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Optimizing fresh food for processing: application for a large Chilean apple supply chain

Universitat de Lleida

TALCA UNIVERSIDAD CHILE

Jordi Mateo, Lluis M. Pla, F. Solsona
Universitat de Lleida

Wadimir Soto, Marcela Gonzalez
Universidad de Talca

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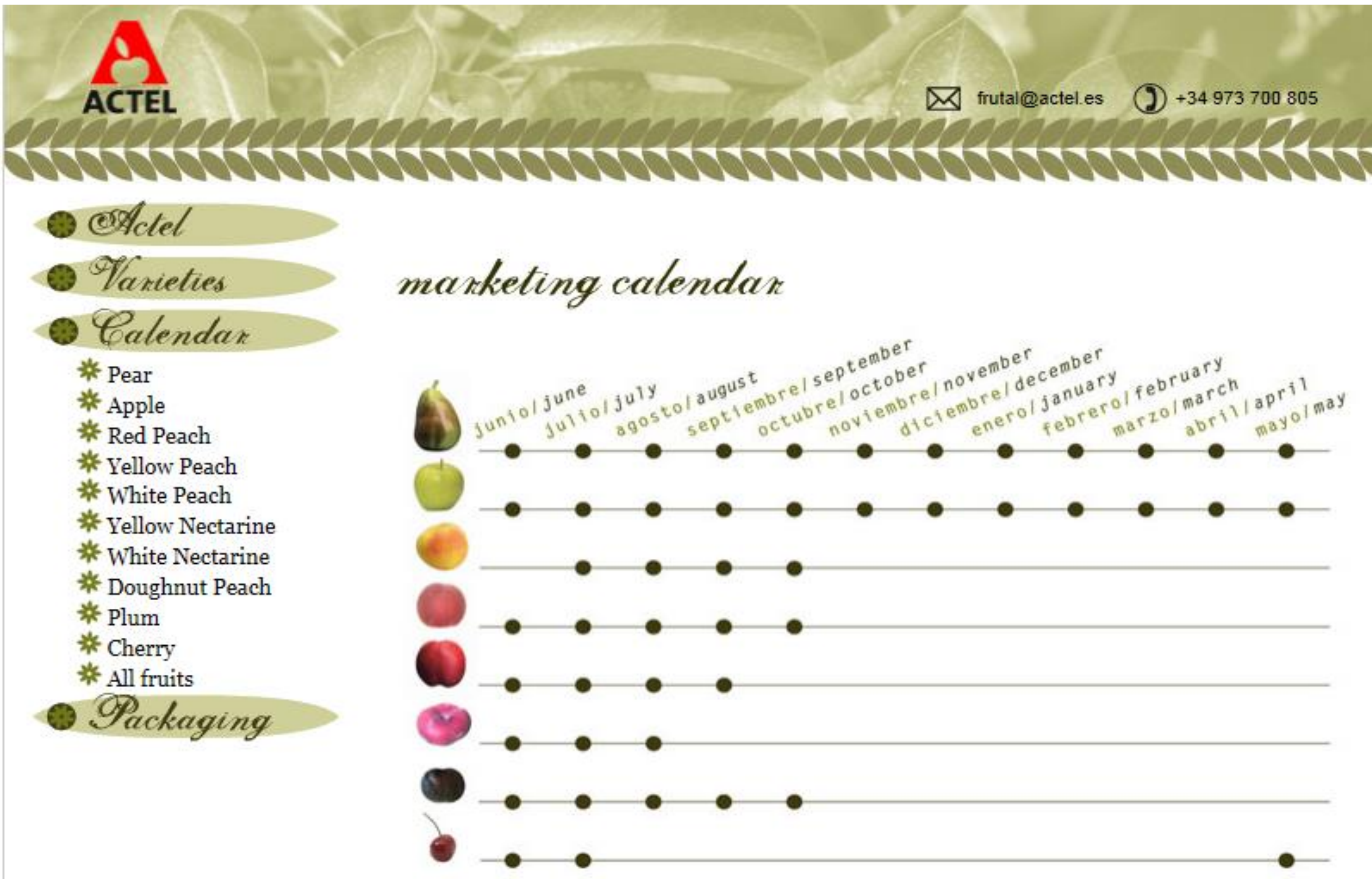
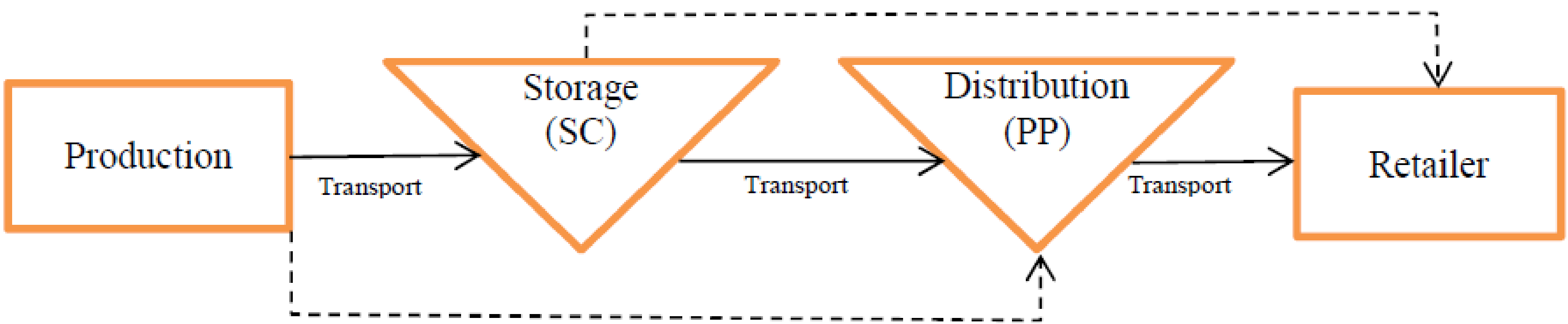
Introduction



