U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: AIRCRAFT WEIGHT AND BALANCE CONTROL

Date: 11/7/95 Initiated by: AFS-330

AC No: 120-27C
Change:

1. PURPOSE. This advisory circular (AC) provides one means, but not the only means, for obtaining approval of a weight and balance control system.

2. FOCUS. This document provides guidance to certificate holders that are required to have an approved weight and balance program by Title 14, Code of Federal Regulations (14 CFR) part 121 or choose to have an approved program under 14 CFR part 135. It should be particularly useful to current 14 CFR part 135 operators who may be affected by requirements proposed in the Commuter Operations and General Certification and Operations Requirements Notice of Proposed Rulemaking (60 FR 16230, March 29, 1995).

3. CANCELLATION. AC 120-27B, Aircraft Weight and Balance Control, dated October 25, 1990, is cancelled.

4. DISCUSSION. An operator may submit, for inclusion into its operations specifications, any method and procedure which shows that an aircraft will be properly loaded and will not exceed approved weight and balance limitations during operation. The approval of such a weight and balance control system is based on an evaluation of the program presented for a particular aircraft and of a particular operator's ability to implement that program. Whatever method is used, the program should account for all probable loading conditions which may be experienced in service and show that the loading schedule developed will ensure satisfactory aircraft loading within the approved limits during ground operations and throughout each flight.

5. CONTENTS. Weight and balance control systems encompass the following:

a. Methods for establishing, monitoring, and adjusting individual aircraft or fleet empty weight and center of gravity (CG) in conjunction with the initial and periodic reweighing of aircraft.

b. A loading schedule composed of graphs, tables, and computations and/or computer programs, etc., whereby the various weight and balance conditions of an aircraft may be established based on pertinent data for use in loading that particular aircraft in a satisfactory manner.

c. Procedures for using the loading schedule to establish that the loaded condition of the aircraft is within approved weight and CG limits.

d. A load manifest to document loading information by personnel responsible for weight and balance control and procedures for its preparation.

e. Procedures for all applicable personnel concerned with aircraft loading and operations, giving complete details regarding distribution of passengers, fuel, cargo, and necessary restrictions to passenger movement on the ground and during flight.

f. Operational performance factors such as takeoff and landing weight accountability; extension and retraction of landing gear, flaps, slats, and thrust reversers; and en route and taxi fuel burnoff, should be provided for in the program.

6. TERMS, DESCRIPTIONS, AND GENERAL STANDARDS.

a. Empty Weight. The weight of the airframe, engines, propellers, rotors, and fixed equipment. Empty weight excludes the weight of the crew and payload but includes the weight of all fixed ballast, unusable fuel, undrainable oil, and total quantity of hydraulic fluid. The empty weight of an aircraft is the maximum certificated weight less the following:

(1) All drainable fuel and oil, except system fuel and oil. System fuel and oil are the amounts required to fill both systems and the tanks, where applicable, up to the outlets to the engines. When oil is used for propeller feathering, such oil is included as system oil.

(2) Other drainable fluids, including potable water and lavatory servicing fluid, thrust augmentation, and deicing fluids.

(3) Crew and crew baggage.

(4) Passengers and cargo (revenue and nonrevenue).

(5) Removable passenger service equipment, food, magazines, etc., including service carts, dishes, trays, and beverages.

(6) Removable emergency equipment.

(7) Other equipment variable for flights.

(8) Spare parts.

b. Operating Weight. The basic operating weight established by the operator for a particular model aircraft should include the following standard items in addition to the empty weight of the aircraft or as otherwise specified by the operator.

(1) Normal oil quantity.

(2) Lavatory servicing fluid, potable water, etc.

(3) Drainable unusable fuel.

(4) Crew and crew baggage.

(5) Passenger service equipment, including service carts, food, dishes, beverages, magazines, etc.

(6) Spare parts normally carried on-board and not accounted for as cargo.

(7) Required emergency equipment for all flights.

(8) All other items of equipment considered standard by the operator.

c. A detailed listing of the items comprising empty weight and operating weight should be included in the operator's program.

d. Structural Limits. Weight and CG limits are established at the time of aircraft certification. They are specified in, or referenced by, the applicable type certificate data sheet or aircraft specification. The operator's weight and balance program should provide for maintaining these limits and should stress the point that the aircraft must be operated at or below its maximum certificated operating weight. The following are general definitions of structural weight limits normally considered in weight and balance programs.

(1) Maximum Zero Fuel Weight. The maximum zero fuel weight means the maximum permissible weight of an aircraft with no disposable fuel and oil (see FAR Sections 121.198(b) and 135.2(e)(3)).

(2) Maximum Landing Weight. This landing weight limit is the maximum weight at which the aircraft may normally be landed. Some aircraft are equipped to jettison fuel to reduce aircraft weight down to the landing limit in an emergency situation.

