2 THE STATISTICAL ANALYSIS OF FINDING OPTIMUM RATIO BETWEEN REAL AIRCRAFT AND SIMULATOR FLIGHTS: AN APPLICATION TO ARMY AVIATION

Taner Altinok *
Aydin Lafci**
Filiz Ersoz***

Abstract

Flight training is a very complicated process. Including the full flight simulators makes this much more complicated, indeed supposed to make it easy. Flight simulators are very important devices, eliminating difficulties, cost and risks likely to be encountered in flight training. It is essential that simulators shall be used to decrease the cost and increase efficiency of trainings. However, flight simulator is not a unique solution, itself. For several reasons, real aircraft shall also be used, at this point, a hyhbrid solution must be established and an optimum training ratio between real aircraft and flight simulators is essential for decisive curriculum. The aim of the work is to find optimum usage ratio between real aircraft (helicopter is considered in this study) and flight simulators in Army Aviation training system. Hence, a field study questionnaire was developed and delivered to 145 experienced army helicopter pilots. The questionnaire consists of three parts. First, the demographic features, including flight

* **Taner Altinok** has M.S. (1987) degrees in mechanical engineering from Middle East Technical University, and mechanical engineering Ph.D. (1993) in energy systems from Gazi University. He became an Associate Professor in 1997. He had worked as a director in the Department of Aircraft and Simulators in the Headquarters of Land Forces Command for 13 years. He was pronounced as professor at 2005. He is presently in principal position in Defense Sciences Institute of Turkish Military Academy in Ankara, Turkey. Tel.: 0090 312 4175190 (ext.5001) E-mail: taltinok@kho.edu.tr.

** **Captain Aydin Lafci** (M.S.) was graduated from Defense Sciences Institute of Military Academy in 2005. He is in Defense Sciences Institute of Turkish Military Academy in Ankara, Turkey. Tel.: 0090 312 4175190 (ext.5019). E-mail: lafciaydin@yahoo.com

*** **Filiz ERSÖZ** has M.S (1992) in Biostatistics from Ankara University, and Biostatistics Ph.D.(1998) from Ankara University. She is presently working as a military expert in Defense Sciences Institute of Turkish Military Academy in Ankara, Turkey. Tel.: 0090 312 4175190 (ext.5019) E-mail: fersoz@yahoo.com

qualifications and experiences of the pilots were figured out. In the second part, importance of simulators, their effectiveness, characteristics and pilots' expectations were researched. Finally, optimum usage ratio between real aircraft and flight simulators was asked. The study population was established from different pilotage status and experience levels in order to set up the homogeneity. Data collected from the study population and subordinate topics in the questionnaire were delineated with factor analysis, ANOVA, reliability tests, Tukey's test of additivity, Chi-square and some other statistical analysis in SPSS 11.0.

Keywords: data analyzing, factor analysis, flight ratio, training, simulator, statistical procedures.

JEL Classification: C12, C49, C80

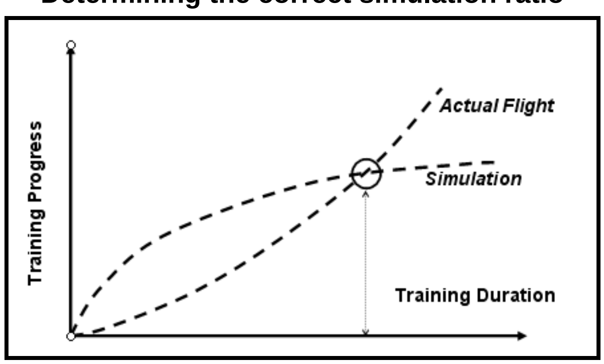
1. Introduction

Flight training is known as one of the most expensive and versatile activity among the other types of training. Flight simulators are very important devices that reduce the difficulties, costs and risks, which are supposed to be encountered in trainings. The astounding speed of technology denotes itself in developing simulators and currently, almost no significant difference left between simulators and the real aircraft from the point of flying sense. Simulators, with their accepted importance and benefits, are used effectively in both initial trainings of pilot candidates and advanced phase trainings of experienced pilots. An effective trade-off between simulators and the real aircraft should be established, because some phases of training in aviation are executed in real aircraft, some in the simulators, and some in both.