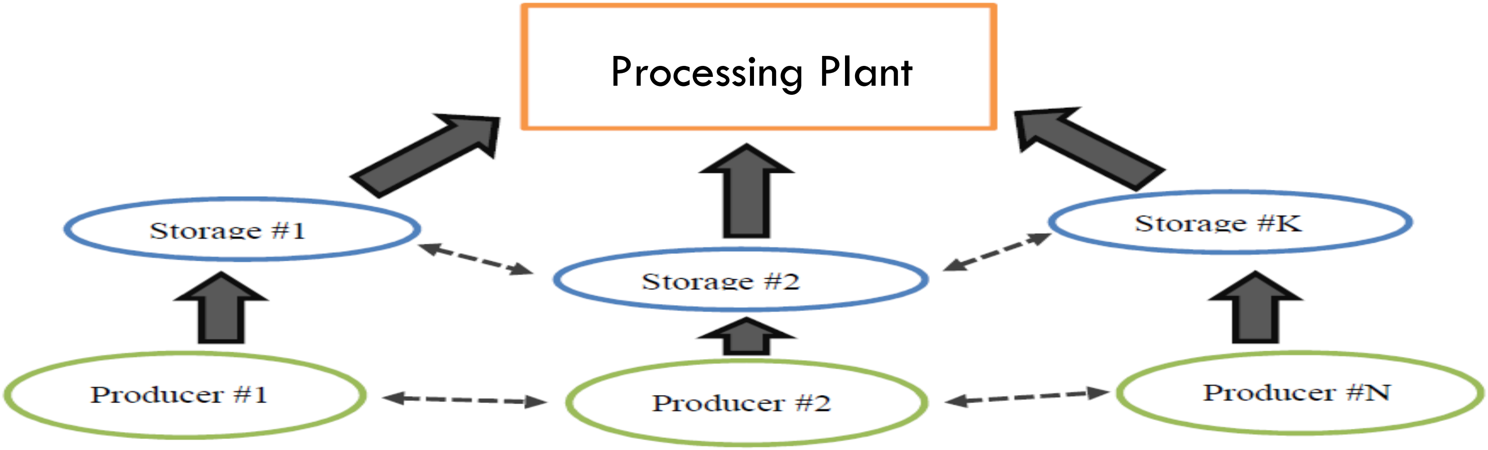
Problem description

- The fruit supply chain:
  - Seasonable production (harvesting vs non-harvesting season)
  - Quality variations
  - Special storage conditions
  - Short delivery time to preserve freshness
  - Packing demands
  - Interaction of different agents



Problem description: Case study

- Real Case from a Driying processing plant



- Objectives:
  - Contract all the product to be processed for a year
  - Stock apples in cold chambers until processed
  - Deliver steadily apples to the plant
  - Buy additional raw material if needed

Formulation of the model

- Sets:

P	Set of available producers.
Ω	Set of different uncertain scenarios.
Q	Set of different apples varieties.
T	Set of different type of apples.
N	Set of cold storage's inside a Warehouse.
C	Set of warehouses.
L	Set of trucks.

