# CHAPTER V[1]

## SCENARIO ANALYSIS RELATED TO DRYING SECTOR CONFIGURATION

**Abstract**. *This work deals with a scenario analysis of a drying sector's configuration. To support this study, a simulation model was built by using Extend™ software and the software library "Grain Facility." Three scenarios were contrasted. Scenario #2 refers to a facility modeled with has one 80 t/h mixed flow dryer, three 40 t/h pre-cleaners, and four 30 t/h four cleaners. Scenario #1 was defined by decreasing dryer capacity to 60 t/h and the number of pre-cleaners and cleaners to two and three respectively. Scenario #3 was defined by increasing dryer capacity to 100 t/h and the number of pre-cleaners and cleaners to four and five respectively. Results showed no significant differences in the operational parameters related to the amounts of received, processed, transferred, and stored products (corn, soybean and wheat). The lowest firewood consumption value was found in scenario #1 (719.28t). This value was 4.95% and 10.12% lower than average values found in scenarios #2, and #3 respectively. Scenario #1also had the lowest electrical energy consumption values. The predicted average (143.53 MWh) was 9.08% and 17.49% lower than similar values from scenarios #2, and #3 respectively.*

**Keywords.** *grain storage facility, drying capacity, Extend™*

### INTRODUCTION

Operationally, grain storage facilities may be divided into sectors, such as receiving, cleaning, drying, storage, and dispatch, which need to be equipped, structured, linked upon a logical flowchart, and managed efficiently. This division and organization is be warranted to conserve product qualities and facility profits (Flores, 1988).

Drying sector is one of the key elements in a grain storage facility, due to the large investment needed, the dryer's possible operational effect upon final product quality, and the amount of fuel and electrical energy the dryer

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consumes. This paper deals with a study intended to demonstrate how changes in dryer capacity influence the grain storage facility's system performance. The experiment was carried out using a dynamic, stochastic, and discrete model that allows simulation of the dynamic of grain storage facility systems.

## BACKGROUND

According to the grain storage facility concept presented herein, the facility's system may be operationally divided into sectors. The receiving sector is in charge of accepting or rejecting a product load that needs to be cleaned, dried, and stored. Structurally, this center may include an office, a grain quality control laboratory, a scale, receiving pits, and wet holding bins.

The cleaning sector contains machines that are used to remove undesired materials, such as broken kernels, and foreign materials from grain or legume mixtures. Products are normally run through pre-cleaner machines before drying and cleaner machines after drying (Vaughan et al., 1968; Weber, 2001; Song, 1990).

The drying sector is the key element for maintaining the product quality. In Brazil, the great majority of grain storage facilities use mixed-flow dryers, also called cascade or rack type dryers (Brooker et al., 1992) with dryer capacities ranging from 15 to 120 tonnes per hour. Firewood is the traditional fuel used to heat the drying air; however, some facilities have been using propane and fuel-oil (Weber, 2001).

The storage sector is responsible for quality maintenance. Thus, it needs to have the types of structures that allow grain or legumes to be held in perfect conditions. These structures may be metal or concrete bins or a type of flat storage, which may have one or more sections. The bottom of flat storage can have flat, W, or V formats. The W and V formats being the most commonly employed in Brazil because they can be emptied using gravity (Weber, 2001). For monitoring and preserving product quality, storage structures can be equipped with thermometry and/or aeration systems. The thermometry system allows monitoring of the grain mass's temperature, a key parameter used for evidencing problems during the storage period. The aeration system is mainly employed for homogenizing and maintaining the product mass's temperature at proper levels.

The dispatching sector is in charge of delivering the stored products by means of truck or railcar. Structurally, this center is comprised of a holding structure built to allow trucks or railcars to be parked beneath it. Thus, the loading process is carried out by gravity force. The holding structures themselves are normally bins or boxes built of metal or concrete.

