Optimization model on the medicine-chest design

Ying Xia

Department of Basic Courses, Hainan Technology and Business College,

Haikou, Hainan, 570203, China

yigch007@163.com

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Abstract. It studies the optimization model of medicine-chest design. Given four different conditions of the medicine-chest design, it sets up a corresponding nonlinear, double objective optimization model to realize medicine-chest design.

Issues raised and analysis

Issues raise from http://mcm.edu.cn/ .Design of medicine-chest should be taken to meet the minimum vertical spacing type under the given four different conditions. According to the title of various requirements, it sets up the optimal mathematical models to obtain the minimum number of vertical spacing type, each type of kit distribution, the minimum number of drug reservoir storage tank and the number of the medicine cabinet. Due to as many as 1919 kinds of kit and the large different in the three dimensions of kit (length, width, height), it firstly assumes that all the kit is in one line in accordance with the gap required on the open space, and the sum of width should be less than the width of the cabinet Multiplied by the layer number, therefore it needs to set the height between floors and the number of layers in each floor height. Then all the kit is classified according to the required floor height, and then the optimization model of reservoir tank is build. When considering the total width redundancy, it only needs to modify the objective function in problem 1.In consideration of the minimal site redundancy of the reserve receptacles, and of the actual effective height, it requires to define the concept of site redundancy, and then considers how to modify the objective function and constraints. To solve the number of reservoir tank and the required minimum number of medicine-chest to a single drug, the maximum daily demand for each drug multiplies by the respective length, then divides by the length of the reservoir tank to get the number of reservoir slots required for the reservoir for a single drug, and taking big principle is used to determine the minimum number of the medicine-chest under the maximum daily demand.

Model assumptions

1. Assume the data is true, valid, representative;
2. Ignore away to the thickness of transverse or vertical bulkhead;
3. Only consider one slot for each kit, do not taking repeat slot.
4. In problems 1 and 2, it only considers the factors of height, width of medicine-chest, ignoring the length of kit, lot validity, drug relevance , dispensary efficiency and other factors;
5. In issue 3 and 4, the effective height and demand are considered for medicine-chest, ignoring batch FIFO principle, and relevant factors such as the appropriate approaches for pharmaceuticals.

Different model establish under the four different conditions

3.1 Design model on vertical spacing partition type of medicine-chest

3.1.1 Estimation on the reservoir layers of medicine cabinet

① Statistic the line chart of kit height distribution

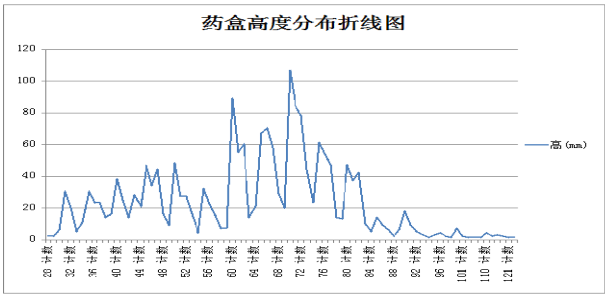

Fig.1 kit height distribution line chart

It is not hard to see from Figure 1, the height of the kit normally distributes. Height under 38 mm has 166 kinds, high in 39 ~ 77 mm has 1477 species, height more than 78 mm is 276 species.

Table 1 Kit height segmented distribution table

Kit height (mm)	≤ 38	[39,77]	≥ 78
Storey type	Low	medium	high
Number of species (kinds)	166	1477	276

Taking into account the 2mm gap should be left between the kit and the upper transverse partitions, the floor height is divided into three sizes: 40mm, 79 mm, 127 mm. The 40mm low-rise storey can store the kit which is less than or equal to 38mm, the 79mm medium -interval can store the kit between 39～77mm, the 127mm top-height storey can store more than 78mm kit.

② The number required for three types of height

Now use Excel to divide all kit into three groups according to the three types of height, and then estimate the number of layers required for each type of setting.

In the 40mm low-rise storey, a total of 166 kinds kit is to be placed, the width of each drug is W_i (i=1,2,…,166), just stay on each side 2mm, you can store the drug, then the minimum value of width to the drug is $W_i + 2 \times 2$, the sum of width needed at least to store all drugs is: $\sum_{i=1} (W_i + 2 \times 2)$, and then divide by the width of the storage cabinet, and integer to get B_i to estimate the number of piles needed for the low-rise storey:

$$B_i = \left\lceil \frac{\sum_{i=1}^{166} W_i + 2 \times 2}{2500} \right\rceil \qquad (i=1,2,3)$$

Similarly, the number of piles of other two types can be calculated, as shown in Table 2:

Table 2 The table on the number of piles to the three types

The height type	Low	Medium	High	Total
The desired number of layers Bi (layer)	1	16	3	20
Medicine-chest height (mm)	40	79	127	
total	40×1+79×16+3×127=1685mm<2500mm			

From Table 2, all the kit can be installed, in consideration of its height, width, and other factors, it can set 20 floors, where there is a layer of low-level type, medium-level type has 16 layers, high-level type has 3 layers.

