CHAPTER 12

DYNAMIC REPRESENTATION: THE DESIGN OF FLOW MAPS

CHAPTER PREVIEW

Maps that show linear movement between places are called flow maps and, because of this quality, are sometimes referred to as dynamic maps. Symbols on quantitative flow maps are lines, usually with arrows to show direction, that vary in width. Some flow lines are uniform in thickness and these are often referred to as "desire lines." Flow mapping began with maps done by Henry Drury Harness in 1837. Little flow mapping was done by government agencies in the United States in the nineteenth century, but with the impetus supplied by the study of economic geography, flow mapping became common in geography textbooks in the early decades of the twentieth century. Flow maps used in textbooks are divided into three classes: radial, network, and distributive. Particular attention must be paid to total map organization and figure-ground principles when designing flow maps because of their complex graphic structures. The projection for the flow map, line scaling and symbolization, and legend design are the chief design elements in flow mapping. Unique solutions, including computer graphics, should be explored in the design stages of producing a flow map.

THE PURPOSE OF FLOW MAPPING

Maps showing linear movement between places are commonly called **flow maps,** or sometimes **dynamic maps.** Flow line symbolization is used when the cartographer wants to show what kind of (qualitative) or how much (quantitative) movement there is between two places. For the quantitative variety, the widths of the flow lines, or bands, connecting the places are drawn proportional to the quantity of movement represented. Any time the cartographer wishes to show movement between places, and has the data to support this theme, a flow map is appropriate. Its purpose may be to show movement of actual items, or movement of ideas.

In most instances, except for the *desire line* case, the cartographer attempts to show the actual route taken by the movement, although this may be difficult because of map scale and the level of generalization selected for the map. Actually, because of the nature of the symbolization process, and the inherent complexity of these maps, all flow line maps become highly generalized. In the last edition of his book, Raisz places them into a class of maps called cartograms.[1] However, not to be confused with value-by-area cartograms, flow maps would be more correctly called linear cartograms.

Flow line symbols may be used on maps to show nonquantitative movement, as mentioned earlier. The lines are unscaled and generally have arrowheads to indicate direction of movement. Lines are usually of uniform thickness. Maps showing shipping routes, airline service, ocean currents, migration flows, and other similar presentations are examples. Early nonquantitative flow maps date back to the late eighteenth century. (See Figure 12.1.) It is possible to map different types of flow data on one map by using different line characters.

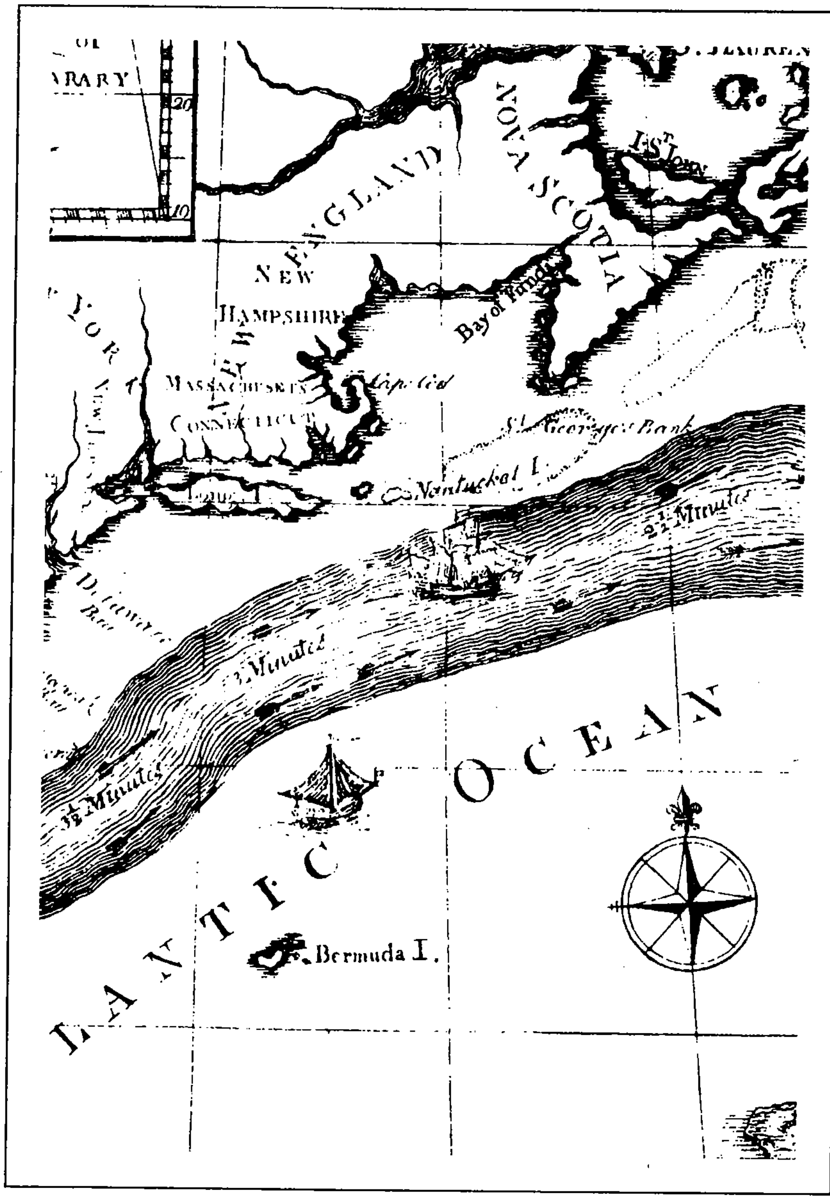

Figure 12.1 Chart of the Gulf Stream, commissioned by Benjamin Franklin, 1786. An early nonquantitative flow map.

QUANTITATIVE FLOW MAPS

Lines on quantitative flow maps are scaled such that their widths are proportional to the amounts they represent. (See Figure 12.2.) Weight, volume, value (dollar), and amount or frequencies are often the units used on quantitative flow maps. Data may be in nominal, ordinal, or interval levels. Absolute or derived values may be used. Direction may or may not be shown on the flow lines. International commodity flows are frequently mapped by quantitatively scaled lines, such as overseas movements of grains, ores, and produce. In many instances, the cartographer does not place amounts on the maps (as in a legend), but relies on the map reader to judge relative amounts visually. (See Figure 12.3.) However, direction of movement is frequently important, so arrowheads are likely part of the symbolization.

Traffic Flow Maps

Mapping traffic flows is uniquely suited to flow line symbolization and is the oldest form of this kind of map. Varying line widths are used to symbolize the number of vehicles passing over portions of rail, water, road, air, or even bird flyways. (See Figure 12.4.) The number of vehicles passing a certain point over the last 24 hours is a typical example. A state traffic map, for another example, may show flow bands proportional to the annual average 24-hour traffic volumes. It is common to see **traffic flow maps** without directional symbols. They are often used to show the organizational and hierarchical nature of urban systems.[2]

Desire Line Maps

Desire line maps represent a special case of quantitative flow map and are unique in that they do not attempt to portray the actual routes followed or the type of transportation used.[3] Typically, they illustrate social or economic interaction by use of straight lines connecting points of origin and destination. (See Figure 12.5.) Often desire lines represent the movement of one person between points (and a number of pairs are drawn on the same map), but they can be drawn between enumeration units and in that case symbolize aggregated movement data. In the former, each line has the same width, and in the latter, line widths are scaled to magnitudes as in typical flow mapping.

The application of desire line maps is best found in those instances where nodal geographical patterns are to be focused on, or possibly where urban hierarchies are being stressed.[4] They have been used frequently in this latter instance to show shopping or commuting structures.

