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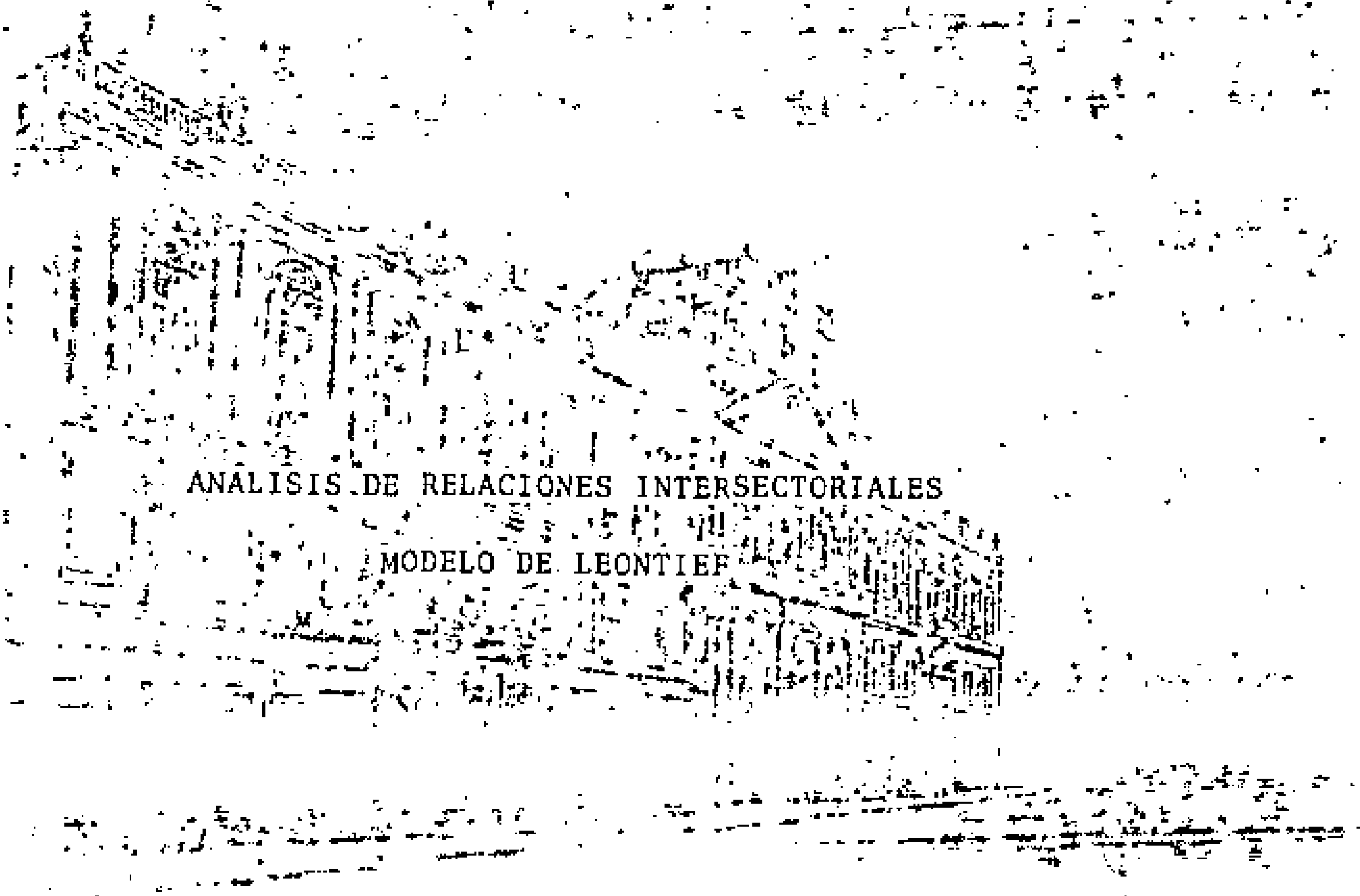
FACULTAD DE INGENIERIA U.N.A.M.

COMPUTACION APLICADA A LA PLANEACION URBANA



ANALISIS DE RELACIONES INTERSECTORIALES

MODELO DE LEONTIEF

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TABLA DE INSUMO-PRODUCTO.

Es un registro de todas las transacciones efectuadas en una economía durante cierto período. En las filas se indican las VENTAS (la distribución de la producción de cada sector). En las columnas se registran las COMPRAS (los insumos de cada sector).

El elemento x_{ij} representa las VENTAS del sector i al sector j, o bien, las COMPRAS del sector j hechas al sector i. La demanda final, de productos provenientes del sector i se representa por Y_i. Finalmente X_i es el valor bruto de la producción del sector i.

El modelo de insumo-producto indica como debe modificarse el flujo de transacciones intersectoriales y por consiguiente, el nivel de la producción bruta, para satisfacer un cambio del nivel o composición de la demanda final. También proporciona los instrumentos de cálculo que permiten la cuantificación de esas modificaciones . Obedece a las hipótesis:

HIPOTESIS 1.

Un tipo de producción requiere proporciones específicas de insumos. Durante el período productivo considerado no ocurren cambios tecnológicos que alteren la estructura productiva de los sectores (por ejemplo,sustitución de insumos).

HIPOTESIS 2.

Es lineal la relación funcional entre la compra x_{ij} al sector j y la producción bruta X_j:

TABLA DE INSUMO-PRODUCTO *

COMPOSICION DE LOS INSUMOS / DISTRIBUCION DE LA PRODUCCION	SECTOR 1	SECTOR 2	SECTOR 3	TOTAL DE VENTAS A SECTORES PRODUCTIVOS	DEMANDA FINAL	PRODUCCION BRUTA
SECTOR 1	x_{11}	x_{12}	x_{13}	$v_1 = \sum_{j=1}^{3} x_{1j}$	$Y_1 = X_1 - v_1$	X_1
SECTOR 2	x_{21}	x_{22}	x_{23}	$v_2 = \sum_{j=1}^{3} x_{2j}$	$Y_2 = X_2 - v_2$	X_2
SECTOR 3	x_{31}	x_{32}	x_{33}	$v_3 = \sum_{j=1}^{3} x_{3j}$	$Y_3 = X_3 - v_3$	X_3
TOTAL DE INSUMOS	$c_1 = \sum_{i=1}^{3} x_{i1}$	$c_2 = \sum_{i=1}^{3} x_{i2}$	$c_3 = \sum_{i=1}^{3} x_{i3}$	$C_1 + C_2 + C_3 = V_1 + V_2 + V_3$		
VALOR AGREGADO	$VA_1 = X_1 - C_1$	$VA_2 = X_2 - C_2$	$VA_3 = X_3 - C_3$		$VA_1 + VA_2 + VA_3 = Y_1 + Y_2 + Y_3$	
PRODUCCION BRUTA	X_1	X_2	X_3			

* En una economía cerrada (sin comercio exterior)

$$x_{ij} = a_{ij} X_j$$

o bien

$$a_{ij} = \frac{x_{ij}}{X_j}$$

donde a_{ij} es una constante llamada coeficiente técnico, que representa la compra de productos intermedios del sector j al i, para producir una unidad de producción bruta del sector j.

Con estos coeficientes, se construye la matriz de coeficientes técnicos o matriz de insumo-producto, que expresa la estructura de costos intersectorial.

MATRIZ DE INSUMO-PRODUCTO
O DE COEFICIENTES TECNICOS

VENTAS → \ COMPRAS ↓	SECTOR 1	SECTOR 2	SECTOR 3
Sector 1	$a_{11}=\frac{x_{11}}{X_1}$	$a_{12}=\frac{x_{12}}{X_2}$	$a_{13}=\frac{x_{13}}{X_3}$
Sector 2	$a_{21}=\frac{x_{21}}{X_1}$	$a_{22}=\frac{x_{22}}{X_2}$	$a_{23}=\frac{x_{23}}{X_3}$
Sector 3	$a_{31}=\frac{x_{31}}{X_1}$	$a_{32}=\frac{x_{32}}{X_2}$	$a_{33}=\frac{x_{33}}{X_3}$

La producción bruta X_j del sector j, es igual a sus ventas a la demanda final más sus ventas a los otros sectores productivos, por ejemplo:

$$X_1 = a_{11} X_1 + a_{12} X_2 + a_{13} X_3 + Y_1$$

$$X_2 = a_{21} X_1 + a_{22} X_2 + a_{23} X_3 + Y_2$$

$$X_3 = a_{31} X_1 + a_{32} X_2 + a_{33} X_3 + Y_3$$

o en forma matricial.

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} - \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

Ahora, factorizando el vector de producción bruta y efectuando la resta matricial:

$$\begin{bmatrix} 1 - a_{11} & - a_{12} & - a_{13} \\ - a_{21} & 1-a_{22} & - a_{23} \\ - a_{31} & -a_{32} & 1-a_{33} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

Bajo la hipótesis de regularidad de la matríz del sistema, se despeja el vector de producción bruta:

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} 1 - a_{11} & - a_{12} & -a_{13} \\ -a_{21} & 1 -a_{22} & -a_{23} \\ -a_{31} & -a_{32} & 1-a_{33} \end{bmatrix}^{-1} \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} \qquad (1)$$

La matriz

$$\begin{bmatrix} 1-a_{11} , & -a_{12} , & -a_{13} \\ -a_{21} & 1-a_{22} , & -a_{23} \\ -a_{31} & -a_{32} , & 1-a_{33} \end{bmatrix}^{-1} = \begin{bmatrix} A \end{bmatrix}$$

recibe el nombre de matriz de Leontief.

Teóricamente la ecuación (1) resuelve el problema: a partir de las variaciones que sufre el vector demanda final, se pueden cuantificar los respectivos incrementos de las componentes del vector producción bruta. Conocidos estos incrementos, utilizando la matriz de coeficientes técnicos, se determinan las transacciones intersectoriales.

Al escribir la matriz de Leontief en la forma

$$\begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} = \begin{bmatrix} 1-a_{11} , & -a_{12} , & -a_{13} \\ -a_{21} , & 1-a_{22} , & -a_{23} \\ -a_{31} , & -a_{32} , & 1-a_{33} \end{bmatrix}^{-1}$$

Los elementos A_{ij} reciben el nombre de coeficientes de requisitos directos e indirectos por unidad de demanda final.

PREPARACION Y APLICACION DEL MODELO.

La construcción del modelo requiere de los pasos:

1. Se preparan estadísticas, en términos monetarios, correspondientes al período de interés.
2. Se construye, con el material preparado en 1, la tabla de insumo-producto.
3. Partiendo de la tabla precedente, se obtiene la tabla de coeficientes técnicos, que muestra las cantidades necesarias de todos los productos para obtener una unidad de producción de un sector dado. Estos coeficientes definen la estructura tecnológica de la economía en estudio.
4. Utilizando las reglas de la inversión matricial, se construye la matriz de Leontief o de requisitos directos e indirectos.

