US army aviation's battlefield POL assurance model simulation based on system dynamics

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Abstract

To solve the issue of the US Army Aviation's battlefield POL assurance, this paper proceeds from the principle of fully guaranteeing the army POL supply to establish the army aviation's POL prediction model and puts the POL parameters of US conventional helicopters into the model. Besides, this paper establishes the system flow graph of the transportation and information delay function based on System Dynamics (SD) to simulate three different battlefield situations. The transportation and information delay are formulated according to the real examples. This paper integrated them into the SD model. The simulation results show that the SD-based model can directly reflect the changing trend of various factors of the POL Assurance. Then accord the result of simulation, input different parameters can be derived the changing curve that can help to realize the computer aided decision.

Keywords: POL demand, system dynamics, US army aviation unit, delay function

1 Introduction

The army aviation's battlefield POL assurance has its own characteristics [1]. It is different from the POL assurance of the air force station and the army aviation's force station [2]. Since the army aviation's usually launches large-scale manoeuvring, POL assurance is a great difficulty for the army aviation's manoeuvring military operation. Besides, the army aviation also has its fixed station, so its POL assurance also shares the characteristics of that of the air force station [3]. When the army aviation is implementing their military tasks, it faces great burdens of POL assurance [4]. If there is no immediate POL supply, even the most state-of-the-art devices and well-designed plans cannot help. How to provide the army aviation with powerful POL assurance can directly influence the make or mar of the battle [5].

US Army Aviation is an important fighting force of its army troops [6]. Many other countries refer to its fighting methods and POL assurance strategies [7]. This paper adopts US Army Aviation as the research object and explores its battlefield POL assurance [8].

2 Model establishment

2.1 DAILY POL CONSUMPTION AMOUNT PREDICTION MODEL OF SINGLE-HELICOPTER FIGHTING

The daily POL consumption amount of the single-helicopter fighting is calculated according to the daily flight time and consumption amount of the single-helicopter fighting. It can be expressed through the following Equation [9].

$$C_d = H_f \cdot S_c, \tag{1}$$

where C_d stands for the daily POL consumption amount of the single-helicopter fighting, H_f stands for the flight hours and S_c stands for the consumption standard of the POL products.

When the POL consumption amount is calculated according to the number of flights, the flight time should be changed to the number of flights, and the consumption standard of the POL products should also be in line with the POL amount regulation for each operation [10].

2.2 DAILY POL CONSUMPTION AMOUNT MODEL OF A HELICOPTER OF A CERTAIN TYPE

$$C_{id} = C_d \cdot N_i \cdot R_i \cdot Q_i, \tag{2}$$

where C_{id} stands for the daily consumption amount of an helicopter of a certain type, N_i stands for the number of flights, R_i stands for the rate of helicopter and Q_i stands for the campaigning frequency.

2.3 THE FIGHTING POL CONSUMPTION AMOUNT PREDICTION MODEL OF AN ARMY OF A CERTAIN HELICOPTER

$$C_i = C_{id} \cdot S_z, \tag{3}$$

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where C_i stands for the POL consumption amount of the single-helicopter army and S_z stands for the days of the military operation.

Besides, the affiliated POL consumption amount of the single-helicopter army military operation can also be worked out through the factors, including the main POL consumption amount of the single-helicopter military operation and the affiliated POL consumption coefficient.

2.4 POL CONSUMPTION AMOUNT PREDICTION MODEL OF THE MULTI-HELICOPTER MILITARY OPERATION

$$Z = \sum_{i=1}^{n} C_i , \quad (4)$$

where Z stands for the POL consumption amount of the multi-helicopter military operation, i=1,2,3,…,n stands for the type of the helicopter.

