“An Inventory Decision Support System to the Glass Manufacturing Industry”

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Summary

1. Problem framework
2. What kind of decisions?
3. Methodology
4. The glass manufacturing process
5. The IPA Approach
6. The *SimulGLASS* package
7. Numerical study example
8. Future developments
9. Conclusions

1. Problem framework

- Generalized Portuguese glass industry production strategy is a **producing-to-order** one;
- Managers are often confronted with decisions on **whether or not** to hold inventories;
- Some lack of suitable **inventory decision support systems**;

2. What kind of decisions?

- For a **production process**, and for a given **production strategy** (make-to-stock, make-to-order, ...) we decide on...

  i) the **base-stock levels** that **minimize the total cost**

  ii) the corresponding **service level**

- Compare the **performance** of alternative production strategies

3. Methodology

i) Process data analysis

ii) Literature review

iii) Model definition

iv) Software development

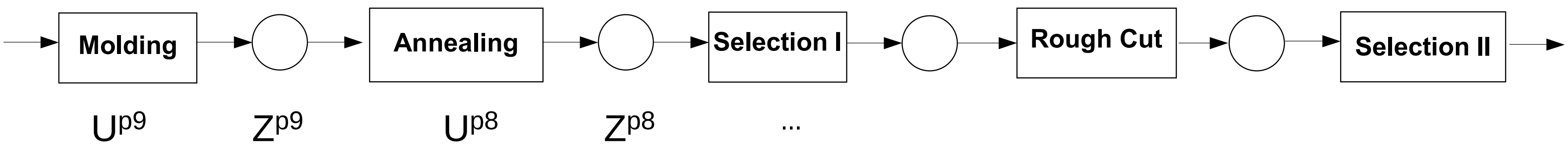
v) The testing stage

vi) Numerical study

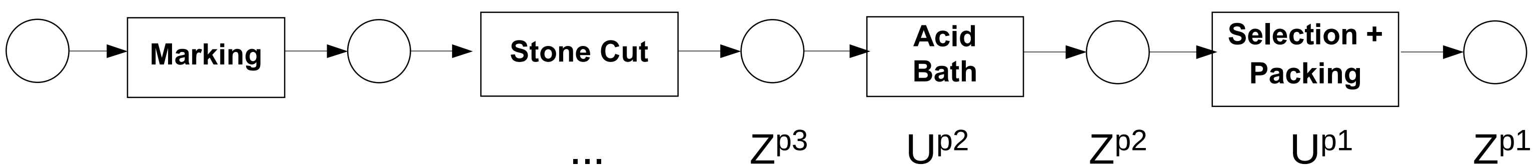
vii) Analysis of results

4. The Glass Manufacturing Process

Hot-area:



Cold-area:



U = Production Limit
Z = Echelon Base-Stock

Operation
Buffer

5. Model Definition

- Multiple machines in series with finite capacity
- Multi-products
- Lot Splitting
- Random Yield
- Random Demand
- Production decisions based on a weighted shortfall heuristic

6. The Infinitesimal Perturbation Analysis (IPA) Approach

- Tool used on complex systems to **compute Grad J** (in order to the control parameters);

