

# An Evaluation of the Factors Contributing to the Frequency of Use of Quantitative Map Symbols

by

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## Introduction

SINCE the turn of the century, a rapid development has taken place in the field of cartography throughout the world. Not only have many more maps been produced than ever before, but more different kinds of maps have been published. This increase in map variety began in the period between the two world wars, and by 1941 Hans Speier could say :

Today maps are distributed on posters and slides, in books, as propaganda atlases, on postcards, in magazines, newspapers and leaflets, in moving pictures and on postage stamps. Maps are not confined to the representation of a given state of affairs. They can be drawn to symbolize changes, or as blueprints of the future. They may make certain traits and properties of the world they depict more intelligible or may distort or deny them. Instead of unknown relationships of facts, they may give information, but they may also plead. Maps can be symbols of conquest or tokens of revenge, instruments of airing grievances or expressions of pride.<sup>1</sup>

Of special interest is the development of thematic or special purpose cartography, since it is this group of maps that account for the marked increase in map variety. Thematic or special purpose cartography is thought of as small scale cartography, though occasionally there are large scale thematic maps. These maps are also called "topical," "single factor," or "distribution" maps. On a special purpose map only one or two ideas are represented ; and uses cartographic techniques to analyse and interpret the various social and physical phenomena of the earth's surface. Therefore, special purpose cartography plays a significant role in geography where few studies, especially in regional and economic geography could be really complete without quantitative distribution maps which show areal differentiation of such factors as population, agriculture, and industry.

Unlike general purpose maps which lack flexibility because of such factors as traditions and specifications, special purpose of thematic maps are adoptable to new expressions in cartography. Even in general purpose maps some

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1. Hans Speier, "Magic Geography", *Social Research*, VIII (1941), p. 310.

important design improvements in colour, lettering, etc., have been affected. However, most of the "new" cartography, both in the treatment of data and their symbolization has been in thematic mapping.

A number of studies have been made in historical cartography, but most of these have traditionally emphasized the development of general purpose or reference cartography, much of it dealing with the very earliest period of modern mapping.<sup>2</sup> A few articles have been published on the historical development of thematic mapping.<sup>3</sup> There has been even less published on the factors contributing to the frequency of use of common quantitative map symbols.

So far, most cartographic research has dealt either with the substantive problems of preparing and manipulating data for map representations,<sup>4</sup> or has been limited to subjective studies of the employment and proper rendering of specific map symbols.<sup>5</sup> Some work has also been done on problems related to the visual effectiveness of the cartographic techniques.<sup>6</sup>

The purpose of this study, therefore, is to examine the important factors bearing on the use patterns of quantitative map symbols.

The frequency with which quantitative map symbols are used is a product of numerous factors. Among these, there are a few which are pre-eminent because of their greater bearing on symbol selection. These factors are as follows :

1. The nature of the data to be represented.
2. The stage of development of symbolic representation.
3. Traditions and conventions.
4. The cartographer's personal judgement and taste.
5. The ease of construction of a symbol.
6. The visual effect of a symbol.

Though a preference for a particular symbol could be the consequence of the effect of any combination or even all of the above factors, each one would not be of equal importance in a given situation. A particular symbol may be preferred for any one of the above reasons. For instance, the nature of the data to be represented, by itself, may determine the choice of a specific symbol. Furthermore, any single symbol may be selected for different reasons than those listed above. Nevertheless, it is possible to account for many of the use patterns of quantitative map symbols in terms of the above factors.

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2. Examples of such studies are, Leo Bagrow and R. A. Skelton, *History of Cartography* (Cambridge, Massachusetts ; Harvard University Press, 1964) and Lloyd A. Brown, *The Story of Maps* (Boston : Little, Brown and Co., 1948).
  3. Arthur H. Robinson, "The Maps of Henry Drury Harness," *The Geographical Journal*, Vol. CXXI (1955), pp. 440-450.
  4. An example of a study of this type is that of Erwin Raisz, "Block-Pile System of Statistical Maps," *Economic Geography*, Vol. XV (1939), pp. 185-178.
  5. An example of a study of this type is that of David I. Blumenstock, "Reliability Factor in the Drawing of Isarithms," *Annals of the Association of American Geographers*, Vol. XLIII (1953), pp. 288—304.
  6. James J. Flannery, "The Graduated Circle : A Descriptive Analysis and Evaluation of the Quantitative Map Symbols," (Unpublished Ph.D. Dissertation, Dept. of Geography, Univ. of Wisconsin, Madison, 1956).