El modelo depende de dos clases de relaciones:

R1. Relaciones contables: las ventas totales de cada sector son iguales a las compras totales efectuadas por los sectores, (condición estática).

R2. Relaciones tecnológicas: Las compras efectuadas por un sector a otro (salvo el autónomo) dependen a través de la función de producción, de su volumen de producción.

Además el valor predictivo del modelo depende del grado en que se realicen las hipótesis:

H1) Los coeficientes técnicos permanecen constantes durante el período que abarca la previsión.

H2) La linealidad del modelo: un cambio determinado en la producción implica cambios proporcionales en los insumos.

APLICACIONES PRINCIPALES DEL MODELO DE LEONTIEF.

1. Cálculo de los efectos derivados de un cambio en la demanda sobre los demás sectores de la economía.

2. Cálculo de los efectos de una elevación general de salarios. Se podrá distinguir en cada sector, el alza debida al aumento de salarios en este sector y la inducida por la elevación de salarios en las industrias que lo abastecen.

3. Previsión y localización de los "cuellos" en un sistema económico. Para tal efecto, se comparan las cifras correspondientes a las producciones calculadas para una demanda final predeterminada, con las cifras máximas obtenidas por los diversos sectores en el pasado.

4. Cálculo de los efectos que pueden originarse por la transformación de un determinado sector en el sistema económico.

EJEMPLO

Para simplificar se consideran sólo tres sectores: agricultura, industria y servicios. Los respectivos cálculos del valor agregado son:

AGRICULTURA

Valor bruto de la producción			100
Menos:	Semillas	5	
	Abonos	10	
	Servicios	10	25
Valor agregado			75

INDUSTRIA

Valor bruto de la producción			150
Menos:	Materias primas agrícolas	15	
	Productos intermedios manufacturados	30	
	Servicios	45	90
Valor agregado			60

SERVICIOS

Valor bruto de la producción			200
Menos;	Productos intermedios manufacturados	20	20
Valor agregado			180

En resumen, el valor total y la composición sectorial del producto bruto es

AGRICULTURA	75
INDUSTRIA	60
SERVICIOS	126
PRODUCTO BRUTO TOTAL	261

La forma en que se realiza el cálculo no permite duplicaciones; consecuentemente, el producto bruto representa una forma de medir el valor de los bienes finales (no sujetos a transformaciones ulteriores).

Con los datos anteriores se construye el cuadro de insumo-producto.

Compras ↓ / Ventas →	Agricultura	Industria	Servicios	Ventas totales a sects. prodvos.	Demanda final	prod. bruta
Agricultura	5	15	0	20	80	100
Industria	10	30	20	60	90	150
Servicios	10	45	0	55	145	200
Total de insumos	25	90	20	135		
Valor agregado	75	60	180		315	
Producción Bruta	100	150	200			450

De este cuadro se deduce la matriz de coeficientes técnicos, dividiendo los elementos de una columna dada, entre su respectiva producción bruta. Efectuando los cálculos, se tiene.

	Agricultura	Industria	Servicios
Agricultura	0.050	0.10	0
Industria	0.100	0.20	0.10
Servicios	0.100	0.30	0

por consiguiente se puede escribir

$$\begin{bmatrix} 0.95 & , & -0.10 & , & 0 \\ -0.10 & , & 0.80 & , & -0.10 \\ -0.10 & , & -0.30 & , & 1 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix} \qquad (2)$$

o brevemente $$AX = Y \qquad (2)$$

Ahora se construye la matriz de Leontief, principiando con el cálculo del determinante del sistema.

$$\Delta = \begin{vmatrix} 0.95 & , & -0.10 & , & 0.00 \\ -0.10 & , & 0.80 & , & 0.10 \\ -0.10 & , & -0.30 & , & 1.00 \end{vmatrix}$$

En este caso, para simplificar los cálculos, se multiplica la tercera fila por 0.10 y los resultados se cierran a la segunda fila:

- 0.01	- 0.03	+ 0.1
- 0.10	+ 0.80	- 0.1
- 0.11	+ 0.77	0

Por consiguiente el determinante toma la forma

$$\Delta = \begin{vmatrix} 0.95 & -0.10 & 0 \\ -0.11 & +0.77 & 0 \\ -0.10 & -0.30 & 1 \end{vmatrix} = \begin{vmatrix} 0.95, & -0.10 \\ -0.11, & +0.77 \end{vmatrix}$$

$$\Delta = 0.95\,(0.77) - 0.1\,(0.11) = 0.7315 - 0.0110 = 0.7205$$

Este resultado prueba la regularidad de la matriz A, consecuentemente se procede al cálculo de la inversa A^{-1}. En esta forma:

$$A^t = \begin{bmatrix} 0.95, & -0.10, & -0.10 \\ -0.10, & 0.80, & -0.30 \\ 0, & -0.10, & 1.00 \end{bmatrix}$$

Los cofactores de esta matriz son :

$$C_{11} = + \begin{vmatrix} 0.80 , & -0.30 \\ -0.10 , & 1.00 \end{vmatrix} = 0.80 - 0.03 = 0.77$$

$$C_{12} = - \begin{vmatrix} -0.10 , & -0.30 \\ 0 , & 1.00 \end{vmatrix} = -(-0.10) = 0.10$$

$$C_{13} = + \begin{vmatrix} -0.10 , & 0.80 \\ 0 , & -0.10 \end{vmatrix} = 0.01$$

$$C_{21} = - \begin{vmatrix} -0.10 , & -0.10 \\ -0.10 , & 1.00 \end{vmatrix} = -(-0.10 - 0.01) = 0.11$$

$$C_{22} = + \begin{vmatrix} 0.95 , & -0.10 \\ 0 , & 1.00 \end{vmatrix} = 0.95$$

$$C_{23} = - \begin{vmatrix} 0.95 , & -0.10 \\ 0 , & -0.10 \end{vmatrix} = - (-0.095) = 0.095$$

$$C_{31} = + \begin{vmatrix} -0.10 , & -0.10 \\ 0.80 , & -0.30 \end{vmatrix} = 0.03 + 0.08 = 0.11$$

$$C_{32} = - \begin{vmatrix} 0.95 & , & -0.10 \\ -0.10 & , & -0.30 \end{vmatrix} = -(-0.285 - 0.01) = 0.295$$

$$C_{33} = + \begin{vmatrix} 0.95 & , & -0.10 \\ -0.10 & , & 0.80 \end{vmatrix} = 0.76 - 0.01 = 0.75$$

Conocidos los cofactores de A^t se puede de inmediato, calcular la inversa A^{-1}, en efecto, dada una matriz A, no singular, se puede construír su inversa de acuerdo con lo indicado en la fórmula

$$A^{-1} = \frac{1}{\det A} (A^t)^{Co} \quad \text{con} \quad \det A = \Delta \neq 0.$$

donde $(A^t)^{Co}$ es la matriz construída, sustituyendo en A^t, la transpuerta de A, cada uno de sus elementos por su respectivo cofactor; en esta forma, utilizando los cofactores calculados anteriormente, se puede escribir:

$$A^{-1} = \frac{1}{0.7205} \begin{bmatrix} 0.77 & , & 0.100 & , & 0.010 \\ 0.11 & , & 0.950 & , & 0.095 \\ 0.11 & , & 0.295 & , & 0.750 \end{bmatrix}$$

Esta es la matriz de Leontief o de requisitos directos o indirectos por unidad de demanda final; con ella se construye el modelo

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \frac{1}{0.7205} \begin{bmatrix} 0.77 & , & 0.100 & , & 0.010 \\ 0.11 & , & 0.950 & , & 0.095 \\ 0.11 & , & 0.295 & , & 0.750 \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \end{bmatrix}$$

Este modelo sirve para calcular las modificaciones de las transacciones intersectoriales para satisfacer un cambio en la composición de la demanda, en efecto, supóngase que se aumenta la demanda final de la agricultura y de la industria y reducir la de servicios, de forma tal que

$$Y_1 = 100 \quad , \qquad Y_2 = 200 \quad , \qquad Y_3 = 100$$

De acuerdo con este programa elemental de planeación se calculan las producciones brutas X_1, X_2, X_3 :

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \frac{1}{0.7205} \begin{bmatrix} 0.77 , & 0.100 , & 0.010 \\ 0.11 , & 0.950 , & 0.095 \\ 0.11 , & 0.295 , & 0.750 \end{bmatrix} \begin{bmatrix} 100 \\ 200 \\ 100 \end{bmatrix}$$

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = 1.3879 \begin{bmatrix} 77 + 20 + 1.0 \\ 11 + 190 + 9.5 \\ 11 + 59 + 75 \end{bmatrix} = 1.388 \begin{bmatrix} 98.00 \\ 210.50 \\ 145.00 \end{bmatrix} = \begin{bmatrix} 136.02 \\ 292.09 \\ 201.26 \end{bmatrix}$$

Para lograr el plan propuesto se requieren

$X_1 = 136{,}02$, $X_2 = 292.09$, $X_3 = 201.26$

de lo cual:

$x_{11} = 0.05\ (136.02) = 6.80$, $x_{12} = 0.1(292.09) = 29.21$, $x_{13} = 0$

$x_{21} = 0.1(136.02) = 13.60$, $x_{22} = 0.2(292.09) = 58.40$, $x_{23} = 0.1(201.26) =$
$= 20.12$

$x_{31} = 0.1(136.02) = 13.60$, $x_{32} = 0.3(292.09) = 87.63$, $x_{33} = 0$

Con estos nuevos datos el nuevo cuadro de insumo-producto será:

NUEVA TABLA DE INSUMO - PRODUCTO

compras ↓ / ventas →	Agricultura	Industria	Servicios	Ventas Totales a Sect. prodvos.	Demanda final	Prod. Bruta
Agricultura	6.81	29.21	0	36.02	100	136.[illegible]
Industria	13.60	58.40	20.12	92.12	200	292.[illegible]
Servicios	13.60	87.63	0	101.23	100	201.[illegible]
Total de insumos	34.01	175.24	20.12	229.37		
Valor agregado	102.01	116.88	181.11		400	
Producción Bruta	136.02	292.12	201.23			629.[illegible]

El último paso del proceso consiste en calcular las diferencias que existen entre la NUEVA TABLA de insumo-producto y la original. Al registrar estas diferencias en una tabla, el resultado es la tabla de diferencias, inducidas por los cambios efectuados en el vector demanda.