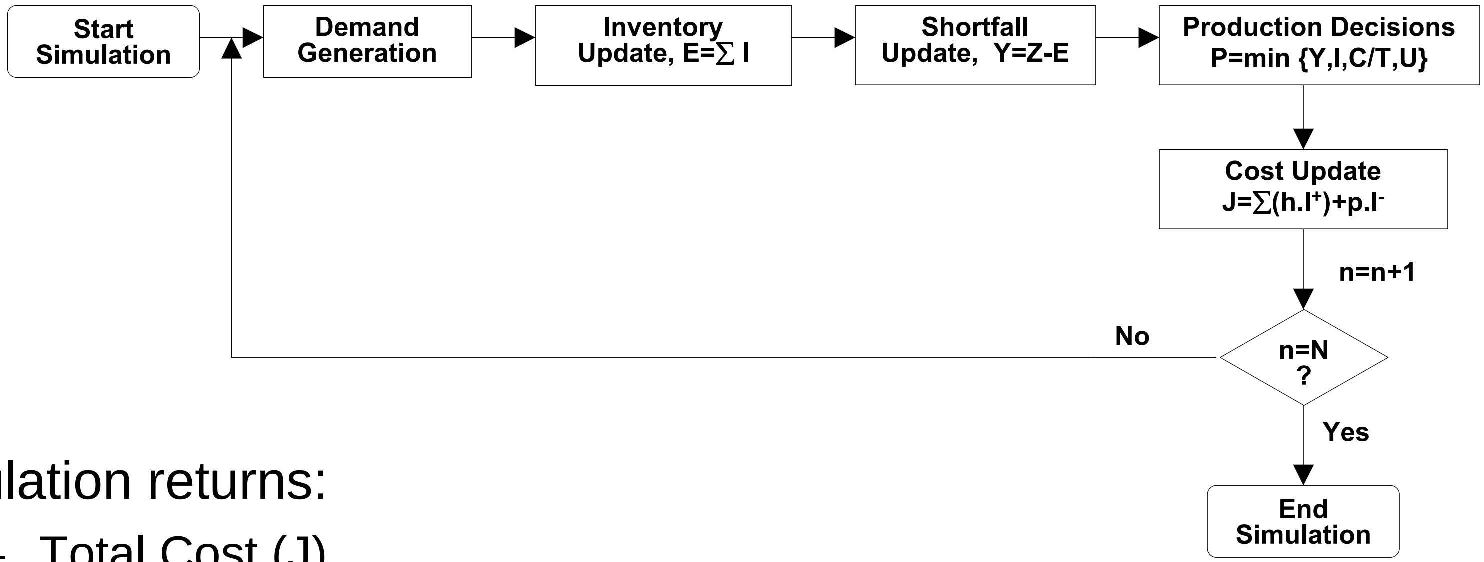
- Classical approach:

  M parameters $\Rightarrow$ M+1 Simulations

- IPA approach:

