)$	Set of manufacturing lines that may produce product family f	$Ab(b)$	Set of warehouses that can be supplied by the supplier b of FGs

Model Parameters			
ca_{crt}	Capacity (units) of supplying RM c of supplier r in period t	$M1, M2$	Very large integers
$costtp_{crp}$	Cost of purchase and transport of one unit of RM c from supplier r to production plant p	$capal_a$	Storage capacity (m²) in warehouse a
caf_{lpt}	Production capacity available (time) of production line l at plant p during time period t	$costtcl_{iaq}$	Cost of transporting one m² of FG i from warehouse a to logistics centre q
cm_i	Loss ratio of FG i. It represents the percentage of faulty m² obtained due to the intrinsic characteristics of the production process in the ceramics sector.	$costina_{ia}$	Cost of making an inventory of one m² of FG i in the warehouse during a time period
cq_i	First quality coefficient of FG i. It represents the percentage of m² that can be sold as first quality.	$costdifa_{ia}$	Cost of backordering one m² of demand of FG i in warehouse a in a time period
$costta_{ipa}$	Cost of transporting one m² of FG i from production plant p to warehouse a	pa_{ia}	Sales value of one m² of FG i in warehouse a
$costp_{ilp}$	Cost of producing one m² of FG i on production line l of production plant p	da_{iat}	External demand (m²) of FG i at the warehouse a in period t
$costsetupf_{flp}$	Setup costs for product family f on production line l of production plant p	ssa_{ia}	Safety stock (m²) of FG i at warehouse a
$costsetup_{ilp}$	Setup costs for FG i on production line l of production plant p	$\alpha 1$	Maximum backorder quantity permitted in a period in warehouses expressed as a percentage of the demand of that period
$tfab_{ilp}$	Time to process one m² of FG i on production line l of production plant p	$costsc_{ib}$	Cost of subcontracting one m² of FG i to FG supplier b

$tsetupf_{flp}$	Setup time for product family f on production line l of production plant p	$minsc_{ib}$	Minimum amount (m²) of FG i to be subcontracted to FG supplier b
$tsetupi_{ilp}$	Setup time for article i on production line l of production plant p	$costttk_{iqw}$	Cost to transport one m² of FG i from logistics centre q to shop w
lmi_{ilp}	Minimum lot size (m²) of FG i on production line l of production plant p	$costdiftk_{iw}$	Cost to backorder one m² of the demand of FG i in a time period at shop w
tmf_{flp}	Minimum run length (expressed as multiples of the time period used) of product family f on production line l of production plant p	pw_{iw}	Sales price of one m² of FG i in shop w
v_{ic}	Units of RM c needed to produce one m² of FG i	dtk_{iwt}	External demand (m²) of FG i in shop w during the time period t
ssc_{cp}	Safety stock of RM c in production plant p	$\alpha2$	Maximum backorder quantity permitted in a period in shops expressed as a percentage of the demand of that period
		$casc_{ibt}$	Supply capacity (m²) of FG i of supplier b in time period t

Decision Variables			
CTP_{crpt}	Amount of RM c to be purchased and transported from supplier r to production plant p in time period t	INA_{iat}	Inventory (m²) of FG i in warehouse a in time period t
INC_{cpt}	Inventory of the RM c at plant p at the end of time period t	CSC_{ibat}	Amount (m²) of FG i subcontracted to supplier b for warehouse a in time period t
MPF_{flpt}	Amount (m²) of product family f manufactured on production line l of production plant p in time period t	S_{ibt}	Binary variable with a value of 1 if FG i is subcontracted to supplier b in time period t
MP_{ilpt}	Amount (m²) of FG i manufactured on production line l of production plant p in time period t	VEA_{iat}	Amount (m²) of FG i sold in warehouse a during time period t
X_{ilpt}	Binary variable with a value of 1 if FG i is manufactured on production line l of production plant p in time period t, and with a value of 0 otherwise	$DIFA_{iat}$	Backorder quantity (m²) of FG i in warehouse a during time period t

Y_{flpt}	Binary variable with a value of 1 if product family f is manufactured on production line l of production plant p in time period t, and with a value 0 otherwise	$CTCL_{iaqt}$	Amount (m²) of FG i transported from warehouse a to logistics centre q in time period t
ZI_{ilpt}	Binary variable with a value of 1 if a setup takes place of product i on production line l of production plant p in time period t, and with a value of 0 otherwise	$CTTK_{iqwt}$	Amount (m²) of FG i transported from logistics centre q to shop w in time period t
ZF_{flpt}	Binary variable with a value of 1 if a setup takes place of product family f on production line l of production plant p in time period t, and with a value of 0 otherwise	$VETK_{iwt}$	Amount (m²) of FG i sold in shop w during time period t
CTA_{ipat}	Amount (m²) of FG i to be transported from production plant p to warehouse a in time period t	$DIFTK_{iwt}$	Backorder quantity (m²) of FG i in shop w during time period t

Table 1. Nomenclature.

The formulation of the model is as follows.

4.2 Objective functions

Formulations of the objective functions of the ceramic supply chain master planning model are presented in the following.