(3) Maximum Takeoff Weight. This is the maximum allowable, total loaded aircraft weight at the start of the takeoff run.

(4) Maximum Ramp Weight. This is the maximum allowable, total loaded aircraft weight for taxi.

7. AIRCRAFT WEIGHT ESTABLISHMENT. Aircraft weight and balance control systems normally contain provisions for determining aircraft weight in accordance with the following procedures:

a. Individual Aircraft Weight and Changes. The loading schedule may utilize the individual weight of the aircraft in computing pertinent maximum certificated weight and balance. The individual weight and CG position of each aircraft should be confirmed at the specified reweighing periods. In addition, it should be reestablished by computing or reweighing whenever the cumulative change to the operating weight exceeds plus or minus one-half of 1 percent of the maximum landing weight or the cumulative change in the CG position exceeds one-half of 1 percent of the mean aerodynamic chord (MAC). In the case of helicopters, whenever the cumulative change in the CG position exceeds one-half of 1 percent of the total CG range, the weight and balance should be reestablished.

b. Fleet Weights, Establishment, and Changes. For a fleet group of aircraft of the same model and configuration, an average operating fleet weight may be utilized if the operating weights and CG position are within the limits established herein. The fleet weight should be calculated on the following basis:

(1) An operator's empty fleet weight is usually determined by weighing aircraft according to the following table: for a fleet of 1 to 3, weigh all aircraft; for a fleet of 4 to 9, weigh 3 aircraft plus at least 50 percent of the number over 3; for fleets over 9, weigh 6 aircraft plus at least 10 percent of the number over 9.

(2) In choosing the aircraft to be weighed, the aircraft in the fleet having the highest time since last weighing should be selected. When the average empty weight and CG position have been determined for aircraft weighed and the fleet operating weight established, necessary data should be computed for aircraft not weighed but which are considered eligible under such fleet weight. If the operating weight of any aircraft weighed or the calculated operating weight of any of the remaining aircraft in the fleet varies by an amount exceeding plus or minus one-half of 1 percent of the maximum landing weight from the established operating fleet weight or the CG position varies more than plus or minus one-half of 1 percent of the length of the MAC from the fleet weight CG, the aircraft shall be omitted from that group and operated on its actual or calculated operating weight and CG position. The Federal Aviation Administration (FAA) will consider submissions by an operator that it is safe to go beyond the limits described in the preceding sentence without having to take that aircraft out of the fleet weight. If it falls within the limits of another fleet or group, it may become part of that fleet. For those cases in which the aircraft is within the operating fleet weight tolerance but the CG position varies in excess of the tolerance allowed, the FAA would accept an operator using the aircraft under the applicable operating fleet weight and with an individual CG position.

(3) Reestablishment of the operator's empty fleet weight or operating fleet weight and corresponding CG positions may be accomplished between weighing periods by calculation based on the current empty weight of the aircraft previously weighed for fleet weight purposes. Weighing for reestablishment of fleet weights is normally conducted on a 3-year basis unless changes in aircraft configuration make it necessary to reweigh and/or recalculate CG sooner.

c. Establishing Initial Weight. Prior to being placed into service, each aircraft should be weighed and the empty weight and CG location established. New aircraft are normally weighed at the factory and are eligible to be placed into operation without reweighing if the weight and balance records have been adjusted for alterations or modifications to the aircraft. Aircraft transferred from one operator, that has an approved weight and balance program, to another operator with an approved program need not be weighed prior to use by the receiving operator unless more than 36 calendar months have elapsed since last weighing. Aircraft transferred, purchased or leased from an operator without an approved weight and balance program can be placed into service without being reweighed if the last weighing was accomplished by an acceptable method and was accomplished within the last 12 calendar months.

d. Periodic Weighing - Aircraft Using Individual Weights. Aircraft operated under a loading schedule utilizing individual aircraft weights in computing the maximum certificated weight are normally weighed at intervals of 36 calendar months. An operator may, however, extend this weighing period for a particular model aircraft when pertinent records of actual routine weighing during the preceding period of operation show that weight and balance records maintained are sufficiently accurate to indicate aircraft weights and CG positions are within the cumulative limits specified in paragraph 7a. Such applications should be substantiated in each instance with at least two aircraft weighed. An increase should not be granted which would permit any aircraft to exceed 48 calendar months since the last weighing. In the case of helicopters, increases should not exceed a time which is equivalent to the aircraft overhaul period.

e. Periodic Weighing - Aircraft Using Fleet Weights. Aircraft operating under fleet weights should be weighed in accordance with procedures outlined for the establishment of fleet weights. Since each fleet is normally reestablished every 3 years and a specified number of aircraft weighed at such periods, no additional weighing is considered necessary. A rotation program should, however, be incorporated so all aircraft in the fleet will be weighed periodically.

f. Weighing Procedure. Normal precautions, consistent with good practices, should be taken such as checking to insure the aircraft has the required items of installed equipment, determining that the fluids are properly accounted for, that the aircraft is clean, and that weighing is accomplished in an enclosed building. Any acceptable scales may be used for weighing provided they are properly calibrated, zeroed, and used in accordance with the manufacturer's instructions. Each scale should be calibrated, either by the manufacturer or by a recognized facility such as a civil department of weights and measures, periodically as recommended in the manufacturer's calibration schedule. If a calibration schedule is not available from the manufacturer, the FAA would find it acceptable to use the scale to weigh the aircraft within one year after the calibration of the scale. The FAA will consider any evidence that would justify a safety determination for accepting a longer period between calibrations.