  M parameters $\Rightarrow$ 1 Simulation

7.1 Software Package - Simulator

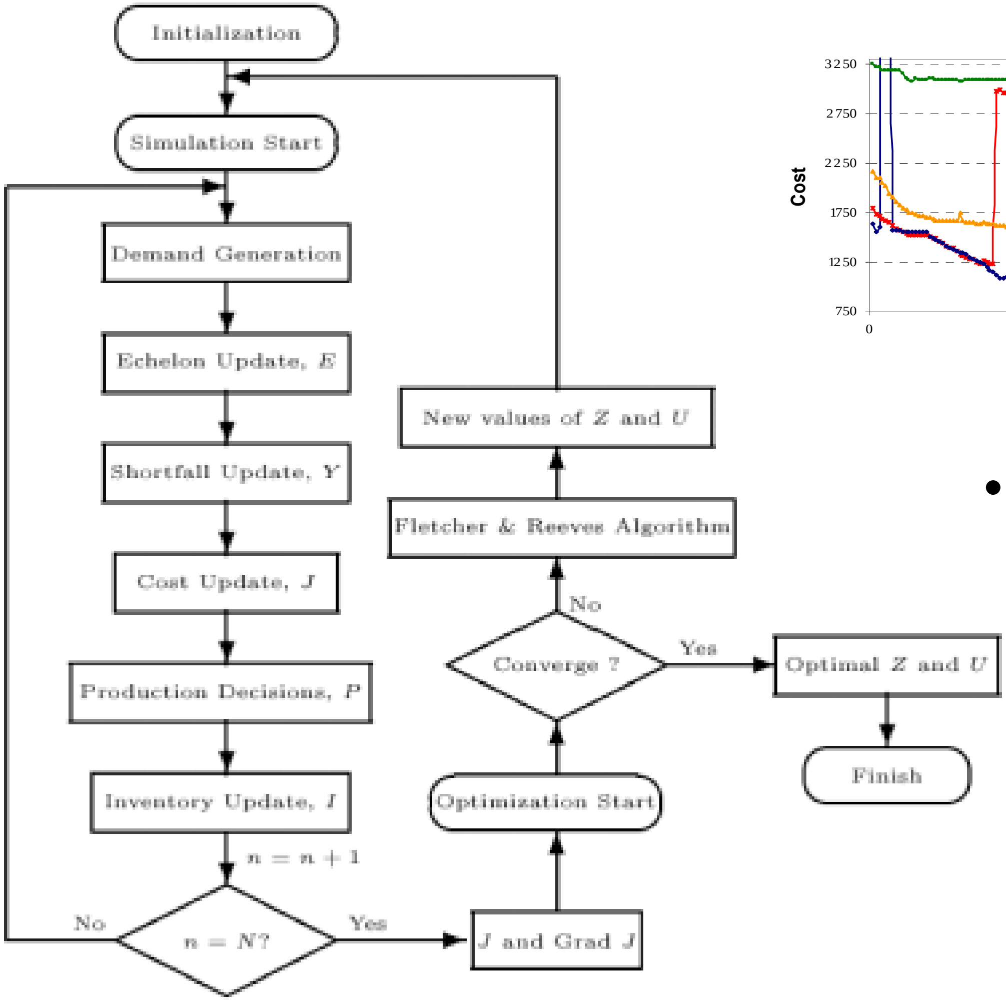


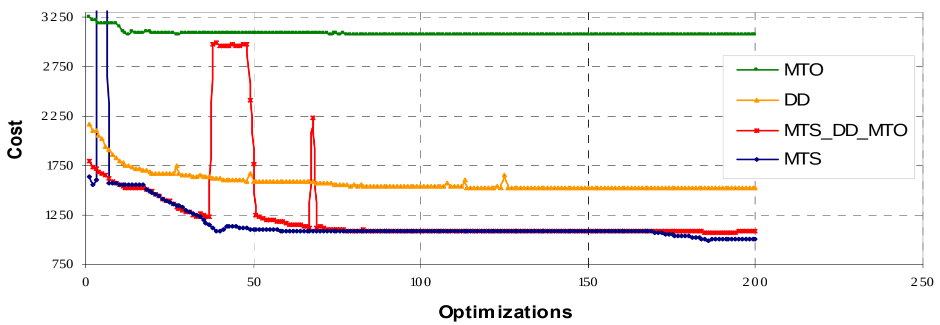
Simulation returns:

- Total Cost (J)
- Cost Gradient (Grad J)

$$J_n^p = \sum_{s=2}^{S}\left[\left(I_n^{ps}\right)^+ h^{ps}\right] + \left(I_n^{p1}\right)^+ h^{p1} + \left(I_n^{p1}\right)^- b^p + \sum_{s=1}^{S}\left(1-\alpha^{ps}\right)\left(h^{ps}-m^p\right)P^{ps}$$

7.2 Software Package - Optimizer





- Optimization algorithm:

