

## Chapter 4.2

# Application of Triplet Notation and Dynamic Programming to Single-Line, Multi-Product Dairy Production Scheduling

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### ABSTRACT

*The application of optimal methods for production scheduling in the dairy industry has been limited. Within supply chain terminology, dairy production was generally considered a push process but with advancements in automation, the industry is slowly transforming to a pull process. In this paper, the authors present triplet notation applied to the production scheduling of a single production line used for milk, juice, and carnival drinks. Once production and cleaning cycles are characterized as triplets, the problem is formulated. Lagrange relaxation is applied and the final solution is generated using dynamic programming.*

### INTRODUCTION

The application of optimal methods for production scheduling in the dairy industry has been limited. The predominate need that has been addressed is the need to forecast supply. As the dairy industry

implements advanced production equipment technologies and demand forecasting becomes stronger, dairies may begin to push back on suppliers and enable efficient production schedules. This paper addresses this emerging area of application.

Raw milk is initially processed into two variations, skim, and whole. One percent and two percent milk are the result of blending appropriate

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ratios of skim and whole milk. Therefore, a single filling line may simultaneously produce all four varieties of milk (Mans, 2007). Other product families such as orange juice, carnival drinks, and buttermilk are also processed using the same filling line although separate storage tanks are used for each product family.

Product is piped into one of two bowls for filling. Between batches of different product families, the equipment must be cleaned. Less extended cleaning can also be required between products within the same product family.

A primary goal of this scheduling approach is to facilitate the transition of the dairy operation from a push system to a pull system. Order due dates will act as constraints in the problem formulation and ultimately guide the order of production. Customers have standing due dates each week for their orders and these dates must be met. Additionally the scheduling approach will reduce inventory held. In the past excess inventory was carried when it was uncertain as to whether an order could be slotted into the production schedule.

A very limited amount of research has been completed in this area. We begin with presentation of literature both directly and indirectly addressing the dairy industry. Chemical industry scheduling models and other type of food processing scheduling models offer insight into appealing approaches to the dairy problem. We then formulate the scheduling problem using triplet notation where the first leg of the triplet represents a production run and the second leg of the triplet represents a cleaning cycle. Constraints are relaxed using Lagrange relaxation and the problem is then solved using dynamic programming.

## LITERATURE

Truckload vehicle scheduling provided the first stepping off point for this research. The nature of productive vehicle movements followed by unproductive movements presented by Miori

(2006, 2008) paralleled the nature of productive scheduling as composed of productive activity followed by unproductive activity such as cleaning and packaging transitions. Batch production scheduling within other industries has been studied at length. The most immediate carry-over in the literature occurs in the chemical industry. Brucker and Hurink (2000) applied a two-phase tabu search to the problem of scheduling batch production to a particular facility. The batches were scheduled in order to meet order deadlines. Production and cleaning times were examined in the tabu search approach as well as in a general job-shop scheduling approach. Wang and Guignard (2002) created a MILP formulation for continuous-time batch processing in the chemical industry. Burkard and Hatzl (2006) applied a heuristic minimizing makespan to batch scheduling problems in the chemical industry. The heuristic was an iterative construction algorithm with recommended diversification and intensification strategies to obtain good suboptimal solutions. Tang and Huang (2007) applied a neighborhood search within a two-stage heuristic to rolling batch scheduling for seamless steel tube production. Cheng and Kovalyov (2001) solved the scheduling of multiple batches on a single machine much like the scheduling that must be performed in this dairy example. The primary objective was to minimize cost while also minimizing maximum lateness, the number of late jobs and the weighted completion time. The authors offered a classification of computational complexities and present efficient dynamic programming algorithms for the problem. Li and Yuan (2006) too discussed scheduling on single machines with the three hierarchical criteria of minimizing makespan, minimizing machine occupation time, and minimizing stock-out cost. Dynamic programming was also used to solve the problem. Yuan, Liu, Ng, and Cheng (2006) applied dynamic programming to single machine batch scheduling problems. Their objective was to minimize makespan when faced with product-family setup times and order release

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