8. LOADING SCHEDULE. Loading schedules should be simple and orderly, based on sound principles, thus reducing the elements of human error. Loading schedules may be applied to individual aircraft or to a complete fleet. When an operator utilizes several types or models of aircraft, a loading schedule, which

may be index-type, tabular-type, or a computer, should be identified with the type or model of aircraft for which it is designed.

9. LOADING PROVISIONS. All seats, compartments, and other loading stations should be properly marked and the identification used should correspond with the instructions established for computing weight and balance of the aircraft. When the loading schedule provides for blocking off seats or compartments in order to remain within the CG limits, effective means should be provided to ensure that such seats or compartments are not occupied during operations specified. In such cases, instructions should be prepared for crewmembers, load agents, cargo handlers, and other personnel concerned, giving complete information regarding distribution of passengers, cargo, fuel, and other items. Information relative to maximum capacities and other pertinent limitations affecting the weight or balance of the aircraft should be included in these instructions. When it is possible by adverse distribution of passengers and/or cargo to exceed the approved CG limits of the aircraft, special instructions should be issued to the pilot in command and appropriate personnel so that the load distribution can be maintained within the approved limitation. A suitable commercially available scale should be available for use when passenger, baggage, and cargo weights are otherwise undeterminable.

10. STANDARD PASSENGER WEIGHTS. Actual weights, or when appropriate, average passenger weights are used to compute passenger loads over any segment of a certificate holder's operations. Actual weights are used for operations with aircraft having nine or less passenger seats and aircraft carrying nonstandard passenger loads as described in paragraph 11. The loading system should readily accommodate nonstandard weight groups, and the manifest should indicate whether average or actual weights, or a combination thereof, were used in the computation.

> Note: The intent of this AC is to provide methods and procedures for developing weight and balance control systems, not to address the entire spectrum of all possible weight configurations. Therefore, the operator should consider providing the FAA with a reliable survey to establish an average passenger weight for its specific operation.

a. Average Passenger Weights. The standard average passenger weights listed in the following table were developed for conventional airline passenger groups. They cannot be arbitrarily adopted for operations with passenger groups that

appreciably differ from the basis or where the mix of male and female passengers is known to be different than a 60 percent male/40 percent female operation. Special average weights or special ratios may be established for particular operations based on surveys that: (1) indicate that those weights consistently provide for loading within prescribed weight and balance limits; and (2) meet the criteria for surveys and statistical analysis outlined in Appendix 1.

STANDARD AVERAGE PASSENGER WEIGHTS

(Includes 20 pounds carry-on baggage for adult passengers)

Summer - for the period of May 1 through October 31:

Adult Passenger (60%/40% male/female mix)	180 pounds
Male	195 pounds
Female	155 pounds

Winter - for the period of November 1 through April 30:

Adult Passenger (60%/40% male/female mix)	185 pounds
Male	200 pounds
Female	160 pounds

Summer/Winter

Children	80 pounds

(Applicable between ages 2 and 12 years)

(1) The table above is for certificate holders authorized to use an approved carry-on baggage program with a specified 2-bag limit as described or referenced in paragraph A-11 of their operations specifications.

(2) For certificate holders authorized to use an approved carry-on baggage program with a specified bag limit of other than 2 bags, the standard average passenger weights will be different. These operators may contact their Certificate Holding District Office for assistance in determining the appropriate standard average passenger weights. Additional guidance for the Aviation Safety Inspector assigned this task is provided in the Airworthiness Inspector's Handbook, FAA Order 8300.10, and in the Air Transportation Operations Inspector's Handbook, FAA Order 8400.10.

(3) For those operators that do not have an approved carry-on bag program described in their operations specifications, all baggage may be either accounted for at actual weight, or in accordance with paragraphs 13b and 13c.

(4) The carry-on bags permitted by an operator's program should be included in the standard average passenger weights. Any movement of these carry-on bags from the cabin to the baggage compartment may not require any weight recalculations but the operator must ensure that CG calculations are not adversely effected.

b. Average Weight for Children. The average weight of children aged 2-12 years normally is used only when needed to accommodate available payload. Otherwise, as passengers, they are considered the same as adult passengers. The weight of children less than 2 years old has been factored into the adult weight.

