Measuring geographic variations in hospitals' capital costs

by Gregory C. Pope

The Health Care Financing Administration (HCFA) has proposed incorporating hospital capital payments into the Medicare prospective payment system. HCFA's proposal includes an adjustment to capital payments for geographic differences in capital costs, derived from the prospective payment system area hospital wage index.

Alternatively, the geographic adjustment could be based on an area construction cost index. Geographic construction cost indexes calculated from the cost per square foot of finished structures or from construction labor and materials input prices are evaluated in this article.

Introduction

At the inception of the Medicare prospective payment system (PPS) in 1983, hospital capital-related costs were excluded from the definition of prospectively paid (operating) costs. Capital-related costs have continued to be reimbursed on a reasonable cost or "pass-through" basis. The Health Care Financing Administration (HCFA) has proposed several regulations to incorporate capital costs into PPS, but prospective payment for capital has been repeatedly delayed by Congress.

HCFA's most recent proposed capital regulations include an adjustment for geographic variations in capital costs based on the area hospital wage index used in the prospective payment system. For every 10-percent increase in the wage index, the Federal portion of capital payments would rise by 4.6 percent. In addition, there is a 1.6-percent add-on for hospitals located in large urban areas (*Federal Register*, 1991).

An alternative geographic payment adjustment would be based on an area construction cost index. In an earlier capital proposal, HCFA included a construction cost index that measured the relative cost of finished structures per square foot among metropolitan statistical areas (MSAs) and State rural areas (*Federal Register*, 1987). A weakness of the cost per square foot index is that if the mix of construction is not the same across areas, anomalous and inequitable index values can result. A second type of construction cost index is derived from area construction labor and materials prices (called an "input price index"). This type of index is used by insurance adjusters, engineers, and others in the construction and valuation industries to measure geographic variations in construction costs.

In this article, I evaluate alternative geographic construction cost indexes. Three independent indexes of construction labor and materials prices (input price indexes) maintained by construction cost estimating firms are compared to the cost per square foot index previously proposed by HCFA. HCFA's most recent geographic cost adjuster based on the area hospital wage index is not evaluated in this article; it was proposed well after the research reported in this article was completed.

Need for a cost index

It is sometimes remarked that hospital capital is bought in a national market and that its price does not vary geographically. Reflecting this view, HCFA's original prospective payment proposal for capital considered capital costs "nonlabor," and hence not subject to geographic adjustment (*Federal Register*, 1986).

Although the interest rates and prices hospitals face for movable equipment may vary only slightly across areas, construction costs for buildings and fixed equipment, the largest component of capital expense, vary significantly. The majority of construction expense is labor costs, and wage rates are far from uniform across the country. Pope and Keller (1986) examined geographic variation in construction costs for the Prospective Payment Assessment Commission using the 1986 Dodge Construction Cost Index. They found that construction costs range from 59 percent above the national average in Fairbanks, Alaska, to 35 percent below the national average in West Plains, Missouri, a difference of 93 percent. Construction costs in one-half of the cities surveyed by the Dodge Construction Cost Index were either 10 percent or more below or 9 percent or more above the national average. Regional differences of up to 25 percent were also noted. Overall, the degree of variability in construction costs is similar to that in hospital wages. Because an adjustment is made in PPS for hospital wage differences, an analogous geographic adjustment for capital construction costs in any prospective payment for capital is warranted.

To account for these large differences in construction costs, HCFA's second capital proposal included an area construction cost index to adjust payment for plant and fixed equipment (*Federal Register*, 1987). This index would be used both to standardize for hospital plant and fixed equipment costs in determining the Federal plant and fixed equipment standardize amount, and then to re-inflate the Federal rate for each area in accordance with its construction costs. Algebraically, the Federal portion of the payment for plant and fixed equipment during transition was given by:

$$R_{ij} = FR * DRG_j * CONSTR_i * TRANS * ADJ$$

where

R_{ij} = the Federal portion plant and fixed equipment payment amount for a discharge in DRG_j to a hospital in area i,

FR = Federal plant and fixed equipment rate per discharge;

DRG_j = DRG weight for DRG_j,

$CONSTR_i$ = construction cost index for area i,

$TRANS$ = Federal transition blend percentage, and

ADJ = any applicable adjustment for a particular hospital (e.g., indirect medical education).

The construction cost index had a substantial influence on the Federal capital payment amount, similar to the role of the area hospital wage index in determining reimbursement for labor-related operating expenses. If, for example, the 1988 Dodge Construction Cost Index were used to adjust payments, the Federal plant and fixed equipment payment rate in Anchorage, Alaska would be 88 percent higher than the rate in El Paso, Texas. Even among major cities, the range would be quite substantial. The Federal plant and fixed equipment payment rate for New York City hospitals, aside from any hospital-specific adjustments, would be 57 percent higher than the rate for Atlanta hospitals.

Proposed construction cost index

HCFA used the Dodge/Data Resources Incorporated (DRI) Construction Potentials data base to develop an area construction cost index based on the cost per square foot of finished structures. The Dodge/DRI data contain information on all major building projects throughout the country, including the value of the project, square feet, and start date. The value of the project includes architect and contractor fees, labor and material costs, and sales taxes, but excludes land costs and property taxes. These data are available from 1970 to 1987 by MSA and State rural area.

Ideally, a PPS construction cost index should reflect the cost of building a "standard" hospital in each area.[1] Unfortunately, hospital construction is not frequent enough in many areas to base a construction index on hospitals only, let alone a standard type of hospital. For any year in the Dodge/DRI data base, roughly one-fourth of MSAs or State rural areas do not have any hospital construction. For example, in 1986, 99 out of 365 areas, or 27 percent, lacked hospital construction.[2] For this reason, HCFA contracted with Dodge/DRI to develop a file of nonresidential institutional construction by MSA and State rural area for each year from 1972 to 1986. Types of construction included in the file were:

- Schools and colleges.
- Non-manufacturing-owned laboratories.
- Libraries and museums.

- Hospitals and other health treatment buildings.
- Capitals, courthouses, city halls, and other government service buildings.
- Houses of worship and other religious buildings.

