

ABSTRACT

A STUDY OF THE ADVANTAGES AND POTENTIAL UTILITY OF THE MICHIGAN STATE PLANE COORDINATE SYSTEM AS A LOCATIONAL REFERENCING SYSTEM WITHIN A STATE-WIDE INFORMATION SYSTEM

by John Owen Tompkins

Increasing attention is being given to the problems involved with establishing area-wide information systems. The necessity of these systems has stemmed from the ever increasing rate of urbanization. This rise in urban-regional population has in turn resulted in increased levels of governmental operations.

State governments have to date played a secondary role in the challenge to develop new operational systems to meet the increasing levels and complexity in the daily pursuit of their functions. Although there have been a number of urban and metropolitan attempts at developing information systems little progress has been made toward state-wide information systems. This thesis is an attempt to advance the concept of such a state-wide system with a special emphasis on the basic geographic referencing system upon which to base the multitude of data flows generated, collected and used in the development of state resources.

The system of locational referencing found to offer the most potential utility and thus proposed by this study is that of the State Plane Coordinate System. It is suggested that tying this system to the U.S. Public Land Survey throughout the State of Michigan by establishing coordinate values for all quarter section corners will provide the most appropriate locational element within a state-wide information system. This locational referencing system may then serve as a uniform state-wide grid network

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upon which geographically-based data of all rural, urban and regional areas may be based. In this manner the locational description of all kinds of natural, human and man-made resources may be exchanged through the facility of electronic data processing systems to all users of this data at the local, regional, or state levels. Because the State Plane Coordinate System is based upon the highly accurate geodetic data (latitude and longitude) which is established throughout the nation by the U.S. Coast and Geodetic Survey, all data on resource characteristics may be exchanged even at the interstate as well as the federal level.

The findings of this study indicate that there is a definite need for the extension of interagency coordination in the collection and use of state resource data. Although this data is predominately collected and compiled by minor civil divisions, there is a widespread need at the state level for a smaller unit of locational reference. For maximum interagency utility, this unit must be standardized and preferably familiar to most users. The quarter section of the common U.S. Public Land Survey's Township-Range-Section system has been recommended for the basic reference unit at the state level. In addition, a multi-state investigation found that most states have not fully discovered or even significantly tapped the potential utility of the State Plane Coordinate Systems.

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PREFACE

Due to the limited material which has been written on this subject, either in published or unpublished form, an intensive information search was conducted. Primary information sources used comprised of a continuous correspondence with state planning agencies throughout the United States. Also contacted were various federal and regional agencies as well as academic institutions and independent scientific research organizations including research and development divisions of industrial corporations, all of which have expressed interest in the advancement of locational referencing techniques. These sources provided numerous unpublished material which proved invaluable to the development of this study.

Valuable secondary information sources were those of several United States government documents and various periodicals published by certain professional societies and associations. Interesting to note, is that among the numerous engineering, planning and geographical journals, a single periodical, Surveying and Mapping, proved the most resourceful.

The development of this thesis was largely a process of focus limitation. Initially, the intent was to design a state cartographic center to facilitate the recently proposed state-wide information system for the State of Michigan. The focus of this study was to be the development of a uniform locational referencing system as its basis of operation. The size of this task was determined too extensive. It was then decided to limit the study to alternative systems of locational reference with a special consideration of the Michigan Coordinate System for application in the state-wide information system. At first, the approach to this

latter focus of study was to examine the systems of locational referencing in current use by Michigan State agencies against various potential systems of state-wide compatibility. However, this inclusive scope of investigating all state agencies was deemed rather ambitious and was limited to twenty selected agencies within the Departments of Commerce, Conservation, and State Highways.

Accomplishment of this study could not have been achieved without the generous cooperation of the good offices of the State of Michigan. The author is particularly in gratitude to the State Resources Planning Division of the Office of Economic Expansion for the accomodating extension of their physical facilities and financial resources. Through this office, the research herein was financially aided by means of a federal grant under the Urban Planning Assistance Program authorized by Section 701 of the Housing Act of 1954, as amended, and as authorized by the Governor's Interdepartmental Resource Development Committee of the State of Michigan. As part of the State Resource Planning Program, the research served as an element of this interdepartmental effort to assist the State of Michigan in maximizing its resource development opportunities toward meeting the needs created by future growth.

The author extends his sincere appreciation to all those who have made the substance of this thesis possible. Special acknowledgement must be given Donald E. Bailey of the Michigan State Resources Planning Division who so generously extended the opportunity to coordinate this academic study with a practical research application. Additional appreciation is given to Professor Donald Krueckeberg of the Department of Urban Planning of Michigan State University who served as the chairman of the advising committee for this thesis and provided essential suggestions and counsel.

Indebtedness is particularly expressed to Richard McGinty of the Lansing Tri-County Regional Planning Commission who initially directed attention to the importance and practicability of research on this subject.

This thesis was prepared while the author was pursuing graduate studies at Michigan State University. Although the research was conducted through the cooperation of the State of Michigan, the views and opinions expressed herein represent solely those of the writer.

CHAPTER I

INTRODUCTION

Purpose and Objectives

The basic aim of this study is to examine and document the utility of alternative methods of geographic referencing. By so doing, the study purports to arrive at the fundamental importance of a uniform locational referencing system.

Research objectives of the study are many. An overall objective is to examine the significance and appropriateness of utilizing the Michigan Coordinate System as being the most advantageous single system for multi-purpose planning research. The more specific objectives of this study are as follows:

1. To examine the nature and characteristics of various forms of geographic identification.¹
2. To examine the requirements of a uniform locational referencing system and its relationship to a unified information system.
3. To examine the locational referencing systems currently in use by the State of Michigan as evidenced by the Departments of Commerce, Conservation and State Highways.
4. To examine the potential utility of the Michigan Coordinate System for locational referencing to these three agencies.

¹The term "geographic identification" has been used interchangeably throughout this study with that of locational referencing.

5. To explore the potential utility of the State Plane Coordinate System for locationally referencing all geographically-based data within the proposed statewide information system.

This study is addressed particularly to anyone who may at some time be in a position to evaluate the functional utility of a system of geographical referencing or identification. This could include administrators as well as politicians at all levels of government who may be instrumental in selecting and justifying a single, uniform method of locational referencing for geographically-based information. Also addressed are the many persons and agencies of the academic sphere who may be interested in the educational and scientific merit of such a system for maximizing research efforts.

The thesis herein offered by this study is specifically discussed at a non-mathematical and non-technical level. The purpose behind this is basic to the objectives of the study, which are principally to stimulate an active and realistic interest in the multi-agency use of a uniform system of locationally referencing all types of geographically-based information. Although the study focuses on the applicability to the State of Michigan, it is also applicable and of great importance to municipal, county and regional agencies, as well as to academic and private research institutions.

Background

A commonly overlooked problem which has only recently seen variant attempted solutions is that of inconsistent locational referencing systems. Dissimilar locational referencing systems have been and continue to be a problem to data collection agencies both public and private alike.

As the planning and analysis of resource development necessitates the interrelation of many sources of data, it is most important that these data are referenced accurately to their respective locations. Any study which attempts to correlate data drawn from two or more dissimilar locational referencing systems too often must generalize the results with respect to location.

Policy decisions in regard to resource development (or any other governmental activity) made at the state level are only the result or outcome of much previous activity. This activity is generally comprised of many stages. Before the decision-makers can establish a public policy, they must consider and evaluate various potential future outcomes of such a policy. In doing so these decision-makers must be equipped with relevant information about the resources involved with this decision. In this sense the information needed is in terms of qualitative and conceptual relationships. However, in order to arrive at this needed information, the facts or data characteristics of these resources and their interrelationships must be first inventoried, compiled, analyzed and evaluated. This qualified form of information must be presented to the decision-makers in such a manner that they may, to the best of their abilities, make the wisest choice of alternative decisions.

Most state resources are either physical, economic or social characteristics and activities which are either a part of the land or based upon it. To study and evaluate information with regard to making the most rational policy decisions on state resources, it is fundamental that the analysis of data characteristics representing these resources be accurate and complete. This accuracy and completeness of data often depend on the system which is used to identify or reference these data

to their respective locations in terms of a position or set of positions on the ground. Any interrelation of data not properly adjusted to their appropriate locations will not be an accurate representation of the facts. Also, data is too often collected by large sub-area aggregations (e.g. by counties), thus any study at a lower sub-area (e.g. by townships) will be hampered by incomplete data. A partial answer to this problem is the adoption of a uniform system of locationally referencing these data.

These systems are generally considered an index to answer where something is located or positioned. This "something" can be any thing or fact; it can be considered any bit or piece of information. Today, unlike merely a generation ago, one thinks of the term "position" as a location not only on land and sea, but in space as well. In this study, the terms location and position will pertain exclusively to geographically-based information.²

In a statewide information system the ability to retrieve data in various forms of geographical or spatial aggregation is of major concern. The manner in which this data is stored will dictate the various forms of retrieval. At the point of data storage the data are designated as to where they are located geographically: (i.e., to what region, county, city, census tract, block, or parcel). The manner in which the data is locationally identified determines the feasible ways to (a) aggregate or

²This excludes only that which cannot be conceivably referenced to any particular area, place or position on the face of the earth. Among these, for example, would be information relating to qualities of vegetation or animals (including human beings), mathematical relationships, as well as operational characteristics of the above and man-made objects.

group information geographically, (b) describe or display geographic relationships. The importance of the method of geographic identification is reflected by the manner in which it affects total costs of the information system including both initial design and subsequent use.

Research on the relative efficiencies of alternative methods of geographic identification has been neglected. Indeed, in many of the recently developed urban planning information systems the subject of geographic identification (often termed geographic coding, locational referencing, areal system, or spatial identification) has been given little special attention and in most systems regarded as a characteristic of the data items themselves. This has resulted in a great waste of research time and monies with a corresponding loss of geographic retrieval quality and flexibility. To a large degree, this problem may be associated with the older methods of data collection and storage in which many types of data were placed on many different maps after which the matter of locational referencing was promptly forgotten. However, for a maximum utility in any automated information system, this subject must be carefully studied and appropriately integrated into the system.

Nevertheless, a substantial savings can be achieved if geographic identification is appropriately considered in the design stage of an automated information system. This initial consideration should be well before the state of any base mapping program, comprehensive field data collection, or adaptation of existing data sources to the information system.

Now that the relative importance of geographic identification has been stressed, a more detailed discussion on this subject is appropriate. The next chapter will present the alternative methods of identifying information to define its geographic location and their relative merits in aggregating data.

CHAPTER II

ALTERNATIVE METHODS OF GEOGRAPHIC IDENTIFICATION¹

There are two basic methods of identifying information to define its geographic location or position. These may be referred to as the name method and the location method. The name method applies to dividing the geographic universe into sub-areas, each of which is given a unique name designation. In this manner data are locationally referenced by identifying them with the name of the sub-area to which they belong.

The name method is an historic system still employed extensively throughout the country which originated from the practice of collecting data for administrative or governmental territories. The characteristics of this method are much the same as those describing the areal arrangements of governmental units themselves.

Such characteristics would include, for example: (a) more or less full areal surface coverage, (b) unequal areal units, (c) dissimilarly shaped areas, and (d) dissimilar population size. An illustration of this point is the state, county, minor civil division system of sub-areas on which the collection of large volumes of data by the U.S. Bureau of the Census is based. The name method can be found in other systems of administrative units such as school, taxation, and election sub-area systems.

¹ This chapter draws heavily on the work of Robert E. Barraclough of the Tri-State Transportation Commission, New York. The writer is indebted to him for permission to use his illuminating points presented in an unpublished paper entitled, "Geographic Aspects of Information Retrieval."



Figure 1. Name Method of Geographic Identification

A common sub-area which serves as the most utilized unit for urban area data collection and analysis by the U.S. Bureau of the Census as well as most research agencies both public and private is the census tract. Census tracts are initially defined to produce units somewhat equal in population, size, homogeneous socially and economically, and with definitive environmental boundaries. As stability of unit boundaries are a requirement for accurate historical analysis of information relative to areal units, there remains a logical need to avoid any change in census tract boundaries over time. However, as the form and composition of our metropolitan areas grow and change, this logical requirement is inevitably cast aside. A strong factor in the change of tract boundaries is the relative increase or decrease in residential density patterns. These densities are, in fact, the basis of defining tract areas or sizes. This can be witnessed in any metropolitan area where census tracts are small in central areas of high density and large in suburban areas of low density.

Aggregation of data may be accomplished in two ways under the name method of identifying information to define its geographic location. One way is to draw directly from the data records all data designated as to a particular level of a sub-area system, such as census tracts or townships. The other is indirect through the use of area correspondence tables in which names are transformed into numerical codes and then aggregated as desired by code. The apparent flexibility of this second approach is constrained by the contents of the area correspondence table. This would require the design of a new correspondence table with every additional set of aggregation area boundaries.

Aggregating with the name method under the first approach above, drawing directly from the data record file, is most inflexible. The greatest disadvantage with this approach is that proposed boundaries of all aggregation areas must be established in advance of data collection and processing. Although an analyst attempts to predict and establish all possible sets of boundaries for the purposes of all foreseeable analyses, it is rarely an accomplishable task. This is so because of two good reasons: one, all possible future analyses cannot be predicted, and two, the proper spatial arrangements for aggregation boundaries depend in part on the data values and the analyst has no accurate knowledge of these values before collection. For analysis of change, over time, it is very advantageous to have boundaries remain constant through time and making observations at regular intervals. However, it must be noted that these constant boundaries may discontinue to properly represent the spatial redistribution of values over time.

In the location method, a system of locational coordinates are superimposed on the geographic universe and used as a reference for geographically identifying the data. A notable distinction between the name method and the location method is that while the primary focus in the first is on division of the universe into uniquely named sub-areas, the primary focus in the latter is on furnishing the universe with co-ordinates enabling reference to any uniquely designated location within its boundaries. The fundamental features of the location method is that the values of the co-ordinates for any point or sub-area describe its position or place while the co-ordinates themselves delineate precisely where the point or sub-area is.

The location method is also of historical and current usage, principally by explorers, navigators and cartographers using the latitude-longitude co-ordinates. Also, surveyors and engineers use co-ordinate systems for identifying the location of monuments, boundaries and highways (a more detailed discussion of the use of co-ordinates will follow in Chapter IV). Locational co-ordinate systems are often employed in map making to facilitate indexing and locating places on a map. These co-ordinate systems are much like an index of columns and rows with locational identification such as A5, C8 or F10. In addition to the many civilian uses of co-ordinates, military co-ordinate systems dating back to the Napoleonic Wars have been used extensively for identifying locations of targets and for other military purposes.

The use of locational co-ordinates in urban planning information systems originated less than twenty years ago with metropolitan transportation studies. The first such study was by the California Department of Highways who used co-ordinates to prepare trip travel desire line charts and trip intensity contour charts. In 1953, the Detroit Metropolitan Area Transportation Study expanded the use of co-ordinates to form the basis for three-dimensional models of trip generation. Since then, the Chicago, Pittsburgh, Twin Cities, Penn-Jersey, Puget Sound, and Tri-State Transportation Studies and others have all made use of grid co-ordinate systems. An important point here is that with each successive study there generally have been improvements in the use of co-ordinate systems.

It is important to note, however, that these basically different methods of geographic identification are not incompatible. Although the location method clearly retains untold advantages, a successful information system should carry both methods. This allows for the primary use of the location

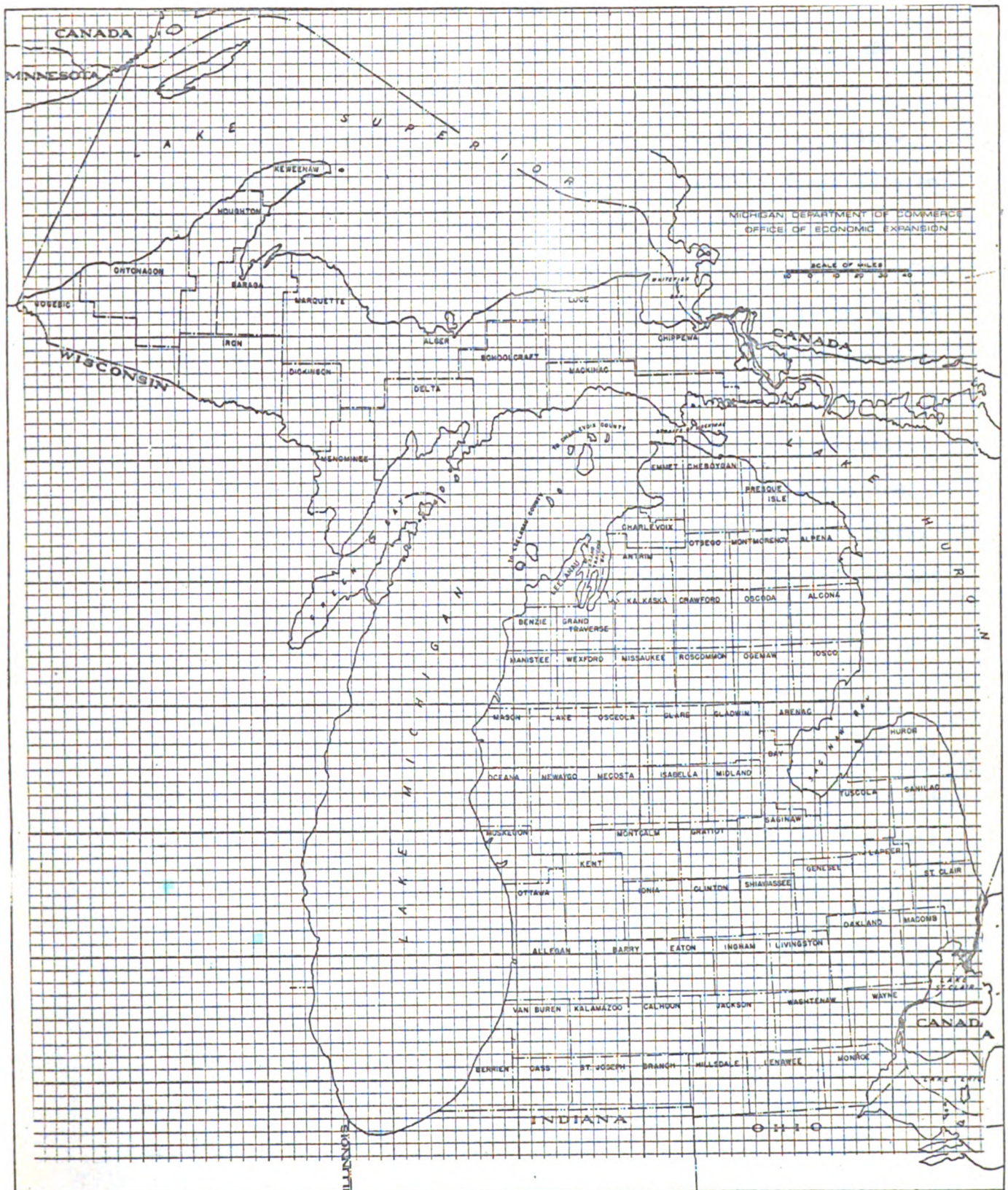


Figure 2. Location Method of Geographic Identification

method with the name method as an adjunct, which can make use of the best quantities of data available by sub-area systems.

