CHAPTER IV[1]

SENSITIVITY ANALYSIS USING A GRAIN STORAGE FACILITY MODEL

Abstract *A sensitivity analysis study was carried out using a grain storage facility model, which was implemented using Extend™* software *and the developed simulation toolset "Grain Facility." The toolset holds a set of blocks that allows simulating: (i) grain processing unit operations, (ii) operational decisions, and (iii) electric energy and fuel consumption. The model refers to one grain storage facility that annually receives approximately 9,500 t of corn, has four receiving pits with a holding capacity of 60 t each, one dryer with a drying capacity of 40 t/h, and four storage bins with a total storage capacity of 6,600 tonnes. The sensitivity analysis experiment was carried with the objective of verifying the impact on firewood and electrical energy consumption of a 10% increase or decrease in the quantity of raw product received and of a 2 percentage point increase or decrease in this raw product's initial moisture content. The 2% reduction in raw product initial moisture content resulted in the highest magnitude impacts, causing firewood consumption, specific firewood consumption, electrical energy consumption, and specific electrical energy consumption at drying sector to decrease an average of 14.90%, 15.10%, 7.90%, and 15.15 % respectively.*
Keywords. *grain storage facility, sensitivity analysis, Extend™*

INTRODUCTION

The performance of a grain storage facility's system is highly tied to stochastic phenomena, such as the harvest process and product market demand. Because of this, dependence on the use of static methodology to generate feasibility analyses and shape grain storage facility decision making is not recommended, as this can lead to erroneous assumptions. Stochastic simulation has been shown as the most appropriated tool for these uses. According to Song et al. (1990), the great advantage of stochastic models is

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that they allow the prediction of not only the average of the outputs but also their variances.

In addition, with developed simulation models, users are able to carry out sensitivity analysis, scenario analysis, optimization, and Monte Carlo simulation. These types of experiments support the decision making process and do not require intervention in the actual system, which can be costly and disruptive.

It is known that the performance of grain storage facilities can be affected by external factors, such as the received amount and the moisture content of raw products. These parameters, for example, can directly impact the performance of the facility's drying sector. Increases in these parameters will require more use of grain dryers, impacting electric and heat energy consumption.

The present article deals with a sensitivity analysis study to verify the magnitude of the impact on grain storage facility performance when the received quantity of raw products is increased and decreased 10% and when the initial moisture content of received raw products is increased and decreased 2 percentage points.

BACKGROUND

According to the operations research concept, a system may be defined as "*any sorted group of objects that perform together or inter-work in order to reach one logical goal*" (Schmidt and Taylor, 1970). This definition is strongly related to the purposes of this study, which are to learn, analyze, design, change, preserve, and, if possible, control system performance (Neelamkavil, 1987). In order to achieve these purposes satisfactorily, it is necessary to select all the involved system elements and then establish their interrelationships (Law and Kelton, 1991). This can be done by means of the simulation technique, which has been demonstrated to be a valuable tool for: (*i*) guiding the decision process, (*ii*) proceeding the evaluations and feasibility analyses, (*iii*) defining solutions for optimizing system performance, and (*iv*) carrying out experiments that do not affect the real system's routine (Monsef, 1997; Neelamkavil, 1987; Maria, 1997).

In the engineering field, simulation has been successfully employed for: (*i*) forecasting results before execution of a specific action, (*ii*) minimizing risks in making decisions, (*iii*) identifying problems before their occurrence, (*iv*) eliminating procedures that do not add value, (*v*) cutting costs related to manpower, energy, water, and physical structure, and (*vi*) revealing a project's integrity and viability according to economic and technical feasibility analyses (Law and Kelton, 1991). However, many authors, including Law and Kelton (1991) and Palisade (2000), state that simulation by itself does not provide exact answers nor optimize system performance. Nevertheless, a well-built model captures significant data and reports this data, which then may be used in conducting simulation experiments, such as: (a) *sensitivity analysis* to check the impact on a system when the values of one or more parameters are modified, (b) *scenario analysis* to allow comparisons between different scenarios when the system's configuration is changed, (c) *optimization* to define the optimum combination of inputs to produce a desired output, and (d) *Monte Carlo simulation* to enable, with a certain level of confidence, the determination of expected system performance according to variation (Krahl, 2000; Imagine That, Inc., 1997).