Demarcation between flow maps and desire line maps is often not a clear division. Because of limitations of scale and the inherent generalization that takes place in symbolization, not to say anything about the lack of data,

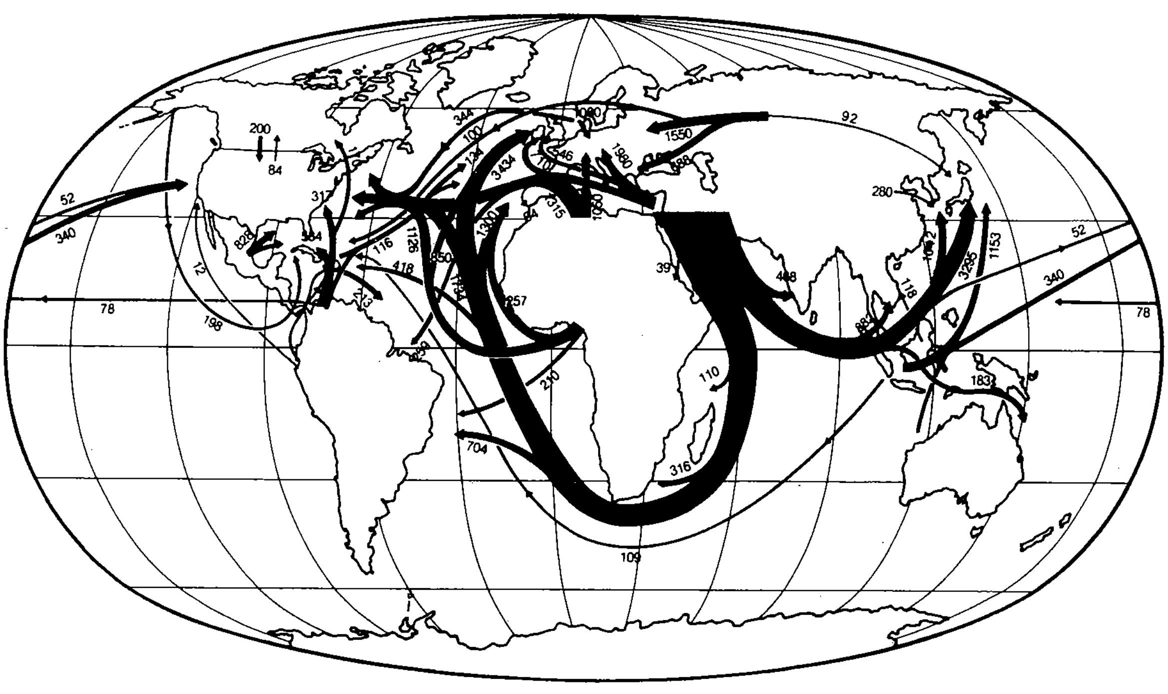

Figure 12.2 International crude oil flow, 1980 (thousand barrels per day).
No legend is used on this map, but the lines are labeled to indicate the magnitude of flow. (*Source: U.S. Department of Energy, Energy Information Administration,* 1981 International Energy Annual.)

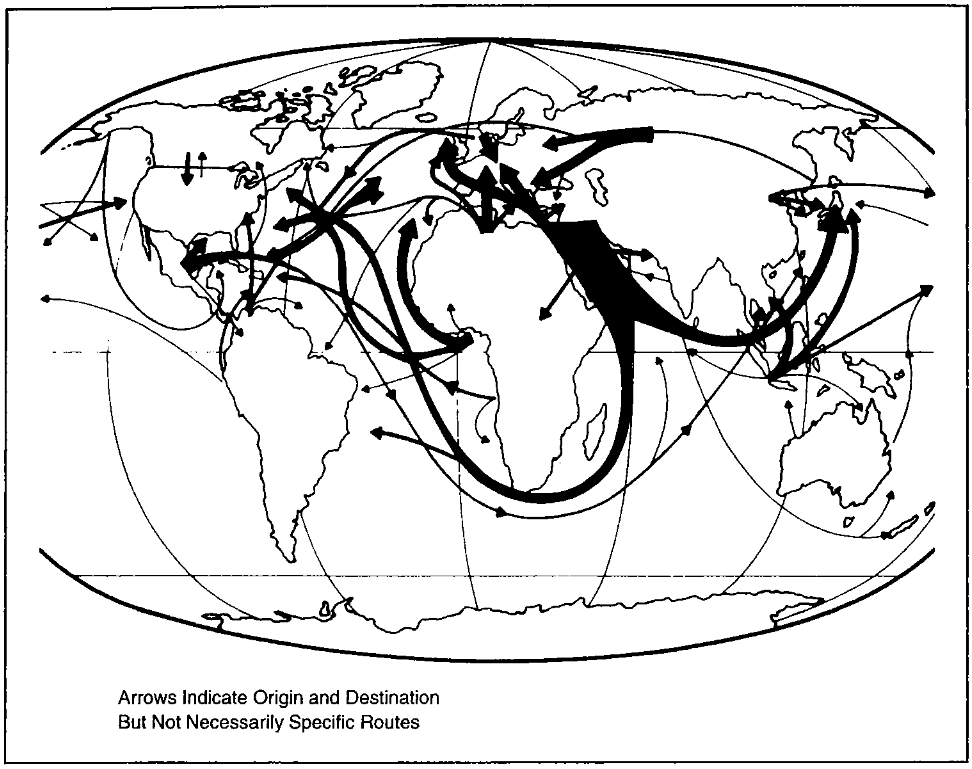

Figure 12.3 International crude oil flow, 1985.
No legend appears on the map and the magnitude of flow lines is not labeled. The reader is to gain an overall impression of the pattern of distribution. (*Source: U.S. Department of Energy, Energy Information Administration,* 1986 International Energy Annual.)

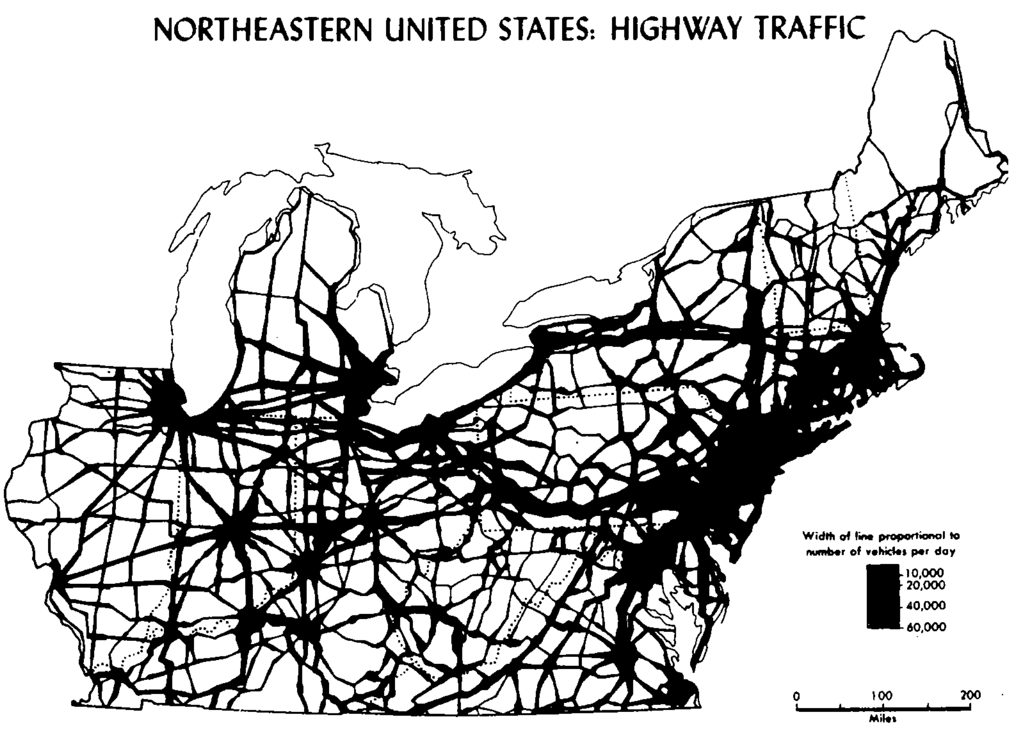

Figure 12.4 A typical traffic flow map.
In many instances such as this, direction of flow is not mapped. Width of lines shows number of vehicles passing in both directions for a specified time period. (*Reprinted by permission of Prentice Hall, Inc.*)

it is often impossible to show exact routes. Generalized, often diagrammatic, routes that may look like desire lines are selected for flow line maps, although the cartographer sets out to do something else. As with other forms of mapping, the purpose of the map will set the stage and ultimately dictate choices.