Basic in a discussion of the relative merits of these two methods is the fact that the location method permits much greater flexibility in aggregating data. Also fundamental, the cost of aggregation by the location method is not significantly greater than by the name method. This cost difference, if indeed it exists, is profoundly offset by the multipurpose utility gained through the flexibility of the location method of geographic identification.

The basis for this greater flexibility in aggregation is the positional or locational value expressed by the geographic identification. This positional value allows the aggregation of any set of units simply by specifying a series of positional statements. Ready aggregations can be made to squares of uniform size or to regularly spaced circles of uniform size in this manner. For example, the first requires only the length of the side of the square unit and a starting point, while the second, only the radius, distance between centers, and a starting point. Aggregation to uniform areal units is of greater benefit to analysis and planning, as the data values within equal area aggregates are themselves, statements of density. Through the location method, aggregation to any regularly shaped set of units (such as squares, circles, equilateral triangles, rings, hexagons or sectors) can be obtained simply with analytic geometry.

For aggregation to non-uniform or irregular areas with the location method the desired areas may be regarded as polygons. Here, the boundaries cannot be explained by analytic geometry, but can be described by a series of co-ordinates of each vertex of each polygon given in a systematic manner from a designated starting point. After establishing the

positional values of the boundaries of all polygons, all data is aggregated into polygons according to which respective series of designated co-ordinates the recorded data falls.

The discussion of aggregation with the location method above has been limited to the designation of positional values for desired aggregates without prior examination of the data. However, it is also possible to examine the spatial distribution of the data characteristics and then designate the boundaries for aggregation. In both cases, however, it is fundamental that all aggregation boundaries be delineated only after the data are collected and processed. This is of basic importance to geographic analysis, since boundaries fixed in advance seldom allow the analyst a way of determining the degree of influence on the data measurements by the pre-set boundaries of aggregation.

In summary, it is clear that the location method of geographic identification has more research utility than the name method. It may also be assumed that this utility will be expanded as the cost of digital computers decreases. In fact, there will soon be an automated digital and point plotting system on the market which will require only the designation of the desired aggregates by delineating boundaries on maps. This requires that all boundaries be specified if the aggregate areas are irregular, but the boundaries of only one unit if the areas are regular. The operational basis of this new system will be the location method of geographic identification.

CHAPTER III

ALTERNATIVE LOCATIONAL COORDINATE SYSTEMS

As many possible systems exist under the location method of geographic identification, it is important to assess their potential against the minimum requirements of a state-wide information system. Inherent in all systems of location method referencing is a system of cartesian coordinates.

Basically, the purpose of a locational coordinate system enables any point or position within a geographic universe to be precisely defined by a set of numerical values. The location of any geographic position is typically represented by two numerical values corresponding to the elements of a cartesian coordinate. Since the earth is not flat, however, the computational use of such coordinate systems are dependent upon their relationship to some model of the earth. In using these coordinate values for any computational purposes, the critical factor is the margin of tolerable error which normally varies with scale of the geographic area of study. This would generally be the case with any information system covering a broad geographical area.¹ Since this is indeed the case with the proposed unified state-wide information system for Michigan, it is necessary to discuss more than localized plane coordinate systems.

¹Teitz, Michiael B., Land Use Information for California Government: Classification and Inventory, Center for Planning and Development Research: Institute of Urban and Regional Development, University of California, Berkeley (Sacramento: State of California, 1965), p. IV-11.

The form of the earth is commonly represented as one of four explicit models. The most complex is the geoid, which approximates a topographical surface of constant gravitational potential. This model is too complicated to be described by equations for computational purposes. When the earth is represented as an ellipsoid of revolution, geodetic coordinates may be delineated upon its surface with a much less complicated set of equations. When the model of the earth is described as a sphere, the applicable coordinates are derived through equations readily adaptable to computation. It must be noted, however, that since the sphere is not as representative of the actual shape of the earth as the geoid or ellipsoid, there will be an element of error between calculated and measured distances. Both the ellipsoid and the sphere permit a variety of projections which transform them to a plane. This transformation also reduces the probability of accurate measurements relative to the true shape of the earth. A plane surface representation allows the use of coordinate or analytic geometry to describe locational relationships and permits analysis of these relationships through two dimensional statistical methods. All accurately derived coordinate systems have been referenced by a set of equations to some version of one of these four models.²

Criteria for Evaluation

A necessary requisite for any discussion of alternative coordinate systems is some type of relative criteria for their evaluation. Waldo Tobler, a professor of geography, has advanced a number of criteria for

²
Ibid., p. IV-12.

evaluating potentially useful locational reference systems. He maintains that although they are to some extent contradictory, they are nevertheless a set of requirements which coordinates should attempt to satisfy. In addition to these criteria, Michael Teitz, a professor of city planning, has suggested two more requirements for evaluating alternative coordinate systems. These latter criteria appear to express more of a degree of functional utility for the design of area-wide information systems. Below is a list of all six of these recommended criteria with a following discussion of each requirement.

1. The coordinates should permit accurate and economical formulae for computation.
2. A rapid and accurate method of determining the coordinates of a position should be available.
3. The coordinates should be widely available and should be equally convenient for use at a local or national level.
4. The coordinates should facilitate the processing and storage of data.
5. The coordinate system should be in existence and in present use.
6. The coordinates should retain the qualities of all previous criteria into the foreseeable future.³

In the first requirement, the factors of accuracy and economy of computation are definitely interrelated. Only through geodetic formulae can the highest level of accuracy be obtained. However, the difficulty of computation is beyond a limit for general utility. The use of coordinates based on formulae for a particular type of map projection achieves, perhaps, the maximum utility and computational simplicity.

³Tobler, Waldo R., "Coordinates of Geographic Inventories," Department of Geography, University of Michigan, 1962, p. 2. (Mimeographed); and Ibid., p. IV - 13.

Together with these positive attributes is an additional loss of accuracy. On the positive side, the factor of computational simplicity allows for a reduction in computation cost and time, especially in systems handling large volumes of data. It also permits the extension of the system's utility as the number of individuals and agencies effectively making use of the information increases. On the negative side it is important to note that the degree of accuracy is not always a constant for all studies. As various studies have different objectives, the accuracies required also vary.⁴ It is apparent that while there is no overall solution, a balance must be made between accuracy and facility of use in the context of particular research objectives.

In the second requirement, once again there exists an inverse relationship between speed and accuracy. The most rapid method of determining coordinates is by map scaling, a system which transposes coordinates from aerial photographs or maps. However, the degree of accuracy is dependent on the scale and the utility depends on the availability of base maps (generally on the U.S. Geological Survey's Topographic Series) or air photos which carry the coordinate system. Conversely, the most accurate method, a carefully executed geodetic survey in the field, is also the slowest and the most costly.⁵ Here again, it is apparent that a balance must be made between time, costs and accuracy according to the desired objectives of the research.

In the third requirement, there is again a stress on coordinate system utility. As information obtained on the national level increases and becomes available to the other governmental levels, a corresponding

⁴Tobler, op. cit., pp. 3-4; and Teitz, op. cit., p. IV-13.

⁵Tobler, op. cit., p. 3.

increase of local data is becoming a useful source for regional, state and national agencies. Any system of coordinates employed by one of these governmental levels as a locational referencing element of an integrated information system should definitely allow use at all levels. However, the requirements of accuracy between the local and national levels, in general, differ considerably. At the local scale the tolerable error may be less than five feet while at the national scale, an accuracy of five miles may be sufficient. An important point here is that by employing a highly accurate system of locational referencing any desired degree of precision can be achieved through an appropriate method of computation. The transition between local and national scales, therefore, need not necessitate distinct systems of coordinates when information has originally been precisely located geographically.⁶ Since many studies at the national level require a lesser degree of locational referencing precision, it is most important that information gathered by federal agencies be geographically identified by a sufficiently accurate coordinate system which permits computation at the state, regional and local levels. This is fundamental to the utility of any integrated information system.

The fourth requirement regarding facility of handling and storage is apparently fulfilled with a coordinate system expressed in the form of numerical values. Although error may arise in the field use of such digital values, the automated use by a digital computer in the proposed state-wide information system would be relatively error free.⁷

⁶Ibid.; and Teitz, op. cit., p. IV - 13.

⁷Teitz, Ibid.

In the fifth requirement, it is assumed that there is already in existence one system of locational coordinates among many incompatible systems which can be effectively used for an integrated system. It further assumes this system has already achieved a certain degree of sophistication and is currently in considerable use. When such conditions can be met, the many problems of inter- and intra-agency acceptance, unanticipated irregularities and cost are minimized.⁸

The last requirement is one that both Teitz and Tobler stress is of basic importance. Within the next twenty to thirty years there will be untold advances in computational facilities as well as potential accuracies and quantities of information. Computation facilities will continue to extend their availability, accessibility and distribution along with an increase in their capacity and economy of operation. Required accuracies will be toward the highest possible degree of precision. These accuracies will be made obtainable by electronic advancements in equipment for geodetic measurement and information processing. Any locational coordinate system selected for a sophisticated area-wide information system must be able to accommodate such advances as well as gain utility through them.⁹

To proceed with the examination of alternative locational coordinate systems, it is important to note that there are numerous systems in use throughout the world. The following discussion of these systems will be

⁸Ibid.

⁹Tobler, op. cit., p. 2; and Ibid.

limited to the main types of coordinate systems currently available in the United States.

As described by Tobler (1962) and Teitz (1965), the systems of locational coordinates will be classified into three major classes: Terrestrial, Spherical and Planar. These system classifications relate to the models or methods employed to derive a representation of the surface of the earth. The following is a list of these coordinate systems as will be discussed below.¹⁰

1. Terrestrial Systems
 - a. Geodetic Coordinates
 - b. Astronomic Coordinates
 - c. U.S. Public Land Survey
 - d. GEOREF - World Geographic Reference System
2. Spherical System
 - a. Alternative spherical coordinate systems
3. Planar Systems (map projections)
 - a. UTM - Universal Transverse Mercator System
 - b. State Plane Coordinate System
 - c. Local systems

1. Terrestrial Coordinate Systems:

The terrestrial systems are coordinates through which various systems of measurement are directly related to the surface of the earth.

1.a. Geodetic Coordinates

This system of latitude and longitude is based on field measurement (triangulation) between specified points on the earth's surface. Before

¹⁰This discussion is primarily drawn from the works of Professor Tobler and Teitz, op. cit., with the exception of the specific notations.

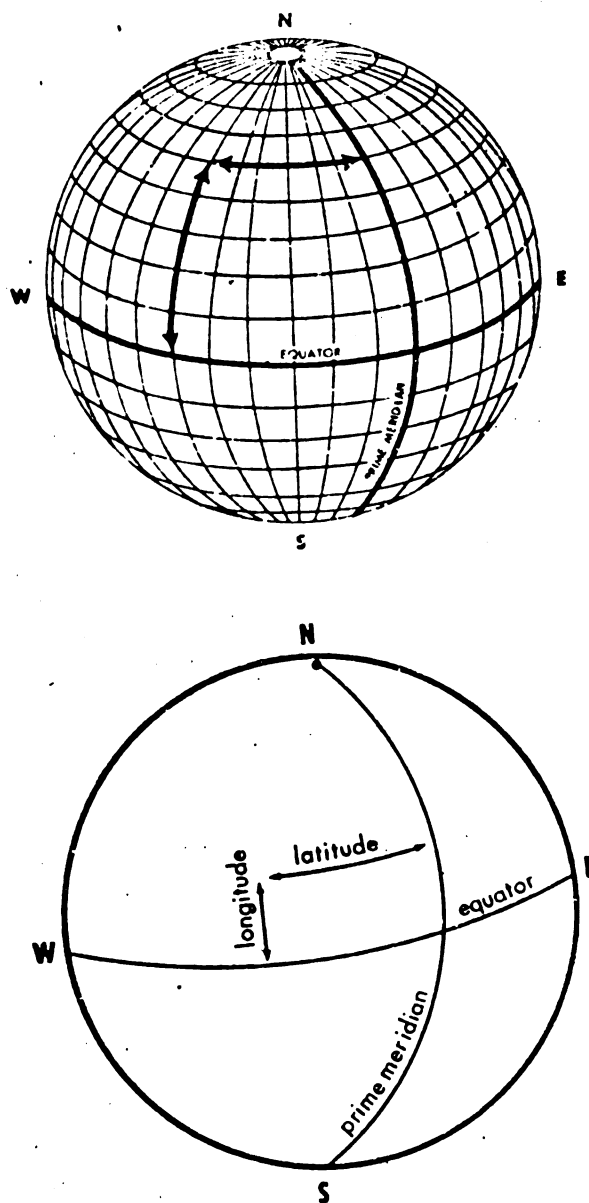


Figure 3. Geodetic (Geographic) Coordinate System

these coordinates become the familiar system of latitude and longitude, the field measurements are reduced to sea level on an assumed model of an ellipsoid and adjusted for triangulation error. Although there are several ellipsoids which may be assumed as a base, the Clarke Ellipsoid of 1866 (adjusted in 1927) has been adopted in the United States while different ellipsoids are employed by the other continents of the world.

Geodetic coordinates are recorded on all maps published by the U.S. Geological Survey and the U.S. Coast and Geodetic Survey. These agencies are responsible for all official measurements (horizontal and vertical control dimensions) of the United States and also for all topographical mapping programs.¹¹ It is possible to scale geodetic coordinates from such map sources, but not without some loss of accuracy. Geodetic coordinates derived through an expensive first order survey remain the most accurate system available.

1.b. Astronomic Coordinates

This system of coordinates is based on celestial observation rather than actual measurement of the earth's surface as in the geodetic system. In the use of this point locational system rather than terrestrial measurement, a resulting error of approximately two miles may be expressed at any one point. The computational difference between the geodetic and astronomic coordinate systems is due to the variance in modular form of the ellipsoid from the geoid. Such a system of astronomic observations does not readily lend to a feasible locational system of geographic referencing.

¹¹ Pitkin, Francis A., "Maps and Air Photographs - A Necessary Tool for State Planning and Development," Surveying and Mapping, Vol. 8, No. 3 (September, 1948), p. 120.

