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*Aerospace • Marine • Offshore •
Land Vehicle • Allied Industries*

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RECOMMENDED PRACTICE

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SURVEY METHODS FOR ESTABLISHMENT OF PASSENGER WEIGHTS, BAG WEIGHTS AND CARRY-ON WEIGHTS

Revision Letter -

**Prepared by
Standards & Practices Committee
Society of Allied Weight Engineers, Inc.
(SAWE, www.sawe.org)**

Change Record

All substantive changes to the current revision of this document are identified by a solid black vertical line on the left border of the text. A summary of those changes is detailed below.

The revisions shown here are only for approved revisions of the 2024 copyright year. The change record history for previous revision years should be referenced in the documents from those years, if applicable.

Rev	Date	Description	Entered by
-	January 24, 2024	• Initial Issue	Mike Byham

Foreword

Once it became clear that the Federal Aviation Administration (FAA) was taking an unorthodox approach to the administration of weight & balance programs with issuance of revision F of Advisory Circular 120-27, it also became clear that the concept of industry standards in this area was being devalued. As such, a desire to retain the ability to produce and use standards on an industry level was expressed by the aircraft weight & balance community. There are several reasons for application of standards, including establishment of a common baseline for assessment of passenger and bag weights. Availability of standards will also reduce an operators' willingness to assume risk to achieve competitive advantage. The opportunity to address this issue as an industry is being made available through a broad collaboration of subject matter experts who are selflessly donating their time to this effort.

This document has been developed through collaboration with the Society of Aircraft Performance and Operations Engineers (SAPOE). This partnership between SAWE and SAPOE offers an excellent example of leveraging institutional domain knowledge from both communities and applying in an area of need where overlap exists. This document wouldn't exist without the support of leadership from both SAWE and SAPOE.

This document is intended to aid engineers and statisticians designing and executing passenger and passenger bag weight surveys for airplane operations conducted in compliance with United States Federal Aviation Administration requirements (14CFR120/121/125/135/91K) as controlled by Operations Specifications A096/A097/A098 and A099.

This document is maintained continuously for consideration and action by the consensus body for recommended changes to any part of the document on an annual schedule from the date of its approval.

Questions regarding this document may be made by e-mail to: STANDARDS@sawe.org.

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1 Scope

This document is intended for use by aircraft manufacturers, aircraft operators and regulatory bodies with oversight of aircraft weight and balance programs. It is intended to provide effective engineering processes to be used in development of standard average passenger and bag weights to meet the current requirements of FAA Advisory Circular 120-27 Aircraft Weight & Balance Control. This document will be updated on a regular cyclical basis as required to maintain currency and relevance.

2 Purpose

The Federal Aviation Administration (FAA) provided aircraft operators with standard average passenger and bag weights from 1968 until 1990 via Advisory Circular 120-27. During this period (1968 – 1990), these weights were published by the FAA without industry input. In 1990 an aviation rulemaking advisory committee (ARAC) was formed to update the weights. In 1995 the process failed and in 2003 a weight & balance aviation rulemaking committee (ARC) was convened that utilized subject matter experts in development of a new analytical scheme to continually review and when necessary, update the standard average weights. Revision D of AC120-27 was published using this new scheme in 2004. In 2005, the advisory circular was updated to revision E. Reviews continued through 2011 using the scheme established through the ARC. In 2013 the FAA abandoned use of this scheme and since then operators have used weights as published in revision E.

The release of revision F of AC120-27 in 2019 completely eliminates FAA publication of standard average passenger and bag weights. Each operator is required to generate and maintain their own average passenger and bag weights or use actual weights.

AC120-27F does allow for use of Centers for Disease Control and Prevention National Health and Nutrition Examination Survey (CDC NHANES) data for applicability to the passenger body weight. However, the advisory circular does not provide sufficient guidance for analysis of the NHANES data. It is left to the individual operator to analyze and produce standard average weights based on the data, potentially leading to multiple interpretations of the same data.

Each operator is also responsible for planning and conducting weight surveys and analyzing results. A mechanism for sharing of data or compiling results for establishment of industry standards is not provided within the advisory circular.

The purpose of this document is to provide best practices for analyzing CDC NHANES data, and establishment of survey and analysis standards to meet current AC120-27F expectations.

3 Associated Documents

This recommended practice is intended to be used in conjunction with the following publications. When the following specifications are superseded by an approved revision, the revision is used.

- Federal Aviation Administration, *Advisory Circular 120-27F Aircraft Weight and Balance Control*, May 2019.
- Federal Aviation Administration, *FAA Operations Specification A096/A097/A098/A099*
- Federal Aviation Administration, *FAA Policy Notice 8900.551*
- Society of Aircraft Performance and Operations Engineers (SAPOE) paper titled *NHANES Use for Standard Average Body Weight* – William Yingling and Charles Ostick (available to SAPOE members)

- Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey (NHANES): www.cdc.gov/nchs/nhanes
- Society of Aircraft Performance and Operations Engineers (SAPOE) paper titled *Cabin Linear Load* – George Nunez, Kristine Henning, et. al. (available to SAPOE members)

4 Definitions, Abbreviations, Acronyms

4.1 Definition of Terms

Definitions of the common terms used in this recommended practice are defined as follows.

Aircraft Performance Monitoring (APM)
Analysis of performance trends of aircraft using manufacturer-provided software or through use of flight data recorder data.

Actual Bag Weight
The weight of an individual bag as weighed on a scale.

Basic Empty Weight (BEW)
The weight comprised of the airframe structure, engines, furnishings, system fuel, and oil identified as undrainable. The BEW may be adjusted for variations in standard items. Items included in the buildup of BEW is defined by the operator.

Carry-On Bag
A bag that the operator allows the passenger to carry on board. It should be of a size and shape that will allow it to be stowed under the passenger seat or in a storage compartment. The operator establishes the exact dimensional limits based on the particular aircraft stowage limits.

Carry-on Allowance
The average weight of the passenger carry-on bag + personal item.

Center of Gravity (CG)
The point at which the aircraft would balance were it possible to suspend it at that point.