11. NONSTANDARD PASSENGER WEIGHTS.

a. Actual Passenger Weights. Actual passenger weights are used for nonstandard weight groups, unless average weights have been established for those groups. This includes athletic squads and other groups which are larger or smaller than the U.S. average. When such groups form only a part of the total passenger load, actual weights, or established average weights for the nonstandard group, may be used for such exception groups and average weights used for the balance of the passenger load. In such instances, a notation should be made in the load manifest indicating the number of persons in the special group and identifying the group; i.e., football squad, etc.

b. Determination of Actual Passenger Weight. Actual passenger weights may be determined by:

(1) Scale weighing of each passenger prior to boarding the aircraft, including handbags carried on board by the passenger; or

(2) Asking each passenger his/her weight and adding to it a predetermined constant to provide for handbags and clothing. This constant may be approved for an operator on the basis of studies by the operator that consider particular routes and seasonal variations, when applicable. Personnel listing passengers on this basis should receive instruction for estimating passenger weights to reasonably confirm their accuracy.

c. Nonstandard Average Passenger Weights - Military Groups. In lieu of actual weights (preferred), the following average weights may be used for military groups, unless the passengers or their carry-on baggage appreciably differ from these standard weights:

Noncombat-Equipped Military Personnel.....195 pounds

Note: This weight includes 20 pounds of hand-carried baggage.

Combat-Equipped Military Personnel.....225 pounds

Note: This represents the standard combat soldier as would be seen on contract flights involving large movements. This includes 195 pounds as shown above, 20 pounds for additional hand-carried mobility pack, and an additional 10 pounds for hand-carried weapons.

12. CREW WEIGHT. For crewmembers, the following approved average weights may be used:

a. Male cabin attendants 180 pounds; female cabin attendants 130 pounds; or 140 pounds average for all flight attendants.

b. Male flight crewmembers 180 pounds; female flight crewmembers 130 pounds.

13. PASSENGER AND CREW BAGGAGE AND MAIL. Procedures should be provided so that all baggage, including that carried aboard by the passengers, and mail is properly accounted for. If desired by the operator, a standard crew baggage weight may be used. Mailbags and checked baggage average weights may be used as described below. Actual weights should be used for aircraft of nine or less passenger seats. Actual weights are used when it is noticeable that the checked baggage or the mailbags exceed the average weights.

a. Average Weight or Actual Weight. An operator may establish average passenger baggage weights predicated on a study of actual baggage weights for the operations or routes involved that consider seasonal and other variables; or it may use the following average weights for each piece of checked baggage.

b. Domestic Operations. Not less than an average of 25 pounds should be used.

c. International Flag and Supplemental Operations. Not less than an average of 30 pounds should be used.

Note: Use of average passenger baggage weights is not advisable in computing the weight and balance of charter flights and other special services involving the carriage of special groups.

d. Normal Operations. All mail bag manifested weight should be used in determining the weights of mailbag shipments. Should it be necessary to separate (break bulk) a manifested shipment or should manifested weights not be available, the FAA would accept the use of average individual bag weights, in circumstances where the average has been determined and substantiated by recent surveys that follow the survey and statistical models suggested in Appendix 1.

14. MOVEMENT OF PASSENGERS AND CREWMEMBERS DURING FLIGHT. The operator should show that the procedures fully account for the extreme variation in CG travel during flight caused by all or any combination of the following variables:

a. Human Movement. The operator should compute the movement of passengers and cabin attendants from their normal position in the aircraft cabin to other areas such as the galley or lavatory. If the capacity of such compartment is one, the movement of either one passenger or one cabin attendant, whichever most adversely affects the CG condition, should be considered. When the capacity of the lavatory or galley is two or more, the movement of that number of passengers or cabin attendants from positions evenly distributed throughout the aircraft may be used. Where seats are blocked off and the movement of passengers and/or cabin attendants is evenly distributed throughout, only the actual loaded section of the aircraft should be used. The extreme movements of the cabin attendants carrying out their assigned duties within the cabin should be considered. The various conditions should be combined in such a manner that the most adverse effect on the CG will be obtained and accounted for in the development of the loading schedule to assure the aircraft is loaded within the approved limits at all times during the ground and flight operations.

b. Landing Gear, Flaps, Slats and Thrust Reverser Extension and Retraction. Possible change in CG position due to the extension or retraction of landing gear, flaps, slats, thrust reverser or other translating equipment, as provided by the manufacturer, should be investigated. The results of such an investigation should be taken into consideration.

c. Fuel. The effect of the CG travel within the aircraft during flight, due to fuel used down to the required reserve fuel or to an acceptable minimum reserve fuel established by the operator, should be taken into consideration.