• Manufacturer's cost function (COSTM)

COSTM = Total procurement cost + Total manufacturing cost + Total transportation to warehouses cost

$$
Minimize \left\{
\begin{array}{l}
\sum_t \sum_p \sum_{r \in Rp(p)} \sum_{c \in Cr(r)} \cos ttp_{crp} * CTP_{crpt} + \sum_t \sum_p \sum_{l \in Lp(p)} \sum_{i \in Il(l)} \cos tp_{ilp} * MP_{ilpt} \\
+ \sum_t \sum_p \sum_{l \in Lp(p)} \sum_{f \in Fl(l)} \cos tsetupf_{flp} * ZF_{flpt} + \sum_t \sum_p \sum_{l \in Lp(p)} \sum_{i \in Il(l)} \cos tsetupi_{ilp} * ZI_{ilpt} \\
+ \sum_t \sum_a \sum_{p \in Pa(a)} \sum_{i \in Ip(p)} \cos tta_{ipa} * CTA_{ipat}
\end{array}
\right\} \quad (3)
$$

• Profit function of warehouse a (WaPROFIT)

WaPROFIT = Sales revenue – Total inventory cost – Total subcontracting cost – Total transportation to logistic centres cost – Total backorder cost

$$
Maximize \left\{
\begin{array}{l}
\sum_t \sum_i pa_{ia} * VEA_{iat} - \sum_t \sum_{i \in Ia(a)} \cos tina_{ia} * INA_{iat} - \sum_t \sum_i \sum_{b \in Bi(i)} \cos tsc_{ib} * CSC_{ibat} \\
- \sum_t \sum_{q \in Qa(a)} \sum_{i \in Iq(q)} \cos ttcl_{iaq} * CTCL_{iaqt} - \sum_t \sum_{i \in Ia(a)} DIFA_{iat}
\end{array}
\right\} \quad (4)
$$

• Cost function of logistic centre q (LCqCOST)

LCqCOST = Total transportation to shops cost

$$Minimize \left\{ \sum_t \sum_{w \in Wq(q)} \sum_{i \in Iw(w)} \cos tttk_{iqw} * CTTK_{iqwt} \right\} \qquad (5)$$

- Profit function of shop *w* (SwPROFIT)

SwPROFIT = Sales revenue - Total backorder cost

$$Maximize \left\{ \sum_t \sum_i pw_{iw} * VETK_{iwt} - \sum_t \sum_{i \in Iw(w)} DIFTK_{iwt} \right\} \qquad (6)$$

4.3 Constraints

The constraints originally proposed by Alemany et al. (2010) are briefly reviewed as follows:
Constraint (7) is the inventory balance equation for RMs.

$$INC_{cpt} = INC_{cpt-1} + \sum_{r \in Rc(c)} CTP_{crpt} - \sum_{i \in Ic(c)} (v_{ic} * \sum_{l \in Lp(p)} MP_{ilpt}) \qquad \forall c,p,t \qquad (7)$$

Constraint (8) establishes safety stocks for RMs.

$$INC_{cpt} \geq ssc_{cp} \qquad \forall c,p,t \qquad (8)$$

Constraint (9) defines the available capacity of supply for RMs suppliers.

$$\sum_p CTP_{crpt} \leq ca_{crt} \qquad \forall c,r \in Rc(c),t \qquad (9)$$

Constraint (10) establishes the available capacity for production lines.

$$\sum_{f \in Fl(l)} tsetupf_{flp} * ZF_{flpt} + \sum_{i \in Il(l)} \left(tsetupi_{ilp} * ZI_{ilpt} + tfab_{ilp} * MP_{ilpt} \right) \leq caf_{lpt} \qquad \forall p,l \in Lp(p),t \qquad (10)$$

Constraint (11) is related to the product families to be produced in each line.

$$MPF_{flpt} = \sum_{i \in If(f)} MP_{ilpt} \qquad \forall p,l \in Lp(p), f \in Fl(l),t \qquad (11)$$

Constraint (12) establishes minimum lot sizes for FGs' production.

$$MP_{ilpt} \geq lmi_{ilp} * X_{ilpt} \qquad \forall p,l \in Lp(p),i \in Il(l),t \qquad (12)$$

Constraints (13) and (14) allocate products and product families to each line. Parameters M1
and M2 are large enough integer numbers.

$$MP_{ilpt} \leq M1 * X_{ilpt} \qquad \forall p,l \in Lp(p),i \in Il(l),t \qquad (13)$$

$$MPF_{flpt} \leq M2 * Y_{flpt} \qquad \forall p,l \in Lp(p), f \in Fl(l),t \qquad (14)$$

Constraints (15)-(18) guarantee the control of the setup of FGs and product families.

$$ZI_{ilpt} \geq X_{ilpt} - X_{ilpt-1} \qquad \forall p,l \in Lp(p), i \in Il(l), t \tag{15}$$

$$\sum_i ZI_{ilpt} \geq \sum_i X_{ilpt} - 1 \qquad \forall p,l \in Lp(p), t \tag{16}$$

$$ZF_{flpt} \geq Y_{flpt} - Y_{flpt-1} \qquad \forall p,l \in Lp(p), f \in Fl(l), t \tag{17}$$

$$\sum_f ZF_{flpt} \geq \sum_f Y_{flpt} - 1 \qquad \forall p,l \in Lp(p), t \tag{18}$$