Certificated Weight and Center of Gravity (CG) Limits
Weight and CG limits are established at the time of aircraft certification. They are specified in the applicable Airplane Flight Manual
(AFM), Rotorcraft Flight Manual (RFM), or Weight and Balance Manual (WBM) as provided by the manufacturer.

Checked Bags
Checked bags are those bags (or other items such as a box) brought by a passenger and placed in the cargo compartment of the aircraft. For the purpose of establishing average weights, checked bags may be grouped into several subsets – each with their own specific average weight. These may include regular standard checked, heavy checked, gate checked and planeside loaded (valet).

Crew Carry-On Baggage
Pilot and flight attendant carry-on allowance stowed in the cabin and considered in the standard operating items.

Crewmember
Pilot or Flight Crew as defined in Advisory Circular 120-27F.

Curtailment
Creating an operational loading envelope that is more restrictive than the manufacturer's CG envelope, to ensure the aircraft will be operated within limits during all phases of flight. Curtailment typically accounts for, but is not limited to, in-flight movement, gear and flap movement, cargo variation, fuel density, fuel burn-off, and seating variation.

Empty Operating Weight (EOW) / Basic Operating Weight (BOW) / Operating Empty Weight (OEW)
The empty weight of the aircraft plus the weight of the required crew, their baggage, and other standard items such as meals and potable water.

Flight Kit
The kit contains aeronautical charts, procedural manuals, computers, and any other items that each flight crew member carries on board the aircraft and into the cockpit.

Heavy Bags
Heavy bags are considered any bag that weighs more than 50 pounds but less than 100 pounds. An operator should use actual weights for bags that weigh 100 pounds or more.

Large Cabin Aircraft
Aircraft originally certificated with a maximum seating capacity of 71 or more passenger seats.

Large Carry-on Bag
A bag that is carried on board with the passenger that will not fit under the seat.

Loading Envelope
Weight and CG envelope used in a loading schedule. Loading the aircraft within the loading envelope will maintain the aircraft weight and CG throughout the flight within the limits established by the type certificate (TC) or Supplemental Type Certificate (STC) that applies to the aircraft.

Loading Schedule
Method for calculating and documenting aircraft Weight and Balance (W&B) prior to taxiing, to ensure the aircraft will remain within all required W&B limitations throughout the flight.

Mean
The simple mathematical average of a set of two or more numbers.

Medium Cabin Aircraft
Aircraft originally certificated with a maximum seating capacity between 70 and 30 passenger seats, inclusive.

Medium Carry-On Bag
A bag or item carried on board that will fit under the passenger seat but is larger than a purse or small backpack. This category includes small computer rollaboards, larger backpacks and overnight bags. This definition applies to operators that use more than 2 categories of carry-on bag/personal items.

Operational Items (Standard Operating Items – SOI)
Personnel, equipment, and supplies necessary for a particular operation but not included in BEW. These items may vary for a particular aircraft and may include, but are not limited to, the following:
1. Crewmembers and bags;
2. Manuals and navigation equipment;
3. Passenger service equipment, including pillows, blankets, and magazines;
4. Removable service equipment for cabin, galley, and bar;
5. Food and beverage, including liquor;
6. Usable fluids, other than those in useful load;
7. Required emergency equipment for all flights;
8. Life rafts, life vests, and emergency transmitters;
9. Potable water;
10. Drainable unusable fuel;
11. Spare parts normally carried aboard and not accounted for as cargo; and
12. All other equipment considered standard by the operator.

Operations Specifications (OpSpecs)
The FAA issues operations specifications to certificated operators (air carriers, repair stations, etc.). It is a legal document that outlines what they are authorized to do.

Passenger Body Weight
The weight of the passenger without clothing (in the case of CDC NHANES data).

Passenger Weight
Passenger weight is the actual weight or the approved average weight of the passenger.

1. An adult is defined as an individual 13 years or older.
2. A child is defined as an individual aged 2 to less than 13 years of age.
3. Infants are children who have not yet reached their second birthday and are considered part of the adult standard average passenger weight.

Personal Item
Items the operator may allow a passenger to carry on board, in addition to a carry-on bag. Typically, an operator may allow one personal item such as a purse, briefcase, computer and case, camera and case, diaper bag, or an item of similar size. Other items, such as coats, umbrellas, reading material, food for immediate consumption, child restraint systems, and service animals, are allowed to be carried on the aircraft and are not counted against the personal item allowance.

Planeside Loaded Bag (gate-checked)
Any bag or item that is checked at the gate (in the boarding area) and subsequently placed in the aircraft cargo compartment or cargo bin. This bag is typically carried to the passenger's final destination and returned through baggage claim (past security).

Planeside Loaded Bag (valet)
Any bag or item that is placed at the door or steps of an aircraft and subsequently placed in the aircraft cargo compartment or cargo bin. This bag is typically returned to the passenger at the destination inside the airport secure area.

Principal Inspector (PI)
The FAA inspector in charge of overseeing operations of an operator at the Certificate Management Office (CMO) or Flight Standards District Office (FSDO). Each operator in the US is assigned a PI.

Rollaboard (or roll-aboard)
A wheeled suitcase that is carry-on luggage. "Rollaboard" is a trademark of the Travelpro company, the original commercial suitcase of this type. The form roll-aboard avoids confusion with the trademark.

Roster Weight
The listing of a group of passengers specifically by name and weight. Operations for specific groups of passengers whose collective weight deviate from the standard average weight should use actual weights. These actual weights may be provided in the form of a roster.

Small Cabin Aircraft
Aircraft originally certificated with a maximum seating capacity between 5 and 29 passenger seats, inclusive.

Small Carry-on Bag
A bag or item other than personal item that is carried on board by the passenger. This bag or item must be able to fit under the passenger seat. A small carry-on bag may be considered a personal item if the operator is surveying for two categories: carry-on bags and personal items.

Standard Deviation
A measure of the amount of variation or dispersion of a set of values about the mean. Most commonly represented in mathematical texts and equations by the lower-case Greek letter sigma σ, for the population standard deviation.

