USAGE OF COMBINED AIRMAN CERTIFICATION BY ACTIVE AIRMEN: AN ACTIVE AIRMAN POPULATION ESTIMATE

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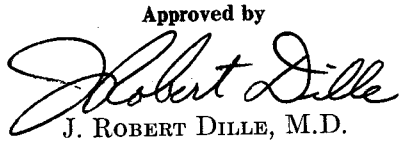

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The opinions and conclusions contained in this report are those of the author and should not be construed as reflecting the views or endorsement of the Federal Aviation Administration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Usage of Combined Airman Certification By Active Airmen: An Active Airman Population Estimate

I. Introduction

Statistical data concerning the final usage of medical and/or airman certification has historically been elusive at best. Volumes of data are generated which serve to define the airman population by active or inactive status, class of medical certification, and numbers of airmen with specific ratings. These data all serve the purpose for which accumulated but collectively they fail to illuminate the important area of what final airman usage is made of the various combinations of medical and airman certification. Such a description would appear to be of significant value to all facets of the civilian aviation community. Obvious benefits are apparent to the administration in terms of descriptive statistics for workload projections in airman/aircraft certification, future facility requirements, economic and budget considerations, and aviation research in general.

The problem of usage determination is compounded by the fact that no single source of airman data, which accounts for the numerous variables involved, has emerged as a reliable means of defining the active airman population by usage of certification.

Current Federal Aviation Regulations provide that all airman certificates, except student and certain special categories, are to be of indefinite duration. The number of airman certificates *per se* issued, therefore, reflects the cumulative total of airmen by ratings but are of limited value in a further description of the current airman population. The fact that a rating is of indefinite duration creates further inconsistencies because of the possibility of a voluntary downgrade by the airman in usage of his airman certification.

Continued validity, for operational purposes, of all airman ratings (certificates) has, by regulation, been made contingent upon possession of a current medical certificate which is commensurate with usage (See Figure 1). Aeromedical Certification records provide a definition of the members of the current airman population but these files are limited in that the class of medical certification does not imply utilization for the corresponding airman rating for which it is required, i.e., first class medical certification does not imply that the airman is airline transport rated. Conversely, the fact that an airman is airline transport rated does not imply that he is utilizing this rating and in turn is required to be medically certified under first class medical criteria.

FIGURE 1. Minimum Medical Certification Required for Operational Usage of Airman Ratings

Airman Category	*Minimum Required Medical Certificate*
Airline Transport Pilot*	First Class
Air Traffic Control Tower Operator	Second Class
Commercial Lighter-Than-Air Pilot	Second Class
Commercial Pilot**	Second Class
Flight Engineer	Second Class
Flight Navigator	Second Class
Free Balloon Pilot	Third Class
Private Lighter-Than-Air Pilot	Third Class
Private Pilot	Third Class
Student Lighter-Than-Air Pilot	Third Class
Student Pilot	Third Class

*Co-pilots are required by regulation to have second class medical certification. Co-pilots, therefore, are treated as commercial pilots in this study.

**Flight Instructors, though not required by regulation to have a specific level of medical certification, would normally possess second class medical certification in conjunction with a commercial or higher airman rating. Flight Instructors are treated as commercial pilots in this study.

Source: Federal Aviation Regulations—Parts 61, 63, and 65.

Finally, an airman may obtain airman and medical certification at a given level and use both for some lower level, as would be the case if an individual was rated as a commercial pilot with second class medical certification and was using his certification for private purposes. The problem of usage is virtually nonexistent among medically certified third class airmen since a third class medical certificate can be used for private and student purposes only, regardless of the airman rating held.

Both the airman certification and medical certification systems are automated and the obvious solution, which would involve matching the two tape files and categorizing the airman by rating and medical certification status, would greatly simplify the problem. However, this solution is not feasible due to lead/lag considerations, workload considerations and backlogs, incompatibility of input control data under the separate systems, differences in the degree of automation, and further magnification of discrepancies between the two tape systems due to input errors. In short, a significant error factor is recognized in a match procedure involving these working files and the error is not measurable.

This study, via usage of statistical methodology described later, is an effort to estimate the active airman population by apparent or effective airman usage of required certification and considers both airman rating and the medical certification factors.

II. Methodology

A. *The Problem Statement.* The problem of estimating the active airman population by usage of certification is reducible to one of estimating population parameters via sampling techniques for the following unknowns:[1]

1. The proportion of medically certified first class airmen utilizing the medical certification for:
   a. airman purposes requiring first class medical certification,
   b. airman purposes requiring second class medical certification,
   c. airman purposes requiring third class medical certification, or
   d. other purposes, unknown or unrecognized as requiring medical certification of any class.
2. The proportion of medically certified second class airmen utilizing the medical certification for:
   a. airman purposes requiring second class medical certification,
   b. airman purposes requiring third class medical certification, or
   c. other purposes, unknown or unrecognized as requiring medical certification of any class.
3. The proportion of medically certified third class airmen utilizing the medical certification for:
   a. airman purposes requiring third class medical certification, or
   b. other purposes, unknown or unrecognized as requiring medical certification of any class.

