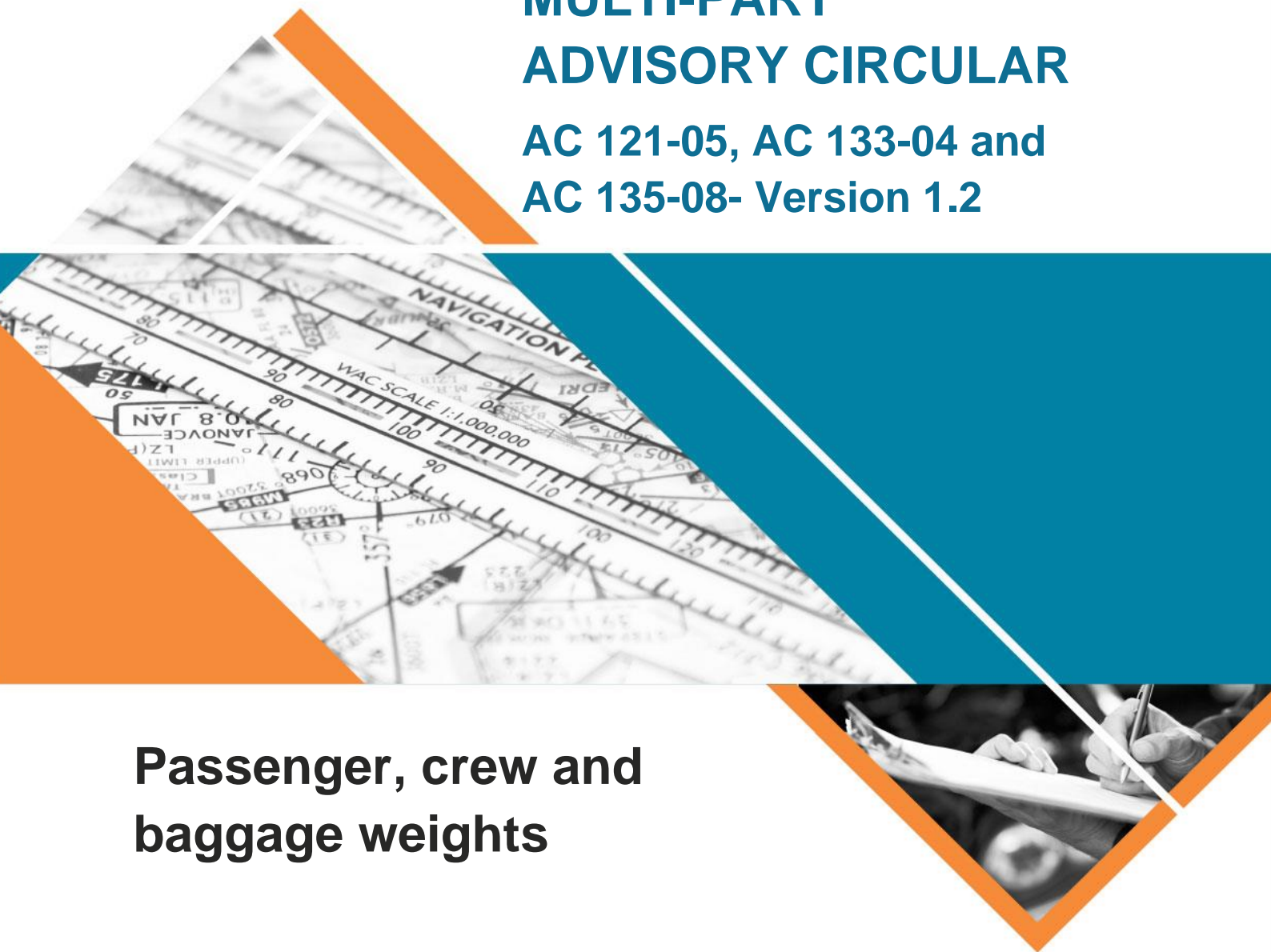Australian Government
Civil Aviation Safety Authority

MULTI-PART ADVISORY CIRCULAR

AC 121-05, AC 133-04 and AC 135-08- Version 1.2

Passenger, crew and baggage weights

Date   March 2025

File ref   D25/77541

Advisory circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory circulars should always be read in conjunction with the relevant regulations.

Audience

This advisory circular (AC) applies to:

- Australian operators of aircraft regulated by the flight operation regulations in Parts 121,133 and 135 of the *Civil Aviation Safety Regulation 1998* (CASR).