Determining flight ratio between real aircraft and flight simulators is a subjective issue. There are very few sources about this topic seen in the literature. For example, Dufaur (2004) set forth that simulation portion of a flight training curriculum shall be 30% in initial, 80% (and more) in familiarization course, 50% during instrument, navigation and terrain flight training (depending upon the mission profile) phases. The criteria to determine these ratios are training progress and training duration as shown in Fig. 1.

Figure 1

Determining the correct simulation ratio



2. Metodology and Analysis of the Questionnaire

The questionnaire was scrutinized according to its parts. In the beginning, demographic features of the pilots were figured out. In part 2, the characteristics and importance of simulators were asked in 20 questions. The optimum ratio was researched in part 3. Finally, the results of this study are drawn as conclusion.

The control and data cleaning of the answer sets for computation availability were performed according to Tabachnick's (2001: 85) check list. At this stage, the correctness of data transfer and missing values were checked out. Then, outliers and normalities were examined with Lilliefors (Normality and q-q plots) and One-Sample Kolmogorov-Smirnov Tests. $p>\alpha$ was analyzed for normality (Ozdemir et al., 1997), where p is observed level of significance, and α is the expected level of significance (Anderson et al., 1999). SPSS 11.0 for Windows was used for statistical analyses. Normality was found valid.

A. Analyzing First Part of the Questionnaire: Demographic Features

The population was a group of very experienced pilots (80% have more than 1 500 flight hours and the least experienced is a four year pilot). All have a simulator experience in different levels (FAA/JAA Level B, C, or D simulators) and 70% have more than 50 flight hours with simulators, ranging up to 250 hours. All pilots were assumed as satisfactory according to their features. There is no pilot who has a flight hour below 500 hours and 83.5% are above 1 500 hours.

B. Analyzing Second Part of the Questionnaire: The Characteristics of Simulators

In this part, participants were asked to answer 20 questions about flight simulator specifications, their contributions, drowbacks, etc. The questions were in 5-point-Likert-type (1: completely disagree; 2: disagree; 3: somehow agree; 4: agree; 5: completely agree). This part seeks the differences of simulator flights with real flights, moreover simulators' contribution to flight training. Reliability (Cronbach's Alpha) was calculated as 0.79. This score can be considered within the acceptable reliability level according to Gliem *et al*. (2003). Moreover, changes of reliability were calculated for each deleted item, and acceptable declines were found in questions #9, #10, #11, and #12. As a result of this operation, it is seen that each question has the same effect on reliability, thus none of them should be excluded. Scale items were observed with Tukey's test of additivity, and found that they are additive *($p<0.001$)* (Ercan et al., 2004).

The sample population in the study is a group of pilots, who had flown more with full flight simulators, because their experiences in these simulators are thought to be helpful. The amount of these pilots is 52. Number of non-fliers is 93. Comparing simply the descriptive statistics (i.e. arithmetic means) of the answers given to 20 questions of second part by sample population and the rest shall give an idea about their approaches to simulators. Cronbach's Alphas of sample population and rest are 0.74, and 0.78, respectively. Both are acceptably high.

Testing statistical significance of both groups is essential to confirm the data collected. In the null hypothesis set for this purpose, it is claimed that there is no significant difference between groups. The hypothesis was considered to be set due to variances, hence Chi-square (X^2) test for two variables was applied at $\alpha=0.05$. Care should be given to the point that the number of observed cells with expected value less than 5 shall not excess 20% of total amount of observed cells (Ergun, 1995). The expected values of questions #2, #10, #12, and #20 were found suitable, and the others were found unsuitable after data were run on computer. These results can be contemplated as there is no significant difference between groups according to these questions. Meanwhile, the hypothesis shall not be rejected according to the rest of questions. The decision is given as there is no significant difference between two groups. Neverthless, factor analysis was tried through the same approach (simulator fliers and the rest), but at different dimension. Additionally, scale topics were investigated whether they had any additivity by using Tukey's test. Finding $p<0,001$ showed it was positive.