Constraint (19) ensures the accomplishment of the family run lenght

$$\sum_{t=t'}^{t'+tmf_{flp}-1} ZF_{flpt} \leq 1 \qquad \forall p,l \in Lp(p), f \in Fl(l), t' = 1,..,T - tmf_{flp} + 1 \tag{19}$$

Constraint (20) ensures that only first quality FGs are transported to the central warehouses.

$$\sum_{l \in Lp(p)} (1 - cm_i) * cq_i * MP_{ilpt} = \sum_{a \in Ap(p)} CTA_{ipat} \qquad \forall p,i \in Ip(p), t \tag{20}$$

Constraints (21)-(24) are related to subcontracting decisions. These constraints also ensure that the amount of FGs subcontracted is transported to warehouses.

$$\sum_{a \in Ab(b)} CSC_{ibat} \geq \min sc_{ib} * S_{ibt} \qquad \forall i \in PFSP, b \in Bi(i), t \tag{21}$$

$$\sum_{a \in Ab(b)} CSC_{ibat} \geq \min sc_{ib} * S_{ibt} \qquad \forall i \in PFST, b \in Bi(i), t \tag{22}$$

$$\sum_{a \in Ab(b)} CSC_{ibat} \leq casc_{ibt} * S_{ibt} \qquad \forall i \in PFSP, b \in Bi(i), t \tag{23}$$

$$\sum_{a \in Ab(b)} CSC_{ibat} \leq casc_{ibt} * S_{ibt} \qquad \forall i \in PFST, b \in Bi(i), t \tag{24}$$

Constraint (25) establishes safety stocks for FGs.

$$INA_{iat} \geq ssa_{ia} \qquad \forall a,i \in Ia(a), t \tag{25}$$

Constraint (26) fixes the capacity of the warehouses.

$$\sum_{i \in Ia(a)} INA_{iat} \leq capal_a \qquad \forall a, t \tag{26}$$

Constraints (27)-(28) are inventory balance equations for FGs in warehouses.

$$INA_{iat} = INA_{iat-1} + \sum_{p \in Pa(a)} CTA_{ipat} - VEA_{iat} - \sum_{q \in Qa(a)} CTCL_{iaqt} \qquad \forall i \in PFNS, a, t \tag{27}$$

$$INA_{iat} = INA_{iat-1} + \sum_{p \in Pa(a)} CTA_{ipat} + \sum_{b \in Ba(a) \wedge b \in Bi(i)} CSC_{ibat} - VEA_{iat} - \sum_{q \in Qa(a)} CTCL_{iaqt}$$

$$\forall i \in PFSP, a, t \tag{28}$$

Constraint (29) is similar to (27)-(28) but also ensures the subcontracted FGs only comes from FG suppliers.

$$INA_{iat} = INA_{iat-1} + \sum_{b \in Ba(a) \wedge b \in Bi(i)} CSC_{ibat} - VEA_{iat} - \sum_{q \in Qa(a)} CTCL_{iaqt} \qquad \forall i \in PFST, a, t \tag{29}$$

Backorder quantities in warehouses are calculated using Constraint (30).

$$VEA_{iat} + DIFA_{iat} - DIFA_{iat-1} = da_{iat} \qquad \forall a, i \in Ia(a), t \tag{30}$$

Constraint (31) limits the backorder quantities in warehouses.

$$DIFA_{iat} \leq \alpha 1 * da_{iat} \qquad \forall a, i \in Ia(a), t \tag{31}$$

Constraints (32) and (33) are the inflows and outflows of FGs through each logistic centre and shop, respectively.

$$\sum_{a \in Aq(q)} CTCL_{iaqt} = \sum_{w \in Wq(q)} CTTK_{iqwt} \qquad \forall q, i \in Iq(q), t \tag{32}$$

$$CTTK_{iqwt} = VETK_{iwt} \qquad \forall w, q \in Qw(w), i \in Iw(w), t \tag{33}$$

Constraint (34) determines backorder quantities in shops.

$$VETK_{iwt} + DIFTK_{iwt} - DIFTK_{iwt-1} = dtk_{iwt} \qquad \forall w, i \in Iw(w), t \tag{34}$$

Constraint (35) limits the backorder quantities in shops.

$$DIFTK_{iwt} \leq \alpha 2 * dtk_{iwt} \quad \forall w, i \in Iw(w), t \tag{35}$$

The model also contemplates non-negativity constraints and the definition of binary variables (36).

$$MPF_{flpt}, MP_{ilpt}, CTP_{crpt}, CTA_{ipat}, INA_{iat}, INC_{cpt}, CTCL_{iaqt}, CTTK_{iqwt}, VEA_{iat}, DIFA_{iat},$$

$$VETK_{iwt}, DIFTK_{iwt}, CSC_{ibat} \geq 0 \text{ and, } X_{ilpt}, Y_{flpt}, ZF_{flpt}, ZI_{ilpt}, S_{ibt} \in \{0,1\} \tag{36}$$

$$\forall f \in F, \forall i \in I, \forall c \in C, \forall l \in L, \forall p \in P, \forall a \in A, \forall q \in Q, \forall w \in W, \forall r \in R, \forall b \in B, \forall t \in T$$

Finally, some decision variables can be defined as integers, but it could change depending on the real-world problem where the model is applied.

