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CARTOGRAPHY

Thematic Map Design

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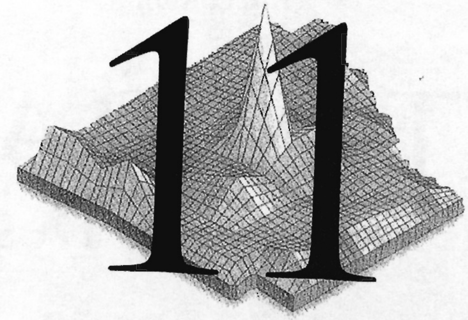
CHAPTER 11



THE CARTOGRAM: VALUE-BY-AREA MAPPING

CHAPTER PREVIEW

Erwin Raisz called cartograms "diagrammatic maps." Today they may be called cartograms, value-by-area maps, anamorphated images, or simply spatial transformations. Whatever name one uses, cartograms are unique representations of geographical space. Examined more closely, the value-by-area mapping technique encodes the mapped data in a simple and efficient manner with no data generalization or loss of detail. Two forms, contiguous and noncontiguous, have become popular. Mapping requirements include the preservation of shape, orientation, contiguity, and data that have suitable variation. Successful communication depends on how well the map reader recognizes the shapes of the internal enumeration units, the accuracy of estimating these areas, and effective legend design. Complex forms include the two-variable map. Cartogram construction may be by manual or computer means. In either method, a careful examination of the logic behind the use of the cartogram must first be undertaken.

We are accustomed to looking at maps on which the political or enumeration units (e.g., states, counties, or census tracts) have been drawn proportional to their geographic size. Thus, for example, Texas appears larger than Rhode Island, Colorado larger than Massachusetts, and so on. The areas on the map are proportional to the geographic areas of the political units. (Only on non-equal-area projections are these relationships violated.) It is quite possible, however, to prepare maps on which the areas of the political units have been drawn so that they are proportional to some space other than the geographical. For example, the areas on the map that represent states can be constructed proportional to their population, aggregate income, or retail sales volume, rather than their geographic size. Maps on which these different presentations appear have been called *cartograms, value-by-area maps, anamorphated images,*[1] and *spatial transformations.*

This chapter introduces this unique form of map. In these abstractions from geographic reality, ordinary geographic area, orientation, and contiguity relationships are lost. The reader is forced to look at a twisted and distorted image that only vaguely resembles the geographic map. Yet cartograms are being used more and more by professional geographers to uncover underlying mathematical relations, general models, and other revealing structures.[2] Cartographers likewise use them for communication of these ideas. Their eventual success as a communication device rests on the ability of the map reader to restructure them back into a recognizable form. Regardless of these complexities, cartograms are popular. Their appeal no doubt results from their attention-getting attributes.

THE VALUE-BY-AREA CARTOGRAM DEFINED

All **value-by-area maps,** or **cartograms,** are drawn so that the areas of the internal enumeration units are proportional to the data they represent. (See Figures 11.1 and 11.2.) This method of encoding geographic data is unique in thematic mapping. In other thematic forms, data are mapped by selecting a symbol (area shading or proportional symbol, for example) and placing it in or on enumeration units. In the area cartogram, the actual enumeration unit and its size carry the information.

Value-by-area cartograms can be used to map a variety of data. Raw or derived data, at ratio or interval scales, census data, or specially gathered data can be mapped in a cartogram. Because of the method of encoding, there is no data generalization. No data are lost through classification and consequent simplification. In terms of data encoding, the value-by-area cartogram is perhaps one of the purest forms of quantitative map, because no categorization is necessary during its preparation. Unfortunately, data retrieval is fraught with complexity, and readers may experience confusion because the base map has been highly generalized.

BRIEF HISTORY OF THE METHOD

As with so many other techniques in thematic mapping, it is difficult to pinpoint the beginning of the use of value-by-area maps. An early version was apparently used by Levasseur in his textbooks in both 1868 and 1875. To quote Funkhouser:

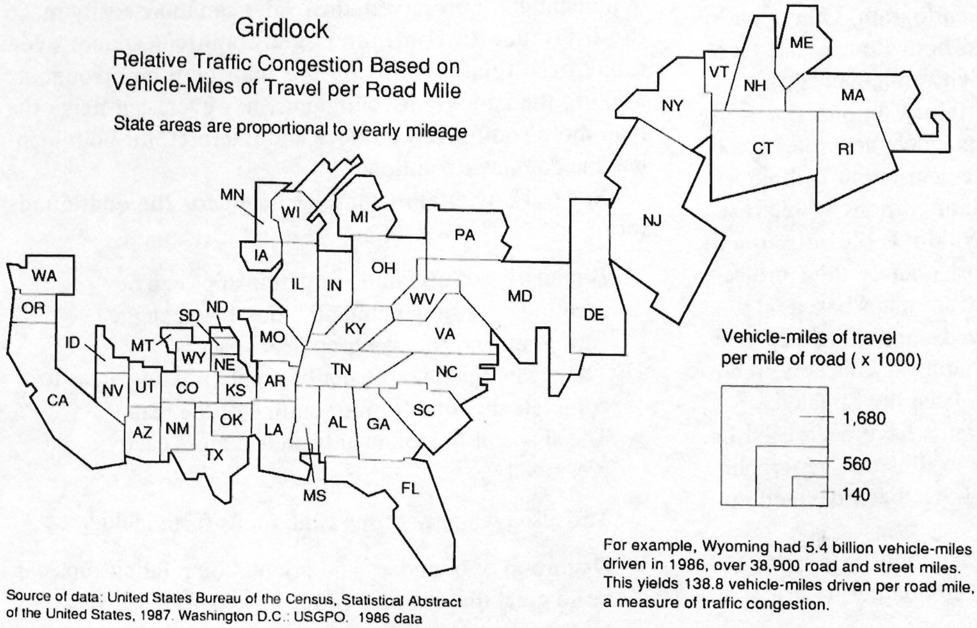


Figure 11.1 Typical value-by-area cartogram.
(Cartogram designed by Bernard J. vanHamond. Used by permission.)