Purpose

This AC describes acceptable methods for calculating passenger, crew and checked baggage weights for an Australian air transport operator. For an operator who chooses not to use actual passenger weights or standard weights, additional options to use exposition-derived weights or passenger-declared weights are also included.

Acknowledgement

Material in this AC has been drawn from New Zealand AC 119-4 Revision 1 (Passenger, Crew and Baggage Weights) with permission from the Civil Aviation Authority of New Zealand.

For further information

For further information or to provide feedback on this AC, visit CASA's <u>contact us</u> page.

Unless specified otherwise, all subregulations, regulations, Divisions, Subparts and Parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998* (CASR).

Status

This version of the AC is approved by the National Manager, Flight Standards Branch.

> **Note:** Changes made in the current version are annotated with change bars.

Version	Date	Details
v1.2	March 2025	Minor updates to exemption instrument identifiers.
v1.1	November 2022	Minor update to include references to the Part 121 exemption relating to exposition-derived weights.
v1.0	June 2021	Initial AC.

Contents

1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
AC	advisory circular
AHM	Airport Handling Manual
AMC/GM	acceptable means of compliance and guidance material
ASAO	approved self-administering organisation
CAR	*Civil Aviation Regulations 1988*
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
EASA	European Union Aviation Safety Agency
FAA	Federal Aviation Administration
IATA	International Air Transport Association
MOS	Manual of Standards
NAA	national aviation authority
PIC	pilot-in-command
SMS	safety management system

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below. Where definitions from the civil aviation legislation have been reproduced for ease of reference, these are identified by 'grey shading'. Should there be a discrepancy between a definition given in this AMC and GM and the civil aviation legislation, the definition in the legislation prevails.

Term	Definition
actual weight	The weight of passengers, crew or baggage determined using appropriately calibrated weighing scales.
carry-on baggage	baggage or personal effects taken into, or to be taken into, the cabin of an aircraft, for carriage on the aircraft, by: (a) a person (including a crew member of the aircraft) travelling on the aircraft; or (b) a member of the personnel of the operator of the aircraft on behalf of a person mentioned in paragraph (a).
checked baggage	baggage or personal effects checked in by a passenger with an operator, or with another person providing a check-in service for an operator, as baggage or personal effects intended for carriage on the aircraft on which the passenger is travelling.

Term	Definition
estimated passenger weight	The weight of a passenger, estimated by suitably trained staff of an operator using a method described in the operator's exposition.
exposition	(a) for an Australian air transport operator, means: (i) the set of documents approved by CASA under regulation 119.075 in relation to the operator; and (ii) if the set of documents is changed under regulation 119.085, 119.095 or 119.105, or in accordance with the process mentioned in regulation 119.100—the set of documents as changed; or (b) for an ASAO, means: (i) the set of documents approved by CASA under regulation 149.080 in relation to the ASAO; or (ii) if the set of documents is changed under regulation 149.115 or 149.120, or in accordance with the process mentioned in paragraph 149.340 (i)—the set of documents as changed; or (c) for a balloon transport operator: (i) the set of documents approved by CASA under regulation 131.085; or (ii) if the set of documents is changed under regulation 131.095, 131.105 or 131.115—the set of documents as changed.
exposition-derived weight	Passenger, crew and carry-on baggage weight derived using a weighing survey program as described in an operator's exposition.
maximum take-off weight	For an aircraft, means the maximum take-off weight for the aircraft permitted by: (a) for an aircraft that is type certificated—the flight manual for the aircraft; or (b) for an aircraft that is not type certificated: (i) if a document, published by the manufacturer of the aircraft setting out the operating limitations for the aircraft, specifies a weight—that document; or (ii) if the certificate of airworthiness for the aircraft specifies a different weight to the weight specified in the document mentioned in subparagraph (i)—the certificate of airworthiness for the aircraft; or (c) if no weight is specified in the document mentioned in subparagraph (i) or in the certificate of airworthiness for the aircraft and the aircraft is a Part 103 aircraft in relation to which a statement of acceptance for the aircraft has been issued by a Part 103 ASAO in accordance with regulation 103.030—the weight specified in the statement of acceptance.
operator	For an aircraft, means: (a) if the operation of the aircraft is authorised by an AOC, a Part 141 certificate or an aerial work certificate—the holder of the AOC or certificate; or (b) otherwise—the person, organisation or enterprise engaged in aircraft operations involving the aircraft.
passenger-declared weight	Weight provided by a passenger on request.
passenger load weight	Combined weight of passengers on board an aircraft for a flight.
standard weight	Passenger, crew and carry-on baggage weights prescribed in the

Term	Definition
	Part 121 Manual of Standards.
weighing survey program	A program that applies a statistical analysis method that incorporates appropriate considerations to derive representative weights for passengers, crew and carry-on baggage.