There are many methods to predict the aviation's main POL consumption. The method of using the mathematical model to conduct quantitative calculation is a major one currently. The military strength distribution of the army aviation during the wartime is measured according to the number of campaigning flights. In the prediction of the main POL consumption of army aviation, it should be calculated according to the campaigning flights of different types of helicopters. Then the military strength distribution and the mail POL consumption of army aviation are in line with each other. Besides, different types of helicopters have different requirements of the remaining POL in the oil tank before landing. Thus, the maximum allowable POL consumption amount can be identified. According to the maximum allowable POL consumption amount and the number of campaigning flights, the oil consumption amount can be gained. The method calls for the collaboration and cooperation of the military operation department. As long as the military operation department confirms the campaigning flights, the oil required amount for the military operation and maneuverer can be quickly and accurately predicted. The specific method is:

Aviation's main POL consumption amount of a certain type of helicopter=the number of helicopters of a certain type × campaigning rate of the helicopter × campaigning frequency × fighting time × main oil consumption rate in the sky × single-helicopter POL base amount × 1 + ground main POL consumption rate.

Namely:

$C_i=NiR_iQ_iS_zO_cK_i(1+R_c)$.

Considering that the army aviation usually adopts various types of helicopters for its military operation, the army aviation's main POL consumption amount should be the sum of the main POL consumption amount of all kinds of helicopters' aviation. Therefore, the following Equation is used to calculate the total aviation's main POL consumption amount:

$$Z = \sum_{i=1}^{n} N_i R_i Q_i S_z O_c K_i (1 + R_c) , \quad (5)$$

where Z stands for aviation's main POL required amount, i for a certain type of helicopter, n for the number of campaigning helicopter types, N_i for the number of i type helicopter, R_i for the campaigning rate of the helicopter, Q_i for the single-helicopter campaigning POL consumption base amount of the i type helicopter, K_i for the main POL consumption rate, R_c for the ground-to-air main POL consumption ratio of the i type helicopter.

3 Identification of the helicopter's basic parameters

3.1 BASIC PARAMETERS OF VARIOUS TYPES OF PARAMETERS

Situation of US army, this paper predicts the major fighting helicopters of US Army Aviation in the future is Apache, Osprey and Black Hawk.

The POL parameters of various kinds of helicopters are shown in Table 1.

TABLE 1 POL parameters of helicopters of different types

Type	Volume of oil tank (litre)	POL consumption amount (litre/hour)	Maximum speed (km/hour)	Military operational radius (km)
AH64	1470	495	365	480
V22	7627	1088	509	690
CH47	8519	1775	280	650
UH60A	1385	429	357	592

3.2 CAMPAIGNING FREQUENCY OF HELICOPTERS

Campaigning frequency refers to the campaigning times in the unit time while the army aviation soldiers are implementing their aviation tasks. It is usually calculated according to the number of campaigning times of each helicopter. It is a major symbol to measure the army aviation soldiers' fighting ability [12]. The number of the campaigning frequency is decided by the number and qualities of the flight personnel, aviation devices, techniques, logistical support ability, fighting fierceness of the battlefield in the process of fighting and other factors. With the changes of relevant factors, the campaigning frequency also changes correspondingly [13].

Campaigning frequency is a sensitive factor influencing the POL consumption, so it should be calculated accurately. After comprehensively considering the factors influencing the value of campaigning frequency, this paper estimates the value of campaigning frequency based on the fierceness of the fighting. Based on the battlefield environment and the daily campaigning times, this paper divides the value of campaigning frequency into three types: highly fierce battlefield situation, medium fierce battlefield situation and less fierce battlefield situation. Referring to the battlefield facts of the 11 campaigning times of the military helicopters each day in the Middle-East Wars and 9 campaigning times of the US military helicopters each day in Gulf War, this paper predicts the possible campaigning frequency of US Army Aviation's helicopters in the future wars (see Table 2).

TABLE 2 Campaigning frequency of helicopter

Helicopter type / Battlefield situation	Campaigning frequency (time/day)
	Helicopter
Highly fierce	3
Medium fierce	2
Less fierce	1

For the convenience of calculating the POL consumption, this paper refers to the battlefield data of Middle East Wars, Gulf War and Kosovo War and gains the probability distribution data of three kinds of battlefield situations. Please refer to Table 3 for details.