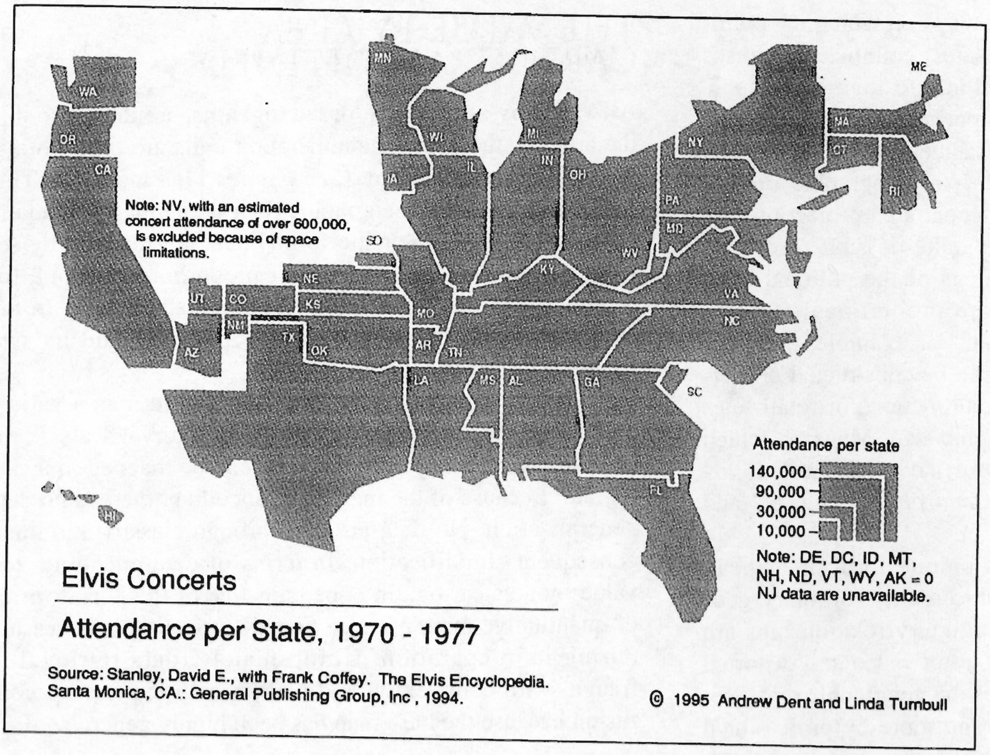


Figure 11.2 Elvis concerts attendance per state, 1970–77. A contiguous value-by-area cartogram showing unique data. This map reveals that unique and rarely mapped data can be the subject of cartogram mapping and can attract unusual attention. *(Map compiled by Andrew Dent and Linda Turnbull, Georgia State University. Used by permission.)*

> *These include colored bar graphs showing the number of inhabitants per square kilometer of the countries of Europe, the school population per hundred inhabitants, the number of kilometers of railroad per hundred square kilometer of territory, etc.; squares proportional to the extent of surfaces, population, budget, commerce, merchant marine of the countries of Europe,* the squares being grouped about each other in such a manner as to correspond to their geographical position. *(Author's emphasis)*[3]

Although not called a value-by-area cartogram by Levasseur, the appearance of the actual graph seems to support the idea that it was indeed such a cartogram. Others have traced the idea of the cartogram to both France and Germany in the late nineteenth and early twentieth centuries respectively.[4] Erwin Raisz was certainly among the first American cartographers to employ the idea; he wrote on the subject 50 years ago.[5] Cartogram construction techniques were treated by Raisz through several editions of his textbook on cartography.[6] In 1963, Waldo Tobler discussed their theoretical underpinnings, most notably their projection system, and concluded that they are maps based on unknown projections.[7] Cartograms have been used in texts and in the classroom to illustrate geographical concepts; their role in communication situations has been investigated.[8]

Since their introduction, cartograms have been used in atlases and general reference books to illustrate geographical facts and concepts,[9] but no book has been devoted entirely to these interesting maps.

This chapter treats area cartograms only. Linear transformations (such as in Figure 1.8 in Chapter 1) are also possible, but are not discussed here.

TWO BASIC FORMS EMERGE

Two basic forms of the value-by-area cartogram have emerged: contiguous and noncontiguous. (See Figure 11.3.) Each has its own set of advantages and disadvantages, which the designer must weigh in the context of the map's purpose.

Contiguous Cartograms

In **contiguous cartograms,** the internal enumeration units are adjacent to each other. Although no definitive research exists to support this position, it appears likely that the contiguous form best suggests a true (i.e., conventional) map. With contiguity preserved, the reader can more easily make the inference to continuous geographical space, even though the relationships on the map may be erroneous. Making the cartogram contiguous, however, can make the map more complex to produce and interpret, for both manual and computer solutions.

Several advantages may be listed for the contiguous form:

1. Boundary and orientation relationships can be maintained, strengthening the link between the cartogram and true geographical space.
2. The reader need not mentally supply missing areas to complete the total form or outline of the map.
3. The shape of the total study area is more easily preserved.

The disadvantages of the contiguous form include:

1. Distortion of boundary and orientation relationships can be so great that the link with true geographical space becomes remote and may confuse the reader.

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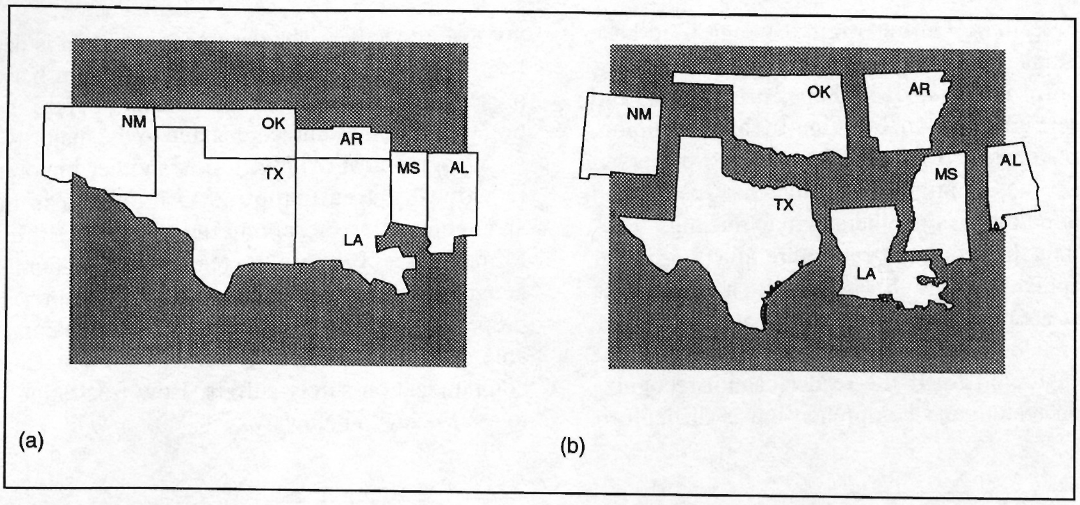

Figure 11.3 Contiguous and noncontiguous cartograms.
Contiguous cartograms like (a) are compact, and boundary relations are attempted. In noncontiguous cartograms, such as (b), enumeration units are separated and positioned to maintain relatively accurate geographic location.

2. The shapes of the internal enumeration units may be so distorted as to make recognition almost impossible.

Noncontiguous Cartograms

The **noncontiguous cartogram** does not preserve boundary relations among the internal enumeration units. The enumeration units are placed in more or less correct locations relative to their neighbors, with gaps between them. Such cartograms cannot convey continuous geographical space and thus require the reader to infer the contiguity feature.

There are nonetheless certain advantages in using noncontiguous cartograms:

1. They are easy to scale and construct.
2. The true geographical shapes of the enumeration units can be preserved.
3. Areas lacking mapped quantities (gaps) can be used to compare with the mapped units, for quick visual assessment of the total distribution.[10]

The disadvantages of the noncontiguous cartogram include:

1. They do not convey the continuous nature of geographical space.
2. They do not possess an overall compact form, and it is difficult to maintain the shape of the entire study area.

MAPPING REQUIREMENTS

Communication with cartograms is difficult at best, because it requires the reader be familiar with the geographic relations of the mapped space: the total form of the study area as well as the shapes of the internal enumeration units. This task may not be too difficult for students in the United States when the mapped area is their homeland and the internal units are states, but how many students in this country are familiar with the shapes of the Mexican states or those of the African nations? Likewise, are European students that knowledgeable about the shapes of the Canadian provinces or the states of the United States? On the other hand, by the very fact that they are unfamiliar with the mapped areas, map readers may pay more attention to the map than they otherwise would.