1.3   References

Legislation

Legislation is available on the Federal Register of Legislation website https://www.legislation.gov.au/

Document	Title
Part 21 of CASR	Certification and airworthiness requirements for aircraft and parts
Part 121 of CASR	Australian air transport operations—larger aeroplanes
Part 121 MOS	Part 121 (Australian air transport operations—larger aeroplanes) Manual of Standards 2020
Part 133 of CASR	Australian air transport operations—rotorcraft
Part 133 MOS	Part 133 (Australian air transport operations—rotorcraft) Manual of Standards 2020
Part 135 of CASR	Australian air transport operations—smaller aeroplanes
Part 135 MOS	Part 135 (Australian air transport operations—smaller aeroplanes) Manual of Standards 2020
CASA EX69/24	Part 121 and Part 91 of CASR – Supplementary Exemptions and Directions Instrument 2024
	Note: At the time of publishing v1.2 of this AC, only section 11 of CASA EX69/24 was relevant to this AC.

Advisory material

CASA's advisory materials are available at https://www.casa.gov.au/resources-and-education/publications-and-resources/guidance-material.

Document	Title
Multi-Part AC 121-08, 133-08 and 135-06	Carry-on baggage
Multi-Part AC 121-09, 133-06 and 135-10	Carriage of special categories of passenger
Multi-Part AC 121-10, 133-07 and 135-11	Passengers seated in emergency exit row seats
Part 121 AMC/GM	Acceptable means of compliance and guidance material - Australian air transport operations—larger aeroplanes
Part 133 AMC/GM	Acceptable means of compliance and guidance material - Australian air transport operations—rotorcraft

Document	Title
Part 135 AMC/GM	Acceptable means of compliance and guidance material - Australian air transport operations—smaller aeroplanes

Other material

International Civil Aviation Organization (ICAO) documents are available for purchase from http://store1.icao.int/.

Document	Title
CAA NZ AC 119-4	Passenger, Crew and Baggage Weights
EASA R20090095.doc 5 May 2009	Survey on standard weights of passengers and luggage - Final report
IATA AHM 531	Procedure for establishing standard weights for passengers and baggage

2   Introduction

2.1   General

2.1.1   This AC describes the available options and methods for determining weights for passengers, crew and baggage relevant to each CASR Part concerned with the conduct of air transport operations (Parts 121, 133 and 135 of CASR). Subpart J of each of these CASR Parts requires an operator to include, in their exposition, procedures for working out the weight of crew members and passengers (including their carry-on baggage). While Part 138 of CASR does not specifically state this requirement in the regulations, aerial work operators may adopt any of the methods described in this AC to achieve compliance with Subpart 138.J of CASR.

2.1.2   Methods using actual weights, passenger-declared weights, estimated weights, standard weights, and exposition-derived weights (from a weighing survey program) are provided to assist organisations to select the most appropriate procedure for their operation.

2.1.3   This document has been structured to assist operators identify sections relevant to their operations and to describe considerations appropriate for each type of operation and weight calculation method.

2.2   Transitioning from pre-2 December 2021 rules

2.2.1   It is likely that operators complying with regulatory requirements prior to the introduction of the new FOR will remain compliant with the regulations related to this AC. This is because many operators may choose to continue to use actual weights, or the standard weights, that were previously described in CAAP 235-1(1) and are now incorporated into the Part 121 MOS.

2.2.2   Organisations that continue to use their existing procedures based on actual or standard weight calculations, and who consider an exposition-derived weight not relevant to their operations, may not need to amend their current procedures other than to describe the process in their exposition and ensure regulatory references are updated.

3 Weight calculation considerations

3.1.1 No provision of the regulations described in this AC should be interpreted as diminishing the responsibility of the operator and pilot-in-command (PIC) to comply with the manufacturer's limitations regarding aircraft weight and balance.