EXPERIMENT ORGANIZATION

This sensitivity analysis experiment was carried out to verify the magnitude of impacts on grain storage facility performance when the received quantity of raw product is increased or decreased 10%, and when the initial moisture content of received raw product is increased or decreased by two percentage points.

The experiment was carried out using a dynamic, stochastic and discrete model that was developed for one of the grain storage facilities belonging to COAMO, an agricultural cooperative headquartered in Campo Mourão, Paraná, Brazil. Technical information about the modeled facility is given in Table 1.

The model was built using the simulation language Extend™, version 4.1.3C and a developed simulation toolset called "*Grain Facility*." "*Grain Facility"* is an Extend™ library, which has a set of blocks that represent structure and equipment used in grain storage facilities. In Figure 1, the main blocks of this library are presented. The model constructed allows simulation of the grain storage facility's dynamic behavior.

Table 2 presents input information for the *Arrival Generators* block. Table 3 presents the dispatch plans for corn. Information listed in Tables 2 and 3 refers to the 1991 crop year.

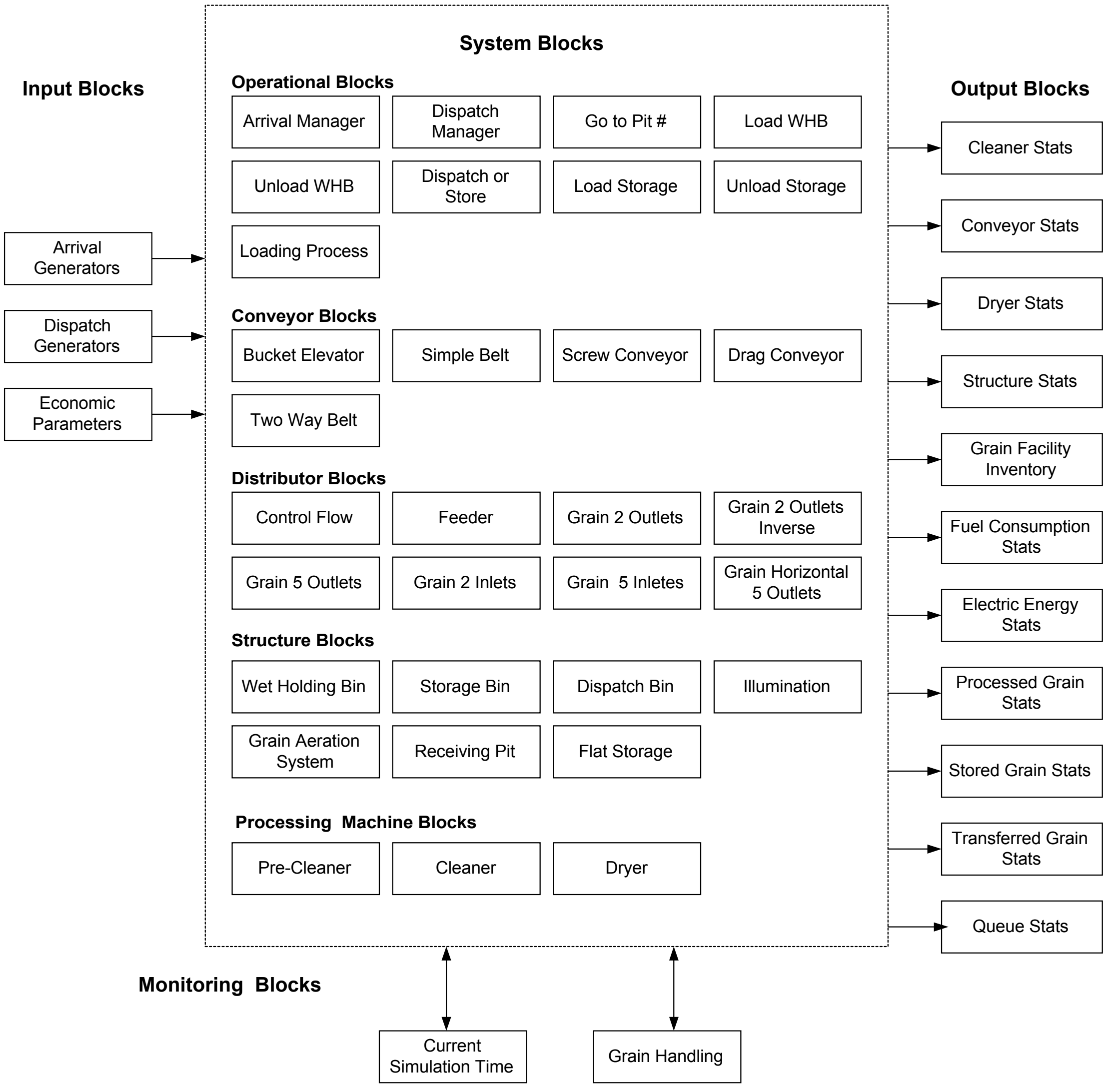

Figure 1- *Grain Facility* Library schematic representation.

Table 1 – Major technical information of the modeled grain storage facility C

Structure	Quantity	Static Capacity (t)
Receiving Pit	4	60
Metal Storage Bin	2	300
Metal Storage Bin	2	3,000
Dispatch Bin	1	42
Processing Machines	**Quantity**	**Hourly Capacity (t/h)**
Pre-Cleaner	2	40
Dryer	1	40
Cleaner	2	30
Conveyors	**Quantity**	**Hourly Capacity (t/h)**
Belt	3	60 and 120
Bucket elevator	6	60 and 120
Screw Conveyor	5	60 and 120

Table 3 – Dispatch plans for corn

Month	Stock portions to be dispatched (%)
1	0
2	0.80
3	2.00
4	6.58
5	8.70
6	10.85
7	2.89
8	2.45
9	12.25
10	10.89
11	11.40
12	31.19

