Bottling process of a winery

Scheduling 2017, Prof. Stein, Columbia University

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A winery could benefit from good scheduling practices due to increased produciton

2016 Production	2025 Production
3,200,000 bottles	4,000,000 bottles

Problems the winery is facing

> Meet demand on time for different products
> Limited storage capacity of bottled wine

Project Objective

> Create an annual schedule for the bottling process for 2025 based on forcaset demand

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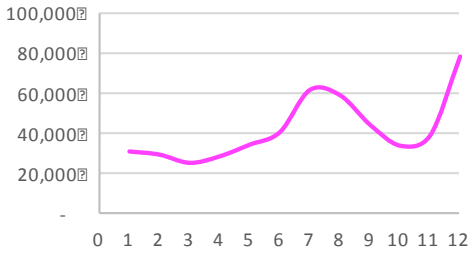
Sunset

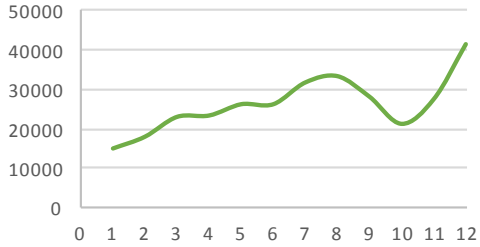
Trend of sales along the year



Once the alcoholic fermentation is completed, wine is bottled to preserve its fruit flavors

Blanc de Blanc

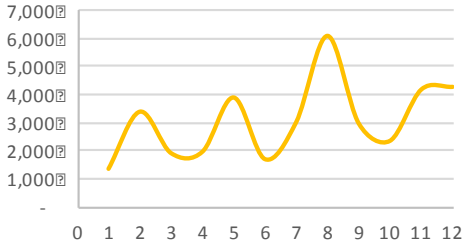
Trend of sales along the year



Matured for 1 to 2 month with oak Chips

Chardonnay

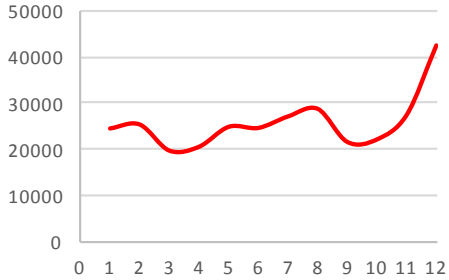
Trend of sales along the year



Matured for 8 to 9 months in French Oak barrels

Reserve du Couvent

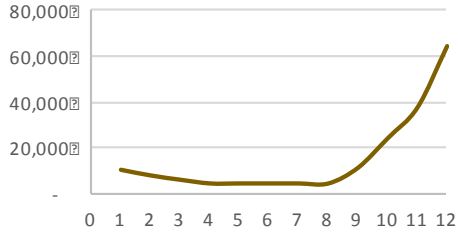
Trend of sales along the year



Matures for 12 months in oak casks and in vats

Prieure

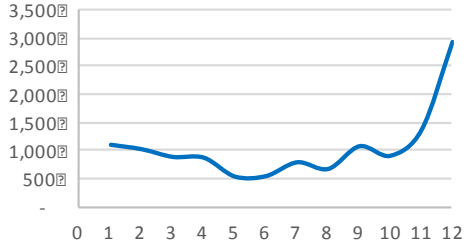
Trend of Sales along the year



Matured for 12 to 14 months in vats

Cuvee de Pritemps

Trend of sales along the year



No maturation needed, wine is drank fresh and young

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Assumptions to organize the data

Assumptions

> One job represents the demand per product per month

Due date

> Due Date (d_j) is estimated as the demand per month per wine.