TABLA DE INCREMENTOS

Compras ↓ / Ventas →	Agricultura	Industria	Servicios	Ventas Totales a Sect. Prodvos	Demanda Final	Produc. Bruta
Agricultura	1.81	14.21	0	16.02	20	36.02
Industria	3.60	28.40	0.12	32.12	110	142.12
Servicios	3.60	42.63	0	46.23	-45	1.23
Total de insumos	9.01	85.24	0.12	94.37		
Valor agregado	27.01	56.88	1.11		85	
Producción Bruta	36.02	142.12	1.23			179.37

Los incrementos negativos se interpretan como decrementos.

En este ejemplo, para que los cálculos no llegaran a niveles prohibitivos, sólo se establecieron tres sectores, pero su clasificación se puede hacer con el detalle que el problema requiera. La primera tabla de Leontief comprendía 44 sectores: 35 industriales, 1 agrícola, 1 de comercio exterior; 1 Estado, 1 economías domésticas, 1 Stocks, 1 bienes de capital, 1 sin clasificar y 1 de cuentas globales de gastos e ingresos.

En general el modelo de Leontief pone de relieve la interdependencia de los diversos sectores y muestra como una acción aplicada al sistema modifica la estructura de la producción. El mismo Leontief, refiriéndose a su modelo, dijo: " esta contabilidad por partida doble muestra la contextura de una economía,como la describen las operaciones comerciales, dentro de una dependencia recíproca."

Recuerde que el modelo de Leontief es complementario al de cuentas nacionales y la mayoría de las veces ambos modelos no suministran los mismos resultados.

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FACULTAD DE INGENIERIA U.N.A.M.

COMPUTACION APLICADA A LA PLANEACION URBANA

APPLYING INFORMATION SYSTEMS IN PLANNING

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Though a number of cities and counties across the country have begun to develop coordinated interagency, general-purpose urban information systems, and though countless individual agencies and departments have for some time supported their own independent data processing applications, effective integration into urban information systems is only just beginning. The examples discussed in the previous section represent the exception rather than the rule. Further, the participation of city, county, metropolitan, and regional planning agencies in the design and use of general-purpose data processing systems has been characteristically weak, whether those systems have been partially or more fully developed. Neither have planning agencies been particularly successful in developing their own, semi-independent information systems. These are among the reasons for the recent inauguration of major research and development projects in six cities aimed at the design and implementation of various prototype municipal information systems.[8] These demonstration projects display considerable potential for general advancement of the field.[9]

While it is difficult to document the extent to which various urban planning agencies are actually making use of information systems, two 1967 surveys shed

[8]Integrated municipal information systems will be developed in Wichita Falls, Texas, and Charlotte, North Carolina; a human resources development subsystem will be developed in St. Paul, Minnesota; a public finance subsystem in Dayton, Ohio; a physical and economic development subsystem in Reading, Pennsylvania; and a public safety subsystem in Long Beach, California. Each city will cooperate with a systems consulting firm and a university research group. The projects, begun in 1970, are expected to be completed in two to three years. A group of nine federal agencies known as the Urban Information Systems Inter-Agency Committee (USAC) has sponsored the research program.

[9]In addition, significant new developments are currently under way in New York City, where the design of a Geographic Data Network has been inaugurated. Under this concept, individual agencies will continue to independently maintain their own data files, while a centralized, user-oriented capability for data interchange is provided. Central to the concept is the development of a Georgraphic Information System (GIST), designed to permit the assignment of geographic coordinates to the elements within a particular data set. Different data files can then be coordinated and compared according to the geographic location of each data item. See Robert Amsterdam, "The Concept of a Data Network and the Development of GIST," in Rickert, Service Systems for Cities; E. S. Savas, Robert Amsterdam, and Eric Brodheim, "Creation of a Geographic Information System," in Papers, Fourth Annual Symposium on the Application of Computers to the Problems of Urban Society (New York: Association for Computing Machinery, 1969); and E. S. Savas, "Heuristic and Opportunistic Incrementalism: the Road to Urban Information Systems," in Rickert, Federal Activities and Specialized Systems.

some light on the growing number of applications. Hemmens surveyed urban development modeling and related data processing activities in the 25 largest SMSAs.[10] Twenty-six of the 34 agencies that were sent questionnaires responded: 16 metropolitan or regional planning agencies, 6 city planning departments, 2 state agencies, a federal agency, and a consulting firm. All reported that they were either using or planning to use computers and data processing in their operations. Table 1 lists those agencies that provided details on computer use. Hemmens found that while none of the agencies employed a fully developed data bank system (that is, one comprised of existing data files, regular data updating procedures, and existing programming systems for manipulation and retrieval), half indicated the existence of operating systems somewhat short of this idea.

A second 1967 survey obtained much broader national coverage, but its reported results are more generalized.[11] Questionnaires were sent to 59 state planning agencies; 239 county, metropolitan, and regional planning commissions; 148 transportation study groups; and 63 city planning departments. The total response was 55 per cent. Many, perhaps most, of the nonrespondents probably had no experience with information systems, but the number who had or expected to could not be determined. As of 1967, 16 city, county, metropolitan, or regional planning agencies and 17 transportation studies reported that they were employing operational, computer-based data processing systems. Two additional urban planning agencies reported joint operation with transportation studies. Forty-two urban planning agencies and ten transportation studies indicated that information systems were currently being developed or designed, and 11 additional agencies reported planned joint undertakings. Finally, 27 urban planning agencies, 12 transportation studies, and 11 joint agency responses indicated that urban information systems were currently under active consideration.

Many of these agencies which three years ago were developing, designing, or considering data processing systems may now be involved in operational applications, but it should be kept in mind that in most cases such systems would be only partially developed. And their relationship to general-purpose municipal or county information systems (where these exist) is unknown. Usually only certain data files, most commonly those dealing with selected land-use and/or transportation characteristics, will have been computerized for urban planning purposes. Often such data will have actually been initially automated by operating agencies (such as the county assessor's office), even though coordinated local information system development may not have been inaugurated.

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[10]George C. Hemmens, "Survey of Planning Agency Experience With Urban Development Models, Data Processing, and Computers," in George Hemmens (ed.), Urban Development Models, Special Report 97 (Washington: Highway Research Board, 1968); George C. Hemmens, "Planning Agency Experience With Urban Development Models and Data Processing," AIP Journal, September 1968.

[11]Clark D. Rogers and Claude D. Peters, "AIP Survey of Automated Information Systems for Urban Planning" (draft), Information Systems Committee, American Institute of Planners, October 1967.

Table 1
Planning Agency Experience with Computer Facilities

AGENCY	COMPUTER	SOURCE	ESTIMATED CURRENT AVERAGE USAGE (hr/week)
Baltimore Regional Planning Council	IBM 1460 & 1620 IBM 7090 & 360/40, UNIVAC 1005	State operated Service bureau	4
Bay Area Transportation Study Commission	Honeywell 120 IBM 7094 CDC 3800	Agency Service bureau Service bureau	50 2-10 1-5
Chicago Area Transportation Study	IBM 1401	Agency	30
Cleveland-Seven County Land Use—Transportation Study	CDC 3200 CDC 360	Agency Service bureau	90 —
Delaware Valley Regional Planning Commission	IBM 360/30 IBM 7094	Agency Service bureau	25 3
Denver Planning Office	IBM 360/30	City operated	less than 1
Eastern Massachusetts Regional Planning Project	IBM 7094 IBM 1401	Service bureau Service bureau	1.2 3.8
Los Angeles City Planning Department	IBM 360/30,/40 IBM 7044; 7094	City operated Service bureau	10
Metropolitan Washington Council of Governments	CDC 3600, GE 235	Service bureau	½-2
New Orleans City Planning Commission	IBM 1401	City operated	4
New York State Departments of Public Works—Subdivision of Transportation Planning and Programming	Burroughs B-5500	State operated	60
Puget Sound Regional Transportation Planning Program	IBM 1401 IBM 7094	Service bureau Service bureau	½
Regional Plan Association of New York	IBM 7094 CDC 3600	Consultant Consultant	— —
Southwestern Pennsylvania Regional Planning Commission	Honeywell 200	Agency	90-100
Southeastern Wisconsin Regional Planning Commission	IBM 360/30	Agency	25
Tri-State Transportation Commission	IBM 1460 IBM 7094; IBM 360/65	Agency Service bureau	75 —

Only larger planning agencies, such as those surveyed by Hemmens, have begun to think in terms of truly integrated, multiple-file, interagency information systems--which of necessity will be likely to require a heavy emphasis upon "practical," day-to-day administrative applications.

Whether planning agency use of data processing systems has been large, small, dependent, or independent, what are the kinds of analytic and planning benefits which have accrued? What are information systems good for? Beyond the essential feature of rapid access to large amounts of data, computerized information systems can be used for four broad planning purposes or tasks: selective data retrieval and display, generation of standardized summary reports, statistical and modeling analysis, and computer graphics and mapping. These are discussed and related to the basic steps of the systems approach in following sections.[12] In addition, the implications of innovations in the 1970 census for improved planning information and information systems are briefly reviewed.

Data Retrieval

The simplest level of planning application is retrieval of specific data items for day-to-day planning operations. A comprehensive information system will, of course, permit considerable flexibility in the types of data which might be available at any given time. A multitude of possible applications of this type could be suggested. Many would be associated with neighborhood or community planning analyses or specialized problem-oriented (or crisis-oriented) short-range studies. For example, current information on the number of building code violations in a particular community may be desired so urban renewal strategies may be set. The current level and characteristics of unemployment in a model neighborhood might help establish a framework for proposed job training projects. Recent building permit and assessment patterns in a suburban community might help establish criteria for zoning revisions.

Often such information is needed quickly, in as much detail as possible, and as up to date as possible. These are probably the three most important advantages of computer-based data banks for day-to-day planning applications. In the past, data on most land-use and socioeconomic conditions have been typically unavailable in convenient printed form, in the wrong format if available, often summarized for large geographic areas only (and not available at the neighborhood level), seriously outdated, extremely difficult or impossible to obtain from operating agencies, and often costly and time-consuming to ob-

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[12] In addition, see Brian Barber, "Information Systems and Metropolitan Planning," in John E. Rickert (ed.), Urban and Regional Information Systems for Social Programs (Kent, Ohio: Kent State University, 1967), for a brief analysis of the interrelationships between five different types of metropolitan planning agencies (defined in terms of scope of activities) and 12 more detailed types of information system usage or capability. In general, it is concluded that most typical data system applications would be of value to each of the different levels of metropolitan planning.

tain even if those agencies are willing and able to cooperate. An ongoing, continuously updated, multipurpose urban information system in which operating agencies such as city building departments, state employment services, and county assessor's offices all participate will mean that much planning-related data will be conveniently and routinely available.