These types of construction were expected to represent geographic variation in hospital construction costs. To calculate the index, HCFA first computed the construction cost per square foot of institutional construction in each area for each of the 15 years. These values were then standardized by a national average value for each year. The 15 annual indexes were then averaged, weighting by annual square feet for each area and year. The final area index was normalized to have a national mean of 1.0 (*Federal Register*, 1987).

The index developed by HCFA has the desirable attribute of exhaustive geographic coverage. By including cost data on nonhospital buildings, HCFA was able to derive index values for all MSAs and State rural areas (although Puerto Rico was not included). Moreover, because HCFA averaged 15 years of data, the index values are generally stable over time (i.e., are similar from year to year).

However, an important shortcoming of the cost per square foot index is that it does not measure variations in the cost of a uniform mix of construction from area to area. The index is based on nonhospital in addition to hospital construction. Even within the hospital category, a mix of different types of construction such as infirmaries and nursing homes is represented in addition to hospitals. In the index, construction costs in one area may be represented by the cost per square foot of a tertiary care medical center, and in another area it may be represented by the cost per square foot of elementary schools. The extent to which the index is biased by failing to hold construction mix constant depends on the variation in cost per square foot among building types and the variation in building mix among areas.

National average construction costs per square foot for various institutional buildings are available from several cost estimating firms. The construction cost data published by these firms is used by insurance adjusters, realtors, architects, engineers, building contractors, and others to estimate costs for various projects. Data were assembled from the three most widely used and respected publications in this area to determine cost per square foot variation among the building types HCFA included in its index (R.S. Means Company, 1988; Dodge Cost Systems, 1987; Marshall and Swift Company, 1988).

Table 1 shows construction cost per square foot variation among and within the building categories that HCFA used in creating the cost per square foot index. Median cost per square foot within each building category provides a summary measure of cost differences among the broad building categories. Ranges, where available, indicate within-category variation. The medians and ranges are for more specific building types within a broader category (e.g., medical centers, nursing homes, and infirmaries within the "Hospitals and other health facilities" category). Because somewhat different specific building types are included in each data source, the medians and ranges are not fully comparable for the R.S. Means Company, Dodge Cost Systems, and the Marshall and Swift Company.

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[1] "Standard hospital" mean one with standard characteristics so that its cost would vary only with area differences in construction costs, not differences in the type of hospital from area to area.

[2] Although all areas had hospital construction at some time during the 15-year period, costs for different years are not comparable because of inflation. To construct a meaningful index, costs must be available for the same time period in different areas.

Table 1
Construction cost per square foot by building category

Building category	R.S. Means Company		Dodge Cost System[1]		Marshall and Swift Company[2]	
	Median	Range	Median	Range	Median	Range
Hospitals and other health facilities	$59	$44-78	$98	$56-193	$105	$57-155
Schools and colleges	50	41-63	65	32-91	74	—
Libraries and museums	55	—	94	74-104	84	—
Capitals, courthouses, city halls, and other government service buildings	58	39-93	103	62-136	98	70-176
Houses of worship	51	42-54	75	—	71	69-128

[1] Cost ranges reflect differences in building quality as well as in building types.
[2] Cost ranges are limited to a particular class of buildings describing most institutional construction, however, cost ranges reflect both quality and type of building differences within this class.

SOURCES: (Dodge Cost Systems, 1986); (R.S. Means Company, 1988); and (Marshall and Swift Company, 1988).

Although there are significant differences among the three sources, they all indicate considerable variation both within and among broad building types. The R.S. Means Company (1988) data show the smallest range in costs. Median costs per square foot range from $50 for schools and colleges to $59 for hospitals and other health facilities, an 18-percent difference. Dodge Cost Systems and the Marshall and Swift Company indicate much larger differences. According to Dodge Cost Systems, schools and colleges cost only $65 per square foot, while government service buildings cost as much as $103 per square foot, a 58-percent difference. The Marshall and Swift Company reports that houses of worship cost $71 per square foot, while health facilities cost $105 per square foot, a 48-percent difference. In all sources, hospitals and other health facilities, along with government service buildings, are the most expensive, reflecting the high costs of building hospitals and jails. Schools and colleges and houses of worship are the least expensive.

Within-category variation is even greater than across-category differences. The cost of hospital and other health facilities ranges from $44 to $78 per square foot according to the R.S. Means Company, which results from the nearly twofold difference between a nursing home and a hospital. In the Dodge Cost Systems data, the range is from $56 for a nursing home housed in a low quality structure to $193 for a medical center in a high quality structure. Holding quality constant, there is still more than a threefold difference between a high quality nursing home ($62 per square foot, not shown in the table) and a high quality medical center. There is also wide variation (between twofold and threefold) among costs per square foot within the government service building category according to the R.S. Means Company and the Dodge Cost System. Similar to Dodge Cost System, Marshall and Swift Company shows wide cost ranges within institutional building categories of twofold to threefold.

If the mix of construction varies among areas, a cost per square foot index could indicate large differences in construction costs where none exists. Because schools, colleges, and houses of worship are considerably less expensive than hospitals, including them in a cost per square foot index with hospitals is not appropriate. In addition, nursing homes are much less expensive than hospitals and should not be included in the same category.

Variations in construction mix among MSAs and State rural areas can be documented from the data HCFA used in compiling its construction cost index. Dodge/DRI supplied these data to HCFA aggregated by hospital/nonhospital categories, so only variations in the share of hospital versus nonhospital construction can be examined. Nevertheless, even this dichotomy provides a useful indication of area variation in mix. Shares of construction were measured by the hospital and nonhospital proportions of square feet of total construction.

During the 15-year period HCFA used to develop the cost per square foot index, the mean MSA share of hospital and other health facility construction was 14.1 percent and the median was 13.5 percent. The hospital share varies from as little as 2.6 percent of total construction in Bloomington-Normal, Illinois, to as much as 37.7 percent of total construction in Jacksonville, North Carolina. Excluding the highest and lowest 10 percent of areas, the share of hospital and other health facility construction still varies from 7.2 percent to 21.5 percent. In particular years, of course, the differences in the hospital share are much greater. In some areas and years, there is no hospital or health facility construction, while in other areas and years it represents 100 percent of institutional construction.

