Planning and scheduling of PPG glass production, model and implementation.

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Glass Business and Discovery Center

Project scope

Support Production Management Decisions

- Optimal long-term production scheduling
- Maximize the profit
  subject to:
  Scheduling constraints
  Product inventory constraints
  Waste glass management

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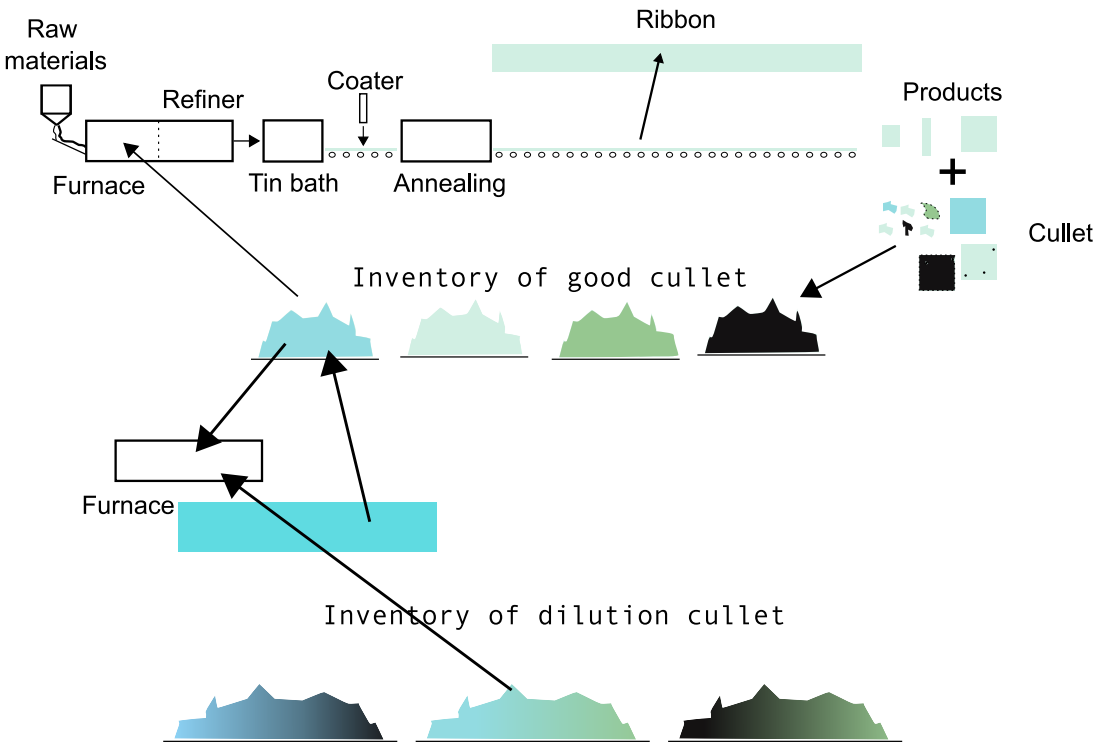
Objectives

1. Development of a Mixed Integer Linear Programming (MILP) model for the **planning and scheduling of the glass production**
   - **Capture the essence** of the process that **is not considered** in the Master Production Schedule
     - Management of waste glass (cullet)
2. Implement a user-friendly software tool to interface with the GAMS model.

Process and products

Continuous process



Features

- 25 products defined by color, examples:
- Sequence dependent changeovers between substrates
- Long transition times (order of days)
- High transition costs
- Complex recycle structure for cullet consumption and production

Problem statement

Given:

- Time horizon of **18 months**
- Set of products
  - deterministic **demand**
  - initial, minimum, and maximum **inventory** levels
  - **production rates**
  - sequence dependent **transitions**
  - operating **costs**
  - **selling prices**
- Transition, and inventory costs
- **Cullet**
  - initial, minimum, and maximum **inventory** levels
  - **production and consumption** rates
  - compatibility matrix between colors
  - **selling price**

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Determine:

- **sequence of production** (production times and amounts)
- **inventory levels** of products during and at the end of the time horizon
- **inventory levels** of **cullet** during and at the end of the time horizon
- **economic** terms: total operating, transition, inventory costs

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Determine:

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- **inventory levels**
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That **maximize the profit**

MILP planning and scheduling models

Models implemented:

- **Scheduling model:** slot based continuous time model (Erdirik-Dogan and Grossmann, 2008)
- **Planning model:** traveling salesman sequence based (Erdirik-Dogan and Grossmann, 2008)

Integrated using **rolling horizon algorithms** to cope with the complexity of the problem. (Lima and Grossmann, 2011)

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Size and performance of the models, for two different case studies
Application of both models **without using a rolling horizon algorithm**
Time horizon = 2 months, time periods = 1 month, 22 products without cullet

Scheduling model

Iteration	Equations	Variables	0-1 Variables	CPU (s)	RGap (%)	Obj
1	4,207	3,253	1,219	98.0	0.0	1,938.05

Bi-level decomposition, first the planning model and then the scheduling model

Iteration	Equations	Variables	0-1 Variables	CPU (s)	RGap (%)	Obj
1	1,625	1,467	601	**0.4**	**0.0**	1,938.48
1	2,046	2,082	169	**0.2**	**0.0**	1,938.05

Obj - value of objective function, profit.

