TRANSPORTATION COST SYSTEM (TRACS)
Statistical and Computer Documentation
(Source Code and Data on CD Rom)

I. PREFACE

A. Purpose and Content

USPS-FY11-36 documents the development of the estimated distribution keys for purchased transportation costs. It contains documentation for the Transportation Cost Systems (TRACS) subsystems used to develop these costs. It also presents FY11 C.V.s (coefficients of variation) and confidence intervals for TRACS estimates.

B. Predecessor Document(s)

The development of the TRACS estimated distribution keys and C.V.s material was presented in Docket No. ACR2010 USPS-FY10-NP24.

C. Corresponding Non-Public or Public Document

A non-public version of this document is provided as USPS-FY11-NP24 Transportation Cost System (TRACS).

D. Methodology

The methodology is the same as in Docket No. ACR2010: USPS-FY10-36.

E. Input/Output

The TRACS distribution keys are used to develop purchased transportation costs as inputs to:

USPS-FY11-32 FY 2011 CRA “B” Workpapers
USPS-FY11-NP14 FY 2011 CRA “B” Workpapers
USPS-FY11-NP2 FY 2011 International Cost & Revenue Analysis (ICRA) Report

II. ORGANIZATION

The relevant source code and outputs from TRACS are provided on the accompanying CD-ROM. The ‘README_TRACS (Public)’ file describes the contents of the CD-ROM, which includes an Excel file containing the C.V.s (coefficients of variation) for TRACS. The programs and systems used to develop the TRACS estimated distribution keys are described in the sections below. The documentation is contained in three appendices:

- **Appendix A : Highway Subsystem**
- **Appendix B : Air Subsystem**
- **Appendix C : Tables**

III. PROGRAM AND SYSTEM DOCUMENTATION

Since TRACS Highway and Air subsystems are so dissimilar, each subsystem is addressed separately in its own appendix.

The following table shows the TRACS sample sizes, by quarter for FY 2011.

TRACS Sample Size by Quarter: FY 2011

	FedEx Night	FedEx Day	UPS	Com. Air	Highway	Total
PQ 1	374	849	233	537	2,565	4,558
PQ 2	373	845	270	538	2,566	4,592
PQ 3	375	849	270	540	2,563	4,597
PQ 4	375	848	270	535	2,566	4,594
FY 2011	1,497	3,391	1,043	2,150	10,260	18,341

Appendix A : TRACS Highway Subsystem

I. Overview

The TRACS-Highway subsystem is a continuous, ongoing statistical sampling system. On a quarterly basis, it produces separate distribution keys for four types of purchased highway contracts: Inter-NDC[1], Intra-NDC, Inter-SCF[2], and Intra-SCF.

The primary sampling unit (PSU) for all four contract types is the route–trip–stop–day, which is defined as all mail unloaded from a truck at one facility on a specific trip, on a specific day. The survey design is essentially the same for all contract types, though each has its own sampling frame. Each highway sampling frame is a list of stop–days[3].

The sample design consists of three stages. At the first stage, within each contract type, the stop–days are stratified based on the type of facility and whether the trip is inbound or outbound. A systematic random sample of stop-days is selected from each stratum. At the second stage, for each selected stop–day, a sub–sample of pallets, wheeled containers and loose items[4] off–loaded at the test facility is selected. From each container selected at the second stage, a third stage sample of items is selected. For pallets and loose items selected at the second stage, there is no third stage sample. All selected mail is recorded.

Weight and volume information by mail category is recorded for the contents of sampled items. Weights are converted to cubic-feet, based on Density Study data. For sampled pallets, the dimensions of the pallet and the percentage of mail on the pallet by mail category are recorded. Data collectors also record the facility where the item, or the pallet, was loaded onto the vehicle (to establish miles traveled) and the percentage of vehicle floor space occupied by palletized mail, containerized items, and loose items (to establish cubic–feet utilized). From the sample data, the cubic–foot–miles transported by each contract type are estimated by mail category. Distribution keys, proportions of cubic–foot–miles by mail category, are calculated for each contract type.

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[1] Network Distribution Center (formerly Bulk Mail Center).
[2] Sectional Center Facility.
[3] Abbreviated name for route-trip-stop-days.
[4] Loose items include pieces, parcels, bundles, sacks, trays, or tubs. Items that are not in wheeled containers or on pallets are called loose items.

II. Statistical Study Design

The universe under study is all mail moved on contracts whose costs accrue to these highway accounts:

Inter-NDC: Account Number 53131 (regular Inter-NDC).
Intra-NDC: Account Number 53127 (regular Intra-NDC).
Inter-SCF: Account Numbers 53124 (regular Inter-SCF), 53609 (regular Inter-P&DC), 53614 (regular Inter-cluster), and 53618 (regular Inter-area);
Intra-SCF: Account Numbers 53121 (regular Intra-SCF), 53601 (regular Intra-P&DC), and 53605 (regular Intra-district).

The four contract types are described below:

- Intra-SCF – Generally these contracts involve carrying mail back and forth between an SCF or Processing & Distribution Center (P&DC) and the Associate Offices (AOs) within its service area. Outbound trips distribute mail from the SCF to the AOs. Inbound trips collect mail from AOs and bring it to the SCF.

- Inter-SCF – These contracts primarily involve carrying mail between SCFs or P&DCs. Inter-SCF trips also stop at AOs along the way.

- Intra-NDC – This category of contracts primarily involves carrying mail between an NDC and other facilities within its service area. Outbound trips distribute mail from the NDC to the SCFs and AOs, while inbound trips collect mail from the SCFs and AOs and bring it to the NDC.

- Inter-NDC – These contracts primarily involve carrying mail between NDCs, but they often include stops at SCFs and some stop at AOs. A contract that involves service between an NDC and an SCF outside of the NDC's service area may also be classified in this category.

  The following table lists all the stops including destinations by facility type for each contract type in PQ4, FY2011.

Table 1. Stops by Facility Type

Contract Type	NDC	SCF/P&DC /HSP	AO/ Others	Total Stops
Intra-SCF	17,641	1,722,916	5,665,231	7,405,788
Inter-SCF	60,641	682,253	387,309	1,100,203
Intra-NDC	77,493	160,576	24,635	262,704
Inter-NDC	46,410	30,056	3,588	80,054

Typically, one contract route entails multiple trips, some being round–trips and others being one–way trips. One trip serves a specific route on specific days of a week. A trip consists of one or more trip segments. A segment is a movement from one facility to the next facility along the trip. There are as many stops on a trip as there are segments. Therefore, a list of trip–segment–destinations is the same as a list of trip–stops.

1. First Stage Sample

The first stage sample is a stratified random sample of stop–days. Stops are stratified based on the type of facility and whether the segment is on an inbound or an outbound trip. Within each stratum, stops are sorted by district and a systematic random sample of stops is selected with probability proportional to the trip's operating frequency. For each selected stop, all possible operating days during the quarter are listed and a test date is randomly selected from the list. The following table shows the first stage sample size by quarter for FY2011.

Table 3: Sample Size by PQ

Postal Quarter	INTRA SCF	INTER SCF	INTRA NDC	INTER NDC	Total Highway
PQ1	749	715	551	550	2,565
PQ2	750	716	550	550	2,566
PQ3	748	715	549	551	2,563
PQ4	750	716	550	550	2,566
FY2011	2,997	2,862	2,200	2,201	10,260

2. Second Stage Sample

For each selected stop–day, the following truck utilization data are recorded: (1) the percentage of floor space that is empty; this is further split based on the percentage of empty equipment and empty floor space; (2) the percentage of the floor space occupied by mail unloaded at the test facility; and (3) the percentage of the floor space occupied by mail that remained on the truck. The utilization data, based on square footage of floor space, are collected at the time the vehicle is opened, but before any mail is removed from or added to the vehicle.