HISTORICAL HIGHLIGHTS OF THE METHOD

Our discussion here is limited by space and coverage, but a few remarks about the history of flow mapping are necessary to place this form of mapping in the correct historical

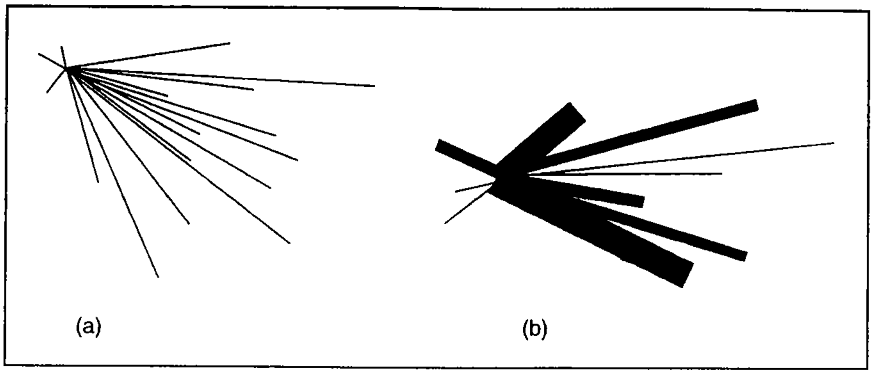

Figure 12.5 Desire line maps.
In (a), the lines are of uniform thickness (often joining origin and destination of the traveler). In (b), the desire lines vary in thickness based on aggregate interaction.

perspective. Quantitative flow mapping began in the "golden age" of statistical cartography in western Europe, in the two decades preceding the middle of the nineteenth century. Never prevalent in agency mapping in the United States, this form of map was utilized heavily in economic geography textbooks throughout the first half of the twentieth century.

EARLY FLOW MAPS

Early statistical cartography had its start in the late 1700s, although a few such maps appeared before that time. One notable entry before the late 1700s was the famous isogonic maps made by Halley in England in 1701.[5] Another was the first contour map showing depths in the English Channel made by Phillippe Buache in France in 1752.[6] By the late 1700s and early 1800s, however, a variety of statistical maps had begun to emerge. By 1835, western Europe had entered the "golden age" of geographic (statistical) cartography, a period lasting until roughly 1855.[7] It should be pointed out that little statistical mapping took place in the United States before 1850.[8]

The earliest quantitative flow maps apparently were done by Henry Drury Harness when he prepared the atlas to accompany the second report to the Railway Commissioners of Ireland in 1837.[9] On one map the relative number of passengers in different directions by regular conveyance was shown, and on the other, the relative quantities of traffic in different directions. In both instances the widths of the flow lines or bands were drawn proportional to the mapped quantities. Actually, the data were derived values. On the traffic conveyance map, the width of the lines is proportional to the average number of passengers weekly. These maps did not show exact routes, but showed straight lines of varying thicknesses connecting points (cities and towns). The maps of Harness remained unknown for nearly a century.[10]

Within 10 years of the production of the flow maps of Harness, Belpaire of Belgium and, more notably, Minard of France began publishing flow maps of essentially similar designs to those of Harness.[11] Charles Joseph Minard was more productive than Belpaire, and Minard's interests were primarily in the areas of economic geography. Minard apparently had no contact with geographers or cartographers, although he was instrumental in popularizing the flow line technique among statisticians. By his own account, he was interested in showing quickly, by visual impression, numerical accuracy,[12] so much so that he often overgeneralized other portions of his maps so that the flow lines themselves would command attention. This design aim is still relevant today. Although Minard did not invent the flow map, one contemporary authority has said that he did bring "that class of cartography [flow maps] to a level of sophistication that has probably not been surpassed."[13]

Minard produced some 51 maps, most of which were flow maps.[14] The mapped subjects of the flow maps were varied, and included such topics as people, coal, cereal, mines, livestock, and others. He mapped the distribution or flow of these commodities not only in France, but worldwide as well. His style, especially on the maps showing movement of travelers on principal railmaps in Europe (1862), is the same as is used today. Perhaps the most unique and provocative of his illustrations is the flow chart showing the demise of Napoleon's army in Russia; as suggested by Tufte, "It may well be the best statistical graph ever drawn."[15]

FLOW MAPS IN ECONOMIC GEOGRAPHY

From the time of Harness, Belpaire, and Minard quantitative flow maps have been used to map patterns of distribution of economic commodities, people (passengers), and any number of measures of traffic densities. As suggested earlier, the flow maps of Minard reached a sophistication of technique never really matched by others since. There was a period of time, however, in the decades of the first half of this century, when a great many quantitative flow maps appeared in college economic geography textbooks, and in many cases with laudable design techniques.

In a study of flow mapping in college geography textbooks by M. Jody Parks, several hundred flow maps were found among 71 books published between 1891 and 1984.[16] Although the author did not consult all books in this category in this time period (an enormous task), the study is remarkable for its breadth and attention to detail, and summarizes carefully the findings of the study and includes numerous examples of this kind of mapping. Although used extensively in this publishing medium, in general flow mapping lagged behind other forms of thematic mapping techniques.[17]

It is interesting to note from the study done by Parks that qualitative flow maps appeared in these books as early as 1891, and that this form outnumbered the quantitative form by three to one.[18] Qualitative flow maps are used to illustrate migration routes, explorer routes, and transportation networks. Desire line maps as a category of qualitative flow maps are used also, especially after 1960. The earliest quantitative maps, from those textbooks studied by Parks, appeared in 1912. Transportation themes are most often illustrated by the quantitative flow maps, especially international import and export of agricultural commodities.[19]

The study by Parks yields a classification of flow map design, including these three distinct patterns: radial, network, and distributive.[20] **Radial flow maps** are easily distinguished by a radial or spokelike pattern, especially when the features and places mapped are nodal in form. Present-day traffic volume maps fit into this category. (See Figure 12.6a.) **Network flow maps** are those used to reveal the interconnectivity of places, especially evidenced by transportation or communication linkages. (See Figure 12.6b.) Airline route maps are good examples.

Flow maps in the third class include those that present the distribution of commodities or migration flows. These are called **distributive flow maps.** Trade flows, such as shipments of wheat among countries, is a good example of this form. (See Figure 12.6c.) Maps that show diffusion of ideas or things are included in this class. Maps illustrating diffusion are often found in textbooks on cultural geography.

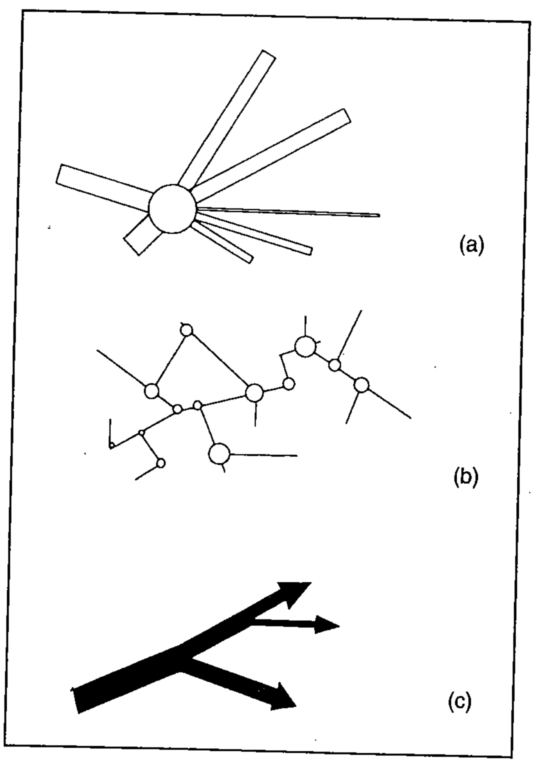

Figure 12.6 Classification of flow line maps in geography textbooks.
A radial type is illustrated in (a), the network type is represented in (b), and the distributive type in (c).