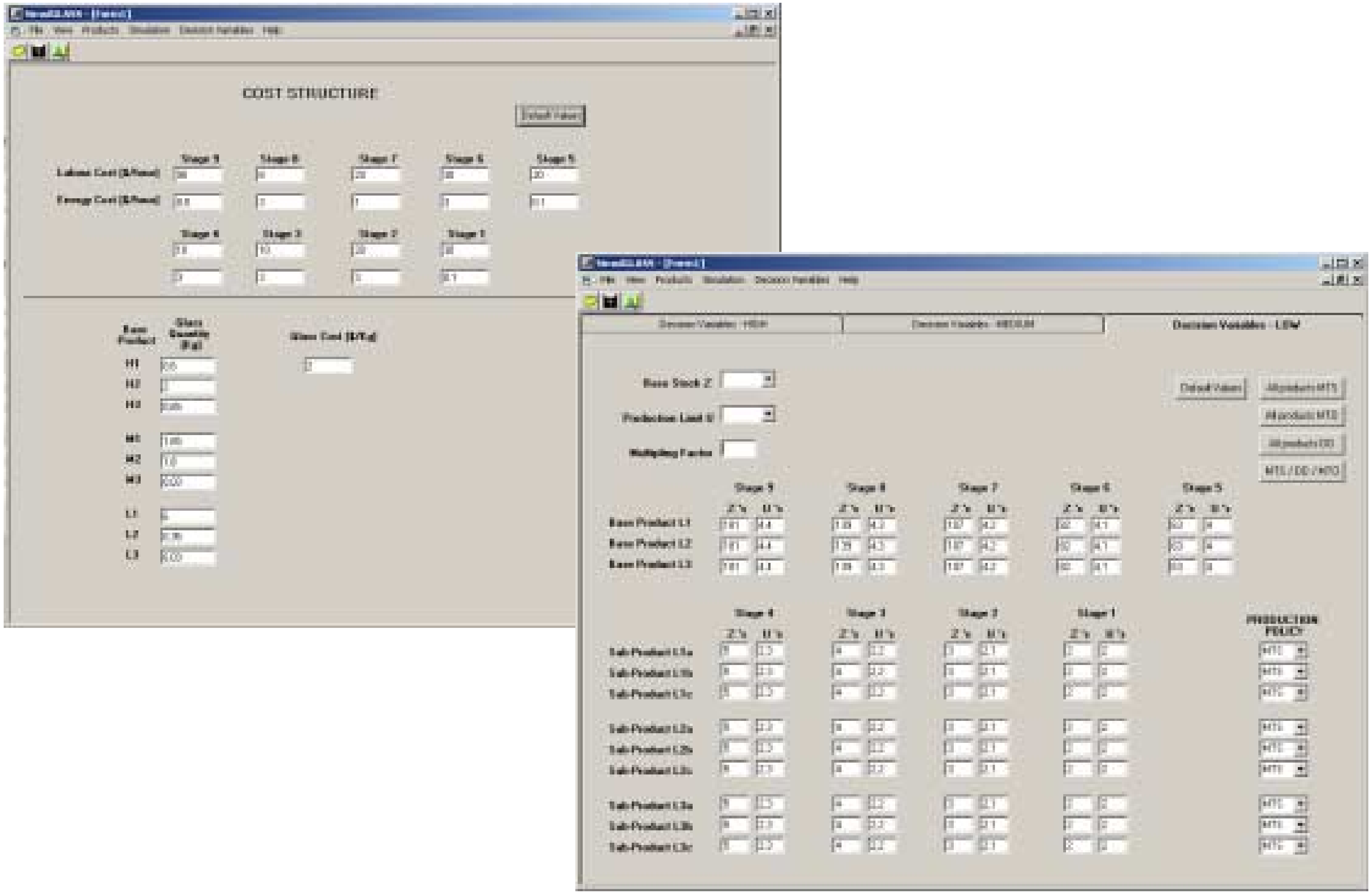
  Fletcher & Reeves

  (Conjugated Gradient Method)

7.3 Software Package - Output

- **Minimum cost** for the simulated strategy;
- Optimal **base-stock levels** for all products at all stages;
- Optimal **Production limits** for all products at all stages;
- **Average lead-time** for all products;
- Corresponding **service level**;
- **Internal Costs** (In-house costs);

7.3 Software Package – User interfaces



7.4 Software Package - Tests

- Derivative accuracy $$\frac{\partial J}{\partial Z} = \frac{J_{perturbed} - J_{nominal}}{\varepsilon}$$
- Function cuts along gradient direction
- Control of state and decision variables

  (Inventory ≥ 0, Production ≥ 0, ...)

