SAWE PAPER NO. 2393
INDEX CATEGORY NO. 9

AIRCRAFT WEIGHING EQUIPMENT: A COST ANALYSIS

BY
Eric Peterson
Intercomp Company

For Presentation at the
56th Annual Conference

Of the

Society of Allied Weight Engineers Inc.
Bellevue, Washington
19-21 May 1997

Introduction

Since 1990, the technology of weighing equipment used on commercial aircraft has improved tremendously. The weighing equipment of today's market enables users to complete weight and balance tasks more efficiently and reliably while improving the overall accuracy of the results.

The decision of the potential buyer on which type of equipment is best for their application - top of jack load cell kits or drive on platform scales - depends on both their objectives and budget.

An analysis must therefore be made to explore advantages and disadvantages of each method and then relate them to the initial up-front investment as compared to the long term operational cost.

As a manufacturer of both types, we are frequently asked which method is better. It is our position that each company's objectives and requirements may immediately indicate which method is best for the application. We therefore assist them in analyzing all of their requirements in an attempt to determine the answer.

The decision of which type of weighing equipment to purchase must therefore be based on two criteria:

1. Does the weighing equipment meet the objectives and is it suitable for the application?
2. Is the price of the weighing equipment within budgetary limitations and is it justifiable?

Advantages and disadvantages to both methods and their compliance to the application must first be considered to ensure either method will meet the objectives of the user. The purchase price may not even be an issue if one method is not suitable for the application.

But because the purchase price of top of jack load cell kits is so much less than that of a platform system, potential customers often do not consider the latter method because it is seen as prohibitively expensive.

This study will identify the main advantages and disadvantages to each method to demonstrate how an airline or maintenance center can determine if the weighing equipment can meet the objectives and criteria of the user.

The main purpose of this paper, however, is to demonstrate the operational costs of either method in an attempt to identify any savings derived therein. For it is the operational cost savings, and not just the purchase price, that must be considered to determine which method is most cost effective and thus, best suited for the application.

In order to determine if the type of weighing equipment available in the market can meet the objectives and criteria of the user, a brief description of the weighing equipment and their inherent advantages and disadvantages must be reviewed.

A Review of Weighing Systems

Top of Jack Load Cell Kits

Weighing on jacks has been the traditional method for weighing aircraft for over forty years. A typical kit consists of load cells, which are mounted on top of a jack and cabled to a central processing unit. A typical CPU can display individual load cell weight and total weight, and in some cases automatically compute the center of gravity.

Two types of jacks can be used to accomplish this process. The traditional method is to use tripod jacks and jack at the primary jacking points. More recently, lower profile jacks have become available which enables jacking under the axles.

For commercial aircraft, top of jack systems are typically configured to include a load cell and jack for each primary or under axle jack point. An A320 would require three load cells and jacks while a B-747 requires a minimum of five load cells and jacks.

Load cells represent a tried and proven method for weighing aircraft. The system is relatively easy to maintain and transport. Load cells enable a weighing to take place during an on going maintenance process and minimizes aircraft post MOD isolation during a tight delivery schedule. Most importantly, load cells are very portable and can be taken off site to weigh aircraft if required (provided the site has the proper jacks).

A significant drawback to using load cells is they can present an unsafe condition for weighing aircraft. Boeing Commercial Airplanes has amended their Weight and Balance Manuals to state "For Safety Reasons, weighing the airplane by jacking at the primary jacking points is not recommended, and should only be used when other procedures are not available". Weighing on axle jacks greatly minimizes but does not eliminate this potential hazard.

Most load cell kits are also limited by accuracy and capacity when applying them to narrow and wide body aircraft. An airline weighing both narrow and wide body aircraft may have to purchase two separate kits as one kit may not serve all models of aircraft. Load cells are also more susceptible to side loads when weighing on the primary jacking points which can further induce errors.

For most top of jack weighing applications, load cells are found to be a difficult to use and time consuming process. The time required to position the equipment, jack the aircraft, level, take the readings and then repeat the process can be a lengthy and tedious task.

As an example, a typical wide body weighing involves at least nine people to operate the hydraulic jack system, spot check the jacking points, operate the kit and perform other necessary procedures. Load cells are therefore seen to be the least efficient method.

Platform Weighing Systems

Platform weighing systems didn't become a refined method of weighing until the mid-1970's. A typical system consists of one scale per wheel and associated ramps, axle spacers, tire stops, transport carts, power supplies and optional central processing units. An A320 would therefore require six platform scales while a B-747 would require eighteen. An airline or maintenance center can purchase one complete system to weigh their entire fleet as no additional support equipment is required.