The second stage sample is a stratified sample of off–loaded wheeled containers, pallets and loose items. Mail being off–loaded from the vehicle is stratified into five groups depending on the type of mail and the level of containerization. These five groups, or strata, are: pallets, wheeled containers, non-containerized Express Mail, loose sacks, and other loose items. The percentage of floor space occupied by each of these five strata is recorded before selecting the second stage sample. The following rules are used to select the second stage sample:

- Up to two pallets are selected.
- For wheeled containers, if two or fewer containers are unloaded, all are selected. Otherwise, a random start and a skip interval of three are used to select containers for sampling. If the combination of the random start and skip interval results in less than two containers being selected, then a second container is also selected. At most, five containers are selected.
- All loose Express Mail items (i.e., sacks, parcels, etc.) are selected.
- Up to eight loose sacks and other loose items are selected, with at least one of each item type. The item types sampled in TRACS–highway are trays, tubs, sacks, bundles, loose parcels and pieces, etc. Items are selected in proportion to their presence on the truck.

3. Third Stage Sample

The third stage sample is a stratified sample of items from each selected wheeled container. Mail in the wheeled container is stratified by item type, and one of each item type is selected. Prior to the selection of the item, the data collector records the container type and the percentage of the container occupied by each item type. These data are used to estimate the cubic–feet for each item type in the container. In some cases, the data collector counts the number of the items in the container, rather than estimating the percentage, to impute cubic–feet from the number of items.

There is no third stage sample for pallets, loose Express Mail, loose sacks or other loose items selected at the second stage. All selected mail is recorded.

For each selected pallet or item, regardless of whether it was selected at the second or third stage, two types of data are recorded: item information and mail information. For pallets, the item information includes the dimensions (height, length and width) of the pallet, and the origin facility code where the pallet was loaded onto the truck. The pallet dimensions are used for expansion; the facility code is used to determine the mileage traveled. For mail information, the percentage of pallet space taken up by mail for up to four mail categories is recorded.

For items, in addition to the origin facility code, the label content line and the item type are also required as a part of the item information. The item type determines which expansion formula applies. For mail in items, the data recorded include the number of pieces and weight by mail category. Weights are converted to cubic‑feet based on the density factors shown in Appendix C, Table 1.

III. Estimation

Quarterly distribution keys are produced for the four contract types: Inter-NDC, Intra-NDC, Inter-SCF, and Intra-SCF. Data are expanded in a three‑step process to obtain cubic‑foot‑miles by mail category for each contract type. In the first step, test data are expanded to the unloaded truck capacity. In the second step, cubic‑foot‑miles are calculated, accounting for all legs the mail has traveled on the test vehicle. In the third step, the cubic‑foot‑miles estimated from individual tests are expanded to all stop-days (the PSU) within each stratum and summed across strata to estimate cubic‑foot‑miles by mail category for the contract type. The ratios of the cubic‑foot‑miles for each mail category to the total cubic‑foot‑miles across all mail categories constitute the distribution key.

The process is slightly different for Intra-SCF. Given the difficulties of maintaining a highway mileage file for the very large number of Intra-SCF routes and stops, the distribution key is based on cubic‑foot‑legs rather than cubic‑foot‑miles. If all Intra-SCF legs were the same length, this would be equivalent to cubic‑foot‑miles. Use of cubic-foot-legs is justified by the reasonable assumption that their lengths do not vary appreciably.

The program used to expand sample data and generate the distribution keys is TRACSSMN.HWYq11.EDITEXP.CNTL(ZEXP). It has three inputs:

(1) TRACSSMN.HIGHWAY.PQq11.EDITED.DATA,
(2) TRACSSMN.CUFT.DEFAULT.FLAT.TEXT.FY11, and
(3) TRACSSMN.MAILCODE.FLAT.CODE.FY11.

The first input is the final analysis file ('Z-file') that contains the clean sample data, with information necessary for expansion. The second input provides the cubic−foot value for various types of containers and items sampled in TRACS. The third file contains the three digit numeric codes for all mail categories, and the density factor associated with each.

The following notation is used in the expansion process:

h	stratum. For Inter-SCF and Inter-NDC, h=1,2,3. For Intra-SCF and Intra-NDC, h=1,2,3,4,5;
n	number of tests performed in a quarter;
i	test index within the stratum;
N	number of frame units for the quarter;
I	frame index;
Day	number of days in a week that a vehicle operates;
Capacity	vehicle capacity in cubic−feet;
%Empty	percentage of vehicle space that is empty;
%Unload	percentage of space occupied by mail unloaded;
%Remain	percentage of space occupied by mail remaining on the truck;
%Container	percentage of space occupied by unloaded wheeled containers;
%Pallet	percentage of space occupied by unloaded pallets;
%Express	percentage of space occupied by unloaded Express Mail items;
%Sack	percentage of space occupied by unloaded non−containerized sacks;
%Other	percentage of space occupied by unloaded other loose items;
S	total legs traveled on this trip, up to the test stop;
s	segment index, or leg, on the trip $\{s=1,2,\ldots,S\}$;
o	origin index − the segment of the origin facility where the item was loaded onto the vehicle $\{o \in 1,2,\ldots,S\}$.
$mile_s$	segment mileage;
r	mail category, $r \in R$;
w	net weight of mail in pounds;
d	density factor in cubic−feet/pound;
cuft	mail cubic−feet;
cfm	mail cubic−foot−mile; and
y	distribution key for the quarter.

Although the expansion process starts from the bottom and works its way up, it may be useful to first look at the formulation, conceptually, from the top down.

The distribution key for the r^{th} mail category,

$$y_r = \frac{cfm_r}{cfm} = \frac{cfm_r}{\sum_r cfm_r}$$

is the ratio of the cubic–foot–miles for the mail category, divided by the total cubic-foot-miles. The cubic–foot–miles for a mail category, from the first–stage expansion, is:

$$cfm_r = \sum_h \sum_i^{n_h} w_h cfm_{hir}$$

where w_h is the stratum weight, and cfm_{hir} is the cubic–foot–miles for a test. The stratum weight accounts for the first stage selection probability of each stratum. This is a Horvitz –Thompson type estimator. See Cochran, Sampling Techniques, 3rd edition, Theorem 9A.5 on page 260 for a proof that this type of estimator is unbiased. More details on the first-stage expansion are provided in Section VII-3. The cubic–foot–miles for a test is

$$cfm_{hir} = \sum_{s=1}^{S} cuft_{hirs} \times mile_{his}$$

where $cuft_{hirs}$ is the cubic–feet of mail that traveled on the s^{th} segment and was unloaded at the test facility, and $mile_{his}$ is the mileage of the segment. Furthermore,

$$cuft_{hirs} = \sum_{o=1}^{s} cuft_{hiro}$$

where $cuft_{hiro}$ is the cubic–feet of mail that was loaded on the vehicle at the beginning of the o^{th} segment and unloaded at the test facility. The cubic–foot–miles for a test are calculated in the second step of the expansion process.

1. Expanding to Unloaded Truck Capacity

Dropping the stratum subscript, the first step in the expansion process produces $cuft_{iro}$, which for the r^{th} mail category is the estimated cubic–feet of mail that was loaded onto the vehicle at the o^{th} facility and unloaded at the test facility, adjusted to the unloaded truck capacity.