TABLE 3 Distribution of battlefield situations

Distribution of battlefield situations	Highly fierce	Medium fierce	Less fierce	Total
Probability of battlefield situations	0.15	0.35	0.5	1.0

3.3 CAMPAIGNING RATE, FOL CONSUMPTION RATE AND BATTLE DAMAGE RATE OF HELICOPTERS

Campaigning rate of helicopters: Campaigning rate refers to the percentage of the number of helicopters that actually participate in the campaigning to the total number of helicopters the army aviation has. It is an important symbol to measure the fighting ability of the army aviation. The value of the campaigning rate is decided by factors, including the helicopter quality, reliability, aviation devices and techniques and logistical support ability. According to relevant data and regulations of the American army, this paper predicts that the campaigning rate of its future army aviation for the helicopters is 70% [14].

The main POL consumption rate in the sky. It refers to the ratio of the maximum allowable POL consumption amount for each helicopter campaigning and the single-helicopter oil consumption base amount, It is an empirical mean date, remaining the same whether in peacetime or in wartime. Helicopters must reserve certain amount of POL to cope with some emergencies on the way back whether in peacetime or in wartime. It is usually statistically calculated for several times. Relevant departments will formulate relevant regulations for different types of helicopters. According to the statistical data, the main POL consumption rate in the sky is 70% [14].

Main ground-to-air POL consumption ratio. It is also called main ground consumption ratio, referring to the percentage of the main POL consumption amount in projects, such as ground run and sliding to the main POL consumption amount in the sky, which is generally 10%[15].

The specific parameters of campaigning rate, ground-to-air main POL consumption ratio and the main POL consumption rate in the sky (see Table 4)

TABLE 4 Specific parameters of helicopter POL consumption

Type	Campaigning rate	Ground-to-air main POL consumption ratio	The main POL consumption rate
Helicopter	70%	10%	70%

POL battle damage rate. Battle damage is an indirect consumption. Since that the aviation troops rely on the support of the fixed stations, the airport facilities become the major attack and damage target of enemies. In the battlefield environment featuring the wide application of modern detecting techniques and precision guided munitions, it is impossible to totally avoid enemy's attach and the losses thus incurred. In the modern asymmetric wars, the weak party's huge battle damage of the POL and the POL assurance ability fully proves the above statements.

The battle damage of POL is usually measured by the battle damage rate. It is influenced by many factors. First is the comparison of the weaponry power. Different fighting parties, different battle damage. In Gulf War and Kosovo War, the Multi-national Force and NATO headed by US boasted an absolute military force edge. In the whole fighting process, it almost achieved zero battle damage of POL, while that of Iraq was as high as 71% and the military oil deports of the Southern Alliance were exploded by 41%. Second is the strategic position of the air force station. The air force station with strategic importance, especially the first-line and second-line airport POL and POL assurance facilities, is usually the major attack target of both parties. Third is the protective ability of POL storage facilities and devices, including the protective conditions of the POL and the protective ability of the POL's surrounding troops. The protection of the oil deports is obviously superior to the vertical oil tank stored in the open air because of the former's low battle damage rate. Fourth is the fighting tempo. On general conditions, the POL battle damage rate in the highly fierce battlefield situation is higher than that of the medium fierce and less fierce battlefield situations. This is also an important reason influencing the instability of the wartime oil consumption rules.

The fighting mode of the modern wars mainly features high-tech local wars. Therefore, the helicopter battle damage of the first level strength of the army aviation in the wartime and the battle damage of the POL assurance ability can immediately be supplemented and supported. It can thus assume that the campaigning helicopters and the POL assurance ability are basically stable without considering the battle damage of the airport POL assurance ability and the stationed airport and omitting the influence of the battle damage of the two on the calculation of the oil consumption demand.

4 Calculation of the main POL consumption amount based on System Dynamics

After confirming the battlefield scale, helicopters' campaigning frequency, POL consumption base amount and ground-to-air oil consumption ratio, this paper uses the SD to establish the model by using the software Vensim (see Figure 1).

The model assumes that the battle continues for 30 days and that the helicopters participating in the battle are ten AH64, V22 and UH60A respectively.