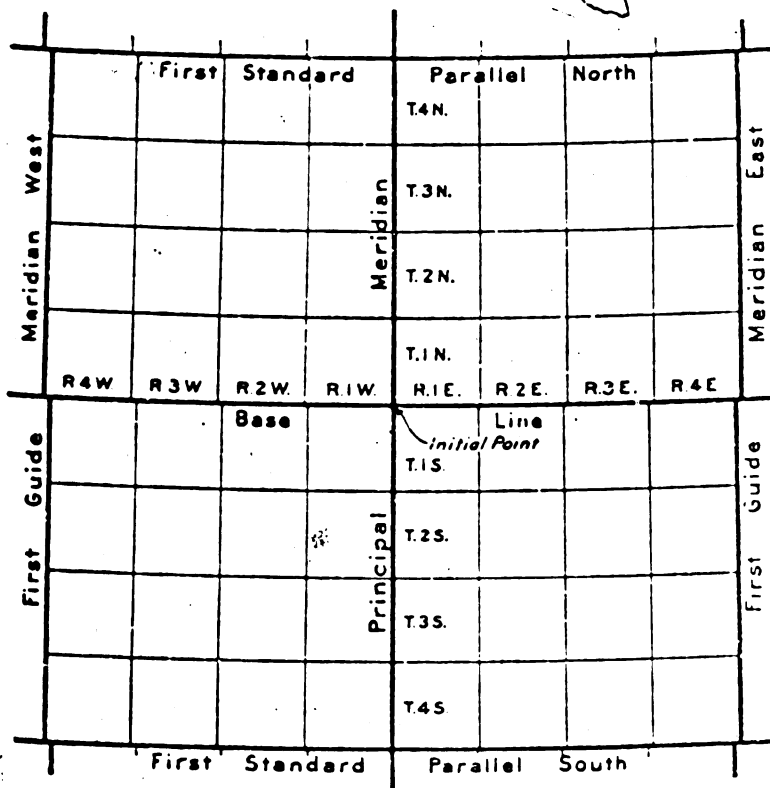
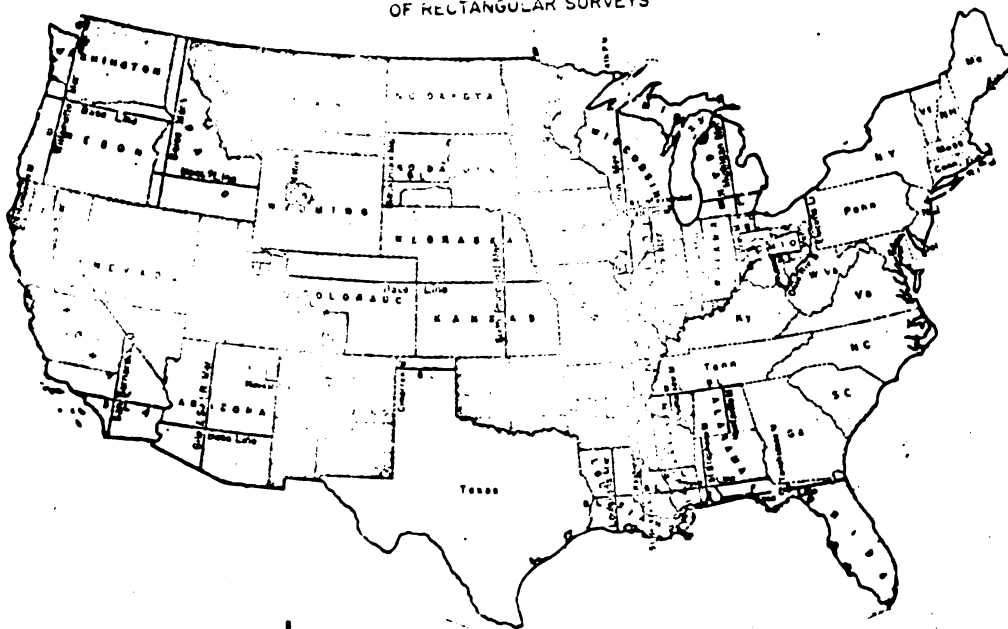
1.c. U.S. Public Land Survey

The Public Land Survey, which is more commonly referred to as the Township and Range system, is not a locational coordinate system. In fact, since it functions as a system of areal identification, it should be more properly considered as a form of the name method of geographic identification. However, it must be considered in this discussion as it has been and continues to be viewed as a legalized coordinate system upon which to base large volumes of collected and recorded information. The greatest amount of information based on this system is that relating to land ownership; an informational element which would be significantly important in any area-wide information system.

Although the units are approximately of equal size, the system is referenced to geodetic coordinates at only a few isolated points. However, this Township-Range system does appear on official topographic maps along with geodetic coordinates permitting positional references to be either directly scaled from these maps or conversion by mathematical formulae. To date, there has been little research toward such a conversion system which could be used to compute the distances between locational positions referenced to the Township-Range system. One recent attempt toward a conversion equation system,¹² stresses the assumption that the Public Land Survey was executed exactly to the official specifications. This may not be the case in certain areas in the United States. Furthermore, this general land survey has not been extended

¹²Tobler, Waldo R., "Areal Conversion in Geography, Appendix I: Conversion from the Public Land System to Latitude and Longitude." Department of Geography, the University of Michigan, n.d. (Mimeographed)

PRINCIPAL MERIDIANS OF THE FEDERAL SYSTEM OF RECTANGULAR SURVEYS



TOWNSHIP 2 SOUTH, RANGE 3 WEST

6	5	4	3	2	1
7	8	9	10	11	12
16	17	18	15	Section 14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

SECTION 14

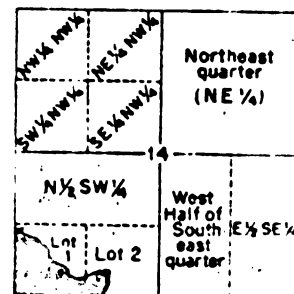


Figure 4. U.S. Public Land Survey System

throughout the different states and many portions of the United States have no such system. Although such above mentioned conversion formulae may be the key to recompilation of large quantities of recorded information onto a more compatible locational referencing system, it is doubtful the Township-Range system could ever be selected as such a unilaterally compatible coordinate system.

1.d. GEOREF System

The World Geographic Reference System, GEOREF, has been developed and used extensively by the United States Air Force. It is actually a modified combination of both the name and location methods of geographic identification. The system was specifically designed for readily identifying locations and is based on the highly accurate system of geodetic coordinates. The GEOREF System is basically an alpha-numeric system which employs letters to rapidly identify the sub-area or quadrilateral bounded by specific latitude and longitude in reference. Advantages of this system are primarily with its rapid designation and its comprehensibly clear verbal transmission. Although this system achieves maximum utility in applications necessitating error-free rapid verbal transmission, it clearly cannot attain such utility in an automated digital information system.

2. Spherical Systems

These systems allow for computational simplification by transforming geodetic latitude and longitude from an assumed ellipsoidal base to an assumed spherical base. In the design of coordinates for this spherical model of the earth there normally involves a selection of alternative measures of latitude and spherical radii.

2.a. Alternative Spherical Coordinate Systems

Various spherical coordinate systems are based on alternative choices of latitude and radii. Alternative measures of latitude may include, for example: authalic, geocentric, geographic, isometric, parametric, or rectifying latitude. Geographic latitude, perhaps, is the most logical as it is essentially the equivalent to that of the original ellipsoidal geodetic coordinates. Alternative measures of radii include at least the following: equatorial radius of the ellipsoid, mean radius of a specific zone, geocentric radius, or radius of curvature in the meridian. The greatest advantage with these assumed spherical systems is that of coordinate computation through the means of more simplified mathematics. Disadvantages of these systems, however, are that for each assumed sphere the computation of areas, directions and/or distances will differ from the corresponding values of the original ellipsoid by varying degrees of significance.

3. Planar System

These systems are more commonly known as map projections which represent the surface of the earth or any portion thereof, on a flat, two-dimensional plane. This entails the transformation of ellipsoidal (geodetic) or spherical coordinates to a plane in such a manner as to retain certain clearly defined properties. Two primary advantages with planar systems are (1) the most simplified computation of coordinates using plane geometry and (2) computational errors may be estimated to compare them against a specified degree of accuracy. These projection systems commonly used on published maps are often referred to as plane coordinates. Plane coordinate systems in general use in the United

States are usually expressed in rectangular (cartesian) coordinates. In this form, coordinates may be readily used to identify, record and store geographically-based information as well as for computational purposes.

There are numerous varieties and variations of projection and plane coordinate systems all of which purport to possess certain advantages. However, since several detailed texts and papers exist on this subject, no attempt will be made here to include them.¹³ This discussion will be limited to those systems in common use throughout the United States and those whose properties appear suitable for use in an area-wide information system.

3.a. Universal Transverse Mercator System - (UTM)

The UTM system, developed by the United States and its allies shortly after World War II as the Military Universal Grid System, is employed primarily by the United States Army. This system which is also known as the Universal Grid System actually consists of two sets of grids; the UTM and the UPS (Universal Polar Stereographic System).

A UTM grid is employed from the equator to eighty degrees north and south latitude, where as the two UPS grids cover the polar regions. Since the UTM covers most of the territory of principal concern, the entire system is commonly referred to by that name. The system divides the globe into sixty north-south zones of six and one-half degrees each. The half

¹³ See C.H. Dietz, Cartography, U.S. Coast and Geodetic Survey, Special Publication No. 205 (Washington: GPO, 1936); David Greenhood, Mapping (Chicago: University of Chicago Press, 1964); and U.S. Department of the Army, Grids and Grid References, Technical Manual No. 5-241-1 (Washington: Department of the Army, 1962).

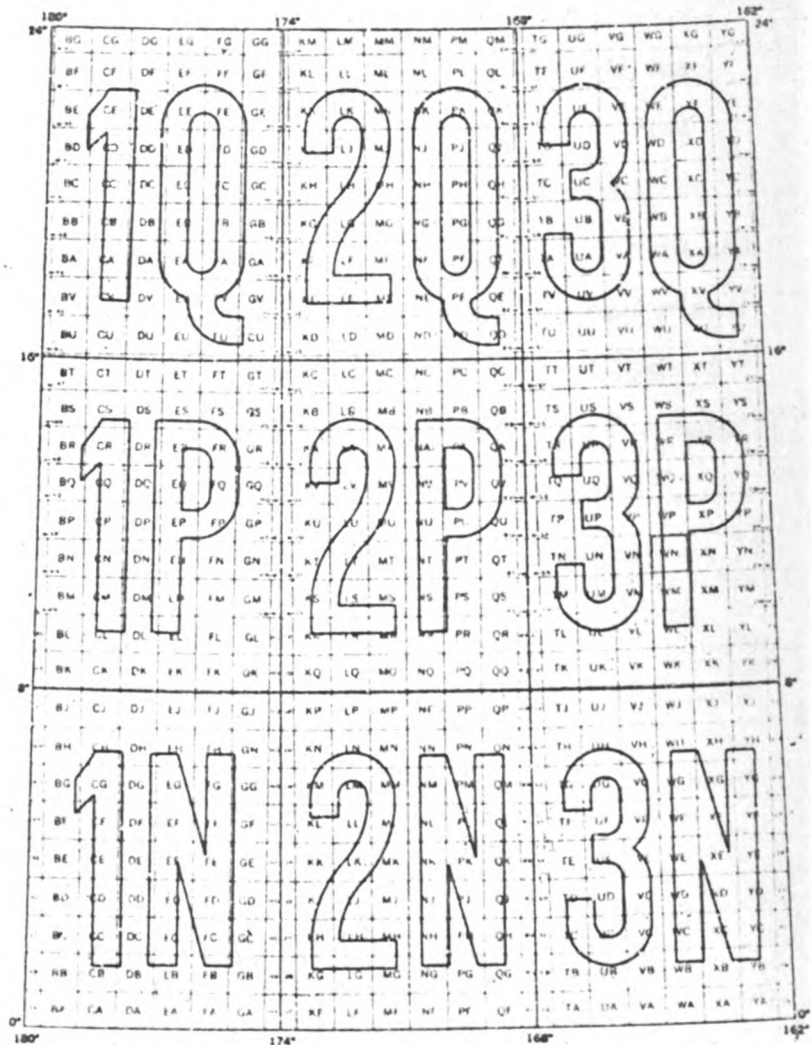
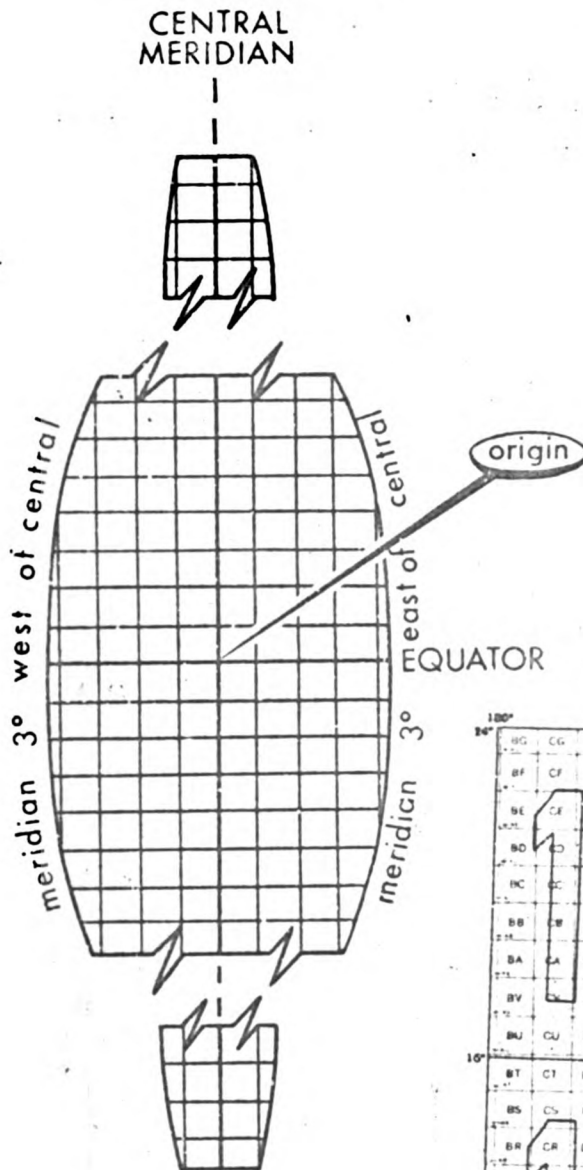


Figure 5. Universal Transverse Mercator System (UTM)

degree provides an overlap area which simplifies computational procedures near zone boundaries.¹⁴ Each zone has an internal accuracy of one part in 2500. Similar to the Air Forces' GEOREF System, the UTM uses alphanumeric identification to facilitate rapid geographic referencing. UTM coordinates are shown on all Army Map Service topographic maps as well as on all recent U.S. Geological Survey topographic maps. The chief advantage of this system is its accuracy. However, the necessity of conversion tables and formulae to interrelate information of adjacent areas extends the costs in terms of complexity and difficulty in use.

3.b. State Plane Coordinate System

Each state in the United States (including Alaska and Hawaii) has its own plane coordinate system specifically designed for and oriented to that state. With only one exception, the Lambert Conformal Conic or the Transverse Mercator projections are employed; two states (New York and Florida) utilize both projections due to their territorial configurations.

The Lambert Conformal Conic projection is an oblique secant type of conic projection. This method allows the portion of the globe of primary concern to be projected onto a grid with a high degree of accuracy.¹⁵ The plane surface of the Lambert conformal projection is represented as the unrolled surface of a cone which intersects the globe at specified

¹⁴ Colvocoresses, Alden P., "A Unified Plane Coordinate Reference System," (unpublished Ph.D. dissertation, Department of Geodetic Science, Ohio State University, 1965), pp. 19-20.

¹⁵ Vance, John A., "Geographic Data Coding Grid," A paper presented at the annual convention of Canadian Good Roads Association, Halifax, Nova Scotia, September 6-9, 1966, p. 17. (Mimeographed)

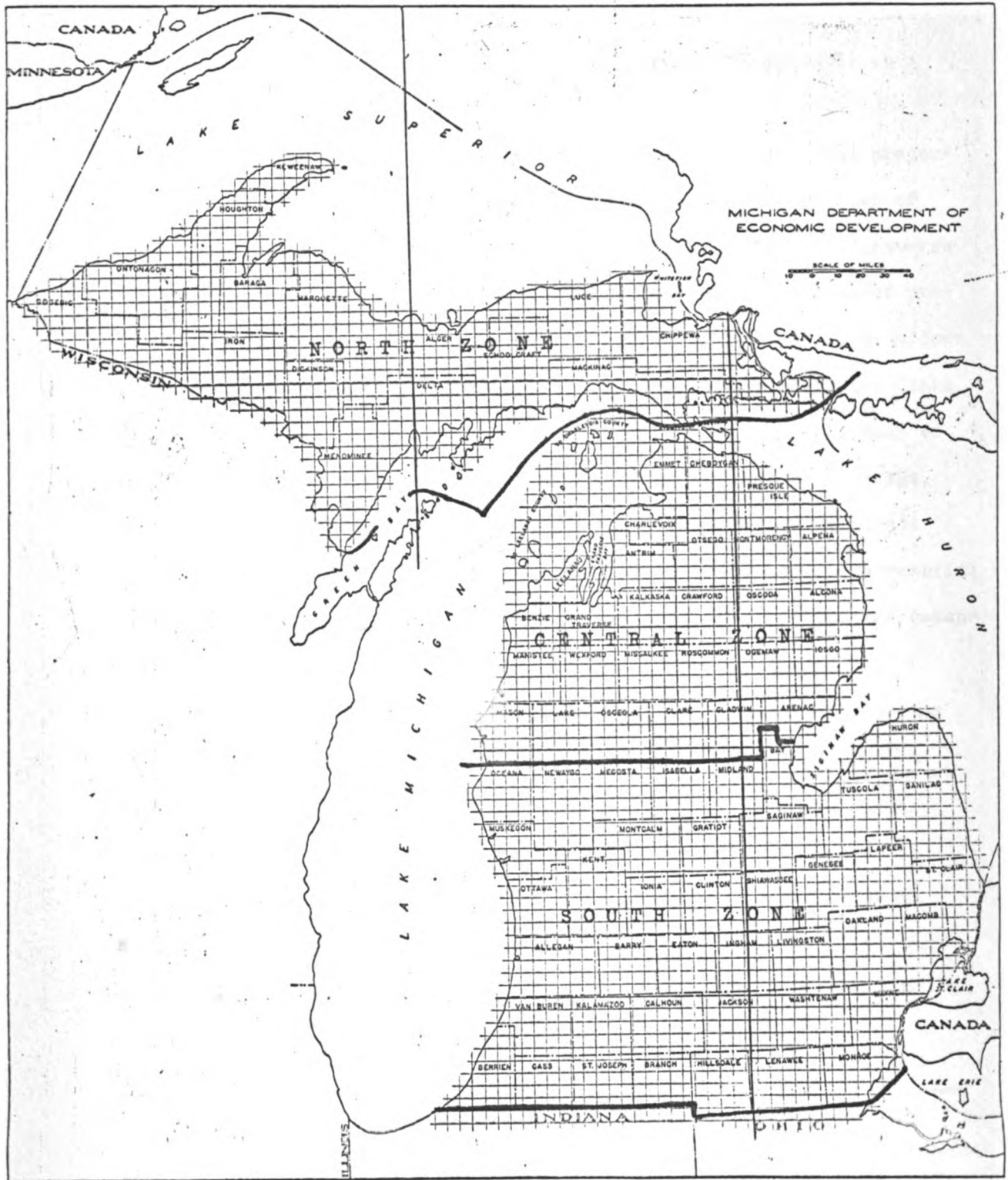


Figure 6. Michigan State Plane Coordinate System

latitudes.¹⁶ This form of projection is particularly applicable to areas of east-west extent.

