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# *Research on Evaluation Method of Primary Trainer Training Effectiveness Based on Aircraft Performance*

**Lu Huaping[1,a], Chen Baisong[2], Zhang Hualei[3]**

*[1]Flight Research Institute, Air Force Aviation University, Changchun, China*
*[2]Aviation Operations Service College, Air Force Aviation University, Changchun, China*
*[3]Aviation Operations Service College, Air Force Aviation University, Changchun, China*
*[a]lhp127@qq.com*

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***Abstract:*** Based on the analysis of the general training effectiveness model and the effectiveness evaluation results of several primary trainers, this paper calculates the sensitivity of each performance parameter of the trainer, in primary flight training stage, The ratio of engine power to takeoff weight of trainer is given as an alternative model for training effectiveness evaluation, and provides a simple way for the trainer effectiveness calculation.

## 1. Introduction

The effectiveness reflects a kind of ability of the system to complete the specified tasks under the given working conditions, which is used to measure the value of equipment or system to complete a specific task, specifically, it refers to the capacity to achieve a certain or to achieve a certain kind of task, and the quality is the reliability of fulfilling the task under certain conditions. Specifically, in flight activities, the essence of the effectiveness research of flight training system is that the whole flight training system can achieve a given goal or a capability to complete tasks in the process of flight training, and is the sum of availability, reliability and reliability in the training system, The main purpose of the study of flight training efficiency is to determine the whole elements of the training chain scientifically and reasonably, comprehensively consider various factors, determine the training cycle and objectives, and improve the efficiency of the training; Another important purpose is to determine the flight training requirements, equipment, technology, training theory and other factors of the future flight training development through reasonable collocation. Therefore, the research of flight training effectiveness is of great significance for the construction of flight training system and the improvement of flight training efficiency.

## 2. Effectiveness Evaluation Model

### 2.1. Research Progress

Since 1970s, Bazzocchi[1] put forward the effectiveness analysis model of military trainer, which was introduced into China in 1980s. At the end of last century, O.L.P. Masefield and E.A.P. Burdak partially modified and improved the Bazzocchi model, and proposed a new evaluation method of trainer training effectiveness, called Masefield-Burdak model. The current research on training effectiveness in China is mostly based on the existing models abroad for optimization, and the research object is mostly limited to the comparison of training efficiency of trainer equipment. Gao Min[2] discussed the concept and evaluation theory of military trainer training effectiveness, established mathematical model of training effectiveness of military trainer. Yu Fen[3] based on a training content calculated the training efficiency of four kinds of trainers by Masefield Burdak model. Li Hanghang[4] improved the training efficiency model of the trainer by using analytic hierarchy process. Jiang Xiafang[5] studied a comprehensive evaluation analysis of selecting type of trainer, and employed to construct the trainer selection model. Huang Jun[6] of Beihang University, who studies the performance index of the trainer by using training efficiency as the constraint, uses training efficiency as the objective function and uses the simplex multi variable numerical optimization method to establish the design scheme of a type of advanced jet trainer with double triangle wing layout for evaluation and optimization. This paper aims to study the influence weight of performance index on flight training effectiveness and the simplified alternative method of effectiveness evaluation by analyzing the training efficiency of different trainers, and try to get a simple and effective evaluation theory of training effectiveness.

### 2.2. Effectiveness Evaluation Model

The research purpose of flight training effectiveness is to build the evaluation model of flight training effectiveness through mathematical analysis method, and to solve and optimize the model, in order to improve the efficiency of flight training. The establishment of the effectiveness evaluation model is mainly through the construction of each index system of the flight training system, decomposing the each influencing factor, and combining the decomposed factors by using various quantitative research methods, and then evaluating. At present, Masefield-Burdak model is widely used by study several key performances of trainers. The Masefield-Burdak model is shown as follows:

$$T_{EV}=(S \bullet W) \bullet F \tag{1}$$

$T_{EV}$ of (1) is the calculated training effectiveness value of trainer; $S$ is the initial score matrix; $W$ is the weight matrix. W is the weight index which reflects the proportion of flight time in the total training phase to the training time needed.