A systematic random sampling procedure considering the three classes of medically certified airmen as the respective subdivisions of the active airman population was utilized to extract sample members. Within each class of medical certification, sufficient members were extracted for a predetermined accuracy in view of the number of proportions to be estimated within each class of medical certification, i.e., more possible combinations reflecting utilization are possible in the medically certified first class subdivision, thus requiring a larger sample size for the desired accuracy with respect to proportional estimates. Reference to the Appendix is recommended for a further detailed discussion of statistical methodology. Suffice it to say here that a sample from active members (medical examination and issuance within the past 25 months) of each class of medical certification was extracted from the working magnetic tape files by computer program means for purposes of estimating the proportions defined in II.A.1, 2, and 3.[2]

As discussed in the introductory remarks, numerous combinations of airman/medical certification can legally exist and, if taken at face value, do not serve to define the usage classification of the combined certification in all instances. All members of the sample were screened considering the known factors of airman rating, class of medical certification, current effective status of medical certification (as indicated by the time lapse since the most recent FAA medical examination) and previous effective status of medical certification (as indicated by the time lapse between the previous FAA medical examination and the current FAA medical examination). The purpose and effect of this screening procedure was to categorize the airmen by apparent or effective usage considering combined airman/medical certification factors. These usage classifications are defined in Figure 2.

[1] A medically certified airman is considered "active" for a maximum of 25 months after his last FAA Physical Examination, i.e., regardless of the class of medical certificate issued, it is valid for third class purposes for a period of time up to 25 months.

[2] Aeromedical Certification working tape files as of October 1, 1966, were used in this study.

FIGURE 2. Classification of Airman/Medical Certification Usage

1. Airline Transport Pilot Purposes (Excluding Co-Pilots).
2. Commercial Pilot Purposes (Including Air Traffic Controllers, Flight Engineers, Flight Navigators, Flight Instructors, Co-Pilots, and Military Pilot personnel).
3. Private or Student Pilot Purposes.
4. Unknown Purposes.

The proportions mentioned at the beginning of this section were subsequently defined by consideration of the factors mentioned above and the derived usage classification indicated for each sample member.

Certain assumptions are inherent in this approach to estimating the population by usage. First, given the screening factors, the classification by usage is static and reflects the most recent certification data available concerning the airman. Anticipation of airman rating upgrades were not considered, except to the extent that records of application for airman rating were searched on three separate occasions at 3-month intervals to reduce the proportion of airmen in the "unknown" category. This is not, however, a serious limitation as any approach must, of necessity, be of a static nature as workload time factors and certainty as concerns such variables as anticipated upgrades are not measurable. Further, the absence of certification data, either previous medical factors or airman rating factors, required a dependence upon the remaining known factors to define usage. Supplemental research was required in these rare instances but some minute error is categorically recognized in this respect. It is doubtful whether any of the aforementioned limitations amount to the problems presented by nonresponse and other bias-producing considerations normally associated with a typical questionaire sample directed to members of the population.[3]

The estimation of the proportions mentioned previously, with their complements, were applied to the known medical certification status of the active airman population by class of medical certification, with the results yielding population estimates according to the usage classifications defined in Figure 2.

B. *Sample Members.* From a population of 56,611 medically certified active first class airmen, 1,476 airman records were randomly selected and extracted from magnetic tape for purposes of estimating the proportional usage classifications. Likewise, from a population of 160,682 medically certified active second class airmen, 1,047 airman records were considered in the estimation of the proportional usage classifications. Only 73 medically certified active third class airman records from a population of 332,594 were considered in estimating the usage proportions among third class airmen because minimal usage alternatives exist for this class. As mentioned previously, appropriate sample size statistical methodology dictated the sample size for each class of medical certification. (See the Appendix for a discussion of sample size determination and sample design.)

C. *An Example of Usage Classification Applied to Sample Members.* The most recent medical record of each sample member was reviewed to determine usage criteria from elements of data supplied by the airman on FAA Form 1004 (Application for Airman Medical Certificate). These data and additional computer assigned data were combined with current airman rating information, i.e., student, private, commercial, airline transport ratings, etc., to arrive at an appropriate usage classification.[4] Questionable cases or instances of multiple airman ratings were given more detailed review considering previous medical records, statements reflecting occupation and employer, and indications of business or pleasure flying. Most cases, however, were classified by usage according to class of medical certificate issued, current airman rating, and length of time since last FAA medical examination. Example cases are presented below to illustrate usage classifications.

Case 1. Fifty-five-year-old male airman issued first class medical certification on July 29, 1966. Currently airline transport rated. Date of previous FAA medical examination, January 1966. Employed by United Airlines. USAGE CLASSIFICATION: Airline Transport Pilot Purposes.

Case 2. Forty-eight-year-old male airman issued first class medical certification August 31, 1966. Current airman ratings include airline transport rating, flight instructor, and commercial ratings. Date of previous FAA medical examination, August 1965. Indicates occupation as business or executive pilot. USAGE CLASSIFICATION: Commercial Pilot Purposes.

Case 3. Twenty-three-year-old male airman issued first class medical certification July 19, 1966.

[3] For a discussion of the problems of "nonresponse" see *Sampling Techniques*, W. G. Cochran, Chapter 13.

[4] Airman ratings were obtained from records maintained by the Airman Certification Branch of the Flight Standards Technical Division.

Currently holds private airman rating. No previous FAA medical examination. Indicates nonaeronautical occupation. USAGE CLASSIFICATION: Private or Student Pilot Purposes.

Case 4. Thirty-nine-year-old male airman issued second class medical certification May 23, 1966. Currently holds commercial rating. Previous FAA medical examination, May 1965. Indicates occupation as commercial pilot, not self-employed. USAGE CLASSIFICATION: Commercial Pilot Purposes.