The Transverse Mercator projection is a form of cylindrical projection. It assumes the axis of a cylinder passes through the center of the earth with the equator the line of tangency. The form of Transverse Mercator employed by the State Plane Coordinate System on states of predominately north-south area is an oblique secant projection. This allows the projection cylinder to intersect the earth's surface along two lines which are parallel to the central meridian of a state or zone. Both of these projection systems are limited to 158 miles as maximum coverage. In both systems the planes intersect the earth at positions mathematically calculated in such a manner that the variation between a terrestrial measurement will not differ from that on the plane by more than the established minimum level of accuracy (1:10,000).¹⁷

In some cases, such with that of Michigan, several Lambert systems are established rather than utilize the Transverse Mercator grid. In this case of the State of Michigan, there are two justifications for this. First, it is beneficial to retain the entire state on a single projectional form (although the Lower Peninsula lies in a north-south direction, the Upper Peninsula is definitely of east-west extent). And second, although the Lower Peninsula extends pronouncedly in a north-south direction, most of the economic interaction is of an east-west

¹⁶ Schuman, E.K., Plane Coordinates, A reprint from "Topographic Division Bulletin, December, 1953," U.S. Geological Survey (December, 1965), p. 143.

¹⁷ Newlin, Philip B., "The State Coordinate Systems," Proceedings, Seventh Arizona Land Surveyors' Conference, April 9, 1960 (Tucson: Engineering Experiment Station, University of Arizona, 1960), pp. 7-9; and Vance, op. cit., pp. 19-21.

flow. Thus, Michigan chose to employ three Lambert grid systems to minimize the areal distortion. These separate but interrelated systems are designated as the north, central and south zones.¹⁸

The number of zones within an individual state varies from one as in Maryland to seven as in California.¹⁹ The entire system consists of approximately 125 zones (separated grids) throughout the United States. The degree of accuracy required within this system is at least one part in 10,000 for each zone although some states have zones with accuracies of up to one part in 40,000.²⁰ Boundaries of these zones coincide with those of minor civil divisions, most predominately county lines. As with the UTM grid, there is some degree of overlaps which permits computational facility with inter-zonal transformations.

Both of these Lambert and Mercator projections are mathematical and are the solution of the equations of points in a three-dimensional region defined by latitude, longitude and the radius vector in terms of the x and y axes in the plane. The computed equations derived from these projections for x and y allow for the spheriodal shape of the earth as well as reduction to sea level.²¹ This system is well suited to needs of the local land surveyor, allowing him an accurate and permanent procedure to use simple plane geometry in the field and readily available

¹⁸Berry, Ralph M., "Uses and Use of the State Plane Coordinate System," A paper presented at the annual conference of the Michigan Society of Registered Land Surveyors, Lansing, Michigan, February 8-10, 1962, p. 5. (Mimeographed); also see Appendix A.

¹⁹Schuman, op. cit., p. 145.

²⁰Newlin, loc. cit.

²¹Schuman, op. cit., p. 143.

and relatively easy conversion tables in the office for computational purposes. This provides for maximum utility of a highly accurate system at the local level. This local accuracy of a nation-wide system renders the State Plane Coordinate System as a highly desirable candidate for a unified state-wide information system. Somewhat comparable to the disadvantage with the UTM, is the mathematical complexity of conversion between zones and between states. This may be offset, however, with the use of electronic computers within any automated information system.

3.c. Local Systems

Local coordinate systems are typically of two types: referenced and unreferenced. The so-called referenced systems cannot be recognized as map projection systems as they are usually defined by the grid coordinates on a map of unknown projection where their relation to geodetic coordinates may or may not be known. In the latter sense, they resemble unreferenced systems. Several major cities use this system as the basis of their engineering work, for example, Cleveland, New York, and Washington.²²

An unreferenced coordinate system is defined as one in which there is no known relation (terrestrial reference) to geodetic coordinates (latitude and longitude). Under this system an arbitrary point which lies both south and west of the local area to be mapped is selected as the origin of the x and y coordinates. The point of origin is usually positioned at a sufficient distance west and south of the area of interest so as to avoid the use of negative coordinate values. The location of a point within the local area is then defined by the perpendicular

²² Also see Walter F. Reynolds, Relation Between Plane Rectangular Coordinates and Geographic Positions, U.S. Coast and Geodetic Survey Special Publication No. 71 (Washington: GPO, 1936).

distance from the x and y coordinates to the point. Measurements are commonly made in feet with no adjustment for the curvature of the earth or reduction to sea level datum.²³

An advantage of this system is that the operational analysis of local information necessitates little skill or cost. This may be justified if the information collected has no permanent value, however, a major contingency of this thesis is that all information worthy of collection by a governmental agency at the public's expense is worthy of record or permanent value. The primary disadvantage under this system is that errors are introduced which are not calculable. Thus, the degree of accuracy within which an adjacent local area may be included is unknown and at best uncertain. A second major disadvantage is that information collected for one purpose cannot be used for another when either the study area of the latter encompasses a larger area than the original study, or the two studies are at different points of time, allowing the originally mapped data to become lost, or the latter study requires a higher degree of accuracy than the first. Although conversion of unreferenced systems to systems related to geodetic coordinates is possible when the accurate position of enough points of both systems is known and is feasible through the use of a computer,²⁴ the awkwardness of the multitude of complicated transformation equations for all the various arbitrary grids would render the complexity of any area-wide information system completely unwieldy.

²³ Schuman, op. cit., p. 134.

²⁴ Vance, op. cit., p. 27.



This chapter has examined some of the characteristic advantages and disadvantages among various systems of locational coordinates considered as potentially appropriate for use in a unified state-wide information system. It is important to note that multi-purpose planning at the state level will increasingly necessitate locationally referenced information at increasingly higher levels of accuracy. Considering both this proposition and the previously discussed criteria for evaluating potentially useful locational reference systems, it appears as if the State Plane Coordinate System offers the most for any area-wide data system. Thus, it must follow that the Michigan Coordinate System would be a logical choice for the locational referencing element in the proposed state-wide information system.

CHAPTER IV

THE STATE PLANE COORDINATE SYSTEM

Developmental Perspective in the United States

History

The necessity for an accurate national network of horizontal control has long been recognized by the federal government as a means of perpetuating national, state, and other official boundaries. In addition, it has served to provide a correlating framework for mapping and charting programs as well as many other purposes. Horizontal control commonly refers to any system of survey points whose horizontal positions have been determined by geographic coordinates. For the past 150 years the U.S. Coast and Geodetic Survey has engaged in establishing the geodetic position of thousands of monumented control points (approximately 150,000) throughout the country. This federal office is charged with the responsibility of the establishment of horizontal and vertical control of the highest order upon which most other control surveys in the nation depend.¹

During World War I, the U.S. Coast and Geodetic Survey was first exposed to the unique system of mapping used by the French. This system was based on the Lambert Conformal Projection and represented many innovations to cartography at that time. It used a single reference datum and a grid system of rectangular coordinates which were especially adapted

¹ Committee on Highway and Bridge Surveys, "State Plane Coordinates," Journal of the Surveying and Mapping Division, American Society of Civil Engineers, Vol. 83, No. 1, Proceedings Paper 1306 (July, 1957), p. 4.

to the quick computation of azimuths (angle between a straight line and the central meridian of a grid system)² and distances in military operations. This offered an accurate, easy procedure of land description as all angles were defined in decimal equivalents rather than in the degrees and minutes of the conventional latitude-longitude system. The French system also included a computational procedure for recovering and re-establishing destroyed monuments or markers.³

In 1933, the U.S. Coast and Geodetic Survey was contacted by a university professor, who admired the utility of the French system, about the feasibility of setting up such projection grids for the various states. This request stressed the need for more adequate land descriptions and for more accurate and permanent monuments among the highly populated New England states.⁴ In that same year a similar request was submitted to the U.S. Coast and Geodetic Survey by the North Carolina State Highway Department. In this case, a state highway engineer sought a method of utilizing the highly accurate datum established by the U.S. Coast and Geodetic Survey over an entire state which would involve only the simplified computations of plane surveying.⁵ Also during this period,

²U.S. Department of the Army, Surveying Computer's Manual, Technical Manual No. 5-237 (Washington: Department of the Army, 1964), p. 450.

³Schuman, E.K., Plane Coordinates, A request from "Topographic Division Bulletin, December, 1953," U.S. Geological Survey (December, 1965), p. 146.

⁴Ibid.

⁵Doran, Philip C., "Geodetic Surveys and North Carolina Coordinate System," A report by the Division of Geodetic Survey, North Carolina State Department of Conservation and Development, 1961, p. 2. (Mimeographed)

most of the progressive engineers in the country had been convinced of the need for plane coordinate systems which could be extended over greater area without distortion errors.⁶ The U.S. Coast and Geodetic Survey in response to these requests and in acknowledgement to the practicality of such an action decided to make the geodetic data of the national survey readily available to all land surveyors and engineers by the establishment of the State Plane Coordinate Systems. By 1935, a separate system had been developed for each state of the union.⁷

The basic problem recognized by the establishment of these state systems had prevented the use of accurate control data for local cadastral and topographic surveys for well over a century. Since 1816, when the national control network was first begun, the U.S. Coast and Geodetic Survey had been establishing accurately located survey monuments throughout the United States.⁸ These monuments were as they are today, established by a system of triangulation based on the trigonometrical proposition that if three parts of a triangle are known (e.g., the measurements of one side and two angles) the elements may be obtained by computation. The monuments or points established by this system have been often referred to as stations and as they represent the framework

⁶ Adams, Oscar S. and C. N. Claire, Manual of Plane-Coordinate Computation, U.S. Coast and Geodetic Survey Special Publication No. 193 (Washington: GPO, 1935), pp. 2-3.

⁷ Mitchell, Hugh C. and Lansing G. Simmons, The State Plane Coordinate Systems, U.S. Coast and Geodetic Survey Special Publication No. 235 (Washington: GPO, 1945), pp. vi and 49.

⁸ New Jersey State Department of Conservation and Economic Development, Bureau of Geology and Topography, "Mapping Digest for New Jersey," Bulletin 66 (Trenton: State of New Jersey, 1965), p. 5.

or rule by which the official measurement of the horizontal and vertical distances on the earth's surface are made, they have been also designated as control stations.⁹

Until the 1930's, these control stations had been only expressed by geodetic data (coordinates expressed in latitude-longitude, azimuths and distances) which had been derived by complicated geodetic formula.¹⁰ Computational procedures and instrument methods required for the use of the geodetic data of these stations resulted in unmanageable and expensive surveys. At this time few engineers and surveyors were skilled in these techniques. In addition, the necessary precision instruments were rarely available, neither were tables of the computational factors required by this sophisticated datum. Thus, the use of geodetic coordinates for the accurate location and correlation was negligible. While many who were familiar with this system felt that the difficulties of its use were overstated, the fact remained that it was not used. It soon became evident that some other approach to utilizing the accurate data of these stations must be developed. The U.S. Coast and Geodetic Survey answered this dilemma by the establishment of the State Plane Coordinate System.¹¹

Thirty years ago the Federal Board of Surveys and Maps¹² recommended to federal and non-federal agencies that,

⁹Mitchell, loc. cit.

¹⁰Doran, loc. cit.

¹¹New Jersey State..., loc. cit.

¹²whose functions have been since transferred to the Bureau of the Budget.

wherever practicable, they adopt the systems of plane coordinates devised for the various states by the Coast and Geodetic Survey, and use these state systems of plane coordinates as bases for such of their surveys and maps as will not, because of their nature or extent, require the use of some other system of coordinates or method of recording.¹³

It further recommended that,

wherever practicable, they should show the appropriate state plane coordinate systems as supplementary projections on all maps and charts produced by them which may have value and use for engineering purposes, but which because of their nature or extent require a geographic base.¹⁴

These recommendations have been followed by many federal agencies, particularly on the topographic maps of the most productive mapping organization of the country, the U.S. Geological Survey, which must be based primarily on geographic projections. Thus, these maps have proved to be a great asset to the local surveyor in reducing a land survey to a state grid and accurately transferring it to the map. This has provided for the coordination of topographic and cadastral information which has been most important in the planning and programming of engineering projects.¹⁵

Today, for every traverse or triangulation station determined by the national geodetic survey in any of the fifty states, there is a corresponding plane coordinate position derived by an accurate and precise mathematical procedure. The U.S. Coast and Geodetic Survey computes and publishes these plane coordinates on all control stations

¹³ Mitchell, op. cit., p. vi.

¹⁴ Ibid., p. vii.

¹⁵ Ibid.

for which it determines geodetic data. Any local surveyor or engineer may use these stations through the medium of their plane coordinates on the state system. He need not be concerned with the geodetic processes by which the control data were obtained or of the mathematics used to convert the geodetic data into state coordinates. This permits him to base his entire survey on plane coordinate data and use the familiar methods of plane-surveying throughout the work. When the land surveyor ties his survey into a nearby control station, a state coordinate position for each corner of the land is created and the survey becomes linked to all the stations of the national geodetic network. In this manner all stations of the national geodetic survey become witnesses to the locational coordinates of land corners whose relation to a state system are known. Corner markers such as fence posts, stakes, trees or any type of artificial marker may be destroyed by numerous natural or man-made causes. However, the positions they occupied on the land can be readily and accurately re-established from any recoverable station of the national network. Thus, any land boundary corner described in terms of a state coordinate system is practically indestructible or at least as permanent as the national network of geodetic control. Limitations on such use of state coordinates occasioned by the lack of control stations in many areas has been reduced each year as the U.S. Coast and Geodetic Survey extends its triangulation network into new localities, and thereby makes more and more data available for reference.¹⁶

¹⁶Ibid., pp. 49-50.

Prior to 1933, there was a lack of any established plane coordinate system of area-wide availability. In addition, there existed no means of designating permanent or legal significance to the use of such a system in a recorded land description. The use of plane coordinates for local surveying, mapping or computation, however, was certainly not unique to the early thirties. It must be noted that a form of such a system was used by the ancient Egyptians when referencing the boundary corners of the valley lands of the Nile. The only thing new with the establishment of the state systems was that they were so tied to the national control network as to be available for general use anywhere in a state when in the proximity of a properly-located control station.¹⁷

In order to facilitate the use of this convenient method of recording the geographic location of property corners a state must officially define the name of its uniquely oriented system, such as the Michigan, Ohio, or Wisconsin Coordinate System. This is necessary so that whenever reference to a particular state's system is made there is no question to the system in reference. Also, this official definition serves to preclude improper usage of a state system as well as ambiguous reference to it. The most appropriate way of accomplishing this official designation is through legislative enactment.

In 1935, the New Jersey State Legislature signed into law the first state plane coordinate system.¹⁸ After this initial legislation, each

¹⁷Ibid., p. v.

¹⁸New Jersey State..., op. cit., p. 6.

succeeding year saw other states officially recognizing the need for such a legal system. To date, twenty-eight states have taken such legislative action. A list of these states and the dates of their legal adoption of the State Plane Coordinate System includes:¹⁹

New Jersey	1935	Ohio	1945
Pennsylvania	1937	Oregon	1945
New York	1938	Rhode Island	1945
North Carolina	1939	Vermont	1945
Maryland	1939	Washington	1945
Massachusetts	1939	Virginia	1946
Texas	1943	California	1947
Louisiana	1944	Maine	1947
Alabama	1945	South Dakota	1947
Connecticut	1945	Tennessee	1947
Delaware	1945	Indiana	1951
Georgia	1945	New Mexico	1957
Minnesota	1945	Wisconsin	1963
Nevada	1945	Michigan	1964

It is interesting to note the significant time-lag between the establishment of the state systems in 1935 and the adoption of these systems by the various states. Some of the most vehement opposition to the enactment of many of the earlier state systems came from representatives of Title Companies who envisioned property descriptions becoming "unnecessarily and dangerously abbreviated when based solely upon the coordinates of land corners."²⁰ These objections were satisfied in most acts by a provision making the description of real estate by coordinates strictly voluntary and supplemental to other forms of legal description,

¹⁹ Mitchell, op. cit., p. 53; Wilkie Cunningham, "Making Land Surveys and Preparing Descriptions to Meet Legal Requirements," Surveying and Mapping, Vol. 14, No. 4 (December, 1954), p. 447; and Letter from J. O. Phillips, Chief, Geodesy Division, U.S. Department of Commerce Environmental Science Administration, Coast and Geodetic Survey, Rockville, Maryland. October 12, 1966.

²⁰ Ibid.

such as reference to the system of U.S. Public Land Survey.²¹ (An illustration of this can be found in Appendix A, Section 8)

Real estate interests, however, are not the main source of the reluctance for official sanction of the state systems. A great number of engineers and surveyors are hesitant and often against the use of the State Plane Coordinate Systems because they believe the mechanics are too complex to merit the necessary interest to expend their extra time to acquire working knowledge of the subject.²² It has also been noted that where an adopted system does not exist a large number of engineers and surveyors still do not appear to know what the system is about or know how to take advantage of it.²³ In either case, most local surveyors make little use of it, even in areas where adequate basic control exists. The two most probable reasons for this are, first, no local requirement is mandatory regarding its use and second, very few local surveyors know how to use it.²⁴

One problem with the advancement of these systems is that the argument for the adoption and expanded use of a geographic control system is somewhat subtle to present. Part of this difficulty lies in the

²¹New Jersey State..., op. cit., pp. 6-7.

²²Dixon, Charles M., "A Practical Application of a Geodetic Control Survey and State Coordinate System," Surveying and Mapping, Vol. 9, No. 2 (June 1949), p. 105.

