Abstract.

A model for optimization is developed in this article in reference to the sending of fruit pallets for export from various packing plants, by land, aiming to solve a problem in the distribution area, between the packing plants and the shipment ports, by the diversity of freights and the existence of non programmed distribution orders, there is an increasing of the land transport costs. The problem consist of coordinating the stationary production of fruit fields with the packing plants, and these ones, with the land freights and the availability of vessels at the shipment ports, where the fruit is shipped abroad. The problem is approached by developing a model of linear programming which has as forecasting parameters the supply and demands, transport cost, validating itself in a Chilean export company, where transport saving in costs up to 2.6% were obtained; likewise additional improvements in the programming, prediction of the demand, and minimising the false freights.

Keywords: Optimization, distribution, packing and storage plants, shipment ports.

1.- Introduction.

To optimize pallets distribution from \( n \) processing plants to \( m \) ports, a problem of disorder and inefficiency arises in the distribution line, which can be noted in the co-ordination between packing plants and ports, it also can be noted, the diversity of freight and the existence of non programmed orders. For these reason this problem, is to be studied in this project to find a technical and economical solution by means of a lineal program. This model will be validated in an export company.

The problem is approached first by studying the present situation of the transport systems in the company, where the flow of fruit pallets is strongly affected by the supply and demand, which is not constant varying within the year. Peak volume exported in the fruit season (December-April) and a very low volume during the rest of the year, hence the necessity to respond quickly before a change of surrounding, without harming clients, suppliers or producers.

The company mainly exports a great variety of fruits, focussed to two great markets: The United States and Europe. But, there are also other growing market like other market like Asia and South America. These ones approximately receive a 18% of the exported total volume, nevertheless, this volume increases each season, due to opening of the markets. This imposes logistic challenges to the company since the demand in these area does not have detailed purchase, as in the case of the U.S.A. and Europe. Consequently, last minutes orders increase cost derived from this operation.

Fruits have different stages of ripening and different packing processes. Each type of fruit has a different demand requirement, which depend on demand of each market.

The company must respond to the demand of the foreign markets, according to the weekly commercial program of the company in charge of the availability of ships in ports in the corresponding dates established for the shipment boarding.

The present situation will be found further in this document in relation to the development of the model, its validation, results and conclusion.

2.- Methodology

2.1 Description of the operation from the plants to the ports

Approximately 80% of the shipment are concentrated in the season Fruit, from December to June, being the peak of volume between January and March. The fruit harvested in the months of November and December and the one of the end of season, presents/displays great logistic challenges, since the produced volume is smaller and a shortage of vessels is produced. For this reason cost of transport are increased when trying to reunite cargo from different plants with no plans programs whatsoever to carry this cargo by land to embarkation port.

The criterion for the choice of the port for the fruit, depends on nearness of the plant or the refer chambre owing to the great availability of vessels and products. However, in the low season the criteria to choose the
port of departure change depending on the factors such as:
- Fruit availability of (shortage).
- Ships availability and schedule.
- Cargo availability at port to fulfill with vessels itinerary and export demand.
- Pricing of fruit at destination final customer (in a determined week).

If the customers' goals, is not achieved to the company image is damaged.

### 2.2 Description and development of the model

In order to develop the model on three types of information are needed:
1. Commercial program of the company, that is the demand the company wishes to satisfy.
2. fortnight information of availability of fruits, in the plants processors and/or reefers chambers supplied by the company.
3. Itineraries of ships, their availability and dates of stay in port, to program the shipments to port and thus to satisfy the demand abroad.

The methodology used here is based on methods of whole linear programming, networks, external logistic distribution and, economy and formulation of polynomials. In this problem a given combination of class and condition of the cargo is as follows thing:
- a solution of problems of flow of minimum cost, minimum route, maximum flow. [1] [2]
- An economic analysis of the transports situation, for the quantification of all the costs associated to the distribution chain.
- A formulation of polynomials of costs and benefits which will be optimized through linear programming.

### 2.2 Description of the variables of the problem

#### Required information

1. Plants packing fruit to the requirement of the company (fixed data).
2. The ports and sea lanes are fixed and depend on the demand abroad (fixed data).
3. The dates of ships arrivals (fixed data).
4. The cycle of the fruit, (harvests and ripening), is fixed and known.
5. The week fruit has priority.
6. Two types of containers are used; two standard and European one.
7. Three types of trucks are used: flat canvassed, reefer container, cooled thermos.
8. pallets Transport cost from different plants to shipment hubs.

Pallets transport cost [5] from plant to port are shown, where blue numbers are freights not being carried out. As the optimisation requires a full matrix, such numbers have a high value (1000) to avoid them for being considered in the optimisation.