## 3. Evaluation

### 3.1. Flight Training Course

The values of the weight matrix are determined by experts scoring. The contents and time arrangement of the course are determined by the flight training program. Take the arrangement of the contents of a flight training program as an example. See Table 1 for the contents and time arrangement of the course.

Table 1: Training Items and Schedule

| **Time** | **Course A** | **Course B** | **Course C** | **Course D** | **Course E** |
|---|---|---|---|---|---|
| Flight Time(h) | 16 | 25 | 28 | 23 | 18 |
| Normalized Value | 0.15 | 0.23 | 0.25 | 0.21 | 0.16 |

The basic performance parameters of aircraft which have great influence on the current training stage are selected as research parameters. The weight value of aircraft performance parameters relative to the course is determined by experts' scoring. The score of the objects to be evaluated is divided into ten levels from 0 to 9. 0 means no effect at all, 9 means the most important role, and the value of intermediate importance is between 0 and 9. The weight matrix of the performance parameter relative to the flight training course is obtained after experts scoring, and the normalized matrix is shown in Table 2.

Table 2: Weight Value of Aircraft Performance Parameters Relative to Course

| **Performance Parameters** | **Course A** | **Course B** | **Course C** | **Course D** | **Course E** | **Weight Value** |
|---|---|---|---|---|---|---|
| Max Speed | 0.06 | 0.14 | 0.13 | 0.11 | 0.14 | 0.12 |
| Max Rate of Climb | 0.22 | 0.21 | 0.13 | 0.16 | 0.10 | 0.16 |
| Practical ceiling | 0.00 | 0.21 | 0.25 | 0.21 | 0.24 | 0.19 |
| Max Range | 0.00 | 0.14 | 0.19 | 0.16 | 0.24 | 0.15 |
| Max Overload | 0.06 | 0.29 | 0.19 | 0.26 | 0.21 | 0.21 |
| Takeoff Distance | 0.33 | 0.00 | 0.06 | 0.05 | 0.03 | 0.08 |
| Landing Distance | 0.33 | 0.00 | 0.06 | 0.05 | 0.03 | 0.08 |

### 3.2. Performance parameters of trainer to be evaluated

With the development of aviation technology, determination of trainer system is subject to the requirements of economy. The trainer reasonable configuration makes the total cost of flight training low, and vice versa. The developing direction of trainer system in the current national air force is reducing the configuration of aircraft types, so the training arrangement content is becoming more substantial and compact. In the comparative analysis, the typical primary trainers with large amount equipment were chosen. And only the impact of training efficiency was considered. The performance parameters of some primary trainers for comparative study are shown in Table 3.

Table 3: Performance Parameter of Typical Primary Trainer

| **Trainer Model** | **Max Level Speed (Km /h)** | **Takeoff Distance (m)** | **Landing Distance (m)** | **Max Rate of Climb (m / s)** | **Practical Ceiling (m)** | **Max Range (Km)** | **Max Overload** |
|---|---|---|---|---|---|---|---|
| Epislon | 378 | 410 | 250 | 9.4 | 7010 | 1260 | 6.7 |
| Fantrainer | 417 | 250 | 250 | 15.2 | 7620 | 1037 | 4.4 |
| T67M | 256 | 190 | 232 | 5.6 | 4575 | 980 | 6 |
| SF260 | 337 | 275 | 270 | 9.1 | 5791 | 1315 | 6 |
| YAK-52 | 300 | 170 | 300 | 7 | 6000 | 900 | 7 |
| EMB-312 | 448 | 380 | 370 | 11.3 | 9144 | 1843 | 6 |
| KT-1 | 518 | 244 | 397 | 17.8 | 11580 | 1333 | 7 |
| SU-49 | 370 | 230 | 250 | 13.5 | 7000 | 1500 | 11 |
| T-6A | 575 | 437 | 739 | 22.9 | 9400 | 1574 | 7 |