Takeoff Weight
The ramp weight reduced by the amount of fuel required to taxi from the gate to the end of the departure runway. This represents the weight of the aircraft at the beginning of the takeoff run.

Tolerable Error
Maximum acceptable error in a population of data.

Usable Fluids
Engine fluids, APU oil, Hydraulic systems fluids, Potable water and Toilet fluids. Typically, these fluids are considered in the BEW or as operational items.

Useful Load
Difference between takeoff weight and BEW. It includes payload, usable fuel, and other usable fluids not included as operational items.

4.2 Abbreviations and Acronyms

Abbreviations and acronyms used in this recommended practice are listed in Table 4-1.

Table 4-1. Abbreviations and Acronyms

Symbol	Description
AC	Advisory Circular
APM	Aircraft Performance Monitoring
BEW	Basic Empty Weight
CDC	Center for Disease Control and Prevention
CG	Center of Gravity
F/A	Flight Attendants
FAA	Federal Aviation Administration
NHANES	National Health and Nutrition Examination Survey
OEW / OWE	Operating Empty Weight
PI	FAA Principal Inspector
SAPOE	Society of Aircraft Performance and Operations Engineers
W&B	Weight and Balance

5 Designing the Survey

5.1 Methods for Determination of Passenger Body Weight

There are three methods allowed in FAA AC120-27F for establishment of passenger weights:

1. Use of CDC NHANES data analysis revised for aircraft operations with clothing allowance as described in section 5.1.1.
2. Use of a passenger weight survey.
3. Use of actual or asked passenger weights.

Each of these options will be discussed within this section.

5.1.1 Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey (NHANES)

The CDC NHANES data are collected and released in 2-year cycles. NHANES Analytic Guidelines recommend merging consecutive cycles into 4-year cycles to improve accuracy. Recommended practice of analysis of the NHANES data is described by the SAPOE paper in Appendix A, NHANES USE FOR STANDARD AVERAGE BODY WEIGHTS – William Yingling and Charles Ostick.

NHANES provides survey data by participant age and gender. The SAPOE analysis provides the adult and child averages to suit the weight & balance requirements specified in AC120-27 (where a child is defined as 2 to less than 13 years of age). This SAPOE data analysis process is consistent with the process developed using CDC guidance during the FAA Weight & Balance Aviation Rulemaking Committee in 2004.

When using the CDC NHANES data, the operator should use SAPOE-established methods for (1) application of Male/Female weights consideration, (2) child weights, and (3) inclusion of infant weight.

5.1.2 Passenger Weight Survey

5.1.2.1 Passenger Weight Survey for Network

In lieu of using the NHANES analysis for body weight, an operator may conduct a survey for the purpose of establishing standard average passenger weight. To establish a standard average passenger weight using a survey, the operator must submit and gain approval for a survey plan from the FAA. The operator must weigh the passenger and all of their cabin baggage separately. The results of this survey should be (1) average clothed passenger body weight, (2) average carry-on weight allowance as determined per section 5.2.2 and if applicable, (3) average planeside-loaded bag weight as determined in section 5.2.3.

Passenger weights obtained through use of the survey are applicable to the season in which the survey is conducted. Adjustments to resultant standard average passenger weight for seasonality

may be applied if appropriate. Surveys should be conducted with considerations as provided in section 6.

5.1.2.2 Passenger Weight Survey for Specific Route

An operator may conduct a survey for a particular route if the operator believes that the average weights on that route may differ from those in the rest of its operations. To establish a standard average passenger weight for a city pair, the operator must submit and gain approval for a survey plan from the FAA. The operator must weigh the passenger and all of their cabin baggage separately (see sections 5.2.2 and 5.2.3). The operator should determine if this survey is directional (e.g., Miami to Port Au Prince may not be appropriate for Port Au Prince to Miami) and must be accomplished for each city pair separately. One method that may be used to determine whether weights are unique by direction is through use of Aircraft Performance Monitoring (APM). For example, APM results showing a higher bias in one direction versus another would indicate the need to sample both cities. The bias may be evaluated for weight differences and the need would be established once a sufficient tolerance level is exceeded. The tolerance levels are addressed in Appendix B. Surveys should be conducted with considerations as provided in Section 6.

5.1.2.3 Passenger Weight Survey Privacy

AC120-27F recommends that an operator that chooses to weigh passengers as part of a survey should take care to protect the privacy of passengers. The scale readout should remain hidden from public view and care should be taken to ensure that any passenger weight data collected remains confidential.

5.1.3 Using Actual Passenger Weights

If actual passenger weights are to be used in operations, there are three primary methods for collecting these weights.

1. Weigh passengers prior to boarding using a certified, calibrated scale
    a. Passengers must be weighed separately (i.e., without bags)
    b. Clothing weight adjustments do not need to be made when weighing passengers
2. Use roster weights provided by customers
    a. If it can be ascertained that roster weights supplied are accurate and include clothing, no additional adjustments are necessary
    b. If the accuracy of the roster weights cannot be verified, then ten (10) pounds should be added to each passenger weight for deviation from weights listed plus clothing
    c. Carry-on bag weights must be considered separately as addressed in section 5.2
3. Ask passengers what they weigh
    a. Add ten (10) pounds to the responses to accommodate deviation from actual plus clothing

Carry-on bag weights must be considered separately as addressed in section 5.2. There are several elements that need to be considered when designing a survey, especially with reference to meeting FAA requirements and expectations.

5.1.4 Passenger Clothing Weight Allowance

There are many considerations to be made when assigning an additional weight for clothing.

1. AC120-27F provides guidance to add five (5) pounds in summer and ten (10) pounds in winter.
2. Clothing weights may be static or vary by season depending on route being served with consideration applied to network connections. For instance – point-to-point travel between two city pairs with little climate variation by season does not require a variation in clothing allowance. However, if the service includes travelers from different points of origin with climate differences, then this should be taken into consideration with seasonal variability.
3. If variation by season is not applied and a seasonal variability exists, then the operator should use the single clothing weight allowance for the winter season.

5.2 Methods for Determination of Passenger Bag Weights

Baggage may be grouped by the operator in multiple ways. Any survey conducted to establish an average weight for such a grouping must include a representative sample of each type of bag included in the grouping.

