Improving supply chain management in a competitive environment

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Abstract

This work addresses the development of a multi-objective MILP (Mixed Integer Linear Programming), devised to optimize the planning of supply chains introducing the use of game theory for decision making in cooperative and/or competitive scenarios. The model developed is tested in a real-world case study, based on the operation of two different supply chains; three different optimization criteria are consider, and both cooperative and non cooperative way of working between supply chain´s is considered.

Conclusions

This work introduces the use of GT as decision technique that determines the optimal SC production, inventory and distributions levels in a competitive planning scenario, when there is a change in the competition behaviour. The problem was modelled using a multi-objective MILP-based approach by introducing the use of game theory, obtaining improved solutions in typical SC planning problems.

Annex

Tables 1-4 provide the information about the considered scenarios, production, etc. and the rest of problem conditions (initial storage levels, transport capacities, etc.)

Table 1. Pay off Matrix Percent of discount.

A/B	0.1%	0.2%	0.3%	0.4%
0.1%	Be(A,B)	Be(A,B)	Be(A,B)	Be(A,B)
0.2%	Be(A,B)	Be(A,B)	Be(A,B)	Be(A,B)
0.3%	Be(A,B)	Be(A,B)	Be(A,B)	Be(A,B)
0.4%	Be(A,B)	Be(A,B)	Be(A,B)	Be(A,B)

Table 2. Data of the problem.

Source	Time	Product	a_{in}	c_{in}	d_{in}	l_{in}	r_{in}
	3						
Plant1	months	P1	20	0.3	32	0.05	0.1
		P2	10	0.15	18	0.07	0.08
Plant2		P1	20	0.28	20	0.04	0.09
		P2	10	0.14	16	0.06	0.07
Plant3		P1	20	0.3	32	0.05	0.1
		P2	10	0.15	18	0.07	0.08
Plant4		P1	20	0.28	20	0.04	0.09
		P2	10	0.14	16	0.06	0.07

Table 3. Distribution data of the problem.

Source	Product	Distribution Center			
		Distr1	Distr2	Distr3	Distr4
Plant1	P1	[a]2.8/5.2[b]	1/1.8	4.2/13.5	2.2/2.8
	P2	2.5/5.2	0.9/1.8	4/13.5	2/2.8
Plant2	P1	1.2/2	1.5/2.5	5.0/15	3.5/6
	P2	1.1/2	1.4/2.5	4.5/15	3.2/6
Plant3	P1	4.4/9	5.9/12	1.1/4	3.5/6
	P2	3.9/9	5.4/12	1.0/4	3.2/6
Plant4	P1	1.5/3	1/2.0	3.8/14	4.1/7
	P2	1.3/3	0.9/2	3.5/14	3.7/7
Available space Rdd		19500	16000	10000	20000

a delivery cost per truc to carry 100 dozen units. b delivery time

Table 4. Demand to be forecasted.

Demand	Distr1			Distr2			Distr3			Distr4		
Product	t1	t2	t3	t1	t2	t3	t1	t2	t3	t1	t2	t3
P1	1000	3000	5000	820	2300	4000	500	1200	2400	1230	3400	5300
P2	650	910	3000	500	720	2400	300	400	1150	710	1050	3100

Other data:

- Trucks can deliver up to 100 dozen of units per travel and has an additional delivery cost (Ad(i,n,j)) of 10 $. The initial inventories are 400 P1 and 200 P2 for both Plant1 and Plant3, and 300 P1 and 200 P2 for both Plant2 and Plant4.
- The labor levels in each time period are (965, 1040, 1130) for Plant 1 and Plant3, and (850, 920, 990) for Plant 2 and Plant4.
- The machine capacities in each time period are (1550, 1710, 1870) for Plant1 and Plant3, and (1850, 2050, 2250) for Plant 2 and Plant4.
- To compare with Liang 2008, the data only changes in the production cost: Plant 1-P1 20, Plant 1-P2 10, Plant 2-P1 18, and Plant 2-P2 9.

The standalone solutions for the SC1 and SC2 are shown in figures 2-3 and table 7.