3.1 Part 121 operations

3.1.1 Subregulation 121.440(2) of CASR requires the operator and PIC to use <u>one</u> of the following methods to work out the total weight of crew members, passengers and carry-on baggage for all persons onboard:

- The actual weights using appropriately calibrated weighing scales (refer to section 4.1 of this AC).
- In accordance with a method for which the operator holds an approval under regulation 121.010 of CASR (refer to section 3.1.2 of this AC).
- Standard weights as prescribed in Chapter 10 of the Part 121 MOS (refer to section 4.4 of this AC).

3.1.2 An exemption is in force permitting operators to use exposition-derived weights from a weighing survey program without having to obtain a specific approval from CASA[1]. Guidance on exposition-derived weights and weighing survey programs is at section 4.6 of this AC.

> **Note**: CASA intends to amend regulation 121.440 of CASR to incorporate the effect of this exemption at the next available regulation amendment opportunity.

3.2 Part 133 and 135 operations

3.2.1 In accordance with weight and balance limits regulations 133.350 and 135.360 of CASR require an operator to have procedures in their exposition describing the loading of a rotorcraft or aeroplane for flight.

3.2.2 The following methods may be used to determine the total weight of passengers:

- actual weights using appropriately calibrated weighing scales (refer to section 4.1 of this AC)
- passenger-declared weights (refer to section 4.2 of this AC)
- estimated passenger weights (refer to section 4.3 of this AC)
- exposition-derived weights from a weighing survey program, described in an operator's exposition and approved by CASA as an acceptable means of compliance (refer to section 4.6 of this AC).

3.2.3 An operator may elect to specify an alternative method in their exposition. If the exposition is being reviewed by CASA as part of an initial AOC application process, the acceptability of that alternative method would be determined as part of that process. If the operator already holds an AOC and decides to change the method in their exposition, and assuming the change was determined by the operator to **not be** a

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[1] Refer to section 11 of CASA EX69/24.

significant change, the exposition remains subject to CASA review as part of the surveillance process.

3.3 Crew member weights

3.3.1 Crew member weights may be calculated using the same methods as used for passenger weight calculations.

3.4 Considerations for passengers who clearly exceed the standard or exposition-derived weight

3.4.1 Procedures should be considered to account for passengers whose actual weight is clearly greater than the passenger weight initially used in a passenger load calculation. In doing so, operators may also need to review legislation relevant to passenger privacy and human rights (not considered in this AC).

3.5 Manuals, logs and records

3.5.1 Prior to commencement of the flight information relating to the weight and balance of an aircraft should be made available to the PIC so they can assess the safety of the proposed flight. It is the responsibility of the operator to make this information available, and the PIC's responsibility to use the information to satisfy themselves that each flight can be conducted safely within operational limits.

3.5.2 The MOS of each relevant Part describes the requirements for applicable weight and balance documents for that Part.

3.6 Last minute changes and offloading

3.6.1 Regardless of the weight calculation method used, an operator's exposition must specify procedures for determining when a last-minute change to a load may be made, including procedures to ensure that a last-minute change to a load does not cause the aircraft to exceed its weight and balance limits.

3.6.2 Procedures for offloading passengers or cargo to ensure limits are not exceeded must also be described in the operator's exposition.

3.7 Self-check-in terminals

3.7.1 When used in conjunction with standard or exposition-derived weights, self-check-in terminals do not remove the onus from an operator to ensure that some form of assessment takes place. When self-check-in terminals are used for smaller Part 121 aircraft a correction process should be specified, designed to address the variation in weight caused by significant groupings of passengers travelling together whose weight falls outside the standard defined categories. One means of achieving this may be to have boarding staff trained to make this type of determination and provide them with an appropriate procedure to ensure this information is considered by the operator prior to dispatch.

4   Weight calculation methods

4.1   Actual weights

4.1.1   The use of actual weights is the most accurate method of maximising payload capacity. Appropriately calibrated weighing scales should be used. Actual weighing is more commonly used by Part 133 and 135 operators. This is, in part, due to the smaller number of passengers being carried, which makes this option less disruptive than it is for Part 121 operators.

4.2   Passenger-declared weights

4.2.1   Part 133 and 135 operators may find using passenger-declared weights more effective than developing a weighing survey program—required to determine exposition-derived weights—themselves. Passenger-declared weights can provide an efficient means of establishing a total passenger load weight.

4.2.2   Operators should have procedures to identify when passenger-declared weights are not appropriate, such as when operating close to limitations. Under these circumstances, the use of actual weights may be required to ensure limitations are not exceeded.

