Application of CPLEX in beer production planning

Jiaqi Zhang1,*

1 College of Transport and Communications, Shanghai Maritime University, Shanghai, 201306, China.

* Corresponding author: 202030610093@stu.shmtu.edu.cn

Abstract. In order to enhance the competitiveness of the industry, enterprises will continue to improve the production and operation management plan by means of reasonable allocation of internal and external resources, improving production technology, shortening the manufacturing cycle and reducing production costs. In this paper, a complex production planning problem of beer is introduced. Based on the production of beer enterprises, the production processes of beer are analyzed. The production scheduling model of beer enterprises is established, and the production plan is analyzed and solved by CPLEX solver.

1. Introduction

1.1 Development status of production scheduling

Production planning is a very important link in the beer production process. How to coordinate the use of raw materials according to the production demand, how to coordinate the use of machinery and equipment to shorten the production cycle and improve the production efficiency are the problems that beer enterprises must deal with to improve the competitiveness of the industry and the speed of market reaction. Therefore, making the optimal production plan and scheduling is a key to the survival and development of beer enterprises.

Since 1980, many foreign beer companies have discovered the potential huge beer consumption market in China and entered China immediately to develop their beer business. However, in 1995, many foreign beer companies gave up China's beer market one by one and returned to overseas development. However, after entering the 21st century, some foreign beer companies chose to cooperate with domestic beer companies through share subscription because they were not willing to give up China's beer market completely. With the help of the advantages of domestic enterprises to continue to develop, domestic beer enterprises gradually accumulated experience in the development process of several years, increasingly familiar with. From 2007 to 2011, with the sound domestic economic situation, beer enterprises have considerable opportunities for development; The national strategy of revitalizing the economy and building the new countryside in several regions also made the beer industry create new historical achievements. The domestic beer industry gradually presents the state that dozens of large beer enterprises such as Harbin Beer, Tsingtao Beer and Yanjing Beer carve up the domestic beer market. As the most important link in the beer production process, how to shorten the production cycle, improve the production efficiency and enhance the competitiveness is particularly important. Therefore, the formulation of the optimal production plan and production scheduling is a major problem urgent to be solved for the survival and development of the beer enterprises, and is also the research focus of the current production enterprises.
1.2 Trends in the beer industry
After the reform and opening up, with the rapid development of social economy, China's beer industry is thriving and developing rapidly. In the most prosperous development stage of beer industry, there are more than thousands of beer enterprises in China. By the 1990s, many large beer enterprises, such as Qingdao Brewery and Yanjing Brewery, had achieved leap-forward growth and become the mainstay of the national beer industry. The development of these enterprises can be summarized as follows:

(1) Enterprise mergers and acquisitions are prevalent, and the industry is more centralized. The beer industry in China is developing towards monopoly, and the scale of mergers and acquisitions among enterprises is also gradually expanding. The merger and acquisition boom of beer enterprises promotes the large-scale and intensive production of beer enterprises, and the number of beer enterprises decreases sharply, and the industrial concentration features are obvious.

(2) The emergence of industry giants. After several decades of enterprise integration, Tsingtao Brewery, Yanjing Brewery, Harbin Brewery and other large beer enterprises as representatives of the industry giants.

(3) Expanding the industry. Today, many big beer companies are diversifying. On the one hand, they stick to the development of the main business of beer; on the other hand, they optimize the allocation of their own resources through their own advantages, dabble in wine, tea drinks, and even real estate and biological engineering industries.

(4) Actively implement information management. With the rapid development of information technology, information technology has penetrated into all walks of life, of course, beer enterprises are no exception. To perfect the information construction of beer enterprises, we need to carry out from two aspects. The first is to enhance the degree of external information construction of beer enterprises to achieve the unimpeded external consultation. Nowadays, many major beer companies have established independent consulting centers to collect, integrate, research and utilize information related to beer marketing and beer sales. Second, strengthen the internal information construction, through the ERP system, set up the enterprise internal LAN and other ways to improve the internal information construction. Improve the production process and apply more modern technology to the beer production process. For example, many enterprises have completed the extraction process of pure draft beer through high-tech means, which significantly improves the freshness and freshness degree of beer.

