AN OPTIMIZATION MODEL TO AGROINDUSTRIAL SECTOR IN ANTIOQUIA (COLOMBIA, SOUTH AMERICA)

J Fernandez
Titular Professor, University Pontificia Bolivariana,
E-mail: javier.fernandez@upb.edu.co

Abstract. This paper develops a proposal of a general optimization model for the flower industry, which is defined by using discrete simulation and nonlinear optimization, whose mathematical models have been solved by using ProModel simulation tools and Gams optimization. It defines the operations that constitute the production and marketing of the sector, statistically validated data taken directly from each operation through field work, the discrete simulation model of the operations and the linear optimization model of the entire industry chain are raised. The model is solved with the tools described above and presents the results validated in a case study.

1. Introduction
Today the floriculture sector is one of the main economic sectors in Colombia, exporting more than a billion dollars annually. Generating not only economic impact in the country but also a social impact, as it is the largest employer in the agribusiness sector as [1]. However, although Colombia is one of the largest producers of flowers in the world, the Colombian flower industry is going through a difficult economic situation, marked by a cyclical revaluation of the peso against the dollar, by increased production costs, including the labor [2], while sale prices remain the same [1]. Given this scenario it is required the use of various tools to maximize the use in this sector of human capital, which represents between 50% and 60% of total production costs. However, progress in the field largely involves standardizing working methods, determination of capacities, volumes and profitability indicators among other things that in this work are referred to the three phases in which the model has been divided: harvesting, post-harvest and marketing.

In this context, we have developed an optimization model for the flower industry, which has been applied to a real case study with discrete simulation techniques and linear optimization with the help of the tools Gams and Promodel respectively.

This article is organized as follows. Section 2 discusses some related work. Section 3 provides an analysis of the sector. Section 4 presents the model and discusses the results. Finally, we present the conclusions and following work in Section 5.

2. Related works

1 Industrial Engineering Faculty, Circ. 1 N-70-01, B 11 Of. 234, Medellin, Colombia
Some of the related work is found in proposals such as [3] in which is developed a model of optimization and improvement of a process, using time study in a company in the floriculture sector. In this proposal were identified the activities that presented problems and subsequently were defined improvement actions. Diagrams tours technique was implemented.

Meanwhile the work of [4] is based on characterizing the system costs of some floral species whose aim was to provide a tool for the industry to develop their business competitively. The ABC costing technique was used.

However, previous studies did not demonstrate the use of combined discrete simulation techniques and linear optimization for the flower industry, which is the added value of this work.

3. Sector situation

3.1. International situation

The global floriculture is characterized by a large number of producing countries, competing in a globalized free market, trying to meet the diverse global markets, which are mainly in developed countries. According to [5] cut flower cultivation is widely spread throughout the world, is included in statistics of 145 countries, according to the International Horticultural Society (ISHS, for its acronym in English), the global surface designed to flowers cut is 60,000 hectares.

It is therefore, that in 2008 global production of flowers per area was distributed as follows: Asia with 75%, Europe 10%, Central and South America 9% 4% North America, Middle East 1% and Africa 1%. As for exports, six (6) countries cover 75% of world exports. The main flower exporting country is the Netherlands with 42%, followed by Colombia, which exports 13%, the other major exporters in the world are: Kenya, Ecuador, Israel and China, with 7%, 5%, 4% and 3% respectively. Of the total supply, 60% is demanded by Germany, United Kingdom, United States, Netherlands, France and Japan. [6]

It is then, that the European continent is the largest consumer of fresh flowers, demanding nearly two-thirds of world exports (65%) in which Germany imports about the same amount that is exported by Colombia (1.043 billion dollars). The second continent that import the most, is the American continent, with 16% share in global consumption of imports of flowers, where the main buyer is the U.S., which imports 90% of total demand for the continent, then followed by Canada and Chile [7].