Case 5. Twenty-four-year-old male airman issued second class medical certification on June 18, 1965. Currently holds private airman rating. Previous FAA medical examination, June 1963. Indicates nonaeronautical occupation. USAGE CLASSIFICATION: Private or Student Pilot Purposes.

Case 6. Twenty-nine-year-old female issued third class medical certification September 8, 1966. Currently holds private airman rating. Date of previous FAA medical examination, August 1964. USAGE CLASSIFICATION: Private or Student Pilot Purposes.

The example cases cited serve to illustrate the technique of usage classification as applied to sample members within each class of medical certification. Usage classifications, within each medical class, were then totaled and the proportions by usage classification estimated for each sample class.

Extrapolation to the total study and current populations was subsequently accomplished to arrive at estimates, by usage of combined certification, of the number of airmen in these populations.

III. Results

A. *Sample Results.* The analysis of combined airman certification factors with respect to sample members resulted in the following usage relationships within the respective subdivisions:

1. Medically Certified First Class Sample Members.

   Medically certified first class airmen determined to be utilizing their medical certificate for airman purposes requiring a first class medical certificate amounted to 363 of the 1,476 sample members, or 24.6%. Medically certified first class airmen usage classified as requiring only second class medical certification totaled 634 of the 1,476 sample members, or 42.9%. Medically certified first class airmen defined as using their certification for third class purposes amounted to 438 of the 1,476 sample members, or 29.7%. The remaining 41 airmen making up the sample from the first class population could not be classified as requiring medical certification of any class. This latter group represents 2.8% of the 1,476 medically certified first class airmen sampled.

2. Medically Certified Second Class Sample Members.

   From the sample of 1,047 medically certified second class airmen, 438 or 41.8% were classified as utilizing their medical certificate for airman purposes requiring the second class medical certificate. Medically certified second class airmen usage classified as requiring third class medical certification totaled 579 of the 1,047 sampled, or 55.3%. The 30 airmen comprising the remainder of those sampled from this class of medically certified airmen could not be usage classified as requiring any class of medical certification. These latter airmen represent 2.9% of the 1,047 sample members.

3. Medically Certified Third Class Sample Members.

   Sixty-nine of the 73 medically certified third class airmen comprising the sample were found to be utilizing their certification for purposes requiring a third class medical certificate. This total represents 94.5% of the 73 sample members. The remaining 4 airmen (5.5%) could not be usage classified as requiring any class of medical certification.

B. *Sample Results Extrapolated to the Study Population and Current Airman Population.*[5] Applying the percentages obtained from the sample yields the following estimates by usage classification with respect to the three classes of medical certification:

1. The Medically Certified First Class Population: The population from which the sample was drawn included 56,611 medically certified first class airmen; the current total is 72,155. Application of the percentage relationships described in III.A.1 to this subdivision of the total study and the current populations yield estimates by usage classification as follows:

[5] The reader is reminded that the precision of any estimate from a sample depends on statistical methodology and "sampling error" as defined in the sampling plan. Such estimates should thus be viewed as point estimates within an acceptable range of accuracy. Reference the Appendix for a further discussion of desired accuracy. Further reference concerning "point estimates" is provided in Chapter 1 of *Statistical Methods* by George W. Snedecor.

TABLE I.—*Medically certified first class airmen by usage classification*

Usage Classification	Medical Certificate Required	Estimated Population Oct. 1, 1966	Estimated Population Oct. 1, 1967	Percent of Total
Airline Transport Pilot Purposes (Excluding Co-Pilots)	First	13,926	17,750	24.6
Commercial Pilot Purposes*	Second	24,286	30,955	42.9
Private or Student Pilot Purposes	Third	16,814	21,430	29.7
Unknown Purposes	None	1,585	2,020	2.8
Total (Actual)		56,611	72,155	100.0

*Includes Air Traffic Controllers, Flight Engineers, Flight Navigators, Flight Instructors, Co-Pilots, and Military Pilot personnel.

2. The Medically Certified Second Class Population: 160,682 medically certified second class airmen were included in the study population; the current population totals 182,654. Percentages derived from sample results were applied to the medically certified second class airmen in the study population and the current population. The estimates by usage classification are presented in Table II.

3. The Medically Certified Third Class Population: The study population included 332,594 medically certified third class airmen; the third class population now totals 368,725. The percentage relationships realized through analysis of sample members and subsequent usage classifications were applied to the study and current populations to arrive at the estimates given in Table III.

TABLE II.—*Medically certified second class airmen by usage classification*

Usage Classification	Medical Certificate Required	Estimated Population Oct. 1, 1966	Estimated Population Oct. 1, 1967	Percent of Total
Commercial Pilot Purposes*	Second	67,165	76,349	41.8
Private or Student Pilot Purposes	Third	88,857	101,008	55.3
Unknown Purposes	None	4,660	5,297	2.9
Total (Actual)		160,682	182,654	100.0

*Includes Air Traffic Controllers, Flight Engineers, Flight Navigators, Flight Instructors, Co-Pilots, and Military Pilot personnel.

TABLE III.—*Medically certified third class airmen by usage classification*

Usage Classification	Medical Certificate Required	Estimated Population Oct. 1, 1966	Estimated Population Oct. 1, 1967	Percent of Total
Private or Student Pilot Purposes	Third	314,301	348,445	94.5
Unknown Purposes	None	18,293	20,280	5.5
Total (Actual)		332,594	368,725	100.0

C. *Total Population Estimates by Usage Classification.* Without regard to the type of medical certificate held, this section is concerned with estimates, by usage classification, of the total population at the time of the study (October 1, 1966) and the total current population as of October 1, 1967. Utilizing the total population estimation models described in the "Summary", the populations were further defined as described below:

1. The Study Population: Applying sample proportions to the total study population yields the following estimates by usage classifications (see Table IV).
2. The Current Population: In the same manner described above, the current total population was estimated by usage classification. Results are presented in Table V.

