A SURVEY TO ESTIMATE THE VALUE OF THE EQUIPMENT INVENTORY OF A LARGE INSTITUTION

Michael Friedman and Stephen Casey, Rutgers University

Summary. A survey to estimate the value of the equipment inventory of the State University of New Jersey (Rutgers University) is presented. The aim of this paper is to further economical and efficient acquisition of this kind of information at universities and similar large institutions by offering a basic prototype.

The goals of the study and the population under study are described. The various stages of our work, starting with informal, exploratory information gathering, and terminating in the designed survey are presented. Whenever applicable, we relate the features of the survey to practical considerations and constraints as well as to statistical considerations.

1. Introduction. Rutgers University, the State University of New Jersey, has three main sites: Camden, Newark and the New Brunswick area. In the New Brunswick area, the University is further divided into several geographically dispersed colleges and campuses. There are also several outlying experimental stations.

The University owns equipment worth more than 70 million dollars, located in over 700 buildings. This equipment includes such diverse categories as computers, vehicles, laboratory instruments, dormitory furniture, typewriters, calculators, refrigerators, etc.

The Federal Office of Management and Budget requires that educational institutions take physical inventories of their equipment at least once every two years as part of the process of determining the costs applicable to grants and other agreements with the Federal Government. The O.M.B. also specifically states that statistical sampling methods may be used to determine the value of the inventory. (The Office of Management and Budget Circular A-21, "Cost Principles for Educational Institutions", Section J-9, states: "Institutions may be compensated for use of their. . . equipment. . . Such compensation shall be made by computing either depreciation or use allowance. . .(which) shall be based on the acquisition cost of the assets involved. . . Charges for use allowance or depreciation must be supported by adequate property records, and physical inventories must be taken at least once every two years to ensure that the assets exist and are usable, used, and needed. Statistical sampling techniques may be used in taking these inventories.")

2. The Population and the Frame. Section J-13 of the O.M.B. circular A-21 states: Equipment means an article of nonexpandable tangible property having a useful life of more than two years, and an acquisition cost of $500 or more per unit. However, consistent with institutional policy, lower limits may be established." At Rutgers, a lower limit of $300 was used, and all items above this limit were intended to become part of the population. (The items under $300 are expensed in the current budget rather than capitalized in the equipment asset section of the balance sheet.)

The population to be studied was then to consist of all items costing at least $300 and currently listed in the inventory records. Any hypothetical items which were not in the records even though they were part of the University inventory, were excluded. The computer records of the items constituted the frame.

In March 1981, the value of the about 42,000 listed items worth at least $300 was $71 million. About 8,000 of these, worth $18 million, belonged to a category called MMF&E (Miscellaneous Movable Furniture & Equipment). The remaining items are referred to as "individually tagged" or simply "non-MMF&E".

Currently, when a non-MMF&E item of equipment is acquired by the University, such information as cost, description, make and model of the asset, and the building, department, and room where it is to be located are entered into inventory records. Subsequently, a member of the Equipment Inventory Department visits the site and attaches to the item a sticker bearing an Asset Identification Number, which is also entered in the computer records. Each non-MMF&E item should then eventually have the Asset Identification sticker.

The above is a description of the ideal circumstances. In fact, it is possible for an item not to be recorded. More importantly, entries in the records may not be currently in the possession of the University. For instance, items may be sold, scrapped, cannibalized, traded in, transferred to another university or institution, stolen or broken, without being removed from the records. Also, items which were not Rutgers property may have been listed as such.

Before 1973, Rutgers University had only a very limited inventory system. In 1973 the University equipment was appraised for inventory and insurance purposes. The appraisers often grouped similar or small items such as sets of furniture items, lots of laboratory equipment, and groups of miscellaneous minor items. These items belong to the MMF&E category. Dollar values were assigned to these groups of items, but no records were kept of the items which belonged to the groups, making it difficult to check the accuracy of the inventory records regarding these (groups of) items. After 1973, some items were still recorded in lots and groups, but records of what items belonged to these groups were also kept. Currently, the use of groups and lots is being discontinued in most cases.

3. Goals of the Study and Preliminary Steps. As was stated in the summary, the goal of our work was to estimate the value of the equipment inventory of Rutgers University. More precisely and specifically the goal of the study became: To estimate the total acquisition cost of those items of equipment whose cost was $300 or more and which are included in the University inventory records, and are in the University's possession, usable, and used. As the statement implies, no attempt was made to estimate the cost of any items which may have belonged to the University, but were not listed in the records.

