A MILP model for planning at operative level in a meat packing plant

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OUTLINE

• Introduction about pork production
• The pork supply chain structure
• Planning production in a meat packing plant
• Challenges and Opportunities
• Conclusions
IS MEAT PRODUCTION AN ISSUE?

In 2012, around 304 million tonnes of meat were produced worldwide. For 2014, FAO forecasts an increase to 311.8 million tonnes.

Nowadays we are approximate 7 thousand of millions of people.

<table>
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<th>Population (Billions)</th>
<th>Year</th>
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<tr>
<td>0.98</td>
<td>2010</td>
</tr>
<tr>
<td>1.26</td>
<td>2015</td>
</tr>
<tr>
<td>1.65</td>
<td>2020</td>
</tr>
<tr>
<td>2.47</td>
<td>2025</td>
</tr>
<tr>
<td>6.06</td>
<td>2030</td>
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<tr>
<td>6.88</td>
<td>2035</td>
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<td>9.15</td>
<td>2040</td>
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<tr>
<td>10.46</td>
<td>2045</td>
</tr>
<tr>
<td>18.96</td>
<td>2100</td>
</tr>
</tbody>
</table>

Source FAOSTAT
WHAT WE NEED?  

More agricultural land?  But the agricultural land is being devoted to build houses.

PRODUCTIVITY

the production costs have increased.

the profitability margin.

Bio-energy
Food and Agriculture Organization of the United Nations had point out **TECHNOLOGY** is the cornerstone to increase productivity.
Here is where OR Researchers could play an important role by developing Decision Support Systems.
TECHNOLOGY

My job is to provide tools to help you to get more money for your company with the resources you already have.
TECHNOLOGY

and moreover how to change your assets to be more productive
PORK INDUSTRY EVOLUTION

- Pork is the most widely produced meat worldwide.
- In many countries, the number of pig farms is being reduced, while the herd size of the remaining ones is increasing.

FAMILIAR

INDUSTRIAL
CHANGES IN THE MANAGEMENT

Before

2 to 5 animals per week

Now

100 to 10000 animals per day

Size of Operations

Decision Making is more complex
CONSUMER EVOLUTION

- Habits and practices are changing.

- Quality.
- Sustainable
- Safety
- Animal welfare.
- Traceability

NEW CHALLENGES TO THE PRODUCERS
Pig production has been evolving towards a progressive concentration in larger and more specialized and efficient production units.
The competition today is more between supply chains than individual firms.
The chain manager now must make decisions on pig production agents considering the integration and coordination of the whole supply chain at different time horizons (Stadler, 2005).
A meat packing plant is the facility where the processing and packing of the meat is done.
• Multiproduct.
• Process planning for product disassembly.
DIFERRENT CUTTING PATTERNS

- $ cost
- $ reward
- Set of products
The mayor difficulty is to balance the benefits of selling products from one part of the carcass when there are no demand from other parts or the carcass.
• **OBJECTIVE FUNCTION** is oriented to maximize the net profit.

• The net profit is obtained through the difference between the incomes from selling the products yielded by the cutting patterns, minus the operational costs incurred. These operational costs involve inventory, freezing costs, unsatisfied demand penalties and labor costs to perform the cutting-patterns.

\[
\sum_{it} \left( p_i^f v_{it}^f + p_i^e v_{it}^e - u^c x_{it} - CM_i^c i_{it}^c - s_i^f d_{it}^f - s_i^e d_{it}^e \right) - \sum_{t} \left( c_i z_{jt} + c_j^e z_{jt}^e \right) - \sum_{itl} \left( CM_{it}^l x_{itl(t+1)} \right) - \sum_{t} \left( CM_{it}^e e_{it}^e \right)
\]
• **Bounds for carcasses to be processed.** The number of carcasses to process in each period needs to be bounded (upper and lower limits), given by the animal availability from suppliers according to different types of carcasses.

\[ H_r^{\text{min}} \leq \sum_{t \in T} H_{rt} \leq H_r^{\text{max}} \quad \forall r \in R \]
**MATHEMATICAL FORMULATION**

**CONSTRAINTS**

- **Cutting patterns balance.** Carcasses are partitioned into sections and for each section a different cutting pattern can be applied.