5. Solution methodology

In order to reach a preferred solution for the ceramic master planning problem in centralized and decentralized SC structures the Tiwari et al. (1987) and Werners (1988)

approaches are adopted to transform the multi-objective FGP model to a mixed integer linear programming (MILP) one.

5.1 Defining the membership functions

There are many possible forms for a membership function to represent the fuzzy objective functions: linear, exponential, hyperbolic, hyperbolic inverse, piece-wise linear, etc. (see Peidro & Vasant (2009) for a comparison of the main types of membership functions). Among the various types of membership functions, the most feasible for constructing a membership function for solving fuzzy mathematical programming problems is the linear form, although there may be preferences for other patterns with some applications (Zimmermann 1975; Zimmermann 1978; Tanaka et al. 1984). Moreover, the main advantage of the linear membership functions is that they generate equivalent, efficient and computationally linear models.

We formulate the corresponding non increasing continuous linear membership functions for objective function as follows (Bellman & Zadeh 1970):

$$\mu_m = \begin{cases} 1 & z_m < z_m^l \\ \dfrac{z_m^u - z_m}{z_m^u - z_m^l} & z_m^l < z_m < z_m^u \\ 0 & z_m > z_m^u \end{cases} \tag{37}$$

$$\mu_M = \begin{cases} 1 & z_M > z_M^u \\ \dfrac{z_M - z_M^l}{z_M^u - z_M^l} & z_M^l < z_M < z_M^u \\ 0 & z_M < z_M^l \end{cases} \tag{38}$$

where μ_m is the membership function of a minimization objetive z_m and μ_M is the membership function of a maximization objetive z_M. Moreover, z_m^l, z_M^l and z_m^u, z_M^u are the lower and upper bounds of the objective functions. We can determine each membership function by asking the decision maker to specify the fuzzy objective value interval (37)-(38). Besides, we can obtain these bounds from the optimisation values of each objective function.

5.2 Transforming the multi-objective FGP model into an MILP model for centralized SC structures

According to Selim et al. (2008), the Tiwari et al. (1987) weighted additive approach can be used to handle the collaborative ceramic master planning problem in a centralized SC structure. By adopting this approach, the problem can be formulated as follows:

$$\left. \begin{aligned} Maximize \quad & w_1\mu_{COSTM} + w_2\sum_a \mu_{W_a PROFIT} + w_3\sum_q \mu_{LC_q COST} + w_4\sum_w \mu_{S_w PROFIT} \\ subject\ to \quad & \mu_{COSTM}, \mu_{W_a PROFIT}, \mu_{LC_q COST}, \mu_{S_w PROFIT} \in [0,1] \end{aligned} \right\} \tag{39}$$

This model also considers Constraints (7) to (36).

w_1, w_2, w_3 and w_4 denotes the weights of manufacturer's, warehouses', logistic centres' and shops' objectives, respectively.

5.3 Transforming the multi-objective FGP model into an MILP model for decentralized SC structures

To deal with the collaborative ceramic master planning problem in a decentralized SC, according to Selim et al. (2008), the Werners (1988) approach can be adopted. By using the Werners' fuzzy and operator, the problem under study can be formulated as follows:

$$
\left.
\begin{aligned}
\textit{Maximize} \quad & \gamma\lambda + (1-\gamma)\left(\frac{1}{1+A+Q+W}\right)\left[\lambda_1 + \sum_a \lambda_a + \sum_q \lambda_q + \sum_w \lambda_w\right] \\
\textit{subject to} \quad & \mu_{COSTM} \geq \lambda + \lambda_1 \\
& \mu_{W_aPROFIT} \geq \lambda + \lambda_a \qquad \forall a \\
& \mu_{LC_qCOST} \geq \lambda + \lambda_q \qquad \forall q \\
& \mu_{S_wPROFIT} \geq \lambda + \lambda_w \qquad \forall w \\
& \mu_{COSTM}, \mu_{W_aPROFIT}, \mu_{LC_qCOST}, \mu_{S_wPROFIT}, \lambda, \lambda_1, \lambda_a, \lambda_q, \lambda_w, \gamma \in [0,1]
\end{aligned}
\right\} \quad (40)
$$

This model also considers Constraints (7) to (36).

A, Q and W are the total number of warehouses, logistic centres and shops in the SC.

6. Application to a ceramic tile supply chain

This section uses the example provided by Alemany et al. (2010) to validate and evaluate the results of our proposal. It is a representative SC of the ceramic tile sector. There are 3 production plants, which produce 4 FGs grouped into 3 product families which rates, minimum run lengths and fixed costs are provided. Each plant contains two production lines. All the product families may be manufactured on the production lines at the various plants. Moreover, there are 2 warehouses, 3 logistics centres and 6 shops. They are considered six weeks periods in the planning horizon. Also, they are provided the following information: bill of materials, transportation costs, setup costs, initial inventory, available production and storage capacities, raw material costs, safety stocks, inventory costs, setup times, production costs, sale prices, subcontracting costs, backorder costs, production run times, minimum lot sizes and demand. Details on this data used can be found in Alemany et al. (2010).