## EXPERIMENT ORGANIZATION

The experiment was carried out by contrasting three scenarios, which basically involved the adoption of three different capacity dryers and different numbers of pre-cleaning and cleaning machines. In scenario #1, dryer capacities are 60t/hr; in scenario #2, dryer capacities are 80t/hr; and in scenario #3, dryer capacities are 100t/hr. To support this scenario analysis, a dynamic, stochastic and discrete model was developed using the simulation language Extend$^{TM}$, version 4.1.3C (Krahl, 2000), together with the *Grain Facility* library. This library has a set of blocks that allows the simulation of structures and equipment used in grain storage facilities. Figure 1 shows the main blocks of this library.

The implemented model was developed according to the technical characteristics of a grain storage facility that belongs to COAMO, an agricultural cooperative headquartered in Campo Mourão, Paraná State, Brazil. The main technical information about the modeled facility is presented in Table 1. Table 2 shows the input information for the *Arrival Generators* block, and Table 3 shows the dispatch plans for corn, soybeans, and wheat. The model constructed is defined by scenario # 2, in which the dryers have a capacity of 80 t/h and there are three pre-cleaning and four cleaning machines.

Scenarios #1 and #3 were established by modifying the scenario #2 model. For scenario #1, the modifications were a decrease in dryer capacity to 60 t/h and a decrease in the number of pre-cleaners and cleaners to two and three respectively (Table 1). For scenario #3, the modifications were an increase of dryer capacity to 100 t/h and an increase in the number of pre-cleaners and cleaners to four and five respectively. In addition, the nominal capacity of the conveyors that input and output the products at the drying sector was adjusted.

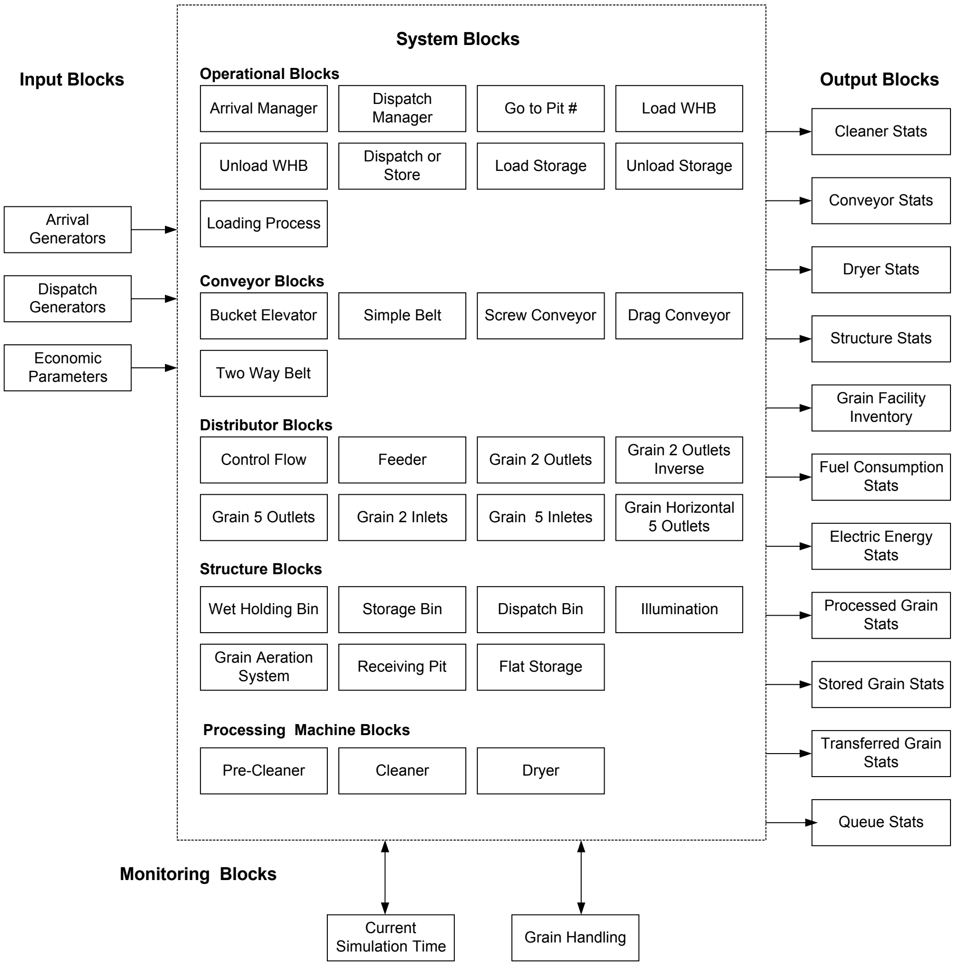


Figure 2: *Grain Facility* library schematic representation

Table 1 – Some technical information of the modeled grain storage facility (Scenario #2)