TABLE IV.—*Study population estimates by usage classification—October 1, 1966*

Usage Classification	Estimated Population	Percent of Total
Airline Transport Pilot Purposes (Excluding Co-Pilots)	13,926	2.5
Commercial Pilot Purposes*	91,451	16.6
Private or Student Pilot Purposes	419,972	76.4
Unknown Purposes	24,538	4.5
Total (Actual)	549,887	100.0

*Includes Air Traffic Controllers, Flight Engineers, Flight Navigators, Flight Instructors, Co-Pilots, and Military Pilot personnel.

TABLE V.—*Current population estimates by usage classification—October 1, 1967*

Usage Classification	Estimated Population	Percent of Total
Airline Transport Pilot Purposes (Excluding Co-Pilots)	17,750	2.9
Commercial Pilot Purposes*	107,304	17.2
Private or Student Pilot Purposes	470,883	75.5
Unknown Purposes	27,597	4.4
Total (Actual)	623,534	100.0

*Includes Air Traffic Controllers, Flight Engineers, Flight Navigators, Flight Instructors, Co-Pilots, and Military Pilot personnel.

IV. Discussion

The preceding analysis, although broad in scope, provides valuable insight with respect to a description of the active airman population. The population estimates by usage deviate quite dramatically from what might be surmised from available statistical data which considers either airman rating or medical certification separately. Available statistical data tends to overemphasize professional usage categories and underemphasize the general aviation usage categories. For example, reference to Table V would indicate that approximately 20% of the active airman population is occupationally connected to aviation. Using current First and Second Class Medical Certification totals (72,155 and 182,654 respectively) would indicate that approximately 40% of total airmen currently certified (623,534) are occupationally connected to aviation. The most current airman rating data available would, likewise, tend to overestimate the proportion of the total airman population occupationally related to aviation.[6]

The general aviation population makes up approximately 75% of the active airman population as indicated by Table V. About 4.5% of the medically certified active airman population have not yet obtained any type of airman rating.

[6] FAA Statistical Handbook of Aviation, 1966 Edition, Table 4.9. Categories are not mutually exclusive, but the effect is obvious by adding commercial and airline transport ratings for the year ending December 31, 1965, which would indicate approximately 29% of the total in the "pilot" category.

Reference to Table VI and VII provides significant testimony to the growth in civil aviation by comparison of the net population totals at the 12-month interval provided by this study. The active airman population experienced a net growth of 73,647 from 549,887 as of October 1, 1966, to 623,534 as of October 1, 1967, or 13.4%.

Airmen medically certified within the past 3 years, as of October 1, 1966 totaled 646,319 of which 96,432 had effectively become inactive by allowing their medical certificate to lapse into the time period from 25 to 36 months since last FAA medical examination. As of October 1, 1967, airmen medically certified within the past 3 years totaled 728,080. Of this total, 104,546 airmen had allowed their medical certification to lapse into an inactive status. Inactivity, therefore, remained relatively constant as measured at 12-month intervals (14.9% in October 1966 and 14.4% in October 1967).

Whatever the motivation, approximately 30% of the active airman population initially obtain higher medical certification than is required by regulation. Part of this "over certification" is attributed to industry requirements but a large percentage of general aviation pilots also obtain higher medical certification than is required. In the study population, 29.7% of the medically certified first class airmen were apparently engaged in private or student pilot activity and 55.3% of the medically certified second class airmen were engaged in private

or student pilot activity. Several possible reasons exist for obtaining higher medical certification. Certainly, anticipated upgrade in airman rating provides motivation for obtaining a higher class of medical certification. More significant, however, is probably the belief that a more thorough examination is obtained by making application for first or second class medical certification. Lastly, some "status" benefit is recognized as motivating airmen to obtain higher medical certification than required.

The same analogy can be made with reference to airman ratings. Airmen obtain higher technical qualifications than required for their intended use.

In the final analysis, whatever the motivation, these factors contribute to the enhancement of aviation safety.

TABLE VI.—*Medically certified airman population summary—October 1, 1966*

Medical Certificate	Time Lapse Since Date of Last Examination					Total
	Active Airmen				Inactive Airmen	
	<7 Mo.	<13 Mo.	<25 Mo.	Subtotal	25–36 Mo.	
First Class	39,109	13,275	4,227	56,611	1,773	58,384
Second Class	65,760	48,945	45,977	160,682	22,352	183,034
Third Class	108,739	73,983	149,872	332,594	72,307	404,901
Total	213,608	136,203	200,076	549,887	96,432	646,319

TABLE VII.—*Medically certified airman population summary—October 1, 1967*

Medical Certificate	Time Lapse Since Date of Last Examination					Total
	Active Airmen				Inactive Airmen	
	<7 Mo.	<13 Mo.	<25 Mo.	Subtotal	25–36 Mo.	
First Class	42,656	18,580	10,919	72,155	2,477	74,632
Second Class	71,526	56,891	54,237	182,654	22,968	205,622
Third Class	119,311	80,048	169,366	368,725	79,101	447,826
Total	233,493	155,519	234,522	623,534	104,546	728,080