Some examples of such groupings are shown below:

- Bags checked at the ticket counter or at the aircraft could be considered standard bags and/or heavy bags.
- Bags checked planeside or at the gate (planeside loaded as gate-checked or valet bags).
- Bags carried on board the aircraft (carry-on bags & personal items).

5.2.1 Checked Bag Weight

Checked bag weights may be assessed using the following methods:

1. Actual
    a. Use of actual checked bag weights requires weighing the bag at check-in, at the gate or planeside before the bag is loaded.
    b. Each bag should be considered separately (i.e., “grouping” should not be considered).
2. Surveyed for average (categorized as either “standard” or “heavy”)
    a. Standard bags are identified in the Advisory Circular 120-27F as any bag checked in the cargo hold as fifty (50) pounds or less.
    b. Heavy bags are classified as any bag weighing greater than fifty (50) pounds but less than one hundred (100) pounds.
    c. Any bag weighing one hundred (100) pounds or more shall not be included in the survey.
    d. Survey for average checked bags must be conducted in accordance with section 6.

Note: Per the Advisory Circular 120-27F, bags weighing 100 pounds or greater must be accounted for using actual weights.

5.2.2 Carry-on Bag and Personal Item Weight

An operator may plan to file their OpSpecs with carry-on bag weights or file for use of a "No Carry-On Bag Program."

If an operator is planning to file for use of a "No Carry-On Bag Program" as detailed in Advisory Circular 120-27F and use surveyed weights, the survey plan should only consider the personal items being carried on board.

Carry-on bag weights may be assessed using the following methods:

1. Actual
    a. Bags may be weighed prior to passenger boarding using a certified, calibrated scale.
    b. The resulting carry-on bag average weight must be added to the average passenger body weight.
2. Average of surveyed bag weights independent of passenger (categorize and weigh bag type and count category carried aboard)
    a. Categorize – define bag category as a group (example with 3 categories below)
        i. Large Carry-on Bag – typical large roll-aboard luggage that will not fit under the seat
        ii. Medium Carry-on Bag – smaller roll-aboard luggage or large backpacks/rucksacks, etc. that will fit under the seat
        iii. Small Carry-on Bag / Personal Item – small computer backpacks, satchels, purses, etc. that will fit under the seat

       Categorize – define bag category as a group (example with 2 categories below)
        i. Carry-on Bag – carry-on baggage that will not fit under the seat.
        ii. Personal Item – carry-on baggage that will fit under the seat.
    b. Weigh – weigh bags within categorized groups.
    c. Count – survey by count the number of each category carried by passengers and determine averages.
    d. Establish an average carry-on bag weight for each category using the surveyed weights.
    e. Carry-on bag average allowance is calculated by applying the ratio of each category of bag carried on board by the carry-on bag weight of each category of bag as calculated in subsection d. (example show in in Figure 6-3).
    f. Survey for average carry-on bag weight must be conducted in accordance with section 6.

5.2.3 Plane-side Loaded Bag Weight (gate or valet)

Plane-side loaded baggage (gate or valet) is that which an operator chooses to differentiate from standard or heavy checked baggage. Operators who choose not to have a plane-side loaded baggage category should ensure that the entire population defined as standard or heavy checked baggage is being represented in the survey.

If the operator intends to consider the plane-side loaded bags as standard checked bags, then refer to section 5.2.1 for survey guidance.

If the operator intends to consider the plane-side loaded bags as their own category, then use one of the following methods to determine their weight:

1. Actual Weights
    a. Bags may be weighed prior to the passenger boarding using a certified, calibrated scale.
    b. Each bag should be considered separately (i.e., "grouping" should not be considered).
2. Survey-derived Average Bag Weights
    a. Survey must be conducted in accordance with section 6.
    b. Survey should be conducted in a manner and location such that plane-side loaded bags are the only bags included in the survey.
    c. It may be acceptable to the administrator or PI to use a categorized carry-on bag weight in place of a survey if the plane-side loaded bags can be shown to be similar to the specified category of carry-on bags. For example, if only rollaboard bags are loaded planeside then the carry-on bag survey subset of rollaboards could be used in place of an additional plane-side bags survey.

5.3 Methods for Determination of Crewmember and Flight Attendant Weights

An operator may choose to use one of the following for crewmember weights: CDC/NHANES weights for flight attendants (F/As) and Civil Aerospace Medical Institute (CAMI) first- and second-class medical certificate weights to establish their standard crewmember weights. The operator also has the option to conduct a survey or use actual weights to establish average crewmember weights appropriate for its operation.

5.3.1 NHANES

Operators may use the weights directly from the NHANES database analyzed for the crewmember and flight attendant demographics for Male / Female ratios. It is also recommended to adjust for age as well.

5.3.2 CAMI

Operators may use CAMI data for development of their crewmember weights. These data may be adjusted to suit the individual operator's demographics and issued medical class.

5.3.3 Survey

Operators may survey their crewmember and flight attendant populations for weight using the same methods as defined in the passenger weight survey section 5.1.2.

5.3.4 Actual

Operators may use actual weights for crewmembers and flight attendants using the same processes as defined in the passenger weight section 5.1.3.

5.3.5 Crewmember and Flight Attendant Clothing Weight Allowance

Operators may utilize various methods to estimate the uniform weights for crewmember and flight attendants including (but not limited to):

1. Weighing representative sample uniform kits;
2. Using vendor-supplied weights;
3. Using a conservative estimate (not to be less than the winter passenger clothing weight of +10 pounds as stated in the AC120-27F).

5.4 Methods for Determination of Crewmember and Flight Attendant Bag Weights

Operators may determine crew bag weights by either surveying or using actual weights.

5.4.1 Survey

Operators may survey for crewmember and flight attendant bag weights using the same methods as defined in the passenger bag weight section 5.2.2.

5.4.2 Actual

Operators may use actual weights for pilots and flight attendant bags using the same processes as defined in the passenger bag weight section 5.2.2.