3.1.2 Optimization model to drug storage tank

When the number of layers of medicine-chest storage is estimated, it can assume that now all layers can be cut open, and can be split into a layer, all medicines will be put in this layer, so the problem is converted into optimization of the specifications of the medicine storage tank under the condition to meet the drug storage capacity. Drug storage groove optimization problem is described as:

$$\min S=\sum_{j=1}^{n} W_j \tag{1}$$

$$s.t.\begin{cases} \dfrac{W_j}{2}<w\le W_j-4 & (j=1,2,\cdots,n) \quad (2) \\ \sum_{j=1}^{n} n_j W_j \le 20W_c & (j=1,2,\cdots,n) \quad (3) \\ W_j \ge 0 & (j=1,2,\cdots,n) \quad (4) \end{cases}$$

Which W_c is the width of the medicine-chest, n_j indicates the number of the j width scale, W_j is the width size for the j reservoir slot, n is the number of width specification, w is for the width dimension of each kit. Here W_c=2500mm is a known quantity, w is the width for each kit, unknown quantity is W_j, n_j, n.

In the above formulas, the formula (1) is the objective function, which means the minimum value of the pitch type, i.e. the sum of lengths of various types is minimum; formula (2) to protect anyone which of the cartridge into the j-type width tank, which must be greater than half the width of the slot to keep off the decline of drugs, or the side overlap, and must be less than the width of the groove which cuts 4mm, in order to stay out a 2mm gap to the groove on both sides of the vertical separator; the formula (3) indicates that all width-sum of specifications under various width must be less than the total width of 20 layers, so that all drugs can accommodate meantime; the formula (4) is non-negative constraints of the decision variables.

3.2 Design to the vertical type baffle spacing under total width redundant

Because of the conditions strengthen, on the basis of problem 1, it adds a minimum new width redundancy target, so on the overall thinking, no needs to change the conclusion in the first level of thinking to problem 1, still uses the conclusion of the three height layers and layers required. Mainly to adjust and optimize the model objective function, now ω_t is the width of kit located number t, W_j is the kit width located number t into which is put the j groove, the width redundancy of the number t kit is:

$$y_t = W_j - W_t - 4$$

The total width of redundancy y is:

$$y=\sum_{t=1}^{1919}\left(W_j - W_t - 4\right) \qquad (j=1,2,\cdots,n;t=1,2,\cdots,1919)$$

Optimization model under the total width redundancy is transformed into:

$$\min f=\sum_{t=1}^{1919}\left(W_j - w_t - 4\right) \qquad (j=1,2,\cdots,n;t=1,2,\cdots,1919)$$

$$s.t\begin{cases} \dfrac{W_j}{2}<\mathrm{w}_t \le W_j-4 & (j=1,2,\cdots,\mathrm{n}) \\ \sum_{j=1}^{n} n_j W_j \le 20W_c & (j=1,2,\cdots,\mathrm{n}) \\ W_j \ge 0 & (j=1,2,\cdots,\mathrm{n}) \end{cases}$$

3.3 Design minimum vertical clapboard type under the site redundancy

3.3.1 Thinking on effective height $H_c\left(=1500mm\right)$

In Question 3, due to considering convenience for supply medicine, the site redundant and effective height need to be considered.

Due to the limit of the space height, so the sum of products between the layers under each floor height and respective floor height should be less than the effective height of medicine cabinet, namely: $\sum_{i=1}^{m} n_i H_i \le H_c$, among them m is for the number of floor height type.

On the other hand, H_i is the height of each layer, in order to ensure the drugs in the medicine slot smoothly in and out of storage, a gap of 2mm should be leaved between pill boxes and on both sides of the horizontal clapboard, but here the thickness of the transverse clapboard is ignored, only considering the height H_i of Number l drug less than 2mm, thus:

$$H_i + 2 \le H_i \left(i = 1,2,\cdots,m; l = 1,2,\cdots,1919 \right)$$

3.3.2 Calculation of the site redundancy

First consider the amount of high redundancy for number t drug kit: $H_y = H_i - H_l - 2$; while its width of redundancy is $W_y = W_j - w_t - 4$, Thereby obtain the redundancy for number l drug as $P_y = H_y \cdot W_y$, namely:

$$P_y = H_y \cdot W_y = \left(H_i - H_l - 2\right)\left(W_j - w_t - 4\right)$$

Thus the site redundancy for all drugs $P_{总y}$ is as follows:

$$\begin{aligned} P_{总\mathrm{y}} &= \sum_{y=1}^{1919} H_y W_y \\ &= \sum_{t=l=1}^{1919} \left(H_i - H_l - 2\right) \left(W_j - w_t - 4\right) \end{aligned}$$