The unloaded truck capacity, in cubic−feet, is the product of the vehicle capacity and the recorded percentage of capacity taken up by all mail unloaded at the test facility. It is also the sum of cubic−feet of unloaded mail across all mail categories:

$$Unloaded_i = Capacity_i \times \%Unloaded_i = \sum_r cuft_{irS} = \sum_r \sum_{o=1}^{S} cuft_{iro} \ .$$

All mail unloaded from the test vehicle is sampled. There are three types of second stage sampling units (SSUs): (1) pallets; (2) loose−items; and (3) containers. The unloaded cubic−feet of mail is developed by computing the cubic-feet for each SSU type separately, and then summing across SSU types. Hence,

$$cuft_{iro} = cuft_{iro}^{(Pallet)} + cuft_{iro}^{(LooseItems)} + cuft_{iro}^{(Containers)}$$

1a. Palletized mail expansion formulas

At most two pallets are selected for each test. All mail on selected pallets is sampled. Data collectors measure the height (*H*), length (*L*), and width (*W*) of each selected pallet and enter the mail category and percentage (%*p*) of the pallet space taken up by mail for up to four mail categories. Let *j* denote the sampled pallet index: *j*=1 and 2. For the pallet loaded on the vehicle at the o^{th} origin facility, the actual cubic−feet on pallet *j* occupied by mail category *r* is

$$H_{ioj} W_{ioj} L_{ioj} \times \% p_{iroj}$$

Hence the truck space taken up by mail class *r,* loaded at origin facility *o,* on unloaded pallets is

$$cuft_{iro}^{(Pallet)} = Capacity_i \times \%Pallet_i \times \frac{\sum_{j \in o} H_{ioj} W_{ioj} L_{ioj} \times \% p_{iroj}}{\sum_{o=1}^{S} \sum_{j=1}^{2} H_{ioj} W_{ioj} L_{ioj}} . \qquad (1)$$

The data set ‘PALLET’ in the 'Z−file' contains all the sample data for pallets.

1b. Loose–item (non–containerized) mail expansion formulas

All the loose item mail found on the truck is stratified into: non–containerized Express Mail, loose sacks, and other loose items. The truck utilization percentages are collected for each. All the non-containerized Express Mail is sampled. For loose sacks and other loose items, a total of eight items is sampled in each test.

Additional notation:

j	*j=1,2,...,J*	sampled Express Mail,
k	*k=1,2,...K*	sampled sack
l	*l=1,2,...L*	sampled other item (*K*+*L*<=8)
TW		tare weight of the item

The mail recorded from the sampled items is expanded to the truck space taken up by each category of loose items through a two–step process.

Step 1) The net weight of the mail in the sampled item is expanded to the cubic–feet of the item by multiplying the item's gross cubic–feet by the proportion of cubic–feet occupied by mail category *r*:

$$
\begin{aligned}
cuft_{iroj}^{(g)} &= cuft_{ioj}^{(g)} \times \frac{w_{iroj} d_r}{\sum_r w_{iroj} d_r} = cuft_{ioj}^{(g)} \times \frac{cuft_{iroj}}{cuft_{ioj}} \\
cuft_{irok}^{(g)} &= cuft_{iok}^{(g)} \times \frac{w_{irok} d_r}{\sum_r w_{irok} d_r} = cuft_{iok}^{(g)} \times \frac{cuft_{irok}}{cuft_{iok}} \qquad (2) \\
cuft_{irol}^{(g)} &= cuft_{iol}^{(g)} \times \frac{w_{irol} d_r}{\sum_r w_{irol} d_r} = cuft_{iol}^{(g)} \times \frac{cuft_{irol}}{cuft_{rol}}
\end{aligned}
$$

The density factor d_r in (2) converts net weight of the mail to the cubic–feet it occupies in the item. Appendix C, Table 1, provides a complete list of the density factors by mail category. The item's gross cubic–feet varies, depending on the type of item, as follows:

a) for trays, flat tubs and con–cons, the gross cubic–feet of the item, $cuft_{iol}^{(g)}$ is as shown in Appendix C, Table 2;

b) for bundles and loose items, the gross cubic–feet of the item, $cuft_{ioj}^{(g)}$ or $cuft_{iol}^{(g)}$, is the same as the net cubic–feet of the mail in the item, or:

$$cuft_{ioj}^{(g)} = \sum_r w_{iroj} d_r = \sum_r cuft_{iroj} = cuft_{ioj}$$
$$cuft_{iol}^{(g)} = \sum_r w_{irol} d_r = \sum_r cuft_{irol} = cuft_{iol} \qquad (3)$$

c) for sacks, pouches, and Express Mail, the gross cubic−feet of the item is the total cubic−feet of the mail plus the tare cubic−feet for the sack/pouch:

$$cuft_{ioj}^{(g)} = \sum_r w_{iroj} d_r + TW_j \times d_j = \sum_r cuft_{iroj} + cuft_j^{(Tr)}$$
$$cuft_{iok}^{(g)} = \sum_r w_{irok} d_r + TW_k \times d_k = \sum_r cuft_{irok} + cuft_k^{(Tr)} \qquad (4)$$
$$cuft_{iol}^{(g)} = \sum_r w_{irol} d_r + TW_l \times d_l = \sum_r cuft_{irol} + cuft_l^{(Tr)}$$

The tare weight, *TW* in (4), is the difference between the gross and the net weight of the sampled item. The density factors for tare weights are shown in Appendix C, Table 3.

<u>Step 2)</u> The gross cubic−feet of mail in a sampled item is further expanded to the truck capacity utilized by the three sampling groups:

$$cuft_{iro}^{(LooseItem)} = Capcity_i \times \left[\begin{array}{l} (\%Express_i \times \dfrac{\sum_j cuft_{iroj}^{(g)}}{\sum_{o=1}^{S} \sum_j cuft_{iroj}^{(g)}} + \\ \%Sack_i \times \dfrac{\sum_k cuft_{irok}^{(g)}}{\sum_{o=1}^{S} \sum_k cuft_{irok}^{(g)}} + \\ \%Other_i \times \dfrac{\sum_l cuft_{irol}^{(g)}}{\sum_{o=1}^{S} \sum_l cuft_{irol}^{(g)}}) \end{array} \right] \qquad (5)$$

All loose−item data are contained in the SAS data set ‘FORM3L’ in the 'Z−file’.

1c. Containerized mail expansion formulas

Every third wheeled container, up to a maximum of five, is sampled. For each sampled container, the data collector records the percentage of the container taken up by each of the item types found in the container. One item is randomly selected from each of the item types. For each selected item, all the mail is counted. The pieces and weight are recorded by mail category.

Additional notations:

c	Sampled container {c=1,2,…C: C<=5};
t	Item type, *t* = Parcel, Sack, ...
p	Percentage of container space taken up by the item type
CONTCUFT	Container size in cubic−feet.

The following steps are taken to expand the containerized mail:

<u>Step 1)</u> The net weight of the mail in the sampled item is first expanded to the gross cubic−feet of the sampled item by multiplying the item's gross cubic−feet by the proportion of the item occupied by mail category *r*:

$$cuft_{iroct}^{(g)} = cuft_{ioct}^{(g)} \times \frac{w_{iroct} d_r}{\sum_r w_{iroct} d_r} = cuft_{ioct}^{(g)} \times \frac{cuft_{iroct}}{cuft_{ioct}} \qquad (6)$$

The density factor in (6) converts the net weight of mail into the cubic−feet it occupies in the item. Appendix C, Table 1, provides a complete list of density factors by mail category. The item's gross cubic−feet varies, depending on the type of item, as follows:

a) for trays, flat boxes, and con−cons, the gross cubic-feet, $cuft_{ioct}^{(g)}$ is as shown in Appendix C, Table 2;

b) for bundles and other loose pieces, the gross cubic-feet, $cuft_{ioct}^{(g)}$ is the same as the net cubic−feet of mail in the item, i.e.

$$cuft_{ioct}^{(g)} = \sum_r w_{iroct} d_r = \sum_r cuft_{iroct} = cuft_{ioct} \, .$$

c) for sacks, pouches, and Express Mail, the gross cubic−foot, $cuft_{ioct}^{(g)}$, is the mail cubic−feet plus the tare cubic−feet of the sack:

$$cuft_{ioct}^{(g)} = \sum_r w_{iroct} d_r + TW_t \times d_t = \sum_r cuft_{iroct} + cuft_t^{(Tr)} \, .$$

The tare weight, *TW* in (c) above, is the difference between the gross and net weight of the sampled item. The density factors for tare weights are shown in Appendix C, Table 3.