6 Planning the survey

The survey plan should describe the dates, times, and locations the survey will take place. The FAA specifies that in developing a survey plan, the operator should consider its type of operation, hours of operation, markets served, passenger mix, and frequency of flights on particular routes. The AC120-27F also states that an operator should avoid conducting surveys on holidays or other dates that are not representative of "normal operations."

Normal operations are the airline's typical scheduled operations excluding holidays, large sporting events, etc. Customer baggage behavior during this time is representative of an airline's typical customer demographics. An airline should review large changes in normal scheduled operations with regard to customers demographics and/or baggage behavior. These changes may include new service levels, change in charging policies, and customer demographics/behavior due to geography. Please refer to Appendix B.3 for discussion on the life cycle of standard average weights.

These considerations should be made with respect to the impact of ensuring the data collected adequately represent the population being targeted. For instance, an operator may wish to include a seasonal or other temporal aspect of defining standard average weights to include holidays or special periods of operation.

6.1 Plan Approval

The FAA requests an operator to submit its survey plan at least 30 calendar-days before the operator expects to begin the survey. Before the survey begins, the operator's principal inspector (PI) should review the plan and work with the operator to develop a mutually acceptable plan. During the survey, the PI or his/her appointee will oversee the survey process to validate the execution of the survey plan. AC120-27F states that once the survey is complete, the PI will review the survey results and issue the appropriate OpSpecs.

Note: It is recommended that operators ensure their survey plan is acceptable to FAA Flight Standards AFS-200 prior to proceeding with the survey.

6.2 Survey location

The FAA requires that surveys be conducted in locations that will result in a sampling of weights that accurately represent the targeted population. For instance, if the survey is being conducted to establish standard average weights applied to all operations, then the survey should be conducted at locations that represent the carrier's operations. AC120-27F specifies that 15% of the carrier's operations is targeted. To ensure connecting passengers have an equal chance of being selected in the survey, an operator should conduct its survey within the secure area of the airport (unless it's a checked bag survey). An operator should also consider selection of locations within the airport that provide a sample that is random and representative of its operations.

An operator may also wish to consider blending results from several airport locations to increase representation of its operations. For instance, conducting surveys at a hub in the US Northeast region and at a hub in the US Southwest region will lead to more representative results than sampling at a single hub even if the number of operations at the single hub reach the 15% threshold.

If the number of locations required to reach the 15% threshold is unreasonable due to a high number of point-to-point or on-demand operations, then the operator may submit a plan that is representative of their operations.

6.3 Sample Size

There are two methods for achieving acceptable data validity per AC120-27F.

1. Tolerable Error – AC120-27F provides a formula to derive the absolute minimum sample size to achieve a 95 percent confidence level. This formula is provided as figure 6-1.
2. Discrete Number of Samples – The FAA also provides a table in AC120-27F for those operators that do not wish to use math or for use in cases where obtaining minimum statistically-significant sample size is difficult. It provides minimum sample size as a sole requirement for survey validity. The table is shown here as table 6.2.

Figure 6-1. Calculation Of Tolerable Error For 95% Confidence Interval

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

Where:

s is the standard deviation

n is the number of points surveyed

x_j is the individual survey weights

$\bar{x}$ is the sample average

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

Where:

e Is the tolerable error percentage

Table 6-2. Minimum Sample Size

Survey Subject	Minimum Sample Size	Tolerable Error
Adult (standard adult/male/female)	2,700	1%
Child	1,400	2%
Checked bags	1,400	2%
Heavy bag	1,400	2%
Planeside loaded bags	1,400	2%
Personal items and carry-on bags	1,400	2%
Personal items only (for operators with a no carry-on bag program)	1,400	2%

Operators conducting surveys only need to reach either (1) a tolerable error of 2% for 95% confidence or (2) minimum sample size to demonstrate validity of survey results per AC120-27F. The goal of any weight survey is to establish a reliable ***average weight*** that may be used for weight & balance planning. The underlying statistical analysis is required to support the use of that average weight.

If the number of samples required to reach the minimum required for survey data validity is unreasonable, then the operator may submit a plan that is representative of their demographics.

6.4 Techniques to Ensure Randomness

The FAA provides the following methods to ensure randomness in the collection of the survey data.

An operator conducting a survey must employ random sampling techniques. Random sampling means that every member of a group has an equal chance of being selected for inclusion in the sample. If an operator conducts a survey that does not employ random sampling, the characteristics of the selected sample may not be indicative of the larger group as a whole. Because of this, any conclusions drawn from such a survey may not be valid.

6.4.1 Random Sampling Methods

The following are two examples of random sampling methods that an operator may find appropriate for the type of survey conducted.

Simple Random Selection
An operator should assign a sequential number to each item in a group (such as passengers waiting on a line or bag claim tickets). Then the operator randomly selects numbers and includes the item corresponding with the number in the sample. The operator repeats this process until it has obtained the minimum sample size.

Systematic Random Selection
An operator should randomly select an item in sequence to begin the process of obtaining samples. The operator should then use a predetermined, systematic process to select the remaining samples following the first sample. For example, an operator selects the third person in line to participate in the survey. The operator then selects every fifth person after that to participate in the survey. The operator continues selecting items to include in the sample until it has obtained the minimum sample size.

6.4.2 Exhaustive Survey Method

Operators may choose to collect weights of all data samples available for each flight in lieu of determining a random method.

Note: Regardless of the sampling method used, an operator has the option of surveying each passenger and bag aboard the aircraft and should give a passenger the right to decline to participate in any passenger or bag weight survey. If a passenger declines to participate, the operator should select the next passenger based on the operator's random selection method rather than select the next passenger in a line. If a passenger declines to participate, an operator should not attempt to estimate data for inclusion in the survey.

6.5 Sample Selection and Identification

Consideration should be made to ensure the carry-on bag data collected are representative of the bags that are actually carried on board the aircraft. For example, an operator should have a method for ensuring the carry-on bags being sampled will fit in the overhead bins or in under-seat stowage as applicable.

For checked bags, consideration must be given to non-luggage/non-standard bags. The FAA describes a non-luggage/non-standard bag as any bag that does not meet the normal criteria for a standard bag as described in the operator's weight and balance program. Standard bags may be defined as a bag that meets the criteria established by the operator for regular treatment.