Figure 1 is an example of such a data request, while Figure 2 shows how, after appropriate computer programming, that request might be answered.[13] Note that

Figure 1
Data Request Application Form:
Metropolitan Data Center Project

APPLICATION DESCRIPTION FORM

APPLICATION NUMBER: T-3

APPLICATION REQUEST: List all properties, buildings, and establishments within Community Renewal Project Area 15. Data items to be included in this listing and the order in which they are to appear in the report are as follows:

1. Parcel Number
2. Building Location Code
3. Establishment Location Code
4. Space Use Code
5. Establishment Name
6. Building Condition
7. Number of Dwelling Units
8. Year Building Built
9. Type of Building Construction
10. Number of Floors
11. Current Zoning Code
12. Attributable Parcel Acreage

Sort by census block within parcel number, within building number, and within establishment number. Summarize the attributable parcel acreage and dwelling unit fields at each census block break.

PURPOSE: To determine the extent of blight in Community Renewal Project 15, and number of families to be displaced on the condition of buildings, existing land uses, and current zoning, in order to develop a Re-use Plan for the area.

USERS: Planning Office
Urban Renewal Administration

FREQUENCY: As Required

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[13]These examples are taken from Manly Johnson and E. P. Alworth (eds.), Metropolitan Data Center Project (Washington: U.S. Housing and Home Finance Agency, 1966). See also Robert L. Wegner, "The Metropolitan Data Center: New Tool for Decision-Making," in Planning 1964 (Chicago: American Society of Planning Officials, 1964). This demonstration project resulted in the coop-

considerable parcel-level detail can be provided, as long as each of the 12 specific data items has been properly incorporated within the information system (that is, identified and referenced to a particular parcel number). As long as each parcel is in turn referenced to a census block number, and each census block number is referenced to or coded by the renewal project area in which it is located, data requests of this type could be filled for <u>any</u> renewal project area. Required computer programming need be done only once, so that subsequent requests of this type could be easily satisfied.

Figure 2
Data Request Computer Printout:
Metropolitan Data Center Project

PAGE 1

REQ.NO. TUL ANALYSIS OF EXISTING CONDITIONS IN COMMUNITY RENEWAL PROJECT AREAS

PARCEL NUMBER	BLDG LOC CODE	EST LOC COD	SPACE USE CODE	ESTAB NAME	BUILDING CNDITION	NO. DWLG UNIT	YR. BLT	TYPE CNST	NO. FLR	ZON #	PARCEL ACRGE	CEN BLK
023011001	01	01	3000000		4		21	26	1	042	396	011
	02	01	3000000		4		21	01	1	042	56	
	03	01	3000000		3		21	02	1	042	077	
023011002	01	01	3225097	SCIRIC	2		57	02	1	042	233	
023011004	01	01	7625072	SMITHS	1			23	1	042	133	
02301105	01	01	3403632	TESCIT	1			26	1	042	266	
		02	2324217	CENSDE	1			26	1	042	265	
023011006	01	01	1407215	TULLIN	2			26	1	042	612	
023011007	01	01	3404111	WHOLIN	2		58	23	1	042	498	
MAJOR TOTAL	9										2036	
023012001	01	01	2425099	CEJDIS	5		20	26	2	042	21	012
		02	3725099	WAKREC	5		20	26	2	042	44	
023012002	01	01	2425097	ENTERP	3		20	26	2	042	98	
023012004	01	01	2004000		3			26	2	042	100	
		02	2625082	INGRAM	3			26	2	043	30	
		03	2325099	CLARKS	3			26	2	042	629	
	02	01	3102512	BIGGUP	3		26	26	2	042	56	
023012005	01	02	1210002		4	2	12	01	1	042	47	
	02	08	1110001		4	5	12	01	1	042	47	
023012011	01	01	3403261	MIDWST	2		35	21	1	042	44	
	02	01	3273261	MIDWST	2		20	21	1	042	178	
	03	01	3403261	MIDWST	2		56	26	1	042	49	
023012013	01	01	7122752	SCOTT	2			03	1	042	64	
023012017	01	08	1110000		3	1	18	01	1	042	49	
	02	08	1110001		3	9	13	01	1	042	17	
023012018	01	08	1110000		4	1	20	01	1	042	45	
023012019	01	08	1110000		4	1	65	01	1	042	26	
023012020	01	01	3403533	SHINER	2		25	36	2	042	58	
MAJOR TOTAL	19					15				—	1303	
023042001	44	01	5444013	MAYBAY						042	590	042
023042002	44	01	5444013	MAYBAY						042	590	
MAJOR TOTAL	2										1180	
GRAND TOTAL	30					15					[illegible]	

30 ITEMS RETRIEVED FOR THIS REQUEST

erative development of partial data systems, each aimed at a particular planning function, in five cities: Denver (comprehensive land-use inventory), Little Rock (school facility planning), Fort Worth (CBD planning), Tulsa (community renewal planning), and Wichita (capital improvement programming).

Report Generation

Data requests and reports such as those [illegible] in Figures 1 and 2 transacted regularly (for instance, annually or semi-annually), especially if they summarize the data by larger geographic [illegible] (for example, for all renewal projects or for the entire city), constitute a standardized type of planning application. For most operating agencies, generation of such regular summary reports is, of course, one of the key applications of data processing. Most of these reports will be concerned with [illegible] or budgetary characteristics, while planning-related reports will be concerned with changes in the status of the land and people resources of an [illegible] area. For example, they might summarize building permits, water connections, code enforcements, welfare caseloads, zoning acreage, school enrollments, or renewal acreage on a detailed annual basis, and covering a number of different planning subareas.

Summary reports might be generated to support major planning activities--such as regional transportation land-use plans, community renewal programs, or comprehensive city plans--and also as part of a regular annual reporting function. Consider, for example, the many planning and development achievements which must be documented annually in HUD-required Workable Programs for Community Improvement in order for localities to qualify for federal housing and renewal assistance. Monitoring and eventual reporting of many of these community and agency achievements--such as dwelling unit construction, building and housing code enforcement, rehabilitation permits, renewal project dispositions, or relocation housing needs and resources--could be facilitated by an information system. Regular updating of the population, employment, housing, and land-use inventories typically conducted by metropolitan transportation land-use studies could also be improved. Figure 3 illustrates a portion of a summary report of this latter type.

It should be noted that both data retrieval and report generation activities can greatly improve the information available for the first two steps of the systems approach to planning--identifying goals and objectives and identifying alternative programs and policies. Problems, objectives, programs, and policies can all be substantially clarified by local data which are relevant, detailed, recent, and easily available. But the use of much planning-related data for immediate purposes--short-range localized planning and standardized areawide reporting--should not obscure their value for more thoughtful, penetrating, long-range analyses of basic planning problems and their relationships. The greater objectivity inherent in the systems approach, and in PPBS applied to urban public administration generally, depends absolutely upon improved data resources--in particular upon the increased knowledge provided by sensitive data retrieval and report generation on the part of planning agencies.

Statistical Analysis

The third phase of the systems approach--predicting relative effectiveness levels--depends in large measure upon quantitative analysis of data. This

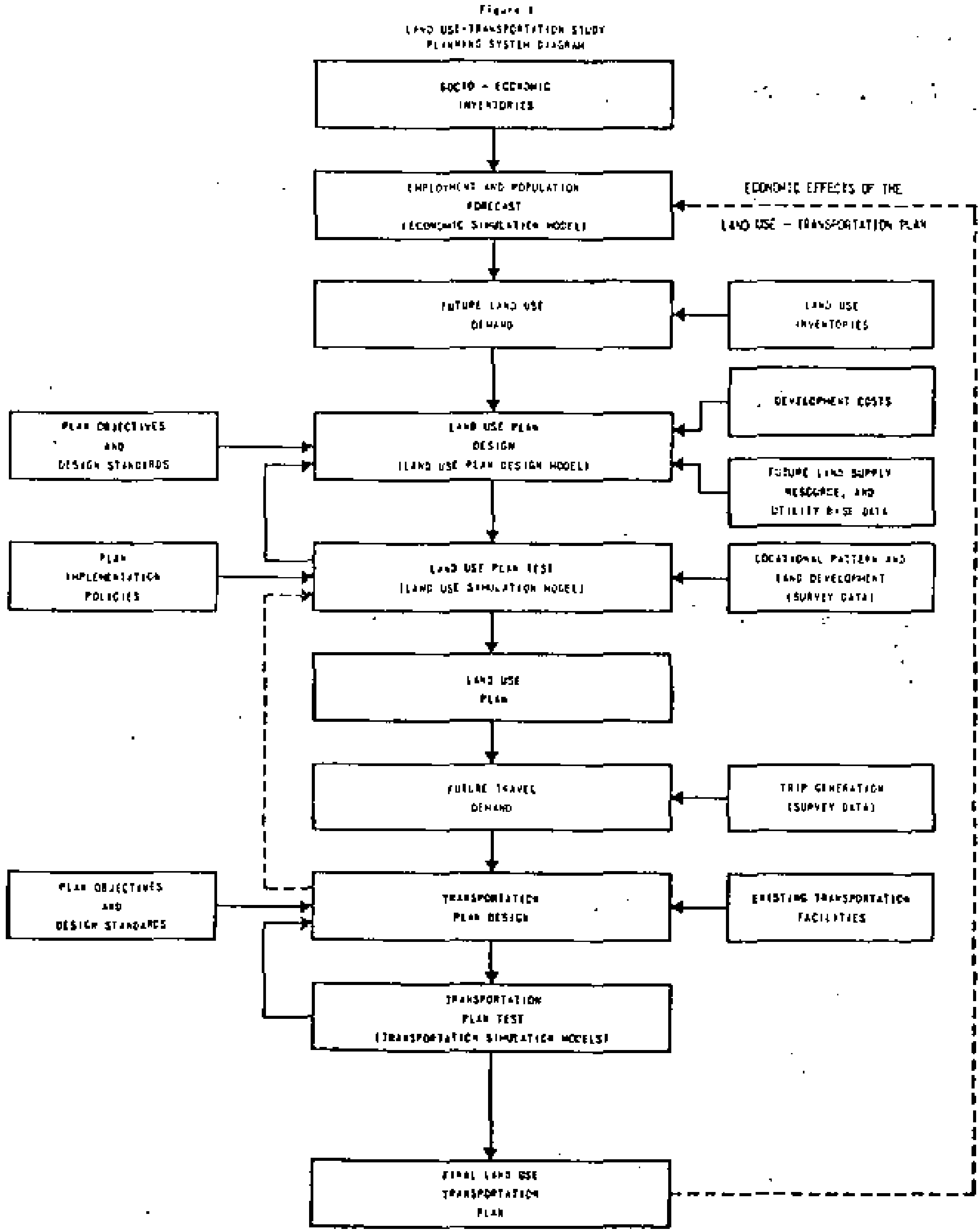
Figure 3
Land-use Inventory Excerpt:
Indianapolis Regional Transportation and Development Study