V. Summary

Assuming regulatory requirements and motivational factors to remain relatively constant with respect to airman certification and its subsequent usage by the airman population, the study has provided a tool by which future populations may be broadly defined. The only significant foreseeable adjustment to this method of estimation occurs with respect to the "Unknown Purposes" category. The impact of the recently initiated program of combined student pilot and medical certificate issuance is likely to have the effect of reducing the "Unknown Purposes" category to insignificant proportions. However, when it is recognized that this category is largely made up of airmen who have not yet soloed, (some airmen who do not require medical certification are also included, i.e., parachutists, glider pilots, etc.) little description is lost by adding this proportional representation to the "Private or Student Pilot Purposes" category within the respective classes of medical certification. Conversely, this "Unknown Purposes" category could still be used to estimate the number of airmen in future populations who have not yet soloed.

The general aviation population appears to be much larger than conventional statistical summaries would indicate (approximately 75–80% of the total active population). Likewise, the professional, occupationally related population estimates indicate a smaller total representation than would be recognized by conventional summary data. The active airman population increased rather dramatically (13.4% in the time period observed) while inactivity remained relatively constant.

The estimation model is presented below and assumes the availability of medical certification input:

$$\hat{N}_1 = X_1(0.246)$$
$$\hat{N}_2 = X_2(0.418) + X_1(0.429)$$
$$\hat{N}_3 = X_3(0.945) + X_1(0.297) + X_2(0.553)$$
$$\hat{N}_0 = X_1(0.028) + X_2(0.029) + X_3(0.055) \text{ or}$$
$$\hat{N}_0 = X_1 + X_2 + X_3 - (\hat{N}_1 + \hat{N}_2 + \hat{N}_3)$$

Where,

$\hat{N}_1$ = The estimated number of medically certified active airmen usage classified under Airline Transport Purposes.

$\hat{N}_2$ = The estimated number of medically certified active airmen usage classified under Commercial Purposes.

$\hat{N}_3$ = The estimated number of medically certified active airmen usage classified under Private or Student Purposes.

$\hat{N}_0$ = The estimated number of medically certified active airmen usage classified as unknown or not requiring medical certification of any class.

And,

X_1 = The actual number of medically certified First Class airmen.

X_2 = The actual number of medically certified Second Class airmen.

X_3 = The actual number of medically certified Third Class airmen.

APPENDIX

Statistical Methodology.

This appendix has been included to present further details with respect to (1) the population estimation model, (2) sample size determination, (3) sample design as concerns the study, and (4) confidence limits of estimated proportions. The estimation of the proportions mentioned in II.A of the study along with the known medical certification status of active airmen resulted in the population estimates presented in the "Results" portion of the study. This appendix will provide the reader with further insight as to the logic and methodology applied in arriving at those estimates.

The Population Estimation Model by Usage Classification.

The following definitive relationships exist with respect to the active airman population and proportions mentioned above:

$$N=N_1+N_2+N_3+N_0$$

Where N equals the active airman population: N_1 equals the number of airmen in the usage classification of airline transport purposes; N_2 equals the number of airmen in the usage classification of commercial purposes, including co-pilots, flight engineers, flight navigators, flight instructors, control tower operators, and military pilot personnel; N_3 equals the number of airmen in the usage classification of private or student purposes; and N_0 equals the number of medically certified airmen whose airman rating is unknown and, therefore, whose usage classification is also unknown.

Also,

$$N=X_1+X_2+X_3$$

Where X_1 equals the number of medically certified first class airmen; X_2 equals the number of medically certified second class airmen; and X_3 equals the number of medically certified third class airmen. Therefore,

$$N_1+N_2+N_3+N_0=X_1+X_2+X_3$$

$$X_1=X_1(P_1+P_2+P_3+P_0)$$

Where P_1 equals the proportion of medically certified first class airmen who are usage classified under airline transport purposes and, therefore, require first class medical certification; P_2 equals the proportion of medically certified first class airmen who are usage classified under commercial purposes and, consequently, require second class medical certification; P_3 equals the proportion of medically certified first class airmen who are usage classified under private or student purposes and thus require third class medical certification; and P_0 equals the proportion of other medically certified first class airmen whose airman rating and usage classification are unknown or who do not require medical certification of any class, i.e., parachutists, mechanics, etc.

$$X_2=X_2(P_2'+P_3'+P_0')$$

Where P_2' equals the proportion of medically certified second class airmen who are usage classified under commercial purposes, thus requiring second class medical certification; P_3' equals the proportion of medically certified second class airmen who are usage classified under private or student purposes and, therefore, require third class medical certification; and P_0' equals the proportion of other medically certified second class airmen whose airman rating and usage classification are unknown or who do not require medical certification of any class.

$$X_3=X_3(P_3''+P_0'')$$

Where P_3'' equals the proportion of medically certified third class airmen who are usage classified under private or student purposes and, therefore, require third class medical certification; and P_0'' equals the proportion of other medically certified third class airmen whose airman rating and usage classification are unknown or who do not require medical certification of any class.