| **Structure** | **Quantity** | **Static Capacity (t)** |
|---|---|---|
| Receiving Pit | 4 | 300 |
| Wet Holding Bin | 2 | 300 |
| Flat Storage | 1 | |
| Cell-01 | | 5,000 |
| Cell-02 | | 8,000 |
| Cell-03 | | 5,000 |
| **Processing Machines** | **Quantity** | **Hourly Capacity (t/h)** |
| Pre-Cleaner | 3 | 40 |
| Dryer | 1 | 80 |
| Cleaner | 4 | 30 |
| **Conveyors** | **Quantity** | **Hourly Capacity (t/h)** |
| Belt | 4 | 120 |
| Two way belt | 1 | 120 |
| Bucket elevator | 7 | 120 |
| Drag conveyor | 2 | 120 |

Table 2 – Information used at the *Arrival Generators* block.

| **Product** | **Distribution Types for Predicting The "*daily harvest success index*" - DHSI** | **Received Amount of Products (t)** | **Harvest Period** | **Moisture Content** | | **Foreign Material Content** | |
|---|---|---|---|---|---|---|---|
| | | | | **% w.b.** | **% of loads** | **%** | **% of loads** |
| Corn | Beta | 7,376 | 01/26/99 | lower than 14.2 | 1.42 | 1.1 to 2.0 | 93.87 |
| (1st Crop) | $\propto_1 = 0.2287$ $\propto_2 = 0.5360$ | | to | 14.3 to 18.2 | 4.22 | 2.1 to 3 | 6.13 |
| | Minimum = 0 Maximum = 317.18 | | 03/06/99 | 18.3 to 24.0 | 57.60 | | |
| | | | | higher than 24.0 | 36.75 | | |
| Corn | Exponential | 7,804 | 07/17/99 | lower than 14.2 | 1.64 | lower than | 3.37 |
| (2nd Crop) | $\beta = 101.355$ | | to | 14.3 to 18.2 | 10.27 | 1.0 | 96.63 |
| | Shift = -1.3697 | | 09/30/99 | 18.3 to 24.0 | 55.12 | 1.1 to 2.0 | |
| | | | | higher than 24.0 | 33.96 | | |
| Soybean | Beta | 53,179 | 02/26/99 | lower than 14.2 | 55.02 | 1.1 to 2.0 | 92.54 |
| | $\propto_1 = 0.3665$ $\propto_2 = 1.7942$ | | to | 14.3 to 18.2 | 39.03 | 2.1 to 3.0 | 6.88 |
| | Minimum = 0 Maximum = 686.70 | | 04/30/99 | 18.3 to 24.0 | 5.85 | 3.1 to 6.0 | 0.56 |
| Wheat | Exponential | 5,118t | 08/16/99 | 14.3 to 18.2 | 54.60 | lower than | 29.22 |
| | $\beta = 100.001$ | | to | 18.3 to 24.0 | 45.40 | 1.0 | 54.55 |
| | Shift = -2.2728 | | 09/29/99 | | | 1.1 to 2.0 | 16.24 |
| | | | | | | 2.1 to 3.0 | |

Table 3 – Dispatch plans for corn, soybeans, and wheat

| Month | Stock portions to be dispatched (%) | | |
|---|---|---|---|
| | Corn | Soybean | Wheat |
| 1 | 0 | 0 | 0 |
| 2 | 20.35 | 0 | 0 |
| 3 | 29.82 | 47.18 | 0 |
| 4 | 0.15 | 14.52 | 0 |
| 5 | 0 | 20.58 | 0 |
| 6 | 0 | 0.67 | 0 |
| 7 | 0 | 6.52 | 0 |
| 8 | 20.45 | 7.81 | 0 |
| 9 | 0.55 | 0.54 | 69.96 |
| 10 | 0.55 | 0 | 0 |
| 11 | 7.03 | 1.32 | 0 |
| 12 | 21.10 | 0.86 | 30.04 |

Table 4 lists the installed electrical energy demands for the grain storage facility sectors, according to defined scenarios.