The situation can even be complex when mapping close to home. How many Tennessee residents know or could recognize the shapes of the counties in Tennessee? Georgia has 159 counties, Texas more than 200. Fortunately, most professional cartographers realize the futility of mapping little-known places with cartograms.

Cartograms can present a unique view of geographical space. Raisz stated many years ago that cartograms "may serve to right common misconceptions held by even well-informed people."[11] Harris and McDowell have suggested that the value-by-area map is a good way to teach about geographical distributions.[12] Tentative evidence indicates that map readers can obtain information from value-by-area maps as effectively as from more conventional forms. For this to happen, however, certain qualities of the true geographic base map must be preserved during transformation. The first of these is the **shape quality.** Preservation of the general shape of the enumeration units is so crucial to communication that the cartogram form should not be used unless some approximation of true shape can be achieved.

Conventional thematic maps are developed by placing graphic symbols on a geographic base map. Regardless of the form of the thematic presentation, the symbols are tied to the geographical unit with which the data are associated. Thus, for example, graduated symbols are placed at the centers of the states. Value-by-area maps, however, are unique in that the thematic symbolization also forms the base map. In a way, the enumeration units are their own graduated symbols, in addition to carrying the information of the conventional base map. On an original geographic base map of, for example, the United States, each state contains four kinds of information—size, shape, orientation, and contiguity. (See Figure 11.4.) In value-by-area mapping, only size is transformed; the other elements are preserved as nearly as possible. Contiguity is somewhat special and may not be as important as the others in map reading.

Individual unit shapes on the cartogram must be similar to their geographical shapes. It is through shape that the reader identifies areas on the cartogram. Shape is a bridge that allows the reader to perceive the transformation of the original. (See Figure 11.5.) If the reader cannot recognize shape, confusion results and comprehension is difficult, if not lost altogether. The designer's problem is deciding how far it is possible to go along a continuum between shape preservation and shape transformation before the enumeration unit becomes unrecognizable to the majority of readers.

Geographical **orientation** is another important element in value-by-area mapping. Orientation is the internal arrangement of the enumeration units within the transformed space. Because the reader must be familiar with the geographic map of the study area to interpret a cartogram properly, the cartographer must strive to maintain recognizable orientation. When distortion of internal order occurs, communication surely suffers. How frustrating it would be to see Michigan below Texas!

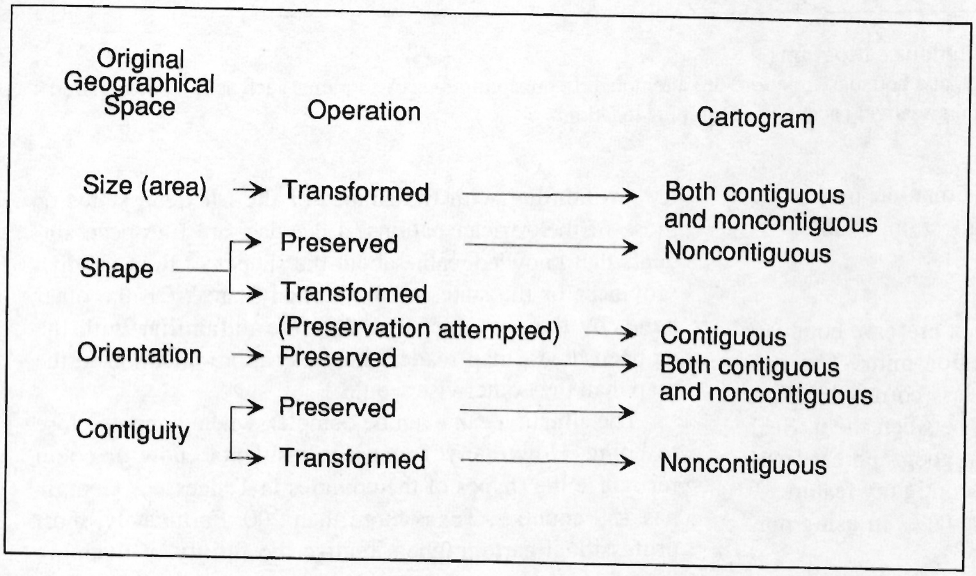

Figure 11.4 Ideal cartographic operations in value-by-area mapping.

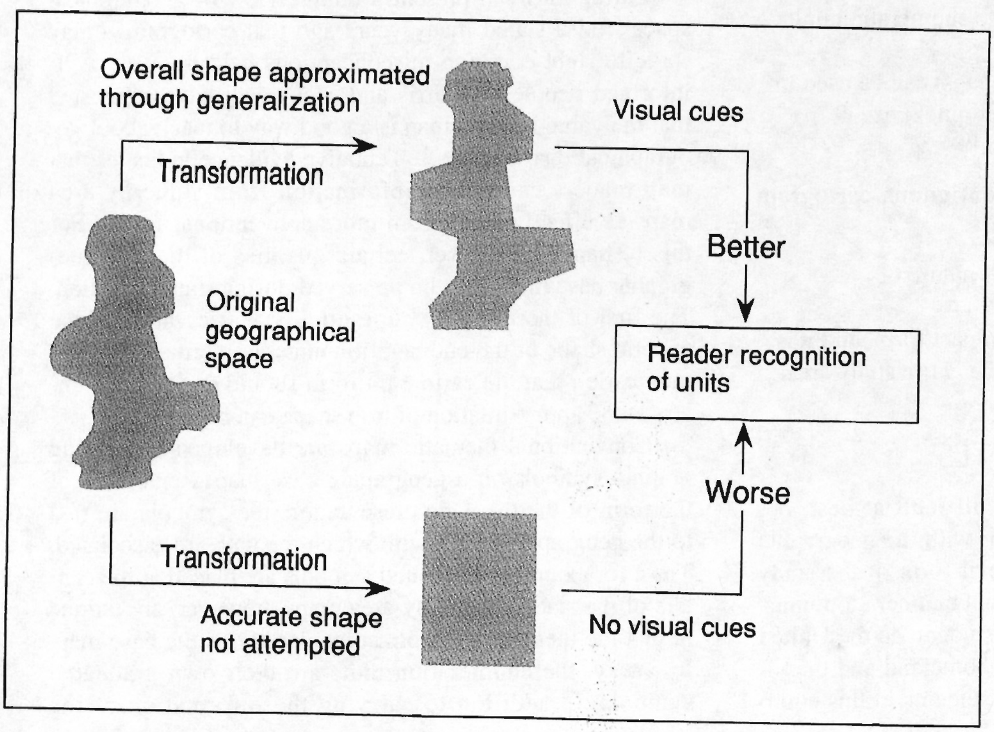

Figure 11.5 The importance of shape in cartogram design. Shape preservation provides necessary visual cues for efficient reader recognition of original spatial units.

Contiguity as an element in cartogram development relates, of course, only to the contiguous form. When producing this kind, it is desirable to maintain as closely as possible the original boundary arrangement from true geographical space. Of the elements mentioned thus far—shape, order, and contiguity—it appears that contiguity is the least important in terms of communication. It is likely that map readers do not use understanding of geographic boundary arrangements in reading cartograms. How many of us, for example, know how much of Arkansas is adjacent to Texas? On noncontiguous varieties, of course, contiguity per se cannot be preserved. It is possible, however, to maintain loose contiguity by proper positioning of the units, although gaps remain between the units.

Of the qualities mentioned (shape, order, and contiguity), shape is by far the most important. Use the value-by-area cartogram technique only where the reader is familiar with the shapes of the internal enumeration units. Do not overestimate the ability of the reader in this regard. Well-designed legends can be helpful, as discussed later in this chapter.