We made a major decision at the beginning of the study. This was to take a 100% sample of items costing at least $10,000. Since it was known that the distribution of cost per item would be very highly skewed, with some items costing above $100,000,it was decided that at least some of the items would be sampled with probability equal to 1.0. As a matter of fact, a tabulation revealed an extremely high concentration of value in the upper cost categories. Thus, for instance, 35.1% of all value was concentrated in 2.2% of all the items.

	Number of Items	Value ($1,000's)
All items above $300	41,976	71,232
Items above $10,000	926(2.2%)	25,029(35.1%)

The amount of $10,000 was set as the lower ceiling for the 100% sample. The Inventory Department stated that checking 800 - 900 items was well within their resources. This was our main criterion for setting the cutoff point.

It needs to be noted that in our context the 100% sample of the expensive items has a special significance. Not only does it help to give us accurate knowledge of total cost of an important part of the inventory. It also makes it possible to strike out from the inventory records all those items which are no longer in the University's possession and use. Thus an important part of the inventory records; i.e., the expensive items, can be made exactly accurate, and the discrepancy between listed value and the estimate of actual value for the whole inventory can be reduced.

This part of the field work was done in August of 1980, when the data base was somewhat different. The work took about 58 man-days. Out of 566 non-MMF&E items with a value of $15,886,207, 43 items with a value of $1,033,488 (6.5%) were missing.

There were also 348 MMF&E entries with a value of $8,795,187. It was found that except in a few cases, where obvious major changes had taken place, the MMF&E entries appeared reasonable or in the case of laboratory fixed equipment greatly understated. The obvious changes amounted to a reduction of $112,340 (1.3%). Any worthwhile effort involving the majority of the MMF&E entries, those not included in the obvious changes, would have to include a detailed reappraisal of the elements that make up these entries. We decided not to carry out such a reappraisal, and to exclude the MMF&E category from further study.

To summarize the first stage of our work, the complete sample of the expensive items showed 93.5% of the non-MMF&E inventory to be intact. We decided not to sample the MMF&E items in the second stage of the study.

The second stage of our study involves a sample of the non-MMF&E items valued between $300 and $10,000. We decided to plan a multistage study with buildings as the primary sampling units. The buildings are widely dispersed, and driving to a new building, parking, and getting in touch with the departmental administrative staff would take up a considerable portion of the field workers' time. We decided that the secondary sampling units would be systematically drawn blocks from within each building. Systematic samples turned out to be very convenient in our situation. The assets within each building can be ordered by room number, and by asset number within each room. This ordered listing can then be divided into blocks of "adjacent" items which are likely to be located close to each other within the building, and a systematic sample can be taken of them. A detailed description of the method in its final form will be given in a later section. It will be seen that this selection procedure is very easy to carry out even by hand, given a proper listing of the items in a building. It also allows us to control the total value of items selected from a building, and to control approximately the number of items selected from a building. It was also important that the sample be in blocks of "adjacent" items because in searching for the items in a building, the field workers need to work with the professors and other employees responsible for various laboratories and other rooms. If a sample of "non-adjacent" items were used, the field workers would not only have to enter another office or laboratory to look for almost every successive item, but would also have to obtain the assistance of many more persons.

4. The Pilot Study. We conducted a pilot study, mainly to learn how much time would be needed to check a certain number of items. A sample of 92 items was chosen from the Psychology Building, a fairly typical large research building, and one of the authors accompanied an inventory worker in the process of checking these items. This part of our work proved to be very valuable, and we strongly recommend its inclusion in the beginning stage of any similar study. It confirmed to us the practicality of our within-building sampling procedure, and gave us concrete knowledge of the problems to be encountered in the field work stage.

For instance, we had to abandon the previously entertained idea of hiring part-time employees to help in the survey work. It became clear that the success of the field work depended on the familiarity of the Inventory Department personnel with the assets and persons in the building. In particular, the task of trying to locate the items which could not be found at first required a great deal of knowledge and expertise. Of the 92 items in the sample, 28 were not found on the first day, and it required 4 additional man-days of work in the office and in the field to locate 16 of these items, and to reach the conclusion that the remaining 12 were not likely to be found. Much of this time was spent in checking other records, such as purchase orders, and talking to various departmental personnel. We expect that a similarly extensive effort would be required in other settings.

5. The Design of the Study. The following is a summary of the design of the survey: All University buildings which had equipment in the individually tagged, $300 - $10,000 category, were divided into five groups based on building location (with University vehicles considered separately). In each group the buildings were ordered by total cost of contained items, and the groups divided into strata.