Formulation of the model

- Parameters:

CC^0_{pqt}	Cost for purchasing in the first stage.
CC^ω_{pqt}	Cost for purchasing in the second stage under scenario ω.
CM_p	Cost to maintain a producer p.
CT_p	Cost to transport from a producer p.
CFT_l	Cost for using truck l.
CTA_{qtc}	Cost for transportation.
CE_{cn}	Cost for storing using a cold tech inside warehouse c using the cold storage n.
CF_{cn}	Cost for using a specific chamber inside warehouse c using the cold storage n.
D^ω_{qt}	Amount of demand for variety q and type t under scenario ω.
O_{pqt}	Amount of raw material from variety q and type t produced by producer p.

Formulation of the model

- Objective Function:

Purchase of producer/variety/time

$$min \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^0_{pqt} XP^0_{pqt} \quad (1a)$$

Number of trips

Selection of producer

$$+\sum_{\Omega\in\omega}\pi^\omega \Bigg[\quad (1b)$$

$$\sum_{p\in P}(CM_p + CT_p)Z^\omega p + \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^\omega_{pqt} XP^\omega_{pqt} + \sum_{l\in L}\sum_{p\in P}\sum_{q\in Q} CFT_l Y^\omega_{lpq}$$

Selection of cold chamber

Quantity of apples

Selection of storage provider

$$(1c)$$

$$+\sum_{q\in Q}\sum_{t\in T}\sum_{c\in C}\sum_{n\in N}\sum_{l\in L}\left(CTA_{qtc} + CE_{cn}\right) X^\omega_{qtcnl} + \sum_{c\in C} + CA_c A^\omega_c \quad (1d)$$

$$+\sum_{c\in C}\sum_{n\in N}\sum_{q\in Q}\sum_{t\in T} + CF_{cn} ME^\omega_{cnqt} + \sum_{l\in L}\sum_{c\in C}\sum_{n\in N} CFT_l YC^\omega_{lcn}\Bigg]; \quad (1e)$$

Formulation of the model

- Constraints:

$$s.t.: \quad MZ_p^{\omega} \geq \sum_{q \in Q} \sum_{t \in T} (XP_{pqt}^{0} + XP_{pqt}^{\omega}), \qquad \forall \omega \in \Omega, \ \forall p \in P \tag{1f}$$

$$XP_{pqt}^{0} |T| \geq \sum_{t' \in T} XP_{pqt'}^{0}, \qquad \forall p \in P, \ q \in Q, \ t \in T \tag{1g}$$

$$XP_{pqt}^{\omega} |T| \geq \sum_{t' \in T} XP_{pqt'}^{\omega}, \qquad \forall p \in P, \ q \in Q, \ t \in T \tag{1h}$$

$$XP_{pqt}^{0} + XP_{pqt}^{\omega} \leq 1, \qquad \forall p \in P, \ q \in Q, \ t \in T, \ \omega \in \Omega \tag{1i}$$

Formulation of the model

- Constraints:

$$\sum_{p\in P}\sum_{t\in T}\sum_{l\in L} W^{\omega}_{pqtl} \geq \sum_{t\in T} D^{\omega}_{qt} \qquad \forall q\in Q,\ \ \omega\in\Omega \tag{1j}$$

$$\sum_{l\in L} W^{\omega}_{pqtl} \leq (XP^{\omega}_{pqt} + XP^{0}_{pqt})O_{pqt} \qquad \forall q\in Q,\ \ p\in P,\ \ t\in T\ \forall\omega\in\Omega \tag{1k}$$

$$\sum_{t\in T} W^{\omega}_{pqtl} \leq QMax_l Y^{\omega}_{lpq} \qquad \forall q\in Q,\ \ p\in P,\ \ l\in L \tag{1l}$$

$$\sum_{l\in L} X^{\omega}_{qtcnl} \leq WC_{cn} ME^{\omega}_{cnqt} \qquad \forall\omega\in\Omega,\ \ \forall c\in C,\ \ n\in N\ \ t\in T,\ \ q\in Q \tag{1m}$$

$$\sum_{n\in N}\sum_{t\in T}\sum_{q\in Q} ME_{cntq} <= |C|A^{\omega}_{c} \qquad \forall\omega\in\Omega,\ \ \forall c\in C \tag{1n}$$

$$\sum_{q\in Q}\sum_{t\in T} X^{\omega}_{qtcnl} \leq QMax_l YC^{\omega}_{lcn} \qquad \forall\omega\in\Omega,\ \ \forall c\in C,\ \ n\in N\ \ l\in L \tag{1o}$$