### The Nature of Data to be Represented

The nature of the data to be cartographically depicted is of utmost significance in the selection of map symbols. The last four decades have seen the transformation of geography from primarily a descriptive discipline to one increasingly concerned with explanation. The first attempts to mold the substance of geography with scientific form were made by Alexander Von Humboldt (1769-1859) and Carl Ritter (1729-1859). It was Von Humboldt, one of geography's founding fathers, who set the tone for scientific geography by presenting explanatory descriptions of areas and comparing them with others. It was not, however, until the twentieth century that geographers made concerted attempts to strengthen the scientific content of their discipline by developing theoretical concepts and then testing them by refined statistical and mathematical procedures.<sup>7</sup>

With this transformation, the type of data that had to be mapped have changed. Not only has the amount of data increased, but there is also a greater diversity in the kind of data that have to be mapped. When geography was mostly a descriptive subject, the data were frequently simple expressions of absolute values. The cartographic techniques that were currently available and in vogue then were more or less sufficient to illustrate this material. With the change in the scope of geography and the consequent increase in the presentation of more complex data, and creation of other forms of visual expression, and particularly the need for improvements in techniques of refining and processing of data became a necessity.

On the basis of the type of data used, quantitative map symbols are divided into two main categories ; firstly, those showing a single type of data which are usually expressed as absolute values ; and secondly, those showing derived values, such as averages, percentages, and densities. To obtain these descriptive measures of central tendency and deviations, plus the expressions of ratios and densities, and thereby make a more realistic and more useful portrayal of the distribution, it becomes necessary for the cartographer to manipulate or process the data statistically before it is plotted. A greater use of statistical procedure has become a significant feature in the recent development of cartography.

The dominance of one or two symbols, such as chorograms and dots in the 1920's and 1930's has disappeared and instead today a greater variety of symbols are used. This trend or change is best illustrated in the textbooks on Economic Geography. The shift to more different kinds of symbols can also be seen in periodicals in geography.

In spite of this trend, however, certain map symbols which were widely used earlier, continue to be used on a large scale. Chorograms and dots fall into this category. Continued use of the older symbols is in some measure

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7. There are several stimulating writings on this topic, e.g., Richard Hartshorne, *Perspective on the Nature of Geography*, Chicago; Rand, McNally and Co., for the Asso. of Amer. Geogr., 1959); P. E. James and C. F. Jones, (eds.) *American Geography, Inventory and Prospect* (Syracuse, New York : Syracuse Chic. Press, for the Asso. of Amer. Geogr., 1954); Griffith Taylor (ed.), *Geography in the Twentieth Century* (New York: Philosophical Library, Inc. 1951, 3rd Enlarged ed., 1957); and Jan O. M. Broek, *Geography, Its Scope and Spirit* (Columbus, Ohio : Charles E. Books, Inc., 1965).

the result of the nature of the kind of data depicted on maps. Perennially most economic and social data have been available by statistical unit areas. Therefore, those cartographic techniques which enable the cartographer to use data without much modification have an obvious advantage. Both dots and choropleths are thus particularly favoured, a factor evidently bearing on their more extensive use.

### **The Stage of Development of Symbolic Representation**

An analysis of the factors that determine the frequency of use patterns of quantitative map symbols reveals that the stage of development of symbolic representation has been of significance in determining the choice of symbols. In any discussion of the stage of development of symbolic representation two facets have to be considered. Firstly, there are the different media that were invented from time to time. These brought about many changes in the drafting as well as the reproduction techniques of maps. Secondly, a large amount of research has been done in the field of cartography during the last few decades. They have had a considerable impact on the cartographer. Therefore, a discussion of these aspects seems appropriate. The technological developments, such as the invention of preprinted materials and the improvements in the techniques of processing and representing data, eliminated some of the former shortcomings of certain map symbols and also led to the construction of maps with higher standards of drafting. For example, during the early part of this century, many special purpose maps were hand lettered by cartographers and draughtsmen. Consequently, many maps are lettered in a haphazard manner and in most cases their type faces defy any form of classification. They vary in legibility, appropriateness, and even in the general form.

The invention of preprinted materials, such as letters, dots, lines, and patterns, printed first on glassine and then, after its invention, on acetate film with a wax-type adhesive backing helped the cartographer to use such lettering, tones and patterns on his maps without going through the laborious chore of drawing them by hand. Preprinted materials are easy to use and save much of the time that was formerly necessary and has also enabled the cartographer to maintain a definite style in lettering and design in his maps. The use of preprinted materials has tremendously improved the visual expression of his maps. Since the late 1940's greater use of preprinted materials, such as patterns and tones, is seen in geographical publications.