<u>Step 2)</u> The gross cubic−feet of mail in a sampled item are further expanded to the sampled container:

$$cuft_{iroc}^{(g)} = \frac{CONTCUFT_c}{\sum_{o=1}^{S}\sum_{t} p_{ioct}} \sum_{t}\left(p_{ioct} \times \frac{cuft_{iroct}^{(g)}}{cuft_{ioct}^{(g)}} \right) \tag{7}$$

The container size, *CONTCUFT,* for various type containers can be found in Appendix C, Table 4.

Step 3) The resulting gross cubic−feet of mail is finally expanded to the truck capacity utilized by all unloaded containers,

$$cuft_{iro}^{(Container)} = Capacity_i \times \%Container_i \times \frac{\sum_{c=1}^{C} cuft_{iroc}^{(g)}}{\sum_{c=1}^{C} CONTCUFT_c} \tag{8}$$

The SAS data set ‘FORM3C’ in the ‘Z−file’ contains all the containerized sample data.

1d. Total cubic–feet of mail unloaded

The cubic−feet of mail which was loaded on the truck at origin *o* and unloaded at the test stop is the sum of the three second stage sampling unit types:

$$cuft_{iro} = cuft_{iro}^{(Pallet)} + cuft_{iro}^{(LooseItem)} + cuft_{iro}^{(Container)}. \tag{9}$$

When added across the origin and the mail category, we obtain the reported unloaded capacity of the vehicle.

$$Unloaded_i = Capacity_i \times \%Unloaded_i = \sum_{r}\sum_{o=1}^{S} cuft_{iro} \ .$$

2. Cubic–Foot–Mile Calculation

Summing equation (9) across all the origin facilities up to a specific leg produces the cubic−foot estimates for the mail that traveled on the leg:

$$cuft_{irs} = \sum_{o=1}^{s} cuft_{iro} \ . \tag{10}$$

Each sample record contains a complete list of legs the mail item traveled on the vehicle. For each leg, the sample record also specifies the origin and destination facilities and the highway miles between the two. The cubic‑foot‑miles for each leg are the product of the cubic-feet estimates and the highway miles for the leg. The cubic‑foot‑miles is the sum of such products across all legs:

$$cfm_{ir} = \sum_{s=1}^{S} \left\{ cuft_{irs} \times mile_{is} \right\}. \qquad (11)$$

The cubic‑foot‑mile calculation specified in equation (11) requires highway miles for all leg segments on sampled routes. The highway‑mileage file contains highway miles for over 7,000 facility pairs, and covers over 90% of the Inter-NDC, Intra-NDC, and Inter-SCF routes. However, the coverage is less than 50% for Intra-SCF routes, so mileage is not used for Intra-SCF contracts.

Similar to equation (11), the test level cubic‑foot‑leg for the Intra-SCF contract type is calculated by:

$$cfm_{ir} = \sum_{s=1}^{S} cuft_{irs} \,. \qquad (12)$$

Prior to Base Year 2000, equations (11) and (12) were adjusted to account for the unused capacity, or empty space, on the truck. The expansion process used since then adopts the ‘compromise method’ introduced by the Postal Service and adopted by the Commission in Docket No. R2000-1 (Op. ¶3300). Mathematically, the ‘compromise method’ is equivalent to removing the empty space adjustment from the expansion process as shown in equations (11) and (12).

3a. Distribution Key

The test level cubic‑foot‑miles obtained from equations (11) and (12) in the previous section is expanded to the stratum level and summed across strata. The distribution key is a set of ratios of the expanded cubic‑foot‑miles for an individual mail category to the total expanded cubic‑foot‑miles summed across all the mail categories.

$$y_r = \frac{\sum_{h=1}^{H}\left(\sum_{i=1}^{n_h} cfm_{ir}\right) w_h}{\sum_{r\in R}\sum_{h=1}^{H}\left(\sum_{i=1}^{n_h} cfm_{ir}\right) w_h} = \frac{cfm_r}{\sum_r cfm_r} = \frac{cfm_r}{cfm}, \tag{13}$$

where the stratum weights are:

$$w_h = \frac{\sum_{I=1}^{N_h} Day_I \times 12}{n_h} \; . \tag{14}$$

3b. Intra-SCF Global Express Guaranteed (GXG) and Within County Periodicals

TRACS uses RPW volumes to develop the Global Express Guaranteed (GXG) key for the Intra-SCF Highway mode. The distribution key proportions for Express Mail International (EMI) and Global Express Guaranteed (GXG) are as follows. The combined values for all TRACS modes, except highway intra-SCF contract routes, are reported as EMI with corresponding values of zero for GXG. The EMI and GXG aggregated proportion for intra-SCF routes is reallocated to these subclasses in proportion to their total RPW weight.

TRACS uses RPW volumes with applied density and distance factors to develop the Within County Periodicals key for the Intra-SCF Highway mode. The distribution key proportions for Within County Periodicals and Without County Periodicals are as follows. The combined values for all TRACS modes, except highway intra-SCF contract routes, are reported as Without County Periodicals with corresponding values of zero for Within County Periodicals. The Within County and Without County Periodicals aggregated proportion for intra-SCF routes is reallocated to these subclasses in proportion to their total RPW weight/cube/distance factor.

Appendix B : TRACS Air Subsystem

I. OVERVIEW

The TRACS Air subsystem is a continuous, ongoing statistical sampling system developed to provide distribution keys for attributing purchased air transportation costs to mail categories. Weight and cubic-foot based distribution keys are constructed for the major network air modes each postal quarter for this purpose. The universe under study is all mail transported by the major air carriers. These include Commercial Air, UPS, FedEx Day Turn, and FedEx Night Turn. Mail transported by air taxi, or under Alaska, Hawaii, HASP and Christmas network services is excluded.

The TRACS Air subsystem samples mail flown from an origin city directly to a destination city or on the first leg of an inbound flight or trip to the mode's hub. The sampling frame for an air mode is a recent historical extract of its assigned weight (lbs.) obtained from the Postal Service's Enterprise Data Warehouse (EDW). The EDW maintains historical routing data for each mail item (sack, tray, loose parcel, etc.) transported by air carrier, including the air mode, origin city, destination city, dispatch date, dispatch time, processing date and time, assigned weight, and primary mail class.

The TRACS Air subsystem sample design utilizes a stratified, multi-stage probability sample of mail. The primary sampling unit (PSU) at the first stage of sampling is a mail class, facility, date and time segment combination. The secondary sampling unit (SSU) is a mail item. The sampling element is a mailpiece. A sampled mail item is fully enumerated; wherein, all mailpieces contained in the mail item are measured. Data collectors capture routing information from each sampled mail item along with content weight and volume (count) by mail category. Appendix C provides a list of the mail categories measured under TRACS. The sample data are recorded into laptop computers using the Computerized On‑Site Data Entry System (CODES).