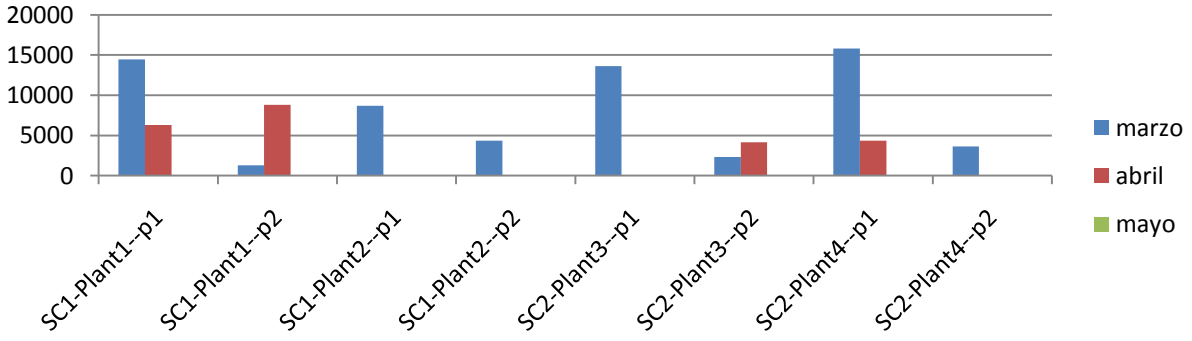

Figure 2. Production Q(inh). Source-Product

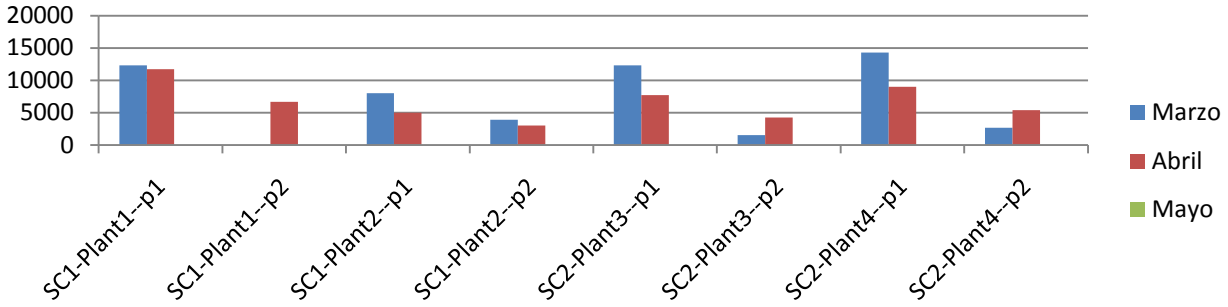

Figure 3. Inventory Level W(inh) Source-Product

Table 7. Distribution of products from plants to distribution centers. T_{inhj}.

SC1 (standalone)			Distr1	Distr2	Distr3	Distr4
Plant1	P1	March	0	820	500	1230
		April	0	2300	1200	3400
		May	0	4000	2400	5300
	P2	March	0	500	300	710
		April	0	720	400	1050
		May	0	2400	1150	3100
Plant2	P1	March	1000	0	0	0
		April	3000	0	0	0
		May	5000	0	0	0
	P2	March	650	0	0	0
		April	910	0	0	0
		May	3000	0	0	0
SC2 (standalone)			Distr1	Distr2	Distr3	Distr4
Plant3	P1	March	0	0	500	1230
		April	0	0	1200	3400
		May	0	0	2400	5300
	P2	March	0	0	300	710
		April	0	0	400	1050
		May	0	0	1150	3100
Plant4	P1	March	1000	820	0	0
		April	3000	2300	0	0
		May	5000	4000	0	0
	P2	March	650	500	0	0
		April	910	720	0	0
		May	3000	2400	0	0

Table 1 is the payoff matrix and it is solved for two cases where both SCs are considered in the problem: 1. - To achieve the original demand (table 8). 2. - For the case when double demand is assumed (table 9).

Table 8. Payoff matrix Competitive case (original demand).