Formulation of the model

- Constraints:

$$\sum_{c \in C} \sum_{n \in N} X^{\omega}_{qtcnl} \geq \sum_{p \in P} W^{\omega}_{pqtl} \qquad \forall \omega \in \Omega,\ \forall q \in Q,\ t \in T,\ l \in L \tag{1p}$$

$$\sum_{t \in T} \sum_{q \in Q} ME^{\omega}_{cnqt} \leq 1, \qquad \forall \omega \in \Omega,\ \forall c \in C,\ n \in N \tag{1q}$$

$$ME^{\omega}_{cnqt} = 0, \qquad \forall \omega \in \Omega,\ \forall q \in Q,\ c \in C,\ n \in N,\ t \in T : t < TE_{cn} \tag{1r}$$

Formulation of the model

- Objective Function:

$$min \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^0_{pqt} XP^0_{pqt} \quad (1a)$$

$$+\sum_{\Omega\in\omega}\pi^{\omega}\Big[\quad (1b)$$

$$\sum_{p\in P}(CM_p + CT_p)Z^{\omega}p + \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^{\omega}_{pqt} XP^{\omega}_{pqt} + \sum_{l\in L}\sum_{p\in P}\sum_{q\in Q} CFT_l Y^{\omega}_{lpq} \quad (1c)$$

$$+\sum_{q\in Q}\sum_{t\in T}\sum_{c\in C}\sum_{n\in N}\sum_{l\in L}\Big(CTA_{qtc} + CE_{cn}\Big) X^{\omega}_{qtcnl} + \sum_{c\in C} + CA_c A^{\omega}_c \quad (1d)$$

$$+\sum_{c\in C}\sum_{n\in N}\sum_{q\in Q}\sum_{t\in T} + CF_{cn} ME^{\omega}_{cnqt} + \sum_{l\in L}\sum_{c\in C}\sum_{n\in N} CFT_l YC^{\omega}_{lcn}\Big]; \quad (1e)$$

Formulation of the model

- Objective Function (2):

$$min \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^{0}_{pqt} XP^{0}_{pqt} + \sum_{\Omega\in\omega} \pi^{\omega}\Bigg[\sum_{p\in P}(CM_p + CT_p) Z^{\omega} p \qquad (2a)$$

$$+ \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^{\omega}_{pqt} XP^{\omega}_{pqt} + \sum_{l\in L}\sum_{p\in P}\sum_{q\in Q} CFT_l Y^{\omega}_{lpq}\Bigg] \qquad (2b)$$

$$+ \sum_{q\in Q}\sum_{t\in T}\sum_{c\in C}\sum_{n\in N}\sum_{l\in L}\Big(CTA_{qtc} + CE_{cn}\Big) X_{qtcnl} + \sum_{c\in C} + CA_c A_c \qquad (2c)$$

$$+ \sum_{c\in C}\sum_{n\in N}\sum_{q\in Q}\sum_{t\in T} + CF_{cn} ME_{cnqt} + \sum_{l\in L}\sum_{c\in C}\sum_{n\in N} CFT_l YC_{lcn}; \qquad (2d)$$

Formulation of the model

- Objective Function (3):

$$min \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^0_{pqt} XP^0_{pqt} + \sum_{c\in C}\sum_{n\in N}\sum_{q\in Q}\sum_{t\in T} CF_{cn} ME^0_{cnqt} \tag{3a}$$

$$+ \sum_{q\in Q}\sum_{t\in T}\sum_{c\in C}\sum_{n\in N}\sum_{l\in L} \Big(CTA_{qtc} + CE_{cn} \Big) X^0_{qtcnl} + \sum_{\Omega\in\omega} \pi^{\omega} \Big[\tag{3b}$$

$$\sum_{p\in P} (CM_p + CT_p) Z^{\omega} p + \sum_{p\in P}\sum_{q\in Q}\sum_{t\in T} CC^{\omega}_{pqt} XP^{\omega}_{pqt} \tag{3c}$$

$$+ \sum_{l\in L}\sum_{p\in P}\sum_{q\in Q} CFT_l Y^{\omega}_{lpq} \tag{3d}$$

$$+ \sum_{q\in Q}\sum_{t\in T}\sum_{c\in C}\sum_{n\in N}\sum_{l\in L} \Big(CTA_{qtc} + CE_{cn} \Big) X^{\omega}_{qtcnl} + \sum_{c\in C} \tag{3e}$$

$$+ \sum_{c\in C}\sum_{n\in N}\sum_{q\in Q}\sum_{t\in T} + CF_{cn} ME^{\omega}_{cnqt} + \sum_{l\in L}\sum_{c\in C}\sum_{n\in N} CFT_l YC^{\omega}_{lcn} \Big]; \tag{3f}$$