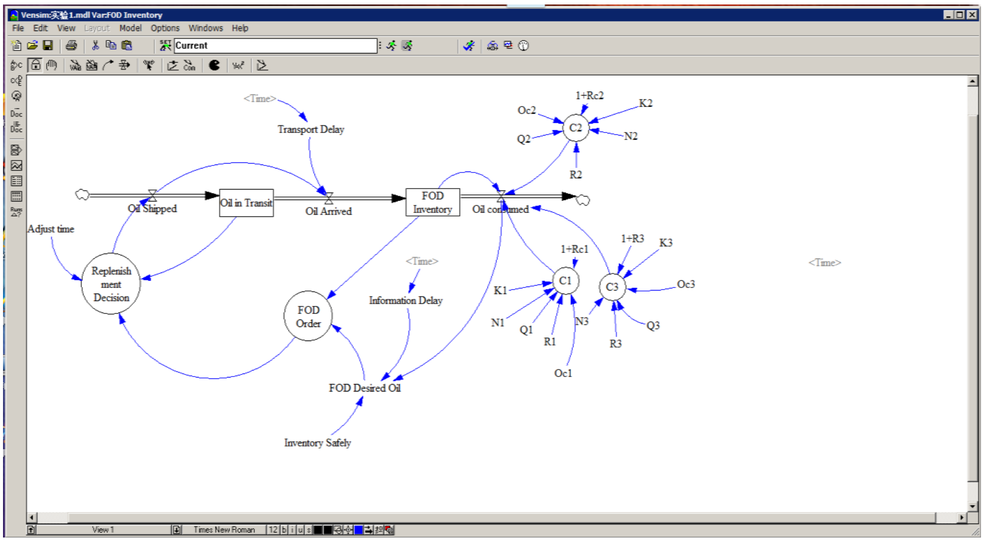

FIGURE 1 SD-based model of main POL consumption amount

System equation:

FOD Inventory= INTEG (POL Arrived-POL consumed, 120);
POL in Transit= INTEG (MAX(POL Shipped-POL Arrived, 0),0);
POL Arrived=POL Shipped/Transport Delay;
Replenishment Decision=MAX(FOD Order/Adjust time-POL in Transit/Adjust time, 0);
FOD Desired POL=Information Delay*POL consumed+ Inventory Safely;
POL consumed=MIN(C1+C2+C3, FOD Inventory);
C1="1+Rc1"*K1*N1*Oc1*Q1*R1;
C2=K2*"1+Rc2"*N2*Oc2*Q2*R2
C3="1+R3"*K3*N3*Oc3*Q3*R3

In terms of information delay and transport delay, this paper shows them respectively through equations in Fig. 2 according to the favourable battlefield situation, the unfavourable battlefield situation and the stalemate.

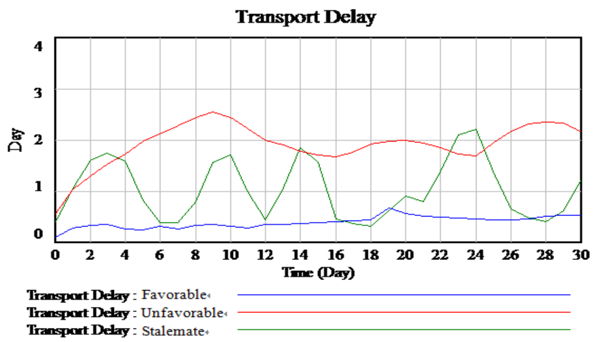

FIGURE 2 Function curve of the battlefield situation in transport delay

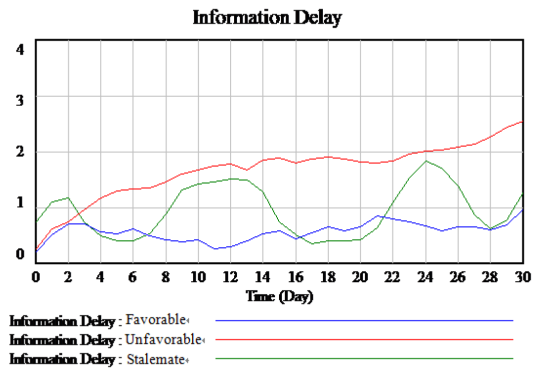

FIGURE 3 Function curve of the battlefield situation in transport delay

After identifying the function of the battlefield situation, this paper operates the model and gains the following simulation results.