Undoubtedly the biggest competitor for Colombia in the continent is Ecuador, who although nowadays exported $ 507 million, representing a little more than half of Colombia's exports, this is tending to grow in the coming years. [7]

3.2. National situation

The flower industry in Colombia is one of the main export sectors of the country, which generated in 2011 more than 180,000 direct and indirect jobs in more than 7,000 hectares in 48 municipalities in the country and by 2012 it is estimated that the total of jobs created was 219,323 jobs, of which 120,640 were direct and 68,683 were indirect jobs. [1] [8] becoming a local development actor and a major player in the global market, according to [10] the flower industry is, after coffee, the largest foreign exchange earner of agricultural goods. 95% of production is exported: 84% goes to the U.S. and 9.8% to the European Union [5]

The flower industry is today the largest exporter of non-traditional agriculture, with sales exceeding one billion dollars, representing 25% of female rural labor, is the largest employer in the area of agribusiness in the country (15 employees per hectare). [1] [7]. In addition, the flower industry for the national economy is one of its main sources of income to represent 6.6% of the Colombian agricultural GDP.

The country has three regions that produce the most flowers. These regions are: Cundinamarca that produces 79% of the national flowers, Antioquia 17% and the rest of the country mainly in the Coffee-
Growers Axis and Valle del Cauca 4%. [8]. in 2009, the flower industry had 7,290 hectares cultivated and offered fresh cut flowers for export. The 79% of the cultivated area is located in the Bogotá savannah, 17% in Antioquia and 4% in other departments, which include Valle del Cauca and the Coffee-Growers Axis [8]. Likewise, Colombia produces more than 50 species and 1500 varieties of flowers, making it the largest exporter of flowers to the United States and the second largest exporter in the world after The Netherlands. [8] [9].

The most produced flower species in Colombia today are: roses, carnations, chrysanthemums, alstroemeria and pompons, being the largest producer of carnations. Whose behavior at the production level for 2012, according to [1] was the following:

| Types                        | %  |
|------------------------------|----|
| Roses                        | 32 |
| Carnations                   | 14 |
| Mini Carnations              | 7  |
| chrysanthemums and pompons   | 8  |
| Alstromelies                 | 5  |
| Others                       | 33 |
| The rest                     | 1  |

On the other hand, Colombia exports 95% of its production of flowers (cut flowers), mainly roses and carnations. A large percentage of these exports is done in an atomized way, i.e., participate in them many agents and / or brokers, which does not allow competitive pricing in the market, and limit the direct involvement of Colombian flower growers in international distribution channels. Although, currently they are getting higher profits by selling the flowers packaged as "bouquets" (flower arranging) and not in boxes, to marketing centers.

Furthermore, the sector is characterized by flower production made mainly by SMEs that export in an atomized way. The 90% of total exports in 2004 (U.S. $ 703 m) was traded by 228 companies, each of which, did not export on average more than $ 3 m. In this sense, the production of flowers is basically for external market and sales have a seasonal pattern. This condition causes the domestic market takes surplus production and non-exportable flowers. It is also characterized by high working capital requirements (cash flow) for the continuous recruitment of labor, with an imported component in low production elements such as agrochemicals and cuttings.

Likewise, the industry benefits from advantages like the FLORVERDE ® seal, with which certify the quality of their products and the efficiency in production processes worldwide. It has robust social responsibility programs, along with the support of national and international entities; tariff preferences to enter the U.S. market granted by the ATPDEA system, facilitate the competitiveness of Colombian flowers in that market.

By having these advantages and features, the Colombian flower industry is in the ability to export 95% of total flower production, specifically cut flowers (roses and carnations mostly) relatively cheap labor and low costs of transport and storage by proximity to the ports of embarkation. However it is also characterized by low utilization of technical change and little research and development of new varieties and production techniques at national level; high costs associated with the specialized transportation of flowers and the introduction to the U.S. market (Cold management systems, hiring phitosanitary control inspectors and controls to prevent drug trafficking, among others). These costs
are borne by exporters, as well as the high exposure to uncontrollable factors such as climate change (hail, frost, excessive rain, and wind), diseases and pests.