In 1945 the first preprinted materials using a heat resistant adhesive were marketed under the trade name "Blue Zip". This development further increased the utility of preprinted materials on maps drawn especially for reproduction. Other techniques, such as scribing pioneered by the U.S. Coast and Geodetic Survey, Army Map Service, and Rand McNally Company beginning in 1946<sup>8</sup> have had only a modest effect on the marked increase with time in the number of maps appearing in the geographical publications. The use of scribing in thematic mapping is usually limited to those maps where colour is employed.

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8. For further information on this technique, the reader is referred to : Inter-Agency Committee on Negative Scribing, *Report on Scribing*, Map Information Office, U.S. Geological Survey, Washington, D.C., 1957.

AN EVALUATION OF FACTORS CONTRIBUTING TO THE FREQUENCY

Most modern maps depend significantly on prior statistical compilations and some form of statistical analysis. The last two or three decades, in particular, show a tendency among cartographers to make use of basic concepts of descriptive and inference statistics. For example, the cartographer employs the density ratio to show concentrations and dispersions of population. In recent years statistical methods have become an essential component of distributional analysis. Many cartographers have stressed, in their textbooks on cartography, the importance of the cartographer acquiring at least an elementary knowledge of statistical methods.<sup>9</sup>

Since the turn of this century, attempts have been made to introduce new techniques of symbolization and also to improve the older symbols. For example, in 1917 the graduated volume symbol was introduced, with the argument that it could depict a wider range of quantitative values on the same map space than was possible through the use of graduated circles.<sup>10</sup> It was suspected by some cartographers, however, that a correct appraisal of the relative sizes included in spheres or cubes could not be made and to avoid this supposed short coming Erwin Raisz invented the "Block Pillar" method.<sup>11</sup> In spite of his attempts, the use of volumetric symbols remained relatively insignificant most likely because of the difficulties and the time involved in the drawing of this symbol.

Attempts were made during the last twenty-five years to improve the methods of construction of some of the older map symbols such as dots and isograms. The ideas put forward in these publications, it is felt, have been significant in determining symbol selection. For this reason, at least a brief glance at some of these proposals seems necessary not only to measure the degree of their influence on the cartographer, but also to obtain some idea of the stage of development of symbolic representation.

In 1949, J. Ross Mackay introduced a method of determining the size and unit values of dots.<sup>12</sup> Two years later he also undertook to solve some of the problems in isopleth mapping, especially the location of isolines.<sup>13</sup> Arthur H. Robinson,<sup>14</sup> J. G. Withycombe,<sup>15</sup> and Charles E. Riddeford<sup>16</sup> drew the attention of the cartographer to the importance of lettering on maps. These are a few examples of the attempts made by well-known cartographers

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9. For example, Arthur H. Robinson, *Elements of Cartography*, (2nd ed. New York, London: John Wiley and Sons, Inc., 1963), pp 147—154.
  10. Sten de Geer, "A Map of the Distribution of Population in Sweden: Method of Preparation and General Results," *Geographical Review*, Vol XII (1922), pp. 72—83
  11. Raisz, *Economic Geography*, XV (1939).
  12. J. Ross Mackay, "Dotting the Dot Map", *Surveying and Mapping* vol. IX (1949), pp. 3—10.
  13. Two of his important articles are: J. Ross Mackay, "Some Problems and Techniques in Isopleth Mapping," *Economic Geography*, Vol XXVII (1951), pp. 1-9; and J. Ross Mackay, "The Alternative Choice in Isopleth Interpolation," *The Professional Geographer*, Vol. V (1953), pp. 2-4.
  14. Arthur H. Robinson, "The Size of Lettering for Maps and Charts", *Surveying and Mapping*, Vol X (1950), pp. 37-55.
  15. J. G. Withycombe, "Lettering on Maps", *Geographical Journal*, Vol. LXXIII (1929), pp. 429—346.
  16. Charles E. Riddeford, "On the Lettering of Maps," *The Professional Geographer*, Vol. IV (1953), pp. 7—10.

to improve special purpose cartography by establishing standards for symbol usage. The use of color in cartography has also been both directly and indirectly investigated. Though it is difficult to determine whether the recommendations made in the studies on color have resulted in any consequential changes in the rankings in the frequency of use of map symbols, those recommendations certainly have led to potential improvements in the visual appearance of maps.