The TRACS Air sample data are expanded each postal quarter sampling period using inverse sampling fractions for strata at each sampling stage along with control ratios utilizing known EDW weight totals. Annual estimates are obtained by summing the postal quarter estimates.

II. STATISTICAL STUDY DESIGN

The TRACS Air subsystem develops weight (pounds) and cubic-foot based distribution keys for volume variable costs associated with each air mode. The universe under study is all mail transported by an air mode from a domestic origin to a domestic destination. Mail transported by air taxi, or under Alaska, Hawaii, HASP, or Christmas networks is excluded.

In mail operations, mailpieces are sorted into mail items, or handling units consisting of trays, tubs and sacks. A mail item may also be a loose parcel. A mail item assigned to an air mode gets scanned electronically and then tagged at a Transaction Concentrator (TC) machine located at an origin postal or private mailer facility. A TC is uniquely identified in the EDW by its alpha-numeric device-id code which is normally six characters. One or more workstations may be associated with a device‑id at an origin facility, and one or more device‑id's in turn may be associated with an origin facility. The tagging process attaches a dispatch and routing (D&R) tag to each scanned mail item. The D&R tag identifies air mode specific information including the air carrier, origin and destination city airport codes, item weight and primary mail class. The primary mail class is the Air Contract Transportation (ACT) tag code. A mail item is assigned an ACT tag code based on the predominant mail class of the mail item's contents. The major mail class codes are: F, P, E and I, corresponding to First‑Class Mail, Priority Mail, Express Mail and International mail, respectively. All other ACT tag code mail class groups are designated 'O' for sampling purposes under the TRACS Air subsystem. The EDW maintains summary weight information for all assigned (tagged) mail items, by device‑id, date, flight and ACT tag code. ACT tag weight totals from the EDW are used in the expansion of the sample data.

A. First–Stage Sample

The PSU for a network air mode is a *mailclass*facility*date*time-segment* combination.[5] The *mailclass* component is the ACT tag code. The *facility* component is the postal or private mailer site where mail items are assigned to the air mode. The *date* and *time-segment* components identify the date and sub‑period when mail items are assigned. The assignment of mail items for a given mail class, facility and date combination may occur over various time segments. A time segment may be a 1‑2 hour, 2‑3 hour, or other period, including a 24 hour period. A time segment determines a unique PSU for a given mail class, facility and date combination.

Prior to each postal quarter, a sampling frame is constructed listing all PSUs expected during the upcoming sampling period. PSUs are stratified by weight (lb.) based size categories. Thresholds (boundaries) are dynamically formulated each quarter using a cumulative √f distribution method and a fixed number of strata.

A specified fixed total sample size is allocated among the strata

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[5] All mail items assigned for air transport for a PSU are subject to sampling, including mail items trucked by an air carrier.

proportional to each stratum's historical weight from the EDW. Prior to the draw, the PSU's are ordered by size within each stratum and a skip sample is then selected after a random starting unit is chosen. Sample dates are randomly assigned to the selected sampling units from all possible non-holiday dates of operation (specific to each air mode) after the dates are ordered and partitioned into a minimum number of equal size (uniform) sub–periods for workload smoothing purposes.

B. Second–Stage Sample

The second stage SSU is a mail item transported by an air carrier on a first leg flight or trip. Examples of mail items include a sack, letter tray, flat tub, and loose parcel. All mail items assigned to a PSU for first–leg transport are subject to sampling.

For a sampled PSU, a sub–sample consisting of 10 mail items (minimum) if available is selected. This sample is assumed a simple random sample. The second-stage sampling frame is an implicit listing of all mail items assigned for air transport at all workstations for all device–id's at the origin facility. If there are fewer than 10 mail items available for sampling at a targeted PSU, then all mail items are selected and sampled. If no mail items are assigned for a targeted PSU, then the test is considered a zero–volume test, subject to administrative confirmation. If a test is missed, it is rescheduled to the same weekday of a future week during the sampling period (unless it is within the last week of the quarter – then rescheduled to any weekday). The mail item population counts necessary for second-stage post-stratification and expansion are obtained from the EDW.

For each sampled mail item, PSU specific routing information is recorded directly into the data collector's laptop CODES computer. The routing information links the sample and EDW frame file records during the data editing and pre–expansion processes. No tertiary stage of sampling is conducted. A census is conducted of each SSUs contents, *i.e.*, all mailpieces (sampling elements) in a selected mail item are measured. Mailpiece volume and weight totals are recorded for each mail category in addition to the sampled unit's gross weight. The data collection procedures governing TRACS Air tests are documented in Section 8, of Handbook F-65, Data Collection User's Guide for Cost Systems, and the TRACS Air Reference Guide.

III. CREATING THE FIRST–STAGE SAMPLING FRAME

The frame of PSUs is constructed approximately five weeks in advance of the postal quarter from recent historical EDW information. The EDW provides the following information for each mail item transported by air mode: device–id, three–character origin and destination airport codes, route identifier, route close–out date and time, ACT tag, assigned weight, and assigned date and time. This information is cross–walked to a file containing origin facility identifier information. The sampling frame for an air mode is a listing of all PSUs expected to have non-zero activity during the upcoming postal quarter.

PSU migrations among strata, including births and deaths occurring after sample selection or as a result of inadvertent sampling of non–targeted PSUs, are addressed through post-stratification prior to first-stage expansion.

IV. FIRST–STAGE SAMPLE SELECTION

A. Selecting the Sample

The total sample size is allocated among the primary strata proportionally to each stratum's recent historical mail weight (lbs.). Prior to this step, an empirical distribution is formulated to filter small–sized units at a prescribed percentile level. The measure of size for strata assignments is average weight (lbs.) by day–of–week (DOW) among PSUs having common mail class, facility and time segment components. Dates are temporarily collapsed to DOW for this purpose. The collapsed PSUs are assigned to strata using a cumulative √f distribution for the strata thresholds. The PSUs are then ordered within each stratum by their size measure. There are four different strata and they are classified as; 1) light, 2) medium-light, 3) medium-heavy, and 4) heavy. A starting unit is randomly selected between 1 and the computed skip interval length for each stratum. A second random assignment process provides the date component for each selected unit, from a mode–specific list of valid non–holiday operational fly dates for the sampling period.

After the random selection and date assignment processes, a workload smoothing process at the district level ensures that the randomly assigned dates for each weekday (Monday–Sunday) are distributed uniformly across equal–sized sub–periods of the full sampling period. Test facility information, including address and district code, is appended to each sample record for administration purposes.

V. PREPARING DATA FOR EXPANSION

Data validation and edit checks are made prior to data expansion. Sample data are checked for completeness, duplicate records, and integrity of field values. Sample data are extensively validated and crosschecked with EDW (linked by D&R barcode and processing date), the Product Tracking System PTS (linked by scanned mail piece barcode) and automatically scanned barcodes (mail piece barcodes scanned by the data collector). Sample data Act Tag Codes, test dates, test facilities, time segments, air modes, and mail categories are independently checked. If the sample data are not independently vetted and confirmed with the EDW data, or if there is a conflict between PTS data or scanned barcodes, then the data are edited, if possible, or if not, then removed.

The Z-file contains unexpanded, edited sample data records for the TRACS Air subsystem. This file is produced in SAS program: TRACSSMN.FEDEX.PQq11.CNTL(ZAIR04). Each Z-file record contains population and effective sample sizes for each sampling stage and stratum within, along with the EDW frame totals required to construct a distribution key estimate for each air mode.