3.3.3 Dual-objective optimization model

It needs to achieve two purposes in this question, the purpose1 is requested the site minimum redundancy, while purpose 2 is to require the number of horizontal baffle spacing type as less as possible, thus a double objective function can be established. This question is asked to add the limit of the effective height and the demand of the gap height between the floor and kit, then:

$$\min f = \sum_{t=l=1}^{1919} \left(H_i - H_l - 2\right)\left(W_j - w_t - 4\right)$$

$$\min T = \sum_{l=1}^{m} H_i$$

$$s.t. \begin{cases} \dfrac{W_j}{2} \langle w_t \le W_j - 4 & \left(j=1,2,\cdots,n; t = 1,2,\cdots 1919\right) \\ \sum_{j=1}^{n} n_j W_j \le 20 W_c & \left(j = 1,2,\cdots,n\right) \\ H_l + 2 \le H_i & \left(i = 1,2,\cdots,m; l = 1,2,\cdots,1919\right) \\ \sum_{i=1}^{m} n_i H_i \le H_c & \left(i = 1,2,\cdots,m\right) \\ W_j \ge 0, H_i \ge 0 & \left(i = 1,2,\cdots m; j = 1,2,\cdots n\right) \end{cases}$$

3.4 Determine the number of drug reservoir tank

3.4.1 In a single drug case

(1) The total length of a single drug to meet the maximum daily demand is set $L_{总l}$:

Set the length of number l drug kit for L_l , the maximum daily demand for the drug is Q_l , thus the total length of the drug to meet the maximum daily demand is $L_{总l}$:

$L_{总l} = L_l \cdot Q_l \quad (l = 1, 2, \cdots, 1919)$.

(2) The number of drug reservoir tank required to store the single drug

Due to the length of the unit medicine storage tank is $1.5m$, that is $1500mm$, then the number of medicine storage slot needed for the single drug is D_l :

$$D_l = \left[\frac{L_{总l}}{1500} - 0.5\right] + 1$$
$$= \left[\frac{L_l \cdot Q_l}{1500} - 0.5\right] + 1 \qquad (l = 1, 2, \cdots, 1919)$$

(3) The number of medicine cabinet storage needed for the single drug

Assume that the single drug in the same store only occupies one drug storage tank in the medicine cabinet， in other words, the number E_l of storage cabinet needed for the single drug Is the number of drug storage slot needed for the single drug. Therefore:

$$E_l = D_l = \left[\frac{L_l \cdot Q_l}{1500} - 0.5\right] + 1 \qquad (l = 1, 2, \cdots, 1919)$$

3.4.2 Determine the number of reservoir medicine-chest

Assume that the existing Numbers of drug kit for $l_1, l_2, \cdots, l_m$ $(m = 1, 2, \cdots, 1919)$, they need the number of storage cabinet respectively is: $E_{l_1}, E_{l_2}, \cdots, E_{l_m}$,which to meet the demand for the biggest day of every day, the required minimum number storage cabinet should be the largest value among $E_{l_1}, E_{l_2}, \cdots, E_{l_m}$, thus the number of medicine cabinet needed to store the1919 drugs is E_{1919} :

$$E_{1919} = \max_{1 \le l \le 1919} \{E_l\}$$

Assessment and Promotion

It establishes optimization model, eliminating a lot of secondary factors to make the model simple and feasible. Combining with the actual situation to establish optimization model has good versatility and promotion. However, according to the height of medicine distribution, three sessions were artificial, and setting the value of segmented point, while weak the calculation difficulty, but does not enough science. The optimization model can be applied to the design of supermarket shelves, the shelves design of chain stores and logistics center warehouse.

References

[1] Qian Zhang, Feng-rong Zhao, song-zi wange tc. The main problem and countermeasures of small medicine cabinet Ward Management [J]. Modern Drug Application.

[2] sheng-lu ren , significant test on linear regression models, mathematical modeling, in 2012 the third period.

[3] Shou-kui Si, algorithms and procedures on mathematical modeling [M], Beijing: Naval Aeronautical Engineering Institute Press, 2007.

[4] Qiyuan Jiang, JinXing Xie, Jun YE, mathematical modeling [M] .4 Beijing: Higher Education Press, 2011.

[5] Xinsheng Yuan, DaHong Shao, Shilian Yu, LINGO and EXCEL in the mathematical modeling of Science Press, 2007.