Factors were analyzed to ease the evaluation and determine the group of variables aiming same purposes (Buyukozturk, 2003). Eigenvalues were set as 1. Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was found as 0.755 in varimax method. Given that 0.755>0.5, the homogeneity of variables in data set are accepted. Test value (p) is 0.000 and less than $\alpha=0.05$ (Table 1) hence, correlation matrix is valid. Data are worth using in principal component analysis (PCA).

Table 1

KMO measure of sampling adequacy and Bartlett's test of sphericity in Questionnaire, Part 2

KMO and BARTLETT's TESTS		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**0.755**
Bartlett's Test of Sphericity	Approx. Chi-Square	768.929
	Degrees-of-freedom	190
	Sig. (p)	**0.000**

According to the PCA of 20 questions, 7 factors were found. Relating to the model, variance of these 7 factors is 64,558% and variance explains the majority of the scale.

Table 2 shows Rotated Component Matrix. Total Variance of factor loadings is 0,436 and above.

Table 2

Rotated component matrix belonging to Questionnaire, Part 2

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	FACTOR 6	FACTOR 7
QUESTION # 15	.795	.118	4.91E-02	.148	8.47E-02	-.138	6.08E-02
QUESTION # 17	.747	.111	.152	.170	7.80E-02	.131	6.73E-02
QUESTION # 16	.638	.153	.139	-2.15E-02	-.146	.102	3.27E-03
QUESTION # 14	.599	.133	4.04E-02	.168	.153	-.113	.388
QUESTION # 20	.468	.165	8.24E-02	.310	-.239	.186	3.47E-02
QUESTION # 13	.453	.244	9.45E-02	-8.03E-02	-2.84E-02	.374	-.348
QUESTION # 5	.436	.401	.297	-6.04E-02	-.193	-.146	-.262
QUESTION # 3	.209	.735	3.82E-02	1.78E-02	-.123	7.01E-02	.174
QUESTION # 2	9.74E-02	.732	3.37E-02	-6.53E-03	.117	.127	-.171
QUESTION # 1	.100	.705	.253	.104	9.88E-02	-1.73E-02	-6.13E-04
QUESTION # 4	.189	.682	-2.00E-02	8.07E-02	-.118	7.62E-02	.317
QUESTION # 7	.144	9.94E-02	.861	.106	-5.24E-02	1.86E-02	.133
QUESTION # 8	2.16E-02	1.03E-02	.777	.278	5.44E-02	.124	8.14E-02
QUESTION # 6	.208	.158	.726	-1.92E-02	5.26E-02	-9.79E-02	-4.62E-02
QUESTION # 19	.202	2.18E-02	8.92E-02	.785	-5.68E-03	-.323	4.04E-02
QUESTION # 18	.164	.103	.265	.757	3.61E-02	.240	-7.51E-02
QUESTION # 9	4.86E-03	2.16E-02	8.89E-02	-.106	.812	.115	-6.26E-03
QUESTION # 10	-1.33E-02	-1.75E-02	-3.91E-02	.113	.779	-.134	3.49E-02
QUESTION # 12	4.72E-02	.117	-2.90E-04	-1.24E-02	-1.97E-02	.867	6.39E-02
QUESTION # 11	.137	.129	.149	-6.19E-02	7.70E-03	6.33E-02	.815
Extraction Method: Principal Component Analysis Rotation converged in 7 iterations. Rotation Method: Varimax with Kaiser Normalization							

When the results of rotated component matrix are examined, questions;

- #5, #13, #14, #15, #16, #17, and #20 are assumed as Factor 1; (simulator training)
- #1, #2, #3, #4 are Factor 2; (transfer of training)
- #6, #7, #8 are Factor 3; (some simulator features)
- #18, #19 are Factor 4; (advantages of simulators)
- #9, #10 are Factor 5; (disadvantages of simulators)
- #12 is Factor 6 (applied training in simulator)
- #11 is Factor 7 (standardization of simulator training).