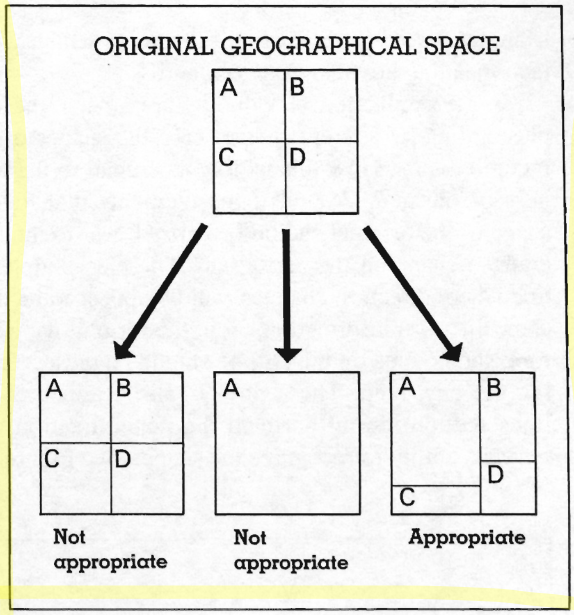

Figure 11.6 Data limitations and value-by-area mapping. If the original data lead to spatial transformation that is unchanged from the original (as on the left), the value-by-area technique is inappropriate. Also inappropriate would be those cases resulting in only one enumeration unit remaining after transformation (as in the center). Most suitable would be those instances when original data are transformed into new spatial arrangements dramatically different from the original (as on the right).

Data Limitations

Although value-by-area maps present numerous possibilities for the communication of thematic data, they are not without their limitations. Within the three principal ways of symbolizing data for thematic maps—point, line, and area—cartograms fall most comfortably into the category of area. Area is the element that must vary within the cartogram, so there are obvious limits outside of which one should not attempt this kind of representation. The limits are dictated by the data and their variability. It would be fruitless to map data that are exactly proportional to the areas of the enumeration units of the geographic base. (See Figure 11.6.) The cartogram would then replicate the original. At the other extreme, there could be a single enumeration unit having the same area as the entire "transformed" space, in which case no internal variation would be shown. No cartogram (or any other map) would be needed. Within these general limits, there exists a range of possibilities.

The chief goal of the cartogram is to illustrate a thematic distribution in dramatic fashion, which requires that the data be compatible with the map's overall purpose. The data set should be compared to the enumeration units on the geographical base. If reversal is evident (large states having small numerical value or vice versa), the cartogram is likely to be worthy of execution. Two measures, the linear regression and rank-order correlation indices, provide a degree of quantitative support. Unfortunately, these methods fall short in that they provide only overall indices of association; they do not indicate variation or agreement between data pairs within the total set. A statistical regression analysis may prove useful, but arbitrary limits must still be selected. More informal ways of determining appropriateness are easily workable.

Whatever procedure is chosen to determine the appropriateness of a data set for cartogram construction, such a determination should always be made before such a map is begun. Those not familiar with such maps often launch into a construction, only to find the results rather disappointing. If the map does not illustrate the distribution in a visually dramatic way, it is best abandoned.

COMMUNICATING WITH CARTOGRAMS

Success in transmitting information by the value-by-area technique is not guaranteed. There are at least three problem areas: shape recognition, estimation of area magnitude, and the stored images of the map reader. The designer should be familiar with the influences of each on the communication task.

RECOGNIZING SHAPES

It is by the shape of objects around us that we recognize them. We often identify three-dimensional objects by their silhouettes, and we can label objects drawn on a piece of paper by the shapes of their outlines. This holds true for recognition of outlines on maps. For example, South America can be seen as distinct from the other continents. The shape qualities of objects that make them more recognizable are simplicity, angularity, and regularity.[13] Simple geometric forms such as squares, circles, and triangles are easily identified. Shapes to which we can attach meaning are also easy to identify.

In the production of value-by-area maps, the cartographer ordinarily attempts to preserve the shapes of the enumeration units. How this is done is crucial to the effectiveness of the map. Many of the elements that identify the shape of the original should be carried over to the new generalized shape on the cartogram. The places along an outline where direction changes rapidly appear to be those that carry the most information about the form's shape.[14] Therefore, such points on the outline should be preserved in making the new map. These points can be joined by straight lines without doing harm to the generalization or to the reader's ability to recognize the shape. (See Figure 11.7.)

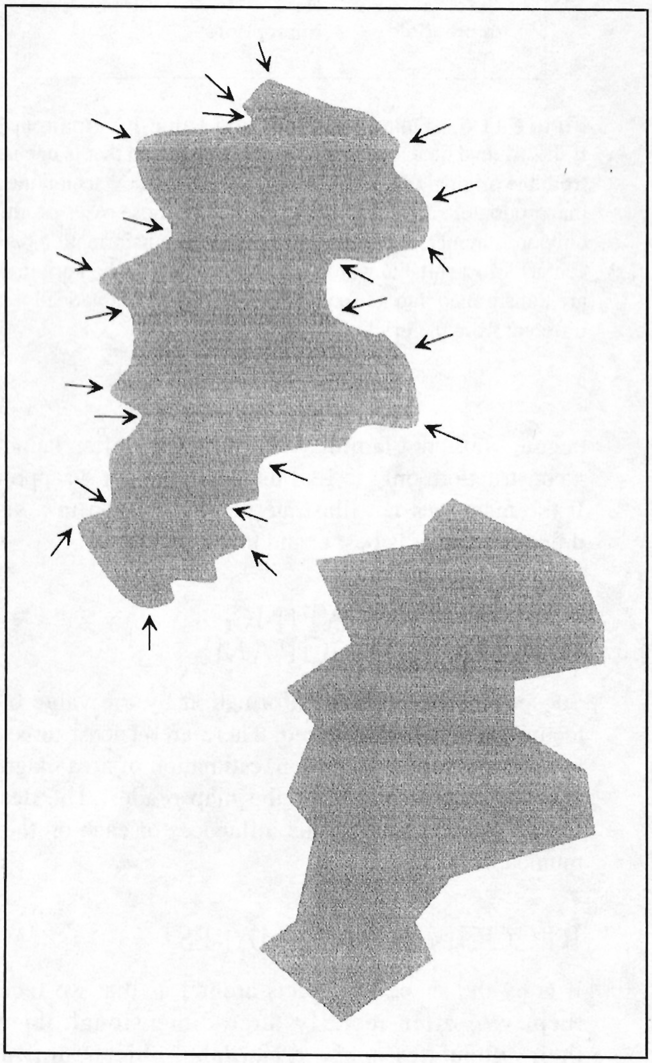

Figure 11.7 Straight-line generalization of the original shape.
Important shape cues are concentrated at points of major change in direction along the outline, as indicated here in the upper drawing. These points should be retained in transformation as a guide in the development of a reasonable straight-line generalization to approximate the original shape, as done here in the lower drawing.

ESTIMATING AREAS

Because each enumeration unit in a cartogram is scaled directly to the data it represents, no loss of information has occurred through classification or simplification. If any error results, it is to be found somewhere else in the communication process—most likely in the reader's inability to judge area accurately. The psychophysical estimation of area magnitudes is influenced by the shapes of the representative areas used in the map legend.