In the typical stratum, two buildings were sampled without replacement with probabilities proportional to total building cost, using the method of Brewer (1963) discussed by Cochran (1977). Within the selected buildings, the items were listed by rooms, and divided into blocks of equal value, with two replicated systematic samples of two blocks taken from each building.

In the statistical analysis, the estimate of the total cost, and the estimate of the standard error rely on formulas (11.41) and (11.44) of Cochran (1977).

6. Determining Strata and Sampling Primary Units. In this section the design is explored in greater detail, and reasons for the particular choices that we made are specified. We believe that this will help workers in situations similar to ours to decide whether or not our methods fit their circumstances.

The buildings were grouped by campus because, for one, while all the Inventory Department personnel are based in the New Brunswick area, many of the University buildings are quite far from New Brunswick. Newark is about an hour's drive away, and Camden is twice as distant. Thus the cost of sampling is much higher in these two campuses than in New Brunswick, and this had to be reflected in a lower sampling fraction. The outlying stations are so far, so widely dispersed, and contain so little value that no personnel will be dispatched there. They will be handled by mail or phone, and only a quite small sampling fraction will be used.

The New Brunswick buildings were split into two groups according to average age of contained items because it appeared likely that a greater proportion of the older items would be missing. The other campuses were not split because they had only few buildings to begin with.

A listing of buildings was produced for each of the five groups. For each building we listed the building number, the number of items, the total value, the average age per item, and the cumulative total value (after the buildings had been ordered by decreasing cost). Table 1 shows how the buildings are divided into groups by campus, and how these groups are stratified. The groups are: 1-New Brunswick, over 8 years; 2-New Brunswick, no greater than 8 years; 3-Newark; 4-Camden; 5-Outlying stations.

Table 1
Division of Building into Strata

Group	Stratum	Number of Buildings	Total Cost
1	1	2	4,290,511
	2	3	3,327,802
	3	4	2,865,907
	4	11	3,021,272
	5	39	3,042,533
	6	144	982,742
2	1	3	3,573,409
	2	10	3,003,556
	3	66	3,040,634
	4	129	674,569
3	1	7	3,357,478
	2	20	880,880
4	1	19	1,451,638
5	1	45	480,932
		502	

It was necessary to reach a decision about the appropriate number of buildings and items to be sampled. The calculations were based on the amount of effort that was needed in the pilot sample of the Psychology Building, where it took about 5 man-days to check 92 items. We were informed by the Equipment Inventory Department that over the two month period that we allotted for the field work, 48 man-days would be available.

Based on our experience from the Psychology Building we assumed that entering each new building cost about half a day of the workers' time, and that 20 items could be checked each day, giving us a cost function proportional to

$$10n + n\bar{m},$$

disregarding travel costs, where n is the number of buildings sampled, and $\bar{m}$ the average number of items sampled per building. On this basis, the Psychology Building would be predicted to take 5.1 days.

Given the resources available to us, we had to trade off the number of buildings against the number of items per building. Given the travel and other costs associated with each new building, and the heterogeneity within buildings, we decided that it would be inefficient to sample less than 20 items from a building. We decided on approximately 25 items per building and approximately 26 buildings. The Inventory Department felt that sampling much fewer buildings than this would not be representative.

According to our assumptions, sampling 650 items in 26 buildings should take 45.5 days. These assumptions seem very conservative, since in the study of items above $10,000, 566 individually tagged items and 348 MMF&E items took only 58 man-days, with the MMF&E items being much more time-consuming. Such conservatism was accepted as most appropriate in this situation, because we needed to be certain that the Inventory Department personnel had enough time to search for and track down all items that could possibly be found. Any situation in which the field workers were pressed for time would be extremely undesirable.

In all five groups, the buildings were ordered by total value. Two methods of sampling buildings were considered: 1) a simple random sample of buildings and a sample of a constant fraction of items within each building, giving us a ratio estimate and 2) a PPS sample of buildings. In either case, it was necessary to subdivide the groups into strata. In simple random sampling, this was necessary in order to have control over the number of items sampled. In PPS sampling, this was necessary in order to control the heterogeneity of the probabilities of selection. Therefore, in the first three groups, the ordering was subdivided into strata of approximately equal value, so that there are 13 strata in groups 1 to 4.

This stratification by total building value also resulted to some extent in grouping buildings of similar functional use together. For instance, the first few strata in the two New Brunswick groups consisted of large research buildings.

We considered a simple random sample of buildings within each stratum, and within each building a sample of a constant fraction of each building's value. This method yields a self-weighing sample. In such a sample, each dollar of listed value would have the same probability of being checked. For each stratum, the estimate of the total stratum value would be

$$\hat{Y} = X \frac{y}{x}$$

where X = total listed value in stratum;
x = total value of items checked;
y = total value of items found.