The differences between construction cost per square foot among building types and construction mix among areas are sufficient to create serious bias in a cost per square foot index. For example, suppose that the cost of building a hospital is identical in area A and area B, but that the share of hospital construction in institutional construction is 5 percent in area A, but 25 percent in area B. Further, suppose that the cost per square foot of hospital construction in each area is $150, but is $80 for other institutional construction. Then, institutional cost per square foot is $83.50 in area A (= 0.05 * $150 + 0.95 * $80), but $97.50 in area B (= 0.25 * $150 + 0.75 * $80). A cost per square foot index indicates 17 percent higher costs ($97.50 versus $83.50) in area B when, in fact, costs are identical.

A cost per square foot index could be improved by comparing costs only within building category, insofar as possible. We adjusted the cost per square foot index for the mix of hospital versus other institutional construction across areas.[3] This "mix-adjusted" index is evaluated

[3] Details of this adjustment can be found in Pope, Hurdle, and Posner (1989).

along with alternative indexes. Although this or further refinements may improve the cost per square foot index, sufficient information to fully standardize for type of construction is not available. Comparing within building types alone is not enough because costs can vary greatly by the size (e.g., one-story building versus a two-story building) and quality of construction even for a single building type. Unfortunately, given the intermittent nature of construction activity, data on cost per square foot of narrowly defined categories are not available for many areas in any year (or even during longer time periods). This was the reason HCFA augmented hospital construction data in the first place. Any index based on average construction cost per square foot will be plagued by construction-mix differences among areas. Alternatives to a cost per square foot index should be considered. An index based on the prices of construction inputs (labor and materials) rather than on the final cost of structures is an attractive alternative.

Input price construction indexes

An input price index measures the cost of purchasing comparable input combinations (labor and materials) in different areas rather than the final cost of structures. Its primary advantage is that it is not affected by area differences in the amount or type of inputs used because of construction mix or quality variation.

The disadvantage of an input price index is that it does not directly measure the amount building contractors charge hospitals for construction. In practice, not all of the prices of the hundreds of construction inputs are measured by available input price indexes. Nor are factors such as contractor's profit or markup, overhead, architects' fees, differences in productivity and efficiency, and costs of complying with building codes included. Further, since available input price indexes measure the cost of a fixed market basket of inputs, they do not reflect variations in actual input combinations from area to area because of the cost-minimizing substitution of less expensive for more expensive inputs.[4]

These disadvantages of an input price index must be weighed against its advantage of avoiding construction-mix bias. Construction input prices are probably highly correlated so that a reasonable sample of materials prices and wage rates for construction trades adequately measures input price variation. Substitution bias is likely to be small because the relative prices (or wages) of construction inputs probably vary only slightly by geographic area, and the substitutability of construction inputs appears to be low. Studies of other important indexes, such as the consumer price index and the PPS hospital wage index, have not found substitution bias to be important (Manser and McDonald, 1988; Braithwait, 1980; Pope, 1989).

The lack of data on contractor's profits, overhead and productivity, architects' fees, and the cost of complying

with local building codes is probably the most important limitation of an input price index. According to R.S. Means Company (1988), on average, the contractor's overhead (e.g., permits, workers' compensation, insurance, supervision, and bonding fees) and profit add 15 percent to the cost of a project. Architectural fees (including engineering fees) add about 10 percent on average, but vary from 8 to 14 percent depending on the size of the project. R.S. Means Company (1988) states that ... "overhead will vary with the size of project, the contractors's operating procedures and location. Profits will vary with economic activity, and local conditions ... [Architectural fees] may vary ... due to economic conditions."

Because geographic variations in overhead, profits, productivity, and architects' fees are a result of local market conditions that are presumably beyond the control of hospitals, they ideally should be reflected in the PPS index. Similarly, variations in hospital building costs because of differences in the stringency of local building codes and regulations are beyond the control of hospitals and appropriately would be incorporated into PPS payments.[5] Finally, cost differences as a result of job size are arguably relevant for inclusion into PPS capital payments. For example, if rural hospitals must pay proportionally higher architects' fees or contractor's profit because of small job size, that greater cost ideally should be measured.

Data on geographic variations in contractor's profits and overhead, architects' fees, productivity, and the cost of complying with building regulations are unavailable. Competitive pressures should keep contractor's overhead and profits and architects' fees from varying substantially for long periods of time from area to area. It is difficult to determine how much complying with building regulations affects relative construction costs. Anecdotal evidence (from our telephone conversations with cost engineers) suggests there is some geographic variation in these factors, but there is considerable disagreement and no hard evidence about the magnitude of the differences. Overall, it seems likely that variation in wage rates and material prices accounts for most of the geographic cost differences, with other factors a relatively uniform percent add-on. If this is true, the advantage of no construction mix bias for an input price index outweighs the disadvantage of not measuring all relevant costs.

Several cost-estimating firms maintain indexes of area construction labor and material prices including concrete, brick, structural steel, lumber prices, and wage rates for electricians, carpenters, plumbers, etc. The three most widely used and most comprehensive geographic indexes are maintained by Dodge Cost System, Marshall and Swift Company, and R. S. Means Company.[6] These same three firms published the construction cost per square foot data that was discussed earlier. The indexes are used by insurance assessors, realtors, engineers,

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[4]An input price index can be adjusted to reflect cost-minimizing substitution (Deaton and Muellbauer, 1980), but all available construction cost indexes are fixed-weight Laspeyres indexes, which assume a fixed market basket of inputs.

[5]Because hospitals are built to high safety standards, they presumably exceed building code standards. Therefore, geographic variations in building codes may not affect the relative cost of building hospitals.

[6]The Dodge Building Cost Index should not be confused with the Dodge/DRI data base used by HCFA to develop the cost per square foot index. The former index measures construction labor and materials input prices, while the latter measures the cost per square foot of finished structures.

architects, developers, etc., in building valuation and appraisal. As such, they are regarded as an acceptably accurate measure of geographic variation in construction costs by professionals in the construction field. All of these indexes are fixed-weight, that is, they measure the cost of the same input bundle in all areas.[7]

A disadvantage of these indexes is that each is based on inputs necessary to build a general building type, not a hospital. If the proportions of construction inputs necessary to build a hospital are substantially different from the input mixes the indexes measure, some inaccuracy could be introduced. However, because input prices are probably highly correlated, any bias is unlikely to be significant. A second disadvantage of the three indexes is that they are proprietary, and it is impossible to fully document their construction. Nevertheless, their widespread use in the construction field should be sufficient to obtain their acceptance for use in PPS.