Topics mapped by the flow line technique are quite varied, and suggest the innovation often employed by cartographers and geographers in using this method. Railway and airline route maps are common (showing interconnectivity between places). Shipments of natural gas, wheat, animals, migration of people, ore, coal, and cotton are just a few examples of the topics commonly represented on flow maps. Trade flows of marine harvests is yet another. Migration routes, such as those taken by American Indians, and the French, Spanish, and English peoples in settling the New World, and other topics have been mapped by the flow map technique. There are few subjects that contain a from-to relation that cannot be mapped by flow symbolization.

This brief examination of flow maps in textbook cartography is intended to provide only a backdrop to the fascinating study of this form of mapping. Space will not permit a detailed presentation of hundreds of examples and the rich variety of design found among these maps. The student of thematic map design is urged to explore examples from the actual textbooks themselves. A worthwhile design activity can be found in such an experience.

DESIGNING FLOW MAPS

Creating effective flow maps through a careful and thoughtful design plan represents one of the more difficult challenges for the map designer. Three aspects of design must be considered: map organization and figure-ground (including the selection of the projection), line symbolization and data scaling, and legend design.

MAP ORGANIZATION AND FIGURE-GROUND

The map's hierarchical plan must be carefully considered. It seems apparent that the flow lines, or desire lines, are to be the most dominant marks on the map. As with other forms of thematic mapping, they should be placed high in the hierarchy so that they clearly stand out as strong figures. (The topic of the visual hierarchy and map design is dealt with in greater detail in the next section, "Designing Thematic Maps.") Several figures in this chapter, notably Figures 12.2 and 12.3, illustrate this idea. However, achieving this hierarchy is sometimes difficult because the flow lines may stretch over several different levels on the maps. For example, lines may first be over land, then water, then land again, and so on. They may intersect other flow lines, creating confusion for the reader.

As with other thematic symbol types, and as explained in the next section, flow lines should have strong edge gradients and be rendered so that visual conflict with other symbols does not result. (See Figure 12.7.) Interposition, which can be achieved easily by not having transparent symbols, is a technique often helpful in designing strong symbols. In the case here in Figure 12.7, rendering the flow lines black (or nontransparent white) is a way to improve the thematic symbols on this map.

Flow maps are ordinarily quite complex visual graphics. On most thematic maps the organization of the graphic

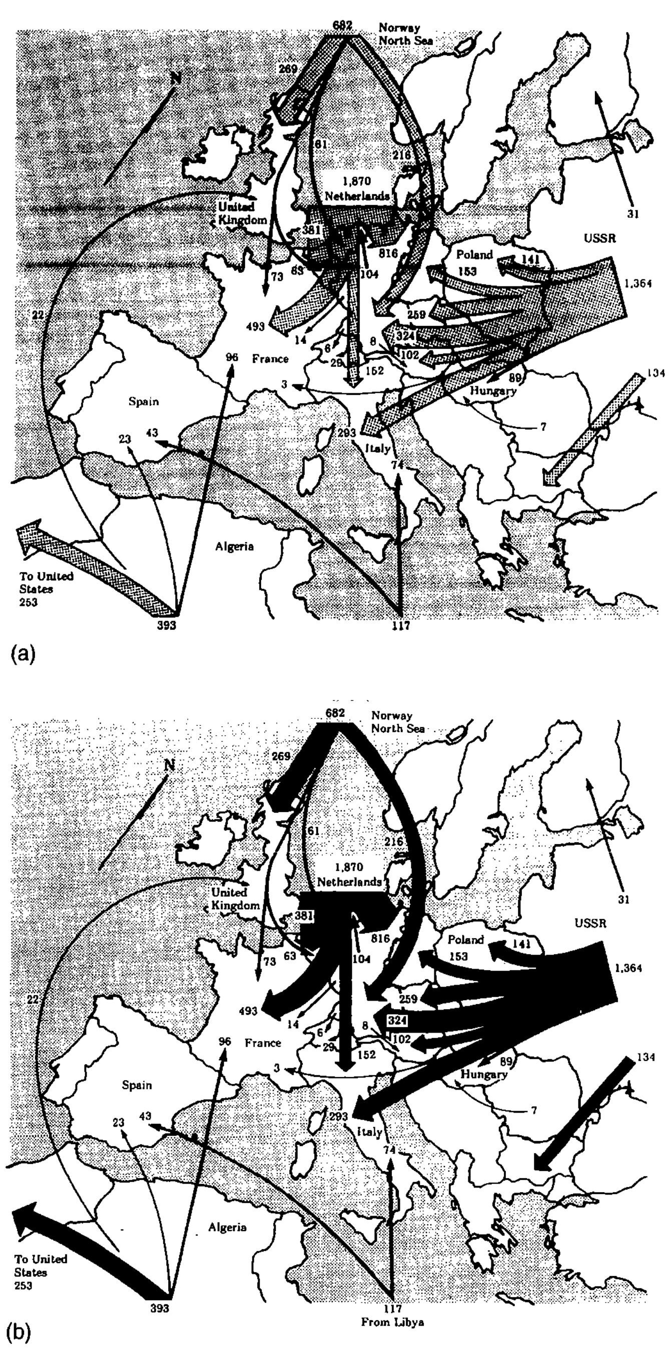

Figure 12.7 Flow lines that lack strong figure characteristics. The flow lines in (a) could be stronger figures by either eliminating the coastlines and boundaries beneath them or by rendering them as black symbols, as in (b). (*Source: U.S. Department of Energy, Energy Information Administration,* 1981 Annual Report to Congress, *vol.* 2 Energy Statistics, *p.112.*)

components, land and water, symbols, titles, legends, and other marks on the maps tends to fall neatly into an easily followed plan. Land and water contrasts are developed by following figure-ground principles, and symbols usually occupy space over land areas. Titles and legends are dealt with similarly. But on many flow maps, especially those illustrating international movements, the thematic symbols are likely to occupy spaces over land or water, or both, and many times the lines themselves are intertwined and appear to rest in different visual levels. The nature of the visual complexity on many flow maps, then, creates unusual and challenging design problems for the cartographer.

Minimally, the cartographer should provide clear land and water distinctions on flow maps. The flow symbols must be dominant figures in perception, with strong edge gradients and clear continuity. Labeling flow lines with their values, often useful to assist the reader, should not interfere with the symbol's visual integrity. Using patterns or screens on flow symbols should not lead to confusion with other areas on the maps. The scaling of the flow lines should not cause them to be too large for the maps, which can result in too little base-map information showing through. Attention to design details such as these will assist the cartographer in reaching successful results.

Projection Selection

Perhaps of equal importance to that of achieving a good visual hierarchy on the flow map is the necessity of selecting an appropriate projection. Placement of the center of the flow, if there is a center, must be strategically planned and this may require careful consideration of the projection, its center, and aspect. Placement and design of the flow lines should be done so that the map does not become an incomprehensible mesh of confusing lines. (See Figure 12.8.) For flow mapping, the equal-area and conformality attributes of projections may not be as important as other factors, such as continental shapes.[21]

Selecting a projection, adopting its center, choosing an aspect for it, and placing it in the map frame must all be considered when developing a flow map. The final map that results from these choices should be one that connotes organization and control of the image, and deftly satisfies the purpose of the map. It is the responsibility of the cartographer to know the flow pattern he or she wishes to portray, then make decisions regarding the projection that best illustrates this pattern. For example, if the flows are single origin to multiple destinations, or if the pattern reflects multinodal origins and a single destination, the employment of the projection should complement the pattern.