Hence, it was thought that 7 factors are parallel to the purpose of the study and yielding the desired results, no any other factor iteration or factor combining were carried out. The Cronbach's alpha among its observation values belonging to the 7 reestablished factors is 0.4696, at average reliability level.

C. *Analyzing Third Part of the Questionnaire: Finding Optimum Ratio between Real Aircraft and Simulator Flights*

Here, optimum ratios were sought to figure out. Part 3 is composed of 8 flight training phases and 120+1 questions in five-point-Likert-type (1: 100% simulator; 2: 60% simulator and 40% helicopter; 3: 50% simulator and 50% helicopter; 4: 40% simulator and 60% helicopter; 5: 100% helicopter).

Reliability results are shown in Table 3. Because the alpha values are apparently very close to 1, responses are excellently reliable and for this reason they may be used in the application. In if-item-deleted circumstances, the decreases are so little that (~0.001), they may be interpreted as all have same importance.

Table 3

Reliability results of flight training phases

Flight training phases	Cronbach's α
Initial training (32 questions)	0.9373
Basic instrument maneuvers (11 questions)	0.9532
Radio instrument maneuvers (10 questions)	0.9564
Tactical flight training maneuvers (20 questions)	0.9503
NVG (Night Vision Goggles) phase (13 questions)	0.9420
Different maneuvers of AS-532 (9 questions)	0.9932
Different maneuvers of UH-60 (10 questions)	0.9892
Different maneuvers of AH-1W/P (15 questions)	0.9906

For analyzing the answers given to the questions in this part of the questionnaire, not only arithmetic means, but also modes were used. Results were tried to find out by interpreting the frequency percentages. Comments were first made for each question in flight training phases one by one, and then for each whole phase, respectively. Almost all distributions were found to be, statistically, normal in analyses.

In order to acquire the perfect solution way, the difficulty of each flight maneuver was also evaluated, besides looking means and modes. Finally, a weightiness and optimum flying ratio belonging to training phases between real aircraft and a flight simulator was calculated. According to this calculation, a list of weights was established. Pilots said that a specific flight training topic/phase should be in,

- Completely in a simulator
- Most frequently in a simulator
- Frequently in a simulator
- Usually in a simulator, sometimes in a helicopter
- In a simulator and helicopter equally
- Usually in a helicopter, sometimes in a simulator
- Frequently in a helicopter
- Most frequently in a helicopter
- Completely in a helicopter

Maneuvers in Initial Training (32 questions)
According to descriptive statistics of the phase; arithmetic mean is 3.30 (σ=0.71), min. 1.80; max. 4.72 and range 2.92. Skewness -0.063 (can be assumed as symmetrical), kurtosis -0.386 (a little shallow curve). Distributions skewing right mean helicopter-intensive training, or vice versa. Finally; the ratio was found as **55%** of the phase shall be flown **in simulator** and **45% in helicopter.**

Basic Instrument Maneuvers (11 questions)
According to descriptive statistics of the phase; arithmetic mean is 4.06 (σ= 0.1), min. 3.93, max. 4.26 and range 0.33. Skewness 1.259 (skewing left), kurtosis 0.781 (sharp curve). Mode and median are equal (4.03) and close to the mean. Finally; the ratio was found as **70%** of the phase shall be flown **in simulator** and **30% in helicopter.**

Radio Instrument Maneuvers (10 questions)
According to descriptive statistics of the phase; arithmetic mean is 4.242 (σ= 0.168), min. 4.00, max. 4.47 and range 0.47. Skewness 0.099 (although the curve skews slightly left, it can be assumed as symmetrical), kurtosis -0.1291 (a little shallow curve). Finally; the ratio was found as **90%** of the phase shall be flown **in simulator** and **10% in helicopter.**