Therefore,

$$N = X_1(P_1+P_2+P_3+P_0)+X_2 (P_2'+P_3'+P_0')+X_3(P_3''+P_0'')$$

And,

$$N_1 = X_1 - X_1(P_2+P_3+P_0)$$
$$N_2 = X_2 - X_2(P_3'+P_0')+X_1(P_2)$$
$$N_3 = X_3 - X_3(P_0'')+X_1(P_3)+X_2(P_3')$$
$$N_0 = X_1(P_0)+X_2(P_0')+X_3(P_0'')$$

Or

$$N_1 = X_1(P_1)$$
$$N_2 = X_2(P_2')+X_1(P_2)$$
$$N_3 = X_3(P_3'')+X_1(P_3)+X_2(P_3')$$
$$N_0 = X_1+X_2+X_3-(N_1+N_2+N_3)$$

A systematic random sample was taken from the three medical classes on the Aeromedical Certification active master tape file as of October 1, 1966. A 95% confidence interval and a $\pm 5\%$ sampling error were accepted with respect to sample proportions. In the sample, from the medical tape file:

n = total number of airmen in the sample.
x_1 = number of Class 1 airmen in the sample.
x_2 = number of Class 2 airmen in the sample.
x_3 = number of Class 3 airmen in the sample.

x_1 can be defined as consisting of:

a_1—those medically certified first class airmen who were usage classified under airline transport purposes.
a_2—those medically certified first class airmen who were usage classified under commercial purposes.
a_3—those medically certified first class airmen who were usage classified under private or student purposes.
a_0—those medically certified first class airmen whose airman rating and usage classification were unknown or who did not require medical certification of any class.

And,

$$x_1 = a_1+a_2+a_3+a_0$$

x_2 can be defined as consisting of:

a_2'—those medically certified second class airmen who were usage classified under commercial purposes.
a_3'—those medically certified second class airmen who were usage classified under private or student purposes.
a_0'—those medically certified second class airmen whose airman rating and usage classification were unknown or who did not require medical certification of any class.

And,

$$x_2 = a_2'+a_3'+a_0'$$

x_3 can be defined as consisting of:

a_3''—those medically certified third class airmen who were usage classified under private or student purposes.
a_0''—those medically certified third class airmen whose airman rating and usage classification were unknown or who did not require medical certification of any class.

And,

$$x_3 = a_3''+a_0''$$
$$n = x_1+x_2+x_3$$

Therefore

$$n = a_1+a_2+a_3+a_0+a_2'+a_3'+a_0'+a_3''+a_0''$$

In expansion of the P Q relationship for the three classes of medical certification in the sample, the following proportions were of interest. P is defined as the proportion of the active airman population who have medical certification commensurate with their derived usage classification. Q is defined as those airmen who have obtained higher medical certification than that which is required for their usage classification.

In the sample, "p" and "q" are the estimates of "P" and "Q" population values.

And,

$$p_1 = \frac{a_1}{a_1+a_2+a_3+a_0} \text{ or } p_1 = \frac{a_1}{x_1} = \hat{P}_1$$

$$\left.\begin{aligned} p_2 &= \frac{a_2}{a_1+a_2+a_3+a_0} \text{ or } p_2 = \frac{a_2}{x_1} = \hat{P}_2 = \\ p_3 &= \frac{a_3}{a_1+a_2+a_3+a_0} \text{ or } p_3 = \frac{a_3}{x_1} = \hat{P}_3 = \\ p_0 &= \frac{a_0}{a_1+a_2+a_3+a_0} \text{ or } p_0 = \frac{a_0}{x_1} = \hat{P}_0 = \end{aligned}\right\} \hat{Q}_1$$

And,

$$p_2' = \frac{a_2'}{a_2' + a_3' + a_0'} \quad \text{or } p_2' = \frac{a_2'}{x_2} = \hat{P}_2'$$

$$p_3' = \frac{a_3'}{a_2' + a_3' + a_0'} \quad \text{or } p_3' = \frac{a_3'}{x_2} = \hat{P}_3' = \Bigg\} \hat{Q}_2'$$

$$p_0' = \frac{a_0'}{a_2' + a_3' + a_0'} \quad \text{or } p_0' = \frac{a_0'}{x_2} = \hat{P}_0' = \Bigg\}$$

And,

$$p_3'' = \frac{a_3''}{a_3'' + a_0''} \quad \text{or } p_3'' = \frac{a_3''}{x_3} = \hat{P}_3''$$

$$p_0'' = \frac{a_0''}{a_3'' + a_0''} \quad \text{or } p_0'' = \frac{a_0''}{x_3} = \hat{Q}_3''$$

Given these estimates of P and their standard errors, estimated values for A_1, A_2, A_3, A_0, A_2', etc., were determined. Where A_i is the population value estimated by a_i.

In the population,

$$N_1 = A_1 = X_1(P_1)$$
$$N_2 = A_2 + A_2' = X_2(P_2') + X_1(P_2)$$
$$N_3 = A_3 + A_3' + A_3'' = X_3(P_3'') + X_1(P_3) + X_2(P_3')$$
$$N_0 = A_0 + A_0' + A_0'' = X_1(P_0) + X_2(P_0') + X_3(P_0'')$$

Or using the estimated proportions, the estimation model becomes:

$$\hat{N}_1 = X_1(\hat{P}_1)$$
$$\hat{N}_2 = X_2(\hat{P}_2') + X_1(\hat{P}_2)$$
$$\hat{N}_3 = X_3(\hat{P}_3'') + X_1(\hat{P}_3) + X_2(\hat{P}_3')$$
$$\hat{N}_0 = X_1(\hat{P}_0) + X_2(\hat{P}_0') + X_3(\hat{P}_0'') = X_1 + X_2 + X_3 - (\hat{N}_1 + \hat{N}_2 + \hat{N}_3)$$

Where $\hat{N}_i$ and $\hat{P}_i$ are estimates of population parameters.