Balance and layout of the map's elements conclude the design activities related to achieving the visual and intellectual plans for the map. Placement of map objects and utilization of space are dealt with so that a pleasing result is reached, which is defined as one in which no other solution seems merited. The map's elements, as with other thematic map forms, are placed in intellectual order and treated graphically to satisfy the plan. Titles, legends, scales, source materials, and other elements are therefore treated accordingly. However, the thematic symbols—the lines themselves—remain the most important features of the map, and all other elements are second in importance.

Essential Design Strategies

A summary of the essential design strategies for flow maps should include these principles:

1. Flow lines are highest in intellectual and therefore highest in visual/graphic importance.
2. Smaller flow lines should appear on top of larger flow lines.

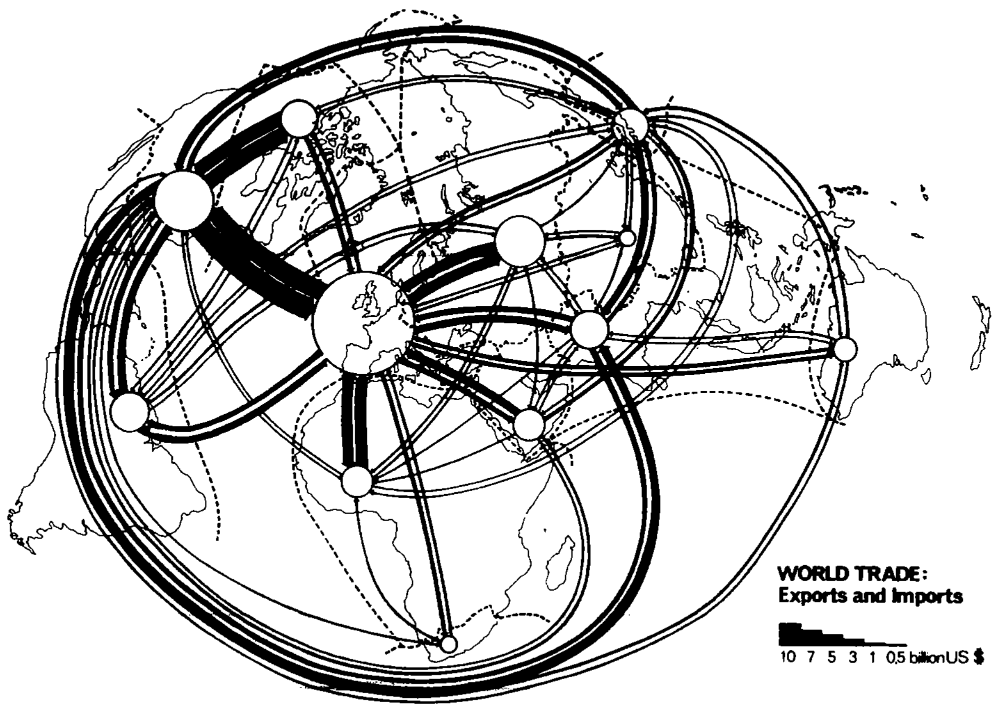

Figure 12.8 World trade: Net exports, 1967. The selection of the projection (uncommon in this case), its orientation in the map frame, and the nature of flow distribution all contribute to a confusing array of lines. (*Reprinted by permission of Van Nostrand Reinhold Company, Ltd.*)

3. Arrows are necessary if direction of flow is critical to map meaning.
4. Land and water contrasts are essential (if the mapped area contains both).
5. Projection, its center and aspect, are used to direct readers' attention to the flow pattern important to the map's purpose.
6. All information should be kept simple, including flow line scaling.
7. Legends should be clear and unambiguous, and include units where necessary.

LINE SCALING AND SYMBOLIZATION

On most quantitative flow maps the widths of the flow lines are proportionally scaled to the quantities they represent. Thus, a line representing 50 units will be five times the width of one symbolizing 10 units. This practice has been employed since the time of Harness, Belpaire, and Minard. Perceptually, the reader is being asked to make this visual judgment, and ordinarily most readers can do this in a linear fashion.[22] Scaling, therefore, appears to be straightforward and should not pose severe problems for the designer.

Chief among the concerns for the designer is the data range that must be accommodated by the widths selected. In many instances this imposes considerable restraint on the project. Ordinarily the best plan is to select the widest line that can be placed on the map (and still preserve the integrity of the base map), and then determine, by looking at the data range, the narrowest line on the map. If the widest line is 1.27 cm (.5 in), and the data range is 5,000 units, then the smallest line would be .000254 cm (.0001 in), obviously too small to draft on the map sheet. Either the widest line would have to be enlarged, already determined to be unacceptable, or some other solution would need to be reached. It is important to note, too, that as the linear symbols become wider, they cease to appear as such, and may take on the qualities of area symbols. This limit should be avoided. There appear to be three ways out of this dilemma: abandon the map in favor of some other form, provide a standard line to represent values below a certain critical value (and symbolize the remaining values by conventional methods), or range grade the values and symbolize the resulting classes by scaling the flow lines proportionally to the midpoint of the classes. In some cases, both the second and third options can be combined on the same map. (See Figure 12.9.)

Other methods in addition to proportionally scaling line widths have been used to symbolize flows. One method is a dot method in which small dots, each representing a unit of flow

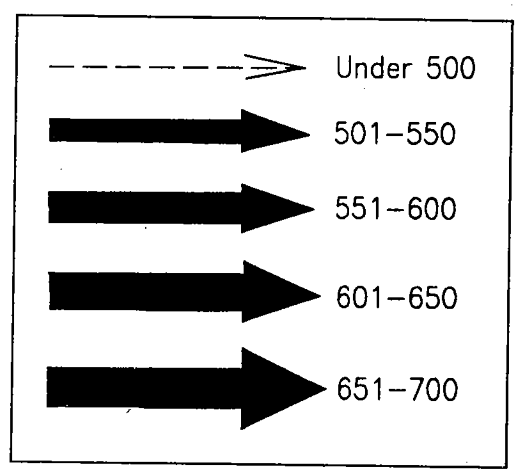

Figure 12.9 Use of a standard line in scaling flow lines. When the data range is too great to scale all flow lines proportionally, a standard line may be selected to symbolize several values.

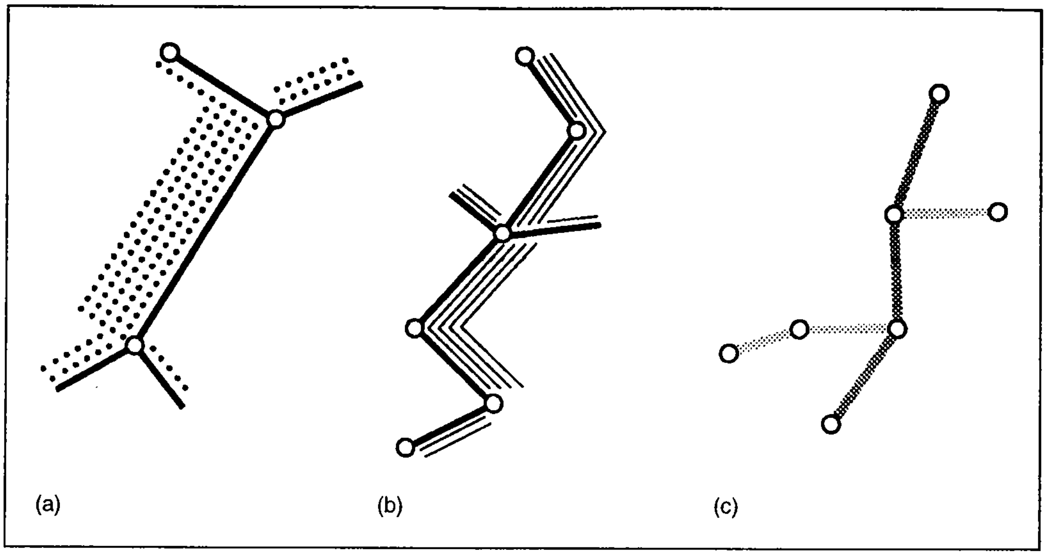

Figure 12.10 Alternative methods of symbolizing quantitative flow lines.
In (a), dots symbolizing a unit of flow are placed alongside two actual routes. In (b), parallel lines are used, with each line representing a unit of flow. Finally, in (c), lines of uniform thickness are given area patterns based on numerical classes.