Release date

> Release time (r_j) is dependent on the fermentation and maturation precess of each wine

Processing time

> The size of each job is forecasted based on the previous years demand and scaled up to 4,000,000 annual bottles

> Processing time (p_j) is then calculated based on the following:

- Total bottling capacity is 20,000 bottles per day
- Bottling is performed 20 days per month (240 days a year)
- Time to switch between products is neglected

Sample of jobs

Jobs	d_j	r_j	p_j
Pri_mar	35	40	0.8
Pri_apr	55	40	0.6
Pri_mai	75	40	0.6
RDC_fev	15	20	3.7
RDC_mar	35	20	2.9
RDC_apr	55	20	3.0
RDC_mai	75	80	3.7
CDP_fev	15	0	0.1
CDP_mar	35	0	0.1
CDP_apr	55	0	0.1
CDP_mai	75	0	0.1
B2B-fev	15	0	2.7
B2B_mar	35	0	3.4
B2B_apr	55	0	3.5
B2B_mai	75	0	3.9
Sun_fev	15	0	4.4
Sun_mar	35	0	3.8
Sun_apr	55	0	4.2
Sun_mai	75	0	5.1

To create the schedule multiple algorthims were explored

L_{max} algorithms

> Problem to solve: $1 \mid r_j, d_j \mid L_{max}$

First Try

> Branch & Bound
> Algorithm extremely complex due to recursivity

Second try

> Enumerate all the schedules
> Compute L_{max} for each schedule
> Take the best on

> Issue: 66 jobs
> number of different schedules: $66!=5.4*10^{92}$

Final L_{max} Algorithm

> Separate the jobs per deadline
> For each month, there is a certain number of jobs which have to be completed
    > we use the time when the schedule of the previous months end
    > then we determine the best schedule based on the release date and the deadline
> Then we compute L_max for each schedule

> Result: L_{max}=11.1 days

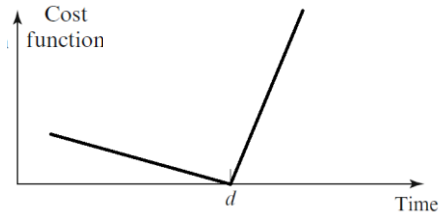
To better account for inventory restrictions, a weighted algorithm was explored

Weighted earliness and tardiness

$$
\begin{aligned}
\text{minimize} \quad & \sum_{i=1}^{n} && w''E_i + w'T_i && \\
\text{subject to} \quad & \sum_{j=1}^{T} && x_{it} = 1, && i = 1, ..., n \\
& \sum_{j=1}^{T}\sum_{i=1}^{n} && s_{ijk}x_{ij} \leq 1, && k = 1, ..., T \\
& && x_{ij} = 0, && i = 1, ..., n,\ j = 1, ..., r_i \\
& \sum_{j=1}^{T} && x_{ij}(j + p_i) = C_i, && i = 1, ..., n \\
& && E_i \geq 0, && i = 1, ..., n \\
& && E_i \geq d_i - C_i, && i = 1, ..., n \\
& && T_i \geq 0, && i = 1, ..., n \\
& && T_i \geq C_i - d_i, && i = 1, ..., n \\
& && x_{ij} \in \{0, 1\}, && i = 1, ..., n\ j = 1, ..., n
\end{aligned}
$$

$$
s_{ijk} = \begin{cases} 1 & \text{if } j \leq k \leq j + p_i, \\ 0 & \text{otherwise.} \end{cases} \quad i = 1, ..., n
$$