Tactical Flight Training Maneuvers (20 questions)
According to descriptive statistics of the phase; arithmetic mean is 2.8475 (σ= 0.542), min. 1.96, max. 3.75 and range 1.79. Rather smaller values are perceptible, meaning that simulator ratio is less. Skewness 0.090 (although the curve skews slightly left, it can be assumed as symmetrical), kurtosis -1.159 (pretty sharp curve). Finally; the ratio was found as **35% in simulator** and **65% in helicopter.**

Maneuvers in NVG Phase (13 questions)

According to descriptive statistics of the phase; arithmetic mean is 2.6485 (σ=0.628), min. value 2.03, max. 4.01 and range is 1.98. Again, rather smaller values can be seen. Skewness 1.346 (skewing left), kurtosis 0.772 (sharp curve). Finally; the ratio was found as **35% in simulator** and **65% in helicopter.**

Different Maneuvers of AS-532 (9 questions)

According to descriptive statistics of the phase relevant to an advanced helicopter model, AS-532 (Cougar); arithmetic mean is 3.628 (σ= 0.468), minimum 3.07, maximum 4.68 and range 1.61. Skewness 1.352 (skewing left), kurtosis 3.191 (again a sharp curve). The ratio was found, as **60%** of the phase shall be flown **in simulator** and **40% in helicopter.**

Different Maneuvers of UH-60 (10 questions)

According to descriptive statistics relevant to another advanced model, UH-60 (Black Hawk); arithmetic mean is 3.593 (σ= 0.44), minimum 2.92, maximum 4.29 and range is1.37. Skewness 0.021 (symmetrical), kurtosis -0.836 (a little shallow). The ratio was found, as simulator-intensive solution is better, namely **75%** of the phase shall be flown **in simulator** and **25% in helicopter.**

Different Maneuvers of AH-1W/P (15 questions)

According to descriptive statistics about the attack helicopter models, AH-1W (Super Cobra) and AH-1P (Cobra), the descriptive numbers are as follow; mean is 3.40 (σ= 0.414), min. 2.47, max. 4.11 and range is 1.64. Skewness -0.414 (skewing a little right), kurtosis -0.711 (slightly shallow). Median (3.54), mode (3.54) and arithmetic means are too close to each other. At last, The ratio was found as **60%** of the phase shall be flown **in simulator** and **40% in helicopter..**

If arithmetic mean of the final values from the phases (Table 4) is to be calculated, total ratio will be get as **60% in full flight simulators** and **40% in real aircraft.**

Table 4

Summary of ratios according to training phases

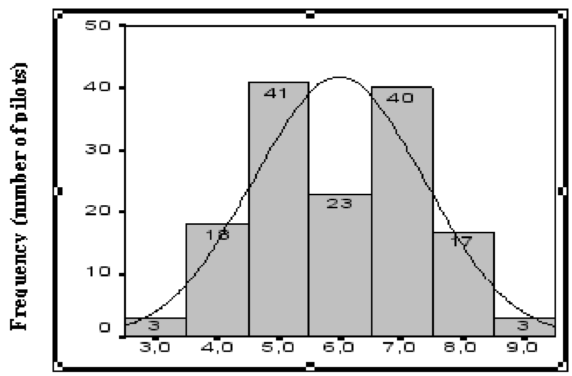
Flight training phases	Flying ratios (%)	
	Simulator	Helicopter
Initial training	55	45
Basic instrument maneuvers	70	30
Radio instrument maneuvers	90	10
Tactical flight training maneuvers	35	65
NVG phase maneuvers	35	65
Different maneuvers of AS-532	60	40
Different maneuvers of UH-60	75	25
Different maneuvers of AH-1W/P	60	40