(for example, 100 vehicles), are placed along the route.[23] Visual impression of volume differences is quickly noted, routes are easily followed and, if necessary, the reader can count the dots to retrieve actual magnitudes. (See Figure 12.10a.)

One other method is to render several lines of uniform thickness parallel to the route, and provide the proper number of these lines to represent the volumes. (See Figure 12.10b.) This method yields results similar to the conventional method and, in addition, the individual lines can be counted for greater precision, if necessary. One disadvantage to this method is that compilation is more difficult and time-consuming.

Yet one other scaling solution can be reached by a method analogous to applying patterns to choropleth maps. In this method, broad lines of uniform thickness are drawn connecting points in the mapped space and, depending on the numerical class into which the line segment falls, are given an areal pattern.[24] (See Figure 12.10c.) Areal symbols are selected as they are in choropleth mapping; that is, higher values are represented by darker (higher percent area inked) patterns or screens. Color may be used instead of patterns or screens to represent the different classes. Here different color intensities of the same hue would be selected to represent the different classes. If the segments were classified into different nominal classes, however, different hues may be chosen.

This list of alternative scaling methods for flow lines is not meant to be exhaustive, but rather to be representative. Enterprising designers will no doubt add to these possibilities and newer solutions may be forthcoming. Regardless of the method, however, the scaling method must visually suggest proportional flow and do so easily.

Treatment of Symbols

No rules have emerged that govern how flow lines should be treated graphically in all maps. The only convention appears to be the way distributive flow lines are treated. (See Figure 12.11.) When mapping flows that separate into smaller flows, the widths of the individual branches should add up to the width of the trunk. This makes intuitive sense. The same applies when smaller branches come together to make a larger one.

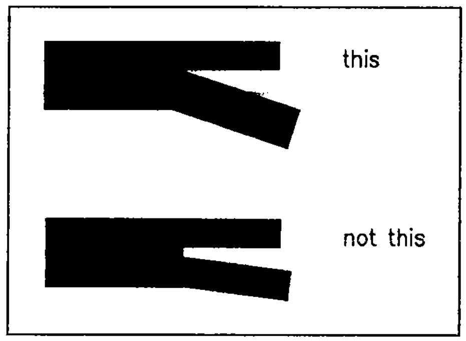

Figure 12.11 Symbolization of flow lines.
When quantitative flow lines branch or unite, their widths are drawn proportionally.

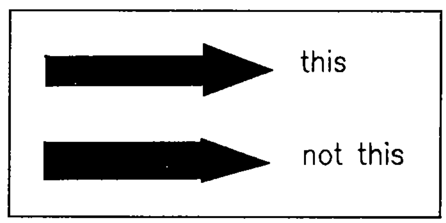

Figure 12.12 Proper arrowheads improve the appearance of flow lines.

If arrowheads are used they should be clear and should be scaled proportionally to the lines to which they belong. Arrowheads with small shoulders should be avoided. (See Figure 12.12.) If flow lines overlap, smaller ones should be made to appear on top of larger ones. (See Figure 12.13.) This is accomplished by breaking the lines of the larger flow line, and having the smaller one continue uninterrupted. This is a simple and effective technique that adds a plastic and fluid dimension to the map. More will be said of interposition in the next section.

LEGEND DESIGN

One of the more difficult tasks in the design of the flow map is the preparation of the legend. The legend is the crucial

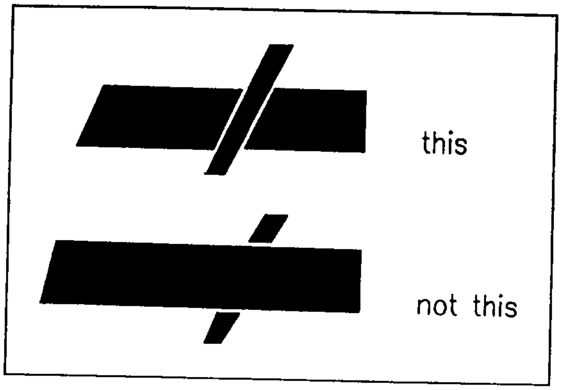

Figure 12.13 Interposition is useful in flow line symbolization.

Interposition is a technique useful in making smaller lines appear to rest on top of larger ones.

link in cartographic communication between cartographer and map reader, as it serves to explain carefully the symbols on the map. The legend must above all be clear and unambiguous. Units of measurements must be prominently displayed and it must be obvious how the lines are scaled, and the flow lines in the legend must appear exactly as they are on the map. If the data have been classed, the class boundaries should be clearly represented.

In one study of flow maps, four general types of legend design were identified: the ruled line, scaled bar or triangle, graduated lines, and key values (including "stairstep" designs).[25] (See Figure 12.14.) There have been no exhaustive studies on flow map legend designs. In the meantime, cartographers must rely on their best judgments. A good idea would be to try out the design solution on representative readers before a final decision is made.

In some cases, the values of the lines on the map may be labeled for greater precision. (See Figure 12.2.) The overall pattern of the lines shows the organization of the movement, and the labeled values provide detailed information for the reader seeking tabular data. Whether or not a legend also is used in these cases depends on the map purpose. In some respects this appears redundant. And in some cases, although the lines are scaled and drawn proportionally, no labels at the lines are provided, and no legend is included. (See Figure 12.15.) Presumably, the cartographer is wishing only to show geographical organization and pattern. It would seem imperative that these drawings be accompanied by written narrative.

UNIQUE SOLUTIONS

A number of innovative and unique solutions for flow mapping have been used by cartographers and geographers. Up to this point in our discussion, the majority of examples have been drawn from a rather conventional pool. Other solutions do exist and can be mentioned to stimulate experimentation. One such example illustrates connectivity by using flow lines of uniform width, and quantity of shipments

