



## **Optimal Production Scheduling in the Packaged Consumer Goods Industry**

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### **Highlights**

- Real-life large-scale consumer goods industrial case study
- MILP-based decomposition algorithm
- Plant reconfiguration
- Flexible production layout

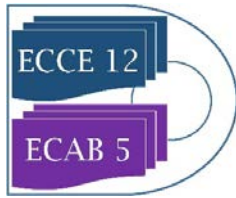
### **1. Introduction**

The ever-increasing competitiveness of large-scale industries necessitates the increase of productivity and minimization of production costs. Production scheduling has a direct impact on the overall efficiency of industrial facilities by minimizing, among others, changeover times which cause production downtimes, waste and energy consumption/use of resources. Potential plant reconfigurations also provide significant room for improvements of the overall productivity. Although production scheduling problems have received significant attention [1], the majority of the work is focused on relatively small to medium size problem instances. A few recent contributions have studied the application of scheduling techniques in medium- and large-scale industries [3]. In this work two MILP-based approaches are proposed for the optimization-based scheduling of a real-life large-scale consumer goods production plant. The first approach focuses on the optimal scheduling of the current plant layout while the second one is applied to a reconfigured flexible layout allowing the decoupling of the formulation and packing stages.

### **2. Methods**

#### **2.1 Current Layout**

An MILP-based decomposition algorithm is proposed for the optimal production scheduling of the current plant layout focusing on the packing stage. The proposed MILP model optimizes the production sequence while considering constraints related to the allocation of the final products as well as the timing of processing steps [2]. Products' due dates, as well as appropriate constraints referring to the production/formulation stage of the plant, are taken into account to ensure near-optimal production schedules. The algorithm operates on an iterative fashion and a subset of the involved product orders is scheduled at each iteration.



## 2.2 Reconfigured flexible layout

In order to avoid varying bottlenecks in the process due to the product dependent maximum production rate of the formulation and the packing stage, the two stages can be decoupled. In the current layout the stages are closely coupled in each line, whereas the flexible layout relaxes these connections and includes an additional shared buffer between the two stages. The solution approach is again based on an MILP model and a decomposition algorithm, the main difference being the inclusion of material balances due to the limited capacity of the buffer.

## 3. Results and discussion

### 3.1 Current layout

A number of different case studies with varying numbers of products have been examined using the aforementioned scheduling algorithm and detailed near-optimal production schedules have been generated. Results indicate that a significant reduction in the changeover time can be achieved even for problems with more than 120 products.

### 3.2 Reconfigured flexible layout

A number of different case studies were examined for the flexible layout as well, again employing an optimization-based decomposition scheduling algorithm. The results demonstrate potential improvements, should this layout be adopted. Good schedules were obtained within very short computation time, which poses a major benefit, as computational efficiency is a key priority in an industrial setting.

## 4. Conclusions

In this work two mathematical frameworks, relying on MILP-based decomposition algorithms, were proposed for the optimization-based production scheduling of a packaged consumer-goods plant. The first approach considers the plant in its current layout, while the second examines a potential flexible layout. A case study with real-life data is used to illustrate the applicability and efficiency of the proposed approaches leading to a noticeable reduction of the changeover times.

## 5. Acknowledgements

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## References

- [1] Méndez, C.A., Cerdá, J., Grossmann, I.E., Harjunkoski, I., Fahl, M., 2006. State-of-the-art review of optimization methods for short-term scheduling of batch processes. *Comput. Chem. Eng.* 30, 913–946.
- [2] Kopanos G.M., Méndez C.A., Puigjaner L., 2010, MIP-based decomposition strategies for large-scale scheduling problems in multiproduct multistage batch plants: A benchmark scheduling problem of the pharmaceutical industry, *European Journal of Operational Research*, 207, 2, 718-735
- [3] Kopanos, G.M., Puigjaner, L., Georgiadis, M.C., 2010. Optimal Production Scheduling and Lot-Sizing in Dairy Plants : The Yogurt Production Line. *Ind. Eng. Chem. Res.* 49, 701–718.