15. RECORD. The weight and balance system should include methods by which the operator will maintain a complete, current, and continuous record of the weight and CG of each aircraft. Such records should reflect all alterations and changes affecting either the weight or balance of the aircraft and will include a current equipment list. Operators should have the facility to update the equipment list as may be required for transfer or sublease of the aircraft. When fleet weights are used, pertinent computations should also be available in individual aircraft files.

16. WEIGHT OF FLUIDS. The weight of all fluids used in the aircraft may be established on the basis of actual weight, a standard volume conversion, or a volume conversion utilizing appropriate temperature correction factors to accurately determine the weight by computation of the quantity of fluid aboard.

17. CONTENT OF OPERATIONS SPECIFICATIONS PROCEDURES FOR AIRCRAFT WEIGHT AND BALANCE CONTROL. The operations specifications should contain the procedures (or make reference to the operator's approved weight and balance control program document) used to maintain control of weight and balance of all aircraft operated under the terms of the operating certificate which assures that the aircraft, under all operating conditions, is loaded within weight and CG limitations. This description should include a reference to the procedures used for determining weight of passengers/crew, weight of baggage, periodic aircraft weighing, type of loading devices, and identification of the aircraft concerned.

18. ADOPTION OF THIS GUIDANCE. To the extent that a certificate holder adopts the suggestions contained in this AC, the certificate holder must ensure that, when appropriate, discretionary language such as "should" and "may" is replaced with mandatory language in the operations specifications and in relevant manuals.

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APPENDIX 1. PROCEDURES FOR CONDUCTING SURVEYS AND ESTABLISHING AVERAGE WEIGHTS

1. FOCUS. The methodology presented can be used to determine standard average weights for passengers, checked baggage, carry-on baggage, mail, other normal averaged items and male/female ratios in lieu of using those standard average values suggested in the Advisory Circular (AC).

2. DETERMINATION OF STANDARD AVERAGE WEIGHT VALUES FOR PASSENGERS, BAGGAGE, AND CARGO/MAIL. It is critical that operators determine that average weights used for passengers, baggage, and cargo/mail do not adversely affect operational safety. In lieu of using the standard average weight values contained in this AC, average weights may be generated by use of a suitable statistical analysis.

a. This appendix contains an acceptable methodology for conducting a statistical analysis and establishing suitable average weights.

b. Average weight values for adults should be based on a male/female ratio of 60/40. Use of a different ratio should be based on acceptable survey data. An acceptable methodology is shown in this appendix.

c. For practical reasons passenger weight values may be rounded to the nearest whole number in pounds, and the checked bag weight may be rounded to the nearest 0.5 pounds.

3. SAMPLING METHOD. Averages should be determined by a random sample, i.e., every member of the group must have a chance of selection. The process may be determined by ticket selection with random selected numbers, flight selections, airport selections with consideration given to check point or gate/flights within those airports. The process used is dependent on the diversity of the carrier's operation. In addition, the random sample must be of a conventional airline population and should consider the type of operation, the market, and the frequency of flights on various routes. Significant variations in the weights should be taken into consideration. A survey plan should cover the weighing of at least 1500 of the items being sampled or as specified in paragraph 6a(1) of this appendix, whichever is larger.

a. Passenger Weights.

(1) Adults and Children. For purposes of this AC only, adults may be defined as persons of an age of 13 or more years. They may be further classified as male or female. No differentiation of sex shall be made for children, who are defined as persons less than age 13.

(2) Survey participants should be given the assurance that all data taken will remain confidential and that under no circumstance are they obligated to participate, although participation should be encouraged. All displays of weight figures shall be arranged so that they are only visible to authorized survey people.

(3) Surveys should be conducted inside an airport location and at a site that will not inconvenience participants or other airline passengers.

(4) Carry-on baggage should be accounted for as part of the total weight of the passenger. If desired, carry-on baggage may be weighed separately and added to the passenger weight.

(5) Survey data should include, but not be limited to: sex, adult or child categorization, survey location, weight with carry-on, weight without carry-on, date conducted, and child carried.

b. Checked Baggage.

(1) The total of checked baggage and/or mail shall be determined by either the sum total of the actual weights of all the pieces or the actual total weights of the contents of the baggage containers they are in.

(2) As an alternative, an approved standard average bag weight, specific to the individual carrier's operation, multiplied by the total count of the number of pieces, may be used. Those average weights may be determined as specified in this document.

(3) Checked baggage averages specified in the AC may be used in lieu of determining specific averages.

(4) A form should be designed to include boarding point, destination, weight of bags or any other information pertinent to the final results. Consideration should be given to size and differences in items being sampled.

c. Mail.

(1) Mail weights may be as specified in paragraph 13d of the AC.

(2) Survey data should include boarding point, destination, weight of bags or any other information pertinent to the final results. Consideration should be given to size and differences in items being sampled.