The Marshall and Swift data provide the best single basis for developing a geographic construction input cost index for use in PPS. Because the Dodge Index has been acquired by the Marshall and Swift Company, the Dodge index will apparently not be available after 1988. The R.S. Means index collects data for only 209 cities. These data are extrapolated to an additional 406 cities, but it appears that the R.S. Means index simply repeats index values for many cities. This methodology understates the true geographic variance in construction costs.

A key advantage of the Marshall and Swift index is that index values can be derived for all areas. Marshall and Swift collects data for a large number of areas. In addition, they are willing to compute index values for unrepresented areas if data on local input prices is supplied to them. Another advantage of the Marshall and Swift index is that they attempt to collect nonunion wage rates where such labor is used, better reflecting true costs. They also obtain labor and material prices from multiple suppliers. Moreover, the Marshall and Swift index produces several geographic indexes based on the input mixes used in different types of buildings. Most hospitals fall into their "class A" buildings (fireproofed structural steel frames with reinforced concrete masonry floors and roofs), which have their own geographic index.

A comparative disadvantage of the Marshall and Swift index is that they collect prices for a smaller number of materials and trades than the Dodge index and especially the R.S. Means index. Potentially the most serious liability of the Marshall and Swift index is their use of three regional bases for their index, rather than a single national base. They claim to adjust index values to make them nationally comparable, but they would not reveal exactly what this adjustment is to the author.

The Marshall and Swift, Dodge, and R.S. Means indexes could be averaged over several years to smooth any year-to-year volatility in the data. However, my evaluation of the stability of these indexes, as discussed later, shows little year-to-year variation. Thus, averaging multiple years to ensure stability is not necessary. An alternative to using any of the data sources alone is to take an average of the three. This would smooth any peculiarities in a particular index. I calculate and evaluate an average input price index in addition to indexes based individually on the three data sources.

Dodge, R.S. Means, and Marshall and Swift report input price index values for cities. For use in PPS, cities are not the most appropriate index areas. Construction cost areas should be defined with the following considerations in mind:

• Construction costs should be fairly homogeneous within an area, so that all area hospitals face the same construction costs.
• The areas should not be so small that arbitrary divisions within markets are imposed that would create inequities.
• The areas should be geographically exhaustive; that is, every hospital should have an index value.
• Available data should be adequate to measure relative construction costs in the areas.
• Finally, the areas should be easy to implement and widely understood and have some administrative precedent in PPS or elsewhere.

Pope and Keller (1986) analyzed geographic variations in construction costs as measured by the 1986 Dodge Construction Cost Index. They found that costs are not homogeneous at the national level, within the 4 census regions, within the 9 census divisions, or in the 50 States. Construction cost areas should be disaggregated to at least MSAs and State rural areas to adequately capture cost variation. These market areas account for 91 percent of the variance in the Dodge index. (By way of comparison, census regions account for 46 percent, census divisions for 58 percent, and States for 76 percent.)

Cost differences may exist within MSAs or the State rural areas. The Dodge index does not compute index values for a large enough number of cities to support general tests of cost homogeneity between the urban cores and suburban rings of MSAs or within State rural areas. However, there are reasons not to further decompose MSAs and State rural areas. First, cost differences within these areas, especially within MSAs, do not appear to be large. Dodge Cost Systems (1987), R.S. Means Company (1988), and Marshall and Swift Company (1988) state that index values are generally accurate for a 30-mile radius, roughly the size of a typical MSA. Index values are usually identical or similar when data exist for multiple cities within an MSA. More variation is present in State rural areas, but index values are usually similar. Second, data are not available to support a more detailed breakdown. Most MSAs contain only one city with an index value and most State rural areas contain only a few cities with index values. Third, MSA and State rural areas have a strong administrative precedent in PPS through their use as the geographic areas for the hospital wage index and for HCFA's proposed construction cost index. These areas are well understood and widely accepted, and any further division would be unfamiliar.

The Dodge, Means, and Marshall and Swift city indexes were translated to the MSA level, with rural areas of each State grouped together. If only one city within an MSA or State rural area had a value, this value was taken to be representative of the entire MSA or State rural area. If more than one city in an area had an index value, a population-weighted average of the values was

taken to represent costs in the entire area. Population was chosen as a proxy for the amount of hospital construction activity in an area during long periods of time.[8] Within MSAs, city population was used to weight city index values; county population was used to weight city values in State rural areas.

Evaluation of alternative indexes

The suitability of six alternative area construction cost indexes for use in prospective reimbursement of hospital capital is evaluated in this section. Four are construction labor and materials input prices indexes and two are the cost per square foot indexes. Special attention is paid to whether the nonuniform mix of construction from area to area results in predictable biases in the cost per square foot cost indexes. The indexes are:

- The Dodge input price index.
- The Means input price index.
- The Marshall and Swift input price index.
- The average of the three preceeding indexes (the average input price index).
- The cost per square foot index developed by HCFA.
- The cost per square foot index adjusted for hospital or nonhospital construction mix.

All indexes were translated to an MSA/State rural area basis, and were normalized to have a population-weighted national average of 1.0.

Geographic coverage

An important criterion in evaluating the construction cost indexes is geographic coverage. If an index has poor coverage, many values would have to be imputed or derived from other sources, which is undesirable. Because MSAs and State rural areas are the preferred index areas, coverage of these areas will be emphasized. The cost per square foot indexes derived from the Dodge/DRI data base achieve complete geographic coverage (except for Puerto Rico). Thus, geographic coverage is of concern only for the input price indexes.

The Dodge, Means, and Marshall and Swift indexes (before they were translated to an MSA basis) are all well balanced among MSA and rural cities and among the four census regions. The R.S. Means index has the highest proportion of rural cities (42 percent), the Marshall and Swift index has the lowest (29 percent). The Dodge index has the largest proportion of cities in the North Central (33 percent), the R.S. Means index has the largest proportion of cities in the South (35 percent), and the Marshall and Swift index has the largest proportion of cities in the West (27 percent), especially the Pacific Division (17 percent).