Employment of color is one of the most complex problems facing the cartographer. The use of color is generally based on the purpose behind the making of map and hopefully also upon the reactions of the human mind and eye to the various colors. Such factors as conventions, preferences, and traditional significance of colors also play an important role in the choice of colors. Robinson discusses these factors in fair detail in his book, *The Look of Maps*.<sup>17</sup> More recently, extensive research has been done by Edwin H. Land on color vision.<sup>18</sup>

Since most maps in geographical publications appear in black and white, a discussion of the grey scale seems appropriate. It has been established that the human eye is sensitive only to about eight shades of grey, between black and white. Consequently the cartographer has to use his restraint in the employment of shading on his maps. It is believed that the human eye tends to overestimate the value ratings of lighter shades of grey and at the same time underestimate the value of darker shades. Therefore, the cartographer is forced to use only a limited number of shades of grey, because value contrast is essential if the necessary visual impression is to be created. To overcome this limitation, the cartographer resorts to the use of patterns such as dots and lines in addition to shading. Moreover, the environment also may modify the appearance of a shade. Attention of the cartographers has been drawn to this problem in recent papers.<sup>19</sup>

It is, however, not possible to determine the exact degree of influence these writings had on the cartographers or how far they were important in determining the frequency patterns in the use of quantitative map symbols. Nevertheless, the appearance of these articles is an indication of the fact that during the last three decades a great emphasis has been placed on the exact form of symbolization. The attention paid in recent years to the details of selection and use of map symbols has been matched by a corresponding improvement in the maps published in geographical publications. It may be significant that the marked interest shown in the problems of employing isogrammic and dot symbols in the literature may account for their consistent ranking in the frequency patterns of symbol use.

17. Arthur H. Robinson, *The Look of Maps: An Examination of Cartographic Design*, Madison: Univ. of Wisc. Press, 1952, pp. 75—97.

18. Edwin H. Land, "Experiments in Color Vision", *Scientific American*, Vol. CC No. 5 (1959), pp. 84—99,

19. For example the reader is referred to G. F. Jenks and Juan S. Knos "The Use of Shading Patterns, in Graded Series". *Annals of Asso. of Amer. Geographers* Vol. LI (1961) pp. 316—234.

### Traditions and Conventions

Cartography, during its long history, has developed certain traditions and conventions. Adherence to these traditions through a long period of time has transformed some of them to the stature of principles. Many traditions and conventions today regarded as "good practices" as Arthur H. Robinson calls them,<sup>20</sup> because they are the product of a long process of trial and error. The frequency of use of quantitative map symbols, show that certain symbols have a consistency of use. It is seen that with time some map symbols came to be regarded with special favour. For example, choroplethic maps are generally used to show distribution patterns of densities. It is not possible, however, to precisely ascertain whether the cartographer chooses this method because of its traditional use to show something such as the density of population or because of the ease of construction of such a map.

In any case, it is an important factor in symbol selection and obviously a major consideration in maps produced in a series over a period of time, such as those published by official government agencies or in revisions of textbooks on economic geography. The United States Census Bureau uses the dot method to show the distribution patterns of agricultural products in the United States. The maps, showing similar data, appearing in textbooks on economic geography also adopts the same technique. It has to be noted, however, that in most textbooks on economic geography the maps showing distribution of agricultural products in the United States are frequently reproductions of the maps published by the Census Bureau. Today the dot method has become a traditional symbol for showing distributional data of the absolute type. Though other factors such as the ease of construction and personal bias of the cartographer may influence the choice of this method of symbolization, the fact that the dot is the traditional symbol used to represent such data has apparently been the most influential factor.

### The Cartographer's Personal Judgement and Taste

The personal bias of the cartographer is yet another important factor in the selection of a particular map symbol. It is probably more significant as a negative factor with inexperienced cartographers. John K. Wright comments that the suitability of a symbol "depends on the map maker's taste and sense of harmony."<sup>21</sup> Similar views were also expressed by Erwin Raisz.<sup>22</sup> Needless to say, not every cartographer has good taste or a well-developed sense of harmony. Though individual bias does bear on symbol selection, particularly with the inexperienced cartographer, the experienced cartographer, hopefully is directed by certain cartographic principles and by the nature of the data he has to present cartographically. For example, the use of dots is the most obvious method to show distributional patterns, especially if the map is to show rural distributions, and an experienced cartographer will invariably choose this technique over any other symbol type.

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20. Robinson, *Elements of Cartography*, p. 12.

21. John K. Wright, "Map Makers Are Human: Comments on the subjective in Mapping," *Geographical Review*, Vol XXXII (1942), p. 542.