2. Problem description and modeling

2.1 Description
In this paper, a complex beer production planning problem in research on production scheduling optimization of X beer production workshop is used to optimize and solve the model. Beer intermittent production process has constant process steps. Beer production process is mainly composed of four processes: malting, saccharification, fermentation and packaging. Different types of beer need to go through different processes. If it is necessary to work out the production plan of a, B and C beer in the next two years, the production process needs to go through four processes, and each process has a number of equipment for production. In order to limit the production capacity and product profit, how to configure the production plan and equipment to maximize the profit is solved. The specific conditions are shown in Table 1, Table 2. and Table 3.

| project            | Malt-ing | Saccharify-ing | Fermentation | Pack-ing |
|--------------------|----------|----------------|--------------|----------|
| Mellow flavor A    | $a_1$    | $b_1$          | $c_1$        | $d_1$    |
| soft flavor B      | $a_2$    | $b_2$          | $c_2$        | $d_2$    |
| Pure draft beer C  | $a_3$    |                | $c_3$        |          |
| Equipment capacity limit | 400      | 380            | 350          | 10000    |

2
### Table 2. Production planning raw materials and storage.

| project              | materials(t/t) |     |     |
|----------------------|----------------|-----|-----|
|                      | wheat          | Auxiliay |   |
| Mellow flavor A      | 7              | 2   | 1   |
| soft flavor B        | 6              | 3   | 1   |
| Pure draft beer C    | 6.5            | 2.3 | 1.2 |
| stock of raw materials | 3000          | 900 | 500 |

### Table 3. Profits, production demand and consumed time of three types of beer.

| product                | profit(1000 YUAN/t) | Production demand(t) | time (h/t) |
|------------------------|---------------------|----------------------|------------|
| Mellow flavor A        | 6                   | 150                  | 40         |
| soft flavor B          | 5                   | 80                   | 45         |
| Pure draft beer C      | 8                   | 50                   | 50         |

### 2.2 Modeling

According to the problem conditions, the mathematical model of the problem is established, and its objective function, decision variables and constraints are sorted out.

1. Objective function: if the maximum profit is required, the objective function is the product of profit and output.

2. Decision variables:
   1. Production capacity of equipment in each process
   2. Consumption of each raw material in the production process

3. Constraints:
   1. Raw material limit: raw materials used in the production process cannot exceed the reserve of raw materials
   2. Meet the demand: the final production should not be less than the demand, and the final production of the four processes should be greater than the demand
   3. Time limit: the time consumed in the production process should not exceed two years, i.e. 730 days and 17520 hours
   4. Capacity limitation: due to the limited capacity of the equipment, the processing capacity of the previous process equipment should be greater than that of the upstream and downstream process equipment, so as to ensure that all the semi-finished products processed by the upstream can be processed by the downstream process equipment.
   5. Total capacity limit: the final production capacity should be less than the capacity limit of the terminal equipment.

According to the order, it can be expressed as follows:

\[
\begin{align*}
\text{S.T} & \\
\sum_{i=1}^{b} m_{aitj}x_t & \leq m_a, & j \in 1..m \\
\sum_{j=1}^{p} y_{itkj} & \geq d_t, & i \in 1..b \\
x_t & \geq d_t, & i \in 1..b
\end{align*}
\]
\[ \sum_{i=1}^{b} t_i x_i \leq T_i, \quad (4) \]
\[ y_{ij} \geq c_j - c_{j+1}, \quad i \in 1..b, \quad j \in 1..p-1 \quad (5) \]
\[ \sum_{i=1}^{b} x_i \leq c_{p-1} \quad (6) \]

Among them, \( x_i \) represents the output of the \( i \)-th beer, \( y_{ij} \) represents the equipment output of the \( i \)-th beer in the \( j \)-th production process, both of which are decision variables. \( b \) represents three kinds of beer, \( m \) represents three kinds of raw materials, and \( p \) represents four production processes.

1. \( mat_{ij} \) is the usage of the \( j \)-th raw material in the \( i \)-th beer;
2. \( k_{ij} \) is a 0-1 variable, indicating whether the \( i \)-th beer needs to go through the \( j \)-th production process; The values of \( k_{ij} \) are shown in the following table.

| project              | process       |
|----------------------|---------------|
|                      | Malt-ing     | Saccharify-ing | Fermenta-tion | Pack-ing | Mellow flavor A | 1 | 1 | 1 | 1 |
| soft flavor B        |              |               |               |         | 1 | 1 | 1 | 1 |
| Pure draft beer C    |              |               |               |         | 1 | 0 | 1 | 0 |

\( d_i \) indicates the demand of the \( i \)-th beer;
3. \( t_i \) is the beer production time in type-\( i \);
4. \( c_i \) represents the equipment capacity of production process \( j \)