Research suggests that for effective communication of area magnitudes, the shapes of the enumeration units should be irregular polygons (not amorphous shapes) and that at least one square legend symbol should be used at the lower end of the data range.[15] It is best to provide three squares in the legend, one at the low end, one at the middle, and one at the high end of the data range. Of course, the overall communication effort may fail because the distortions from true shapes brought about by the method can interfere with the flow of information.

A COMMUNICATION MODEL

It has been stressed thus far that communicating geographic information with cartograms is difficult unless certain rules are followed. First, shape-recognition clues along the outline of enumeration units must be maintained. Second, if the cartographer cannot assume that the reader knows the true geographical relationships of the mapped area, a geographic inset map must be included. Third, the cartographer should provide a well-designed legend that includes a representative area at the low end of the value range.

These three design elements are placed in a generalized communication model of a value-by-area cartogram in Figure 11.8.[16] In this view, design strategies should accommodate the map-reading abilities of the reader. In Step 1, all the graphic components are organized into a meaningful hierarchical organization so that the map's purpose is clear.

Accurate shapes of the enumeration units are provided in Step 2 by retaining those outline clues that carry the most information—the places where the outline changes direction rapidly.

In the United States, people are exposed from early childhood to maps of the country through classroom wall maps, road maps, television, and advertising. Recently, satellite photographs have added to the already clear images of the country's shape in the minds of the population. How well these images are formed varies from individual to individual. Some people have well-formed images not only of the shape of the United States, but also of the individual states; others have difficulty choosing the correct outline from several possible ones. Successful cartogram communication may well rest on the accuracy of the reader's image of geographical space. Without a correct image, the reader cannot make the necessary match between cartogram space and geographical space. Confusion results if this connection is not made quickly.

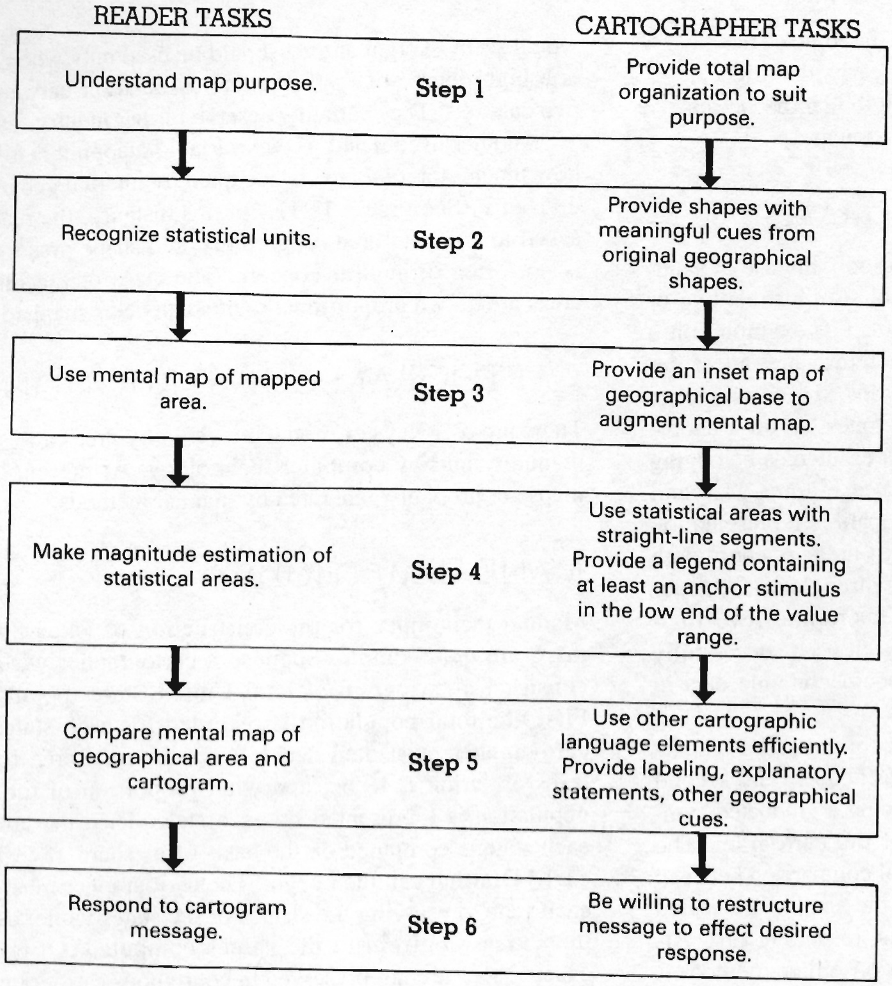

Figure 11.8 Cartographer and reader tasks in a generalized value-by-area cartogram communication model. Many of the steps are likely to occur simultaneously, not sequentially—especially Steps 2 through 5. *(Source: Borden D. Dent, "Communication Aspects of Value-by-Area Cartograms,"* American Cartographer 2 [1975]:*154–68.)*

In Step 3, the readers search through the represented geographic areas in an attempt to match what they see with their stored images.[17] Because the reader's stored images may be inaccurate, the designer should include a geographic map of the cartogram area in an inset map.

The map reader in Step 4 estimates the magnitudes of the enumeration units by comparing them with those presented in the legend. Effective legend design makes this task easier. Anchor stimuli in the legend should be squares, including at least one at the low end of the value range.

In Step 5, written elements, such as labels and explanatory notes, are included to assist the map reader in identifying parts of the map that may be unfamiliar at first. Finally, the designer should be willing to restructure the message to make the communication process better (Step 6). Inasmuch as the cartographer may not know what the reader thinks, because the cartagrapher and reader are usually separated in time and space, the first five tasks become even more important.

Advantages and Disadvantages

Unfortunately, cartograms have not been studied in enough detail to reveal exactly what impresses map readers about them or exactly how they are read. Preference-testing research has discovered that cartograms do communicate spatial information, are innovative and interesting, display remarkable style, and present a generalized picture of reality. Value-by-area maps are often stimulating, provoke considerable thought, and show geographical distributions in a way that stresses important aspects. On the other hand, they are viewed as difficult to read, incomplete, unusual, and different from reader's preconceptions of geographical space. Probably the most serious drawback is that no established methodology leads to consistent results. No two people devise identical cartograms of the same area. (This may be considered a strength rather than a drawback.) For the untrained map reader, the new configurations can cause visual confusion, detracting from the purpose of the map rather than adding to it.

The advantages of this thematic mapping technique are:[18]

1. To shock the reader with unexpected spatial peculiarities.
2. To develop clarity in a map that might otherwise be cluttered with unnecessary detail.
3. To show distributions that would, if mapped by conventional means, be obscured by wide variations in the sizes of the enumeration areas.

Disadvantages include:

1. Some map readers may feel repugnance at the "inaccurate" base map that results from the study.

2. Map readers may be confused by the logic of the method unless its properties are clearly identified.
3. Specific locations may be difficult to identify because of shape distortion of the enumeration areas.

TWO-VARIABLE CARTOGRAMS

The discussion thus far has concerned only the use of a single data set (variable), but it is possible to illustrate two or more data sets on a single cartogram. For example, on a cartogram of the United States in which the states are represented proportional to their populations, the cartographer can render individual states by gray tones, as on a choropleth map. The state areas may be represented as belonging to classes in another distribution. (See Figures 11.9 and 11.10.) This appears to be a very compatible representation of two distributions, as both relate to area. A choropleth map presupposes an even distribution throughout each enumeration unit, as does a cartogram. This form of **two-variable value-by-area cartogram** has been used successfully in mapping the spatial variation of socioeconomic data in Australian cities.[19]

Other second variables can be accommodated on cartograms by graduated point-symbol schemes. The second distribution can be represented by placing a graduated symbol within each enumeration unit of the cartogram. The reader must make the visual-intellectual comparison between the size of the enumeration unit and the size of the scaled symbol. This may be difficult for some readers at first. Although little research has been done on either method, it would seem likely that they should be used only where there is a high degree of mathematical association between the two data sets. They certainly deserve further inquiry.