ACRONYM*	DISTRICT			NUMBER				
	58	59	61	62	63	64	65	66
THUA	1198	4601	1377	1554	1268	2330	2427	378
SFAHU	1194	4546	720	912	1082	2305	2366	376
FA2HU	4	13	570	520	166	22	60	2
FA3MOR		42	77	95	19	3		
GRHU			10	27	1		1	
SFALAN	6760	18430	760	1070	1810	6940	3390	2360
FA2LAN			290	300	100	20	50	
HU3LAN		110	10	50	10	10		
GRLAN				10				
TRNLOD		70						20
SARROW	4720	8670	1430	1310	2240	4790	3410	1730
PARKLO			310	40	240	10	30	
CULACT								
PUASAM	50	210			80			
REREPA	220	1070	80	300	710		60	
CEMETE	230	400			40			10
QUARMI				670		930		
USENUR	132920	159310	740	5240	10210	25640	10690	48000
WATARE	460	150	360	2410	1140	780		20
AUJUNK			40		120	70	10	
TLURU	12724	33800	4667	5748	13793	12572	8763	6832
TLNURU	133380	159460	1140	8320	11470	27420	10700	48020
AREA	146104	193260	5807	14068	25263	39992	19463	54852

* Acronym	Data Item
THUA	Total housing units 1964
SFAHU	Single-family housing units 1964
FA2HU	Two-family housing units 1964
FA3MOR	Housing units three or more family 1964
GRHU	Housing in group quarters 1964
SFALAN	Acres in one-family residential use 1964
FA2LAN	Acres in two-family residential use 1964
HU3LAN	Acres in three or more family use 1964
GRLAN	Acres in group quarters residential use 1964
TRNLOD	Acres in transient lodging use 1964
SARROW	Acres in streets, alleys and R.R.R.O.W.
PARKLO	Acres in parking lots
CULACT	Acres in cultural activities
PUASAM	Acres in public assembly and amusements
REREPA	Acres in recreational use
CEMETE	Acres in cemeteries
QUARMI	Acres in quarrying and mining
USENUR	Acres in vacant and agricultural use
WATARE	Acres in water
AUJUNK	Acres in auto junkyard use
TLURU	Acres in urban use
TLNURU	Acres in non-urban use (vacant, agricultural, mining, water, and auto junkyard use)
AREA	Total acres in zone

Note: 25 additional land-use types, covering industrial, transportation, commercial, services, and other categories are also distinguished. The inventory covered 87 separate planning districts.

Figure 4
Land-use Transportation Planning Sequence: Southeastern Wisconsin Regional Planning Commission



analysis can be greatly facilitated by a computer-based information system, not only because of the quantity and ready availability of needed data, but also through the use of a variety of standardized software packages for statistical analysis and modeling, available from computer manufacturers, service bureaus, and governmental agencies. Because of the importance of computer modeling in urban transporation planning, to use a major example, the U.S. Bureau of Public Roads has developed a number of standard computer programs for trip generation, modal split, trip distribution, and traffic assignment analyses. Experimental urban development models have also depended heavily upon computers, and upon associated urban information systems, though many of these models are not well documented and available for ready use in other urban areas.

Both standard statistical analyses (using "canned" programs) and experimental or research analyses (requiring original and often time-consuming computer programming) can be conducted in collaboration with and through the use of urban information systems. Because the emphasis is on prediction and forecasting, this level of information system application essentially supports long-range planning activities. It also tends to call for the use of large amounts of detailed data, so that complex social, economic, and environmental relationships can be explored. Statistical analysis activities are likely to represent the "trickiest" and most demanding use of an information system. It should be recognized that there are varying degrees of difficulty or scope in potential analytical applications, ranging from relatively simple two-variable cross-tabulations or linear regression analyses, conducted perhaps in support of some narrowly defined or specialized planning effort, to highly complex multivariate statistical analyses or activity distribution models, conducted in support of major transportation land-use planning programs. Figure 4 depicts how various data inventories support the use of four different types of mathematical models in southeastern Wisconsin's transportation land-use planning program.

A major problem of communication between model developers, data processing specialists, and model users has sometimes been experienced in the use of large-scale urban analysis models.[14] Lessons learned from these innovative attempts at employing more complex analytic techniques should not be lost on other statistical analysis applications. In particular, there is a tendency for the technical aspects of model building to absorb all of the energies of systems analysts and quantitative methods specialists, and for these model developers to become somewhat isolated from nontechnical planning staff and others who will eventually utilize resulting models. Every effort should be made to involve planning agency staffs in initial model design and conceptualization and to make them adequately familar with the mechanics of model operation. In addition, the limitations of certain types of data--availability, compatibility, coverage, format, and other features--may serve to frustrate and constrain both model builders and users. Information system capabilities, the special province of data processing specialists, must consequently also be clarified early in the process of statistical analysis.

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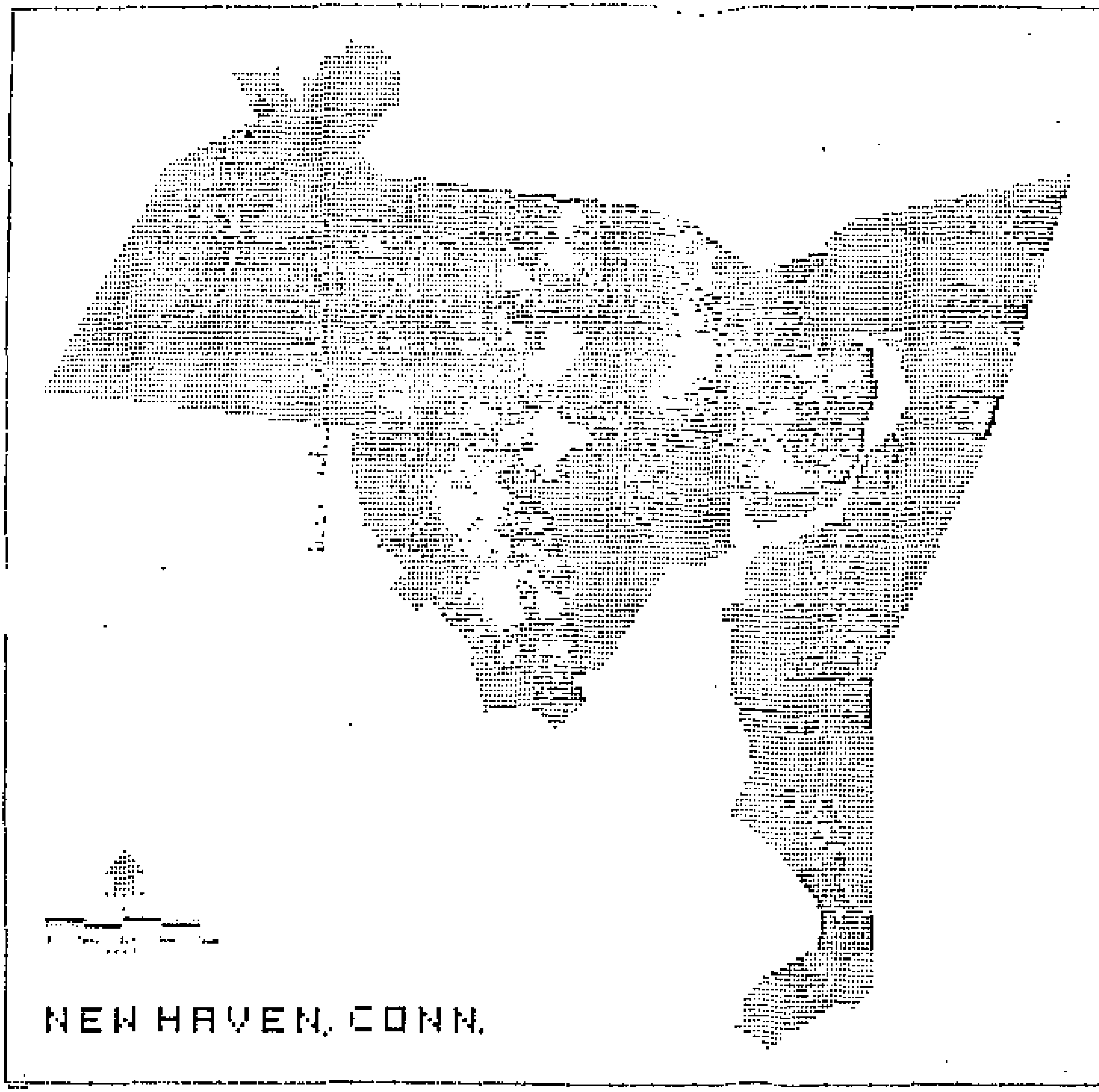
[14] Hemmens, "Survey of Planning Agency Experience."

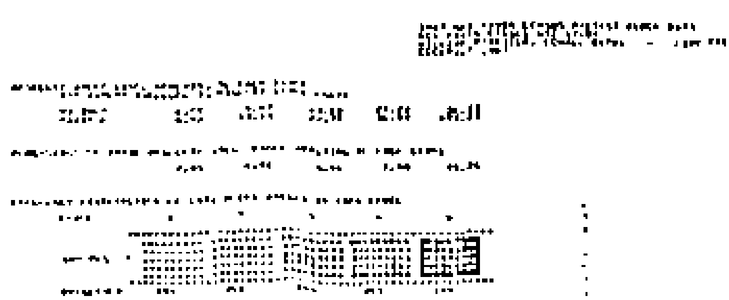
Figure 5
SYMAP Computer Mapping: New Haven Census Use Study



POPULATION DENSITY
(PEOPLE PER ACRE)

1967 NEW HAVEN BLOCK DATA

SYMAP IV CONTOUR OPTION



Computer Graphics

One of the more intriguing aspects of computer-based information systems lies in the potential for computer mapping and other graphic output. Computer mapping is of particular interest because a wide variety of spatially distributed data can be mapped quickly and cheaply compared with traditional draftsman techniques. Mapped display of data can, of course, depict many planning conclusions and findings more meaningfully than other forms of presentation. Computer mapping requires two basic software packages (computer programs): one to assign data to geographic grid coordinates; the other to print maps from the grid coordinate information. Considerable effort has been involved in developing these programs. The two principal geo-coding systems presently available are the census bureau's DIME file[15] and the University of Washington's Street Address Conversion System (SACS).[16] Two currently available mapping systems are Harvard University's SYMAP[17] and the New York State Division of Transportation Planning and Programming's MAP 01.[18] A modification of the latter, called MAP 360, is presently being developed by the census bureau.[19]

The SYMAP program (which can also produce bar charts, graphs, population pyramids, etc.) permits the development of five different types of base maps. One uses points (single X, Y coordinates) for the display of data, another uses straight lines (two or more connected X, Y coordinates), while a third, the most common, uses zones or subareas (as defined by three or more connected X, Y coordinates). Because the symbols representing data are assigned individually to these points, lines, or zones, each type of map is known as a conformant map. A fourth, special-purpose, type, the proximal map, is used to construct geometric zone boundaries around X, Y coordinate point data. The fifth type, the contour map, uses X, Y coordinate point data to construct equal-valued contour lines. For many of these types of base maps, it is then possible to assign up to 12 value ranges or data categories to each of the data items being mapped. An example of population density ranges mapped by city blocks is given in Figure 5. The less flexible MAP 01 program is de-

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15George L. Farnsworth, "Current Developments in Dual Independent Map Encoding," in Rickert, Federal Activities and Specialized Systems.