### 2.3 Formulation of the model

The model is solved with a computer platform in which the situation of sent pallets from plants to port is boarded. The situations of supply and demand considering
- Balanced Supply and demand;
- Supply greater than demand;
- Supply smaller than demand.

Two optimisations are made from a type of plant, the first single one with a type of fruit and second one several types of fruits.

#### 2.3.1 First Optimization.

Maximum capacity is defined as the one allowed by the truck, and the minimum one is that one the company is ready to pay if less pallets than the maximum capacity of the truck are carried (minimum capacity) In this optimisation: “Single full loaded trucks with the minimum allowed capacity are considered to carry out the journey to port (i.e. if the trucks carries 10 pallets, collection will for 20 pallets since its minimal capacity of collections is for 20 pallets in order not to increase the land transport).

For example: Rapel plants: maximum capacity: 20 pallets standard bases and 25 European base; minimum capacity of pallets allowed: 18 base and 22 European base. If a truck takes 15 pallets standard bases the collection will be by 18 pallets and not by 15, this means 3 pallets of false freight, (it is paid by them but they are not transported), This is what is wanted to be avoided with this project.

The objective Function is sumatory of the individual costs, to satisfy to minimum cost a given demand, in number of pallets, with a pre-established date and place. That is to say, sumatory of cost of transfer of pallet, coming from the plant or reefer chamber. Then the objective function is the following one formulates.

\[
\text{MINF}(x) = \sum_{k=1}^{6} \sum_{i=1}^{12} (P_{ik} \cdot C_{ik})
\]

\[F(x): \text{Function of amounts to transport, by transport costs.}\]
\[P_{ik}: \text{Amount of pallets to transport between plant i and port k.}\]
\[C_{ik}: \text{cost of transporting pallet between plant i and port k.}\]
\[i: \text{Index of plants.}\]
\[k: \text{Index of ports.}\]

Restrictions formulation

1. \[P_{i} <= O;\]
2. \[P_{i} \in Z^{+};\]
3. \[\sum_{i} P_{ik} >= 0;\]
4. \[D_{t} <= O;\]
5. \[\sum_{i} P_{ik} <= O; \text{ con i fijo y k changing.}\]
6. \[C_{M} >= P_{Vik};\]
7. \[C_{M}C_{ik} <= P_{Vik}.\]
with:
P_i: Amount of pallets to take from plant “i”. (Endogenous variable)
P_{ik}: Amount of pallets to take from plant “i” to port “k”. (Endogenous variable)
O_i: Amount of pallets offered from plant “i”. (Exogenous variable)
D_t: Total pallets Demand. (Exogenous variable)
O_t: Total pallets from plant “i” Supply. (Exogenous variable)
CM: Maximum truck capacity..
P_{Vik}: Amount of pallets for trip between plant “i” and port “k”.
CM_{Cik}: Minimum truck capacity for trip between plant “i” and port “k”, to avoid fake load.

Summit to the followed restrictions:

1) The amount of pallets to take from each plant (individually, it means, for each kind of fruit to each port), must be less or equal to the amount offered from that plant.
2) The variable “number of pallets to take from each plant” must be an exact number, not fractions.
3) y 6) The “variables” can not be negative
4) The total demand must be less or equal (in each port) to the total Supply from each plant.
5) The sum of the amount of pallets to take off and transport, from each plant to all open ports must be less or equal to the amount of pallets offered from that plant.

D_t: Total pallets Demand. (Exogenous variable)
O_t: Total pallets from plant “i” Supply. (Exogenous variable)
CM: Maximum truck capacity.
P_{Vik}: Amount of pallets for trip between plant “i” and port “k”.
CM_{Cik}: Minimum truck capacity for trip between plant “i” and port “k”, to avoid fake load.
i: index of plants .
k: index of ports.

The model proves through the first optimisations, the wide use of truck resource to lower land costs. Land journeys are classified in full or partial ones. The full ones optimises the freight costs based on a number of pallets by journey.

Once the first optimisation, is finished, leftover pallets are left due to the multiplicity of offers at plants, and the lack of fruits production in accurate amounts at packing plants, so the remaining pallets must be attached to a new calculation sheets to be optimised under a pre-established new criterion.

2.2.3 Second optimisation.

This optimisation is made by mixing pallets with different types of fruits, in a same truck. But the combinations must be feasible not to affect the quality of the product. (for example kiwis can be combined with cherries; the apples with pears but not with kiwis). Then if the combined amounts of pallets, are greater or equal to the minimum transport capacity of the trucks of the plant, the second optimisation can be made as such: "full Trucks and with minimum capacity allowed, from a single plant, using different types of compatible fruits in a single truck.

