ISSN : 0974 - 7435 Volume 10 Issue 20

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(20), 2014 [11996-12000]

A dispatch model of ammunition supply in wartime

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ABSTRACT

Ammunition dispatch is an important part of ammunition support work in wartime, its rationality directly affects whether ammunition supply goes on well. This paper analyzes the ammunition dispatch problems from the perspective of technical implementation and application in wartime, and builds a multi-object optimization model to optimize the transportation time and the number of probability ammunition arrived safely. By comparison with conventional dispatch model, we find that the proposed model has many advantages for ammunition dispatch, and it can provide a practical method for ammunition support commanders to shorten the transportation time and increase the number of probability ammunition arrived safely.

KEYWORDS

Probability ammunition; Important degree; Demand rate; Priority rank; Dispatch model.

INTRODUCTION

Modern warfare has the characteristics of major combat strength, short duration and huge material consumption, and how to use the scientific method to quickly dispatch materials, especially for ammunition. So the ammunition dispatch is an urgent problem in the current support work. At present, many scholars have done many studies about the ammunition dispatch[1-3]. However, their studies are mainly the usual ammunition dispatch, and they rarely study about the parallel case of transportation time and security under war conditions. Therefore, the paper builds a dispatch model in wartime, whose parallel goals are the number of probability ammunition and transportation time.

INTRODUCTION AMMUNITION DISPATCH MODEL

Assuming the $A_1, A_2, \cdots, A_M$ are ammunition demand points, the required number of ammunition are x_i (i=1,2,⋯,M), the $B_1, B_2, \cdots, B_N$ are all the ammunition support points in the demand region, their reserved number of ammunition are y_j (j=1,2,⋯,N). It takes t_{ji} from B_j to A_i. The security from B_j to A_i is represented by the line safety e_{ji} ($0 < e_{ji} < 1$). The number H_i（i=1,2,⋯, M）of probability ammunition to safely reach the demand points, is the product sum of line safety and the number of transportation ammunition on the corresponding line.

The program $\omega = \{(B_1, y_{1i}, t_{1i}, e_{1i}), (B_2, y_{2i}, t_{2i}, e_{2i}), \ldots, (B_K, y_{Ki}, t_{Ki}, e_{Ki})\}$ is a dispatch program of the A_i. The K is a support point number. The y_{Ki} is the number of supply ammunition from B_K to A_i. The y_K is the reserved number of the B_K, and the $y_{Ki} \le y_K$ is satisfied. The paper studies a reasonable dispatch program, which makes the demand points get more number of probability ammunition, but also makes transportation spend less time under the relevant constraints. If the $T(\omega)$ represents the total time of ammunition transportation in the dispatch program ω, the $H_i(\omega)$ represents the number of probability ammunition to reach the demand points, the ψ represents the set of all dispatch programs. Then the reasonable dispatch model is expressed as follows.

$$\begin{cases} \min T(\omega) \\ \max H_i(\omega) = \sum_{j=1}^{K} y_{ji} \times e_{ij} \\ st. \quad \omega \in \psi \end{cases} \tag{1}$$

AMMUNITION DEMAND PRIORITY

The ammunition demand priority is actually a prioritized list of the ammunition demand. It is helpful to focus the limited ammunition to the demand points that are the most in need of support. The paper mainly analyses the ammunition demand priority from important degree and demand rate.

The important degree

The important degree is usually determined by the weighted sum of the urgency α_1 of combat missions, the easy degree α_2 of implementation of supply, the timeliness α_3, the importance α_4 of combat troops and supply region α_5. The important degree is as follows.

$$\delta_i = \sum_{p=1}^{5} \alpha_p \beta_p \tag{2}$$

The δ_i represents the important degree of i-th ammunition demand point, the α_p represents p-th index value, and the β_p represents p-th index weight.

The Demand Rate

The demand rate is the ratio between the demand number of a demand point and the total demand number. It is as follows.

$$\lambda_i = \frac{x_i}{\sum_{i=1}^{M} x_i} \tag{3}$$

The λ_i represents the demand rate of the A_i, and the x_i represents its demand number.

Generally, the greater important degree of demand point is, the higher its priority is. At the same time, the smaller demand rate of demand point is, the easier it is to be met. Therefore, if the important degree of demand point is great and its demand rate is small, then its priority is high.