### 3.3. Calculation

In the calculation of trainer effectiveness evaluation, the input values are the performance vector of the trainer, the course training time vector and the performance weight vector to the flight course, and the effectiveness calculation is the output value. According to the data in Table 3, the initial score vector value of the initial trainer effectiveness is calculated. Combined with the weight value and training time vector in table 1, table 2 and table 3, the trainer effectiveness score and ranking are shown in Figure 1.

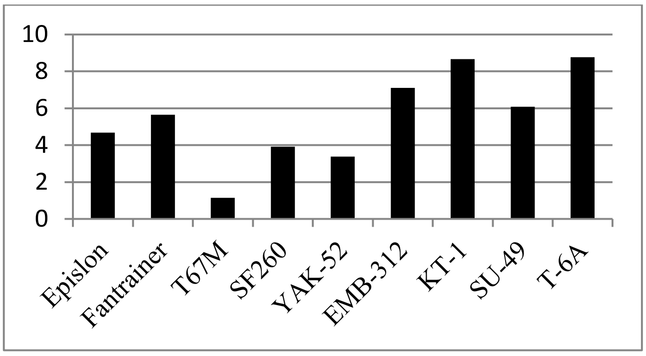


Figure 1: Evaluation of trainer effectiveness calculation score

It can be seen from Figure 1 that in the overall evaluation of trainer performance scores, there are three trainers with higher scores, T-6A of the United States, KT-1 of South Korea and EMB-312 of Brazil. These trainers have one common feature, which are designed according to the intermediate trainer, and their aircraft performance is far superior to others. There are three trainers with medium scores in the second level, they are Russia SU-49, France Epislon and Germany Fantrainer. The overall performance of these three trainers is lower than that of the first three. The trainers performance characteristics are different. Russia SU-49 is derived from sports aircraft, and can withstand overload as high as 11, ranking the first among all evaluated aircraft types; As a junior trainer, French Epislon is not as powerful as the first three junior / intermediate trainers in overall performance, but also has no obvious short board and weakness, so it is a qualified junior trainer; The German Fantrainer has a unique design and adopts the structure of turboshaft engine driven central fan. The cockpit has a good view, no slipstream effect caused by the front propeller, and the overall performance is not weak. However, due to the layout of the central fan, the maximum overload is just only 4.4, ranking the first from the bottom among all the evaluated trainers, which is a drag on the score. In addition, its overload is too small to meet the requirements of current flight training. The third level is the lower score of two trainers, YAK-52 in Russia and SF-260 in Italy. These two trainers are designed and manufactured for typical primary training, with low engine power and weak overall performance. The last level is the British T67m trainer. T67m, as the only two parallel seats model in the evaluated trainer, has low engine power and large gap in flight performance compared with other trainer s. After T67m was purchased by the US air force, it was numbered T-3a and only used as a screening trainer. On the whole, the evaluation of trainer effectiveness calculation score of each trainer is basically consistent with the current requirements of trainer performance of various countries.

## 4. Result Analysis

### 4.1. Sensitivity Analysis of Performance on Effectiveness

In the effectiveness calculation method, the weight value is scored by the senior pilots according to the relationship between the content of flight training course and the performance of the trainer, which reflects the requirements of flight training course for each trainer performance; the training time matrix is based on the flight hours in the current training program. The weight value and training time jointly reflect the influence of the trainer performance and the time arrangement of the flight training program. Figure 2 shows the sensitivity of the trainer performance parameters on the training effectiveness.

It can be seen from Figure 2 that the maximum overload, practical ceiling and maximum rate of climb are the most important factors affecting the effectiveness results, followed by the flight range and level speed. The takeoff and landing distance have a great impact on individual classes, and the overall impact is small, so the sensitivity is the lowest.