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Size and performance of the models, for two different case studies
Application of both models **using** a rolling horizon algorithm
Time horizon = **15 months**, time periods = 1 month, 22 products **with cullet**

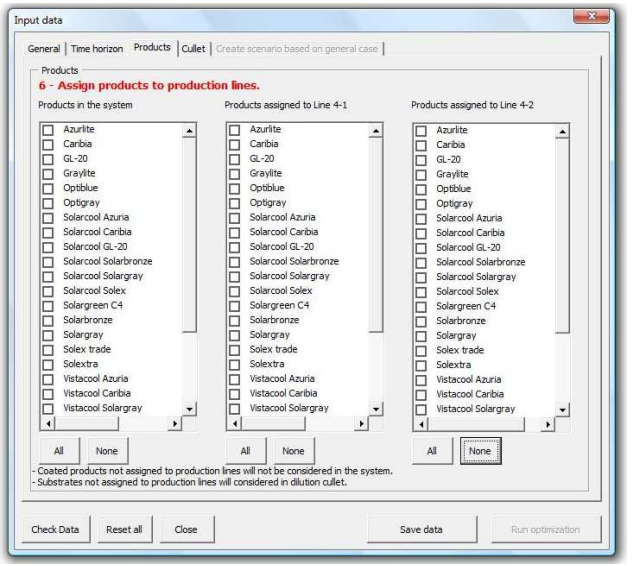
Iter.	Equations	Variables	0-1 Variables	Slots	CPU (s)	RGap (%)	Obj
1	10,072	12,516	3,350	-	3,600	14.1	6,936
2	13,977	19,500	2,384	9	100	0.0	-2,970
3	20,155	26,402	4,473	9	3,600	5.0	534
4	21,823	31,205	2,576	17	200	0.0	-6,136
5	28,213	38,177	4,673	17	3,600	1.7	-2,127
6	28,461	41,052	2,629	23	100	0.0	-5,290
7	34,914	48,042	4,821	23	3,600	5.4	-1,424
8	36,546	52,836	2,893	31	3,600	0.6	-4,794
9	43,062	59,844	5,032	31	3,600	6.2	-1,162
10	43,416	62,750	3,004	37	3,600	0.7	-4,291

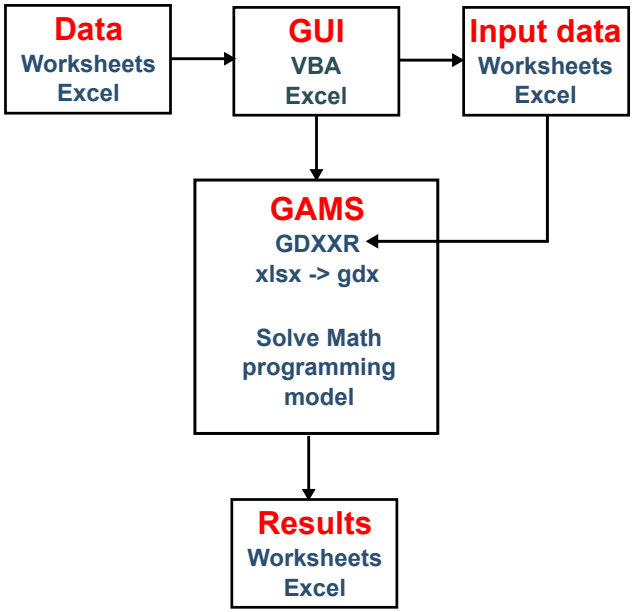
Obj - value of objective function, profit, but including penalties for violation of some constraints.

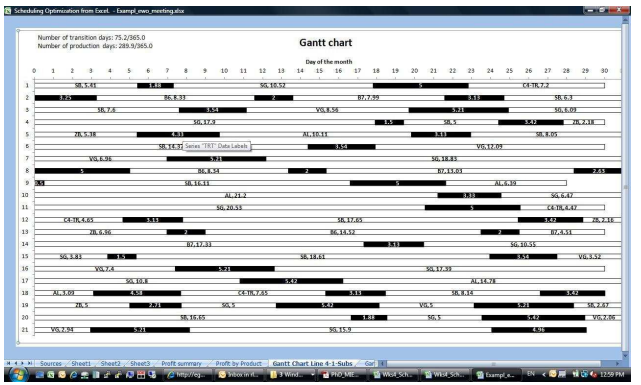
Implementation of the model

Software structure

- **Main components:** Model, GAMS, Excel
- Graphical User Interface (GUI) developed in VBA for Excel
- Manipulation of input data and output results structure developed in VBA for Excel







Concluding remarks

- A customized decision support system for glass production is complete.
- In the scope of strategic studies in PPG, the model was used to analyze strategic product portfolio decisions under production constraints.
  - The results have indicated that changes in the current portfolio may result in higher profits.