6.1 Implementation and resolution

The proposed models been developed with the modelling language MPL and solved by the CPLEX 12 solver in an Intel Xeon, at 2.93 GHz, with 48 GB of RAM. The input data and the model solution values have been processed with the Microsoft SQL Server Database (2008).

We define each membership function by obtaining upper and lower bounds of each objective function. The upper and lower bounds obtained by maximizing and minimizing each objective function separately are presented in Table 2.

6.2 Evaluation of results

As stated previously, we adopt the weighted additive approach proposed by Tiwari et al. (1987) to deal with the collaborative CSCMP problem in a centralized SC structure. To

explore the influence of different weight structures on the results of the problem several problem instances are generated. Solution results of the model obtained by Tiwari et al. (1987) weighted additive approach are presented in Table 3. It is clear that determination of the weights requires expert opinion so that they can reflect accurately the relations between the different partners of a SC. In Table 3, w_1, w_2, w_3 and w_4 denotes the weights of manufacturer's, warehouses', logistic centres' and shops' objectives for each instance. On the other hand, Table 3 adds the degree of satisfaction of the objective functions for the proposed method.

Objectives	Upper bound	Lower bound
COSTM	785545	543825
W_1PROFIT	302078	171296
W_2PROFIT	332787	198072
LC_1COST	1359	1329
LC_2COST	1187	1162
LC_3COST	1227	1199
S_1PROFIT	66552	64784
S_2PROFIT	65825	64154
S_3PROFIT	68787	67044
S_4PROFIT	66448	64727
S_5PROFIT	68486	66643
S_6PROFIT	59838	58288

Table 2. Upper and lower bounds of the objectives.

	Problem instances								
	1	2	3	4	5	6	7	8	9
$w1$	0.25	0.4	0.3	0.3	0.4	0.2	0.3	0.3	0.3
$w2$	0.25	0.2	0.2	0.2	0.1	0.2	0.4	0.2	0.1
$w3$	0.25	0.2	0.2	0.1	0.1	0.3	0.2	0.4	0.1
$w4$	0.25	0.2	0.3	0.4	0.4	0.3	0.1	0.1	0.5
μ_{COSTM}	0.7666	0.7707	0.7655	0.7655	0.9834	0.7672	0.7747	0.7760	0.9536
$\mu_{W1PROFIT}$	1.0000	1.0000	1.0000	1.0000	0.9507	1.0000	1.0000	1.0000	0.9956
$\mu_{W2PROFIT}$	0.5738	0.5670	0.5681	0.5681	0.1153	0.5738	0.5779	0.5780	0.1726
$\mu_{LC1COST}$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4662	0.5629	0.0000
$\mu_{LC2COST}$	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000	1.0000	0.0000
$\mu_{LC3COST}$	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	1.0000	0.0000
$\mu_{S1PROFIT}$	0.8335	0.8335	1.0000	1.0000	1.0000	0.8335	0.4694	0.3224	1.0000
$\mu_{S2PROFIT}$	0.6118	0.6118	0.9506	0.9506	0.9506	0.6118	0.6118	0.3830	0.9506
$\mu_{S3PROFIT}$	0.9187	0.9187	1.0000	1.0000	1.0000	0.9187	0.5965	0.5965	1.0000
$\mu_{S4PROFIT}$	0.9175	0.9175	1.0000	1.0000	1.0000	0.9175	0.5477	0.5477	1.0000
$\mu_{S5PROFIT}$	0.8919	0.8919	1.0000	1.0000	1.0000	0.8919	0.4653	0.4653	1.0000
$\mu_{S6PROFIT}$	0.8651	0.8651	1.0000	1.0000	1.0000	0.8651	0.5752	0.5752	1.0000

Table 3. Solution results obtained by Tiwari et al. (1987) approach.

Table 4 shows the degree of satisfaction of each objective function obtained by Werners (1988) approach with different values of the coefficient of compensation (γ). It is observed

from Fig. 2 that the range of the achievement levels of the objectives increases with the decrease of the coefficient of compensation, taking the maximum possible value in the interval 0.5-0. That is, the higher the compensation coefficient γ values, the lower the difference between the degrees of satisfaction of each partner of the decentralized SC. So, for high values of γ, we can obtain compromise solutions for the all members of the SC, rather than solutions that only satisfy the objectives of a small group of these partners. Table 4 shows in general terms, the reduction of the degree of satisfaction of logistics centres 1 and 3 and shop 2, at the expense of substantially increasing the degree of satisfaction of the logistic center 2 and the rest of shops. Also, the degree of satisfaction related to warehouse 1 increases while reducing the degree of satisfaction associated to warehouse 2.