This is because the journeys to port from a single plant are economical, because they drive straight to port; versus the inter journeys trips plants. On the other hand, if this optimisation is made, it will also give a certain number of pallets leftover that was grouped by combinations of fruits. Then the formulation of the model is the following one:

\[
\min F(x) = \sum_{k=1}^{12} \sum_{i=1}^{6} (P_{ik} \cdot C_{ik})
\]

F(x): Function of amounts to transport, by transport costs.
P_{ik}: Amount of pallets to transport between plant i and port k.
C_{ik}: Cost of transporting pallet between plant i and port k.
i: Index of plants .
k: Index of ports.

Restrictions formulation :

1) P_i <= O_i;
2) P_i \in \mathbb{Z}^+;
3) P_i >= 0;
4) D_t <= O_t;
5) \sum P_{ik} <= O_i ; \text{con i fijo y k changing.}
(A) CM >= P_{Vik};
(B) CM_{Cik} <= P_{Vik}.
(C) RF = true.

with:
P_i: Amount of pallets to take from plant “i”. (Endogenous variable)
P_{ik}: Amount of pallets to transport between plant i and port k. (Endogenous variable)
O_i: Amount of pallets offered from plant “i”. (Exogenous variable)
D_t: Total pallets Demand. (Exogenous variable)
O_t: Total pallets from plant “i” Supply. (Exogenous variable)
CM: Maximum truck capacity..
P_{Vik}: Amount of pallets for trip between plant “i” and port “k”.
CM_{Cik}: Minimum truck capacity for trip between plant “i” and port “k”, to avoid fake load.
RF: combinations fruit restrictions
3.- The test of model

The model is tested in two types of week, one of high volume and other of lower volume, then given low to the demand and supply, (2005-48 and 2005-49 separately); I assign in average a 45.37% of the rest of the fruit which is assigned in the second optimisation.

For the weeks of high volume of fruit (2006-11 and 2006-12) I assign in average a 86.77% of the demand, of the rest of the fruit which is assigned in the second optimisation.

The indicates detail is as follows:

Results of first optimisation

Weeks with low volume to transport.

Satisfied demand
Week 48 (2005): 33,60 %.
Week 49 (2005): 57,14 %.

Weeks with high volume to transport.

Satisfied demand
Week 11 (2006): 88,31 %.
Week 12 (2006): 85,22 %.

Results of second optimization

Weeks with slow volume to transport.

Satisfied demand
Week 48 (2005): 79,52 %.
Week 49 (2005): 97,78 %.

Weeks with high volume to transport.

Satisfied demand
Week 9 (2006): 95,33 %.
Week 12 (2006): 96,25 %.

In the second optimisation either in low and high demand (volume) is fulfilled a 95%, 96% and 97% was reaches of each period of the season respectively. In order to assign the rest of demand in an inter plants optimisation is being researched now.

4. CONCLUSIONS

With the obtained information it is concluded that the model implementation improves the current situation of the company; for this cost/benefits ratio tends to be 1; with a value of 0.026 value, which results in cost savings around to 2.6%.

2004-2005 season is taken as a projection of costs for 2006,2007 y 2008 seasons, by means of a decomposition method, in order to obtain the actualised net benefits. The results are shown in table 1.


<table>
<thead>
<tr>
<th>Years</th>
<th>Cost (US$) Without Project</th>
<th>Cost (US$) With Project</th>
<th>Savings (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>253688,06</td>
<td>247893,07</td>
<td>5794,99</td>
</tr>
<tr>
<td>2007</td>
<td>269095,77</td>
<td>250423,67</td>
<td>18672,10</td>
</tr>
<tr>
<td>2008</td>
<td>275918,27</td>
<td>246812,66</td>
<td>29105,61</td>
</tr>
</tbody>
</table>

It is concluded that with the obtained data, the project implementation improves the current situation of the company; for this cost/benefits analysis was used in a projection where the year to 2007, saves around 3% in relation to a similar situation (without a model) showing a gradual raise of 7% in the year 2007 and even a 10% in the year 2008.

Another conclusion is based on the improvement of the demand in the growing markets like Asia and South America, which reaches a 18% of the whole volume, of exports. These fact shows a growing volume each season, given the fact that the demand in these market is not easily computable.

These given model will permit to do last minute programming to avoid the available trucks to be dispatched without a full availability, like wise, for the vessels capacity.

3.91% of pallets sent on board was optimise due to the fact that these where stored at various packing plants in amounts less than those permitted to be transported by each.

These little percentage of pallets do not assure a minimal cost and it will probably be possible that these one may be come false freights. A 3º criterion must be found to send these pallets to port accordingly.

Interplant journeys was not used as an optimisation alternative owing to two reasons:
- it is not economically feasible
- the company does not have ac cost matrix for interplant journeys due to lack of information in these respect.

4. REFERENCIAS


Empresa de Alimentación, Actas V Congreso Chileno de Investigación Operativa, Valparaíso, Chile


Instrucciones de EXCEL Solver, Internet.