The solving ammunition priority is a multi-objective selection process. It can be solved by this method, which is the important degree and demand rate into the optimum value and the worst value [4]. Suppose δ_{i1}, δ_{i2}, λ_{i1} and λ_{i2} is respectively the optimum value and the worst value of important degree, the optimum value and the worst value of demand rate. Then the proximity degree of important degree and demand rate of the A_i to its optimal value is shown below [5].

$$\eta_{i1}=\gamma_1 \frac{\delta_i}{\delta_{i1}}+\gamma_2 \frac{\lambda_{i1}}{\lambda_i} \qquad i=1,2,\ldots,M \tag{4}$$

The proximity degree of important degree and demand rate of the A_i to its worst value is shown below [6].

$$\eta_{i2}=\gamma_1 \frac{\delta_{i2}}{\delta_i}+\gamma_2 \frac{\lambda_i}{\lambda_{i2}} \tag{5}$$

The γ_1 represents the weight of important degree, the γ_2 represents the weight of demand rate, and are respectively 0.7 and 0.3. in the paper.

The relative proximity degree of the A_i to its optimal value is as follows.

$$\eta_i=\frac{\eta_{i1}}{\eta_{i1}+\eta_{i2}} \tag{6}$$

By the formula (2)~(6), the ammunition demand points obtain respectively relative proximity degrees η_i $(i=1,2,\ldots,M)$. According to the descending arrangement, the η_i $(i=1,2,\ldots,M)$ are arranged. The priority of ammunition demand points in the front of the queue is high, and should give priority to transport their demand ammunition.

THE SOLVING PROCESS

Because of the urgency of the war, there will be a limited time T for ammunition support. Within the time T, ammunition must be transported to the designated locations, otherwise the dispatch program will be meaningless. The t_{1i},t_{2i},⋯,t_{pi},⋯,t_{Ni} are respectively transportation time from B_j (j=1,2,⋯,N) to A_i, the T_i is the limited time to transport to the A_i. If the $t_{pi} \le T_i$ is satisfied, then the ammunition support point can be involved in the supply, otherwise the point can not be involved in the supply. Finally, the number of ammunition demand points to meet the supply requirement is n.

According to the e_{pi} descending order, the n support points arrange $(B_1,x_{1i},t_{1i},e_{1i})$, $(B_2,x_{2i},t_{2i},e_{2i})$,…, $(B_n,x_{ni},t_{ni},e_{ni})$. If there is $k1\,(1\le k1\le n)$, making $\sum_{j=1}^{j=k1-1} x_{ji} < x_i \le \sum_{j=1}^{j=k1} x_{ji}$ satisfy, then the program $\omega_1=\{(B_1,x_{1i},t_{1i},e_{1i}),(B_2,x_{2i},t_{2i},e_{2i}),\ldots,(B_{k1},x_{k1i},t_{k1i},e_{k1i})\}$ is a dispatch program of the maximum number of probability ammunition. At the same time, we search all support points within the region to meet the limited supply time, and get other dispatch program for the A_i.

We solve the optimized values of all dispatch programs for the A_i, which are as follows.

$$G_i(p)=\frac{H_i(p)}{x_i}\times\varepsilon_1+\frac{T_i-\max(t_{1i},t_{2i},\ldots,t_{pi})}{T_i}\times\varepsilon_2 \tag{7}$$

The $G_i(p)$ represents the optimized value of the dispatch programs ω_p, the $H_i(p)$ represents the number of probability ammunition of the ω_p, the $\max(t_{1i}, t_{2i}, \ldots, t_{pi})$ represents the transportation time of the ω_p, the ε_1 and ε_2 are two index weights, and are respectively 0.6 and 0.4.in the paper.

If the $G_i(p)$ is the largest in all optimized values, then the program ω_p is the best dispatch program for the A_i. In turn, we search the dispatch programs of other ammunition demand points. Finally, we can get the optimal dispatch programs of all ammunition demand points.

Through the above description, we know that the major differences between the proposed dispatch model and conventional dispatch model are as follows.