4. Proposed model

It has been proposed a model based on the floriculture production chain, specifically in the Environmental Guide for floriculture proposed by [11], in which the development process that allows the production of flower comprises four stages: Propagation (plants mothers), Propagation (Banks rooting), production and Post-harvest and support stages of the production process: Construction and maintenance of infrastructure and activities. And the production scheme referenced in [12] called Colombian Florist cluster anatomy, which evidence the elements that feed the system and provide inputs for both harvest and post-harvest also shows the stages of production and presentation of the finished product. Then there are the distribution systems, transportation and marketing, which are mostly in foreign markets, and finally, the cluster support institutions.

Then, the proposed model has been defined, based on three sub-models: the cutting sub-model, post-harvest sub-model and marketing model.

4.1. Cutting submodel

In this study we proceeded to the respective time-making for the case study and their respective statistical validation using Statgraphics tool and statistical module Input Analyzer Arena simulation software and the establishment of model assumptions, the definition of model variables such as: the processing time cutting stages, initial resource number (flower), number of locations, time between cutting cycles, number of branches and branches average time for the simulated model entities of 5, 7 and 9 stems.

Then with the help of the tool Promodel, we proceeded to define the elements of the model as the locations (Consolidation Bouquet, Measurement and Cut, Place rubber and cap, Shaking and place in bucket, receipt and deposit), entities (Flower type (1,2 and 3), consolidation of stems, branches type (1,2 and 3)), arrivals (arrivals were configured like flowers (1,2 and 3) receiving the beds by the number of stems), networks (from receiving to the warehouse), variables (defined quantities and times for each operation of the process, the cycle time for each bed, ie for each number of stems, the total number of stems of each bed and the total number of branches) and renders of the model. As shown in the following figure:

![Figure 1. Cutting Simulation Model](image-url)

Finally, we proceeded to set the simulation model, with the aim of determining the standard operation time in the whole process.
Table 2. Cutting times.

| Operation               | Real average | Simulated average |
|-------------------------|--------------|-------------------|
| Consolidation Bouquet   | 0.26         | 0.26              |
| Measuring and cutting   | 0.11         | 0.11              |
| Place rubber and cap    | 0.23         | 0.21              |
| Shake and Placing       | 0.04         | 0.05              |

Where it was determined that the current average cutting time for a bouquet is 0.63 minutes versus an average simulated time of 0.62 minutes, so that an skilled operator in normal conditions, cut 483 stems per hour on average.

It was observed also that the most critical operations of the cutting process are: consolidation stems at an occupancy rate of 28.21% of the total cycle time and place rubber cap with a percentage of 23.26%. Data was statistically validated by applying the central limit theorem creating confidence intervals for each of the 30 replicas simulated operations.

4.2. Postharvest Submodel

We proceeded to the respective time-making for the case study and their respective statistical validation using the Statgraphics tool, as well as the establishment of model assumptions, the definition of model variables as the amounts of meshes in each transaction processed.

Then, with the help of the tool Promodel, we proceeded to define the elements of the model as the locations (Cold Storage, classification, Boncheo, Court, Labeling, and Packaging Rinse), entities (meshes, stems, packages and boxes), arrivals (meshes arrivals were set), nets (from the classification to the storage), resources (operators defined for each operation of the process), attributes (att_meshes and att_general), variables (number of ordered meshes defined, number of branches in boncheo, number of sectors in cutting, the number of branches in labeling and rinsing, the number of packed boxes and number of stored boxes) and renders of the model as shown in the following figure:

![Simulation model of post-harvest](image)
Finally, we proceeded to set the simulation model, with the aim of determining the standard operation time in the whole process.

| Operation | Real average | Simulated average |
|-----------|--------------|-------------------|
| Classification | 4,52 | 3,66 |
| Boncheo | 1,37 | 1,11 |
| Cutting | 0,19 | 0,15 |
| Labeled | 0,11 | 0,09 |
| Rinse | 0,24 | 0,19 |
| Packing | 2,39 | 1,94 |

From this, it was determined that the real average time of a post-harvest to a mesh that is transformed in a bouquet, and then in box is 8.82 minutes, compared to an simulated time of 7.14 minutes.