The design of this type of equipment has improved significantly through the decade so that accuracy and ease of use can be optimized. A properly designed product eliminates traditional potential errors induced by side loads, out of level conditions, temperature changes, etc. Scales are now lighter in weight and perform a wide variety of corrections including those for altitude and latitude making them as sophisticated as any method available in the marketplace.

One of the most important factors associated with platform scales is they are considered the safest method for weighing aircraft. The aircraft is not susceptible to dropping from load cells on jacks which can cause extensive and costly damage to an aircraft.

Most significantly however, is that weighing on platforms is a very efficient process that takes minimal operation time and personnel. A wide body weighing requires no more than 5-6 personnel. The aircraft can literally be weighed in under an hour. This enables other maintenance tasks to be completed and the aircraft returned to service in a shorter time frame.

Certain drawbacks may exist with platform scales that are worth considering. Platform scales are generally less portable when compared to a load cell system and jacks (load cells are even more portable when only the kit and not the jacks need to be brought to the weighing site). They also require a tow distance of at least seven feet and when combined with the area required to accommodate the tow can require more of an area than the hangar will permit. The necessity to tow the aircraft also prevents any other ongoing maintenance tasks from being completed.

These are all factors that must be considered when analyzing the method that is best for a customer's weight and balance procedure. They should be considered before cost even becomes an issue because one method simply may not be feasible or meet the objectives of the customer.

Delta Airlines for example, has determined it is logistically easier to weigh at different hubs throughout the U.S. and therefore transports its top of jack load cell kit and jacks in a compact LD-3 container. This reduces the level of scheduling and coordination required as the kit is brought to the aircraft instead of the aircraft being brought to the kit. Similarly, the Boeing Modification Center is limited by available space and does not have the travel area to accommodate platform scales. These factors clearly indicate weighing on load cells are the best for these customers.

Alternatively, airlines and maintenance centers have found they can weigh more efficiently, faster and without a safety risk when using platform scales.

Therefore, if either method meets the customer’s objectives, the final consideration is then the cost of the system.

There are two types of cost which must be considered.
1. Up front initial investment of the weighing equipment.
2. Operational cost savings as it relates to the return on investment.

These two costs must be analyzed in greater detail to make a thorough evaluation of both methods. One must consider the time, speed, efficiency and man hours required as related to operation costs in order to determine the true cost and advantage of either system.

Cost Analysis

As previously stated, the main purpose of this paper is to explore the operational costs in an attempt to demonstrate which method of weighing is most economical and presents the greatest cost savings over the life span of the weighing system.

The initial up-front investment cost must first be reviewed. Below are standard average costs for both types of equipment separated by narrow and wide body configurations. Note that the Jack System includes the price of both a load cell kit and jacks. It should also be noted that a narrow body aircraft type, for the purpose of this study, is considered to be an aircraft with no more than six wheels (ex. A-320, B-737), while a wide body kit is considered to be an aircraft with eighteen wheels (B-747). Prices may vary depending on the configuration of the weighing system, but for the purposes of this analysis, the following demonstrates general costs for either aircraft type.

Weighing Type	**Narrow Body**	**Wide Body**
Load Cells & Jack System	$40,000.00	$70,000.00
(cost of jacks)	($25,000.00)	($45,000.00)
Platform System	$50,000.00	$150,000.00

For an application which would require the weighing of a B-747, a customer would therefore be comparing the price of a jack weigh system of $70,000.00 to a platform system for $150,000.00. There is therefore a cost difference of $80,000.00.

Note: For purposes of this study, it is assumed the Jack System must include prices for both under axle jacks and weighing system because, as mentioned, most airframe manufacturers do not recommend weighing on the primary jacking points. The customer will therefore have to purchase a complete under axle weighing system to accomplish the jack weighing process. Prices for the jacks are itemized should a customer already own an under axle jack system.

One can see why upper management commonly asks why they would need to spend an additional $80,000.00 on a platform system when the same task can be completed for $70,000.00. This question is a primary reason why a continued study must be performed.

The customer must determine the operational costs of either system and then use those figures to determine the cost savings and the point at which the savings pays for the difference in purchase price.

To gain an average sampling of operational costs, Intercomp Company conducted a survey of international airlines and third party maintenance centers in order to formulate industry averages for time and man hours it takes to weigh both narrow and wide body aircraft on top of jack and platform scales.

It should be noted that the survey was not conducted under the premises of being a direct representation of statistical averages. Margin of error is unknown. Responses were received

from both airlines and maintenance centers from regions such as North America, South America, Asia, Middle East and Europe in order to gain a better statistical representation of the figures. The figures therefore provide a realistic insight into the operations of a wide range of industry users of both methods. Based upon our experience, these numbers generally equal what we see in the field.