Table 4 – Installed demand (kW) per grain facility sector

| Grain Facility | Installed Demand (kW) | | |
|---|---|---|---|
| Sector | Scenario #1 | Scenario #2 | Scenario #3 |
| Receiving | 64.40 | 64.40 | 64.40 |
| Pre- Cleaning | 14.72 | 20.60 | 26.50 |
| Drying | 45.63 | 71.39 | 86.11 |
| Cleaning | 38.27 | 47.84 | 57.40 |
| Storage | 55.20 | 55.20 | 55.20 |
| Dispatch | 22.08 | 22.08 | 22.08 |
| General Use | 1.50 | 1.50 | 1.50 |
| **Total** | 241.80 | 283.01 | 313.91 |

Scenario analysis was performed considering the following parameters: processed, transferred, stored, and dispatched amounts of product (corn, soybeans, and wheat) and firewood and electrical energy uses.

For each studied scenario, five model runs were performed and averages and 99 % confidence intervals determined. The simulation time was programmed for one year (8,640 hours).

## RESULTS AND DISCUSSION

Table 5 presents the predicted 99% confidence interval for received, processed, transferred, and stored amount of products in the three studied scenarios. Figure 3 presents a schematic of the confidence interval bands for processed and transferred amounts. This last parameter corresponds to the quantity of product that had to be transferred to another grain facility for processing due facility limitations.

Table 5 – Predicted 99% confidence interval bands for received, processed, transferred, and stored amounts of products

| Scenario | Amount of products – (t) | | | |
|---|---|---|---|---|
| | Received | Processed | Transferred | Stored |
| #1 | 73,474.00 | 62,689.18 ± 2,416.06 | 5,945.57 ± 2,618.26 | 51,477.72 ± 3,834.02 |
| #2 | 73,474.00 | 64,031.42 ± 1,462.57 | 4,533.57 ± 1,590.92 | 53,642.34 ± 3791.62 |
| #3 | 73,474.00 | 63,593.19 ± 897.10 | 4,968.29 ± 1,015.19 | 52,698.57 ± 2,247.81 |

According to the information in Table 5 and Figure 3, it can be noted that values obtained for the three scenarios are very similar. The highest average amount of product processed is found in scenario # 2. This value is 2.09% and 0.68% above the values obtained from for scenarios #1 and #3 respectively. This means that, from an operational perspective, any one of the scenarios could be chosen if one is opting to maximize processed amounts.

Considering firewood consumption, the 99% confidence intervals determined for model outputs were: 719.28t ±24.77t, 754.91t ±23.94t, 792.08t ±22.61t for the scenarios #1, # 2, and #3 respectively. Comparing the average values, the greatest firewood consumption was found in scenario #3 (792.08 t). This value is 10.12% and 4.92% higher than the firewood consumption values from scenarios #1 and #2 respectively. Table 6 shows the values of simulated firewood specific consumption for the studied scenarios. The highest values were from scenario #3. It can be verified that firewood specific consumption values for processing corn, soybean, and wheat were 9.65%, 1.53% and 9.20% lower respectively in scenario #1 than in scenario #3. Therefore, considering the firewood consumption, the better option is scenario #1's dryer arrangement.

