

LUÍS CÉSAR DA SILVA

STOCHASTIC SIMULATION OF THE DYNAMIC BEHAVIOR OF GRAIN
STORAGE FACILITIES

Thesis submitted to Universidade
Federal de Vicosa as the requirement of
Agricultural Engineering Graduate
Program for obtaining the title of "*Doctor
Scientiae*".

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*To my wife, Sônia,
and my children,
Humberto and Raphael.*

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VITA

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ABSTRACT

Silva, Luís César da, D. S., Universidade Federal de Viçosa, May 21, 2002.
Stochastic Simulation of the Dynamic Behavior of Grain Storage Facilities.
Major Professor: Dr. Daniel Marçal de Queiroz. Advisory Committee: Dr. Rolando Arturo Flores, Dr. Evandro Castro de Melo, and Dr. Carlos Arthur Barbosa Silva.

A grain storage facility may be defined as a designed and structured system for receiving, cleaning, drying, storing, and dispatching grains and legumes. To perform these tasks appropriately, structures, processing machines, and conveyors are logically linked and management decisions are made.

Due to the dynamic of grain storage facilities and external random factors, such as the harvest process and market demand, evaluation and analysis using static techniques are not recommended. Static methodologies may lead decision makers to erroneous conclusions or put them in an awkward position when trying to correlate the several variables involved. For these reasons, simulation proves to be a more than adequate method to better understand the studied decision parameters; and it is ideal for conducting sensitivity analysis, scenario analysis, optimization, and Monte Carlo simulation.

Thus, a simulation toolset was developed to allow engineers, designers, managers, and other decision makers to model the dynamic behavior of new and existing grain storage facility and conduct related experiments and feasibility analyses. This toolset, called "*Grain Facility*," was developed by using ExtendTM software, version 4.1.3C. "*Grain Facility*" is an ExtendTM library holding a set of blocks that enable the user to: (i) input information which rules system operations, (ii) simulate unit operations related to the grain storage facility environment, (iii) collect and display information during the simulation process, and (iv) generate reports and graphics.

For the development of models using the "*Grain Facility*" library and for the following study's verification and validation sections, data were obtained from the *Cooperativa Agropecuária Mourãoense Ltda.* (COAMO), an

agricultural cooperative headquartered in Campo Mourão, Paraná State, Brazil. The data refer to: (i) monthly electric energy consumption, (ii) annual consumption of firewood used in the grain drying process; (iii) daily quantity of product received; (iv) monthly quantity of product dispatched; (v) a flowchart of the grain storage facilities visited, and (vi) technical information about processing machines, conveyors, and structures.

This study's outcomes show that "*Grain Facility*" has significant problem solving potential. It allows the structuring of models that have various applications, such as (i) conducting grain storage facility feasibility analyses, (ii) estimating electric energy and fuel consumption at grain storage facilities, (iii) acting as teaching tools to make cases under study more readily understandable, and (iv) analyzing new and existing systems to make them more efficient or to provide direction for facility remodeling and technological updating.

EXTRATO

Silva, Luís César da, D. S., Universidade Federal de Viçosa, 21 de maio de 2002. Stochastic Simulation of the Dynamic Behavior of Grain Storage Facilities. Professor Orientador: Daniel Marçal de Queiroz. Professores Conselheiros: Rolando Arturo Flores, Evandro Castro de Melo e Carlos Arthur Barbosa Silva.

Unidades armazenadoras de grãos podem ser definidas como sistemas projetados e estruturados para receber, limpar, secar, armazenar e expedir grãos e oleaginosas. Para alcançar estas metas apropriadamente, estruturas, máquinas de processamento e transportadores são interligados segundo um fluxograma lógico, e decisões operacionais são tomadas.

Devido à dinâmica do sistema unidade armazenadora de grãos, e influências de fatores aleatórios externos, como o processo de colheita e a demanda do mercado, não são recomendados o emprego de métodos estáticos em estudos de avaliações e análises para este tipo de sistema. Isto deve-se ao fato de que os métodos estáticos podem levar os tomadores de decisões a cometer erros, como também envolve-los em situações embaraçosas ao procurar estabelecer correlações entre as variáveis envolvidas. Por esta razão, a simulação se apresenta como a técnica mais adequada por permitir um melhor entendimento dos parâmetros selecionados para a tomada de decisão, além de propiciar a condução de experimentos tais como: análise de sensibilidade, análises de cenários, otimização e simulação de Monte Carlo.

Desta forma, visando permitir engenheiros, projetistas, gerentes e demais tomadores de decisões simular a dinâmica operacional, conduzir experimentações, e realizar análises de viabilidade, considerando unidades

armazenadoras existentes e novas, foi desenvolvido uma ferramenta para estruturação de modelos de simulação. Esta ferramenta, denominada *Grain Facility*, foi desenvolvida utilizando o software ExtendTM, versão 4.1.3C. *Grain Facility* é classificada como uma biblioteca do ExtendTM que contém um conjunto de blocos que propiciam: (i) introduzir dados que governam o sistema, (ii) simular as operações unitárias associadas ao ambiente das unidades armazenadoras de grãos, (iii) coletar e apresentar informações durante a simulação, e (iv) gerar relatórios e gráficos.

Para o desenvolvimento da biblioteca *Grain Facility*, dos modelos e dos estudos de verificação e validação, dados foram obtidos junto à Cooperativa Agropecuária Mourãoense Ltda. – COAMO, com sede em Campo Mourão, Paraná, Brasil. Os dados referem ao: (i) consumo mensal de energia elétrica, (ii) consumo anual de lenha utilizada no processo de secagem, (iii) quantidades diárias de produtos recebidas, (iii) quantidades mensais de produtos expedidas, (iv) fluxogramas das unidades armazenadoras visitadas, e (v) informações técnicas sobre equipamentos e estruturas.

Com base nos resultados obtidos, pode ser concluído que *Grain Facility* possui um significativo potencial na solução de problemas, uma vez que esta ferramenta permite a estruturação de modelos que são úteis em aplicações como: (i) análises de viabilidade, (ii) entendimento dos casos em estudo, (iii) estimativa do consumo de energia elétrica e combustível no processo de secagem, e (iv) análises de sistemas novos e existentes, bem como das necessidades de expansão, remodelação e inovação tecnológica.