²³Watts, Robert G., "Simplicity of State Plane Coordinate System in Surveying," Surveying and Mapping, Vol. 25, No. 4 (December, 1965), p. 543.

²⁴Ibid.

fact that this argument is normally advanced through the exclusive efforts of the professional land surveyor, when the utility of accurate control extends far beyond the pure and simple surveying operation. Essentially, the overall objective to be achieved by the use of such a system is that of resource appraisal and physical development. Since land is generally considered our basic resource, not lending to depletion or consumption, its description, appraisal, development and conservation of appropriate use is of foremost importance.²⁵ All other resources are either part of the land or dependent on land-based facilities for its production, development and utilization. Because of the unique nature of this resource, its users have an obligation to utilize it appropriately, economically, without misuse or abuse, and without detriment to other users. Therefore, it behooves all those concerned with the physical development and utilization of the land to engage in extensive research, study and planning. Proper planning and analysis, however, cannot be undertaken without an examination of all characteristics of the parcel or area of land in consideration. And finally, an examination and appraisal of this information is but a futile task without a systematic means of graphic delineation.²⁶

Maps, by definition, are a graphic representation of the surface of the earth or any portion thereof. The inclusiveness of detail varies with the objective of a map, but the element of location or position is

²⁵Wright, Marshall S., "Contribution of Control to Conservation," Surveying and Mapping, Vol. 13, No. 3 (September, 1953), p. 356.

²⁶Michigan Society of Registered Land Surveyors, "Report of the Sub-Committee on State Coordinates," n.d., p. 4. (Mimeographed)

fundamental to all maps. Only through position can the characteristics regarding a parcel or area of land be related. A map has often been considered the vehicle by means of which a plan for land use and conservation emerges and takes on definite form and substance consistent with rational forethought.²⁷ In the process of land development the element of position is basic to all design and construction operations. It is apparent that the concept of position or locational reference is an integral part of the objective of resource description, appraisal and development.²⁸

In the context of this objective the term "map" typically connotes a form of topographic maps. Although accurate topographic maps based on a coherent system of control are the very foundation of adequate land planning, the term map is far more comprehensive. As a common element of research and analysis, information on resource characteristics must be inventoried (i.e. identified, located and indexed). It is important to note that the term "resources" cannot be limited to only natural resources such as minerals, vegetation and wildlife. In any study and analysis for the physical development of land the term includes physical resources such as highways, industrial and commercial facilities, dwelling units, and public utilities. Also included are human resources such as population types, characteristics and concentrations as well as interrelated resource flows such as income and employment distribution,

²⁷Herlihy, Elizabeth M., "Surveys and Maps Required at the State Planning Level," Surveying and Mapping, Vol. 10, No. 3 (September, 1950), p. 220.

²⁸Michigan Society of Registered Land Surveyors, loc. cit.

trip-travel routes and trends, and military operations. All of these must be considered in the comprehensive objective of planning resource utilization and development.²⁹

Although in some cases various resources may be identified without the use of maps, they cannot be rationally delineated in their appropriate locational interrelationships unless referenced to specific positions. The basis for any locational referencing element which is to be integral part of any regional or state-wide resource inventory or plan is a standardized plane coordinate system.³⁰ It is fundamental that this coordinate system be familiar and readily available to all interested users such as state, regional and local agencies, academic research institutions, industry and private individuals who may be concerned with such locational analysis. One of the greatest advantages of utilizing such a standardized coordinate system is that any number of various separate studies may be correlated when all are locationally referenced to a single coordinate system.

Current Status

In order to ascertain the current status of State Plane Coordinate System use in the various states which have legally authorized and defined a specific system for use throughout the state, a representative sample of these states was contacted and questioned on this subject. The following is a discussion of the results of this correspondence in

²⁹Ibid., p. 5.

³⁰Ibid.

chronological order of each state's legal adoption of its respective State Coordinate System.

New Jersey: The New Jersey Bureau of Geology and Topography has the responsibility to maintain and extend a monumental plane coordinate system which originally comprised approximately 12,000 control points. At present, due to the fact that a four-man field party is expected to maintain this system, they cannot keep up with replacement work and extension is impossible.³¹ The State Highway Department also uses the state coordinate system to establish alignments in highway design. Air survey firms are also using the control of the New Jersey system and private engineering companies have established a considerable number of coordinate positions for major construction projects.³²

Pennsylvania: Ever since the authorization of the Pennsylvania Plane Coordinate System in 1937, there have been no authorized funds to establish the on-ground markers or monuments necessary to make this an effective operational system. Some degree of progress has been made since 1937 by virtue of control stations established by the U.S. Coast and Geodetic Survey and the U.S. Geological Survey through their various projects requiring accurate geographic control. The Bureau of Topographic and Geologic Survey has an eventual goal of a systematic coordinate system with related control points so that no location within the state is more than one mile from a valid surveyor's reference point. The Bureau

³¹Letter from Harold Barker, Jr., Topographic Engineer, Division of Resource Development, New Jersey State Department of Conservation and Economic Development, Trenton, New Jersey, September 15, 1966.

³²New Jersey State..., op. cit., p. 7.

contends that the state grid system would then unquestionably offer a uniform language for documenting any point or location.³³

North Carolina: The Division of Geodetic Survey of the North Carolina State Department of Conservation and Development has been actively serving all agencies at both state and local levels that demonstrate a need for accurate maps and land surveys. The Division has been particularly of great value to the Community Planning Division of that Department in its local planning assistance. When the latter Division assists a community in procuring topographic mapping (through H.U.D.'s 701 program), the Geodetic Survey will run a traverse loop around the city, establishing a large number of permanent control stations. This substantially reduces the amount of field work necessary for the contracted aerial photo mapper and thus the total mapping costs to the city. This also allows all subdividers and developers to then tie their work to this control.³⁴ The North Carolina Coordinate System, when implemented, has the advantage of setting up a network of precisely located geodetic control points which can be used by all engineers and surveyors to produce accurate maps. These accurate maps are extremely essential in the locational referencing of missile sites, airfields, water and sewage lines, tax maps, state and county boundaries as well as public and private property surveys.³⁵

³³Letter from A.A. Socolow, Chief Geologist, Bureau of Topographic and Geologic Survey, Pennsylvania State Department of Internal Affairs, Harrisburg, Pennsylvania, August 31, 1966.

³⁴Letter from George J. Monaghan, Administrator, Division of Community Planning, North Carolina State Department of Conservation and Development, Raleigh, North Carolina, August 22, 1966.

³⁵Letter from Wilbur C. Fuller, Director, Division of Geodetic Survey, North Carolina State Department of Conservation and Development, Raleigh, North Carolina, August 29, 1966.

Maryland: The Maryland Coordinate System is utilized by numerous state, county and other agencies. However, the principal user is the State Roads Commission.³⁶ This Commission allocates approximately \$75,000 annually to extend and maintain the geodetic control markers located along the highway system. These control points are used mainly for highway centerline surveys and for topographic mapping by photogrammetry. The Commission indexes all descriptions and plane coordinate values of field markers and makes them available to all surveyors and engineers who may desire these data for their work. The state coordinate system is also used in the compilation of all highway maps prepared and distributed by the Commission. The principal advantage in using the state grid for these state-wide maps is that the projection permits the joining of adjacent county maps without noticeable distortion or appreciable gaps. This is extremely advantageous as county maps are used to prepare the base for Maryland State maps and all other maps of larger areas used for highways planning and report purposes. Since all the U.S. Geological Survey topographic maps covering the State of Maryland show the state coordinate grid, all of this valuable mapped information can be accurately projected to county or state maps by direct transfer using the grid lines as control. County highway maps derived in this manner have provided a simple procedure to reference cities, towns, places, reservations, and other boundaries to the state coordinate grid. The Commission in cooperation with the State Planning Department also prepares and

³⁶Letter from James J. O'Donnell, Director, Maryland State Planning Department, Baltimore, Maryland, August 26, 1966.

distributes an index of state coordinate control points entitled Maryland Manual of Coordinates.³⁷ This manual includes some 11,000 references to urban places plus 517 railroad station locations, 655 housing project locations and 493 selected points to define highway locations.³⁸

The State Tax Commission in an effort to perpetuate an efficient property assessment program has based a state-wide system of tax maps on the state coordinate network. Although the program was a large expense initially, its assistance to other state and local agencies has been of great value. For example, state and county highway departments can readily plot proposed routes on the maps which show the properties affected as well as their value, a factor which may suggest alternative routes. The same benefits can be derived from other public or private agencies plotting any type of utility right-of-way.³⁹ The system of tax maps consists of 1,600 base maps all of which indicate state coordinates. Although these coordinates are currently used only as a reference for compilation, it is anticipated that a computer method will be developed for detailed analysis of real property and its many facets by the use of state coordinate values.⁴⁰

³⁷Letter from George W. Cassell, Chief, Bureau of Highway Statistics, Planning and Programming Division, Maryland State Road Commission, Baltimore, Maryland, October 10, 1966.

³⁸Maryland State Planning Department, Maryland Manual of Coordinates, (Baltimore: State of Maryland, 1962), pp. 1-167.

³⁹Shoemaker, William L., "Tax Maps for Maryland," Surveying and Mapping, Vol. 15, No. 4 (December, 1955), p. 475.

⁴⁰Letter from Cassell, op. cit.

The system of plane coordinates is also utilized for property surveys of all new or existing property acquired for the State by the Department of Public Improvements. The procedure provides for each property corner to be designated by plane coordinate values. All property plots are cross-indexed by the coordinate value of the property's northwest corner.

Photogrammetric maps prepared for various state and local planning agencies all utilize the state coordinate system. Field control points for photogrammetry are set by monuments which also serve as an extension of the network of horizontal control throughout the state. In addition to the above, use is made of the coordinate system for reference purposes by the State Police, the County and State Civil Defense Agencies, and numerous surveying and engineering firms.⁴¹

Massachusetts: The Massachusetts Coordinate System was developed and is principally used by the Department of Public Works.⁴² As the Highway Division is located within this Department, it can be considered the main user of this locational coordinate system. In Massachusetts the State system is utilized extensively by private, municipal, county and state agencies. Nevertheless, its use is further advanced and encouraged

⁴¹Ibid.

⁴² Letter from Frederick A. Fallon, Director, Bureau of Planning Assistance, Massachusetts State Department of Commerce and Development, Boston, Massachusetts, August 23, 1966.

by the Land Court System requirements.⁴³ This system was originally established in 1898 to administer the many local systems of plane rectangular coordinates based upon U.S. Coast and Geodetic Survey geodetic control data..⁴⁴

Connecticut: The Connecticut Coordinate System is primarily used by the Highway Department, Park and Forest Commission, Water Resources Commission, and Aeronautical Department. Before its legal adoption, the system was put into operation by various welfare agencies during the Great Depression of the 1930's under the sponsorship of the State Highway Department and Yale University. The Highway Department continues to administer and supervise the system through a functional unit known as the Connecticut Geodetic Survey. This Department uses the coordinate system in all its location, topographic, boundary and other surveys. The major advantages have been its permanency and facility of interrelating area-wide survey data with accuracy.⁴⁵

Nevada: The Nevada Coordinate System is mainly used by the Department of Highways. Its primary value has been the ability to readily coordinate various projects on a common base. This has made interrelating and planning for future facilities much simpler and reduced the time and

⁴³Letter from A. P. Nichiporuk, Location and Surveys Engineer, Massachusetts State Department of Public Works, Boston, Massachusetts, September 16, 1966.

⁴⁴New Jersey..., op. cit., p. 6.

⁴⁵Letter from James V. Cesario, Geodetic Engineer, Connecticut State Highway Department, Wethersfield, Connecticut, September 7, 1966.

cost of preliminary work involved. The state coordinate system often is confronted with considerable opposition since it does not deal directly with a ground length but requires the length to be modified to a grid length. The Nevada Department of Highways, therefore, modifies the system in urban areas to reflect ground distances in order to receive a wider acceptance of the system.⁴⁶

Ohio: The Ohio Coordinate System is predominately used by the Divisions Geological Survey and Oil and Gas within the Department of Natural Resources. In the Geological Survey its application has been found invaluable for locational referencing of points in the meets and bounds areas such as the Virginia Military tract. The State is non-uniform in its land survey and the use of plane coordinates lends uniformity to all surveys throughout Ohio. The State Highway Department also uses this coordinate system in describing lands acquired for rights-of-way purposes, particularly in the meets and bounds areas.⁴⁷

Oregon: The use of the Oregon Coordinate System until very recently, had been largely confined to photogrammetric mapping and control surveys by the State Highway Department for route location purposes. Parallel to this period, the accuracy requirements as defined by the Oregon Statute for use of the State coordinate system were largely ignored. It is anticipated that the current interest in the system which has been renewed

⁴⁶Letter from Paul J. Dube, Planning Survey Engineer, Nevada State Department of Highways, Carson City, Nevada, September 20, 1966.

⁴⁷Letter from Russell A. Brant, Assistant Chief, Division of Geological Survey, Ohio State Department of Natural Resources, Columbus, Ohio, September 15, 1966.

by the professional planners will bring about the methods of attaining the objectives of a rigid coordinate control system.⁴⁸

The Metropolitan Planning Commission of Portland has been recently developing a computerized data bank system utilizing the state coordinate system. The principle of the data bank concept is based on the use of computer storage capacities, combined with computerized xyz coordinate plotting systems to provide instantaneous map print-out of all types of land-based data. To make such a system work over large areas all basic land data had to be fused into a common mathematical system, each bit of land data having a unique coordinate value. All lines and boundaries delineating structures or other land-based features had to be defined by a series of digital positions represented by coordinate values. The Oregon Coordinate System has proved excellently suited for this purpose.⁴⁹

The State Division of Planning and Development recently has become interested in this data bank concept and is currently undertaking a pilot multi-county project encompassing the Willamette Valley River Basin in cooperation with the Bureau of Municipal Research at the University of Oregon. A recent report has been published by this Division which lists approximately 4,500 state coordinate positions by township. This

⁴⁸Wood, Kendall B., State Coordinate Positions 1966 - Willamette Bain, A report compiled in cooperation with the Oregon State Department of Commerce, Division of Planning and Development (Portland, Oregon: State of Oregon, 1966), p. 2.

⁴⁹Ibid., pp. 2-3. Also see Portland Metropolitan Planning Commission, Progress Toward a Metropolitan Databank, (Portland, Oregon: Metropolitan Planning Commission, 1965).

list represents a pooling of land data which is all referenced to a common uniform grid by many various state, county and local and private agencies.⁵⁰ Another publication by this Division entitled "Map Models, Concepts and Applications" also being developed by the University of Oregon will soon be forthcoming.⁵¹

Rhode Island: Although the Rhode Island Coordinate System has been legally adopted, it has enjoyed extremely limited use by the state. Basically, this is because of a paucity of control points which exists throughout most of the state. However, in areas where control data are available the State Division of Roads and Bridges uses this State coordinate system in the surveying and construction layout of highways in the Interstate System. In the future, when more control becomes available, it is hoped that all engineering surveys will be based on this data.⁵²

Washington: The use of the Washington Coordinate System has received attention throughout the state from the Bureau of Surveys and Maps of the State Department of Natural Resources. This Bureau, in addition to being authorized to compile, maintain records and publish maps and data regarding land surveying was empowered to cooperate with and advise

⁵⁰Wood, op. cit., pp. 1-106.

⁵¹Letter from W.E. Hickey, State Planning Supervisor, Division of Planning and Development, Oregon State Department of Commerce, Portland, Oregon, August 30, 1966.

⁵²Letter from Arthur W. Suddard, Location Engineer, Division of Roads and Bridges, Rhode Island State Department of Public Works, Providence, Rhode Island, October 4, 1966.

all departments and subdivisions of the state, county and municipalities as well as all registered engineers and land surveyors of the state to accomplish the following objectives:

- (1)... recovery of section corners or other land boundary marks;
- (2)... monumentation of accepted section corners, and other boundary and reference marks... adequately connected to adjusted U.S. Coast and Geodetic Survey triangulation stations and the coordinates of the monuments computed to conform with the Washington Coordinate System... ;
- (3)... facilitation and encouragement of the use of the Washington State Coordinate System; and
- (4)... promotion of the use of the level net as established by the U.S. Coast and Geodetic Survey.⁵³

To accomplish these objectives and carry out its responsibilities, the Bureau has designed a cataloging system of indexing a modified form of the state plane coordinate system. This system of cataloging has produced a valuable technique of information storage and retrieval called coordinate indexing.⁵⁴ The modification of the coordinate system was mainly for its adoption to the State's electronic computer installation.⁵⁵

Virginia: The Virginia State Coordinate System is primarily used at the state level by the Departments of Highways and Public Works. The Highway Departments ties its construction surveys and rights-of-ways into the State coordinate system wherever possible. The Public Works Department

⁵³ State of Washington, "State Agency for Surveys and Maps," Washington State Laws, Chapter 58.24, pp. 3-4.

⁵⁴ Ingalls, Burton R., "Washington's Extended Use of State Plane Coordinates," A paper presented at the annual Surveying Teacher's Conference, Naches, Washington, August 5, 1957 (Olympia: State of Washington, Bureau of Surveys and Maps, 1957), p. 7.