Another use related to two-variable mapping is to show how much of a total area is occupied by internal geographic divisions. (See Figure 11.11.) In this instance, the reader is asked to compare area proportions, and shape preservation is not often of central concern. The sizes of the internal areas are drawn proportional to the data being mapped.

CARTOGRAM CONSTRUCTION

There are two ways of producing value-by-area cartograms: manually and by computer technology. At present, more maps are probably generated by manual methods.

MANUAL METHODS

Manual techniques for the construction of value-by-area maps are quite simple. Suppose a cartographer wishes to construct a cartogram of total United States population. First, the total population is recorded for each state. The cartographer must then decide what the total area for the transformation is to be, and what proportion of the total population is represented by each state. Then the area for each state is computed on the basis of its share. (See Table 11.1.) Drafting can then begin. The cartographer must draft each state, preserving the shapes of the states while making their areas conform to the values computed. Of course, exact shapes are not preserved in contiguous cartograms.

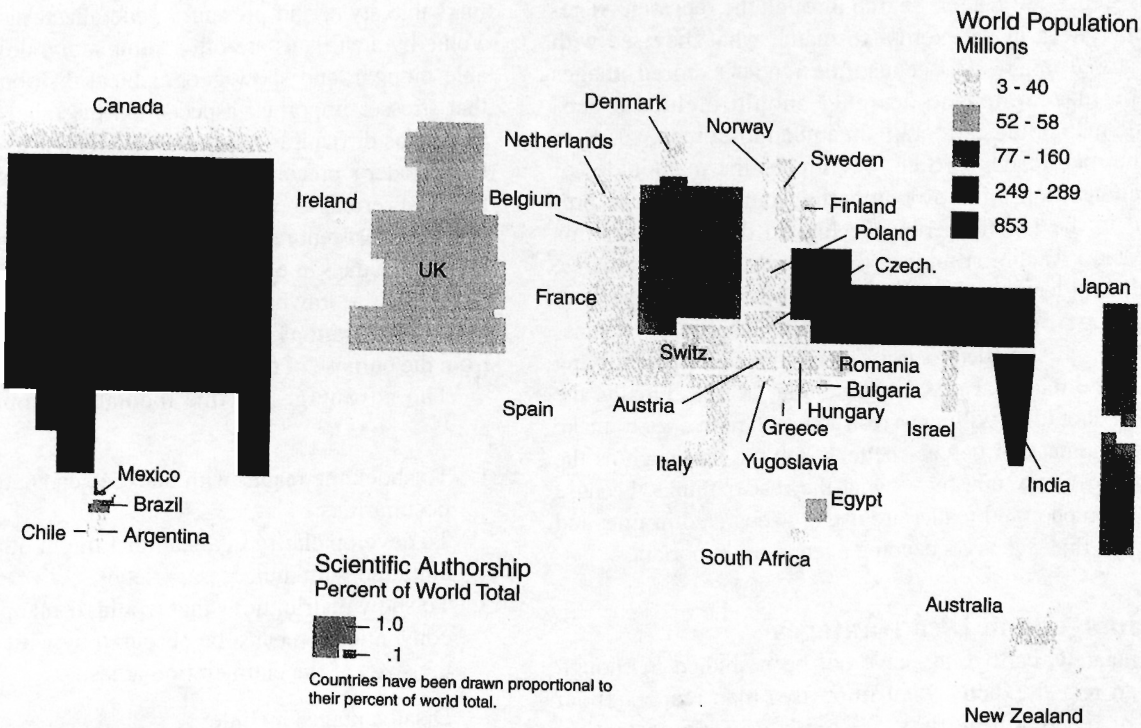

Figure 11.9 Contribution of countries to world scientific authorship.
(Source: Anthony R. deSouza, "Scientific Authorship and Technological Potential" (editorial), Journal of Geography *[July/August 1985]: 138. Reprinted by permission of the National Council for Geographic Education. Population layer added later and not part of the original map.*

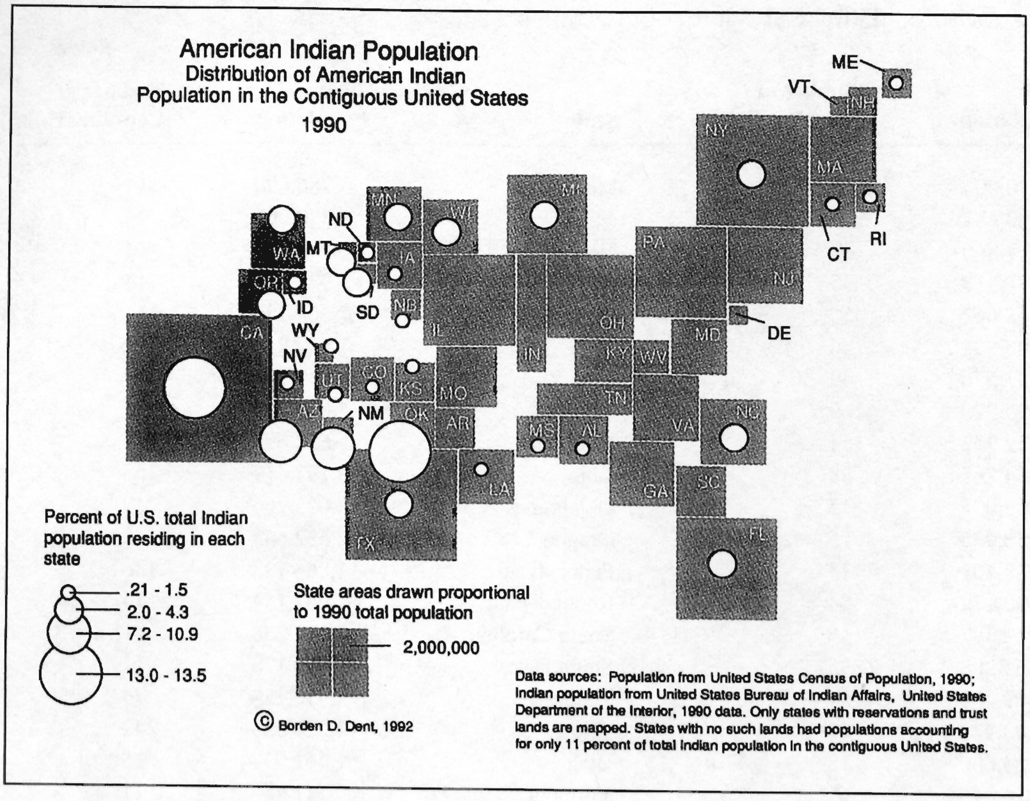

Figure 11.10 Value-by-area cartogram with superimposed distribution. Placing a second variable over a population cartogram may reveal interesting new patterns, or patterns not evident if mapped on geographical space. Experimentation is the key idea. Here it is clear that American Indians are concentrated in these states having relatively small total population (except California).