	ϒ									
	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1	0
μ_{COSTM}	0.7728	0.7722	0.7733	0.7723	0.7672	0.7672	0.7672	0.7672	0.7666	0.7672
$\mu_{W1PROFIT}$	0.929	0.9262	0.9274	0.9317	1,0000	0.9762	0.9622	0.9622	1,0000	0.9622
$\mu_{W2PROFIT}$	0.6405	0.6468	0.6442	0.6416	0.5736	0.5967	0.6099	0.6093	0.5732	0.6093
$\mu_{LC1COST}$	0.6405	0.6405	0.6405	0.6405	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
$\mu_{LC2COST}$	0.6405	0.6405	0.6405	0.6405	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000
$\mu_{LC3COST}$	0.6405	0.6405	0.6405	0.6405	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
$\mu_{S1PROFIT}$	0.6405	0.6405	0.6405	0.6405	0.8335	0.8335	0.8335	0.8335	0.8335	0.8335
$\mu_{S2PROFIT}$	0.6405	0.6405	0.6405	0.6405	0.6118	0.6118	0.6118	0.6118	0.6118	0.6118
$\mu_{S3PROFIT}$	0.6405	0.6405	0.6405	0.6405	0.9187	0.9187	0.9187	0.9187	0.9187	0.9187
$\mu_{S4PROFIT}$	0.6405	0.6405	0.6405	0.6405	0.9175	0.9175	0.9175	0.9175	0.9175	0.9175
$\mu_{S5PROFIT}$	0.6405	0.6405	0.6405	0.6405	0.8919	0.8919	0.8919	0.8919	0.8919	0.8919
$\mu_{S6PROFIT}$	0.6405	0.6405	0.6405	0.6405	0.8651	0.8651	0.8651	0.8651	0.8651	0.8651

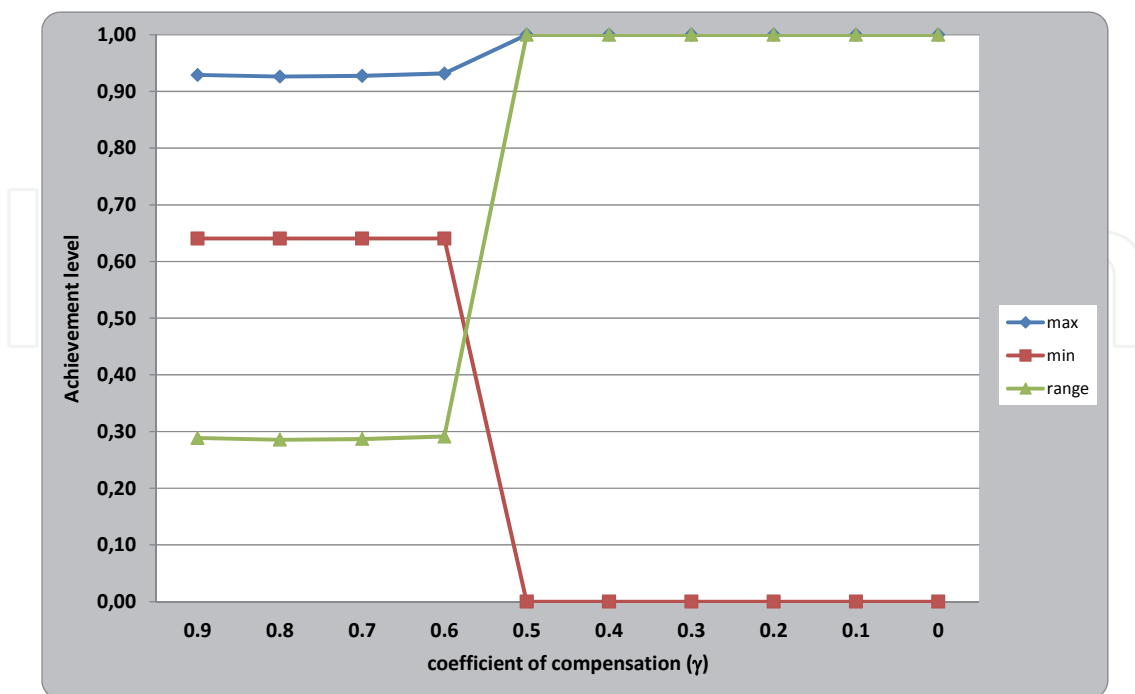Table 4. Solution results obtained by Werners (1988) approach.

Fig. 2. Range of the achievement levels of the objectives.

7. Conclusion

In recent years, the CP in SC environments is acquiring an increasing interest. In general terms, the CP implies a distributed decision-making process involving several decision-makers that interact in order to reach a certain balance condition between their particular objectives and those for the rest of the SC. This work deals with the collaborative supply chain master planning problem in a ceramic tile SC and has proposes two FGP models for the collaborative CSCMP problem based on the previous work of Alemany et al. (2010). FGP allows incorporate into the models decision maker's imprecise aspiration levels. Besides, to explore the viability of different FGP approaches for the CSCMP problem in different SC structures (i.e. centralized and decentralized) a real-world industrial problem with several computational experiments has been provided. The numerical results show that collaborative issues related to SC master planning problems can be considered in a feasible manner by using fuzzy mathematical approaches.

The complex nature and dynamics of the relationships among the different actors in a SC imply an important degree of uncertainty in SC planning decisions. In SC planning decision processes, uncertainty is a main factor that may influence the effectiveness of the configuration and coordination of SCs (Davis 1993; Minegishi and Thiel 2000; Jung et al. 2004), and tends to propagate up and down the SC, affecting performance considerably (Bhatnagar and Sohal 2005). Future studies may consider uncertainty in parameters such as demand, production capacity, selling prices, etc. using fuzzy modelling approaches.