4.2.3   Passenger-declared weights have inherent inaccuracies as passengers may not know their actual weight, especially when fully dressed. An adjustment allowance should be added to any passenger-declared weight, as a factor or a fixed additional amount.

4.3   Estimated passenger weights

4.3.1   Operators may choose to define a method that uses estimated passenger weights which includes any carry-on baggage. Caution should be exercised in circumstances where the aircraft load is approaching maximum capacity, as this method is likely to be inappropriate.

4.3.2   An estimated weight could be defined as the sum of the mean weight plus one standard deviation from the mean. For example, if the weighing survey program found a mean weight of 85 kg and a standard deviation of 16 kg, then an acceptable estimated weight is 101 g.

4.3.3   The air operator's estimated weight procedures should address issues such as:

– appropriate safety margins to ensure weight and balance limitations are not exceeded
– who will assess individual passenger weights prior to boarding and how that assessment will be effectively carried out
– what training and on-going checking of staff will be in place
– how amendments to the weight and balance documents will be made.

4.3.4   Procedures should include guidance on when to use a more representative weight for passengers, and details of any such weight adjustments to be included in the weight and balance documents.

4.3.5   Individual passenger weights can only be assessed in general terms. It is unlikely that an operator will be able to estimate an individual passenger's weight any more accurately than to the nearest 20 kg.

4.3.6   However, it is expected that an operator will be able to identify significant differences in weight, for example differentiate between an 85 kg passenger and a 120 kg passenger. Procedures for this estimate and how to record those occurrences for safety monitoring purposes, should be included in the operator's exposition.

4.3.7   When a more representative weight is applied to an individual passenger, it is unlikely to equate to their actual weight. However, it will mitigate any cumulative error that is possible when a significant number of heavier passengers travel on the same flight.

4.4   Standard passenger weights

4.4.1   Standard passenger weights are prescribed in Chapter 10 of the Part 121 MOS and provide a common standard of accuracy for aircraft seating capacities ranging from seven to more than 500. They have been broken down by gender and age groups to improve accuracy, as a single standard weight would have to account for the significant variability between groups.

> **Note:** Standard weights published in the Part 121 MOS do not include carry-on baggage. An allowance of 7 kg has been established in that MOS and is in addition to the published weights.

4.4.2   More often standardised passenger weights are used in larger aircraft operations where weighing individual passengers would impose significant delays. Standardised weights assume that the individual weights of all passengers will equate to a mean passenger weight consistent with the standard weight used.

4.4.3   When using a standard passenger weight, the discrepancy between the actual passenger load weight and the calculated passenger load weight may cause aircraft weight limitations to be exceeded. This discrepancy becomes more significant as the size of the aircraft, and therefore the seating capacity, reduces. In such circumstances, the operator should describe procedures that identify the risk of exceeding limits and ensure an effective response is implemented.

4.4.4   For example, if a standard weight of 77 kg per passenger was used in a 12-seat aircraft instead of actual weights, the statistical probability of overloading the aircraft is as high as 25%. This probability diminishes to 0.0014% if the same standard weight of 77 kg is used on a 400-seat aircraft. For this reason, no provision is made for the use of standard weights in aircraft with less than seven seats. Load calculations for these aircraft should be made using actual weights by weighing all occupants and baggage.

4.4.5   As part of an ongoing process to have an up-to-date standard passenger weight, regular reviews of passenger weights should be conducted, such as described by the International Air Transport Association's (IATA) guidelines for conducting passenger weight surveys[2].

4.4.6   In consultation with operators, CASA may conduct research or surveys of passenger weights when there is sufficient evidence to indicate a significant variation has occurred.

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[2] IATA Airport Handling Manual AHM 531- Procedure for Establishing Standard Weights for Passengers and Baggage.

This may necessitate an amendment by CASA to the standard weights prescribed by the Part 121 MOS, and operators should monitor and incorporate these changes into their exposition via an effective change management process.

4.5 Determination of revised standard weight values for passengers for smaller aircraft

4.5.1 To ensure that the use of revised standard passenger weight values does not adversely affect operational safety, a statistical analysis should be carried out. On aircraft with a maximum operational passenger seat configuration of six to nine (inclusive), an increment of 8 kg should be added to the standard passenger weight to obtain the revised standard passenger weight values.