⁵⁵ Ibid., p. 4.

also references land surveys for state institutions to the system in all areas where control is available. In addition, eighteen political subdivisions within Virginia either require or officially suggest that subdivision survey control be tied to coordinate system stations.⁵⁶

California: The California State Division of Highways had been the main state agency to use the California Coordinate System in its route location and construction work. The system, however, is becoming an extremely popular tool in the San Francisco East Bay Area thanks to the cooperative efforts of the East Bay Council on Surveying and Mapping.⁵⁷

In 1952, representatives from the State, Alameda and Contra Costa Counties, the East Bay Municipal Utility District, and several East Bay cities interested in surveying or mapping problems organized the East Bay Council on Surveying and Mapping. This organization has successfully continued to carry out the following objectives since its inception:

1. To coordinate the efforts of the many agencies -- Federal, State, County, City, District and private -- making surveys

⁵⁶State of Virginia, Division of Industrial Development and Planning, "Virginia Coordinate System, Appendix H," (Richmond: State of Virginia, 1962), p. 6.

⁵⁷An interesting vignette of the local popularity of this coordinate system was noted by an Oakland, California newspaper columnist. This journalist, known editorially as the Daily Knave, had indicated an interest in both the East Bay Council on Surveying and Mapping and its ardent promotion of the California Coordinate System. His interest eventually resulted in an invitation to a Council meeting which was to be held at the Alameda City Hall. The envelope bearing his invitation was addressed simply: "y = 479,337.85, x = 1,448,706.27, California Coordinate System, Zone 3." Yet, it was properly and promptly delivered to his office. It appears that even the postmen are more aware of the utility of the system than many surveyors. "The Postman Rang Once - He Knew His Coordinates," Surveying and Mapping, Vol. 14, No. 2 (June, 1954), p. 159. (a reprint from the "Daily Knave, a regular feature of the Oakland Tribune, February 2, 1954)

and maps in Contra Costa and Alameda Counties in order to minimize duplication and overlapping.

2. To adopt uniform specifications for surveying and mapping.
3. To develop and encourage use of standard practice in record procedures so that information is readily understandable and available from agency to agency.
4. To discuss, coordinate and plan for the control surveys and base mapping of the East Bay; to direct the trend of surveys and maps of the area; and to advocate the consolidation of efforts to promote efficiency.
- 5.. To promote continuation and completion of the local supplementary control surveys; to serve as the coordinating agency for any program launched by the Federal Government, the State, or adjacent area; to determine priorities.
6. To publish a bulletin or progress report periodically for the information of participants.
7. To encourage the increased understanding and use of horizontal control surveys and the California Coordinate System by engineers.
8. To encourage the increased understanding and use of vertical control surveys and a uniform datum plane.
9. To encourage an educational program whereby the public will become more aware of the value of good surveys and maps.⁵⁸

In 1947, the same year of legal adoption of the California Coordinate System, the City of Alameda established a policy which required any property description written by the city to be referenced to State coordinates. An ultimate goal is to have coordinates recorded for every property corner.⁵⁹

Much progress has been made toward increasing the availability and reliability of control in the East Bay Area. Currently, the urban areas

⁵⁸Memorandum from Bruce Grant, Administrative Office Engineer, East Bay Council on Surveying and Mapping to Messrs. Louis Grant, Harry Shatto, and Council Technical Committee, February 14, 1957.

⁵⁹Woodridge, C.A., "Real Property Descriptions Based on the California Coordinate System," Surveying and Mapping, Vol.12, N.4 (December, 1952),p. 393.

within this two county district are almost completely covered with large scale maps which have been carefully referenced to the State coordinate system. These maps have made it possible to easily convert house number addresses to coordinate values in which form they are compatible to computer processing for a variety of socio-economic studies.⁶⁰ The first complete application of this approach was by the State Department of Public Health in a research project designed to correlate neighborhood characteristics and other locational considerations against the incidence of cancer. This general approach should prove useful to further research of other community problems, such as those relating to health, education, transportation, protection and recreation. Thus, the utility of referenced maps continues to yield unanticipated benefits to the local communities from a program initially undertaken only to provide a good system of recording operations on accurate base maps.⁶¹

The City Planning Department of Oakland is developing a system of zoning maps based on maps referenced to the State grid. Another use of the California Coordinates has been the indexing of maps by various local agencies including the East Bay Municipal Utility District, and the cities of Los Angeles and San Diego. The City of San Diego is

⁶⁰Letter from Bruce Grant, Vice Chairman, East Bay Council on Surveying and Mapping, Oakland, California, October 3, 1966.

⁶¹Letter from Bruce Grant, Administrative Office Engineer, East Bay Council on Surveying and Mapping to Mr. Ray Peters, Chairman, East Bay Council on Surveying and Mapping, September 8, 1964.

developing an index of all maps and construction projects by determining the coordinates and block numbers for every street intersection using electronic data processing. The City soon anticipates a centralized record file of all construction projects regardless of their responsible agency.⁶²

Maine: The Maine Coordinate System has been legally enacted, but its utilization and availability for use are extremely limited. The only geodetic control established in the state was set up during the Depression by one of the New Deal agencies and was restricted to the southwestern tip of the State. In the words of a highly responsible state administrator,

In summary, the use of this (State coordinate) system is not mandatory, it is seldom used and the extent to which it could be used is problematical. It is our feeling that it is of no use to us and if such a system is to be used the Universal Transverse Mercator grid system now prescribed by the Department of Defense is preferable, particularly since it is compatible with the same system as used in neighboring states and Canadian provinces.⁶³

South Dakota: The South Dakota Coordinate System apparently is not in use by any state agency.⁶⁴

Tennessee: The principal user of the Tennessee Coordinate System is the State Division of Geology. The Division is responsible for the

⁶²Ibid.

⁶³ Letter from L.H. Stanley, Director, Maine State Office of Civil Defense and Public Safety, Augusta, Maine, August 25, 1966.

⁶⁴ Letter from Francis Chichester, Acting Director, South Dakota State Planning Agency, Pierre, South Dakota, August 24, 1966.

state's cooperation with the U.S. Geological Survey and with T.V.A. in all topographic mapping. The Division also establishes the location of all mine entrances, mineral bodies, and the like with reference to the coordinate system.⁶⁵

Another state agency utilizing this system is the State Highway Department which describes and references all lands and related construction on the Interstate System in terms of the State coordinate system. On the State primary system substantial progress has been made in the precise description of land and construction features by coordinates and with all new work on the secondary system being so described, it is anticipated that the entire highway system will be referenced to the State grid as rapidly as circumstances permit. It is believed that the expanded availability of control points along the highway system will facilitate wider use of the coordinate system in the description of land for transfer purposes.⁶⁶

Indiana: Similar to many other states the Indiana Coordinate System has not been appreciably utilized by State, county, local or private agencies. The only State agency currently using this system is the Division of Water of the Department of Natural Resources. The principal advantage of the system as noted by this Division is that of its

⁶⁵ Letter from Harold V. Miller, Executive Director, Tennessee State Planning Commission, Nashville, Tennessee, August 24, 1966.

⁶⁶ Ibid.

uniformity. An example of this agency's application of the system is that of accurately relating a dam or points on a dam to any point on the spillway or in the reservoir proper, as well as along clearing lines, property lines, silt sediment ranges, or in recreational areas. The entire project site is related horizontally to the boundaries of other geographical units in various locations. This approach allows all distances to be taken from a common point of reference, and thus, each respective survey is linked together even though their location might be quite remote and corresponding surveys completely independent.⁶⁷

Two basic reasons for the general dearth of State coordinate use are that of the location and scarcity of control points. The relatively few control stations are very often located in exceptionally remote or isolated areas. At the present cost of surveying practices, it becomes increasingly difficult to rationalize the need for referring a local project, such as a bridge, road, subdivision or other structure to an isolated and distant point.⁶⁸

However, if all section corners were related to a common state-wide system, the proximity of control to any local project would allow total utilization of the State coordinates. In 1965, a bill was passed making it mandatory for each county Surveyor to reference a minimum of five percent of all original section corners in his county during a twenty year period at the end of which all original corners would be either

⁶⁷Letter from Leo J. Strack, Head, Surveying and Mapping Section, Division of Water, Indiana State Department of Natural Resources, Indianapolis, Indiana, September 14, 1966.

⁶⁸Ibid.

established or re-established. This overall program is progressing much slower than was anticipated, primarily because of low operational budgets, a shortage of qualified personnel, and a significant backlog of pending legal surveys. The Indiana Society of Professional Land Surveyors is currently conducting a study of the progress being made by the counties toward the objectives of this "Section Corner Law." The Society has strongly endorsed the State Plane Coordinate System and actively promoted its use and extension for many years.⁶⁹ The membership of this same Society is currently seeking the establishment of a State Bureau of Surveys and Maps within the Department of Natural Resources. If approved, this agency "would have the responsibility for the state mapping program, be a depository for maps, surveys and control data, a disseminator of map and survey information, a promoter of the use of the Indiana Coordinate System, and an authority on map and surveying standards."⁷⁰ It appears that only efforts at either the State or Federal level will be able to put the coordinate system on a working basis.⁷¹

⁶⁹Ibid.

⁷⁰State of Washington, Bureau of Surveys and Maps, Bulletin, Olympia, Washington, June, 1966.

⁷¹Letter from Strack, loc. cit.

Developmental Perspective in MichiganHistory

Quite similar to the background of the State Plane Coordinate Systems in other states, the Michigan Coordinate System was originally advanced and promoted by professional land surveyors. The Michigan Society of Registered Land Surveyors under the mentorship of Ralph Moore Berry, Professor of Geodetic Engineering at the University of Michigan, attempted to push a bill through the legislature which would legally establish the system for the State of Michigan. Although the bill had twice passed the Senate, it could not kindle enough support to bring it through the House of Representatives.⁷²

Early in 1964, collective support for this bill began to formulate among professional planners as well as land surveyors. Support came also from several state agencies including the Departments of Administration, Conservation, Economic Expansion (presently an office in the Commerce Department) and Highways; the regional planning agencies of Lansing and Detroit, as well as other county planning commissions.⁷³ Opposition to the bill came from a representative of the Michigan Township Association who was under the apprehension that it would mandatorily change the system of reference for all maps. This was not the case,

⁷²Letter from William C. Roman, Head, Planning Division, Michigan State Department of Economic Expansion to Mr. Bernard M. Conboy, Executive Director, Department of Economic Expansion, January 15, 1964.

⁷³Interview with William C. Roman, Executive Director, Lansing Tri-County Regional Planning Commission, October 5, 1966.

however. After demonstrating that the bill merely provided a system which any private or governmental agency could use on a permissive basis for locational referencing in mapping, surveying or other purposes involving geographical identification, this opposition withdrew all objection.⁷⁴ The legislation was finally approved in April, 1964 after an active campaign by the bill's ardent advocates.⁷⁵

As adopted, the Michigan Coordinate System differed substantially from that which was originally proposed by the U.S. Coast and Geodetic Survey in 1935. This earlier proposal divided the Lower Peninsula into two vertical (north-south) zones extending into the Upper Peninsula, with the remaining area to the west being contained in a third zone. All three of these zones were based on the Transverse Mercator projection. The original pattern of the system was re-examined in view of more current information on future development prospects within the State of Michigan. At this point, two significant aspects became readily apparent. First, it was noted that a continuing trend of urban and industrial development was being concentrated in the southern part of the State along an east to west "urbanization corridor" running

⁷⁴Memorandum from William C. Roman, Head, Planning Division, Department of Economic Expansion to Mr. Bernard M. Conboy, Executive Director, Michigan State Department of Economic Expansion, Subject: The Michigan Coordinate System, January 31, 1964.

⁷⁵Berry, Ralph M., "The New Michigan Plane Coordinate System," A paper presented at the Regional Convention of the American Congress on Surveying and Mapping, Kansas City, September, 1964, p. 1.

parallel with Interstate Highway 94.⁷⁶ Also, there are two additional "urbanization radials" emanating from the Detroit Metropolitan Area: one to the northwest through Lansing, Grand Rapids and Muskegon to Lake Michigan; the other to the north bearing slightly west extending through Oakland County, Flint, Saginaw, and Bay City to the Saginaw Bay. It must be noted that the framework for these corridors of development was established initially by the railroad network laid out nearly a century ago. Assuming it would be of improper design to divide this area of interrelated social, economic, and geographic interests, the entire southern half of the Lower Peninsula was determined as best represented by a single zone.⁷⁷

The second aspect of significant note was that the Upper Peninsula represented a single self-contained geographic unit. It was observed that it was also a basically common cultural and economic community, only remotely related to the rest of the state, in short, the entire Lower Peninsula. The Upper Peninsula was also viewed as a geographic entity lying in a fundamentally east-west direction, appropriate for a single zone.⁷⁸

Due to the particular nature of the geography, economy and urbanization of the state, the Lambert conformal conic projection was selected

⁷⁶Berry, Ralph M., "Uses and Use of the State Plane Coordinate System," A paper presented at the annual conference of the Michigan Society of Registered Land Surveyors, Lansing, Michigan, February 8-10, 1962, p.5.

⁷⁷Berry, Ralph M., "Use of the Michigan Coordinate System," n.d., p. 27. (Mimeographed)

⁷⁸Ibid.

for referencing the new Michigan Coordinate System in a series of three east-west zones. These Lambert projection zones which provide a high degree of locational accuracy for areas of indefinite east-west extent within a north-south limit of approximately 158 miles were designed to include:

South Zone: Extending completely across the Lower Peninsula from west to east, and extending northerly from the south boundary of the state (with Ohio and Indiana) to the west-east line comprising the northern limits of Oceana, Newaygo, Mecosta, Isabella, Midland, and Bay Counties and extending through Saginaw Bay to include the entire "Thumb Area."

Central Zone: Including all the remaining counties in the Lower Peninsula, as well as all offshore islands which are included within these counties. Sufficient northerly extent will be available to permit use of this zone for computations of the adjacent land areas on the north side of the Straits of Mackinac.

North Zone: Including the entire Upper Peninsula, but extension to Isle Royale will involve a large scale factor on that island. Since this is federally-owned property and a national park the probabilities of concurrent survey with the mainland seem small. The projection will be adjusted to the best scale-factor on the mainland, regardless of Isle Royale.⁷⁹

A variation of this system from the rest of the adopted State Plane Coordinate Systems throughout the United States was the attempt to eliminate the normal necessity of reducing all measured distances to the surface of the reference ellipsoid. Since Michigan was basically flat throughout the state with an approximate mean elevation of eight hundred feet above sea level, the new Michigan Coordinate System was designed and computed on a reference surface approximately eight hundred feet above the Clark Spheroid of 1866.⁸⁰ This system was developed by

⁷⁹ Berry, "Uses and Use of State Plane Coordinate Systems," op. cit., p. 5.

⁸⁰ Berry, "The New Michigan Plane Coordinate System," op. cit., p. 5.

Professor Berry through the use of double-precision techniques on the electronic computer at the Computing Center of the University of Michigan.⁸¹

However, some authorities in the field of geodetic engineering take issue with this deviation from the standard form of the State Plane Coordinate System. They maintain that although the Michigan system reduces the ground to scale error to a minimum, it remains unrelated to the systems of adjacent states which results in a discontinuity for any locational referencing to an interstate basis. Thus, the system cannot serve as a truly national grid.⁸²

An inquiry into the exact nature of this alleged operational difficulty brought the following comments from Daniel Kennedy, Central Region Engineer, U.S. Geological Survey, the agency responsible for all of the state's topographic mapping:

For the past two years, we have computed our horizontal control in Michigan on the new system, and we are in the process of converting existing grid values to the new system.

The new system has caused no operational inconvenience since, with one exception, it can be handled in the same way as any other State coordinate system referred to the Lambert projection. This exception is that in computing traverses on the New Michigan system, measured lengths are reduced to 800 feet rather than sea level or more expediently by subtracting 800 feet from the average elevation of the line and reducing to sea level as in our State systems.

The resultant magnified projection differs only slightly (1:26,000) from projections based on sea level datum, and on a 7½-minute basis, this presents no joining problem with maps in adjacent states.⁸³

⁸¹U.S. Department of Commerce, Coast and Geodetic Survey, Plane Coordinate Projection Tables - Michigan (Washington: GPO, 1965), p. 1.

⁸²Colvocoresses, "A Unified Plane Coordinate Reference System," (unpublished Ph.D. dissertation, Department of Geodetic Science, Ohio State University, 1965), p. 38; and American Bar Association, Section of Real Property, Probate and Trust Law, 1966 Report of the Committee on Improvement of Land Title Records (unpublished draft), July 25, 1966. p. 9.

⁸³Letter from Daniel Kennedy, Central Regional Engineer, U.S. Geological Survey, Rolla, Missouri, July 27, 1966.

The basic framework of locational control points which serve to define the Michigan Coordinate System is that part of the national network of geodetic points established within the State by the U.S. Coast and Geodetic Survey. The geodetic coordinates (latitude and longitude) of the control network have been converted to Michigan State coordinates by appropriate calculation, thus producing a State grid which represents the basic datum of the Michigan Coordinate System.⁸⁴ The total number of these points of control is significantly low and their spacing rather distant at about twenty to twenty-five mile intervals.⁸⁵

Current Status

Mainly due to the fundamental problem of inadequately spaced points of coordinate control, the Michigan Coordinate System, such as the case with several other states, does not enjoy any significant use by either public or private practitioners. The only two State agencies which occasionally make locational reference to this system are the Design Division of the Departments of State Highways and the Engineering Division of the Department of Conservation. The former division uses the State Coordinate System in less than ten percent of its field work, depending upon the proximity of control points and the survey supervisor on the job. Only when the necessary time and resources exist, does the survey supervisor consider tying into the system. His decision is largely

⁸⁴Berry, "The New Michigan Plane Coordinate System," op. cit., p. 6.