The checked bag weights should be categorized as per the operator's policies and application through their weight and balance programs. For example, if an operator uses a separate checked bag weight category for golf clubs, they should weigh golf clubs and categorize as such separately. If the operator does not accommodate golf clubs separately in their weight & balance program, then the golf club bag should be treated as standard regular or standard heavy during the survey depending on its weight.

Operators using their standard average survey bag weights should consider all bags not stored in the cabin as checked bags. However, operators might develop procedures for identifying bags that would typically be considered carry-on and/or planeside loaded baggage and incorporate such average weights into their approved carry-on and Weight & Balance control program. When an operator develops such procedures, the operator may use the standard average weights they determined by survey, specified for carry-on, planeside loaded, and checked baggage.

When weighing carry-on bags, AC120-27F states that operators should account for all items taken aboard the aircraft. The operator should be clear in identifying how each category of bag (e.g., carry-on bag, personal item, etc.) will be accommodated in the survey.

For operators utilizing a carry-on-bag program, the items carried on board by passengers must either be a carry-on bag or a personal item. If the survey is performed using two categories of carry-ons, and a passenger boards with two items, the larger of these items should be considered a carry-on bag and the smaller should be considered a personal item.

For the purposes of the survey, operators may prefer to define the carry-on bags into more than two categories. The results should be resolved into two categories for inclusion on Op Spec A097/A098/A099 as carry-on bag weight and personal item weight. For example – when using three different categories of carry-on bags, it is permissible to allocate half of the medium-sized

bag average weight to the carry-on bag average weight and half to the personal item average weight.

Figure 6-3 shows an example using three bag categories – large carry-on, medium carry-on and small carry-on/personal items.

Categorize – define bag type as a group

- Large Carry-on Bag – typical large roll-aboard luggage
- Medium Carry-on Bag – smaller roll-aboard luggage or large backpacks/rucksacks, etc.
- Small Carry-on Bag / Personal Item – small computer backpacks, satchels, purses, etc.

Weigh – weigh bags within categorized groups and define averages

- 1,992 Large Carry-on average weight = 21.3 LBS
- 2,996 Medium Carry-on average weight = 13.0 LBS
- 1,192 Small Carry-on/Personal Item average weight = 5.5 LBS

Count – survey by count the number of each type carried by passengers and determine averages

- 6,008 Large Carry-on bags for 13,499 passengers = 0.445 / pax x 21.3 = 9.5 LBS
- 10,289 Medium Carry-on bags for 13,499 passengers = 0.762 / pax x 13.0 = 9.9 LBS
- 3,003 Small Carry-on/Personal Items for 13,499 passengers = 0.222 / pax = 1.2 LBS

Weights for Op Spec A097/A098/A099

Carry-on Bag Average Weight = 21.3 / 2 + 13.0 / 2 = 17.2 (round to 17 LBS)

Personal Item Average Weight = 13.0 / 2 + 5.5 / 2 = 9.6 (round to 10 LBS)

Weights Ratioed for Operations

Total Carry-on Average Weight = 9.5 + 9.9 + 1.2 = 20.6 LBS (round to 21 LBS)

Figure 6-3. Sample Carry-on Bag Average Weight Calculation

7 Executing the Survey

The FAA expects that once a survey begins, the operator should continue the survey until complete, even if the initial survey data indicates that the average weights are lighter or heavier than expected.

7.1 Data to be Included in the Calculation of Standard Average

Consideration should be made on impact of typically accepted statistical methods on rigorousness of results. For example, use of eliminating 2 standard deviation data from CDC NHANES passenger weights survey is different than eliminating 2 standard deviation excursions from checked bag survey data. Where eliminating the statistical tails of the CDC NHANES data may lead to a more accurate representation of the actual flying public, there is no such benefit for elimination of any of the data collected in a checked bag survey.

7.2 Data Rounding

Significant digits will be established using common mathematical conventions. When rounding for whole numbers, a conservative engineering rounding technique will be used where the tenth-place digit will be rounded up for a reading of "5 tenths" or greater and rounded down for a reading of "4 tenths" or less. For example, 34.4 will be rounded to 34 and 34.5 will be rounded to 35.

7.3 Calculation of Average Weights

Simple calculation of averages is shown in Figure 7-1.

Figure 7-1. Calculation of Average Weight

$$Average\ Weight = \sum weights \div \eta\ items\ weighed$$

NOTE: For non-luggage/non-standard bags, operators may use any appropriate combination of actual weights and average weights based on survey results. The FAA also states that operators should establish a method to calculate the effect on CG of a non-luggage/non-standard bag that may occupy more than one compartment on the aircraft. One recommended method is to include an appropriate curtailment in the design and build of the CG envelope.

7.4 Submitting the Survey Data

A complete package for submission of the survey weights to Flight Standards AFS-220 for analysis and approval should include the following elements:

1. Overview and purpose
2. Standard average passenger weight development
3. Center for Disease Control and Prevention National Health and Nutrition Examination Survey (if applicable)
4. Detailed adjustments for:
    a. Male to female ratio adjustment (if applicable)
    b. Infant weight adjustment

   c. Clothing weight allowance
5. Statement of average clothed passenger weight (for use in Op Spec A097/A098/A099)
6. Carry-on bag weight development (i.e., how will it be calculated with the data)
7. Survey timeline
8. Survey results:
   a. Passenger body weight (if applicable)
   b. Carry-on bag weights and counts
   c. Personal item weights and counts
   d. Valet bag weights and counts (if applicable)
   e. Crew body weights (if applicable)
   f. Crew bag weights and counts
9. Calibration certificate and validation of scales (if applicable)
10. File containing all data

8 References

[1] Federal Aviation Administration, *Advisory Circular 120-27F Aircraft Weight and Balance Control*, May 2019.