SC1/SC2		0.00%		0.10%		0.20%		0.30%		0.40%	
		SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2
0%	z1($)	515,516	286,997	515,516	286,997	465,907	337,370	406,249	397,740	275,731	530,071
		802,513		802,513		803,277		803,989		805,801	
	z2(hours)	1,138		1,138		1,181		1,209		1,268	
	Benefit ($)	2,319,483	1,382,002	2,319,483	1,380,333	1,933,092	1,763,420	1,716,750	1,976,116	1,253,269	2,433,028
	CST($)	3,350,516	1,955,997	3,350,516	1,954,328	2,864,907	2,438,159	2,529,249	2,771,597	1,804,730	3,493,171
0.10%	z1($)	621,159	181,684	515,516	286,997	515,516	286,997	465,907	337,370	406,250	397,740
		802,843		802,513		802,513		803,277		803,989	
	z2(hours)	1,125		1,138		1,138		1,181		1,209	
	Benefit ($)	2,864,351	833,315	2,316,648	1,380,333	2,316,648	1,378,664	1,930,693	1,761,315	1,714,627	1,973,735
	CST($)	4,106,670	1,196,684	3,347,681	1,954,328	3,347,681	1,952,659	2,862,508	2,436,054	2,527,126	2,769,216
0.20%	z1($)	702,559	100,734	621,159	181,684	515,516	286,997	515,516	286,997	465,908	337,370
		803,293		802,843		802,513		802,513		803,277	
	z2(hours)	1,117		1,125		1,138		1,138		1,181	
	Benefit ($)	3,148,722	544,265	2,860,862	832,300	2,313,813	1,378,664	2,313,813	1,376,995	1,928,294	1,759,210
	CST($)	4,553,841	745,734	4,103,181	1,195,669	3,344,846	1,952,659	3,344,846	1,950,990	2,860,109	2,433,949
0.30%	z1($)	702,559	100,734	702,559	100,734	621,159	181,684	515,517	286,997	515,517	286,997
		803,293		803,293		802,843		802,513		802,513	
	z2(hours)	1,117		1,117		1,125		1,138		1,138	
	Benefit ($)	3,144,863	544,265	3,144,863	543,620	2,857,373	831,285	2,310,978	1,376,995	2,310,978	1,375,326
	CST($)	4,549,982	745,734	4,549,982	745,089	4,099,692	1,194,654	3,342,011	1,950,990	3,342,011	1,949,321
0.40%	z1($)	702,559	100,734	702,559	100,734	702,559	100,734	621,160	181,684	515,517	286,997
		803,293		803,293		803,293		802,843		802,513	
	z2(hours)	1,117		1,117		1,117		1,125		1,138	
	Benefit ($)	3,141,004	544,265	3,141,004	543,620	3,141,004	542,975	2,853,884	830,270	2,308,143	1,375,326
	CST($)	4,546,123	745,734	4,546,123	745,089	4,546,123	744,444	4,096,203	1,193,639	3,339,176	1,949,321

Table 9. Payoff matrix Competitive case (double demand).