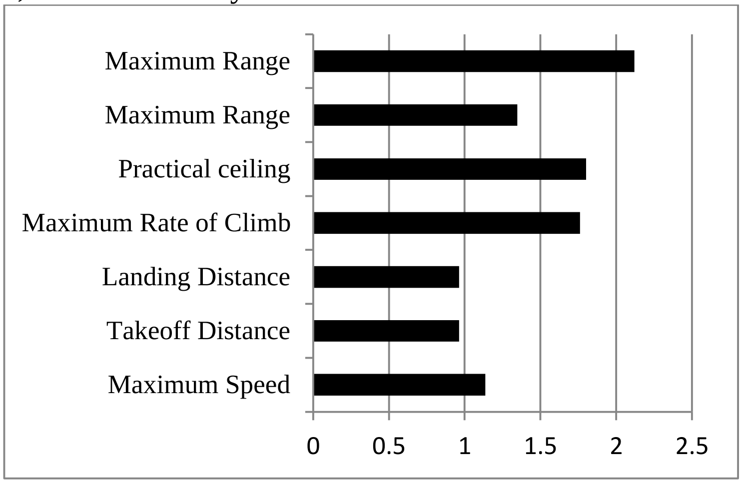


Figure 2: Sensitivity of trainer performance parameters on training effectiveness

The maximum overload, rate of climb and practical ceiling reflect the trainer mobility for the requirements of flight training. The takeoff distance and landing distance is low, which reflects the ease of students to fly alone. The flight level speed and flight range are static parameters of the aircraft. Among these parameters, the strength design of the aircraft is reflected by the maximum overload and the maximum level speed; the other mobility indicators mainly reflect the engine performance, the stronger engine performance, and the higher performance evaluation score. As a primary trainer, the key is to train the students for basic operation skills with low altitude and low speed, establish the preliminary air feeling, make the students master the basic aircraft control skills, and lay a good foundation for further training. Therefore, for the junior trainer, it is necessary to have certain mobility first, and the flight range reflects the endurance ability, and as a trainer, The proper flight range means having a certain time to stay in the sky, which can meet the basic needs of the air classroom teaching; Practical ceiling and maximum level speed reflect the performance of the trainer, determine whether they can meet the requirements of the primary training course, and the takeoff distance and landing distance reflect the difficulty of students to fly alone, which is the requirement to ensure that the current training stage has certain difficulty.

## 4.2. Research about the Ratio of Power to Weight

For these trainers, the score of good maneuverability is relatively higher. Maneuverability depends on the aircraft design orientation and is related to the overall aerodynamic layout. However, in general, the primary trainer is limited to the requirements of economy, the performance is usually relatively simple. Therefore, the ratio of engine power to aircraft weight can reflect the maneuverability of the aircraft, Of course, the actual situation also depends on the power and propeller pull in efficiency and other factors, but in general, the ratio of power to weight basically reflects the maneuverability. The T-6A engine with the highest performance score is a PT6A-68 turboprop engine with 1274KW, the KT-1 of the Korean with the second performance score, a PT6A-62 engine with 709kw, the EMB-312 of Brazil with 559kw, and the T67m with 119kw. Table 4 shows the ratio of engine power to maximum takeoff weight, which can directly show the maneuverability of the trainer to be evaluated.