4.5.2 Revised adult standard weight values should be based on a male to female ratio of 70:30 for all flights. This conservative approach acknowledges that the standard weight of males is greater than females and is aligned with the recommendation of EASA[3]. If an operator wishes to use a different ratio on specific routes or flights then the exposition should describe the supporting data, showing that the alternative male to female ratio is conservative and covers at least 84% of the actual male to female ratios on a sample of at least 100 representative flights.

4.6 Exposition-derived weights

4.6.1 An exposition-derived weight is obtained from the results of a weighing survey program. An operator can develop a procedure to calculate passenger, crew and baggage weights relevant to their operations and include it in their exposition. The foundation of this method, the weighing survey program, relies on statistical analysis of a large sample of passengers, and is therefore more relevant to larger Part 121 operations.

4.6.2 For Part 121 operators, an exemption has been issued to support the use of exposition-derived weights without needing to obtain a specific approval from CASA[4].

Note: CASA intends to amend regulation 121.440 of CASR to incorporate the effect of this exemption at the next available regulation amendment opportunity.

4.6.3 Operators that cannot obtain a large enough sample to be able to complete an adequate survey from their own data may use data from:

– a CASA or other NAA-sponsored passenger survey

or

– an Australian population weight survey.

4.6.4 Alternatively, operators within similar operational environments may wish to pool their resources and conduct a combined survey of their passengers to establish a more reliable survey result that each operator could use for their exposition-derived passenger weight.

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[3] Survey on standard weights of passengers and luggage - Final report - R20090095.doc 5 May 2009
[4] Refer to section 11 of CASA EX69/24.

4.6.5   Operators must be satisfied that the survey data is representative of the operator's passenger composition before the results of the survey can be used as the operator's exposition-derived weight.

Weighing survey program

4.6.6   An exposition-derived weight may be determined from a survey that is carried out by, or on behalf of, the operator that follows:

–   the methodology as described in Appendix A.3 of this AC
     or
–   other appropriate statistical procedures accepted by CASA.

4.6.7   The exposition-derived weight will normally be a mean weight established by a passenger survey. To mitigate the risk of cumulative errors the survey program should provide assurance that the resulting mean weight has been obtained using a reliable methodology. Such errors can be caused by the application of an unrepresentative weight to passengers whose real weight is clearly greater than that weight.

4.6.8   Each passenger weight survey should be used to generate a weight distribution curve that identifies the spread of passengers across specific weight bands. A bell distribution curve of survey results indicating the number of samples obtained for each specific weight band is useful to show the mean weight relative to the survey population, as well as the extent of extreme sample results.

4.6.9   The process for continually monitoring survey results, and the conditions under which a survey-based decision is made, should also be described in the operator's exposition.

Exposition-derived weight review period

4.6.10   Exposition-derived weights should be reviewed on a defined basis to confirm they remain representative of the passengers being carried. For example, after a period of five years, or when random sampling indicates a deviation of 2% from the weight used. Operators should verify that their exposition-derived weights reflect changes in the type of passengers being carried.

4.6.11   Operators must ensure that changes to exposition-derived weights resulting from any internal review are incorporated in the exposition via an effective change management process.

5 Baggage weights

5.1 Distinction between baggage and cargo

5.1.1 The regulations make a distinction between baggage and cargo. Baggage is the personal property of passengers or crew members which will be carried on an aircraft by agreement with the operator.

5.1.2 Baggage can be further distinguished into carry-on baggage and checked baggage. Checked baggage should be weighed (except for baggage that is subject to a standard baggage weight under Part 121 of CASR). Carry-on baggage should be accounted for by increasing the standard or exposition-derived weights to allow for the extra weight of the baggage.

5.2 Checked baggage weights

5.2.1 For operations originating within Australia, facilities are available to preserve the current practice of weighing all checked baggage using scales. However, some international flights inbound to Australia may not have facilities available to them to allow the weighing of checked baggage prior to departure. Part 121 operators may use a standard checked baggage weight for international flights originating outside of Australia when actual baggage weights cannot be obtained.

5.2.2 Additionally, some carriers may have received trans-ship baggage which has a standardised baggage weight allocated to a group of bags. For these flights, a statistically generated per piece baggage weight described in an operator's exposition may be acceptable. Part 121 operators wishing to use standard baggage weights in such circumstances should describe procedures that ensure the use of standard baggage weights for a particular route will not result in weight and balance limitations of the aircraft being exceeded.

Appendix A

Exposition-derived weights

A.1 Weighing survey program

The use of data obtained through means other than those described in this Appendix may be submitted in support of an exposition-derived weight. However, CASA will need to be satisfied that the data has been obtained by means it considers satisfactory before the exposition-derived weights are accepted.