Respondents were asked to respond to the following questionnaire. The response averages for each category are included.

Aircraft Weighing Cost Analysis Survey

Please provide the information requested for each function as per the type of aircraft and method of weighing specified in each column.

Function	**Narrow Body Platform Weighing**	**Wide Body Platform Weighing**	**Narrow Body Jack Weighing**	**Wide Body Jack Weighing**
Aircraft Preparation (in Hours)	5	7	5	7
Equipment Preparation & Set Up (in Hours)	1	1	1.5	2
Aircraft Weighing (in Hours)	1	1	1	4
Equipment Take Down & Stowage (in Hours)	1	1	1	1
Avg. # of persons	5	6	7	10
Avg. Labor Rate (in U.S.$ if known)	$45	$45	$45	$45
Avg. # of Weighings Each Year	14	21	12	12

Function Description

1. Aircraft Preparation - to include for all de-fueling, inventory checklist, and associated procedures conducted just prior to setting up the weighing equipment.
2. Equipment Preparation - to include for all procedures rolling out weighing equipment, minor checks of weighing equipment, warm up, set up, etc.
3. Aircraft Weighing - Actual time from applying load, multiple weighing, offloading, etc.

4. Equipment Take Down & Stowage - to include for all procedures of removing weighing equipment, take down, and storage.
5. Avg. # of persons - Number of personnel present and actively involved in aircraft preparation, equipment preparation, aircraft weighing and equipment take down & stowage.
6. Avg. Labor Rate - The average labor rate of the average number of persons involved.
7. Avg. # of Weighings Each Year - state the number of weighings for each aircraft and method in a sample calendar year. You may average fleet size if weighing has been sporadic in last few years.

A formula must be used to determine the operational costs of either system. The end result can be used as the average weighing cost. Because the "Aircraft Preparation" category results remained constant for either type of aircraft and weighing equipment, the figures were not included in the formula (these figures are also not relevant because other personnel are often involved in this process who may not be involved in the actual weighing). Also note that average hours required to weigh includes the categories of Equipment Preparation & Set Up, Aircraft Weighing and Equipment Take Down & Stowage.

The formula also does not reveal the cost of keeping the aircraft on ground and / or delays in returning to service by using one method over the other. It was determined that because airlines most often weigh in the evening when the aircraft is normally grounded, either method could be completed in enough time to return the aircraft to service and thus, incur no additional cost. It should be noted however, that if an airline or maintenance center cannot allocate the required 7-12 hours to complete a weighing, the down time costs incurred should be annotated in any similar formula.

Aircraft Weighing Cost Formula

Hrs. Required to Weigh x Required Personnel = Man Hours

Man Hours x Labor Rate = Cost of Aircraft Weighing

When the formula is applied to the two types of aircraft and methods, the cost of weighing the aircraft is determined as follows:

Narrow Body Platform Weighing
3 hrs. x 5 men = 15 man/hrs. x $45.00 labor rate = $675.00 cost per weighing

Wide Body Platform Weighing
3 hrs. x 6 men = 18 man/hrs. x $45.00 labor rate = $810.00 cost per weighing

Narrow Body Jack Weighing
3.5 hrs. x 7 men = 24.5 man/hrs. x $45.00 labor rate = $1,102.50 cost per weighing

Wide Body Jack Weighing
7 hrs. x 10 men = 70 man/hrs. x $45.00 labor rate = $3,150.00 cost per weighing

The formula clearly demonstrates that a narrow body platform weighing costs $427.50 less than a jack weighing, while more significantly, a wide body platform weighing costs $2,340.00 less than jack weighing. This therefore demonstrates platform weighing represents a significant cost savings as opposed to jack weighing.

The next step of the formula requires the per cost weighing to be multiplied against the forecasted number of aircraft weighings per year. This provides an annual cost for the operation.

The operational costs are therefore applied to a working model in order to determine the time frame for which a company can account for the difference in the purchase price. This will be referred to as the threshold - the point in time when the cost savings makes up for the difference in the purchase price. To do this, the model will assume an airline or maintenance center will either weigh twelve narrow body or twelve wide body aircraft per year.

Threshold Formula

Number of a/c weighed per year x operational cost of weighing each a/c = total operational cost of weighing fleet per year

Narrow Body Jack Weighing: 12 aircraft x $1,102.50 = $13,230.00 / year
Narrow Body Platform Weighing: 12 aircraft x $675.00 = $8,100.00 / year

On an annual basis, narrow body platform weighing saves the customer $5,130.00.