All three indexes attain good coverage of the 320 MSAs (85 percent or more), although none is complete. The Marshall and Swift index does not cover

15 MSAs, or 5 percent; the Dodge index does not cover 45 MSAs, or 14 percent; and the R.S. Means Index does not cover 48 MSAs, or 15 percent. Most MSAs (more than 200 for each index) contain only one city with an index value, although some contain two or more. The MSAs with multiple city values tend to be the larger, more populous ones. The values for these MSAs in the indexes that were created from the Dodge, Means, and Marshall and Swift data are therefore weighted averages of central city and suburban values. In smaller MSAs, the entire MSA is usually represented by one central city value. For each index, 90 percent or more of the 49 State rural areas contain at least 1 city with an index value.[9] The Dodge and Means indexes miss three State rural areas, while the Marshall and Swift index miss five.[10] Some State rural areas contain a substantial number of cities with index values, as many as 21 Dodge cities in rural California. However, for each index, the majority of State rural areas contain five or fewer cities with values. The average input price index attains nearly complete geographic coverage: It has values for all State rural areas and all but six MSAs. In addition to smoothing irregularities in the individual indexes, greater geographic coverage is an advantage of the average index.

Variability of the indexes

Table 2 gives the standard deviations (weighted by population) and selected percentiles of the six construction cost indexes. Recall that each index has been normalized to have a population-weighted national average of 1.0. Their higher standard deviations show that the two cost per square foot indexes are more variable than the four input price indexes (i.e., average input price, Dodge, Means, and Marshall and Swift). This is expected because the cost per square foot indexes reflect variations in construction mix and quality in addition to input prices. Adjusting the cost per square foot index for hospital versus other institutional construction mix only slightly reduces the variance, indicating that most of the mix differences are within these broad categories. The Means index is the least variable of the indexes, which is also expected because many of its index values are repeated from a smaller number of cities for which actual data are collected as noted earlier.

Another manifestation of higher variability because of construction-mix differences is the greater range of the cost per square foot indexes. The cost per square foot indexes have more extreme outliers than the input price indexes. Somewhat surprisingly, the mix-adjusted HCFA index has the greatest range of all. The Means index has the smallest range. The cost per square foot indexes are consistently more variable within smaller areas (not shown in the table) as they are nationally. For instance, the HCFA index has a larger coefficient of variation and range than any of the other indexes among MSAs in seven of the nine census divisions.

Greater variability does not necessarily imply an incorrect measurement of relative construction costs. (The

[8]Because both "old" and "new" capital are paid for under PPS, the appropriate weight measures the relative amount of long-run construction activity, not the amount of new construction in any year. Alternatives to a population weight are the number of hospital beds or the square feet of hospital construction over a long time period (e.g., 30 to 40 years).

[9]New Jersey does not have any rural counties, thus there are 49 State rural areas instead of 50.

[10]In the analysis that follows, no values were imputed for missing areas. These areas were excluded from the computation of the various statistics for a given index.

Table 2

Table 2
Construction cost indexes: Standard deviation and percentiles

| Statistic | Cost per square foot | | Labor and materials prices | | | |
	Unadjusted	Adjusted	Average	Dodge Cost System	R.S. Means Company	Marshall and Swift Company
Standard deviation	0.175	0.167	0.124	0.141	0.107	0.133
Percentiles						
Maximum	1.66	1.69	1.44	1.51	1.35	1.47
95th	1.29	1.24	1.15	1.17	1.14	1.16
75th	1.05	1.05	1.02	1.02	1.01	1.03
50th	0.94	0.94	0.96	0.95	0.95	0.96
25th	0.86	0.86	0.88	0.87	0.90	0.87
5th	0.76	0.78	0.82	0.79	0.84	0.81
Minimum	0.71	0.66	0.77	0.69	0.82	0.77
Range	0.96	1.02	0.68	0.81	0.53	0.69

1.00 = U.S. average

NOTES: The standard deviation is weighted by population. Puerto Rico, the Virgin Islands, and Guam are excluded. The adjusted cost per square foot index is adjusted for hospital or nonhospital construction mix.

SOURCES: (Dodge Cost Systems, 1986); (R.S. Means Company, 1988); (Marshall and Swift Company, 1988); and Dodge/DRI Construction Potentials Data base (for cost per square foot indexes).

Means index, for example, is probably not variable enough.) However, a higher degree of variability within small areas does increase the likelihood that an index suffers from "boundary problems," that is, divergent index values among contiguous or nearby areas that a priori would be expected to have similar values. Boundary problems in a PPS construction index are undesirable because they would lead to substantially different payment rates to nearby hospitals when their costs are not likely to be very different. In addition to being inequitable, large differences in payment rates across boundaries could distort hospital location decisions over long periods of time.

The greater variability of the cost per square foot indexes indicates that they are more prone to boundary problems than the input price indexes. Indeed, it is not difficult to find boundary problems in the cost per square foot index. For example, Yuba City and Sacramento, California, are contiguous MSAs, yet their cost per square foot index values differ by 33 percent (0.88 versus 1.17). In contrast, their average input price index values differ by only 2 percent (1.11 versus 1.13). Among the central Indiana MSAs of Bloomington, Indianapolis, Lafayette, Muncie, Kokomo, Anderson, and Terre Haute, cost per square foot index values differ by as much as 58 percent (0.86 to 1.36), but input prices measured by the average index differ by 5 percent or less (0.95 to 1.00). These examples demonstrate that the cost per square foot index is plagued by severe boundary problems in a number of areas (for more examples see Pope, Hurdle, and Posner, 1989).

Means by geographic area

Table 3 presents population-weighted means of the six indexes by region, metropolitan and rural area, and metropolitan area population. Corresponding values for the PPS area hospital wage index are shown as a

Table 3
Construction cost indexes and prospective payment system (PPS) hospital wage index by region and metropolitan area population

| Area | Cost per square foot | | Labor and material prices | | | | |
	Unadjusted	Adjusted	Average	Dodge Cost System	R.S. Means Company	Marshall and Swift Company	PPS Hospital
Region							
Northeast	1.24	1.23	1.10	1.09	1.08	1.13	1.07
North Central	0.97	0.97	1.00	1.00	0.99	1.00	0.98
South	0.87	0.88	0.88	0.86	0.90	0.87	0.88
West	0.99	1.01	1.10	1.13	1.10	1.08	1.15
Metropolitan area population							
Metropolitan area	1.04	1.03	1.02	1.03	1.02	1.02	1.06
More than 1 million	1.09	1.08	1.08	1.09	1.07	1.07	1.13
0.5-1 million	0.99	1.00	0.97	0.96	0.97	0.97	0.98
Less than 0.5 million	0.96	0.96	0.95	0.95	0.95	0.95	0.96
Rural area	0.88	0.90	0.92	0.91	0.94	0.92	0.82

1.00 = U.S. average

NOTES: Puerto Rico, the Virgin Islands, and Guam are excluded. The adjusted cost per square foot index is adjusted for hospital or nonhospital construction mix.