[2] Federal Aviation Administration, *Order 8900.1 Flight Standards Information Management System (FSIMS) Change 709*, June 2020

[3] William Yingling and Charles Ostick, *NHANES Use for Standard Average Body Weight*, Society of Aircraft Performance and Operations Engineers (as revised)

[4] George Nunez, Kristine Henning, et. al., *Cabin Linear Load,* Society of Aircraft Performance and Operations Engineers (as revised)

[5] Federal Aviation Administration, *Advisory Circular 20-161 Aircraft Onboard Weight and Balance Systems*, April 2008

[6] Federal Aviation Administration, Civil Aerospace Medical, *Aerospace Medicine Technical Reports*

Appendix A NHANES Use for Standard Average Body Weight (SAPOE Publication)

For use in aircraft weight and balance, a method to determine standard average weights for body mass of passengers and crew is defined. The method uses data from the US Centers for Disease Control (CDC) National Health and Nutrition Examination Survey (NHANES) in a manner consistent with guidance from the Federal Aviation Administration (FAA), especially Advisory Circular (AC) 120-27 “Aircraft Weight and Balance Control”. Justification for aspects of the definition is discussed. Results are applicable to Operation Specifications (OpSpecs) approval using survey-derived average weight values.

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Appendix B Application of Weights

B.1 Submission of OpSpecs

The templates for OpSpecs A096 through A099 have been developed to provide an understanding of weights applied to the operation. This is also how they have traditionally been used. However, the application of these OpSpecs has been reinterpreted by FAA Flight Standards. The OpSpecs are now being used to provide documentation of approved survey results for weights of adult passengers, children, crew members and carry-on bags. The carry-on bag weights are provided as individual bag weights in two categories – carry-on bag and personal item. The weights listed on the OpSpecs typically do not translate directly to operations on a literal basis.

Choosing which OpSpecs to use depends on two factors – cabin size and whether the cabin can accommodate full-size carry-on bags. The following recommendations are taken directly from the guidance provided to the FAA inspectors in the 8900.1 CHG 709.

Aircraft cabin size is defined as follows:

An aircraft originally certificated with…	**Is considered…**
71 or more passenger seats	Large-Cabin Aircraft
30 to 70 passenger seats	Medium-Cabin Aircraft
5 to 29 passenger seats	Small-Cabin Aircraft

NOTE: An aircraft originally certificated with fewer than 5 seats uses actual passenger and baggage weights.

OpSpecs A096 allows for use of actual weights regardless of aircraft cabin size. OpSpecs A096 also allows for use of establishment of standard average weights for flight crew and flight attendants and their bags, if so desired.

B.1.1 OpSpecs A099 Large-Cabin Aircraft

1) Operators of large-cabin aircraft may use the following methods to determine passenger weights:

- Standard average weights based on CDC/NHANES-provided data,
- Survey-derived average weights, or
- Actual weights.

2) Operators of large-cabin aircraft may use the following methods to determine baggage weights:

- Survey-derived average weights, or
- Actual weights.

3) Operators of these aircraft should have procedures along with controls for identifying situations that would require the use of nonstandard weight groups or actual weights.

B.1.2 OpSpecs A098 Medium-Cabin Aircraft

Operators should evaluate medium-cabin aircraft to determine whether to treat the aircraft as a large- or small-cabin aircraft. For a medium-cabin aircraft to be treated as a large-cabin aircraft, the aircraft must meet either of the following:

1) Loadability Criteria.

- The center of gravity (CG) of the operational empty weight (OEW) is within the manufacturer's loading envelope.
- The CG of the zero-fuel weight is within the manufacturer's loading envelope when loaded with a full load of passengers and all cargo compartments are filled with a density of 10 pounds per cubic foot.

2) Loading Schedule Criteria.

- The operator must use a loading schedule based upon zones.
- The aircraft cabin may have no more than four rows of seats per zone with not less than four zones.

B.1.3 OpSpecs A097 Small-Cabin Aircraft

Operators of small cabin aircraft may request authorization to use the following methods when calculating the aircraft W&B:

a) Actual weights of passengers and baggage, or
b) CDC/NHANES standard average and survey-derived average passenger weights, and
c) Survey-derived average baggage weights based on an FAA-accepted survey if:
    - The aircraft was certified under part 23 normal category, part 25, or part 29 (or is able to prove the aircraft has equivalent part 23 normal category or part 29 performance data); and
    - The operator curtails the CG envelope according to a method acceptable to the FAA.

B.2 Weights Applied to Operations

There is confusion in the application of the OpSpecs weights to the operation. The new intent of the OpSpecs is to document the survey results. Application of these survey results has been made subject to approval at the local level (individual POI). This is an interpretation provided by Flight Standards (AFS-200).

Most weight & balance systems do not separate carry-on bags, personal items, and passenger body weights. These systems typically use a single weight for each passenger that incorporates each element of weight build-up. As such, the operators should clearly document in their approved weight & balance manuals how the system average weights are computed from the survey weights approved in their OpSpecs.

For example:

Operator A's Op Spec provides a breakdown of passenger carry-on baggage into two buckets – a carry-on bag allowance and a personal item allowance. The FAA Operations Research Analyst (ORA) reviewed operator A's data and approved a break-out of 17 LBS for carry-on and 9 LBS for personal item (based on the ORA allocation of average weights as follows – Personal Item = ½ Small + ½ Medium, Carry-On Weight = ½ Large + ½ Medium). Sample survey data are shown in Table B-1 below.

Table B-1. Carry-on Bag Weight Survey Data

	Carry-on Bags Weight			
	Small	Medium	Large	Totals
Count	1192	2996	1992	6180
Average	5.5	13.0	21.3	14.2
Std Deviation	3.2	4.6	5.9	7.4
Error for 95% Confidence	3.3%	1.3%	1.2%	1.3%
Confidence at 2% Error	75.8%	99.8%	99.9%	99.7%

When operator A blends the ratio of the carry-on bags and weights to actual passengers as boarding their flights, an average allowance of 20.6 LBS was produced. Survey count data with ratios applied to surveyed weights is shown in Table B-2 below.