In the Z-file program, updated EDW frame extract records are checked for missing values and duplicate records. A job abort is triggered if an empty field or non-unique record is encountered at the workstation and mail category level. The frame records for each subpopulation of an air mode are then post-stratified by weight at the PSU level. The original first-stage strata thresholds determined during sample selection are updated in this program to reflect changes occurring during the sampling period. The thresholds are formulated within each subpopulation using a cumulative $\sqrt{f}$ distribution. The first-stage post-stratification process adjusts the original sampling frame for PSU migrations (births and deaths) across strata occurring after the sample was selected.

In the Z-file program, the sample data at the second stage SSU (mail item) level are post-stratified by workstation to incorporate known EDW mail class (ACT tag) totals into the second-stage expansion process. Prior to this step, the program checks the sample data records for missing variable values and non-unique mail class entries. A job abort occurs if either condition is found. Ounce-pound conversion and other data record checks and edits are conducted prior to this program. Non-countable sample records are summarized and reported before being bypassed from downstream processing. Effective second-stage sample sizes are appended to the sample data records during the second-stage post-stratification process.

The sample data records at the workstation and mail category within level are merged with frame records by PSU and mail class. Strata population counts and weight (lb.) controls for each sampling stage are appended. Effective first-stage sample sizes for sampled strata are appended in this step. Extraneous frame records for unsampled PSUs and workstations are filtered. The merged data are output to the Z-file.

VI. EXPANSION

The data expansion process is similar for all air modes under the TRACS Air subsystem, with the exception of an average density factor to convert estimated weight to estimated cubic feet for FedEx Day Turn.

At the second stage of expansion, the sample data are post-stratified by workstation within each PSU and a mail category total is estimated for the PSU by a combined [strata] ratio estimator. In this process, the sample data for each secondary stratum (workstation) are expanded by the stratum's inverse sampling fraction, computed as the reciprocal of the ratio of the sample item count to the known mail item count from the EDW for the stratum. An intermediate control factor, computed as the ratio of known total weight for all device-id's in the PSU to known total weight for the sampled-only device-id's in the PSU, is applied to control for unsampled device-id's. This factor is unity if a PSU has a single device-id or if at least one mail item is sampled from each device-id in the PSU. The combined [strata] ratio estimate of a total is computed for each mail category from the ratio of known total weight for the PSU to estimated total weight for the PSU (all mail categories combined).

PSU mail category estimates from the second stage expansion process are expanded to first-stage post-stratified classifications for each air mode subpopulation using a separate [stratum] ratio estimator. For the expansion phase, subpopulations are defined by facility type. The subpopulation groups for Commercial Air are: 1) private mailers, 2) the JFK International Service Center (ISC), and 3) all other postal facilities. The subpopulation groups for Fed Ex Day Turn and UPS are: 1) private mailers, and 2) all other postal facilities. The subpopulation groups for Fed Ex Night Turn are: 1) private mailers, 2) the JFK ISC, 3) San Francisco AMC, 4) Los Angeles ISC, Chicago AMC, Irving Park (Chicago) PDC and 5) all other postal facilities. For each mail category in a primary sampling stratum, the sum of the estimated PSU weight or volume totals in the stratum is expanded by the ratio of known total weight for the stratum from the EDW to the sum of estimated PSU total weight (all mail categories combined) for the stratum. For each mail category, the sum of the estimated strata totals in a subpopulation is controlled to known total weight for the subpopulation from the EDW. The control factor is unity if at least one PSU is sampled from each primary stratum.

A. Distribution Key Formulas

The TRACS Air subsystem produces distribution keys each quarter for each air mode based on weight, volume and cubic feet of mail. For a cubic-foot based distribution key, weight estimates are converted to cubic feet estimates using average densities (average lbs. per cubic foot) for specific mail class groups. Cubic-foot measures are unavailable in the EDW at the mail class level. As a result, a regression model is formulated to apportion EDW aggregated cubic feet to mail classes using known total weight and cubic feet for mixed city containers by mail class.

Program TRACSSMN.FEDEX.PQqyy.CNTL(DENSITY) is run each quarter for the air mode serving Priority Mail to develop density factors for P and F mail classes (ACT tag groups). In this program, known EDW total cubic feet (dependent variable) for all mail classes is regressed on known total weight for each mail class (independent variables) using historical origin airport and departure date data from the sampling period. The general formula associating total cubic feet (C) and mail class P or F total weight is:

(d.1) $C = C_P + C_F$, or equivalently,

$$C = (C_P / W_P) * W_p + (C_F / W_F) * W_F .$$

In the above equation, C_P / W_P and C_F / W_F are the reciprocal densities for mail classes P and F, respectively.

The general formula for the multiple linear regression model, fitting total cubic feet C to F and P total weight at the combined origin airport *(o)* and departure date *(t)* level, is:

(d.2) $C_{o,t} = d_P * W_{P,o,t} + d_F * W_{F,o,t}$.

In equation (d.2), the coefficients d_P and d_F for the independent variables, $W_{P,o,t}$ and $W_{F,o,t}$, are the reciprocal densities shown in equation (d.1) at the origin-airport-day level.[6]

After density estimates are developed, they are adjusted to represent average densities relative to all mixed city and bypass container mail. The original and adjusted density ratios (d_F / d_P) and (d'_F / d'_P), respectively, are equal.

Electronic data records containing total weight and total cubic-feet measures for F and P mail classes, by origin airport and departure date, are extracted from EDW operational data in a file named: TRACSSMN.FEDEX.DAYNET.EDWCUBE.MIXED.FY11q. This file and an origin airport identifier file (TRACSSMN.FEDEX.DAYNET.EDWCUBE.MAPMC.FY11) are inputs to the density program. Records pertaining to trucked routes, offshore airports and other air modes are filtered. To account for a lag between the flight

[6] There is no intercept term in the equation since zero mail volume corresponds to zero cubic feet.

departure date and the invoice date for flights on a weekend or Monday, records for the three days are collapsed to a single ‘combined weekend’ day for each origin airport, resulting in summary records for a 5-day week: Tuesday through Friday and the combined weekend day.

The adjusted densities for each quarter of FY 2011 are provided in the following table:

Day Turn Densities by Q for FY 2011

Q	F Density	P Density	Overall Density	Data obs.	t-value d_F	t-value d_P
1	11.27	5.71	6.64	4,269	70.54	233.19
2	10.38	5.88	7.00	4,248	62.47	182.21
3	10.38	6.06	6.90	4,205	104.12	259.28
4	11.17	6.19	7.19	4,137	107.49	250.76

The following variable and index notation is used in the sample data expansion formulas for the TRACS Air subsystem:

A: air mode.

c: mail class (ACT tag) component of PSU, $c \in C = \{E, P, I, F, "O"\}$.

d: device-id ($d \in D_c$ *).*

D_c*: the set of device-id's for a PSU reporting non-zero activity for the mail class component (c) of the PSU.*

d'_P*,* d'_F*: reciprocal density factors (adjusted) for mail class index es: P, F.*

h: 1st-stage index for post-stratification of PSU's into 1..L_h *strata based on known (EDW) weight.*

*i = 1,2,…,nh: PSU = mailclass*facility*date*time-segment (4 component combination) is the cluster number within stratum h, with a total of nh clusters.*

j = 1,2,...,mhi: SSU = mail item (mail handling unit, e.g., sack, tray, loose parcel, etc.) is the unit number within cluster I of stratum h, with a total of mhi units.

k: 2nd-stage index for post-stratification of SSU's into 1..L_k *work-station-based strata.*

M, m: 2nd-stage SSU population and sample sizes (counts), respectively.