For each studied situation, five simulation model replications (runs) were made. Averages and 99% confidence intervals, using t-distribution, were determined for the performance parameters related to firewood and electrical energy consumption. Firewood is used as the heat energy source in the drying operation. The length of each simulation refers to one operational year (8,640 hours).

Table 4 shows the predicted 99% confidence interval for firewood consumption, specific firewood consumption, and electrical energy consumption, and specific electrical energy consumption for the five contrasted suited situations. “Normal situation” figures are the output from an unadjusted simulation of the actual storage facility.

In Table 4 and Figure 2, it can be observed that average firewood consumption increases 11.5% with the simulated increase in raw product quantity and increases 2.65% with the increase in product’s initial moisture content. When the quantity of raw product quantity is decreased, average firewood consumption decreases 12.30%, and when the product’s initial moisture content is decreased, firewood consumption decreases 14.90%. It is observed that more significant differences occur when the initial moisture content is decreased. A similar occurrence was not detected when the initial moisture content was increased. This could be because the model was constrained by a maximum moisture content of 30% w.b.

Table 4 – Results of sensitivity analysis

Parameter	Normal Situation	Received Quantity Increased 10%	Received Quantity Decreased 10%	Initial Moisture Content Increased 2 points	Initial Moisture Content Decreased 2 points
Firewood consumption (t)	343.80 ±4.23	383.40 ±5.40	301.40 ±8.34	352.92 ±2.54	292.60 ±3.44
Specific firewood consumption (kg of firewood / t of product inputted at dryer)	36.32 ±0.41	36.72 ±0.50	35.57 ±0.99	37.27 ±0.37	30.83 ±0.37
Electrical energy consumption (MWh)	77.60 ±0.40	83.03 ±0.52	71.65 ±1.13	78.45 ±0.39	71.74 ±0.47
Specific electrical energy consumption capacity (kWh / t of product inputted at the dryer)	3.63 ±0.04	3.66 ±0.06	3.55 ±0.10	3.71 ±0.03	3.08±0.04