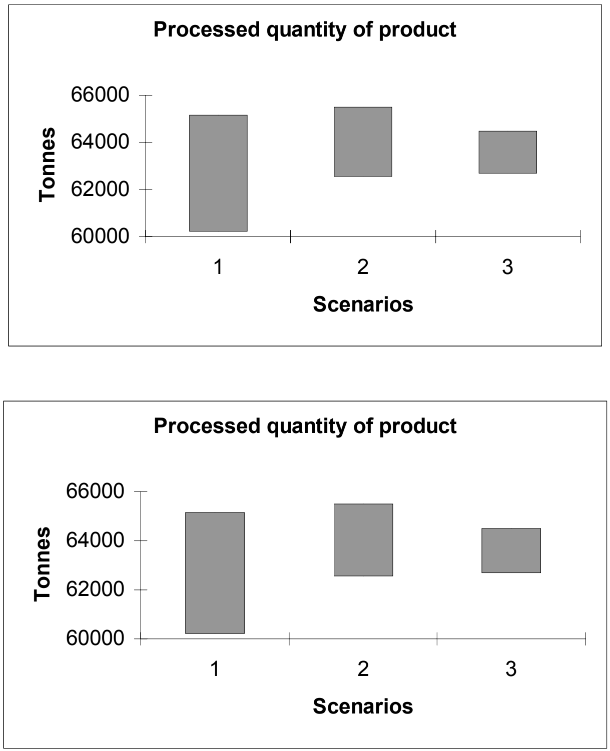


Figure 3 – Boundaries representation of 99% confidence intervals for processed and transferred quantities of product.

Table 6 - Specific firewood consumption in kg of firewood per tonne of product

| Scenarios | Corn | Soybean | Wheat |
|---|---|---|---|
| #1 | 26.20 ± 1.72 | 12.80 ± 0.92 | 15.80 ± 0.92 |
| #2 | 26.80 ± 0.92 | 12.60 ± 1.13 | 16.40 ± 1.13 |
| #3 | 29.00 ± 1.46 | 13.00 ± 0.00 | 17.40 ± 1.84 |

The 99% confidence intervals for annual electrical energy consumption in scenarios #1, # 2 and # 3 were 143.53 ± 8.10, 156.57 ±9.98, and 168.64 ±13.92 MWh respectively. The highest average value was found in scenario #3, which was 14.88% and 7.15% higher than the electrical energy consumption values from scenarios #1 and #2 respectively.

The 99% confidence intervals for the highest annual electrical energy demand from scenarios #1, # 2 and # 3 were 232.05 $\pm$15.98, 258.06 $\pm$ 6.83, and 288.01 $\pm$32.72 kW respectively. The highest average value was found in scenario #3 (288.01 kW), which was 19.42% and 10.40% higher than the values from scenarios #1 and #2 respectively.

Table 7 shows the values predicted for annual electrical energy consumption in the studied scenarios' grain storage sectors. Consumption was predicted according to installed demand values listed in Table 4.

According to Table 4, the total installed demand for scenarios #1, #2 and #3 was 241.80, 283.01, and 313.91 kW respectively. The major differences arose from the pre-cleaning, drying, and cleaning sectors. The most pronounced difference was found between drying sectors in which installed demand values were 45.63, 71.39, and 86.11 kW for scenarios #1, # 2 and # 3 respectively.

In Figure 5, predicted average annual electrical consumption was plotted for different grain facility sectors. The greatest differences were found between the drying sectors, in which average electricity consumption was 47.37, 60.46, and 68.76M Wh for scenarios #1, #2, and #3 respectively. The electricity consumption value for scenario #3 was 31.10% and 12.07% higher than in scenarios #1, and #2 respectively.

In Table 6, the specific electric energy consumption for the drying sector is presented. As can be noted, scenario #1 had the lowest consumption value. The presented values are strongly linked with the installed demand in the drying sector (Table 4) and the product's initial moisture content (Table 2).

Therefore, scenario #1 was the best scenario if one is trying to reduce consumption of electric energy.