Sample Size.

The study is concerned with presenting estimates, not only for the population as a whole, i.e., the proportion of airmen who obtain medical certification commensurate with that required by their usage classification (P) and the proportion who acquire medical certification for a higher level than that dictated by their usage classification (Q) but also with the presentation of estimates of P_i for the classes of medical certification and in expanding Q_i for the classes of medical certification to indicate the proportions by classification (see formulas on pages 10 and 11.) whoseusage classification dictates another lower class of medical certification, i.e., $\hat{P}_2$, $\hat{P}_3$, $\hat{P}_0$, and $\hat{P}_3'$, and $\hat{P}_0'$, which make up $\hat{Q}_1$ and $\hat{Q}_2'$ respectively.

Members of the medically certified airman population are identifiable by class of medical certificate issued. Further a desired variance (V) was defined with respect to sample proportions (p_i). Extracting from sampling theory as presented by Cochran, sample size was arrived at as follows: [7]

$$n = \sum \frac{P_i Q_i}{V}$$

Where $_i$ refers to a subdivision within the population. There are eight subdivisions within the active airman population as indicated on pages 10 and 11 thus eight separate P Q relationships. This amounts to computing a sample size for each subdivision within a particular class of medical certification Another way of expressing this is to say that the total population may be viewed as three separate subpopulations and that a sample size was computed for each of the subdivisions of a class of medical certification (subpopulation) and summed to get the sample size from the particular class or subpopulation (n_i).

Thus,

$$n_1 = \sum \frac{P_i Q_i}{V} \qquad \text{where i} = 0, 1, 2, 3$$

$$n_2 = \sum \frac{P_i' Q_i'}{V} \qquad \text{where i} = 0, 2, 3$$

$$n_3 = \sum \frac{P_3'' Q_3''}{V}$$

And,

$$n = \sum \frac{P_i Q_i}{V} + \sum \frac{P_i' Q_i'}{V} + \sum \frac{P_3'' Q_3''}{V}$$

Or,

$$n = n_1 + n_2 + n_3$$

Calculations for n_i and n are as follows:

$$V = \frac{d^2}{t^2} = \text{desired variance of the sample proportion}$$

[7] Cochran, William G., (1953), *Sampling Techniques;* John Wiley and Sons, New York, Second Edition, Chapter 4.

Where,

$d = 5.0\%$ (Sample Error)
$t = 1.96$ (95% Confidence)
$V = \frac{0.0025}{3.84} = 0.000651$

For n_1, (the sample size from medically certified First Class airmen):

$$n_{11} = \frac{P_1 Q_1}{V} = \frac{(0.60)\ (0.40)}{0.000651} = 368.7 \text{ or } 369$$

$$n_{12} = \frac{P_2 Q_2}{V} = \frac{(0.60)\ (0.40)}{0.000651} = 368.7 \text{ or } 369$$

$$n_{13} = \frac{P_3 Q_3}{V} = \frac{(0.60)\ (0.40)}{0.000651} = 368.7 \text{ or } 369$$

$$n_{10} = \frac{P_0 Q_0}{V} = \frac{(0.60)\ (0.40)}{0.000651} = 368.7 \text{ or } 369$$

Where n_{11} is the expected sample size from the subdivision of First Class medically certified airmen who are represented by $\frac{a_1}{x_1} = \hat{P}_1$ (See page 10).

n_{12}, n_{13}, and n_{10} respectively indicate the expected sample size from the remaining three classifications possible among medically certified First Class airmen. Remember here that $\hat{P}_2$, $\hat{P}_3$, and $\hat{P}_0$ make up $\hat{Q}_1$ for this class.

Therefore,

$$n_1 = 1476$$

For n_2, (the sample size from medically certified Second Class airmen):

$$n_{22} = \frac{P_2' Q_2'}{V} = \frac{(0.65)\ (0.35)}{0.000651} = 349.4 \text{ or } 349$$

$$n_{23} = \frac{P_3' Q_3'}{V} = \frac{(0.65)\ (0.35)}{0.000651} = 349.4 \text{ or } 349$$

$$n_{20} = \frac{P_0' Q_0'}{V} = \frac{(0.65)\ (0.35)}{0.000651} = 349.4 \text{ or } 349$$

Where n_{22} equals the expected sample size from the subdivision of Second Class medically certified airmen who are represented by $\frac{a_2'}{x_2} = \hat{P}_2'$. $\hat{Q}_2$ is made up of $\hat{P}_3'$ and $\hat{P}_0'$.

Therefore,

$$n_2 = 1047$$

For n_3, (the sample size from medically certified Third Class airmen):

$$n_3 = \frac{P_3'' Q_3''}{V} = \frac{(0.95)\ (0.05)}{0.000651} = \frac{0.0475}{0.000651} = 72.9 \text{ or } 73$$

This situation differs from those presented for n_1 and n_2 because $\hat{P}_3''$ and $\hat{Q}_3''$ are the only classifications present in third class medically certified airmen for which the specified variance (V) was required.

Summing for n_1, n_2, and n_3:

$$n = \sum \frac{P_i Q_i}{V} + \sum \frac{P_i' Q_i'}{V} + \sum \frac{P_3'' Q_3''}{V}$$

Or,

$$n = n_1 + n_2 + n_3$$
$$n = 1476 + 1047 + 73$$
$$n = 2596$$

In effect, the eight subdivisions were summed to realize n.

n_i equals the sample size required from each class of medical certification. Therefore, n_1 equals x_1, n_2 equals x_2, and n_3 equals x_3, in terms of the notation presented on pages 10 through 12.