4.3. Marketing Submodel

For the Marketing submodel, has been taken as reference a linear optimization, whose role was raised around throughput, term used in the theory of constraints (TOC) to refer to operating profit, expressing utility in terms of sales minus unitary costs.

We grouped the varieties of flowers according to the classification proposed by the catalog of flowers [13] and the classification made by the [14]. We selected only those varieties that in addition to high demand in Europe are also produced in Colombia. Defining high demand in Europe as those varieties of flowers that had been, according to Market News Center [14], among the top 15 varieties market for the years 2011 and 2012. Both demand and selling price in Europe were obtained from weekly reports Market News Service [14], taking the years 2011 and 2012.

The behavior of price and demand was separately analyzed in monthly series to identify seasonality. The cost of transport was obtained from Proexport (Colombia) through the Fee Routes tool; the rate provided by this tool was in terms of the weight of the goods, so it was necessary to convert the average weight for a stem of different types of flowers.

The proposed optimization model is of the form:

$$\text{Max } \sum((D_{ij} \times P_{ij} \times X_{ij}) - ((C_{ci} + C_{ti}) \times X_{ij})) \times \text{Throughput}$$

S.A:

$$X_{ijk} \leq D_{ijk}$$ (Restriction of demand)

$$\sum(\sum(X_{ij} \times H_{ij}) \leq H_{ti}$$ (Restriction of capacity).

Where:

- $i$: Variety of flower
- $j$: Month of the year
- $X_{ij}$: The number of flower stalks types $i$, to market in month $j$.
- $D_{ij}$: The demand for the type of flower stalks units $i$ in month $j$.
- $CC_{ij}$: Cost of harvest and post-harvest flower per stem type $i$ in month $j$.
- $C_{ti}$: Shipping Cost flower per stem type $i$ in month $j$.
- $P_{ij}$: The selling price of the flower $i$ in month $j$. 


Taking data for the period 2011-2012, we preceded to the implementation of GAMS tool to solve the issue, so that:

Figure 3. Flowers marketing optimization model

The following are the results obtained by the proposed model for the analyzed varieties of flowers:

| [N° Stems] | Ene | Feb | Mar | Abr | May | Jun |
|------------|-----|-----|-----|-----|-----|-----|
| Rose Large | 185349 | 239030 | 217196 | 213480 | 229778 | 209979 |
| Cris. Spray | 56514 | 59444 | 61425 | 71361 | 86746 | 0 |
| Cris. S.Bud | 11189 | 11934 | 11444 | 11819 | 14543 | 13695 |
| Rosa M&P | 21592 | 25929 | 26357 | 23760 | 21847 | 21962 |
| Gerbera Min | 34794 | 37970 | 47667 | 47214 | 57542 | 46928 |
| Gerbera Lar | 7665 | 8206 | 10333 | 10093 | 13274 | 10958 |
| Alstroemer | 10458 | 10844 | 11730 | 10093 | 13274 | 10958 |
| Rosa Spray | 210 | 0 | 0 | 77748 | 18353 | 0 |

| [N° Stems] | Jul | Ago | Sep | Oct | Nov | Dic |
|------------|-----|-----|-----|-----|-----|-----|
| Rose Large | 186747 | 179219 | 179800 | 198825 | 199715 | 187571 |
| Cris. Spray | 0 | 0 | 0 | 77748 | 18353 | 0 |
| Cris. S.Bud | 13760 | 15185 | 16879 | 22277 | 21238 | 11645 |
| Rosa M&P | 18196 | 13640 | 14954 | 18794 | 18205 | 20511 |
| Gerbera Min | 44106 | 45624 | 49412 | 46267 | 42597 | 38325 |
| Gerbera Lar | 9122 | 9288 | 10280 | 9500 | 8087 | 7112 |
| Alstroemer | 18244 | 17281 | 15828 | 13211 | 11935 | 10688 |
| Rosa Spray | 9652 | 9034 | 9099 | 8995 | 9726 | 9089 |
5. Conclusions and future work

The proposed model for the flower industry has managed to develop from three sub-models: the cutting sub-model, the post-harvest sub-model and the marketing sub-model, the first two have been resolved with discrete simulation and the last one with linear programming, whose support tools for resolution have been adapted to the needs of the system.