Although the linear membership function has been proved to provide qualified solutions for many applications (Liu & Sahinidis 1997), the main limitation of the proposed approaches is the assumption of the linearity of the membership function to represent the decision maker's imprecise aspiration levels. This work assumes that the linear membership functions for related imprecise numbers are reasonably given. In real-world situations, however, the decision maker should generate suitable membership functions based on subjective judgment and/or historical resources. Future studies may apply related non-linear membership functions (exponential, hyperbolic, modified s-curve, etc.) to solve the CSCMP problem. Besides, the resolution times of the FGP models may be quite long in large-scale CSCMP problems. For this reason, future studies may apply the use of evolutionary algorithms and metaheuristics to solve CSCMP problems more efficiently.

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9. References

Alemany, M.M.E. et al., 2010. Mathematical programming model for centralised master planning in ceramic tile supply chains. *International Journal of Production Research*, 48(17), 5053-5074.

Barbarosoglu, G. & Özgür, D., 1999. Hierarchical design of an integrated production and 2-echelon distribution system. *European Journal of Operational Research*, 118(3), 464-484.

Bhatnagar, R. & Sohal, A.S., 2005. Supply chain competitiveness: measuring the impact of location factors, uncertainty and manufacturing practices. *Technovation*, 25(5),443-456.

Bellman, R.E. & Zadeh, L.A., 1970. Decision-Making in a Fuzzy Environment. *Management Science*, 17(4), B141-B164.

Bilgen, B. & Ozkarahan, I., 2004. Strategic tactical and operational production-distribution models: a review. *International Journal of Technology Management*, 28(2), 151-171.

Chen, M. & Wang, W., 1997. A linear programming model for integrated steel production and distribution planning. *International Journal of Operations & Production Management*, 17(6), 592 - 610.

Davis, T., 1993. Effective supply chain management. *Sloan Management Review*, 34, 35-46.

Dhaenens-Flipo, C. & Finke, G., 2001. An Integrated Model for an Industrial Production–Distribution Problem. *IIE Transactions*, 33(9), 705-715.

Dudek, G. & Stadtler, H., 2005. Negotiation-based collaborative planning between supply chains partners. *European Journal of Operational Research*, 163(3), 668-687.

Eksioglu, S.D., Edwin Romeijn, H. & Pardalos, P.M., 2006. Cross-facility management of production and transportation planning problem. *Computers & Operations Research*, 33(11), 3231-3251.

Ekşioğlu, S.D., Ekşioğlu, B. & Romeijn, H.E., 2007. A Lagrangean heuristic for integrated production and transportation planning problems in a dynamic, multi-item, two-layer supply chain. *IIE Transactions*, 39(2), 191-201.

Erengüç, S.S., Simpson, N.C. & Vakharia, A.J., 1999. Integrated production/distribution planning in supply chains: An invited review. *European Journal of Operational Research*, 115(2), 219-236.

Fahimnia, B., Lee Luong & Marian, R., 2009. Optimization of a Two-Echelon Supply Network Using Multi-objective Genetic Algorithms. In Proceedings of *WRI World Congress on Computer Science and Information Engineering, 2009*, 406-413.

Hernández, J.E., Alemany, M.M.E., Lario, F.C. & Poler, R., 2009. SCAMM-CPA: A supply chain agent-based modelling methodology that supports a collaborative planning process. *Innovar*, 19(34), 99-120.

Jung, J.Y., Blau, G.E., Pekny, J.F., Reklaitis, G.V. and Eversdyk, D., 2004. A simulation based optimization approach to supply chain management under demand uncertainty. *Computers & Chemical Engineering*, 28(10), 2087-2106

Jung, H., Frank Chen, F. & Jeong, B., 2008. Decentralized supply chain planning framework for third party logistics partnership. *Computers & Industrial Engineering*, 55(2), 348-364.

Kallrath, J., 2002. Combined strategic and operational planning – an MILP success story in chemical industry. *OR Spectrum*, 24(3), 315-341.

Kumar, M., Vrat, P. & Shankar, R., 2004. A fuzzy goal programming approach for vendor selection problem in a supply chain. *Computers & Industrial Engineering*, 46(1), 69-85.

Lee, A.H.I., Kang, H.-Y. & Chang, C.-T., 2009. Fuzzy multiple goal programming applied to TFT-LCD supplier selection by downstream manufacturers. *Expert Systems with Applications*, 36(3, Part 2),.6318-6325.

Liang, T., 2006. Distribution planning decisions using interactive fuzzy multi-objective linear programming. *Fuzzy Sets and Systems*, 157(10), 1303-1316.

Liang, T.F. & Cheng, H.W., 2009. Application of fuzzy sets to manufacturing/distribution planning decisions with multi-product and multi-time period in supply chains. *Expert Systems with Applications*, 36(2, Part 2), 3367-3377.

Liu, M.L. & Sahinidis, N.V., 1997. Process planning in a fuzzy environment. *European Journal of Operational Research*, 100(1), 142-169.

Luh, P.B., Ni, M., Chen, H. & Thakur, L. S., 2003. Price-based approach for activity coordination in a supply network. *Robotics and Automation, IEEE Transactions on*, 19(2), 335-346.