4. SCALES. The weighing scales to be used for conducting weight surveys shall have a capacity of at least 400 pounds. All weights should be displayed at a minimum interval of 1 pound and should be accurate to within ± ½ pound. The tolerance shall not exceed ± 1 pound for every 200 pounds of weight.

5. WEIGHT DATA. The recording of weight data may be done manually or automatically. All data should be retained for permanent records and as substantiation of data results.

6. EVALUATION OF DATA. The methodology described in the following subparagraph a. should be used if the survey is being conducted to determine average weights. If the survey is being conducted to determine only male/female percentages, use the methodology in subparagraph f.

a. Calculation of Passenger Average Weight.

(1) Sample size. For calculating the required sample size it is necessary to estimate the standard deviation based on standard deviations calculated for similar populations. It is common practice to compute the precision of a sample estimate for some specified degree of reliability. A reliability of 95 percent is commonly used, i.e., there is a 95 percent probability that the true value will fall within the specified confidence interval, around the estimated value. In order to keep the sample size at an economical level and to achieve an acceptable degree of accuracy, it is necessary to use this value for calculating the standard passenger average.

(2) Consequently, for the parameters of weight distribution three cases of mean and standard deviation have to be distinguished:

μ, σ = The true value of the average passenger weight and standard deviation which are unknown and which are to be estimated by weighing passenger samples.

μ^1, σ^1 = The initial estimates of the average passenger weight and standard deviation (values obtained from earlier survey samples).

$\bar{x}, s$ = The estimates for the current true values of μ and σ calculated from the sample.

b. Formulas. The following formulas will be necessary in determining the correct results:

(1) FORMULA - Calculation of the sample size:

$$n = \max\left[1500, \frac{(1.96 * \sigma^1 * 100)^2}{(e^1 * \mu^1)^2}\right]$$

where:

n = No. of passengers to be weighed (sample size),

e^1 = Allowed relative confidence range (accuracy) for the estimate of μ by $\bar{x}$,.

Note: The allowed relative confidence range specifies the accuracy to be achieved when estimating the true mean. For example, to estimate the true mean to within ± 1 percent, e^1 will be 1 in the above formula.

1.96 = Value from the Gaussian distribution for 95 percent significance level of the resulting confidence interval.

(2) FORMULA - Calculation of the arithmetic mean:

If the sample of passengers weighed is random, the arithmetic mean of the sample, $\bar{x}$, is an unbiased estimate of the true average weight μ of the population.

$$\bar{x} = \frac{\sum_{j=1}^{n} x_j}{n}$$

(3) FORMULA - Calculation of the standard deviation:

$$s = \frac{\sqrt{\sum_{j=1}^{n} (x_j - \bar{x})^2}}{\sqrt{n-1}}$$

where $(x_j - \bar{x})$ is the deviation of the individual value from the sample mean.

(4) FORMULA - Calculation of the accuracy of the sample mean:

The accuracy (confidence range) which can be ascribed to the sample mean, as an indicator of the true mean, is a function of the standard deviation of the sample (which is why this had to be estimated initially by μ' and σ'). It has to be checked after the sample has been evaluated and can be done using the following formula:

$$e = \frac{1.96 * s * 100}{\sqrt{n} * \bar{x}} \quad (\%).$$

e should not exceed:
1 percent for an adult average weight;
2 percent for an average male or female weight; or
4 percent for checked baggage and mail weights.

(5) FORMULA - Calculation of the confidence range of the sample mean:

This means that with 95 percent probability, the true average weight p lies within the interval:

$$\bar{x} \pm \frac{1.96 * s}{\sqrt{n}}$$

c. Example - Adult Average Weight. The following example may be applied to any sample item. It shows the various steps required for establishing the sample size and evaluating the sample data. It is provided primarily as a guide for statistical computations. All weight figures used throughout the example are entirely fictitious.

d. Calculation of The Required Sample Size. For calculating the required sample size, estimates of the standard (average) passenger weight and the standard deviation are needed. The initial estimates from an earlier survey may be used for this purpose. If such estimates are not available, a small representative sample of about 100 passengers should be weighed so that the required values can be calculated. However, the representative small sample cannot serve to be the total sample requirement. The following example assumes an 86-passenger sample.