SC1/SC2		0.00%		0.10%		0.20%		0.30%		0.40%	
		SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2
0%	z1($)	1,067,454	576,381	1,036,881	606,955	962,086	682,893	892,129	754,005	797,121	850,485
		1,643,835		1,643,836		1,644,979		1,646,134		1,647,606	
	z2(hours)	2,292		2,295		2,360		2,404		2,448	
	Benefit ($)	4,746,545	2,617,618	4,573,118	2,787,646	3,992,513	3,362,399	3,625,870	3,722,524	3,283,878	4,056,806
	CST($)	6,881,454	3,770,381	6,646,881	4,001,557	5,916,686	3,362,399	5,410,129	5,230,535	4,878,121	5,757,777
0.10%	z1($)	1,094,944	549,032	1,067,454	576,381	1,036,881	606,955	962,086	682,893	892,129	754,005
		1,643,976		1,643,835		1,643,836		1,644,979		1,646,134	
	z2(hours)	2,287		2,292		2,295		2,360		2,404	
	Benefit ($)	4,957,796	2,400,167	4,740,731	2,614,424	4,567,508	2,784,248	3,987,558	3,358,346	3,621,352	3,718,034
	CST($)	7,147,685	3,498,232	6,875,640	3,767,187	6,641,271	3,998,159	5,911,732	4,724,133	5,405,611	5,226,045
0.20%	z1($)	1,274,981	370,421	1,094,944	549,032	1,067,454	576,381	1,036,881	606,955	962,086	682,893
		1,645,402		1,643,976		1,643,835		1,643,836		1,644,979	
	z2(hours)	2,268		2,287		2,292		2,295		2,360	
	Benefit ($)	5,750,339	1,598,178	4,951,738	2,397,218	4,734,917	2,611,230	4,561,898	2,780,850	3,982,603	3,354,293
	CST($)	8,300,302	2,339,021	7,141,626	3,495,283	6,869,826	3,763,993	6,635,661	3,994,761	5,906,777	4,720,079
0.30%	z1($)	1,274,981	370,421	1,274,981	370,421	1,094,944	549,032	1,067,454	576,381	1,036,881	606,955
		1,645,402		1,645,402		1,643,976		1,643,835		1,643,836	
	z2(hours)	2,268		2,268		2,287		2,292		2,295	
	Benefit ($)	5,743,300	1,598,178	5,743,300	1,596,209	4,945,679	2,394,269	4,729,103	2,608,036	4,556,288	2,777,452
	CST($)	8,293,263	2,339,021	8,293,263	2,337,053	7,135,567	3,492,334	6,864,012	3,760,799	6,630,051	3,991,363
0.40%	z1($)	1,274,981	370,421	1,274,981	370,421	1,274,981	370,421	1,094,944	549,032	1,067,454	576,381
		1,645,402		1,645,402		1,645,402		1,643,976		1,643,835	
	z2(hours)	2,268		2,268		2,268		2,287		2,292	
	Benefit ($)	5,736,260	1,598,178	5,736,260	1,596,209	5,736,223	1,594,241	4,939,620	2,391,319	4,723,289	2,604,842
	CST($)	8,286,223	2,339,021	8,286,223	2,337,053	8,286,223	2,335,084	7,129,509	3,489,384	6,858,198	3,757,605

Notation

Sets

N Products
I Sources (production sites)
H Period of time
J destiny (distribution centers)
G Supply chain
I_G(i,g) Subset of sources I that belongs to each supply chain g

Parameters

a(i,n) Production cost of the product n at the source i.
c(i,n) Inventory cost of the product n at the source i.
d(i,n) Backorder cost of the product n at the source i.
l(i,n) Hour by work by unit of product n produced at source i.
r(i,n) Machine hour by unit of product n produced at source i.
vv(n) Inventory space by unit of product n.
k(i,n,j) Delivery cost by dozen of product n from the source i to the destiny j.
Ad(i,n,j) Additional delivery cost of product n from the source i to the destiny j.
u(i,n,j) Delivery time of product n from source I to destiny j
S(i,n,j) Capacity of truck

Rdd(h,j) Maximum storage space in destiny j.
M(i,h) Maximum machine level available at source i in period t.
F(i,h) Maximum labor level of work at source i in period t.
Djj(n,h,j) Nominal demand of product n in period h of destiny j.
Bdd(g) Total Budget for Supply Chain g.
eb Escalating factor for (regular production cost, backorder cost, and inventory cost)
II(i,n,h) Initial storage.
Ps(i,n,j) Price of product n from source i to destiny j.
MInd(i,n) Minimal distribution.
Maxd(i,n) Maximum distibution.
Minp(i,n) Minimum production capacity.
Maxp(i,n) Maximum production capacity.
Desc(g) Discount in the price at Supply Chain g.

Variables
Q(i,n,h) Production of product n in the source i at time h.
W(i,n,h) Inventor y level by source i of the product n at time h.
E(i,n,h) backorder of the source i of the product n at time h.
T(i,n,h,j) Distributed units from the source i of product n at time h to destiny j.
z1(g) total cost of Supply Chain g. ($)
CST(g) Overall cost by Supply Chain.

Binary variables
X(i,n,h,j) Is 1 if the source i send product n at time h to destiny j.
Y(i,n,h) is 1 if the source i produce product n at time h.