22. Erwin Raisz, *General Cartography* New York : McGraw-Hill Book Company, Inc., (1948). p. 2.

The use of color is yet another instance where the geographer should act more on established principles than on his personal whims and fancies. Thus Robinson comments :

In cartography our choice of color may be to please or it may be to promote the purpose of the map. Except within the broadest limits personal preferences should play a small role in the choice of colors.<sup>23</sup>

There are accepted colors to show specific kinds of data, for instance, blue is used to show precipitation, reds and yellows for temperature, and green for vegetation. From the above factors one may infer that with the growth of the field and the consequent development of principles and traditions, the influence of the personal attitudes and prejudices of the cartographer lessen.

### **The Ease of Construction of a Symbol**

The ease of converting data into a form convenient for cartographic expression and the speed with which the symbol selected could be placed on the map are two other factors which certainly are considered in choosing a quantitative map symbol. The infrequent use of visual three dimensional symbols, such as spheres introduced in 1917 by Sten de Geer,<sup>24</sup> quite likely was the result of the difficulty or the time it took to draw them. The fact that three dimensional symbols are not easily commensurable has been a factor bearing on their limited use only in the last five or ten years. It seems obvious therefore, that in the early years after its introduction, the main reason for the limited use of volumetric devices were the problems encountered in drawing the symbols.

The contrary is true of the graduated circle and the choroplethic techniques. From its inception up to the present time, the choropleth has been widely used. Both the conversion of data to mappable form and placing of these patterns, tones, or colors within statistical unit areas on the map are easy and quick. Such conveniences are obviously related to the extensive use of the symbol on special purpose maps. The considerable use of the graduated circle, in geographical publications, also may be attributed to the ease of its employment. The traditional method of determining the radii of the circles by use of the square roots of the values to be shown plus the easy drafting of a circle with an inking compass made the construction of this symbol perhaps easier than the choropleth. This factor is equally true in the case of the dot map, though probably to a lesser degree.

### **The Visual Effect of a Symbol**

The final major factor bearing on the Selection of a particular map symbol is the visual effect it has in the mind of the map reader. Arthur H. Robinson observes that,

The vehicle for presenting such materials (of the social scientists) should be capable of creating in the mind of the reader, so far as is possible, precisely the intellectual meaning and interpretation of the author.<sup>25</sup>

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23. Robinson, *The Look of Maps*, p. 85

24. Sten de Geer, *Geographical Review*, XXII (1922), pp. 72—83.

25. Robinson, *The Look of Maps*, p. 8.



## AN EVALUATION OF FACTORS CONTRIBUTING TO THE FREQUENCY

As a result of the research carried out by investigators from a number of disciplines, on a wide range of subjects having both a direct and an indirect relationship to the design of maps in the last two decades,<sup>26</sup> there has been more concern with the design of maps so as to illicit a particular response from the map reader. It may be accepted that these findings have had some influence, especially in recent years on the structuring of maps, so as to make for a more effective presentation of data. Therefore, in the last fifteen years a significant degree of attention has been given to the exact form of map representation. According to John C. Sherman, "The form of symbolization in terms of creating an intellectual stimulus will finally determine the effectiveness of the map."<sup>27</sup>

### Summary

In general it is quite clear that probably no single factor can explain the popularity of a given quantitative map symbol. Usage is normally the result of the interaction of a number of factors. The importance of each of the factors varies from time to time as well as from map to map and cartographer to cartographer. Certain of the factors are a consequence of the others, or at least have some relationship to them. For example, the need to represent more complex data probably may have led to the invention of new symbols or to improvements in older symbols, so that they are visually more effective and factually more precise. The greater amount of data that needed cartographic representation in recent years undoubtedly affected the development of the use of symbols in new ways, such as the use of isarithms for depicting densities. The desire to use symbols that could be easily and quickly mapped favoured the use of those symbols based on preprinted patterns and tones such as choropleths. It is difficult to separate these factors out in specific cases, but the over all relationships seem evident.

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26. As an example the reader is referred to the following : Max Ackert, "On the Nature of Maps and Map Logic," Trans. by W (L. G.) Joeng, *Bull. of the Amer. Geographical Society*, XL (1908), pp. 344-351 ; Hans Speier, pp. 310-330 ; Land, pp 84-99 ; and Gosta Ekman, Ralf Lindman, W. William-Olson, "A Psychophysical Study of Cartographic Symbols," *Reports from the Psychological Laboratory*, No. 91, Univ. of Stockholm Sweden, (1961).
27. John C. Sherman, "New Horizons in Cartography: Functions, Automation and Presentation," *International Year Book of Cartography*, (1961), p. 16.