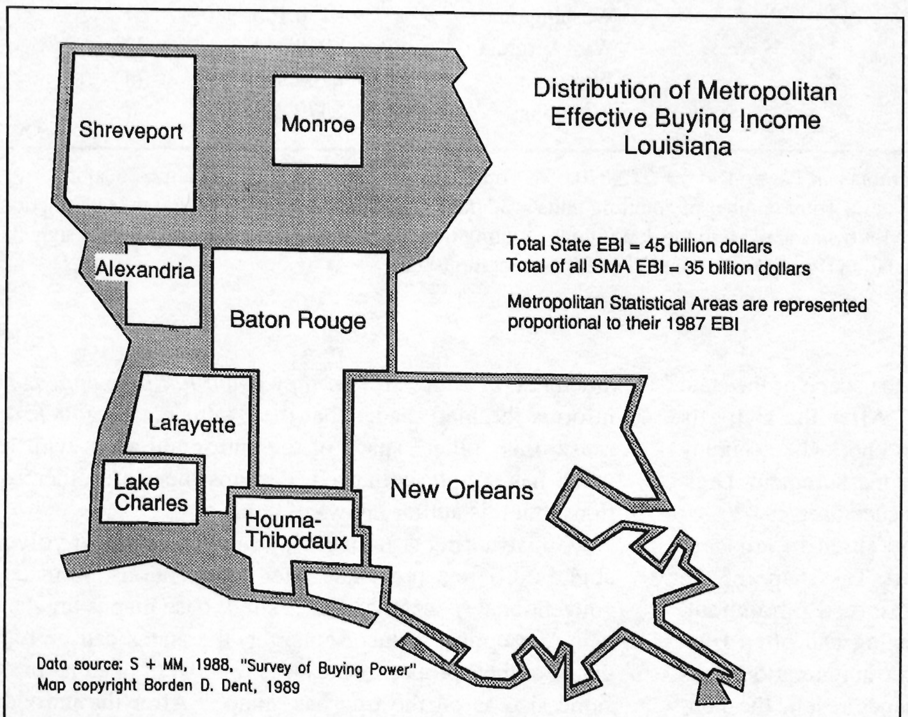

Figure 11.11 Cartogram to show geographical proportion. In this presentation SMAs are drawn proportional to their buying power and are shown relative to the total buying power of the state. Shapes of the SMAs are not as important in this form of cartogram, although relative location is.

To facilitate the drafting of the states, it is convenient to begin by computing what some small areal division represents in terms of population. For example, the population of every .01 square inch can be calculated by dividing the total population into the total number of square inches determined for the cartogram (this unit size is selected simply because of the convenience of obtaining this grid paper). By dividing the population determined for each .01 square inch unit into the state's total population, the number of these .01 **counting units** can be ascertained. The cartographer need only

Table 11.1 Data Sheet for a Population Cartogram of the United States

State	1980 Population	Number of Counting Units	State	1980 Population	Number of Counting Units
Alabama	3,890,006	60	Montana	786,690	14
Alaska	400,481	6	Nebraska	1,570,006	25
Arizona	2,717,866	42	Nevada	799,184	14
Arkansas	2,285,513	35	New Hampshire	920,610	14
California	23,668,562	350	New Jersey	7,364,158	116
Colorado	2,888,834	46	New Mexico	1,299,968	21
Connecticut	3,107,576	49	New York	17,557,288	277
Delaware	595,225	9	North Carolina	5,874,429	91
Florida	9,739,992	154	North Dakota	652,695	11
Georgia	5,464,265	88	Ohio	10,797,419	168
Hawaii	965,935	15	Oklahoma	3,025,266	49
Idaho	943,935	15	Oregon	2,632,663	42
Illinois	11,418,461	175	Pennsylvania	11,866,728	186
Indiana	5,490,179	84	Rhode Island	947,154	14
Iowa	2,913,387	46	South Carolina	3,119,208	49
Kansas	2,363,208	35	South Dakota	690,178	11
Kentucky	3,661,433	57	Tennessee	4,590,750	74
Louisiana	4,203,972	67	Texas	14,228,383	242
Maine	1,124,660	18	Utah	1,461,037	25
Maryland	4,216,446	67	Vermont	511,456	11
Massachusetts	5,737,037	91	Virginia	5,346,279	84
Michigan	9,258,344	147	Washington	4,130,163	67
Minnesota	4,077,148	63	West Virginia	1,949,644	32
Mississippi	2,520,638	39	Wisconsin	4,705,335	74
Missouri	4,917,444	77	Wyoming	470,816	7

Total population (excluding District of Columbia and Puerto Rico) = 222,670,654. Total map area adopted in cartogram = 35 sq in. Counting unit size adopted for project = .01 sq in. Total number of counting units = 3,500. For each state, a ratio of the state's population to the national population was determined. The ratio was applied to the 3,500 total counting units to compute the number of units assigned to the state. For computation in this table, population figures were rounded to the nearest thousand.

arrange these small counting units until the shape of the state is approximated. (See Figure 11.12.) After the shape is achieved, the cartographer may wish to check the accuracy of the state's area by a quick planimeter measurement. Digital readout planimeters are available for such uses.

Each state's shape is adjusted and fitted to adjacent states until the cartogram is completed. The shape of the entire study area must be roughly preserved throughout. This is not difficult but is time-consuming and often frustrating. It is wise to construct the larger enumeration units first, then the smaller ones. If odd shapes result, the noncontiguous cartogram may be selected.

A question is often raised about how to treat enumeration areas with zero value. It is this author's opinion that having two or three areas with zero value should not prevent the map from being made. Those areas having zero values should be omitted from the cartogram, *but their names should be listed in a note at the bottom of the map as having zero values so that they could not be mapped.* This informs the map reader that they were not *forgotten.* In a sense, this "other" space of the cartogram areas with zero value has simply collapsed. Perhaps there are other solutions, but this author knows of none.

Constructing a noncontiguous cartogram involves a slightly different procedure after computations are made. A conventional (generalized, if desired) base map is drawn. By using an optical reducer-enlarger, the states can be reproduced at their proportionate sizes relative to one that has the same size as on the true base map.[20] After the individual state areas are determined and rough shapes are formed, the cartographer positions the state outlines on a draft map to form the shape of the total study area. Relative geographical position of each state is sought. The newly sized states may be positioned in accordance with the centers of the states on a conventional map. Of course, the advantage of the noncontiguous form is the preservation of individual state shapes.

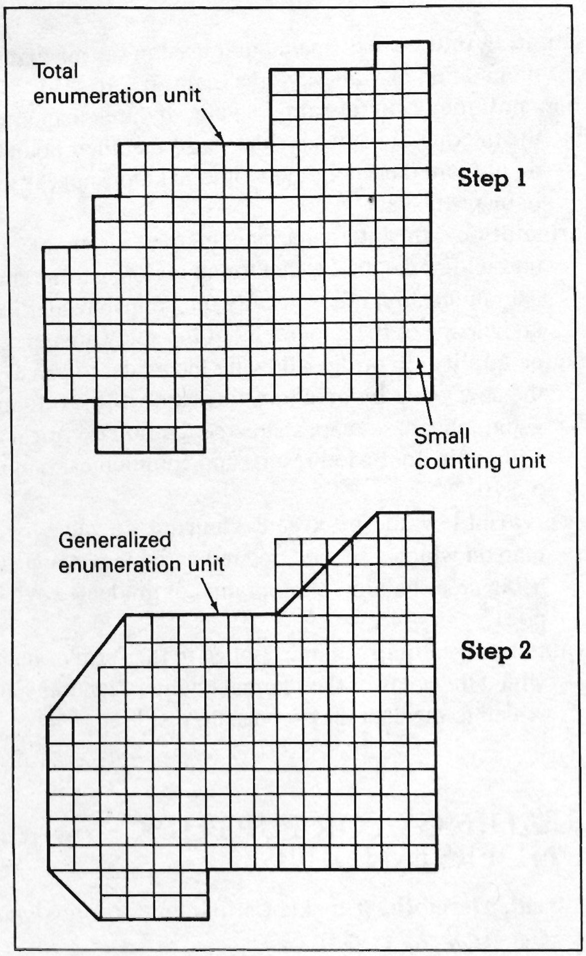

Figure 11.12 Constructing the cartogram.
Small counting units are used to "build" the size and shape of the enumeration units (e.g., countries, states, counties) in Step 1. Step 2 involves smoothing to the approximate final shape.