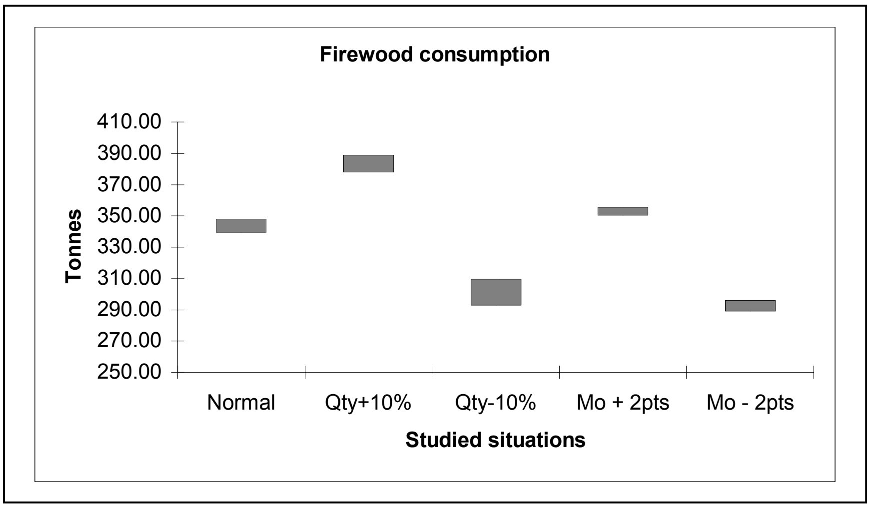

Figure 2 – Schematic representation of 99 % confidence interval boundaries for firewood consumption.

For specific firewood consumption, according to the information shown in Table 4 and Figure 3, it was noticed that the magnitude of impacts were more accentuated for modifications of initial moisture content, since the predicted 99% confidence interval for the normal situation and for quantity of received raw product alternatives are similar. The greatest difference occurred when the initial moisture content was decreased two percentage points. In this instance, the specific firewood consumption average dropped 15.11 %.

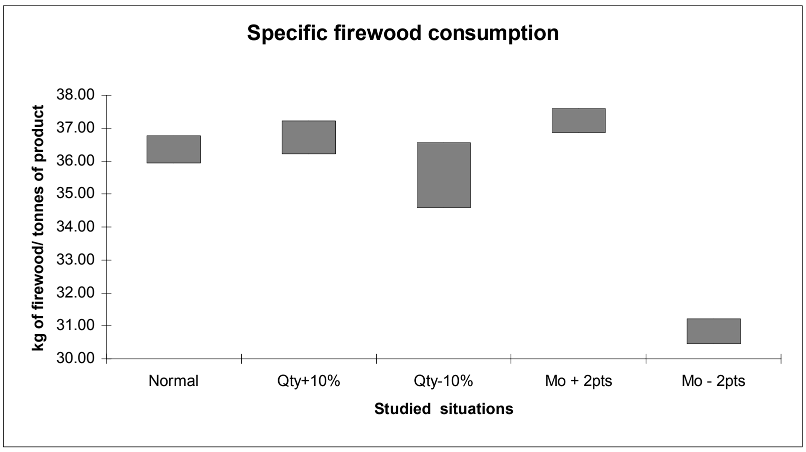

Figure 3 – Schematic representation of 99 % confidence interval boundaries for specific firewood consumption.

Table 4 and Figure 4 schematically represent electric energy consumption data. It was verified that the average electric energy consumption increases 6.99% when the quantity of received raw product increases 10% and decreases 7.66% when that quantity decreases 10%. It was also found than a\ 2 percentage point increase in raw material initial moisture content caused average electric energy consumption to increase 1.1%, while a 2 percentage point decrease in initial moisture content caused that consumption to decrease 7.90%. This large percentage decrease in the consumption of electricity with the decrease in product moisture content is most explained by reduced dryer use, as dryers consume the most electrical energy at grain storage facilities.