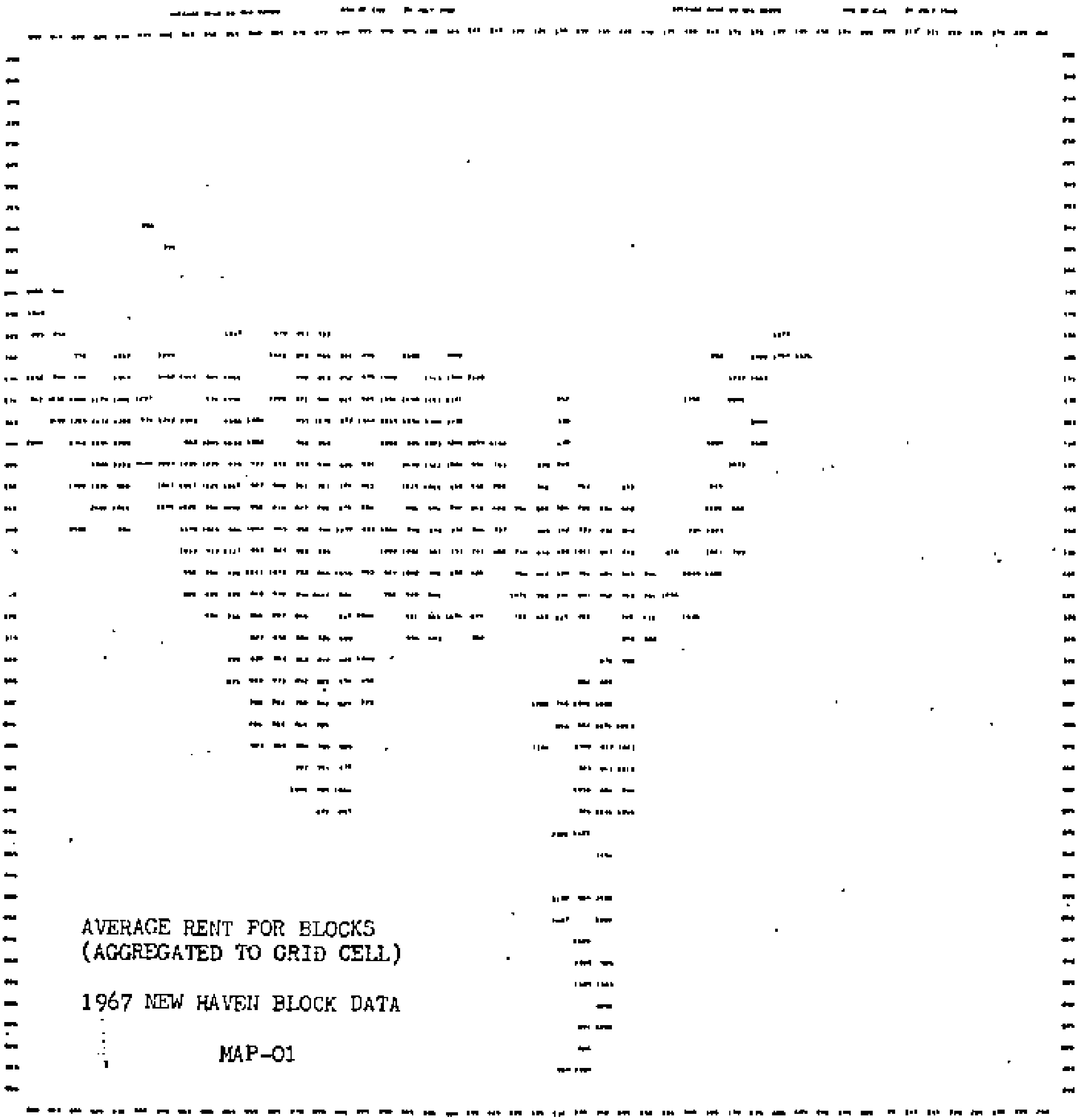
16Charles Barb, "Street Address Conversion System," in Rickert, Federal Activities and Specialized Systems; Robert B. Dial, "Street Address Conversion System," in Planning 1965 (Chicago: American Society of Planning Officials, 1965).

17Laboratory for Computer Graphics and Spatial Analysis, User Reference Manual for Synagraphic Computer Mapping SYMAP, Version 5 (Cambridge: Harvard University, 1968). See also Allan Schmidt, "The SYMAP Computer Mapping Program," in Rickert, Federal Activities and Specialized Systems.

18Kendal H. Bishop and Steven C. Gibson, Mapping by 1401 Computer Using MAP 01, Publication CP00-014-02 (Albany: Division of Transportation Planning and Programming, New York State Department of Public Works, 1966).

19Farnsworth, "Map Encoding."

Figure 6
MAP 01 Computer Mapping: New Haven Census Use Study



signed principally to print X, Y coordinate point data at their respective grid locations (see Figure 6).[20]

1970 Census Implications

The decennial census of population and housing has traditionally provided much of the most fundamental data used by urban planners. In order to make the current 1970 census more responsive to the needs and interests of users, the U.S. Bureau of the Census has in the past few years developed, tested, and implemented a number of significant innovations.[21] They will not only make census products themselves much more useful, they will afford major opportunities for improving and integrating other urban data files. They will make it possible for census results to become a key component of multipurpose urban information systems. The two main innovations--geographic coding guides and the increased availability of small-area data--emerged initially from research conducted by the New Haven Census Study[22] and are being investigated further in the Southern California Regional Information Study (SCRIS).[23]

The potential of geographic coding guides is enormous, and their use will represent a major step forward in urban planning, research, and analysis. The great value of coding guides lies in the fact that nearly all planning-related data (including census data) is spatially distributed, and each item of data is found at a unique location. Many planning questions and problems are in turn concerned with spatial subareas, small sections of the urban community which happen to contain particular groupings of various data items. Other planning questions and subject areas are concerned with the spatial relationship between specific locations and subareas--mainly distances and daily transportation flows. If data items can be associated with a unique location (street address or parcel number), and each location in turn associated with various subareas (blocks, census tracts, city wards, traffic

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[20] Both examples are taken from William H. Maxfield, "Computer Mapping of Census Aggregated Data: The New Haven Census Use Study Experience," in Rickert, Federal Activities and Specialized Systems. See also Donald F. Cooke, "Systems, Geocoding, and Mapping," in Rickert, Federal Activities and Specialized Systems; and Donald F. Cooke and William H. Maxfield, "The Development of a Geographic Base File and Its Uses for Mapping," in Rickert, Social Programs.

[21] U.S. Bureau of the Census, 1970 Census User Guide, Second Draft (Washington: U.S. Government Printing Office, 1969); George McGimsey, "The 1970 Census: Changes and Innovations," AIP Journal, May 1970. See also William T. Fay, "The Geography of the 1970 Census: A Cooperative Effort," in Planning 1966 (Chicago: American Society of Planning Officials, 1966).

[22] Caby C. Smith, "The New Haven Census Use Study: A General Description," in Rickert, Social Programs.

[23] George L. Farnsworth, "Census Use Study," in Rickert, Service Systems for Cities.

zones), considerable flexibility will exist for aggregating data at different levels and for performing spatial interchange analyses. This is essentially the purpose of the census geographic coding guides and related techniques.[24]

These geographic base files have four important features:

1. The basic Address Coding Guide (compiled using specially prepared block maps in each Standard Metropolitan Statistical Area) relates each street address range (for example, 400-480 B Street) to a specific block face or street segment number, block, census tract, ZIP code zone, and other census areas. All data reported by street address can then be summed by block and aggregated in turn according to each of the higher levels.

2. Local planning agencies and other users are free to add additional geographic code numbers for subareas of special interest (traffic zones, planning districts, community areas, etc.) by associating them via computer with block face serial numbers. This permits considerable flexibility in analysis, including the ability to aggregate detailed data by newly created geographic areas.

3. In order to permit census returns (as well as any local data file) referenced by street address to be geographically coded, a computer program package known as ADMATCH has been developed to ensure that reported street addresses are compatible with the address ranges in the geographic coding guide. This will also permit other elements within an urban information system to be coordinated with census data.

4. A second program package known as Dual Independent Map Encoding (DIME) has been developed which assigns node numbers to each street intersection, and standardized X, Y grid coordinates to each node. These coordinates can then be used to calculate distances, areas, and densities, and can also be used to define the boundaries of special analysis subareas. They will also permit the use of computer mapping techniques, as described above.

A second major area of improvement in the 1970 census involves the much greater availability of small-area data. The anticipated availability of data by four different geographic areas is summarized in Table 2.[25] Population and housing data for city blocks will be available for the first time for all cities over 50,000 in population, with their environs also tabulated. Twenty data items will be published by block, and 250 will be available on summary computer tapes. Four hundred data items for nearly all urban areas will be available on tape only for enumeration districts and block groups. Both the areal coverage and data content of census tract reporting have been enlarged, with some 30,000 data items available on tape for the detailed sample survey phase. ZIP

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[24]George L. Farnsworth, "Current Developments in Dual Independent Map Encoding," in Rickert, Federal Activities and Specialized Systems; Heidi Cochran, "Address Matching," in Rickert, Federal Activities and Specialized Systems; Joseph Daly and Robert Voight, "The 1970 Census Address Coding Guide Improvement Program," in Rickert, Service Systems for Cities.

[25]McGimsey, "The 1970 Census."

code tabulations will also be included for the first time. The census bureau has established a data access and use laboratory to facilitate access to unpublished data and has encouraged local public and private groups to establish summary tape processing centers for the same purpose. (Note that only a small fraction of available data will actually be published.)

Table 2
Availability of Small Area Data: 1970 Census

Type of area	On summary computer tapes[a]		In published reports	
	Cells of data[b]	Tentative completion dates	Cells of data	Tentative completion dates
City blocks	250	Jan.-July 1971	20	Jan.-July 1971
Block groups and enumeration districts	400	Aug.-Dec. 1970	none	.....
Census tracts 100 per cent items[c]	3,500	Oct. 1970-Apr. 1971	260	Mar.-Apr. 1971
Sample items[c]	30,000	Jan.-Oct. 1971		
Zip code areas[d]	800	July 1971	none	.....