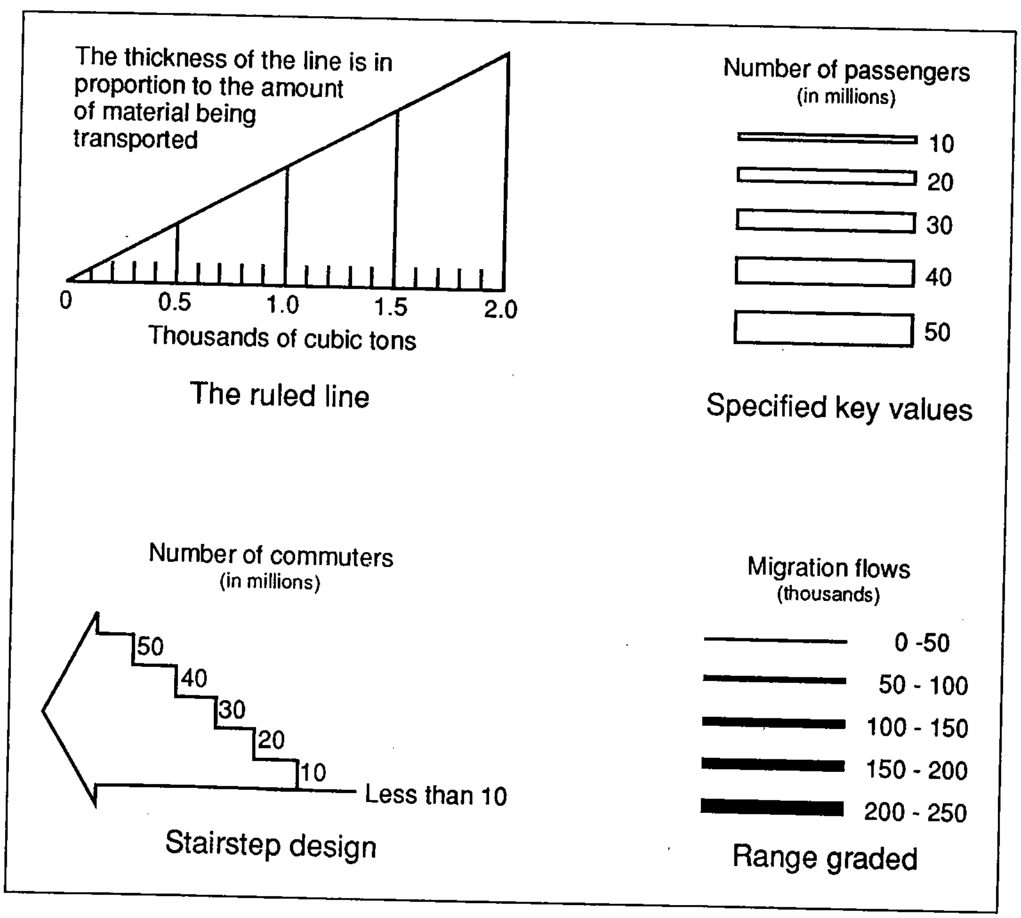

Figure 12.14 Legend designs for quantitative flow maps.

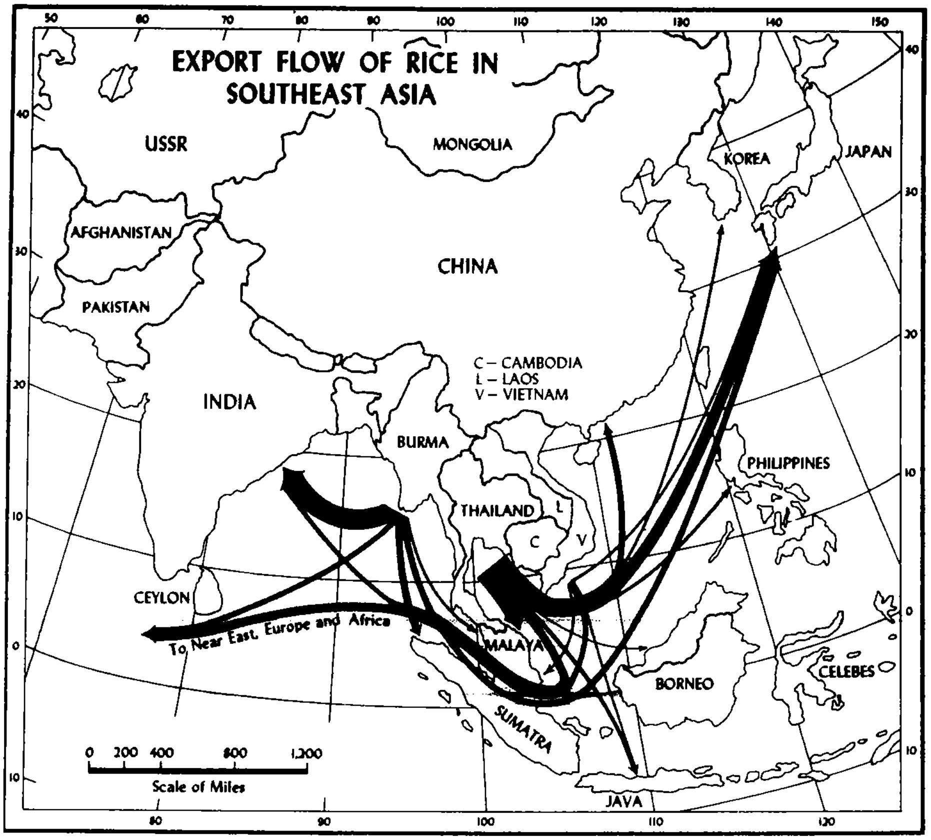

Figure 12.15 Export flow of rice in Southeast Asia.
See the text for an explanation. (*Reprinted by permission of Prentice Hall, Inc.*)

by proportional circle.[26] (See Figure 12.16a.) Another interesting solution, quite different, shows movements of coal by constant-width flow lines connected at their ends by bar graphs scaled to the magnitudes of shipments.[27] (See Figure 12.16b.)

A kind of flow line has been used in centrographic studies. In these examinations, geographical centers of gravity for different time periods are connected by lines of uniform thickness.[28] (See Figure 12.16c.) The visual result shows the geographical trend over time and the flow lines show the connectivity from time to time. These are largely descriptive studies, although centrographic analyses can be employed inferentially also.

Desire lines have been used in very unique ways. Conventional use of desire lines would include lines of uniform thickness (although they may be scaled to proportional widths, and are generally without directional arrows), usually placed on a geographic base map. One unusual use has them placed on a square root–transformed base map.[29] (See Figure 12.17.) In this instance the map projection origin (the "origin" of the desire lines) is located in Toronto, and the lengths of the desire lines are no longer linear. Although these kinds of unique solutions may reveal patterns otherwise hidden, map readers may need, by way of an explanatory legend, some tips on map-reading strategy.

Very heavily generalized and more stylized flow map solutions also have been used. (See Figure 12.18.) In the example used here showing the international trade of mineral fuels (mostly oil), the geographic base map has been abandoned in favor of a block-type organizational chart. The author does not provide any clues about the sizes of the countries and

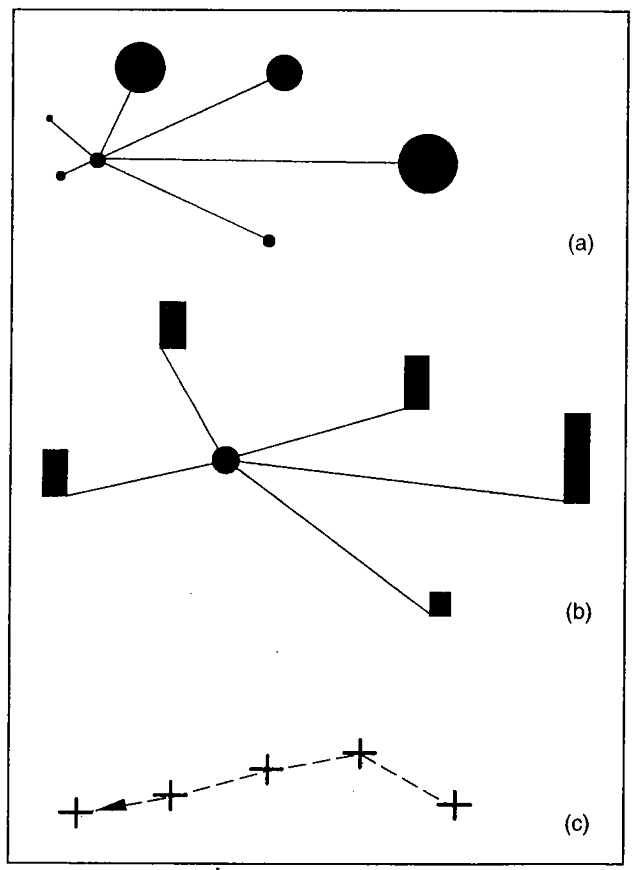

Figure 12.16 Innovative solutions to flow line representation and scaling.
See the text for an explanation.