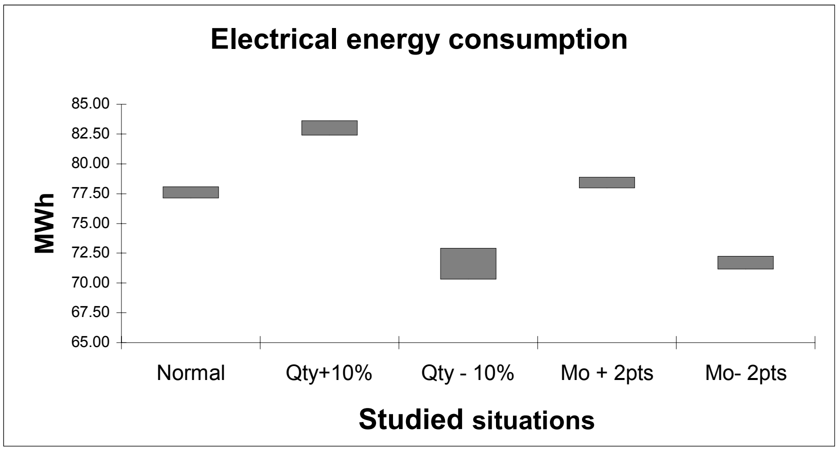

Figure 4 – Schematic representation of the 99 % confidence interval boundaries for annual electrical energy consumption.

For specific electric energy consumption in the drying sector, according to the information presented in Table 4 and Figure 5, the greatest difference occurred when initial moisture content is changed. The increase and the decrease for the initial moisture content of the raw material caused average specific electric energy consumption to increase 2.20% and decrease 15.15%, respectively. This could be because raw product with lower moisture content needs less recirculation in the mixed flow dryer.

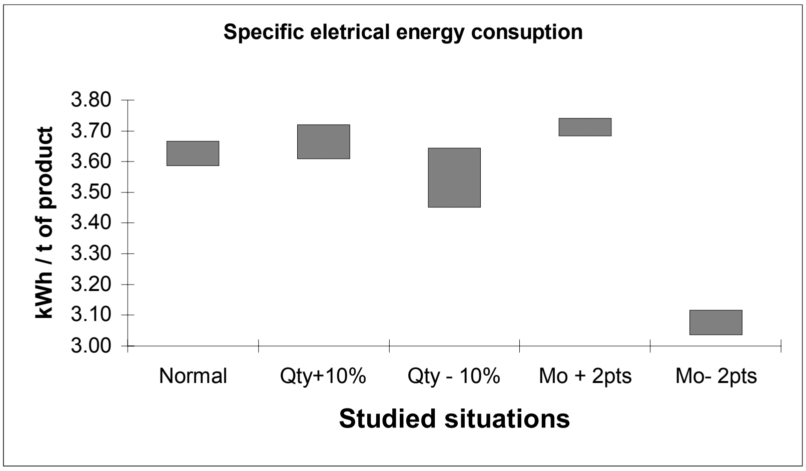

Figure 5 – Schematic representation of the 99 % confidence interval boundaries for specific electrical energy used capacity in drying sector.

CONCLUSION

This paper presents a sensitivity analysis experiment, carried out to verify the magnitude of impacts on grain storage facility firewood and electrical energy consumption when the received quantity of raw products is increased and decreased 10% and when the initial moisture content of received raw products is increased and decreased by two percentage points.

The results demonstrate that the highest magnitude impacts occurred when initial moisture content of received raw products is decreased two percentage points. Contrasting outcomes from the normal system simulation with the simulation in which initial moisture content is decreased 2 percentage points, it was verified that in the adjusted simulation: (i) average firewood consumption decreases 14.90%, with consumption values decreasing from 343.80t ±4.23 t to 292.60t ±3.44 t, (ii) average specific firewood consumption decreases 15.11%, with consumption values decreasing from 36.32 ±0.41 to 30.83kg ±0.37 kg per tonne of corn input at the drying sector, (iii) average electrical energy consumption drops 7.90%, with consumption values decreasing from 77.60±0.40 to 71.74 ±0.47 MWh, and (iv) average specific electrical energy consumption decreases 15.15%, with consumption values decreasing from 3.63±0.04 to 3.08 ±0.04 MWh per tonne of corn input at the drying sector.

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