N, n: 1st-stage PSU population and sample sizes (counts), respectively.

r: mail (rate) category element ($r \in \vec{R}$ *).*

$\hat{\vec{R}}$*: estimated distribution key vector (* $\vec{R}$ *).*

S: subpopulation (domain) in air mode (A).

w_{hij}*: denotes the sampling weight for unit j in cluster I of stratum h.*

x: sample weight (lbs) measure ($x \in y$ *) for ratio estimator auxiliary variable .*

$\hat{X}$*: estimated total weight (lbs.) for ratio estimator auxiliary variable (sum of estimated total weights for all* $r \in \vec{R}$ *).*

X*: known (EDW based) total weight (control lbs.) from database.*

y: sample data measure of weight (lbs.), cubic feet or volume.

y_{hij}*: observed values of the analysis variables for unit j in cluster i of stratum h.*

$\hat{Y}$*: estimated weight, cubic feet or volume total (Y).*

At the second stage of expansion, the total *(Y)* for mail category *(r)* for a sampled PSU *(i)* in stratum *(h)* is estimated by a combined [strata] ratio estimator *(Yrc)*[7], with subsequent control to known mail class *(c)* device-id weight totals, as follows:

(1.1) $$\hat{Yrc}_{A,S,r,h,i} = \frac{1}{\delta}\left(\frac{\hat{Y}_{A,S,r,h,i}}{\hat{X}_{A,S,h,i}}\right) X_{A,S,h,i}$$, where

(1.2) $$\hat{Y}_{A,S,r,h,i} = \left(\frac{\sum_{d \in D_c} X_{A,S,h,i,d}}{\sum_{d^* \in D_c} X_{A,S,h,i,d^*}}\right) \sum_{d \in D_c} \hat{Y}_{A,S,r,h,i,d}$$, for

(1.3) $$\hat{Y}_{A,S,r,h,i,d} = \sum_{k^* \in d} \frac{M_{A,S,h,i,d,k^*}}{m_{A,S,h,i,d,k^*}} \sum_{j=1}^{m} y_{A,S,r,h,i,d,k^*,j}$$, and

(1.4) $$\partial = \begin{cases} d'_{P}, & \text{if } y = ft^3 \text{ and } (c) = P \\ d'_{F}, & \text{if } y = ft^3 \text{ and } (c) \neq P \\ 1, & \text{otherwise}, \end{cases}$$

(1.5) $$\hat{X}_{A,S,h,i} = \sum_{r \in R} \hat{Y}_{A,S,r,h,i}$$, for $y = x$, and

(1.6) $$X_{A,S,h,i} = \sum_{d \in D_c} \sum_{k \in d} X_{A,S,h,i,d,k}$$.

In equation (1.2), *d** in the denominator of the ratio designates a device−id for PSU *(i)* for which at least one workstation *(k)* is represented in the captured sample data. If all device−id's in the PSU are represented in the sample, then this ratio is unity. In equation (1.3), *k** designates a sampled workstation stratum (post-stratified estimator) for which at least one SSU is measured. Equation (1.4) shows the adjusted density factors from equation (d.2) for the reciprocal density

[7] To account for small second−stage sample sizes during post-stratification, a combined [strata] ratio estimator of a total is formulated in lieu of a separate [stratum] ratio estimator.

factor in equation (1.1) required to estimate cubic feet from the estimate of weight (used for Fed Ex Day Turn). In equation (1.6), known total weight for PSU (i) is obtained by summing the known total weights for all component workstations *(k)* for all device–id's *(d)* in D_c.

At the first stage of expansion for subpopulation *(S)* under air mode *(A)*, total *(Y)* for a mail category *(r)* is estimated from the estimated PSU *(i)* totals in each primary stratum *(h)*, $\hat{Y}rc_{A,S,r,h,i}$ in equation (1.1), by a separate [stratum] ratio estimator of a total, $\hat{Y}rs$, with subsequent controls to known total weight at the mail class *(c)* level, as follows:

(2.1) $$\hat{Y}rs_{A,S,r} = \sum_{c \in C} \hat{Y}rs_{A,S,r,c} \left(\frac{\sum_{h \in c} X_{A,S,c,h}}{\sum_{h^* \in c} X_{A,S,c,h^*}} \right)$$, where

(2.2) $$\hat{Y}rs_{A,S,r,c} = \sum_{h} \left(\frac{\sum_{i=1}^{n} \hat{Y}rc_{A,S,r,c,h,i}}{\sum_{i=1}^{n} \hat{X}_{A,S,c,h,i}} \right) X_{A,S,c,h}$$, for

(2.3) $$\hat{Y}rc_{A,S,r,c,h,i} \equiv \hat{Y}rc_{A,S,r,h,i}$$ (from equation 1.1),

(2.4) $$\hat{X}_{A,S,c,h,i} = \sum_{r \in R} \hat{Y}rc_{A,S,r,c,h,i}$$, for y=x,

(2.5) $$X_{A,S,c,h} = \sum_{d \in D_c} \sum_{k \in d} X_{A,S,c,h,d,k}$$, and

(2.6) $$X_{A,S,c} = \sum_{h} X_{A,S,c,h} \,.$$

In equation (2.1), the expanded sample total, $\hat{Y}rs_{A,S,r,c}$, from equation (2.2) for mail class *(c)* in subpopulation *(S)* is controlled to the known total weight for all strata *(h)* comprising *(c).* This ratio accounts for empty (non–sampled) strata in mail classes within each *(S)*, if any. In this equation, *(h*)* denotes non–empty strata, for which sample data have been recorded. If sample data are recorded for all *(h)* in *(S),* then the ratio is unity. Empty (non-sampled) mail classes for an entire mode and quarter substitute unweighted sample data for the same mail class and quarter from all other air modes. Empty mail classes within a subpopulation retain the mailclass, but are redefined to a non-empty subpopulation. Equation (2.2) is the separate [stratum] ratio estimator formula with numerator component, $\hat{Y}rc_{A,S,r,c,h,i}$, shown in equation (2.3).[8] Equation (2.3) is exactly equation (1.1), where $\hat{Y}rc$ in equation (1.1) is re-expressed to identify the mail class component *(c)* of a PSU explicitly (per its definition) instead of implicitly.

For air mode *(A)*, the estimated total *(Y)* for mail category *(r)* is the sum of the subpopulation *(S)* estimates as follows:

(3.1) $$\hat{Y}_{A,r} = \sum_{S} \hat{Y}rs_{A,S,r} \ .$$

For air mode *(A),* a distribution key element *(r)* in $(\vec{R})$ for the weight, volume or cubic feet measure *(y)* is estimated as follows:

(4.1) $$\hat{r}_{A,Y} = \frac{\hat{Y}_{A,r}}{\sum_{r \in R} \hat{Y}_{A,r}} \ .$$

B. VARIANCE ESTIMATION

The TRACS Air subsystem estimator for the distribution key element, $\hat{r}_{A,Y_r}$, in equation (4.1) is a complex type estimator which incorporates auxiliary variable information for expansion ratios at each stage of sampling. It also incorporates mail class controls for various aggregate levels upon tieback to known EDW weight (lbs.) for the sampling period. Moreover, numerous estimates are constructed each sampling period for each air mode and shape-based mail category within for the mail characteristics of interest: weight and volume.

An alternative to a direct (tractable) formula representation (or re-sampling methodology) for estimating sampling error is Taylor series (first order)

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[8] In equation (2.2), the sample total for stratum *(h)* in the numerator of the separate [stratum] ratio estimator is itself an estimate calculated as the sum of the combined ratio estimates, $\hat{Y}rc$, for the sampled PSU *(i)* totals in *(h)* from equation (1.1).

approximation; wherein, sampling variation can be estimated among first-stage sampling units (ultimate clusters). To ensure that the sampling error estimates are conservative and not under-estimates (on average), the first-stage finite population correction (fpc) is ignored.