It was found, however, that such a sampling scheme gave us too little control over x; its coefficient of variation would be, for instance, about .18 for 2 buildings selected from Stratum 4 of group 1. This problem would make it difficult to obtain an unbiased estimate of the variance.

Therefore, we decided to use PPS sampling. Because some of the strata had only a few buildings in them, and we did not want to deal with the consequences of selecting a building twice, we used the without-replacement method of Brewer (1963) described in Cochran (1977). If z_i is the proportion of the stratum value that is in the ith unit (with every $z_i < .5$) then the first unit is drawn with probabilities proportional to $d_i = z_i(1-z_i)/(1-2z_i)$. If the jth unit is drawn first, the second unit is selected with probabilities $z_i/(1-z_j)$. For this method of selection the probability that the ith unit will be included in the sample is $\pi_i = 2z_i$, and the probability that both the ith and the jth unit are included is

$$\pi_{ij} = \frac{2z_i z_j}{D} \frac{(1-z_i-z_j)}{(1-2z_i)(1-2z_j)}, \text{ where } D = \Sigma d_i.$$

Stratum 1 in the first group has only two buildings in it, so that PPS sampling without replacement was not applicable. Instead, in each of the buildings a sample proportional in value to the building value was chosen. The last stratum in each group has large variations in building values, and also many buildings with as few as one item (see Table 1). From each of these strata, two sets of items corresponding to \$4,000 of value were chosen randomly by methods similar to our within building methods (to be described later), without regard to building membership. (This samples approximately the same fraction of value in these two strata as in the other strata.) This means that these sets of items could include items from several buildings, especially if items from the end of the stratum were chosen.

7. Sampling Within Primary Units. The within building sampling technique was devised to be simple to carry out, to yield a sample which tended to have more than one item per room, to sample expensive and less expensive items in proportion to the fraction of the total building value that they represent, and to permit an unbiased estimate of the within building variance of the estimate. The method consisted of selecting two replicated systematic samples from within each building.

The average cost per item in each stratum was calculated. As mentioned before, we aimed at 25 items per building. We found empirically that multiplying the average cost per item by 20, to yield the (approximate) cost to be sampled within each selected building, gave us samples close to 25 items per building.

For each selected building, a listing of all the items was obtained, ordered by room and by asset number. This listing also contained the cost, the cumulative cost from the beginning of the listing, description of the item, the year of purchase, manufacturer, model, serial number, and departmental account number. The last four were often useful in locating and identifying the asset.

The building was then divided in half using the cumulative cost column, yielding two halves of equal cost. Each half was considered divided into cost intervals, all of which are equal to one-quarter of the total value to be sampled from the building (this value is the average cost per item in stratum multiplied by 20 and adjusted slightly so that there will be an integral number of cost intervals in each half of the building). Two systematic samples of one interval from each half were then selected. The cumulative cost column in the listing was used in marking off those items which belong wholly or in part to the selected cost intervals. These items were then located and checked by the Equipment Inventory personnel. Note that for the items at the beginning and at the end of the cost interval, only a portion of the dollar value is included in the sample.

The five groups of buildings included all the items to be studied, except for the University's fleet of 526 vehicles, whose listed cost is \$2,270,342. The vehicles are consideraby easier to check than other items, and therefore a large proportion of them was sampled. The consecutive list of the vehicles was divided into 104 blocks of 5 and a block of 6. Ten of these blocks were then chosen at random.

8. Results. Of the 518 sampled assets in the \$300 - \$9,999 category (exclusive of vehicles), 64 were either not located or were no longer in the possession of the department, usable and used. Out of the 50 selected vehicles only 4 were no longer part of the inventory.

At the end of March 1981, the book value of the University's individually tagged items in the \$300 - \$9,999 class was \$36,275,661. On the basis of the survey it was estimated that 91.65% of this value satisfied the criterion of being usable, used, and needed. The estimated standard error of this estimate is 1.81%.

At the same time, there was \$17,038,773 worth of individually tagged items costing at least \$10,000. Of those on record in August 1980, 93.49% (in value) were found to be present and used in the 100% survey. For the purpose of obtaining an estimate for the entire non-MMF&E inventory in March 1981, let it be assumed that 93.49% of the value listed in March 1981 was intact, though this is certainly an underestimate. The total value of the University's non-MMF&E inventory is then estimated to be \$49,166,243 with an estimated standard error of \$657,114. This means that we can assert, at a level of confidence somewhat higher than 95%, that the true value of the individually tagged inventory was at least 48 million dollars in March 1981.

References

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