8.1 Numerical Study Example - Data

- Process Parameters
  - 27 Products (Pareto's Law)
    - High demand level (80%)
    - Medium demand level (15%)
    - Low demand level (5%)
  - 9 Machines (stages) and random yield
  - 4 production shifts/day
  - 4 Production strategies: MTS, MTO, DD and M/D/M

8.2 Numerical Study Example - Results

- Costs:

Production Strategy	Optimal Cost	Confid. Interval	In-house Cost
MTO	3079,6	± 1,9 %	**488,6**
DD	1529,4	± 0,7 %	540,4
M/D/M	1075,8	± 0,8 %	595,2
MTS	**999,1**	± 1,4 %	631,5

[m.u.]

- Lead-times:

STRATEGY	MTO	DD	M/D/M	MTS
Demand Level	Lead-times [shifts]			
High	**7,21**	2,71	**1,24**	**2,73**
Medium	**6,66**	2,67	2,61	1,17
Low	**4,67**	2,74	4,87	0,73
All products	6,18	2,71	2,91	1,54

9.1 Conclusions

- Development of an efficient tool to support production management teams;
- Evaluation of alternative production strategies;
- IPA provides rapid identification of good solutions;

9.2 Future developments

- Use firm data base to update process parameters (processing times, yield rates, ...)

- Development of more complex model (with random capacity and processing times);

- Dealing with random yield

- Alternative optimization algorithms (*Broyden-Fletcher-Goldfarb-Shanno*, ...);

A.1 Production Decisions

$$P^{p_m s} = \min\left\{ Y^{p_m s}, \frac{C^s}{T^{p_m s}}, I^{p(s+1)}, U^{p_m s} \right\}, \quad \textbf{for stage } s$$

$$\frac{\partial P^{p_m s}}{\partial Z^\circ} = \begin{cases} \dfrac{\partial Y^{p_m s}}{\partial Z^\circ}, \textbf{ if } s \textbf{ is shortfall bound} \\ \dfrac{\partial I^{p(s+1)}}{\partial Z^\circ}, \textbf{ if } s \textbf{ is inventory bound} \\ 0, \quad \textbf{if } s \textbf{ is production bound} \\ \dfrac{\partial\left(\dfrac{C^s}{T^{p_m s}}\right)}{\partial Z^\circ}, \textbf{ if } s \textbf{ is capacity bound} \end{cases} \textbf{, for any stage } s$$

A.2 Performance Measure - Cost

$$J_n^p = \sum_{s=2}^{S} \left[\left(I_n^{ps} \right)^+ h^{ps} \right] + \left(I_n^{p1} \right)^+ h^{p1} + \left(I_n^{p1} \right)^- b^p + \sum_{s=1}^{S} \left(1 - \alpha^{ps} \right) \left(h^{ps} - m^p \right) P^{ps}$$

$$\frac{\partial J_n^p}{\partial Z^\circ} = \sum_{s=2}^{S} \frac{\partial \left(I_n^{ps} \right)^+}{\partial Z^\circ} h^{ps} + 1\left\{ I_n^{p1} > 0 \right\} \frac{\partial \left(I_n^{p1} \right)^+}{\partial Z^\circ} h^{p1} - 1\left\{ I_n^{p1} < 0 \right\} \frac{\partial \left(I_n^{p1} \right)^-}{\partial Z^\circ} b^p + \\ + \sum_{s=1}^{S} \left(1 - \alpha^{ps} \right) \left(h^{ps} - m^p \right) \frac{\partial P_n^{ps}}{\partial Z^\circ}$$

A.3 IPA Validation

Validation procedure consists in show that:

- All variables are diferentiable;
- Define their values;
- ***Expected Value*** and **Diferentiation** are permutable operatores;