For air mode (A), the estimated variance of the total sum (Y) for mail category (r) is the sum of the stratum (h) variance estimates as follows:

$$\hat{V}_{A,r}(\hat{Y}_{A,r}) = \sum_{h=1}^{H} \hat{V}_{A,r\ h}(\hat{Y}_{A,r})$$

where if $n_h > 1$,

$$\hat{V}_{A,r}(\hat{Y}_{A,r}) = \sum_{h=1}^{H} \frac{n_h}{n_h - 1} \sum_{i=1}^{nh} (y_{hi.} - \bar{y}_{h..})$$

$$y_{hi.} = \sum_{j=1}^{mhi} w_{hij}\ y_{hij}$$, for

$$w_{hij} = \left(\frac{\sum_{h \in c} X_{A,S,c,h}}{\sum_{h^* \in c} X_{A,S,c,h^*}} \right) \left(\frac{X_{A,S,c,h,i}}{\sum_{i=1}^{n} \hat{X}_{A,S,c,h,i}} \right)$$

, (shown in equations (2.1 and 2.2), and

$$y_{hij} = \hat{Y}rc_{A,S,r,h,i}$$ (show in equation 1.1),

$$\bar{y}_{h..} = \left(\sum_{i=1}^{nh} y_{hi} \right) / n_h$$

And if n_h = 1,

$$\hat{V}_{A,r\ h}\ (\hat{Y}_{A,r}) = \begin{Bmatrix} \text{missing if nh}' = 1 \text{ for h}' = 1, 2, ..., \text{H} \\ 0 \text{ if nh}' > 1 \text{ for some } 1 < \text{h}' < \text{H} \end{Bmatrix}$$

For air mode (A), the standard deviation of the total sum (Y) for mail category (r) is as follows:

$$Std\ (\hat{Y}_{A,r}) = \sqrt{\hat{V}_{A,r}(\hat{Y}_{A,r})}$$

A relative measure of sampling error, coefficient of variation (c.v.), is estimated, $cv(\hat{r}_{A,Y})$, for each mail category element estimate $(\hat{r}_{A,Y})$ of the distribution key vector $(\vec{R})$. For air mode (A), the c.v. for each mail category element is as follows:

$$cv\ (\hat{r}_{A,Y}) = \frac{Std\ (\hat{Y}_{A,r})}{\hat{Y}_{A,r}}$$

C. EXPANSION PROGRAMS AND INPUTS

The programs and inputs used to expand sample data and generate the distribution keys and cv’s are:

All air modes:

Program:	TRACSSMN.FEDEX.PQq11.CNTL(KEYAIR3)
Inputs:	TRACSSMN.MAILCODE.FLAT.CODE.FY11

Commercial Air	TRACSSMN.AIR.ZFILE.PQq11.CAIR
FedEx Day	TRACSSMN.AIR.ZFILE.PQq11.DAY
FedEx Night	TRACSSMN.AIR.ZFILE.PQq11.NIT
UPS	TRACSSMN.AIR.ZFILE.PQq11.UPS

Appendix C : Tables

Table 1: Mail Codes, Shapes, Descriptions and Surface Density Factors

Mailcode	Shape	Description	Density (lbs/cu ft)
111	Letter	1C Single Piece	16.1947
111	Flat	1C Single Piece	22.5531
111	Parcel	1C Single Piece	6.3398
111	NM-Flat	1C Single Piece Nonmachinable Flat	22.5531
112	Letter	1C Nonautomation Presorted	17.6948
112	Flat	1C Nonautomation Presorted	23.633
112	Parcel	1C Nonautomation Presorted	6.3398
113	Letter	1C Auto - Non-carrier route	17.6948
113	Flat	1C Auto - Non-carrier route	23.633
113	Parcel	1C Auto - Non-carrier route	6.3398
121	Letter	1C Single Piece Cards	16.1947
122	Letter	1C Nonautomation Presorted Cards	17.6948
123	Letter	1C Auto Cards - Non-carrier route Cards	17.6948
399	Letter	Within County Periodicals	27.7784
399	Flat	Within County Periodicals	27.7784
399	Parcel	Within County Periodicals	27.7784
400	Letter	Outside County Periodicals	27.7784
400	Flat	Outside County Periodicals	27.7784
400	Parcel	Outside County Periocicals	27.7784
511	Letter	Standard ECR Basic	21.0702
511	Flat	Standard ECR Basic	27.9177
511	Parcel	Standard ECR Basic	7.964
513	Letter	Standard ECR High Density	21.0702
513	Flat	Standard ECR High Density	27.9177
513	Parcel	Standard ECR High Density	7.964
514	Letter	Standard ECR Saturation	21.0702
514	Flat	Standard ECR Saturation	27.9177
514	Parcel	Standard ECR Saturation	7.964
521	Letter	Standard Non-automation	21.0702
521	Flat	Standard Non-automation	27.9177
521	Parcel	Standard Non-automation	7.964
521	NM-Flat	Standard Not-automation NF	13.3749
522	Letter	Standard Automation	21.0702
522	Flat	Standard Automation	27.9177
522	Parcel	Standard Automation	7.964
522	NM-Flat	Standard Automation NF	13.3749
523	Letter	Standard Not Flat Machinable (NFM)	13.3749
523	Flat	Standard Not Flat Machinable (NFM)	13.3749
523	Parcel	Standard Not Flat Machinable (NFM)	13.3749
531	Parcel	Standard Non-Automation Pcl Nonprofit	27.9177

531	NM-Flat	Standard Non-Automation NF Nonprofit	13.3749
532	Parcel	Standard Auto Pcl Nonprofit	27.9177
532	NM-Flat	Standard Auto NF Nonprofit	13.3749
533	Letter	Standard Not Flat Machinable (NFM) Nonprofit	13.3749
533	Flat	Standard Not Flat Machinable (NFM) Nonprofit	13.3749
533	Parcel	Standard Not Flat Machinable (NFM) Nonprofit	13.3749
601	Flat	Package Services Parcel Post	8.3971
601	Parcel	Package Services Parcel Post	8.3971
605	Letter	Package Services Bound Printed Matter Flats	23.9404
605	Flat	Package Services Bound Printed Matter Flats	23.9404
605	Parcel	Package Services Bound Printed Matter Parcels	23.9404
604	Letter	Package Services Media Mail or Library Mail	18.479
604	Flat	Package Services Media Mail or Library Mail	18.479
604	Parcel	Package Services Media Mail or Library Mail	18.479
700	Letter	USPS Mail	17.6948
700	Flat	USPS Mail	27.9177
700	Parcel	USPS Mail	11.9186
800	Letter	Free Mail	20.2793
800	Flat	Free Mail	20.2793
800	Parcel	Free Mail	20.2793
899	Letter	International Mail	
899	Flat	International Mail	
899	Parcel	International Mail	
999	Letter	Competitive Mail	
999	Flat	Competitive Mail	
999	Parcel	Competitive Mail	

Table 2: Known Item Size

Item Type	*Known Cubic-Feet*
Full size envelop tray	0.749
Half size envelop tray	0.374
Flat tub or box	1.490
Small parcel tray	2.813
Con-con	8.50

Table 3: Default Tare Weight Density Factors

Item Type	*Density Factor (pound/ft^3)*
Sack with tare weight <=1.5 (lb.)	3.05

Sack with tare weight >1.5 (lb.)	6.66
Express Mail	3.05

Table 4: Known Container Size

Container	*Default Cubic-Feet*
BMC-OCR	110.61
ERMC	49.34
GPC/GPMC/APC	48.64
Hamper	30.96
Wiretainer	33.33
Short Postal Pak	42.22
Other Wheeled	48.64
Tall Postal Pak	76.67