COMPUTER SOLUTIONS

Computer programs are available for the generation of contiguous spatial transformations, notably one by Tobler,[21] and another by two Russian cartographers, Gusein-Zade and Tikunov.[22] The chief drawback of these programs is their inability to preserve shapes accurately, because the goal is to achieve contiguity and equal densities throughout. They also reduce flexibility in design. For the noncontiguous type, the size of polygons can be scaled in a variety of ways, including the use of optical reducer-enlarger projectors and photocopiers.

Cartograms, and especially computer solutions, can take many forms. Perplexed by what he thought to be inadequate mapping of the British census, social geographer and cartographer Daniel Dorling has experimented with a variety of forms to represent census statistics. He has said, for example, "The information in the census concerns not land but people and households. In visualizing these, a primary aim can be that each person and each household is given equal

Their main disadvantage [of cartograms] is that they are unfamiliar, but we do not learn from familiarity.
Source: Daniel Dorling, "Map Design for Census Mapping," *The Cartographic Journal* 30 (1993): 167–183.

representation in the image."[23] His solution, which was facilitated by computer, was to draw a circle in each ward in Britain so that each circle was proportional to the population that it *represented.* Each circle was placed as nearly as possible to its original geographical neighbor as possible. This solution is quite unique and the final image provides a startling view of the population.

At least one author suggests that computer solutions may not be desirable because "the novelty of an automated approach may lead to intemperate haste in its utilization, whereby both the merits and weaknesses of topological transformation may be submerged in the deluge of products."[24] As in other computer applications in cartography, the machine can greatly reduce time and drudgery of production, but it must not replace or interfere with the designer's choices.

NOTES

1. V. S. Tikunov, "Anamorphated Cartographic Images: Historical Outline and Construction Techniques," *Cartography* 17 (1988): 1–8.
2. Peter Haggett, *The Geographer's Art* (Oxford, England: Blackwell, 1990), pp. 55–56.
3. H. Gray Funkhouser, "Historical Development of the Geographical Representation of Statistical Data," *Osiris* 3 (1937): 269–403: quotation from p. 355.
4. John M. Hunter and Jonathan C. Young, "A Technique for the Construction of Quantitative Cartograms by Physical Accretion Models," *Professional Geographer* 20 (1968): 402–6.
5. Erwin Raisz, "The Rectangular Statistical Cartogram," *Geographical Review* 24 (1934): 292–96.
6. Erwin Raisz, *General Cartography* 2nd ed. (New York: McGraw-Hill, 1948), pp. 257–58; and Erwin Raisz, *Principles of Cartography* (New York: McGraw-Hill, 1962), pp. 215–21.
7. Waldo R. Tobler, "Geographic Area Map Projections," *Geographical Review* 53 (1963): 59–78; see also Waldo R. Tobler, *Map Transformations of Geographic Space* (unpublished Ph.D. dissertation, Department of Geography, University of Washington, Seattle, 1961), p. 146.
8. Borden D. Dent, "Communication Aspects of Value-by-Area Cartograms," *American Cartographer* 2 (1975): 154–68.
9. There are numerous examples of such atlases. The following are particularly interesting: Tony Loftas, ed., *Atlas of the Earth* (London England,: Mitchell Beazley,

1972); Rezine Van Chi-Bonnardel, *The Atlas of Africa* (New York: Free Press, 1973); and Michael Kidron and Ronald Segal, *The State of the World Atlas* (New York: Simon and Schuster, 1981); cartograms have also been used to explore ways of presenting census data, as found in Danial Dorling, "Map Design for Census Mapping, *The Cartographic Journal* 30 (1993):167–83.
10. Judy M. Olson, "Noncontiguous Area Cartograms," *Professional Geographer* 28 (1976): 371–80.
11. Raisz, "The Rectangular Statistical Cartogram," pp. 292–96.
12. Chauncey Harris and George B. McDowell, "Distorted Maps. A Teaching Device," *Journal of Geography* 54 (1955): 286–89.
13. Borden D. Dent, "A Note on the Importance of Shape in Cartogram Communication," *Journal of Geography* 71 (1972): 393–401.
14. Ibid.
15. Borden D. Dent, "Communication Aspects," pp. 154–68.
16. Ibid.
17. Searching stored map images was addressed in an early paper: Borden D. Dent, "Postulates on the Nature of Map Reading" (paper presented at the annual meeting of the Georgia Academy of Science, 1976).
18. T. L. C. Griffin, "Cartographic Transformation of the Thematic Map Base," *Cartography* 11 (1980): 163–74.
19. Ibid.
20. Olson, "Noncontiguous Area Cartograms," pp. 371–80.
21. Waldo R. Tobler, "A Continuous Transformation Useful for Districting," *Annals* (New York Academy of Sciences) 219 (1973): 215–20.
22. Sabir M. Gusein-Zade and Vladimir S. Tikunov, "A New Technique for Constructing Continuous Cartograms," *Cartography and Geographic Information Systems* 20 (1993):167–73.
23. Dorling, "Map Design for Census Mapping," pp. 167–83; see also Daniel Dorling, "Visualizing Changing Social Structure from a Census," *Environment and Planning* 27 (1995):353–78; and Daniel Dorling, "Cartograms for Visualizing Human Geography," in eds. Hilary M. Hearnshaw and David Unwin, *Visualization in Geographical Information Systems,* (New York: Wiley, 1994), pp. 85–102.
24. Griffin, "Cartographic Transformation," pp. 163–74.

GLOSSARY

cartogram name applied to a variety of representations; used synonymously with value-by-area map or spatial transformation, p. 208

contiguous cartogram a value-by-area map in which the internal divisions are drawn so that they join with their neighbors, p. 209

counting unit small spatial unit used in the manual preparation of value-by-area maps, p. 216–217

noncontiguous cartogram a value-by-area map in which the internal divisions are drawn so that their boundaries do not join their neighbors; internal units appear to float in mapped space, p. 210

orientation the internal arrangement of the enumeration unit within the total transformed region; cartogram communication relies heavily on the map reader's knowledge of the geography of the study area, p. 211

shape quality a bridge allowing the reader to perceive the new value-by-area transformation of the original geographic base map; shape recognition is critical—without it, confusion results and communication fails, p. 210

two-variable value-by-area cartogram a value-by-area map on which a second, related variable is mapped using area shading (chorograms) or graduated symbols, p. 215

value-by-area map name applied to the form of map in which the areas of the internal enumeration units are scaled to the data they represent, p. 208

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