Analysis of Answers Given to General Ratio Question

In the end of questionnaire part 3, a single question about general ratio between a real aircraft and a full flight simulator was also asked, unrelated with the flight training phases. This question was thought of, because should any question be somehow missed, to close the gap, and/or to bring an objective point of view to the training topics one by one, which were sought subjectively and roughly at first. Also, a kind of verification of the calculations can be done by this way. After having observed the answers given by 145 participant pilots to the last question of the questionnaire, the descriptive values were found as: the arithmetic mean is 5.98 (σ=1.382), which is corresponding to 50% in simulator and 50% in helicopter; minimum percentile value is 3, which is corresponding to 80% in simulator and 20% in helicopter; maximum percentile value is 9, which is corresponding to 20% in simulator and 80% in helicopter. Skewness is 0.022 and kurtosis is -0.822 (slightly shallow, may be a result of wide range). Median is 6.00, and mode is 5.00. Mean and median are very close to each other. Distribution has complete normality and the curve is symmetrical (See Figure 2).

Figure 2

Histogram of answers given to general ratio question



Finally, if all types of pilot training, including initial, advanced, recurrent, combat capability, etc. are being thought with these data, optimum flight ratio between full flight simulators and real aircraft is 50.82%-49.18%, respectively. Figure 2 shows, simulator usage is slightly more than real flight by two votes.

Response options of the general ratio question are composed of 11 categories, which were partitioned by 10%. These categories needed to be examined whether they meant differently among each other. Some suspicion about the quality of questions and value of the answers may possibly reveal, unless no difference is detected. For this reason, difference can be measured with goodness-of-fit test performed among categories. It was claimed in the null hypothesis established that there is no difference between every single category. One-sampled Chi-Square test (X^2) was applied to test the hypothesis with α=0.05. In the SPSS test, it was observed that $p=0.00 < \alpha=0.05$, hence hypothesis was rejected. It means that there is statistically significant difference and the suspicions about the quality of questions and value of the answers are irrelevant and unnecessary. Analysis and results are reliable.

3. Conclusion

Practical approach to virtual world was sought in this study. The results showed that simulator ratio was dominant as expected in ab initio, instrument and advanced training phases. The interesting result was in NVG and tactical flight phases, because helicopter flight ratio was much more than the expected ratio. The reliability of the second part, which was about simulators' attributes and their contributions, was satisfactory, but reliability of the third part was so much higher. Totally, these show the questions were thoroughly understood, and honestly responded. Two basic topics were researched in the study. According to the flight phases; 60% simulator and 40% helicopter ratio shall be suitable, but according to overall flight curriculum (not mentioned specifically) 50.82% simulator and 49.18% helicopter ratio is the final result. Surprisingly very very close results. The first result does not mean that it is useless. It is difficult to comprise the whole flight-training subjects, therefore a typical, basic model was taken, and then a general question was asked. 60%-40% ratio can be used in establishing flight-training programs in squadrons, but 50.82%-49.18% can be used in higher levels, such as cost efficiency analyses for decision-makers.

Bibliography

A.E. Dillard, *Validation of Advanced Flight Simulators for Operational Evaluation and Training Programs*, 2002.

I. Ercan, B. Ediz, I. Kan, *Hastalarin Sosyo-Ekonomik Durumlarina Gore Saglik Hizmetlerinden Memnuniyetlerinin Incelenmesi*, Inonu Universitesi Tip Fakultesi Dergisi, XI, 3, Malatya, Turkey, pp. 161-167, 2004.

M. Ergun, *Bilimsel Araştırmalarda Bilgisayarla Istatistik Uygulamaları - SPSS for Windows*, Ocak Yayınlari, Ankara, Turkey, 1995

J.A. Gliem, and R.R. Gliem, *"Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales"*, Midwest Research to Practice Conference in Adult, Continuing, and Community Education, 2003.

R. Kumar, *Research Methodology - A Step by Step Guide for Beginners*, SAGE Publications, 1996.

O. Ozdemir, *et al*., Turkish Electronic Journal of Medicine, vol. I, No. 2, 1997.

B. G. Tabachnick, and L. S. FIDELL, *Using Multivariate Statistics (4th edition)*, Needham Heights: Allyn&Bacon, 2001.