$n = 86$

Step 1: Estimated average passenger weight

Step 2: Estimated standard deviation

i	x_j (lb)		$(x_j-\bar{x})$	$(x_j-\bar{x})^2$
1	176.1		+20.5	420.2
2	150.1	$\mu = \bar{x}$	5.5	30.2
3	171.1		+16.1	259.2
4	164.2		+ 8.6	73.9
5	119.2	$= \frac{\Sigma x_j}{n}$	36.4	1324.9
6	137.2		18.5	342.2
7	196.8		+41.2	1697.4
8	239.6		+84.0	7056.0
	.	$= \frac{13385.4}{86}$	.	.
	.		.	.
.	.		.	.
	.		.	.
85	139.3	$= 155.616$ lb.	-16.3	265.6
86	166.2		+10.6	112.4
Σ 86	13,385.4			168,559.3

$$\sigma^1 = \frac{\sqrt{\sum_{j=1}^{n} (x_j-\bar{x})^2}}{\sqrt{n-1}}$$

$$= \frac{\sqrt{168,559.3}}{\sqrt{85}}$$

$$= 44.531 \text{ lb.}$$

Step 3: The required number of passengers to be weighed should be such that the confidence range, e^1, does not exceed 1 percent.

$$n = \max\left[1500, \frac{(1.96 * \sigma^1 * 100))^2}{(e^1 * \mu^1)^2}\right]$$

$$= \max\left[1500, \frac{(1.96 * 44.53 * 100))^2}{(1 * 155.616)^2}\right]$$

$$= \max(1500, 3146)$$

$$\therefore n = 3146$$

Result: At least 3,146 passengers have to be weighed to achieve the required accuracy. A plan for weighing this sample size of passengers should then be worked out.

e. Determination of Passenger Average Weight.

Step 1: After having collected the required number of passenger weight values, the average passenger weight can be calculated. For the purpose of this example, it has been assumed that 3,180 passengers were weighed. The sum of the individual weights amounts to 509,673.0 pounds.

$$n = 3,180.$$

$$\Sigma x_j = 509,673.0 \text{ lbs.}$$

$$\bar{x} = \frac{509,673.0}{3180}$$

$$= 160.27 \text{ lbs.}$$

Step 2: Calculation of the standard deviation.

$$\sum (x_j - \bar{x})^2 = 3,621,079.6 \text{ (given)}$$

$$s = \frac{\sqrt{\sum_{j=1}^{n} (x_j - \bar{x})^2}}{\sqrt{n-1}}$$

$$= \frac{\sqrt{3,621,079.6}}{\sqrt{3179}}$$

$$= 33.75 \text{ lbs.}$$

Step 3: Calculation of the accuracy of the sample mean.

$$e = \frac{1.96 * s * 100}{\sqrt{n} * \bar{x}}$$

$$= \frac{1.96 * 33.75 * 100}{\sqrt{3180} * 160.27}$$

$$= 0.73\%$$

Step 4: Calculation of the confidence range of the sample mean.

$$\bar{x} \pm \frac{1.96 * s}{\sqrt{n}} =$$

$$\bar{x} \pm \frac{1.96 * 33.75}{\sqrt{3180}} =$$

$$160.27 \pm 1.2$$

The result of this calculation shows that there is a 95 percent probability of the actual mean for all passengers lying within the range of 159.07 to 161.47 pounds.

f. Calculation of Male/Female Ratio. The methodology described in this section should be used only if the purpose of the survey is to determine the percentage mix of male/females. Once determined, use the male and female weights from paragraph 10 of the AC and the percentages found in the survey to calculate the standard average adult weight.

Let:

k_m ≡ number of males in the sample

k_f ≡ number of females in the sample

$k \equiv k_m + k_f \equiv$ total sample size

$p \equiv$ percentage of males

$q \equiv$ percentage of females

$p + q \equiv 100$

$s_p = s_q \equiv$ standard deviation of percentage

$\bar{x}_a \equiv$ standard average adult weight

$\bar{x}_m \equiv$ standard average male weight from paragraph 10 of the AC

$\bar{x}_f \equiv$ standard average female weight from paragraph 10 of the AC

$s_m \equiv$ standard deviation of male weight

$s_f \equiv$ standard deviation of female weight

$s_{\bar{x}} \equiv$ standard error of average adult weight

(1) Formulas. The following formulas should be used in determining the correct results:

(i) FORMULA - Calculation of the percentage of male and female passengers and the standard deviation.

$$p = \frac{k_m}{k} * 100 \ (\%)$$

$$q = \frac{k_f}{k} * 100 \ (\%)$$

$$s_p = \frac{\sqrt{p*q}}{\sqrt{k-1}}$$

(ii) FORMULA - Calculation of 95 percent confidence range for both male and female percentages.

$$p \pm 1.96 * s_p$$

(iii) FORMULA - Calculation of standard average adult weight using male and female weights from paragraph 10 of the AC.

$$\overline{x}_a = \frac{\overline{x}_m * p}{100} + \frac{\overline{x}_f * q}{100}$$

(iv) FORMULA - Calculation of the standard deviation of the standard average adult weight.

$$s_{\overline{x}_a} = \sqrt{\left(p^2 * \frac{s_m^2}{n_m}\right) + \left(q^2 * \frac{s_f^2}{n_f}\right) + \left((\overline{x}_m - \overline{x}_f)^2 * s_p^2\right)}$$

(v) FORMULA - Calculation of the accuracy of the standard average adult weight.