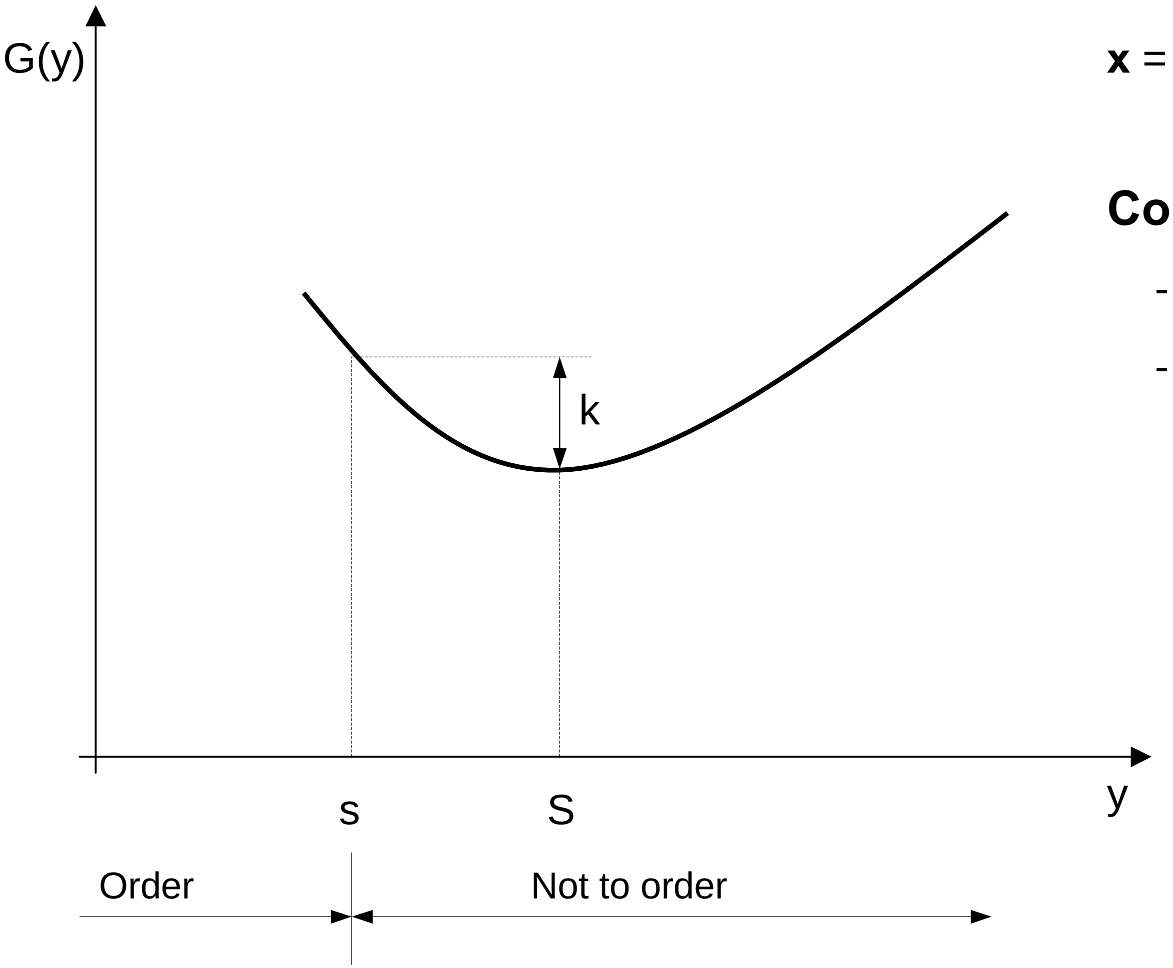
A.4 Optimality Condition

- The optimal base-stock levels, **Z**, for the performance measure COST and for any production strategy are such that the following relation holds:

$$Pr\left(D_n^p \leq I^{p1}\right) = \frac{b^p}{b^p + h^{p1}}$$

- Once the **SERVICE LEVEL** is defined, the estimation of the penalty costs becomes a simple task.

A.5 (s,S) Policy definition



x = Inventory Level

Control Policy:

- if x < s order up to S;
- If x ≥ s not to order;