SOURCES: (Dodge Cost Systems, 1986); (R.S. Means Company, 1988); (Marshall and Swift Company, 1988); and Dodge/DRI Construction Potentials Data base (for cost per square foot indexes).

comparison. The regional results are striking. The cost per square foot of institutional construction is 24 percent higher than the national average in the Northeast, but construction input prices are only 10 percent higher than the national average, according to the average input price index. Conversely, in the West, input prices are 10 percent higher than the national average, but cost per square foot is 1 percent less than the national average.

The cause of these regional differences is not entirely clear. They are not primarily a result of different mixes of hospital versus other institutional construction because that adjustment has little effect on the square foot cost means. One possibility is that the milder climate in the West (especially the Pacific Division) leads to a less expensive type of construction than in the Northeast. If this were true, however, one would expect the South also to have lower costs per square foot relative to input prices than the North Central, which is not the case. A second possibility is that the markup on input prices—profits, architects' fees, productivity—is higher in the Northeast. But since the markup is a small proportion of total construction costs, the magnitude of the difference in markups necessary to account for the regional differences is implausible.

Presumably the Northeast and West difference in cost per square foot versus input prices is because of different mixes or qualities of construction, although some of the factors mentioned above may also contribute. The magnitude of the differences is surprising, as one would not expect construction mix or quality to vary dramatically across areas as large as census regions.

To gain more insight into the Northeast and West difference in cost per square foot versus input prices, several engineers and managers in the medical construction industry were consulted. These experts expressed differing opinions about the source of the regional cost per square foot versus input price difference. Several persons interviewed pointed to the greater degree of unionization in the Northeast as a source of higher costs. However, it is not clear why unionization would differentially affect cost per square foot and input prices because the wage rates gathered by the Dodge, Means, and Marshall and Swift indexes are generally for union labor. More stringent building code regulations in the Northeast were also mentioned, as were differential labor productivity, higher sales taxes, and greater congestion in the Northeast.

In contrast to the regional differences, all the indexes show a similar pattern of increasing costs from rural to metropolitan areas and with greater MSA population. Consistent with its greater variability, the (unadjusted) cost per square foot index has about 2 percent higher values, on average, in metropolitan areas, and about 5 percent lower values, on average, in rural areas, than the input price indexes. Especially noteworthy is the 9-percent difference in cost per square foot between MSAs with populations under 500,000 and rural areas (average index values of 0.96 and 0.88, respectively) versus a difference of only 3 percent (0.95 and 0.92) in the average input price index.

These larger metropolitan and rural differences in costs per square foot create some urban and rural boundary problems in the costs per square foot index. For example, Little Rock (0.90), Pine Bluff (0.92), and Fayettville (0.92), Arkansas, MSAs have index values approximately 25 percent higher than that for rural Arkansas (0.73). In contrast, input prices are virtually identical in metropolitan and rural Arkansas (the average input price index values are 0.83 for rural Arkansas and from 0.82 to 0.85 for Little Rock, Pine Bluff, and Fayettville). Similarly, cost per square foot is 10 to 20 percent higher in Columbus (0.95), Toledo (1.01), and Dayton, Ohio (1.05), than in rural Ohio (.86). Conversely, input prices differ by less than 5 percent between these MSAs and rural Ohio—the average input price index values are 1.01, 1.04, and 0.99 for the three MSAs and 1.00 for rural Ohio.

All the construction indexes show less metropolitan and rural differences than the PPS hospital wage index. Hospital wages are 6 percent above average in urban areas and 18 percent below average in rural areas. In contrast, construction input prices (measured by the average index) are only 2 percent above average in urban areas and 8 percent below average in rural areas. This can be explained by the large materials component in construction costs. Materials prices are much more similar in urban and rural areas than are wages and are even occasionally higher in rural areas because of transportation costs.

Similarity of the indexes

The six construction cost indexes are fairly highly correlated—all population-weighted pairwise correlations exceed 0.7—indicating a reasonable amount of agreement in measuring relative construction costs for particular areas. The input price indexes are highly intercorrelated; the correlations among the Dodge, Means, and Marshall and Swift indexes are 0.91 and 0.94. They consistently measure relative construction costs. The correlations of the input price indexes with the cost per square foot indexes are lower than their intercorrelations. The Dodge, Means, and Marshall and Swift correlations with the cost per square foot indexes range from 0.70 to 0.81. This indicates that input prices and cost per square foot provide a somewhat different measurement of relative construction costs.

Although it is the most widely used measure of association between two sets of numbers (in this case index values), the correlation coefficient gives an incomplete characterization of the relationship among indexes. Two indexes may be perfectly correlated, but have very different values. This will occur if the linear association between the indexes is exact, but the slope from the regression of one on the other is different than 1.0. An alternative characterization of similarity between two of the indexes is obtained by computing the percent difference of the two index values for each MSA and State rural area.

Table 4 presents the average absolute percent difference between the average input price index and the five other construction cost indexes, and also percentiles of the percent differences. The (unadjusted) cost per square foot index differs the most from the average input price index, by 8.9 percent on average, weighted by population. Typically, then, relative construction costs per square foot in an area are nearly 9-percent different from relative input prices. Adjusting for hospital and other institutional construction mix reduces this difference somewhat, to 7.9 percent, but this remains a large

Table 4

Percent difference between alternative construction cost indexes and the average input price index

Statistic	Cost per square foot		Labor and materials prices		
	Unadjusted	Adjusted	Dodge Cost Systems	R.S. Means Company	Marshall and Swift Company
Average absolute percent difference[1]	8.9	7.9	2.6	2.4	2.4
Percentiles					
Maximum	48.8	34.0	11.4	13.2	8.2
99th	41.0	31.1	7.4	7.6	6.8
95th	23.2	20.4	4.9	5.1	5.3
75th	7.5	6.4	1.6	2.4	1.5
50th	-0.4	-1.3	-0.5	0.4	-0.2
25th	-7.0	-6.3	-2.4	-1.3	-2.4
5th	-16.8	-14.6	-6.1	-4.3	-5.3
1st	-20.6	-18.8	-9.3	-5.8	-7.1
Minimum	-32.4	-27.9	-12.8	-6.4	-7.7

[1]Weighted by population.