Figure 12.17 Desire lines on a square root-transformed projection, centered on Toronto, Canada.
(Reprinted by permission from D. Michael Ray, "The Location of United States Manufacturing Subsidiaries in Canada," Economic Geography *47* [1971]:*392.)*

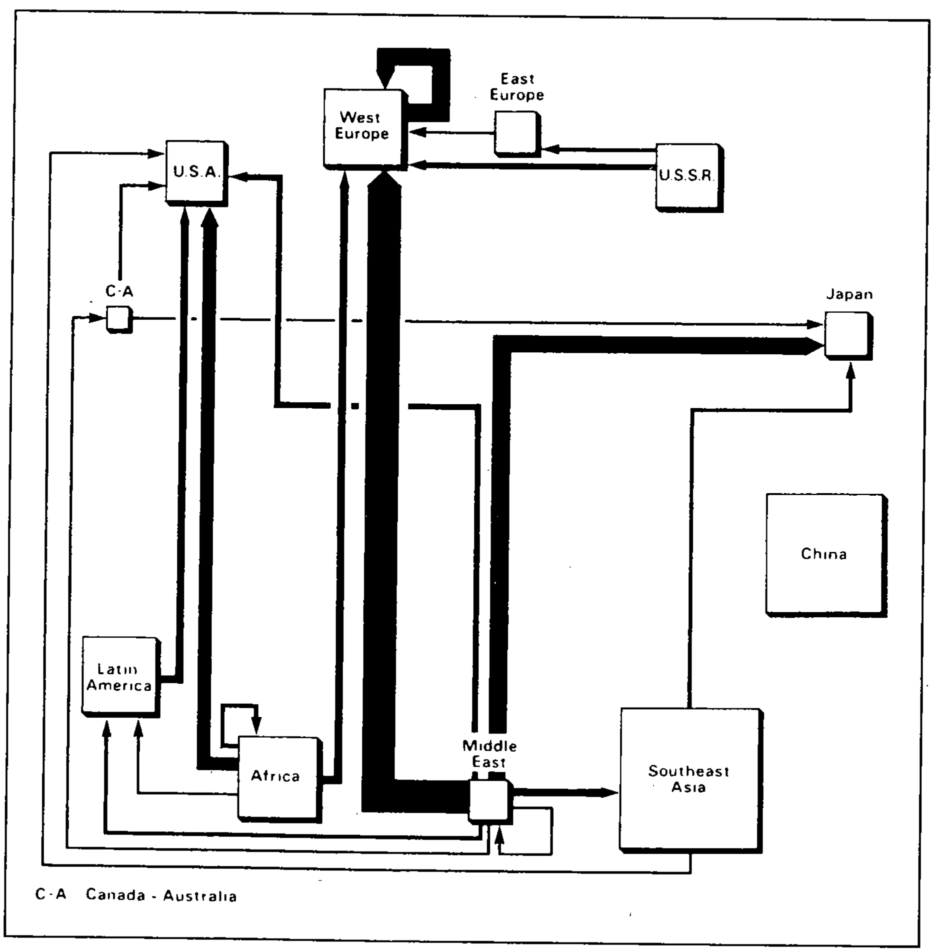

Figure 12.18 Heavily generalized quantitative flow map.
See the text for an explanation. *(Reprinted with permission from Butterworths.)*

Table 12.1 Summary of Thematic Mapping Techniques with Examples of Appropriate Data

Technique	When Appropriate	Data Example
Choropleth map	Portraying a geographical theme of continuous or discrete phenomena occurring within areal enumeration units	Derived values, ratios, proportions: violent crime by county
Common dot map	Used to show spatial numerousness of discrete geographic phenomena	Absolute number: dairy cattle
Proportional symbol map	Displaying discrete phenomena at points, or to represent aggregate data at points	Absolute number or derived values: employment in retailing by cities
Isarithmic map	Used when total form of continuous phenomena is warranted	Absolute values, ratios, proportions: population density
Value-by-area cartogram	This map is used for continuous or discrete phenomena when data are available by enumeration unit	Absolute values, ratios, proportions: dollars spent on education per capita
Flow map	Used to show movement of goods or ideas between places; used to show interaction between places	Absolute values: tons of wheat shipped

regional rectangles, and there is no legend describing the widths of the flow lines. However, it is clear that western Europe, the United States, and Japan are the three main destinations in international fuel shipping. This type of presentation illustrates organization in the activity, although at the expense of not showing actual geographical routes.

Computer Solutions

Computer solutions to flow mapping have not gone unnoticed by cartographers. In one cartographic study, internal migration data for the United States, in the form of a 50×50 (states) "from-to" table, was used in the development of a computer program to automatically draw flow lines or bands.[30] Line-width scaling, arrowhead design, flow line overlap, and other typical graphic solutions have to be dealt with as in manual design solutions. The advantage in using the computer, however, is that alternative designs can be examined quickly. A solution is provided here in Figure 12.19.

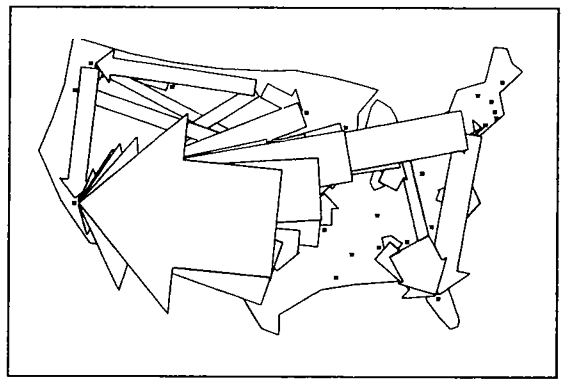

Figure 12.19 Computer solutions to a flow mapping problem.
(Reprinted by permission from Waldo R. Tobler, "Experiments in Migration Mapping by Computer," American Cartographer *14 [1987]: 159.)*

SUMMARY OF MAPPING TECHNIQUES

Six different mapping techniques have been presented in this part of the book: choropleth mapping, the common dot-mapping method, proportional symbol mapping, isarithmic mapping, value-by-area or cartogram mapping, and flow mapping. This group probably accounts for the majority of thematic *quantitative* maps rendered today, whether by manual or computer means. It is a good idea at this juncture to review *when* each is to be used, and to give examples, before you continue through the remainder of the chapters. The review may be accomplished by examining Table 12.1.

As you review this material it is a good idea to remember that matching map technique with the data mapped continues to be somewhat subjective and will usually vary with the scale of the study or map. For example, at one scale the phenomena may be considered continuous, but at larger scales, you may find that the phenomena are indeed discrete. At small scales, dairying may be continuous (although clumped perhaps), but at the farm scale, cows are indeed discrete.

"scale effect"

After you have a firm grasp of the use of each method, and a feeling for the kind of appropriate data for each, you should resume your work through the next part of the text, which presents methods for better map *design* and *cartographic production.*

NOTES

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6. Ibid.
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25. Parks, "American Flow Mapping," pp. 67–68.
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GLOSSARY

desire line map unique flow map in which actual routes between places are not stressed, but interaction is; direction of flow often not shown, p. 223

distributive flow map flow map on which the distribution of commodities or migration is the principal focus, p. 226

dynamic map term often used to describe the ordinary flow map, p. 222

flow map map on which the amount of movement along a linear path is stressed, usually by lines of varying thicknesses, p. 222

network flow map flow map that reveals the interconnectivity of places, p. 226

radial flow map class of flow map that is characterized by a radial or nodal pattern, p. 226

traffic flow map particular kind of flow map in which movement of vehicles past a route point is shown by scaled lines of proportionally different thicknesses, p. 223

READINGS FOR FURTHER UNDERSTANDING

Friis, Herman. "Statistical Cartography in the United States Prior to 1870 and the Role of Joseph C. G. Kennedy and the U.S. Census Office." *American Cartographer* 1 (1974): 131–57.

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