McDonald, C.M. & Karimi, I.A., 1997. Planning and Scheduling of Parallel Semicontinuous Processes. 1. Production Planning. *Industrial & Engineering Chemistry Research*, 36(7), 2691-2700.

Mentzer, J.T., DeWitt, W., Keebler, J.S., Min, S., Nix, N.W., Smith, C.D. & Zacharia, Z.G., 2001. Defining Supply Chain Management. *Journal of Business Logistics*, 22(2), 1-25.

Minegishi, S. & Thiel, D., 2000. System dynamics modeling and simulation of a particular food supply chain. *Simulation Practice and Theory*, 8(5), 321-339.

Mula, J., Peidro, D., Díaz-Madroñero, M. & Vicens, E., 2010. Mathematical programming models for supply chain production and transport planning. *European Journal of Operational Research*, 204(3), 377-390.

Nie, L., Xu, X. & Zhan, D., 2006. Collaborative Planning in Supply Chains by Lagrangian Relaxation and Genetic Algorithms. En *Intelligent Control and Automation, 2006. WCICA 2006. The Sixth World Congress on*. Intelligent Control and Automation, 2006. WCICA 2006. The Sixth World Congress on. 7258-7262.

Ouhimmou, M., D'Amours, S., Beauregard, R., Ait-Kadi, D. & Singh Chauhan, S., 2008. Furniture supply chain tactical planning optimization using a time decomposition approach. *European Journal of Operational Research*, 189(3), 952-970.

Park, Y.B., 2005. An integrated approach for production and distribution planning in supply chain management. *International Journal of Production Research*, 43(6), 1205-1224.

Peidro, D. & Vasant, P., 2009. Fuzzy Multi-Objective Transportation Planning with Modified SCurve Membership Function. En Global Conference on Power Control and Optimization. 101-110.

Selim, H., Araz, C. & Ozkarahan, I., 2008. Collaborative production-distribution planning in supply chain: A fuzzy goal programming approach. *Transportation Research Part E: Logistics and Transportation Review*, 44(3), 396-419.

Stadtler, H., 2009. A framework for collaborative planning and state-of-the-art. *OR Spectrum*, 31(1), 5-30.

Stadtler, H., 2005. Supply chain management and advanced planning--basics, overview and challenges. *European Journal of Operational Research*, 163(3), 575-588.

Tanaka, H., Ichihashi, H. & Asai, K., 1984. A formulation of fuzzy linear programming problem bases on comparision of fuzzy numbers. *Control and Cybernetics*, 13, 185-194.

Timpe, C.H. & Kallrath, J., 2000. Optimal planning in large multi-site production networks. *European Journal of Operational Research*, 126(2), 422-435.

Tiwari, R.N., Dharmar, S. & Rao, J.R., 1987. Fuzzy goal programming -- An additive model. *Fuzzy Sets and Systems*, 24(1), 27-34.

Torabi, S.A. & Hassini, E., 2009. Multi-site production planning integrating procurement and distribution plans in multi-echelon supply chains: an interactive fuzzy goal programming approach. *International Journal of Production Research*, 47(19), 5475.

Vidal, C.J. & Goetschalckx, M., 1997. Strategic production-distribution models: A critical review with emphasis on global supply chain models. *European Journal of Operational Research*, 98(1), 1-18.

Walther, G., Schmid, E. & Spengler, T.S., 2008. Negotiation-based coordination in product recovery networks. *International Journal of Production Economics*, 111(2), 334-350.

Werners, B., 1988. Aggregation models in mathematical programming. En *Mathematical Models for Decision Support*. Springer, 295-305.

Zimmermann, H.-J., 1975. Description and optimization of fuzzy systems. *International Journal of General Systems*, 2(1), 209.

Zimmermann, H.J., 1978. Fuzzy programming and linear programming with several objective functions. *Fuzzy Sets and Systems*, 1(1), 45-46.
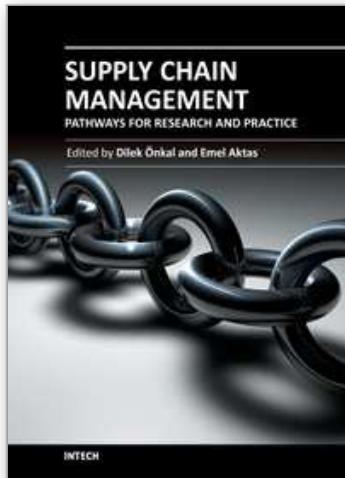
Supply Chain Management - Pathways for Research and Practice

Edited by Prof. Dilek Onkal

Challenges faced by supply chains appear to be growing exponentially under the demands of increasingly complex business environments confronting the decision makers. The world we live in now operates under interconnected economies that put extra pressure on supply chains to fulfil ever-demanding customer preferences. Relative attractiveness of manufacturing as well as consumption locations changes very rapidly, which in consequence alters the economies of large scale production. Coupled with the recent economic swings, supply chains in every country are obliged to survive with substantially squeezed margins. In this book, we tried to compile a selection of papers focusing on a wide range of problems in the supply chain domain. Each chapter offers important insights into understanding these problems as well as approaches to attaining effective solutions.

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