Wide Body Jack Weighing: 12 aircraft x $3,150.00 = $37,800.00 / year
Wide Body Platform Weighing: 12 aircraft x $810.00 = $9,720.00 / year

On an annual basis, wide body platform weighing saves the customer $28,080.00.

The purchase price difference between a narrow body jack and platform system is $10,000.00. The increased difference in price to purchase a narrow body platform system can be accounted for within two years. Therefore, the threshold is two years.

The purchase price difference between a wide body jack and platform system is $80,000.00. The increased difference in price to purchase a wide body platform system can be accounted for in slightly more than two years. Therefore, the threshold is approximately two years.

In both examples of the model, it is most important to note that an airline or maintenance center using a jack weighing system will incur a greater expense over time, whereas the platform system user begins to generate a savings (and/or income should they perform third party work).

Weighing equipment of sound quality will typically have an operational life of at least fifteen years. Under this premise, considering the airline or maintenance center still weighs only 12 narrow or wide body aircraft per year and not accounting for inflation, the following cost savings would be realized when comparing platform to jack weighing. Years three through fifteen (twelve years) are used to calculate per year savings assuming it takes two full years to reach the threshold.

Narrow Body Weighing: $5,130.00 per year savings x 12 yrs = $61,560.00
Wide Body Weighing: $28,080.00 per year savings x 12 yrs. = $336,960.00

These figures represent the operational cost savings over the operational life of the system.

It is most important to note that if third party work is performed, weighing on platform scales can present a sizable generator of income because the work can be performed at a relatively low cost. As an example, a company can charge as much as $8,000.00 for the weighing of a B-747. By using the above wide body platform weighing cost of $810.00, the company can generate a profit of approximately $7,000.00 per weighing.

Another interesting discovery revealed by the survey were the costs incurred when using the figures provided for average number of aircraft weighed.

By applying the figures to the operational cost formula, we see that respondents weighing on load cells incurred substantially higher operational costs while weighing less aircraft than those using platform scales.

Narrow Body Jack Weighing: 12 aircraft x $1,102.50 = $13,230.00 / year
Narrow Body Platform Weighing: 14 aircraft x $675.00 = $9,450.00 / year

The operational cost formula demonstrates the respondents using jack weighing systems weighed two less aircraft per year and incurred $3,780.00 more in operational costs.

Wide Body Jack Weighing: 12 aircraft x $3,150.00 = $37,800.00 / year
Wide Body Platform Weighing: 21 aircraft x $810.00 = $17,010.00 / year

The operational cost formula demonstrates the respondents using jack weighing systems weighed nine less aircraft per year and incurred $20,790.00 more in operational costs.

Conclusion

We must again review the criteria which must be considered when evaluating which type of weighing equipment is best for the customer.

1. Does the weighing equipment meet the objectives and is it suitable for the application/environment?
2. Is the price of the weighing equipment within budgetary limitations and is it justifiable?

The user can only determine the answers to the first question. As demonstrated, significant advantages and disadvantages exist with each type of weighing equipment that can clearly indicate which type is best.

But all too often, users are confronted with the glaring purchase price differences which separate the two types of equipment. This difference commonly drives their decision to purchase the less expensive of the two considering today's tightening budgetary restraints.

It is therefore incumbent on the user to analyze the operational costs of both methods. The formulas can then become an excellent working model to determine costs.

Depending on labor rates and the number of aircraft weighed per year, platform weighing systems clearly provide an operational cost savings when compared to jack weighing systems. This also does not take into account the inherent safety realized with platform scales. One accident on a jack weighing system can cause excessive damage which then eliminates the need to perform this study. This can be considered the intangible cost.

Most importantly, the threshold in the purchase price of platform vs. jacking systems is realized after two years.

As airlines and maintenance centers become more cost conscious, they are increasingly making purchase decisions based upon these types of analysis. In fact, many require a return on investment within 3-5 years.

This analysis demonstrates that platform weighing systems can easily be justified provided that the company has an industry standard labor rate and weighs at least twelve aircraft per year.

The answer to question two of the criteria used to select a weighing system does not relate to only purchase price. The purchase price of a platform weighing system may not be immediately justifiable, but the operational cost savings indicates it is the most prudent choice

ATTACHMENT A

Respondents to Survey

KLM Royal Dutch Airlines

Singapore Airlines

Royal Brunei Airlines

Royal Jordanian

VARIG Airlines

Alitalia

Gulf Aircraft Maintenance Company (GAMCO)

Kuwait Airways

Hong Kong Aircraft Engineering Co.

South African Airways

Singapore Technologies Aviation Services Co. (SASCO)

Note: Responses were received from other airlines and maintenance centers, but due to confidentiality reasons, they asked that their name not be identified in conjunction with this study.