TABLE 1 : The major differences

	the proposed dispatch model	**the conventional dispatch model**
optimization goal	multi-goal	single goal
transport issues	much consideration	little consideration
support order	accurate calculation	rough estimate
support accuracy	high	Low
support quality	good	Poor

As seen in TABLE 1, the model in the paper is better than the conventional dispatch model in many ways, especially in solving the dispatch problems between multi-demand and multi- support points.

APPLICATION CASE

Assuming the A_1, A_2, A_3 and A_4 are the four ammunition demand points, their supply limited times are respectively 35, 35, 30 and 40, and the required amount of ammunition are respectively 48, 37, 41, and 50, which are from seven ammunition support points in the vicinity of the demand points. Their reserved numbers of ammunition are respectively 8, 15, 29, 27, 38, 29, and 35. The judgment data of important degree of ammunition demand points are shown in TABLE 2. The transportation time and safety from support points to demand points are shown in TABLE 3.

TABLE 2 : The relative data of important degree

	α_1、α_2、α_3、α_4、α_5	β_1、β_2、β_3、β_4、β_5
A_1	0.5、0.8、0.6、0.7、0.4	0.32、0.12、0.19、0.15、0.22
A_2	0.8、0.7、0.6、0.5、0.7	0.32、0.12、0.19、0.15、0.22
A_3	0.9、0.6、0.7、0.5、0.8	0.32、0.12、0.19、0.15、0.22
A_4	0.7、0.6、0.5、0.4、0.6	0.32、0.12、0.19、0.15、0.22

As shown in TABLE 2, by the formula (2), we can obtain the important degree of ammunition demand points, which are respectively δ_1=0.563, δ_2=0.683, δ_3=0.716 and δ_4=0.583. By the formula (3), we can obtain demand rate that are respectively λ_1=27%, λ_2=21%, λ_3=23% and λ_4=29%. By the formula (4)~(6), we can obtain relative proximity degree, which are respectively η_1=0.445, η_2=0.549, η_3=0.553 and η_4=0.447. Therefore, the support orders are A_3, A_2, A_4, *and* A_1.

TABLE 3 : The transportation time and safety from support points to demand points

	B_1	**B_2**	**B_3**	**B_4**	**B_5**	**B_6**	**B_7**
A_1	18/0.89	24/0.91	21/0.86	28/0.88	34/0.91	36/0.88	32/0.89
A_2	13/0.93	23/0.92	25/0.90	24/0.87	29/0.94	31/0.89	38/0.85
A_3	15/0.93	18/0.85	26/0.89	23/0.87	35/0.88	32/0.91	27/0.95
A_4	20/0.97	18/0.93	26/0.92	33/0.93	41/0.93	29/0.91	36/0.96

In accordance with the relevant data in TABLE 3, we get the dispatch program of four ammunition demand points. By the formula (7), we can get their optimal dispatch programs. The calculation process of dispatch program is shown in TABLE 4.

TABLE 4 : The calculation process of dispatch program

	the e_{ji} descending order	ω	$H_i(\omega)$	$T(\omega)$	the optimized ω'	$H_i(\omega')$	$T(\omega')$
A_3	$x_{73}x_{13}x_{33}x_{43}x_{23}$	$x_{73}x_{13}x_{33}$	38.79	27	$x_{13}x_{23}x_{43}$	35.67	23
A_2	$x_{52}x_{32}x_{62}x_{42}$	x_{52}	34.78	29	x_{52}	34.78	29
A_4	$x_{74}x_{44}x_{34}x_{64}$	$x_{74}x_{44}x_{34}$	47.46	36	$x_{24}x_{64}$	45.79	29
A_1	$x_{51}x_{71}x_{41}$	$x_{51}x_{71}x_{41}$	37.34	34			

As seen in TABLE 4, the dispatch program gives priority to support the high-priority demand points. It is larger for the number of probability ammunition, and it is also shorter for transportation time. For lack ammunition of demand point A_1, we need to apply for leapfrog support.

CONCLUSIONS

Modern warfare has the characteristics of high speed, high mobility, and high consumption, which requires fast and efficient ammunition support. The dispatch model in the paper can meet the mission requirements in the limited constraints. At the same time, the model increases the number of probability ammunition, shortens the transportation time, and improves the effectiveness of ammunition support. It provides a new idea and method for ammunition support commanders to solve the dispatch problems between multi-demand and multi- support points.

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