⁸⁵McFarlan, H. J. "Local Control Aids the Property Surveyor," Surveying and Mapping, Vol. 13, No. 2 (June 1953), p. 181.

dependent upon his personal and professional interest in the objectives of the system.⁸⁶

The Engineering Division of the Department of Conservation utilizes the State system in approximately one percent of all their locational referencing. Property surveys, boundary problems and the definition of property for acquisition and construction make up the normal tasks which may include the use of the system. This use is again dependent upon the accessibility to available points of horizontal control and the foreseen necessity for using it.⁸⁷

It is apparent that the motivation to utilize the Michigan Coordinate System is extremely lacking at the State level. If State agency use and extension of this system is not soon advanced, much of its utility and advantageous use will never develop to a point of large-scale benefit in Michigan.

⁸⁶ Interview with Burton Groves, Survey Supervisor, Design Division, Michigan State Department of Highways, October 18, 1966.

⁸⁷ Interview with Kenneth Jansma, Acting Head, Design Unit, Engineering Division, Michigan State Department of Conservation, October 18, 1966.

CHAPTER V

SYSTEMS OF LOCATIONAL REFERENCING IN CURRENT USE BY THE STATE OF MICHIGAN

Information Needs

In order to ascertain the nature of the specific information needs of Michigan State agencies with regard to their respective systems of identifying or referencing this information geographically, it was decided that a selected sampling of agencies within three different departments which handled significant amounts of geographically-based data would be most appropriate. The three State Departments chosen on this basis were those of Commerce, Conservation and Highways.

A starting point for the selection of the representative agencies within the three state departments was from a previous study conducted by the Technology Planning Center of Ann Arbor, Michigan in cooperation with the State Resources Planning Division. This study represented a four-month investigation of interagency information flows of the state. Its purpose was to establish a basis upon which to build a planning approach to a unified state-wide information system for the present and future needs of the state's resource activities. Concluding that the role of information was fundamental to the operation of the state's activities, the report stressed that:

... information -- its availability, accuracy, completeness, timeliness and format -- play a vital role in policy making, planning, decision-making, operations, and program evaluation. Thus, the

effectiveness of State of Michigan agencies in all areas is, to a great extent, based on the quality of available information.¹

Through emphasizing the functional necessity for the optimal use of all information processed by the many agencies of the state, the report pointed out:

In order to discharge their assigned responsibilities, individual state agencies require various kinds of information (i.e., demographic, economic, technological, physical, etc.). Furthermore, the information must be presented in a form suitable to the purposes of the agency using it. Such data is obtained from various sources, or is collected by the agency itself. Sometimes, however, desired information is not available, or it is not available in a useful form.

From a state-wide standpoint, information needs are multiplied by the requirements of many agencies. At the same time, however, it can be hypothesized that many agencies share common information needs, and in some instances may collect similar, or even identical, information.

From the viewpoint of state comprehensive planning, it is apparent that many functional problem areas exist which involve multiple agency participation. Functional problems associated with the "physical development of land" are representative of such a multiple agency involvement. For such interrelated problems, there is a strong need for centralized information data banks designed to satisfy the information inquiries of a wide spectrum of organizational users, whether they be planners, administrative control, or operations personnel.²

The focus of this previous study was on a singular sub-system within the state-wide information system concept. This area of concern was that of land-based information relating to land development. To most appropriately ascertain the nature of the information related to land development used by all agencies of the state, a representative sample was

¹ Technology Planning Center, Inc., Interagency Information Reconnaissance Study, A report prepared in cooperation with the State Resource Planning Division, Michigan State Departments of Commerce (Lansing: State of Michigan, 1966), p. iii.

² Ibid., p. v.

selected by the investigators of those agencies most concerned with this data.³ As the major concern of the present research study is also on land data or, more specifically, geographically-based information which necessitates a system of locational identification for referencing purposes, the agencies chosen for investigation were basically similar to those selected for the prior study within the Departments of Commerce, Conservation and Highways. A final total of twenty representative divisions and sections was established.

An analysis of the findings of this previous investigation aided its authors in constructing a comprehensive set of information elements and components relating to land-based information. This list of primary information elements and components is particularly land-oriented as it includes those data existing as qualities, quantities, and activities which derive meaning and purpose only through reference to their geographic location.

For the objectives of the present study this set of elements, components and sub-components proved to be most appropriate with one notable exception. The important modification to the Technology Planning Center set of land-oriented information elements was the element of location. For their investigation this element was considered parallel with elements such as physical qualities, improvements, activities, land values, tenure and people data. As the focus of the present study is centered on the element of location and its relationship to all forms of geographically-based information, the location element was considered against rather

³Ibid., p. 8.

than with the six other elements. All other information components and sub-components previously referenced specifically to parcels within the list were altered to represent any activity or characteristic which could be used in terms of any number of different locational references. Table I on the next page includes the fourteen various forms of locational referencing considered in this study.

In this manner each of the components and sub-components of the above elements were ascertained in the form of agency use by mode of locational reference. By this alteration of study design, it was able to best determine the inflexibility and potential interagency utility of all forms of currently used land-based information. In general, the inflexibility was due to the limited nature of the system or systems used for a particular information sub-components' locational reference. (See Appendix B for complete set of information elements, components and sub-components, including all agencies in this investigation.)

TABLE I

ALTERNATIVE FORMS OF LOCATIONAL REFERENCING

By Parcel:	Parcel Number Parcel Address Legal description (town-range-section) Tax assessors system (lot, block number) Plane Coordinate System
By Administrative Unit:	County Township Municipality School District Regional District
By Planning or Statistical Unit:	Traffic Analysis Zone Census Tract Census Block Special Planning Unit

Source: Adapted from TPC Study, p. 35.

Current Levels of Locational Referencing

An analysis of the findings from the interviews conducted with the twenty selected state agencies clearly indicates, as anticipated, many problematical uses of information. Some of the more notable points of interest are:

1. The most predominant level of locational referencing among all agencies is by administrative or political unit. Highest among these five units is that of counties with the degree of township and municipality use respectively a near second and third.

2. Reference by parcel when used by agencies is overwhelmingly by the legal description form of town-range-section. The next most used forms are those of parcel number and parcel address. It is interesting to note that by far the least used system is that of plane coordinates. The only two agencies which occasionally utilize this system (as discussed in Chapter IV) do so primarily on the physical characteristics elements of information components.

3. Notable in the referencing by planning or statistical units is that although there are no standardized sub-area units such as census tracts or blocks presently reporting information related to physical characteristics of land, many agencies have designed special planning units generally for their own particular research activities.

4. Components and sub-components of the information element relating to social characteristics, with the exception of total population, is seldom used in conjunction with other data on physical characteristics and activities by the three state departments under study. When population characteristic data is used by these departments, it is referenced mainly by administrative units, with the county level being used most.

5. Traffic analysis zones, similar to special planning units and their particular agency use, are principally used within the Department of State Highways, as anticipated. School districts are completely void of use with the exception of the Urban Planning Section of the Highway Department. (See Appendix C for a detailed presentation of all findings in the form of taxonomic matrices.)

Adequacy of Present Levels

A significant majority (75 percent) of the agencies contacted expressed a desire to have more information available by smaller units of aggregation than they have been able to obtain. A similar proportion (73 percent) of these indicated a present need for data aggregated by townships or smaller sub-area units for research analysis. The remaining agencies expressing such a desire stated a specific need for more information available at the most diminutive level by land parcel. One agency, the Traffic Division of the Department of State Highways, indicated a

desire for all types of data by the most precise form of locational reference, preferably grid coordinates. The locational accuracy of these data were stated as being most important to the development of traffic flow models.

Among the numerous agencies desiring the availability and accessibility of information at lower levels of disaggregation certain inadequacies were frequently noted. Most frequently indicated were units of activity patterns or land use. Land use data in general is seldom assigned a reference to any standardized statistical unit, thus requiring any agency desiring to utilize this information in conjunction with other data to devise its own system of units or to approximate the relationships in terms of other statistical units of data. The latter is most often the case with results commonly stated in generalizations. The next most mentioned need for lower levels of reference was that of economic data relating to land. This land valuation and cost information were common among agencies concerned with the acquisition and disposition of property as well as those involved with merely the implications of this in the analysis of cost/benefit relationships. An often noted additional problem with this data was its currency if available, or more specifically accessibility, to state agencies. Another indicated informational inadequacy somewhat related to the last was that of land ownership data. Information on property owner, deed, mineral rights, easements, or occupants is seldom readily accessible, if available, to state agencies. Although most agencies (75 percent) indicated a need for either more information currently in use, or data not now being used but desired, by smaller units of locational reference, all agencies (one hundred percent) expressed that, if available,

smaller units of a standardized system of locational referencing could and would most likely be employed.

Anticipated Levels Desired in Future

Here again, when questioned whether the future and its anticipated compounding of presently complex development problems would require more accurate and detailed systems of information collection and compilation, all agencies agreed. All twenty representative agencies within the Departments of Commerce, Conservation and State Highways indicated that in the not too distant future there will be a need for information of all kinds to be locationally referenced by a uniform or standardized system which would readily lend to correlational use of all or any of this data.

Analysis of Findings

After an examination of this investigation's findings, it became apparent that many agencies were using certain similar forms of information aggregation with one thing in common -- a desire for a systematic method of disaggregating this data. In numerous cases those agencies desiring information by smaller units of locational reference could only obtain the data they needed in the form of county totals. Also of note was the fact that many agencies utilizing similar types of information were interested in different forms or levels of generality describing that same information. This has obviously brought about a great inflexibility in the use of informational flows between the state agencies.

In order to gain the flexibility which is fundamental to the advantageous exchange and coordination of inter-agency information flows a uniform system must be instituted within the offices of the state. This

system should attempt to unify the basic forms of locational referencing used for information aggregation by all state agencies. In the institution of a new system for the recording and manipulation of a variety of informational flows, it is often difficult to derive ready, rational or consistent use of such a system. Thus, in many investigative analyses the advanced choice is typically a system not unfamiliar to those who must adopt a new system or procedure, but simply not in common and consistent use. To achieve these objectives of interagency information exchange, aggregation and disaggregation as indicated necessary by any specific agency, it appears that a locational referencing system must be established with a basic geographical unit serving as the lowest common denominator. The unit advanced by the previously mentioned Technological Planning Center study was that of the land parcel. This land parcel concept has recently been adopted by several local agencies in their urban information system.

However, due to the response of the agencies interviewed in regard to their opinions as to the merit and utility of the basic land parcel for their information needs, the parcel concept appears as an unfavorable choice. The premise upon which the land parcel concept is based is, however, a sound one. An obvious deterrent for its proper use is, as noted above, the problem of unfamiliarity and its associated constraints. As indicated in the findings of this investigation, the system of legal description in the form of town, range and section units enjoys a common use within state agencies. Hence, this system of locational reference is in general familiar to all state agencies. In as much as the problems of adapting this U.S. Public Land Survey system alone to an automated

information system have been discussed (Chapter III), it becomes apparent that this mode of land parcel reference must be integrated with a system of locational referencing which will lend accuracy as well as a format readily adaptable to electronic data processing. The Michigan State Coordinate System appears to meet the latter system's requirements extremely well.

CHAPTER VI

IMPLICATIONS AND CONCLUSIONS: A COMPTABLE SYSTEM OF LOCATIONAL REFERENCING FOR THE STATE OF MICHIGAN

As the development of state resources can generally be considered the development of land-based resources, it becomes fundamental that the description of these resources be precisely defined in order to accurately appraise their maximum development potential. In the United States the most precise locational description is obtained by referencing land measurements or surveys to points of the national geodetic control network. However, within the State of Michigan, as is the case in many other states, the paucity of these control stations renders this procedure too much of an immediate economic burden to weigh against the possible future benefits acclaimed by its use. In lieu of this, Michigan surveyors have been referencing their work for over a century to the section lines and corners of the United States Public Land Survey system set up in this state between 1830 and 1855.¹ All land titles, land boundary and corner locations as well as all land description records in the state have been based on this system.

The original Land Office Survey in Michigan, many under wilderness conditions, was based upon comparatively lax controls and employed relatively inaccurate measurement procedures. Considerable variances often

¹Henning, George D., "Land Surveys in Michigan," Surveying and Mapping, Vol. 8, No. 3 (September 1948), p. 149.

are found between the actual locations of lines and corners as established and the locations indicated in the field notes and records of the original survey. However, although measurement errors have been verified in the Public Land Survey, the locations where lines or corners were originally positioned must be legally acknowledged and accepted. This is most important as all land parcels since then have been deeded to owners on the basis of these boundaries.² Therefore, a practical solution to the problem of legally adhering to this system with its valuable source of land description information appears to be to tie it into a system of grid coordinates which provides a maximum utility for accurate locational referencing of all forms of geographically-based data. Systems of plane coordinates have admirably proven their ability to this latter purpose and for area-wide locational referencing the State Plane Coordinate System provides this utility at the greatest scale. Thus, to accrue the benefits from both systems the Michigan State Coordinate System could be integrated and linked to the United States Public Land Survey system throughout the state.

It is currently possible to convert the section corners of the Public Land Survey into latitude and longitude or directly into plane coordinates for map plotting and computational purposes through the use of a digital computer. This particular method designed by Tobler assigns coordinate values to about the nearest one-quarter mile on the assumption that the Public Land Survey designations are where they would be if the system had been laid out by the most precise techniques. However, as mentioned above,

² Ibid.

this is not the case. Professor Tobler states that "the legal strategy is to assign to the actual locations a status of incontestable correctness, irrespective of any errors which may have been introduced during the (original) survey. To adjust the calculated values to conform to their legal positions requires detailed historical and empirical corrections, and can be quite tedious." Nevertheless, he maintains that the empirical corrections and adjustments for systematic departures could be developed for an area as large as an individual state and incorporated into a computer program.³ Hence, it should be safe to assume that such a conversion program could be designed for tying the Township-Range-Section system into the Michigan State Plane Coordinate System.

Using the combination of the U.S. Public Land System with its voluminous land descriptions and boundary records and the Michigan Coordinate System with its abilities of accuracy and permanency, an answer to the problems of devising a basic spatial unit begins to formulate. A key factor in arriving at a single best unit for all state agencies within a unified state-wide information system is the plane coordinate system's great utility for mathematically aggregating and disaggregating data. As indicated in the findings of the twenty state agencies, the predominant unit of reference is by minor civil divisions (counties, townships and municipalities) and the principal system of locational reference is by legal description or the Township-Range-Section system. In as much as the township and county units are merely a summation of quarter sections, sections and townships in an orderly spatial hierarchy, the ability to aggregate

³Tobler, Waldo R., "Areal Conversion in Geography, "Appendix I: Conversion from the Public Land Survey to Latitude and Longitude," Department of Geography, University of Michigan, n.d. (Mimeographed)

or disaggregate data by areal units familiar to all state agencies appears to be built-in. Thus, it becomes evident that the most appropriate basic unit of reference should be a diminutive subdivision of the U.S. Public Land Survey system.

The next question advanced is, what specific subdivision of this system should be adopted as the basic areal unit for all locational referencing purposes? Here, the selected unit must be one which can be used advantageously by all state agencies as well as serve as a basic link in a state-wide grid network. This state-wide locational referencing grid must also serve as a precise area-wide framework for all urbanized areas in the state, particularly those metropolitan areas with a multiplicity of autonomous local jurisdictions. Establishment of a uniform grid throughout the state permits all local and regional agencies to base their urban, metropolitan and regional data bank systems on this grid and thus allows for new flexibilities of information at all governmental levels of the state. As the solution to community development problems is dependent on information from a number of city, county and state agencies, it is fundamental that the locational referencing system and basic unit of reference offer a maximum facility for both inter-departmental and inter-governmental exchange of data. In consideration of all the above factors the selected basic unit of reference for the proposed unified state-wide information system for the State of Michigan must first provide a maximum utility to state agencies and their resource development activities. However, in doing so, the state should also consider a basic areal unit which would lend a maximum of potential utility to its subordinate governmental agencies. Such a basic geographic unit appears to be that of the quarter section.

Recently, the Southeastern Wisconsin Regional Planning Commission adopted the U.S. Public Land Survey quarter section as the basic unit of geographic identification for all planning and engineering data within its seven-county area. This agency has actively promoted the placement of the quarter section corners on the State Plane Coordinate System to a point where all data can be readily related by both graphic and computer methods to both the Public Land Survey and the Wisconsin Coordinate System. Kurt W. Bauer, Executive Director of this regional agency states:

The utilization of one-quarter section as the basic geographic unit of identification provides, we believe, an extremely flexible system for data collection since quarter sections can be used to readily approximate larger planning units such as civil divisions, traffic analysis districts, and even watersheds. The system also lends itself to the identification of smaller units such as blocks, lots and individual parcels of land. This is so because Wisconsin, in common with other public land survey states, requires that all real property descriptions be tied to the U.S. Public Land Survey corners. Thus, the placement of these corners on the State Plane Coordinate System permits the eventual assignment of coordinate values not only to individual lots, blocks, and parcels but also to various public works facilities such as centerlines of highways and sewer, water, power, and communication lines.⁴

Thus, it may be seen that this integrated system of locational referencing offers great potential utility as a means of intra- and inter-agency information exchange at all levels of government within the state of Michigan.

The use of the state coordinate system, however, offers more flexibility than simply the manipulation of standard rectilinear geographic units. Its continuous numeric system permits the use of various analytic mathematical tools in electronic data processing operations. Computer programs

⁴ Letter from Kurt W. Bauer, Executive Director, Southeastern Wisconsin Regional Planning Commission, Waukesha, Wisconsin, September 9, 1966.

may be designed to summarize any type or amount of geographically-based data for areal units of any size or shape. Programs may be designed to summarize data within a given radius of a point, within any sector of a circle, or for computing the area and summarizing data of irregularly shaped polygons. Grid coordinates may also be used to calculate distances between points and simulate quantitative movements through networks of areal units.⁵

The use of coordinates to form a spatial grid permits the summation of any given data values to be expressed in densities. Given various information such as number of persons, number of dwelling units, median income, vehicle miles travelled, retail sales or employment, it is possible to compute values for a number of three-dimensional surfaces within any specified region. Each continuous set of density values for any particular data characteristic represents a separate "map model" surface.⁶ Today, with the availability of electronic x-y coordinate digitizers, the conversion of all two-dimensional maps and images is possible. Since state agencies utilize mapped information from all conceivable sources, the digital map models must be statistically comparable. Comparability

⁵ McGinty, Richard T., "Tooling Up for the 1970 Census: A Description of the Approach Being Taken by the Lansing Tri-County Regional Planning Commission," A paper presented at the annual convention of the American Institute of Planners, Portland, Oregon, August 14-18, 1966, p. 5.