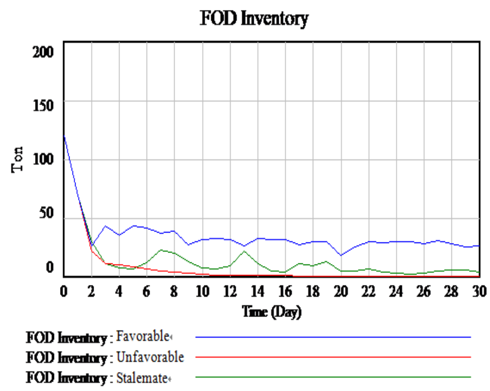

FIGURE 4 Simulation results of the FOD inventory

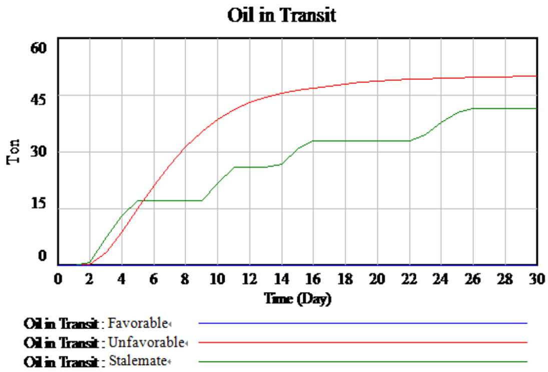

FIGURE 5 Simulation results of the oil amount in transit

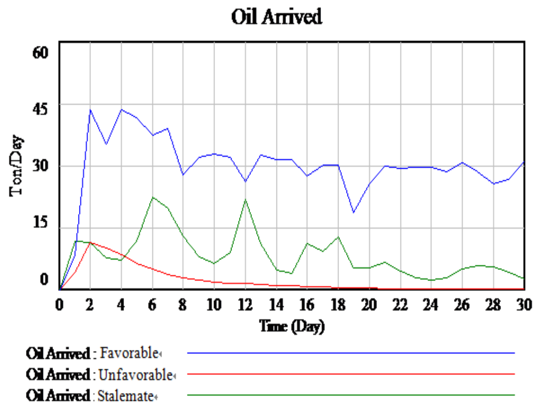

FIGURE 6 Simulation results of the arrived oil amount

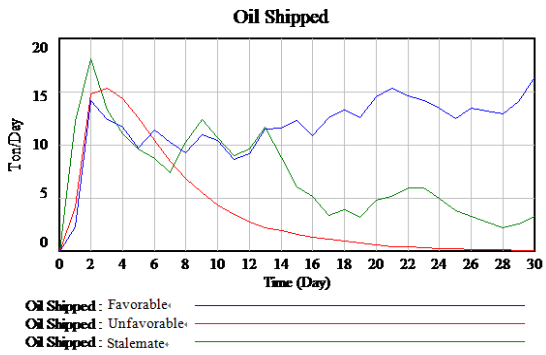

FIGURE 7 Simulation results of the shipped oil amount

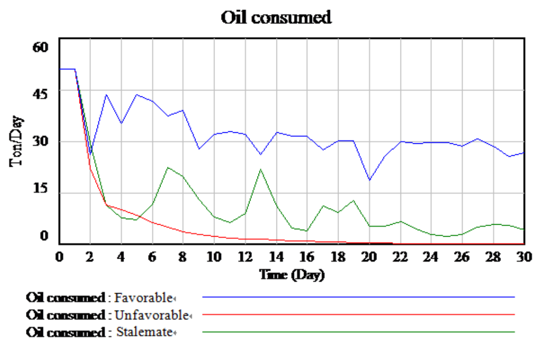

FIGURE 8 Simulation results of the consumed oil amount

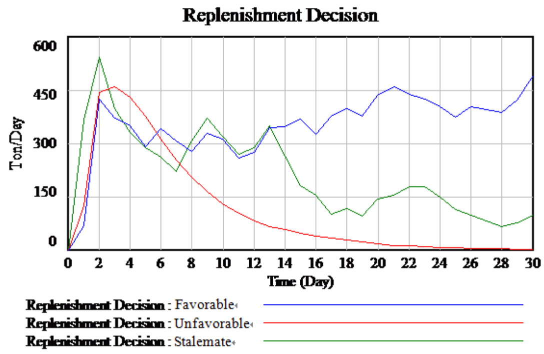

FIGURE 9 Simulation results of the oil amount of the replenishment decision

From the simulation results, it can be seen that, in the favourable battlefield situation, the POL supply is adequate; since the beginning of the battle, the arrived oil amount has kept increasing gradually and stabilizes at a high level, which suggests that there are lots of oil amount reaching the frontline; since the beginning of the battle, the oil amount in transit has begun, and on the second day, there is certain oil amount in transit, which is gradually increased to about 50 tons and then stays steadily at a certain level; when there is enough oil, the frontline army aviation can fully finish their military tasks by consuming a large amount of oil; the decision-maker also decides to increase the oil replenishment, thus resulting in gradual increase of the loaded oil amount to 15 tons per day.

In the unfavourable battlefield situation, it is hard to ensure the POL supply due to the damage of the POL pipelines or transport lines. The oil in transit cannot reach the FOD. Though oil in transit gradually increases, the arrived oil decreases. Since the POL cannot be delivered to FOD, the decision-maker reduces the oil replenishment. Due to gradual decrease of the oil amount in FOD, the aviation army has to decrease its POL consumption to implement the military tasks.

In the stalemate, the simulation results show that the oil amount arrived in the FOD is characterized by significant irregular wave vibration status, and the oil in transit is lower than that in the unfavourable battlefield situation, but higher than that in the favourable battlefield situation. The POL of the FOD cannot satisfy the demand of the battlefield, and the FOD inventory is low. The decision-maker increases the oil replenishment, which is higher than that at the beginning of the battle, but decreases with the increase of the oil in transit.