Table 4: Evaluation Ratio Of Engine Power To Flight Weight

| Trainer Model | Engine Power(KW) | Max Takeoff Weight (Kg) | Ratio of Power to Weight |
|---|---|---|---|
| Epislon | 224 | 1250 | 0.179 |
| Fantrainer | 485 | 2300 | 0.211 |
| T67M | 119 | 952 | 0.125 |
| SF260 | 261 | 1350 | 0.193 |
| YAK-52 | 268 | 1290 | 0.208 |
| EMB-312 | 559 | 2550 | 0.219 |
| KT-1 | 709 | 3205 | 0.221 |
| SU-49 | 313 | 1500 | 0.209 |
| T-6A | 1274 | 2948 | 0.432 |

It can be seen from table 4 that the T-6A is equipped with high-power turboprop engine, its power to weight ratio is far higher than other trainers, and its performance is far ahead of others too. The overall effectiveness evaluation score is the highest among participating trainers in the evaluation. The ratios of power to weight of EMB-312, KT-1 and Fantrainer are similar, and the overall effectiveness evaluation scores are similar. The power of T67m engine is smaller, and its ratio of power to weight is relatively low compared with other aircraft, and its effectiveness evaluation score is also low. In general, in the primary flight training stage, the trainers with high effectiveness evaluation scores are all equipped with high-power turboprop engine. From the ratio of the maximum power of the engine and the maximum takeoff weight, it is basically equivalent to the effectiveness evaluation score. Therefore, to a certain extent, the power weight ratio of the trainer can also be used to preliminarily calculate the effectiveness value of the trainer to be evaluated.

It has fully proved by practice that if only one student is used from the screening stage to graduation, it is technically feasible, but the cost is very high. It is very different between the advanced training and initial training for aircraft performance. It is obviously neither economical nor necessary to use one good performance aircraft in the early stage of selecting students. Therefore, many countries adopt the training system of two or three kinds of trainer. At the beginning, they use simple trainer, and at the later stage, they use more advanced trainers close to combat aircraft. Although it can be seen from Figure 1 that the T-6A trainer has the highest efficiency score, its performance is undoubtedly surplus for the most elementary training. Therefore, the T-6A aircraft has the highest efficiency score, The U.S. military set up the DA-20 as a screening trainer before the T-6A training stage, rather than entering the T-6A training stage as soon as it came up.

## 5. Conclusion

As far as the trainer system is concerned, its training effectiveness is reflected in three aspects: safety, applicability and economy. "Safety" refers to maintaining a reasonable elimination mechanism when completing specified training tasks under certain training intensity. "Availability" refers to the training effectiveness of the trainer to meet the performance requirements of the main combat aircraft in the future, as well as the reliability, maintainability and supportability of the trainer to meet the requirements of the training tasks in the future. "Economy" means to evaluate the actual effect of the trainer on accelerating the generation of combat effectiveness based on the life cycle cost of the trainer, and comprehensively measure the training benefit from the perspective of the whole training system. Obviously, the primary premise of "economy" is that the training effectiveness of the trainer meets the demand. Therefore, the training efficiency consists of training effectiveness and cost. High training effectiveness plus low training cost is the real high training efficiency. The current effectiveness evaluation method does not consider the economic demand, which will be the key research direction in the future.

In order to complete the training tasks in the intermediate stage, the performance of the three primary/ intermediate trainer with the highest evaluation effectiveness must be higher than the simple primary trainer. Their performance is bound to be excessive for completing the tasks in the primary flight training stage, and the rising cost caused by improvement performance also needs to be comprehensively considered, Although it is better to have strong performance, the basic principles of the trainer system can meet the needs of all countries. The economy is also very good, and an uneconomic model cannot enter the trainer sequence, no matter how powerful its performance is, otherwise there is no need for the trainer to exist.

For the trainer system, the level of training is not reflected neither by the performance of the aircraft, nor by the difficulty of the training courses, but by the skill level of the students. That is to say, in a certain period of time, the greater the achievements of the students, the higher the training effectiveness. Trainer performance only provides a platform for students' training, but the performance must adapt to students' acceptance. A new pilot can't be expected to fly high-altitude and difficult courses or advanced aircraft. In the arrangement of aircraft performance and the selection of training courses, the characteristics of flight training must be taken into account, and the flight performance, cockpit human-computer interaction, environmental control, training courses and other factors and other flight performances should be comprehensively measured according to students' characteristics, which is also a further effectiveness research of the trainer system.

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