This constraint ensures a balance between cutting patterns and the number of carcasses processed. Equality is forced because the infeasibility to let unprocessed raw material, due to perishability issues.
CONSTRANTS

• Cutting pattern yield. Different cutting patterns can be applied on the carcass to make different products. A cutting pattern is therefore defined by a combination of a set of products and their respective yields. The following constraint calculates the total amount of product $i$, retrieved from all the cutting patterns applied in each period.

$$x_{it} = \sum_{j \in J_{t \in T}} r_{ij} \cdot z_{jrt} \quad \forall i \in P, \forall t \in T$$
It is recognized that the pork industry works with perishable products subject to spoilage. In order to extend the life of the product, it undergoes to a freezing process. Thereby, a product can be sold in two presentations, fresh and frozen. A product is considered fresh if it is sold within 4 days after elaboration. On the other hand, frozen products can be kept this way for almost 2 years. However, the profit of selling frozen products decays considerably.

- **Fresh and frozen balance.** This constraint determines the amount of product to be frozen and the ones to keep fresh to be sold in the next periods.

$$x_{it} = \sum_{l \in L} x^{f}_{l(t+1)} + x^{c}_{l(t)} \ \forall i \in P, \forall t \in T$$
CONSTRAINTS

• **Fresh product to be sold.** As mentioned, fresh products are not allowed to be kept for more than 4 days. Constraint 7 calculates the total amount of fresh products that can be sold in a period \( t \), but were produced in previous periods.

\[
v^f_{it} = \sum_{l \in L} x^f_{i(t-l) t} \forall i \in P, \forall t \in T
\]

• **Frozen product to be sold.** Fresh products need to stay at least 2 days in the freezing tunnel, to be considered frozen. The following constraint balance the inventory of frozen products at each period.

\[
v^c_{it} = i^c_{i(t-1)} + x^c_{i(t-\tau)} - i^c_{it} \forall i \in P, \forall t \in T
\]
MATHEMATICAL FORMULATION

CONSTRAINTS

• Demand of frozen products. Ensures that the requested level of each frozen product is addressed, allowing the existence of unsatisfied-demand in the case the raw materials are insufficient.

\[ v^c_{i,t} + d^c_{i,t} = D^c_{i,t} \]

• Demand of fresh products. Ensures that the requested level of each fresh product is addressed, allowing the existence of unsatisfied-demand in the case the raw materials are insufficient.

\[ v^f_{i,t} + d^f_{i,t} = D^f_{i,t} \quad \forall i \in P, \quad \forall t \in T \]
MATHEMATICAL FORMULATION

CONSTRAINTS

• Labor capacity.

\[
\sum_{j \in J} \sum_{r \in R} z_{jrt} \cdot t_{j} \leq T_{t} \quad \forall t \in T
\]

\[
\sum_{j \in J} \sum_{r \in R} z_{jrt}^{E} \cdot t_{j} \leq T_{t}^{E} \quad \forall t \in T
\]

• Wharehouse capacity for fresh products.

\[
\left( \sum_{l=0}^{l_{f}} + \sum_{l=0}^{l_{f}} x_{i(t-l),t+l}^{F} + \sum_{i \in P} \sum_{l=1}^{l_{f}} x_{i(t-l)}^{F}\right) \leq C_{l}^{F} \quad \forall t \in T
\]

• Wharehouse capacity for frozen products.

\[
\sum_{i \in P} i_{it}^{C} \leq c_{t}^{e} + C_{t}^{C} \quad \forall t \in T
\]

• Freezing tunnel capacity.