[a]The anticipated cost per reel is $60 (tape included). UNIVAC and IBM seven-track or nine-track tapes will be available.

[b]The term cell "refers to each figure or statistic in the tabulation for a specific geographic area."

[c]The 100 per cent data items cover the questions to which every household must respond. The sample items cover additional questions asked of 15 per cent or 20 per cent of the households. The 5 per cent sample questions will not be tabulated for census tracts.

[d]Within SMSAs, data will be tabulated for five-digit ZIP code areas. Elsewhere data will be tabulated for three-digit ZIP code areas.

DIVISION DE EDUCACION CONTINUA
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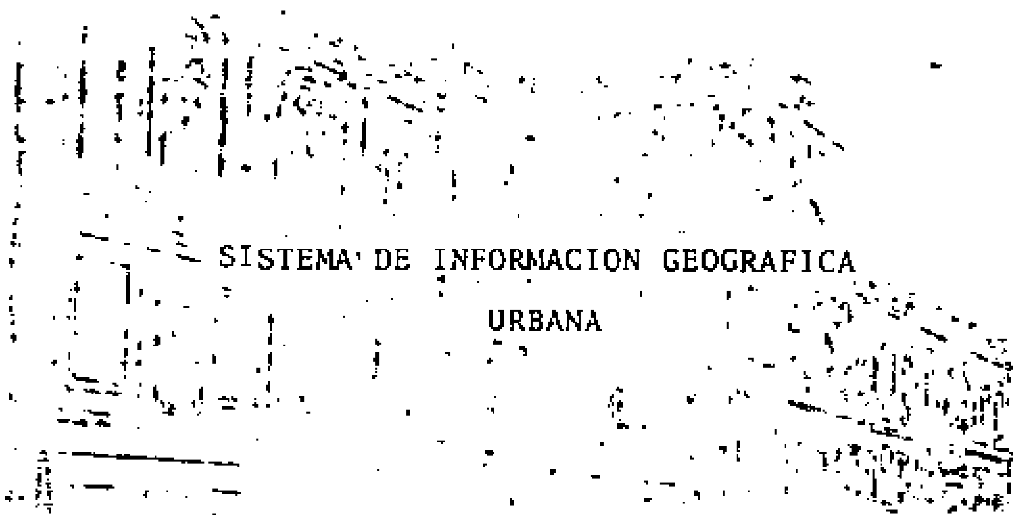
COMPUTACION APLICADA A LA PLANEACION URBANA.



SISTEMA DE INFORMACION GEOGRAFICA URBANA

Agosto, 1981

Palacio de Minería Calle de Tacuba 5 primer piso México 1, D. F. Tel: 521-40-20 Apdo. Postal M-2285

UNIVERSIDAD NACIONAL
AVENMA

DIVISION DE ESTUDIOS SUPERIORES
FACULTAD DE INGENIERIA
SUBJEFATURA DE SISTEMAS

COMPUTACION APLICADA A LA PLANEACION URBANA

DECFI, AGOSTO 10-14

SISTEMA DE INFORMACION GEOGRAFICA URBANA

VISION GENERAL

Ing. Alberto Torfer Martell

Ana Elena Ferrer Ramírez

RESUMEN

Se presenta un sistema de información urbana con geocodificación que permite la integración de información de diversas fuentes, facilitando su agregación y presentación, especialmente en función de la distribución geográfica. Realizar este tipo de operaciones por medios manuales o sin un marco de referencia adecuado, consumiría cientos de horas hombre.

El sistema puede ser una herramienta muy útil tanto en la toma de decisiones administrativas como en la planeación.

35

CONTENIDO

CAPITULO I.-

INTRODUCCION

El medio ambiente ecológico, social y económico actual, está planteando demandas nuevas e imprecedentes, en las posibilidades administrativas y de planeación.

La explosión demográfica está provocando esfuerzos en nuestro medio ambiente. Durante los últimos 50 años se han producido más bienes, que durante todos los años anteriores registrados en la historia. Los vehículos están saturando las vías de comunicación. El aumento de fraccionamientos está inundando los sistemas de alcantarillado. El gran consumo de energéticos está contaminando el medio ambiente.

La efectividad de los gobiernos locales, se deteriora constantemente mientras las demandas siguen en aumento. Por ejemplo, la cantidad de basura por persona está aumentando constantemente. Al mismo tiempo, el tamaño y densidad del área metropolitana aumenta el problema de los basureros. En algunos casos se debe transportar la basura largas distancias para llegar a las áreas apropiadas. A esto se une el aumento de crímenes, necesidades de más escuelas, agua potable, alcantarillado, etc.

Todos estos problemas recaen en los administradores. Tienen que resolver los problemas duales del deterioramiento de la productividad y el incremento de demandas de nuevos servicios.- todo esto con presupuestos reducidos.

De acuerdo con estos problemas, se plantean interrogantes cada vez más complejas. Muchas de estas preguntas requieren datos de múltiples áreas geográficas y funcionales. Por ejemplo:

¿Qué impacto tendrá un nuevo fraccionamiento, sobre las escuelas, transportes, protección policiaca, drenaje, agua y alcantarillado?.

¿Cuál sería el impacto probable de una orden de reordenamiento urbano?.

¿Cómo se puede incrementar la productividad de los sistemas de protección contra incendios, con objeto de satisfacer las nuevas demandas?.

¿Cómo se deben desplegar los recursos actuales de patrullas policiacas para cubrir los cambiantes patrones sociales y criminales, sin sacrificar la seguridad pública?

Estos complejos problemas a nivel político no se pueden decidir con sistemas de información que únicamente proporcionan una orientación fucional. Se deben recolectar datos a través de fronteras funcionales y geográficas. Si no se tienen las respuestas adecuadas, es imposible la administración y planeación del medio ambiente ecológio, social y económico, actualmente complejo.

CAPITULO II.-

GEOCODIFICACION URBANA

La Geocodificación Urbana es una técnica reciente de procesamiento de datos, que se ha desarrollado para satisfacer los requerimientos de información de las agencias gubernamentales estatales y locales. Básicamente, relaciona la localización geográfica con las bases de datos existentes (por ejemplo, la localización geográfica se puede relacionar con los archivos de incidencias de policía, archivos de población escolar, etc.); la geografía es el común denominador que puede ligar virtualmente todos los datos. Los archivos del departamento de policía contienen información acerca de dónde y cuándo ocurren los casos. Los archivos de propiedad, así como los de permisos de construcción, contienen datos acerca de dónde se localizan las cosas. Los archivos de salud contienen información acerca de quién y dónde, etc., y se podría continuar la lista indefinidamente.

El problema es cómo relacionar estos datos salvando el obstáculo que representa la diversidad de límites administrativos. Todas las agencias tienen sus propios métodos particulares para registrar su información. La solución sería relacionar de alguna manera esta información, con un común denominador (esto es, una localización geográfica). De esta manera, se podría recuperar toda la información perteneciente a esa localización, sin importar en qué base de datos se tenga. Esto es, en esencia, la geocodificación. La geocodificación urbana puede integrar y correlacionar los datos a través de los límites administrativos de diversas dependencias, añadiendo de esta manera, toda una nueva dimensión al procesamiento de datos. Con la geocodificación, muchas dependencias pueden estudiar las bases de datos extremadamente diversificadas de otras, relacionando los datos en una base de datos geográficos común obteniendo respuestas a preguntas específicas. Anteriormente, bajo condiciones manuales, los complejos proyectos relacionados con el intercambio de datos entre diversas dependencias, hubiera sido prohibitivamente costoso en términos de hora-hombre; inclusive imposibles.

GEOCODIFICACION URBANA.-

La Geocodificación urbana puede ser vista como un proceso en tres pasos:

1) Utilizando mapas se analizan las relaciones físicas o geográficas entre las diferentes características relativamente estables del medio ambiente. ¿Cuáles son los usos básicos del suelo (por ejemplo, granjas, minería, residencial)? ¿Cuáles son las características físicas del área (Terreno, cuerpos de agua, tipo de suelo)? ¿Cuáles son algunos de los rasgos de infraestructura (presas, caminos)?

2) De nuevo, usando mapas, junto con datos estadísticos de varias bases de datos, se determinan los patrones de actividad generados por los diferentes usos del suelo. Cuáles son las rutas de tránsito colectivo, las poblaciones escolares, los valores de propiedad individual?

3) Se analizan los cambios propuestos para uso del suelo, facilidades o servicios que afectarán a estos patrones de actividad. Por ejemplo, ¿Cómo se pueden redistribuir las estaciones de bomberos para dar protección a nuevos edificios actualmente en construcción? ¿Cuál sería el efecto de un nuevo puente o carretera?.

Estos tres pasos podrán consumir incontables horas hombre si se hacen manualmente; se tendría que investigar en archivos enteros de diferentes departamentos. Con el geoprocesamiento de la información, una computadora podría hacer toda la búsqueda y correlación de los datos.

VENTAJAS DE LA GEOCODIFICACION

La ventaja más grande de la geocodificación es su potencial habilidad para incrementar la productividad; supera la suma de la utilidad de las aplicaciones individuales. Puede coadyuvar a mejorar la productividad operacional y de planeación de dependencias funcionalmente independientes, y a la eficiencia de todo el gobierno. A través de la mejor información, se podrá aumentar la eficiencia e inclusive, se podrán reasignar recursos. Esta posibilidad de reasignación es una de las ventajas principales del uso de estos sistemas. ...

Ya que la Geocodificación Urbana utiliza las bases de datos existentes, se podría perfeccionar la calidad total de las bases de datos individuales; de las siguientes maneras:

- Se podría eliminar la duplicación de una gran cantidad de datos, porque todos los identificadores geográficos serían mantenidos en la base de datos geográficos y no en los archivos de datos operacionales.

- Se podrían estandarizar los identificadores geográficos usados por todos los archivos de datos.

- Se podría checar la calidad e integridad de los datos almacenados.

- Se podría reducir el trabajo tedioso de codificación de identificadores particulares en las transacciones.

Cuando los funcionarios puedan evaluar exactamente las facilidades y servicios públicos requeridos por el desarrollo y puedan comparar estas demandas con los servicios y facilidades disponibles, entonces existirá una base válida para tomar decisiones. Se podrían consolidar fácilmente los datos de diferentes dependencias para formar una base general para toma de decisiones. Por ejemplo, la mayoría de los estados requieren de un informe del impacto del medio ambiente para un mejor desarrollo. Esto puede ser un requisito complejo que involucra datos de muchas dependencias independientes entre sí. ¿Cómo se afectará el medio ambiente? ¿Las facilidades existentes (escuelas, agua, etc.) serán capaces de soportar la carga adicional, o se tendrán que aumentar?. Las respuestas a estas preguntas requieren de la interrelación de una gran variedad de datos locales y ésta es otra ventaja del procesamiento geográfico - la de ser capaz de integrar datos a través de límites jurisdiccionales y funcionales.