3. Programming and solving by using CPLEX

3.1 Code demonstration

Based on the formula in the previous chapter, the program is programmed with OPL language, and the code is as follows:

```c++
//parameters
int beer = 3;
int process = 4;
int materia = 3;
range b = 1 .. beer;  //three types of beer   range pro = 1 .. process;  //four steps
range m = 1 .. materia;  //type of used materials
int demand[b] = [150,80,50];  //the demand of three types of beer
int material[b] = [3000,900,500];  //the stock of materials
float material_use[b][m] = [[7,2,1],[6,3,1],[6.5,2.3,1.2]];  //materials used in production of different types of beer
int t_lim_each[b] = [40,45,50];  //the profit of each type of beer
int profit[b] = [6,5,8];  //total time limit
int mach_cap[pro] = [400,380,350,10000];  //the production capacity of each machine
int if_pro[b][pro] = [[1,1,1,1],[1,1,1,1],[1,0,1,0]] ;  //the value of kij
```
//variables
dvar float+ x[b] ;
dvar int+ y[b][pro] ;
//expression
    maximize sum (i in b)
        x[i] * profit[i] ;
//constraints
    subject to {
        material_limits:
            forall (j in m)
                sum(i in b) material_use[i][j] * x[i] <= material[j] ;
        demand_meet:
            forall (i in b)
                x[i] >= demand[i] ;
        demand_meet_plan:
            forall(i in b)
                sum(j in pro) y[i][j] * if_pro[i][j] >= demand[i] ;
        time_limit:
            sum(i in b) x[i] * t_lim_each[i] <= t_lim ;
        production_ability1:
            forall(i in b, j in pro)
                y[i][j] >= (mach_cap[i] - mach_cap[i+1]);
        production_ability2:
            sum(i in b) x[i] <= mach_cap[process - 1] ;

3.2. Solution
Run the code in CPLEX, finally, a solution with the maximum target value of 2260 yuan is obtained, and the result is shown in Figure 1.

![Fig. 1. solution.](image)

The capacity of equipment in the four processes is shown in the figure below.
Table 5. Process and equipment conditions.

| project          | process       | sum |
|------------------|---------------|-----|
|                  | Malt-ing      | Saccharify-ing | Fermenta-ion | Pack-ing |
| Mellow flavor A  | 90            | 20            | 20           | 20       | 150   |
| soft flavor B    | 30            | 30            | 30           | 30       | 120   |
| Pure draft beer C| 50            | 0             | 0            | 0        | 50    |

4. Summary and Prospect
A large number of beer enterprises always have weak self-restraint ability, low product grade, unreasonable resource allocation and other defects. Therefore, how to enhance the overall ability of China's beer enterprises, increase the high-tech content of products, and enhance the international competitiveness of beer products has long been an influential research topic. However, the production process of beer itself is relatively fixed, and its many technological methods, the production process is not coherent, the nature of the process and the object is complex, and the production information is not perfect, which makes the planning and scheduling used in beer production more difficult.

Nowadays most beer enterprises in production planning and production scheduling are completed by the lowest levels of manual operation, such easy to cause the production of beer hoarding or shortage problem, directly for beer caused serious influence the normal operation of enterprises, not only can cause huge economic losses to the enterprise, but also conducive to beer enterprise brand image. At present, the exploration of these problems is still in the basic period, and the traditional mathematical methods are usually used to solve these problems, but the effect is not satisfactory. With the leap of science and technology, many intelligent optimization algorithms have been born, which have been developed through simulation or interpretation of some natural phenomena, giving people new thinking and ways to solve difficult problems. These algorithms may take a lot of time to solve problems, but the results delight users and are widely used beyond traditional mathematics. In this paper, beer production workshop is taken as the research object, and the production planning problem model is described and solved with examples.

References
[1] Zhang Yuanlv. The Optimization Research Of The Beer Production Processing [D]: South China University of Technology, 2014
[2] Zhang Guangxin. Research on Application of automatic control machine in beer production process [M]: Zhejiang University, 2002
[3] Song Cunli. Research on production scheduling problem and its function optimization algorithm [M]: Dalian University of Technology
[4] Cheng Qinglei. Research on resource marketing strategy of beer companies [M]: Ocean University of China, 2012
[5] Chu Jian, Rong Gang. Process Industry Integrated Automation Technology [M]: Beijing Machinery Industry Press, 2004
Chen Ming. Humanized design concept in urban road design application study [J]. Journal of urban planning. 10.19569 / j.carol carroll nki cn119313 / tu 2016.28.012