To sum up, the SD-based army aviation's oil assurance model can directly predict that, during the wartime, the changing trend of various factors influencing the POL assurance can be simulated only by changing the specific POL consumption parameters and amount of helicopters of different types.

5 Conclusion

From the simulation results, it can be seen that the SD-based army aviation's oil assurance model can fully simulate the changing trend of various factors influencing POL assurance under different battle situations. If the battle situation changes instead of just being the favourable battlefield situation, unfavourable battlefield situation and the stalemate, it is only necessary to change the value of the transport delay and information delay functions and choose corresponding helicopter campaigning times so as to correctly simulate the POL consumption of the army aviation during the wartime. Thus, the simulation curves can provide decision-makers with bases for their formulation of the POL assurance plan.

References

[1] Anderson T W, Arrow K J, Walsh E.A Mathematical of An Air Transportation System *The Rand Corporation*
[2] Robbins M L, Mclver D W Precision-Guided Logistics *The Rand Corporation*
[3] Hunger J.D, Wheelen T L 2007 Essentials of Strategic Management *Information Security* (3) 22-5
[4] Huang Y 2003 The Models Research on Optimization of Military Forces *System Science and Systems Engineering*
[5] Transportation Analysis Model and Simulation Functional Process Improvement Draft Decision Report[EB/OL] http://www.transcom.mil
[6] Joint Deployment and Redeployment Operation [EB/OL] http://www.transcom.mil
[7] Logistics Handbook for Strategic Mobility Planning [EB/OL] http://www.transcom.mil
[8] Analysis of Mobility Platform [EB/OL]. http: // ustcweb.safb.af. mil
[9] Global Deployment Analysis System Advances in End to End Mobility Modeling [Eb/OL]. http://www.transcom.mil
[10] US Military Sealift Command *2012 In Review*
[11] 2012 USTRANSCOM Annual Report *United States Transporation Command* 2012
[12] 2011 USTRANSCOM Annual Report *United States Transportation Command* 2011
[13] *Comparative Study on Construction of China-us Military POL Support Informationization* Logistical Engineering University 2011
[14] Tang J 2011 Study on Combat Fuel Supply of Army Aviation *Logistical Engineering University*
[15] Study on the POL Support Force Construction of Joint Battle *Logistical Enineering University* 2011

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