Sample Design.

The sample size determined above considers that a desired variance has been defined with respect to the several proportions of interest among the classes of medical certification.

Following a scheme of systematic sampling, every k_ith item was selected as dictated by the considerations set forth above with respect to sample size among classes of medical certification.[8] k_i is defined as $\frac{X_i}{n_i}$.

Therefore,

$$k_1 = \frac{X_1}{n_1} = \frac{56{,}611}{1{,}476} = 38.4 \text{ or } 38$$

From a table of Random Numbers a starting point of 2 was selected within the interval 1–38. Hence, starting with the second First Class medical record on the active master tape file, every 38th record was selected for enclosure in the sample, i.e., 2, 40, 78, 116, etc.

Similarly, for n_2:

$$k_2 = \frac{X_2}{n_2} = \frac{160{,}682}{1{,}047} = 153.4 \text{ or } 153$$

[8] Neiswanger, William A. (1956). *Elementary Statistical Methods;* The MacMillan Company, New York, Revised Edition, Chapter 4.

The random starting point in the interval 1–153 was 64. Therefore, starting with Second Class medical record number 64, every k_2th item or every 153rd record was selected to comprise $n_2 = 1{,}047$.

For n_3:

$$k_3 = \frac{X_3}{n_3} = \frac{332{,}594}{73} = 4{,}556.1 \text{ or } 4{,}556$$

With a random start in the interval 1–4556 of 434, every 4556th record was selected to comprise $n_3 = 73$.

Simple random sampling theory as presented by Cochran was utilized in a systematic sampling plan since the alphabetic sequence of the file is unrelated to the estimates sought by the procedure and since systematic sampling is a more expeditious means of sampling from a sequential tape file.

Confidence Limits.

The normal approximation to the confidence limits for P_1, P_2', and P_3'' are presented below as dictated by the formula:

$$p \pm \left[t\sqrt{1-f}\sqrt{\hat{P}\,\hat{Q}/(n-1)} + \frac{1}{2n} \right]$$

Where $f = n/N$ (the sample fraction) and t is the normal deviate corresponding to the confidence probability.[9]

First Class Estimated Proportions:

$$\hat{P}_1 = 0.246 \qquad \hat{Q}_1 = 0.754$$

$$0.246 \pm \left[1.96\sqrt{1-\frac{1476}{56611}}\sqrt{\frac{(0.246)\ (0.754)}{1476-1}} + \frac{1}{2(1476)} \right]$$

$$0.246 \pm \left[1.96\sqrt{1-0.02607}\sqrt{\frac{0.18548}{1475}} + \frac{1}{2952} \right]$$

$$0.246 \pm [1.96\sqrt{0.97393}\sqrt{0.000125} + 0.000339]$$

$$0.246 \pm [1.96\ (0.987)\ (0.0112) + 0.000339]$$

$$0.246 \pm [1.96\ (0.011054) + 0.000339]$$

$$0.246 \pm [(0.021666 + 0.000339)]$$

$$0.246 \pm 0.022$$

$$\hat{P}_{1U} = 0.268 \qquad \hat{P}_{1L} = 0.224$$

Second Class Estimated Proportions:

$$\hat{P}_2' = 0.418 \qquad \hat{Q}_2' = 0.582$$

$$0.418 \pm \left[1.96\sqrt{1-\frac{1047}{160{,}682}}\sqrt{\frac{(0.418)\ (0.582)}{1047-1}} + \frac{1}{2(1047)} \right]$$

$$0.418 \pm \left[1.96\sqrt{1-0.00652}\sqrt{\frac{0.243276}{1046}} + \frac{1}{2094} \right]$$

$$0.418 \pm [1.96\sqrt{0.99348}\sqrt{0.000232} + 0.000478]$$

$$0.418 \pm [1.96\ (0.997)\ (0.0152) + 0.000478]$$

$$0.418 \pm [1.96\ (0.015154) + 0.000478]$$

$$0.418 \pm [(0.029702 + 0.000478)]$$

$$0.418 \pm 0.030$$

$$\hat{P}_{2U}' = 0.448 \qquad \hat{P}_{2L}' = 0.388$$

Third Class Estimated Proportions:

$$\hat{P}_3'' = 0.945 \qquad \hat{Q}_3'' = 0.055$$

$$0.945 \pm \left[1.96\sqrt{1-\frac{73}{332{,}594}}\sqrt{\frac{(0.945)\ (0.055)}{73-1}} + \frac{1}{2(73)} \right]$$

$$0.945 \pm \left[1.96\sqrt{1-0.000219}\sqrt{\frac{0.051975}{72}} + \frac{1}{146} \right]$$

$$0.945 \pm [1.96\sqrt{0.999781}\sqrt{0.000722} + 0.006849]$$

$$0.945 \pm [1.96\ (0.999)\ (0.0269) + 0.006849]$$

$$0.945 \pm [1.96\ (0.026873) + 0.006849]$$

$$0.945 \pm [(0.052671 + 0.006849)]$$

$$0.945 \pm 0.060$$

$$\hat{P}_{3U}'' = 1.000 \qquad \hat{P}_{3L}'' = 0.885$$

[9] Cochran, William G. (1953), *Sampling Techniques;* John Wiley and Sons, New York, Second Edition, Chapter 4.

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