Table B-2. Carry-on Bag Count Survey Data

	Carry-on Bags Count			
	Flights	Pax		
	115	13499		
	Small	Medium	Large	
Count	3003	10289	6008	
Per Pax	22.2%	76.2%	44.5%	Total
Weighted Average	1.2	9.9	9.5	20.6

Therefore, 21 LBS will be used as the carry-on/personal item weight additive in application to operator A's system passenger weights.

B.3 Lifecycle of Standard Average Weights

Per AC120-27, in order for survey-derived average weights to be effective, an operator's W&B control program should include a safety risk assessment and safety management principles from Safety Management Systems (SMS). The operator's periodic assessment should include a method to review its underlying program that considers any survey of passengers or bags. The FAA recommends operators accomplish such a review every 36 calendar-months, as well as when the operator obtains data or information suggesting a possible change affecting the program. Examples of such changes include the operator changing carry-on bag or checked bag policies,

charges for carry-on or checked baggage, and route changes where seasonal variances may not be appropriate. If such an assessment determines that any assumption or behavior has changed, the operator should consider providing notice of a change within 90 calendar days of completing the safety risk assessment and submit mitigating action(s), if necessary. Mitigating actions might include making changes to the program, revalidating survey data, or updating the OpSpecs.

It is important to note that the 36 calendar-month clock starts with the completion of the last survey, not with Op Spec A097/A098/A099 approval. The expiration date will be documented in each table on a per item basis in the Op Spec.

Although the guidance requires a 36-month assessment, operators may incorporate a plan that may use continuous monitoring. There are several methods that may be applied as discussed in this section.

B.3.1 Safety Risk Management Reporting

The first level of monitoring incorporates data from operators' safety programs, such as Aviation Safety Action Program (ASAP), Event Review Committees (ERC) and Flight Operations Quality Assurance (FOQA). Identification of trends that would implicate average passenger or bag weights as an issue should be investigated. These trends would include reports of possible elevator authority problems (rapid, slow, and un-commanded rotations at takeoff), systemic flight over- or under-burns, and aircraft performance not meeting expectations (e.g., poor climb performance).

B.3.2 Use of Aircraft Performance Monitoring Data

Aircraft Performance Monitoring (APM) data may be assessed to identify specific routes or areas of operations where the standard average weights may not be appropriate. This is possible since APM assesses actual fuel burn performance using the assumed aircraft weight (built up using standard average passenger and bag weights). The APM program compares the actual performance versus the manufacturer-provided predicted data (commonly called "book") to derive a bias. This bias is typically presented as a percentage of actual fuel burn rate over book. The APM data may be normalized to an average bias for each tail. Then the difference from this average for each city pair that each aircraft flies may be determined. If a specific city pair is found to be consistently different from average across all individual aircraft, then it can be assumed that this difference is likely driven by the weight assumptions being used.

This phenomenon is observed when transitioning from summer to winter weights and vice versa. Since the transition of weight assumptions is made on a single date and customers' behavior with respect to clothing does not change appreciably from one day to the next, the APM bias can be seen as changing due to the difference in assumed weight only.

The estimated tolerance for seeing this in the data is near the 5 LBS per passenger difference provided by the current summer to winter clothing transition. Another limitation to using these data are the requirement for large datasets with multiple different aircraft to create meaningful results.

B.3.3 Use of Gate Cameras

Some operators have installed cameras on the jetways. The images produced by the cameras may be ingested by software using AI technologies to count people and bags as they are boarded.

It may be possible to set up a continuous monitoring system that would count bags by type and produce an automated report that would find significant systemic deviation from standard average assumptions – whether it is system-wide, or by area of ops, city pair or even aircraft type. Use of this technology could mitigate or even negate the need to survey for carry-on bags in the future.

B.3.4 Use of On-Board Weight and Balance Systems

If a rigorous and approved weight and balance measuring system is approved and installed on an operator's aircraft, then this system may be used as a continuous method for validating average assumed weights, negating the need to resurvey. More information on certification and operational use of these systems in FAA Advisory Circular 20-161.

B.3.5 Corrective Actions

Corrective actions may include an adjustment to the standard average or identification of a need for a separate application of average weight (e.g., by city pair)

B.4 Impact to Operations

It is expected that implementation of revised passenger and baggage weights will have an impact on a carrier's operations. There may be an impact to flights that are at or near performance limits.

However, if the operator is using APM to track fuel flow and updating aircraft bias accordingly, there should be a net zero effect. This means that comparing flights before and after changes to assumed weights will find that the actual fuel loaded and burned should be similar.
Operators should also evaluate and ensure all floor loading limits are considered appropriately. More information on how to comply with floor loading limits may be found in a SAPOE document titled "Cabin Linear Load." This document may be found on the SAPOE website as referenced in Section 8 of this document.

Appendix C Cabin Linear Load (SAPOE Publication)

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Appendix D Equipment Recommendations

D.1 Scales

D.1.1 Calibration

Advisory Circular 120-27F requires that all scales are certified and calibrated by the manufacturer or a certified laboratory, such as a civil department of weights and measures. The operator may also calibrate the scale under an approved calibration program. The operator should also ensure that the scale is calibrated within the manufacturer's recommended time, or time periods, as specified in the operator's approved calibration program.

D.1.2 Capability

Scales should be capable of the weights targeted for surveying. For example, if only weighing carry-on bags, then using scales that are capable of weighing up to 150 pounds should be sufficient. If a scale is being used for weighing passengers, then scales should be capable of weighing an expected maximum passenger weight.

D.1.3 Readability

Readability to significant digit and precision should be stated. For instance, a scale may have readability to 0.1 pounds and a stated precision of +/- 3%. When collecting survey data, values should be recorded to the same precision as the accuracy of the collection method, including considerations such as any calibration tolerance or estimation on analog scales. For example, when using scales calibrated with readability to the nearest pound, values should be recorded to the pound.

D.1.4 Tare Weights

If a scale is being used that requires the application of a tare weight, the tare weight should be established and removed from the scale reading during the collection of weights.

D.1.5 Repeatability

Each time a scale is moved and at the start of each survey session, a calibration weight should be used to ensure the accuracy of the scale and to remove bias. It is recommended to record results in a log including specific scale tag, serial number, or other means of identification.