⁶ Barraclough, Robert E., "Geographic Aspects of Information Retrieval," A paper presented at the annual meeting of the Urban Planning Information Systems Conference, University of Pittsburgh, Pittsburgh, Pennsylvania, September 26, 1964, p. 17.

may be achieved, however, through the use of the State Plane Coordinate System to provide the basic horizontal control. Digital map models based on state coordinates may be intercorrelated in much the same manner that a series of transparent maps are overlaid for purposes of visual comparison.⁷

Currently, maps are the principal medium of presenting and analyzing data within the numerous agencies of the state. Most of these maps are made manually at considerable expense in both time and money and still do not facilitate statistical analysis, since the mapped data cannot be manipulated. A few agencies have introduced electronic data processing for phases of their operational activities which has permitted rapid and low-cost manipulation of information. However, in most instances only the previously discussed (Chapter II) name methods of geographic identification of data have been used, limiting outputs to mere tabulations. Through the use of a uniform locational referencing system, machine mapping and "map models" should become as inexpensive as tabulations.⁸ A great overall savings may be accrued through the multi-purpose use of information based on a standardized, uniform system of locational referencing. Therefore, the Michigan Coordinate System along with the basic areal unit of reference by quarter sections is advanced for the recommended system of locational referencing element of the recently proposed state-wide information system of the State of Michigan.

⁷Blakesley, Robert G., "Planning Databank Challenges the Surveyor and Mapmaker," A paper presented at the joint convention of the American Congress on Surveying and Mapping and the American Society of Photogrammetry, Washington, D.C. March 6-11, 1966, p. 7.

⁸Ibid., p. 18.

APPENDICES

APPENDIX A

MICHIGAN SOCIETY OF REGISTERED LAND SURVEYORS

MICHIGAN COORDINATE SYSTEM LAW

STATE OF MICHIGAN
72ND LEGISLATURE
REGULAR SESSION OF 1964

Introduced by Reps. Bursley, Gordon, Rasmussen, Mrs. Hager, Davis, Cobb and Tisdale

ENROLLED HOUSE BILL No. 203

AN ACT to describe, define and officially adopt a system of coordinates for designating the position of points on the surface of the earth within this state.

The People of the State of Michigan enact:

Sec. 1. (1) The system of plane coordinates which has been established by the United States coast and geodetic survey for defining and stating the positions or locations of points on the surface of the earth within this state is hereafter to be known and designated as the Michigan coordinate system.

(2) For the purpose of the use of this system the state is divided into a north zone, a central zone and a south zone.

(3) The area now included in the following counties constitutes the north zone: Gogebic, Ontonagon, Houghton, Keweenaw, Baraga, Iron, Marquette, Dickinson, Menominee, Alger, Delta, Schoolcraft, Luce, Chippewa and Mackinac.

(4) The area now included in the following counties constitutes the central zone: Emmet, Cheboygan, Presque Isle, Charlevoix, Leelanau, Antrim, Otsego, Montmorency, Alpena, Benzie, Grand Traverse, Kalkaska, Crawford, Oscoda, Alcona, Manistee, Wexford, Missaukee, Roscommon, Ogemaw, Iosco, Mason, Lake, Osceola, Clare, Gladwin and Arenac.

(5) The area now included in the following counties constitutes the south zone: Oceana, Newaygo, Mecosta, Isabella, Midland, Bay, Huron, Muskegon, Montcalm, Gratiot, Saginaw, Tuscola, Sanilac, Ottawa, Kent, Ionia, Clinton, Shiawassee, Genesee, Lapeer, St. Clair, Allegan, Barry, Eaton, Ingham, Livingston, Oakland, Macomb, Van Buren, Kalamazoo, Calhoun, Jackson, Washtenaw, Wayne, Berrien, Cass, St. Joseph, Branch, Hillsdale, Lenawee and Monroe.

Sec. 2. (1) As established for use in the north zone, the Michigan coordinate system shall be named, and in any land description in which it is used it shall be designated the Michigan coordinate system, north zone.

(2) As established for use in the central zone, the Michigan coordinate system shall be named, and in any land description in which it is used it shall be designated the Michigan coordinate system, central zone.

(3) As established for use in the south zone, the Michigan coordinate system shall be named, and in any land description in which it is used it shall be designated the Michigan coordinate system, south zone.

Sec. 3. The plane coordinates of a point on the earth's surface, to be used in expressing the position or location of such point in the appropriate zone of this system, shall consist of 2 distances, expressed in American survey feet and decimals thereof. One of these distances, to be known as the "x-coordinate", shall give the position in an east and west direction; the other, to be known as the "y-coordinate", shall give the position in a north and south direction. These coordinates shall be made to depend upon and conform to the coordinates, on the Michigan coordinate system, of the triangulation and traverse stations of the United States coast and geodetic survey within this state, as those coordinates have been determined by the survey.

Sec. 4. When any tract of land to be defined by a single description extends from 1 into another of the above coordinate zones, the positions of all points on its boundaries may be referred to either of the 2 zones, the zone which is used being specifically named in the description.

Sec. 5. (1) For the purposes of more precisely defining the Michigan coordinate system the following definition by the United States coast and geodetic survey is adopted:

(a) The Michigan coordinate system, north zone, is a Lambert conformal projection of the Clarke spheroid of 1866, magnified in linear dimension by a factor of 1.0000382, having standard parallels at north latitudes 45 degrees 29 minutes and 47 degrees 5 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 87 degrees zero minutes west of Greenwich and the parallel 44 degrees 47 minutes north latitude. This origin is given the coordinates: $x = 2,000,000$ feet and $y = 0$ feet.

(b) The Michigan coordinate system, central zone, is a Lambert conformal projection of the Clarke spheroid of 1866, magnified in linear dimension by a factor of 1.0000382, having standard parallels at north latitude 44 degrees 11 minutes and 45 degrees 42 minutes, along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 84 degrees 20 minutes west of Greenwich and the parallel 43 degrees 19 minutes north latitude. This origin is given the coordinates: $x = 2,000,000$ feet and $y = 0$ feet.

(c) The Michigan coordinate system, south zone, is a Lambert conformal projection of the Clarke spheroid of 1866, magnified in linear dimension by a factor of 1.0000382, having standard parallels at north latitude 42 degrees 6 minutes and 43 degrees 40 minutes along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 84 degrees 20 minutes west of Greenwich and the parallel 41 degrees 30 minutes north latitude. This origin is given the coordinates: $x = 2,000,000$ feet and $y = 0$ feet.

(2) The position of the Michigan coordinate system shall be as marked on the ground by triangulation or traverse stations established in conformity with standards adopted by the United States coast and geodetic survey for first-order and second-order geodetic control surveys, whose geodetic positions have been rigidly adjusted on the North American datum of 1927, and whose coordinates have been computed on the system herein defined. Any such station may be used for establishing a survey connection with the Michigan coordinate system.

Sec. 6. No coordinates based on the Michigan coordinate system, purporting to define the position of a point on a land boundary, shall be presented to be recorded in any public land records or deed records unless such point is within $\frac{1}{2}$ mile of a triangulation or traverse station established in conformity with the standards prescribed in section 5 of this act.

Sec. 7. The use of the term Michigan coordinate system on any map, report of survey, or other document, shall be limited to coordinates based on the Michigan coordinate system as defined in this act.

Sec. 8. Wherever coordinates based on the Michigan coordinate system are used to describe any tract of land which in the same document is also described by reference to any subdivision, line, or corner of the United States public land surveys, or to any subdivision plat duly recorded in accordance with Act No. 172 of the Public Acts of 1929, as amended, being sections 560.1 to 560.80 of the Compiled Laws of 1943, the description by coordinates shall be construed as supplemental to the basic description of such subdivision, line, or corner contained in the official plats and field notes filed of record, and in the event of any conflict the description by reference to the subdivision, line, or corner of the United States public land surveys, or recorded subdivision plat, shall prevail over the description by coordinates.

Sec. 9. Nothing contained in this act shall require any purchaser or mortgagee to rely on a description, which depends exclusively upon the Michigan coordinate system.

Approved _____ March 20, 1964

1:44 P.M.

/s/ GEORGE ROMNEY

Governor.

APPENDIX B

STATE AGENCIES INTERVIEWED

Department of Commerce

Aeronautics Commission

Public Service Commission

Office of Economic Expansion

Community Planning Division

State Resources Planning Division

Industrial Division

Research Division

Department of Conservation

Engineering Division

Forestry Division

Geological Survey Division

Lands Division

Outdoor Recreation Resource Planning Section

Parks Division

Research and Development Section (for Fish & Game Divisions)

Water Resources Commission

Department of State Highways

Local Government Division

Route Location Section

Programming Division

State Resources Transportation Planning Unit

Traffic Division

Urban Planning Section

INFORMATION ELEMENTS, COMPONENTS, AND SUB-COMPONENTS

I. PHYSICAL QUALITIES

A. Geological data

1. Depth of ores
2. Richness of deposit (value)
3. Depth and characteristics of overburden
4. Nature of waste materials in ores and mineral deposits
5. Depth and characteristics of bedrock

B. Soil data

1. Soil texture
2. Soil depth
3. Organic content
4. Mineral composition
5. Permeability
6. Rockiness
7. Erosion factors
8. Drainage condition

C. Vegetative cover

1. Type and extent of forage plant species (including forest inventory)
2. Age of growth(s)
3. Rate(s) of growth or attrition
4. Density
5. Health

D. Topography

1. Elevation
2. Degree and direction of slope
3. Cut or fill land

E. Surface water data

1. River basin characteristics
2. Lake and stream inventory
3. Stream flow patterns
4. Watershed
5. Quality

F. Ground water data

1. Water table height
2. Depth
3. Quality and quantity

G. Atmospheric data

1. Climatological data
2. Extent and source of air pollution

H. Fish and wildlife data

1. Type and extent of species
2. Rate of growth and attrition

II. IMPROVEMENTS

- A. To land (in the land)
 - 1. Leveling
 - 2. Smoothing
 - 3. Drainage bed
 - 4. Roadbeds
- B. Structures (on the land)
 - 1. Residential
 - 2. Agricultural
 - 3. Transportation and communications
 - 4. Commercial and industrial
 - 5. Recreational
- C. Utility Facilities
 - 1. Water system
 - 2. Waste disposal
 - 3. Gas
 - 4. Electricity
 - 5. Pipe lines
- D. Presence of "special problem" improvements, e.g., establishments which emit air pollutants, use radioactive substances (x-ray), flammable liquids, health hazards, etc.

III. ACTIVITIES

- A. Activity - Land Use
- B. Limitations on activities
 - 1. Public limitations
 - a. zoning
 - b. construction specifications
 - c. pollution control
 - 2. Private limitations
 - a. restrictive deed covenants

IV. LAND VALUES

- A. Market Value Data
 - 1. Price at last sale
- B. Tax and Valuation Data
 - 1. Assessed valuation
 - 2. Tax exemptions
 - 3. Taxes paid

V. TENURE

- A. Private Ownership
 - 1. Owner's name and address
 - 2. Type of deed

3. Occupant's name
4. Mineral rights
5. Easements
6. Rent-lease data
7. Vacancy information
8. Public uses of private land

- B. Public Ownership
 1. Governmental owner
 2. Controlling governmental agency
 3. Private uses of public land

VI. SOCIAL CHARACTERISTICS

- A. Occupancy
 1. Residential Occupant
 - a. Number of occupants/locational unit - (pop.)
 - b. Place of work
 - c. Means of transportation to work
 - d. Prior address
 - e. Birth-death data related to parcel
 2. Commercial/industrial occupant
 - a. Parcel numbers of all parcels comprising store or plant site
 - b. Number of employees
 - c. Means of transportation used in getting to work
 - d. Labor force data
 - e. Retail sales
 - f. Business failures at this parcel
 3. Other occupancy groups
- B. Licenses and Permits
 1. Business
 2. Construction
 3. Operational
 4. Professional and vocational
 5. Water use
- C. Identity
 1. Name(s) of occupant(s)
 2. Social security number
 3. Sex - (Male - Female)
 4. Age
 5. Race/descent
 6. Marital status
 7. Citizenship
- D. Operational Status Data
 1. Employment data - (Income)
 2. Law enforcement data
 3. Welfare data
 4. Health data
 5. Military service data
 6. Education data

APPENDIX C LOCATIONAL REFERENCING

		By Parcel				By Administrative or Political Unit				By Planning or Statistical Unit					
		Parcel Number	Parcel Address	Legal Desc. Town-Range S.	Tax Assessors Lot-Block S.	Plane Coord. System	County	Township	Municipality	School District	Regional Dist.	Traffic Anal. Zone	Census Tract	Census Block	Special Planning Unit
I	A.	2 10		8 40		2 10	8 40	8 40	1 5		3 15				2 10
	B.			8 40		1 5	11 55	8 40	5 25		6 30				4 20
	C.			7 35		1 5	9 45	5 25	2 10		4 20				2 10
	D.			7 35		1 5	10 50	9 45	6 30		6 30				4 20
	E.	2 10		10 50		1 5	12 60	10 50	5 25		6 30				5 25
	F.			7 35		1 5	8 40	8 40	6 30		4 20				4 20
	G.			1 5			5 25	3 15	3 15		3 15				1 5
	H.			4 20			5 25	4 20	3 15		1 5				2 10
II	A.			8 40		2 10	8 40	7 35	4 20		4 20				4 20
	B.	2 10	2 10	12 60	3 15	1 5	15 75	13 65	11 55	1 5	7 35	4 20	7 35	3 15	8 40
	C.	3 15	2 10	9 45	2 10	1 5	10 50	10 50	8 40		3 15		1 5		4 20
	D.	1 5	2 10	5 25			3 15	3 15	1 5						
III	A.	3 15		12 60	1 5	1 5	16 80	15 75	17 85	1 5	7 35	4 20	6 30	3 15	6 30
	B.	2 10	1 5	11 55	2 10	1 5	10 50	10 50	8 40	1 5	4 20	2 10	3 15	2 10	3 15
IV	A.	4 20	1 5	9 45	2 10		9 45	9 45	6 30		3 15	1 5	4 20	1 5	2 10
	B.	2 10	2 10	8 40	2 10		8 40	8 40	5 25		3 15	1 5	2 10	1 5	2 10
V	A.	5 25	4 20	10 50	1 5		10 50	8 40	6 30	1 5	4 20	2 10	3 15	2 10	3 15
	B.	5 25	3 15	11 55	2 10		10 50	10 50	6 30		4 20	3 15	4 20	3 15	5 25
VI	A.1.a.	1 5	2 10		1 5		15 75	10 50	10 50		9 45	3 15	7 35	6 30	7 35
	b.														
	c.	1 5	2 10		1 5		5 25	5 25	4 20		4 20	2 10	4 20	4 20	2 10
	d.	1 5	2 10		1 5		5 25	5 25	5 25		5 25	2 10	5 25	4 20	2 10
	e.	1 5	1 5		1 5		2 10	2 10	2 10		2 10	1 5	2 10	2 10	1 5
	f.	1 5	1 5		1 5		1 5	1 5	1 5		1 5	1 5	1 5	1 5	1 5
	2.a.	1 5	1 5		1 5		4 20	5 25	4 20		5 25	1 5	2 10	1 5	2 10
	b.	1 5	1 5		1 5		7 35	5 25	6 30		5 25	2 10	4 15	3 15	3 15
	c.	1 5	1 5		1 5		4 20	4 20	4 20		4 20	1 5	3 15	1 5	2 10
	d.	1 5	1 5		1 5		6 30	5 25	5 25		5 25	1 5	5 25	3 15	2 10
	e.	1 5	1 5		1 5		6 30	4 20	4 20		5 25	1 5	3 15	2 10	3 15
	f.						1 5	1 5	1 5		1 5		1 5		1 5

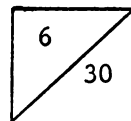
LOCATIONAL REFERENCING

By Parcel					By Administrative or Political Unit					By Planning or Statistical Unit				
VI	B.1			2 10			1 5	1 5	1 5			1 5		
	2	1 5	2 10	4 20			1 5	1 5	2 10			1 5		1 5
	3		1 5	4 20			3 15	2 10	2		1 5		1 5	1 5
	4		1 5	1 5					1 5					1 5
	5			1 5			1 5	1 5						
	C.1			1 5			3 15	2 10	2 10		1 5	2 10	3 15	3 15
	2													
	3		1 5				9 45	5 20	4 20		3 15	2 10	3 15	4 20
	4		1 5				8 40	5 25	4 20		3 15	2 10	3 15	4 20
	5		1 5				4 20	4 20	4 20		2 10	2 10	2 10	1 5
	6		1 5				2 10	1 5	1 5		2 10	1 5	1 5	1 5
	7													
	D.1		1 5				7 35	4 20	3 15		4 20	2 10	4 20	3 15
	2													
	3													
	4						1 5				1 5		1 5	1 5
	5													
	6		1 5				6 30	4 20	3 15		2 10	2 10	4 20	3 15

Key

Tabulation of Interview Responses

Absolute Number



Percent of
Total (20)

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