The IATA Airport Handling Manual AHM 531 - Procedure for Establishing Standard Weights for Passengers and Baggage is an acceptable means of compliance for establishing an exposition-derived weight.

An operator electing to use an exposition-derived weight must adopt a weighing survey program that applies an effective statistical analysis method. The revised standard passenger weight values may only be used in circumstances consistent with those under which the survey was conducted, and for no more than a defined period—usually a maximum of five years. An operator's responsibility to regularly monitor passenger weight values is consistent with the safety management system concept of continual monitoring and improvement.

Potential passenger anxiety about being weighed should be considered and methods employed to protect privacy. To encourage passengers to co-operate in the survey, it is recommended that they be suitably informed about the reasons for being weighed. Assurance should be given that the passenger and their weight will remain totally anonymous in terms of the data recorded.

The choice of scales used during a survey can have an influence on the final survey result. Scale displays should be able to be arranged in such a way that they are only visible to authorised persons. The design of the weighing machine should be such that it does not cause any inconvenience to passengers and airline operations and t that it does conform to relevant occupational safety and health regulations. Scales used in the survey will require current calibration certificates that meet trade and commerce scale standards.

A.2 Weighing survey program considerations

Operators should review the following considerations when designing their procedures for a weighing survey program:

- **Weight sampling method:** the mean weight of passengers and their carry-on baggage must be determined by weighing randomly selected samples (i.e., all passengers must be equally likely to be chosen for weighing).
- **Sample composition:** evidence is required to demonstrate that the sampled passengers are representative of the typical passenger cohort when considering:
  - the type of operation
  - the frequency of flights on various routes
  - gender ratios (refer paragraph 4.5.2 of this AC).
  - inbound and outbound flights
  - time of day and time of year (season, school holidays)
  - seating capacity of the aircraft.
- **Sample size:** the survey program must cover the weighing of at least the greater of the following:

- a number of passengers calculated from an earlier survey or a trial sample, using normal statistical procedures and based on a 2% margin of error (see worked example below)
        - a total of 50 multiplied by the maximum operational passenger seat configuration.
- **Passenger weights:** passenger weights must include the weight of any belongings that are carried when entering the aircraft (infants should be weighed together with their accompanying adult) and should include carry-on baggage. If desired, carry-on baggage may be weighed separately and subtracted from the combined passenger/carry-on baggage weight.
- **Weighing location:** the location for weighing passengers should be as close as possible to the aircraft, at a point where a change in passenger weight by disposing of, or acquiring more, personal belongings is unlikely to occur before boarding the aircraft.
- **Weighing machine:** the weighing machine to be used for weighing passengers should have a capacity of at least 150 kg. The weight should be displayed at minimum graduations of 500 g. The weighing machine should be accurate to within 0.5% or 200 g, whichever is greater.
- **Recording of weight values:** survey data should include (but not be limited to) the number of adults, gender ratios, survey location, flight number, rejection ratio, and weight with or without carry-on baggage.

A.3   Worked Example

The following statistical equations may require the input of a suitably qualified person to ensure the calculations are performed correctly. While details of the calculations are included here for completeness, in practice many operators are likely to implement these calculations in a suitable software package such as Microsoft Excel.

To establish a standard passenger weight using a weighing survey program, the following steps can be followed:

a. Estimate the true values[5] of the standard passenger weight (μ') and standard deviation (σ') using data from a previous or small-scale survey.
b. Use these estimates to calculate the required sample size (N) for the current weighing survey program, i.e., the number of people to be randomly selected and weighed to determine the exposition-derived weight.
c. Weigh N randomly-selected passengers, then calculate the mean weight ($\bar{x}$) and the standard deviation (s).
d. Calculate the 95% confidence interval for the exposition-derived weight from Step 3.
e. Check that the margin of error of the 95% confidence interval is within 2%.

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[5] The true values are the mean passenger weight (μ) and standard deviation (σ) if the weights of every passenger (within the specific operational context) were known.

Step 1

If a weighing survey has been conducted previously, then use the values of $\bar{x}$ and s determined in the most recent survey (see output of Step 3 below). Otherwise, conduct a small-scale survey of approx. 100 randomly selected passengers, and calculate the mean and standard deviation as illustrated below (the figures used in this worked example are entirely fictitious).