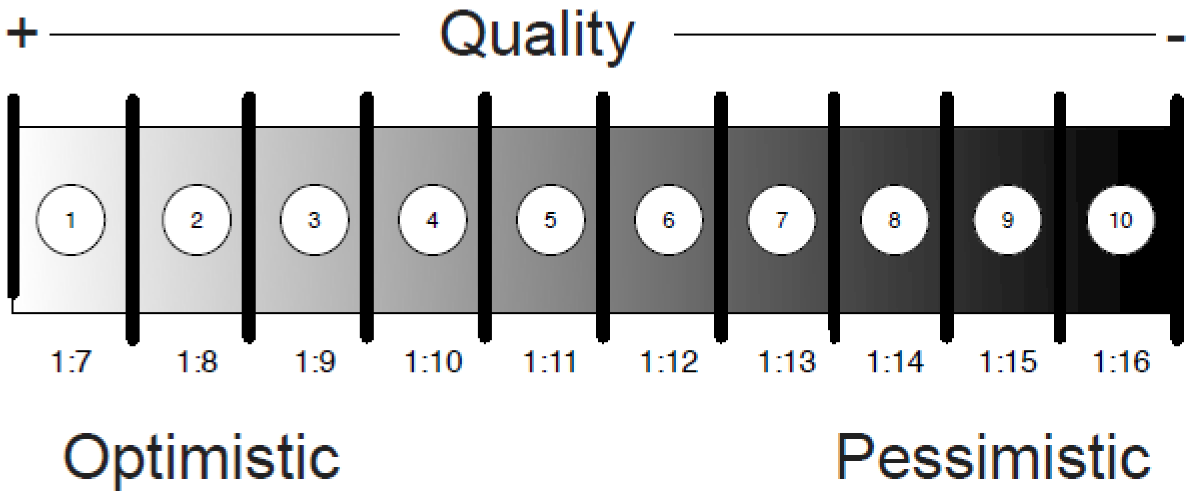
Application of the model

- Dimensions:

Instance	P	Q	T	N	C	L	Ω
Case 1	50	6	3	10	11	3	13
Case 2	272	6	3	10	11	3	13

Application of the model

- Scenarios:



Application of the model

- Scenarios:

Ω	π^ω	Quality	CC^0	%	C^ω
1	1%	1:6	12500 \$	16%	14500 \$
2	1%	1:7	12500 \$	19%	14875 \$
3	1%	1:8	12500 \$	22%	15250 \$
4	5%	1:9	12500 \$	25%	15625 \$
5	13%	1:10	12500 \$	27%	15875 \$
6	23%	1:11	12500 \$	30%	16250 \$
7	23%	1:12	12500 \$	33%	16625 \$
8	15%	1:13	12500 \$	35%	16875 \$
9	10%	1:14	12500 \$	38%	17250 \$
10	5%	1:15	12500 \$	40%	17500 \$
11	1%	1:16	12500 \$	35%	17875 \$
12	1%	1:17	12500 \$	38%	18125 \$
13	1%	1:18	12500 \$	40%	18500 \$

Results and discusion

- Implemented with ILOG OPL and solved with Cplex v12.6
- Pentium 2.10GHz. / 4Gb RAM

SS	48.136.250,53 $
Time (min)	10
GAP	0.21%

Results and discusion

- By scenario:

EVIP	-80.856,45$
%	0.16%

Ω	Quality	
1	1:6	23.551.400,00 $
2	1:7	28.523.536,00 $
3	1:8	31.519.698,00 $
4	1:9	36.109.420,00 $
5	1:10	40.130.498,00 $
6	1:11	44.375.572,00 $
7	1:12	48.772.750,00 $
8	1:13	52.686.322,00 $
9	1:14	57.039.850,00 $
10	1:15	60.969.608,00 $
11	1:16	65.908.666,00 $
12	1:17	70.501.160,00 $
13	1:18	75.338.598,00 $
	..	
	..	

Results and discusion

- VSS:

$$VSS = SS - EQS = 48.136.250,53 - 48.163.901,31,6 = -27.650,78\$ \qquad (6)$$

Future work & conclusions

- The deterministic model is enough under present formulation
- A revision of the stochastic model could be advisable (scenario generation).
- There is few advantage in using recourse action
- First stage decisions are the most important

Thanks for your attention