NOTES: Excludes Puerto Rico, the Virgin Islands, and Guam. The adjusted cost per square foot index is adjusted for hospital or nonhospital construction mix.

SOURCES: (Dodge Cost Systems, 1986); (R.S. Means Company, 1988); (Marshall and Swift Company, 1988); and Dodge/DRI Construction Potentials Data base (for cost per square foot indexes).

discrepancy. Conversely, the three input price indexes differ only slightly on average from their average, all by about 2½ percent. Although different from the cost per square foot indexes, they consistently measure relative construction costs.

For some areas, relative cost per square foot is very different from relative input prices. In a few areas, relative costs per square foot are almost 50 percent higher than or 32 percent lower than relative input prices (refer to the maximum and minimum in the first column of Table 4). In 10 percent of areas, relative cost per square foot is 23 percent higher (the 95th percentile) or 17 percent lower (the 5th percentile) than relative input prices. In many areas, the two types of indexes show moderately different costs. More than one-half of all area index values differ by plus-or-minus 7 percent (the 75th and 25th percentiles). Adjusting the cost per square foot index reduces some of the extreme differences, but they remain quite large.

In contrast, none of the input price indexes differ from their average by more than 13 percent in any area. The Marshall and Swift index had the fewest extreme values: No area differs by more than 8 percent from the average input price index. For the input price indexes, all but about 10 percent of areas are within plus-or-minus 5 percent of the average (the 95th and 5th percentiles). About one-half of all areas are within plus-or-minus 2 percent of the average index (the 75th and 25th percentiles). Although different from the cost per square foot indexes, the three input price indexes provide a consistent, although not identical, measurement of relative construction costs. They contain no real anomalies.

Table 5 displays construction index values for the 20 most populous 1980 MSAs as examples of alternative index values for some important areas. The regional differences between the cost per square foot and input price indexes noted previously are the most striking aspect of these values. For instance, costs per square foot in New York City are 45 percent above the national average, while labor and material input costs are only 27 percent above average according to the average input price index. Conversely, the cost per square foot of institutional construction is 3 percent above average in Los Angeles, but input prices are 18 percent above average. Similar Northeast-versus-West differences are evident for Boston, Pittsburgh, Anaheim, Newark, San Diego, and Oakland. For most of the MSAs, the three input price indexes are very similar. The largest differences are for Nassau-Suffolk, which may have to do with the particular cities measured in these counties (i.e., whether close to New York City or farther out on Long Island).

Anomalous index values

In some areas, the cost per square foot index differs by a very large amount from the average input price index. Some of these anomalies in the former index can be explained by area differences in construction mix. Because hospital construction is more expensive than other construction, areas with high shares of hospital construction will tend to have implausibly high cost per square foot index values. Indeed, some small MSAs dominated by large medical complexes have very high square foot index values relative to otherwise comparable nearby MSAs. During the past 15 years, 29 percent of total institutional construction in Iowa City, Iowa, has been in the hospital and health facility category. The large tertiary care University of Iowa Hospitals are located in Iowa City. In the adjacent and more populous Cedar Rapids, Iowa, hospital construction had only a 12-percent share. This appears to account for the anomalously high Iowa City cost per square foot index value of 1.33, versus the Cedar Rapids value of 0.83. By way of comparison, according to Marshall and Swift, construction input costs in Iowa City are only 3 percent higher than in Cedar Rapids. Similarly, 31 percent of institutional construction in Rochester, Minnesota, home of the Mayo Clinic, was in the hospital category compared with only 15 percent of institutional construction in Minneapolis-St. Paul, Minnesota, a much more populous nearby MSA. This difference in their hospital shares undoubtedly contributes to their anomalous square foot index values of 1.32 (Rochester) and 0.92 (Minneapolis-St. Paul). The Marshall and Swift index values are 1.01 and 1.05, respectively.

Table 5

Construction cost indexes for the 20 most populous metropolitan areas

Area	Cost per square foot		Labor and materials prices			
	Unadjusted	Adjusted	Average	Dodge Cost System	R.S. Means Company	Marshall and Swift Company
New York, New York	1.45	1.45	1.27	1.31	1.21	1.29
Los Angeles, California	1.03	1.01	1.18	1.21	1.17	1.16
Chicago, Illinois	1.08	1.05	1.03	1.02	1.01	1.06
Philadelphia, Pennsylvania	1.14	1.07	1.10	1.14	1.06	1.10
Detroit, Michigan	1.10	1.09	1.09	1.15	1.06	1.05
Boston, Massachusetts	1.30	1.27	1.14	1.16	1.12	1.16
District of Columbia	1.12	1.13	0.97	0.96	0.97	0.99
Houston, Texas	0.83	0.86	0.90	0.89	0.95	0.86
Nassau-Suffolk, New York	1.34	1.38	1.21	1.10	1.22	1.31
Pittsburgh, Pennsylvania	1.27	1.20	1.03	1.07	1.04	0.96
Baltimore, Maryland	1.09	1.10	0.98	0.99	0.97	0.97
Atlanta, Georgia	0.82	0.84	0.87	0.87	0.91	0.83
Minneapolis, Minnesota	0.92	0.94	1.05	1.09	1.01	1.04
Dallas, Texas	0.84	0.84	0.90	0.94	0.92	0.84
Anaheim, California	0.94	0.97	1.17	1.18	1.16	1.16
Cleveland, Ohio	1.16	1.07	1.12	1.13	1.12	1.11
Newark, New Jersey	1.38	1.30	1.11	1.06	1.09	1.17
San Diego, California	1.01	1.02	1.15	1.19	1.14	1.12
St. Louis, Missouri	1.11	1.02	1.01	1.00	1.02	1.02
Oakland, California	1.04	1.09	1.26	1.28	1.27	1.24

1.00 = U.S. average

NOTES: Metropolitan statistical area population rankings are based on 1980 populations. The adjusted cost per square foot index is adjusted for hospital or nonhospital construction mix.