\[
\sum_{i \in P}(x_{i(t-1)}^{C} + x_{i,t}^{C}) \leq C_{t} \quad \forall t \in T
\]
CASE OF STUDY

We are working with data from different companies
A Scheduling and Capable-to-Promise Application for Swift & Company

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Swift & Company uses an integrated system of 45 linear-programming models based on three model formulations to dynamically schedule its beef-fabrication operations at five plants in real time as it receives orders. This scheduling application resulted in documented improvements in key metrics, such as order fulfillment, on-time delivery, and the percentage of a week’s scheduled production for which there are existing orders. The application enabled Swift & Company to execute its business strategy and obtain a 200 percent return on investment in its first year of production.

Key words: industries: agriculture, food; programming: linear, applications.
Moreover. The model gives the ability to ask ‘what if? questions such as

- What is the effect on profit as further cutting patterns and extra products become available?
• The fattened pig ready for slaughtering is the output from several productive and reproductive biological processes.
• The fattening is the last biological process before the pig is marketed as a live animal, and sent it to the slaughterhouse to be processed as a meat.
As pigs reach marketable weights near the end of the finishing phase, a pork producer must devise a marketing strategy to determine when to sell pigs, which and how many pigs to sell.
The major complexity faced in this problem is in managing the biological variance; owing to it, pigs reach optimal conditions for slaughter at different times of the fattening period.
Figure 1. The structure of the pork supply chain considering two levels, fattening farms and the meat packing plant.
CONCLUSIONS

• The new competitive strategy in pig farming is no longer based on individual farms units, but rather integrated into a supply chain.

• Traditionally, judgement based on experience had been the basis for the production planning. However recent changes have driven to a more complex business planning enviroment, and thereby made the development of more formal planning methos necessary.

• Analitical tools has the potential to increase profits through a better undertanding and new insights for their marketing strategy and production operation.

• Adoption of OR methods in the PSC progress slowly like in other industries of the primary sector. It may benefit of the development of user-friendly DSSs in a narrow collaboration with the industry.
THANK YOU!

If you have any comment, suggestion, …please write to:

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**THE SOW REPLACEMENT PROBLEM**

- The piglet production capacity

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*Fig. 1. Sow herd dynamic behaviour.*
THE SOW REPLACEMENT PROBLEM

• The piglet production capacity

Fig. 1. Sow herd dynamic behaviour.
P: Set of products.
J: Set of cutting patterns
K: Set of carcass sections.
T: Planning horizon (days)
L: Shelf life of for fresh products.
R: Set of type of carcasses.
$p_i^F$: Selling price per fresh product i.
$p_i^C$: Selling price per fresh product i.
$C_j$: Operational cost of pattern j.
$C_j^E$: Operational cost of pattern j in overtime.
u^C: Freezing cost per kilogram.
$cm^C$: Holding cost of frozen products.
$cm_i^F$: Holding cost of fresh products.
CME: Holding cost by outsourcing.
$S_i^F$: Penalization for unsatisfied demand of fresh product i.
$S_i^C$: Penalization for unsatisfied demand of frozen product i.
SET AND INDEXES

$CT_t$: Freezing tunnel capacity at period $t$.
$D_{it}^F$: Demand of fresh product $i$ in period $t$.
$D_{it}^C$: Demand of frozen product $i$ in period $t$.
$CI^F$: Warehouse capacity for fresh products.
$CI^C$: Warehouse capacity for frozen products.
$t_j$: Cutting operation time for pattern $j$.
$T_t$: Available work hours at each period.
$T_t^E$: Available overtime hours.
$r_{ij}$: Yield of product $i$ in pattern $j$.
$H_r^{max}$: Total number of available carcasses of type $r$ to process in all planning horizon.
$H_r^{min}$: Minimum number of available carcasses of type $r$ to process in all planning horizon.
$\tau$: Minimum period of time a product must stay frozen before sale.
REFERENCE