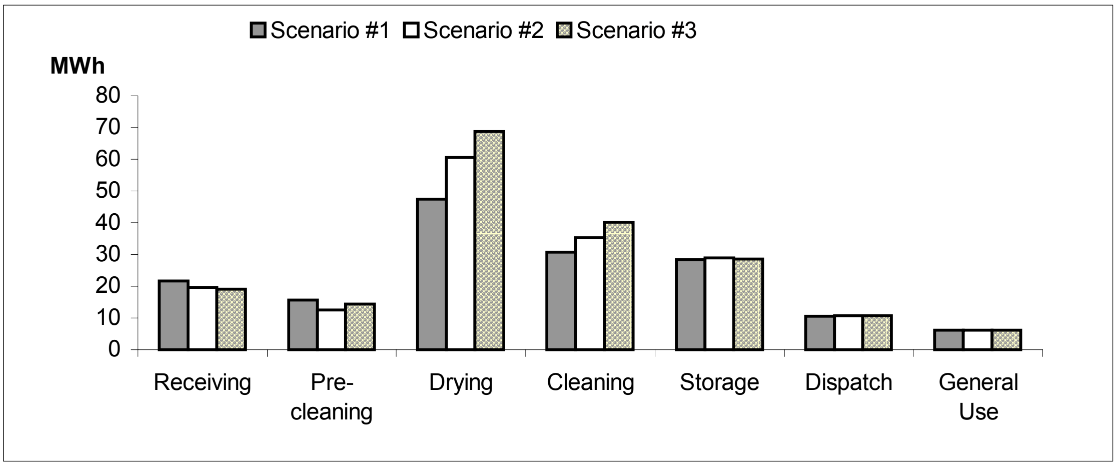


Figure 5 – The predicted average annual electric energy consumption, according to grain storage facility sectors in the studied scenarios.

Table 6 – Specific electric energy consumption for products at the drying sector

| Product | Specific electric energy consumption (kW/ kg of product) | | |
|---|---|---|---|
| | Scenario #1 | Scenario #2 | Scenario #3 |
| Corn | 1.687 ±0.023 | 2.133 ±0.341 | 2.368 ±0.264 |
| Soybean | 0.836 ±0.031 | 1.093 ±0.112 | 1.183 ±0.073 |
| Wheat | 1.089 ±0.066 | 1.445±0.288 | 1.580 ±0.242 |

## CONCLUSION

Considering the parameters amount of product received, processed, transferred, and stored, it was found that the values generated in each scenario were very similar. Specifically, the model's predicted average values for the amount of product processed in scenarios #1, #2 and #3 were 62,698.18t, 64,031.42t, and 63,593.19t respectively. The highest value for amount processed was found in scenario # 2; 2.09% and 0.68% above the values obtained from scenarios #1 and #3 respectively. Thus, from operational point of view, the amount processed is essentially the same in all scenarios.

Firewood consumption was found to be the least in scenario #1, with a predicted annual average value of 719.28 tonnes. This value was 4.95% and 10.12 % below the average values observed in scenarios #2 and #3.

Electrical energy consumption was also found to be the least in scenario #1. The 99% confidence intervals for annual electric energy consumption for scenarios #1, # 2 and # 3 were 143.53 ±8.10, 156.57 ±9.98, and 168.64 ±13.92 MWh respectively. The average consumption value predicted for scenario #1 was 9.08% and 17.49% lower than the consumption values from scenarios #2 and #3 respectively.

In summary, for studied conditions, it can be concluded that the grain storage facility's actual configuration, scenario #2, appeared well designed because operationally very similar results were obtained from the three scenarios. However, the best results in terms of electric energy and firewood consumption were came from scenario #1. Realizing that scenario #2 refers to an existing grain storage facility, a change in dryer sector configuration might not be economically justified. But, if it one were designing a new facility, the scenario #1 represents the best design. It had the lowest investment and operational cost of all modeled scenarios.

## REFERENCES

Brooker, D. B., F. W. Bakker-Arkema, and C. W. Hall. 1992. *Drying and storage of grains and oilseeds*. New York: Van Nostrand Reinhold.

Flores, R. A. 1988. Quality is chief priority in grain storage units. *Agribusiness Worldwide.* 11 (10): 9-16.

Krahl, A. 2000. The Extend simulation environment. *Proceedings of the 2000 Winter Simulation Conference.* Eds. J. A. Joines, R. R. Barton, K. Kang, and, P. A. Fishwick, pp 280-289. IEEE, Piscataway, NJ.

Song, A., D. S. Chung, and R. Nassar. 1990. A stochastic compartmental model simulating a grain cleaning process. *Trans. ASAE* 33(3): 877-884.

Vaughan, C. E., G. R. Bill, and J. C. Delouche. 1968. *Seed processing and handling*. Section K: 235-250. Handbook No. 1, Seed Technology Laboratory. Mississippi State University. Mississippi: Mississippi State.

Weber, E. A. 2001. *Armazenagem agrícola.*[*Farm storing*]. Guaíba, RS, Brazil: Livraria e Editora Agropecuária,