99.2	90.7	89.7	64.4	81.8	85.8	73.6	71.1	60.5	98.3	58.4	110.0	75.6	65.1	88.2
69.1	94.8	52.2	79.6	52.9	74.3	64.9	69.3	58.2	65.8	61.0	91.5	84.8	98.6	95.0
91.0	66.9	67.0	61.1	72.6	96.3	79.1	61.2	86.1	58.2	99.5	60.2	92.7	59.4	68.5
88.9	93.8	80.1	70.4	88.4	97.1	82.8	57.2	73.2	88.2	96.3	77.5	82.4	90.8	93.2
93.5	82.3	94.9	71.3	58.9	67.3	98.3	96.6	82.0	59.4	54.2	87.3	89.9	121.5	85.2
68.4	63.7	62.3	89.7	98.1	89.4	86.5	81.1	69.5	95.7	67.9	85.7	80.9	92.1	91.9
96.7	72.8	72.7	88.5	86.7	72.1	72.2	89.0	64.5	80.0	77.6	65.4	93.5	78.8	64.1
68.5	105.3	93.2	73.0	58.7	97.1	98.1	83.2	82.7	93.0	56.7	64.3	56.5	98.6	67.7

There are 120 passenger weights in this table given in kilograms (kg). To calculate the mean, take the sum of all passenger weights and divide by 120:

$$\mu' = (99.2 + 90.7 + 89.7 + ... + 56.5 + 98.6 + 67.7) \div 120 = 79.5 \text{ kg}$$

The standard deviation is a little more complicated; the formula is given below, however this calculation is most easily performed using standard functions in Microsoft Excel or similar (see AVERAGE, STDEV):

$$\sigma' = \sqrt{\frac{\sum_i (x_i - \mu')^2}{N-1}} = \sqrt{\frac{(99.2 - 79.5)^2 + (90.7 - 79.5)^2 + \cdots + (67.7 - 79.5)^2}{120 - 1}} = 14.6 \text{ kg}$$

Note that in this calculation N is the total number of weights, the capital sigma ($\sum_i$) means add up the terms to the right of the symbol, and x_i represents each entry in the table.

Step 2

Next, the values of μ' and σ' from Step 1 will be used to calculate the number of passenger weights needed to find the exposition-derived passenger weight (in the formula below, a 2% margin of error is assumed):

$$N \geq \left(\frac{1.96 \times \sigma' \times 100}{2 \times \mu'}\right)^2 = \left(\frac{1.96 \times 14.6 \times 100}{2 \times 79.5}\right)^2 \cong 323.91$$

Therefore at least 324 passengers must be weighed to determine the exposition-derived weight.

> **Note**: Data used in this example is clustered quite tightly; the number of passenger weights required for a weighing survey program increases with the square of the standard deviation, so in populations that include a wider spread of weights significantly more passengers may need to be weighed.

Step 3

Collect the required number of passenger weights (in this example, at least 324) and then, using the method outlined in Step 1, calculate the mean weight ($\overline{x}$) and the standard deviation (s).

To illustrate the method, a total weight of 28,609 kg from 324 passengers is assumed:

$$\overline{x} = 28,609 \div 324 = 88.3 \text{ kg}$$

$$s = \sqrt{\frac{\sum_i (x_i - \mu')^2}{N-1}} = \sqrt{\frac{(95.1 - 88.3)^2 + (77.7 - 88.3)^2 + \cdots + (85.2 - 88.3)^2}{324 - 1}} = 15.4 \text{ kg}$$

> So, the exposition-derived weight, as determined in this survey of 324 passengers, is 88.3 kg.

Step 4

Next, calculate the 95% confidence interval[6] for the exposition-derived weight obtained in Step 3:

$$\overline{x} \pm \frac{1.96 \times s}{\sqrt{N}} = 88.3 \pm \frac{1.96 \times 15.4}{\sqrt{324}} = 88.3 \pm 1.7 \text{ kg}$$

Step 5

As a final step, check that the margin of error is within 2% (see Step 2):

$$\text{margin of error} = \frac{1.96 \times s \times 100}{\overline{x} \times \sqrt{N}} = \frac{1.96 \times 15.4 \times 100}{88.3 \times \sqrt{324}} = 1.9\%$$

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[6] It is incorrect to state that there is a 95% probability that the true mean weight (μ) lies in this interval. Rather if this survey were conducted repeatedly (with passengers selected randomly on each occasion), then the true mean weight would tend to lie within the calculated confidence intervals 95% of the time.