SOURCES: (Dodge Cost Systems, 1986); (R.S. Means Company, 1988); (Marshall and Swift Company, 1988); and Dodge/DRI Construction Potentials Data base (for cost per square foot indexes).

Not all of the implausible values in the cost per square foot index can be explained by extreme shares of hospital construction. Although they have the same share of hospital and other health facility construction, the cost per square foot index value for Pittsfield, Massachusetts, 1.46, exceeds New York City's value of 1.45, in spite of a Marshall and Swift construction input index value of 1.29 for New York versus 1.03 for Pittsfield. Pittsfield is, however, the site of a tertiary care medical center. Such centers have very high construction costs per square foot.

The relatively low costs per square foot of some MSAs in the West compared with some MSAs in the Northeast are also not accounted for by their relative shares of hospital construction. Although they both have high shares of construction in the hospital and other health facility categories, Altoona, Pennsylvania, has one of the Nation's highest institutional construction costs (1.42), while San Francisco (1.01) is only average. In contrast, according to Marshall and Swift, labor and material costs are 37 percent higher in San Francisco than in Altoona. San Diego actually had more construction in the hospital category than Syracuse, New York, but their index values are 1.01 and 1.27, respectively. The Marshall and Swift index, on the other hand, shows San Diego to be about 8 percent more expensive than Syracuse. These unexplained anomalies may arise from building mix differences within the hospital category, or from differences in nonhospital construction mix. For example, if a larger proportion of the hospital and other health facility construction in the West is for nursing homes rather than hospitals, their index values will be lower. Or if certain areas have a higher share of expensive government building construction rather than school construction, they will have implausibly high index values.

Stability of the indexes

One of the attributes of a desirable construction cost index is reasonably stable values from year to year. Although some change is necessary to incorporate new market conditions, large fluctuations are a sign that the index is not accurate and reliable. Moreover, stability gives hospitals a reasonable degree of confidence in the payments they can expect. HCFA averaged 15 years of the Dodge/DRI data base to ensure the stability of the institutional cost per square foot index. The cost of the stability achieved for the HCFA index is that it may not fully reflect current market conditions because some of the data used in computing it is more than a decade old.

How stable are the Dodge, Means, and Marshall and Swift input price indexes? To answer this question, data for the Dodge, Means, and Marshall and Swift indexes were obtained from the previous year. Thus, the Dodge 1986 index was compared with the Dodge 1987 index, the Means 1987 index compared with the Means 1988 index, and the Marshall and Swift April 1987 index compared with the Marshall and Swift April 1988 index. (The comparison of the Means index was dropped after it was discovered that the 1987 and 1988 data were identical.) All indexes were translated to an MSA/State rural area basis. The index values for an area can differ from year to year either because values for particular cities change or because a different subset of cities within an MSA or State rural area have index values for each year.

The Dodge and Marshall and Swift indexes are quite stable from year to year. The year-to-year correlation is 0.99 in both cases, and the population-weighted average absolute percent difference across MSAs and State rural areas is 1.5 percent for the Dodge index and 1.2 percent

for the Marshall and Swift index. For both indexes, index values for 90 percent of MSAs and State rural areas are within plus-or-minus 3.2 percent in the different years. The largest year-to-year difference for any area in the Dodge index is 5.6 percent, and the Marshall and Swift index is 7.3 percent. Because the annual differences are so small, averaging several years of the Dodge or Marshall and Swift indexes to generate a stable index is not necessary. The most recent data can be used to reflect current market conditions without sacrificing stability.

Conclusions

The major shortcoming of the construction cost index that HCFA proposed in 1987 for use in PPS is its lack of face validity. Index values for a number of areas are anomalous, and the average level of the index in the West seems implausibly low compared with the average level in the Northeast. These shortcomings of the cost per square foot index may be explained by its failure to measure the cost of a uniform mix of construction across areas. Although the cost per square foot index could be improved by holding construction mix constant insofar as possible, any index derived from the cost per square foot of actual building projects is likely to be plagued by area variations in the mix and quality of construction.

A promising alternative to a cost per square foot index is one based on construction labor and material input prices. This type of index is not biased by area variations in construction mix and quality. It does fail to measure contractor's overhead, profit, and productivity, architect's and engineer's fees, and other factors in final construction cost, but most of the geographic variation in costs is because of input price differences. Input price indexes are used by professionals in the construction and valuation fields to measure geographic variations in cost. As such, they should have wide acceptance for use in PPS.

Several cost-estimating firms produce geographic indexes of construction input prices that are widely used and respected in the construction field. These indexes provide index values for cities. They can be translated to MSAs or State rural areas by weighting the city values by population. Three independent input price indexes consistently measure relative construction costs with essentially no anomalies.

The Marshall and Swift index is the best basis for a construction input price index to be used in PPS. With a small amount of additional data collection, complete geographic coverage can be attained with this index. Because the index is very stable from year to year, only 1 year of data is necessary to calculate it. The Dodge input price index will apparently not be available in the future, and the R.S. Means index collects data for a much smaller number of cities than the Marshall and Swift index (209 versus 706).

A limitation of the Marshall and Swift index is that it is proprietary. Other things being equal, an index or data from a government source would be preferred. The proprietary nature of the Marshall and Swift index makes it impossible to fully document its construction. In spite of a lack of complete documentation, its widespread use in the construction field should be sufficient to obtain its acceptance.

In its most recent capital proposal, HCFA incorporated a geographic adjustment factor for hospital capital payments based on the PPS area hospital wage index (*Federal Register*, 1991). HCFA considered the Marshall and Swift construction cost index, but concluded that it explained less of the variation in hospital capital costs than the hospital wage index. Also, HCFA felt that the proprietary nature of the Marshall and Swift data was a disadvantage. These are reasonable bases on which to prefer the hospital wage index adjuster. Nevertheless, the Marshall and Swift construction cost index remains a viable alternative that has greater face validity than a hospital wage adjustment, and may be a more accurate and equitable geographic adjustment factor for capital construction costs.

Acknowledgments

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