$$e = \frac{1.960 * s_{\bar{x}_a}}{\bar{x}_a} * 100(\%)$$

(vi) FORMULA - Calculation of the 95 percent confidence range of the standard average adult weight.

$$\bar{x}_a \pm 1.96 * s_{\bar{x}_a}$$

(vii) FORMULA - Calculation of the sample size.

$$k = \max\left(1500, \frac{(\bar{x}_m - \bar{x}_f)^2 * p * q}{\left(e * \frac{\bar{x}_a}{1.96}\right)^2 - \left(\frac{p^2 * s_m^2}{n_m} + \frac{q^2 * s_f^2}{n_f}\right)}\right)$$

Note: Data from the surveys yielding the averages in paragraph 10a of the AC may be used to derive the sample size needed for update surveys. These values apply: $n_m = 1039$; $n_f = 640$; $\bar{x}_m = 195$; $\bar{x}_f = 155$; $p = .619$; $q = .381$; $\bar{x} = 180$; $s_m = 35.1$ and $s_f = 34.8$.

Thus, for male/female averages, $e = .02$, and

$$k = \max\left(1500, \frac{(40^2 * .619 * .381)}{\left(\frac{.02 * 180}{1.96}\right)^2 - \left[\left(\frac{(.619)^2 * (35.1)^2}{1039}\right) + \left(\frac{(.381)^2 * (34.8)^2}{640}\right)\right]}\right)$$

$$= \max(143, 1500)$$

$$\therefore k = 1500$$

This sample size can be used until the average weights in the AC are updated with later survey data.

g. Example - Male/Female Average. The following example may be applied to any sample. It shows the various steps required for evaluating the sample data. It is provided primarily as a guide for statistical computations. All weight figures used throughout the example are entirely fictitious.

Given: Sample of 1,500 passengers, 910 male and 590 female.

Step 1. Calculating the percentage of males and females.

$$P = \frac{k}{n} * 100$$

$$= \frac{910}{1500} * 100$$

$$= 60.7\%$$

$$q = 100.0 - 60.7 = 39.3\%.$$

step 2. Calculation of the standard deviation. Note that the standard deviations for the percentage of men and women are equal.

$$s_p = \frac{\sqrt{p*q}}{\sqrt{n-1}}$$

$$= \frac{\sqrt{60.7*39.3}}{\sqrt{1499}}$$

$$= 1.26\%$$

Step 3. Calculating the confidence range.

$$p_m \pm 1.96 * s_p =$$

$$60.7 \pm 1.96 * 1.26 =$$

$$60.7\% \pm 2.47\%$$

This indicates that there is a 95 percent probability that the actual percentage of men is between 58.2 percent and 63.2 percent, and that the percentage of women is between 36.8 percent and 41.8 percent, i.e., 58.2/41.8 and 63.2/36.8.

Step 4. Calculation of the standard average adult weight. Use the standard average male and female weights shown in paragraph 10a of the AC (assume summer weights for this example) and the percentages of men and women found in the survey. When doing this calculation, divide p_m and q_f by 100 to express them in decimal form.

$$\bar{x}_a = \frac{\bar{x}_m * p}{100} + \frac{\bar{x}_f * q}{100}$$

$$= \frac{195 * 60.7}{100} + \frac{155 * 39.3}{100}$$

$$= 179 \text{ lbs.}$$

Step 5. Calculation of the standard deviation of the average adult weight. When doing this calculation, divide p_m, q_f, and s_p by 100 to express them in decimal form.

$$s_{\bar{x}_a} = \sqrt{\left(p_m^2 * \frac{s_m^2}{n_m}\right) + \left(q_f^2 * \frac{s_f^2}{n_f}\right) + (\bar{x}_m - \bar{x}_f)^2 * s_p^2}$$

From the survey supporting the AC averages:

$s_m = 35.1$; $n_m = 1039$; $s_f = 34.8$; $n_f = 640$; $\overline{x_m} = 195$; and $\overline{x_f} = 155$. Thus,

$$s_{\overline{x}_a} = \sqrt{\left((.607)^2 * \frac{(35.1)^2}{1039}\right) + \left((.393)^2 * \frac{(34.8)^2}{640}\right) + 40^2 * .0126^2}$$

$$= .99$$

Step 6. Calculation of the accuracy of the standard average adult weight.

$$e = \frac{1.96 * s_{\overline{x}_a}}{\overline{x}_a} * 100$$

$$= \frac{1.96 * .99}{179} * 100$$

$$= 1.1\%$$

Step 7. Calculation of the confidence range of the standard average adult weight.

$$\overline{x}_a \pm 1.96 * s_{\overline{x}_a} =$$

$$179 \pm 1.96 * .99 =$$

$$179 \pm 1.9 \text{ } lbs.$$

This indicates that there is a 95 percent probability that the actual standard average adult weight is between 177 and 181 pounds.

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