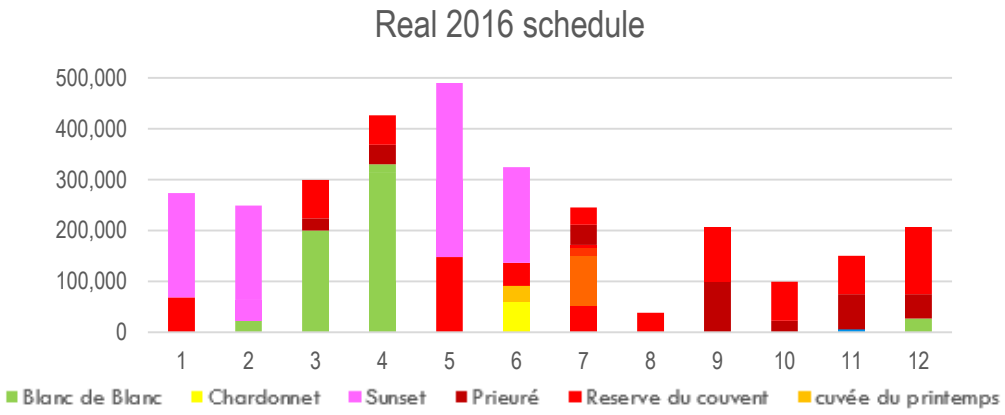
1 > The objective function is a weighted sum of Earliness and Tardiness

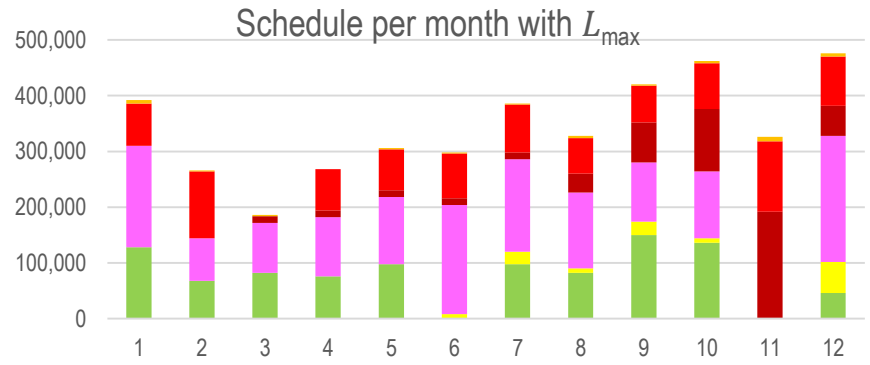


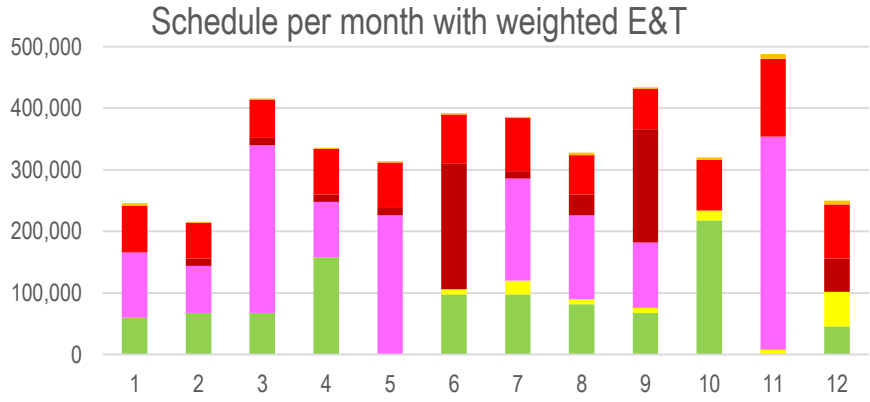
2 > Our program puts more weight on Tardiness by a factor of 1:10

Both algorithms produced satisfactory schedules

2016 schedule modeled schedules







> Less inventory due to better spreading of bottling per wine

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Even with approximations, good results were obtained

Lessons learned

> The number of operation increase very auicly with the number of jobs -> need to be careful in the algorithm

> We can decrease the inventory cost by implementing better scheduling practices

> Dealing with two opposite objectives: inventory and tardiness

Next steps

> Make the schedulue more realistic by including more processes in the factory (ticketing, packaging and so on)

> Take into considerations sesonal labor allocation constraints (harvesting season)

> Include stochastic elements in the schedule

> Improve the assigmnet algorithm for the assignment for different cuves for different wines


Thanks,
questions?