Facing the model itself, it was established average standard times for cutting threads and post-harvest to ensure adequate amounts of supplies for marketing model, from this, it was concluded that the simulated time for cutting a stem is 0.62 minutes, the post-harvest time for a box is 7.14 minutes, so the time of producing a flower box for export under the proposed models is cutting 6.21 minutes and 7.14 minutes for post-harvest, for a total of 13.35 minutes per box.

Now, for a total volume estimated by the optimization model of 4,448,592 stems, i.e. 88 972 boxes, the cycle time to meet this demand will be 1,187,774 minutes, equivalent to 2200 workdays of 9 hours, which is a critical indicator in the sector to meet a demand of this kind, if we take that the sector directly employs 120,640 direct jobs and under the assumption that all employees are in this lawsuit, we would expect a productivity of 0.73 cases per direct employment against which must be set efficiency strategies to meet the new market approaches.

As future work, it is been carrying out research to optimize the dairy sector, to provide clear evidence against the new schemes and productivity models for the country.

6. References

[1] ASOCOLFLORES. Report of activities 2011. Available at: http://issuu.com/asocolflorespc/docs/informe_de actividades_2011-12?mode=window&backgroundColor=%2323222222. 2012.

[2] Agriculture in the Americas. Creativity and Quality Key to Floricultores and present and future of marketing. The Journal of the Agricultural Sector. Volume 36 Number 345. October 2005. Media and Media Publishers.

[3] Jurado, T. M. Application of a study of methods for improving processes snapdragon in the Cornfield Flowers LTDA. 2008.

[4] Duke, A. M., Trejos, E. A., & Duke, V. E. System characterization of chain costs of flowers Tropical (Heliconia) in the department of Risaralda. Scientia Et Technica, 331-336. 2007.

[5] GRINCOMEX. Characterization of International Distributors Flowers of Eastern Antioquia. Catholic University of East Magazine. Issue 27 January-July 2009.

[6] ICESI University, ASOCOLFLORES. Floriculture: A world-class export sector. Available at: http://www.icesi.edu.co/icecomex/images/stories/pdfs/asocolflores.pdf. 2009.

[7] Bolivian Foreign Trade Institute. Market Profile flowers. Available at: http://www.ibce.org.bo/documentos/perfil_mercado_flores.pdf. 2011.

[8] National Administrative Department of Statistics-DANE. Report of Results: Census Flores Production Farms. In 28 municipalities of Sabana de Bogotá and Cundinamarca 2009. Available:<http://www.dane.gov.co/files/investigaciones/boletines/flores/Informe_resultados_2009.pdf> Accessed: February 7, 2012. 2010.

[9] ASOCOLFLORES, Ministry of Agriculture and Rural Development. The finest quality Grown Colombian cut flowers in the world. Bogota: Editorial Design Books and Journals Ltd. 2008.

[10] Reina, M. P. Acosta Oviedo S. Florist Sector against Revaluation: Current Situation and Policy Alternatives. ASOCOLFLORES Project prepared by FEDESARROLLO. Available: Accessed: February 7, 2012. 2008.

[11] ASOCOLFLORES. Environmental Guide for floriculture ASOCOLFLORES. Publishing and Audiovisual Producers Produmediros Available:
http://www.minambiente.gov.co/documentos/floricultor.pdf> Accessed: January 28, 2012.

[12] Henao, O.L and Herrera A. The cluster model in floriculture: technifies and modernizes business strategies. Agribusiness and Proflora Acopafior. 2011.

[13] ASOCOLFLORES. Catalog of flowers 2000. 2000.

[14] International Trade Center. Market News Service: Cut Flowers and Ornamental Plants. Disponible en: http://www.intracen.org/policy/cut-flowers/market-news/. 2013.