La integración y correlación de la información a través de líneas funcionales, puede mejorar las siguientes áreas de política gubernamental y toma de decisiones:

- Asignación de recursos
- Ubicación de facilidades
- Uso del suelo
- Análisis de mercados
- Trabajos de ingeniería relacionados con los puntos anteriores.

Todas estas actividades son esenciales para la planeación de un mejor desarrollo. Todas las fases del desarrollo podrían ser cuidadosamente estudiadas por los planificadores, utilizando un sistema de procesamiento geográfico. Por tanto, se podrían trazar vastas redes de caminos, cañerías y líneas de energía para las necesidades óptimas presentes y futuras. Se podrían localizar eficientemente las estaciones de policía y bomberos, así como otras oficinas municipales. Se podrían localizar hidrantes para casos de incendio con objeto de dar la mejor protección posible a casas y oficinas. Se localizarían convenientemente escuelas y tiendas. Las líneas de transporte colectivo prodrían ser construidas donde más se necesitaran. Si se hiciera manualmente, cada proyecto representaría un enorme trabajo en términos de tiempo, dinero y recursos humanos. Sin embargo, un sistema de información urbano, podría correlacionar todos los datos necesarios para apoyar decisiones y políticas de importancia.

CAPITULO III.-

PRESENTACION GENERAL DEL SISTEMA.

Un sistema de información urbana con geocodificación puede pensarse como una herramienta cuyo valor depende completamente de la habilidad y experiencia del usuario. El sistema capacita al usuario para agregar y desplegar rápidamente datos geográficos. Proporciona información para ayudar a los directivos y administradores a tomar decisiones efectivas. El sistema no toma las decisiones por sí mismo.

Los conceptos básicos de la geocodificación pueden ilustrarse mejor a través de un ejemplo: Evaluar el impacto de aplazar la construcción de un sistema de alcantarillado, en un área donde el crecimiento excede a los servicios; en otras palabras, las facilidades de alcantarillado - actuales no pueden satisfacer un crecimiento adicional. Un retraso - sería una de las posibles opciones para enfrentarse al problema, hasta que se pudieran construir facilidades adicionales que abarataran el costo total del proyecto.

La geografía del área se representa como una serie de mapas sobrepuestos.

1.- El primero (Figura 1) muestra la geografía física relacionada de un área hipotética de planeación; el río, los arroyos, y sus cuencas de drenaje asociadas. Las líneas punteadas representan los límites de las cuencas. El significado de las cuencas de drenaje es que cada una está servida por una sola red de alcantarillado, con una capacidad - dada.

2.- La segunda sobrepuesta (Figura 2) muestra las facilidades físicas o de infraestructura. En este ejemplo, se muestra la red de carreteras, Otras sobrepuestas podrían mostrar escuelas, tiendas, áreas recreativas, etc.

3.- La tercera sobrepuesta (Figura 3) muestra los límites pólíticos del área. En este ejemplo, zonificación de distritos?(comercial rodeada por residencias, rodeada por agricultura). Otras sobrepuestas podrían involucrar red de caminos, límites de parcelas, etc.

4.- La siguiente sobrepuesta (Figura 4) muestra los límites administrativos. En este ejemplo, se muestran las zonas escolares, pero también se podrían usar distritos de bomberos, distritos electorales, etc. En esta etapa, el mapa muestra la fisonomía física, facilidades de - infraestructura, límites políticos y límites administrativos. Con esta descripción básica de las relaciones físicas y geográficas, se podría hacer manualmente un análisis elemental.

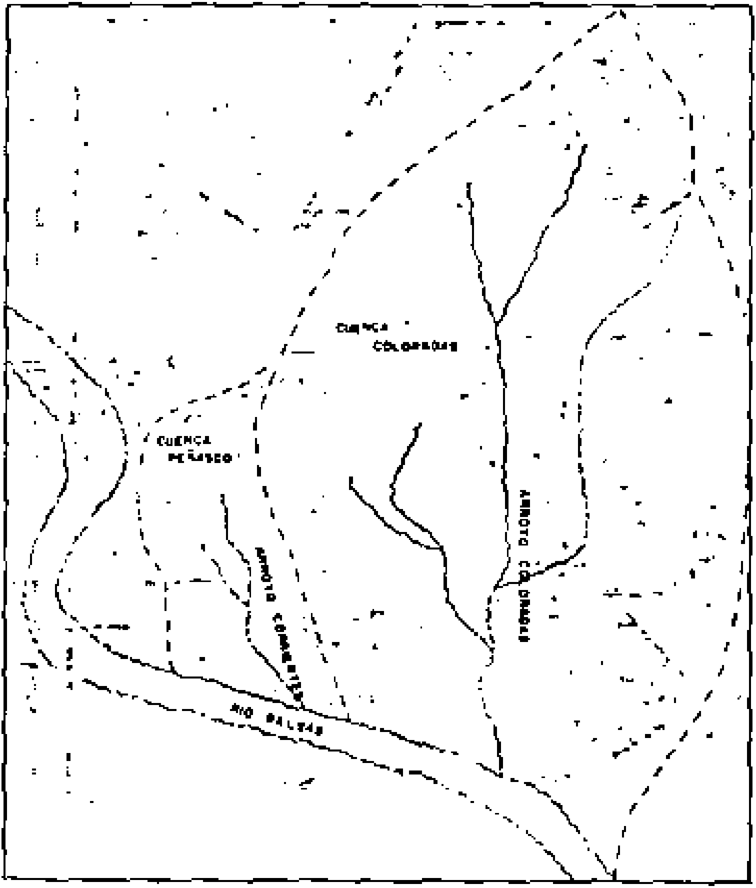


Figura 1. EJEMPLO DE UN MAPA TOPOGRAFICO SIMPLIFICADO

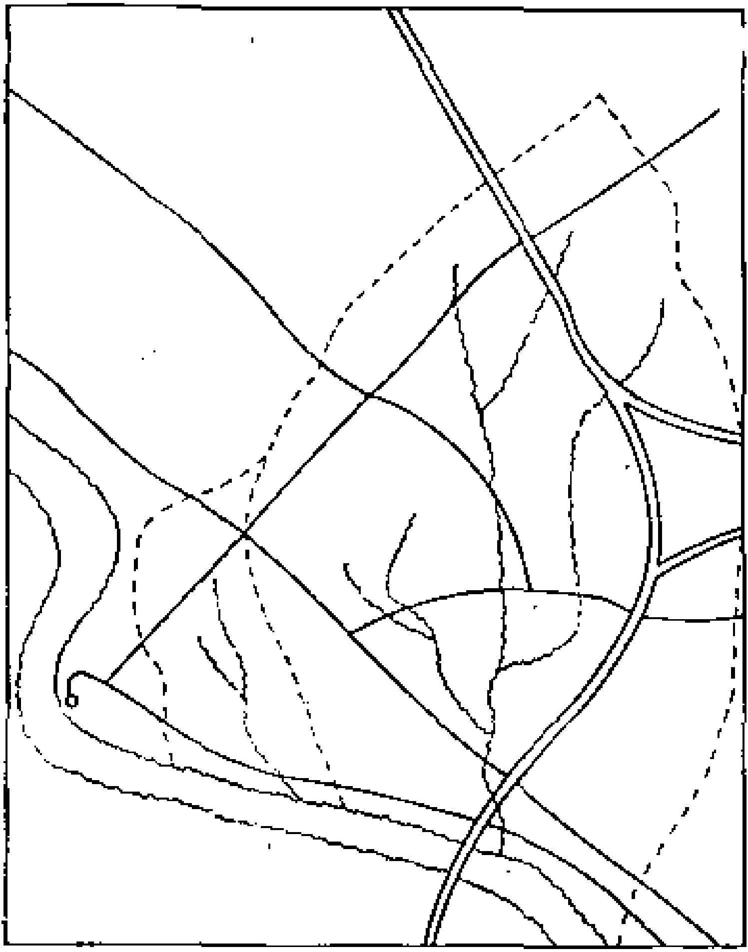


Figura 2. SOBREPUESTA DE OBRAS DE INFRAESTRUCTURA

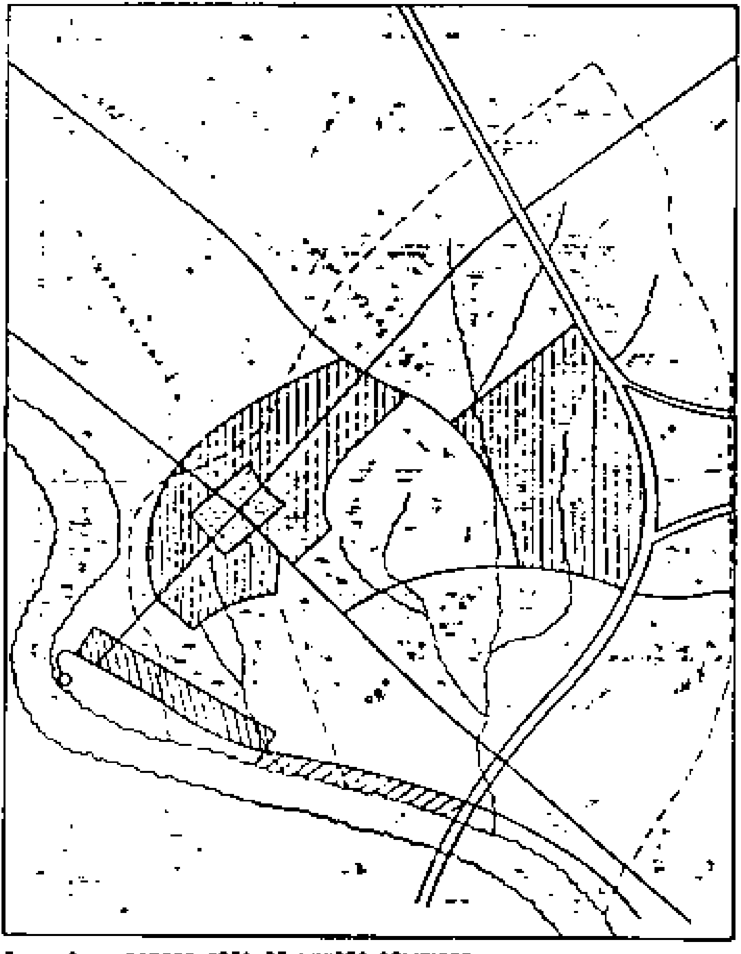


Figura 3.   SOBREPUESTA DE LIMITES POLITICOS

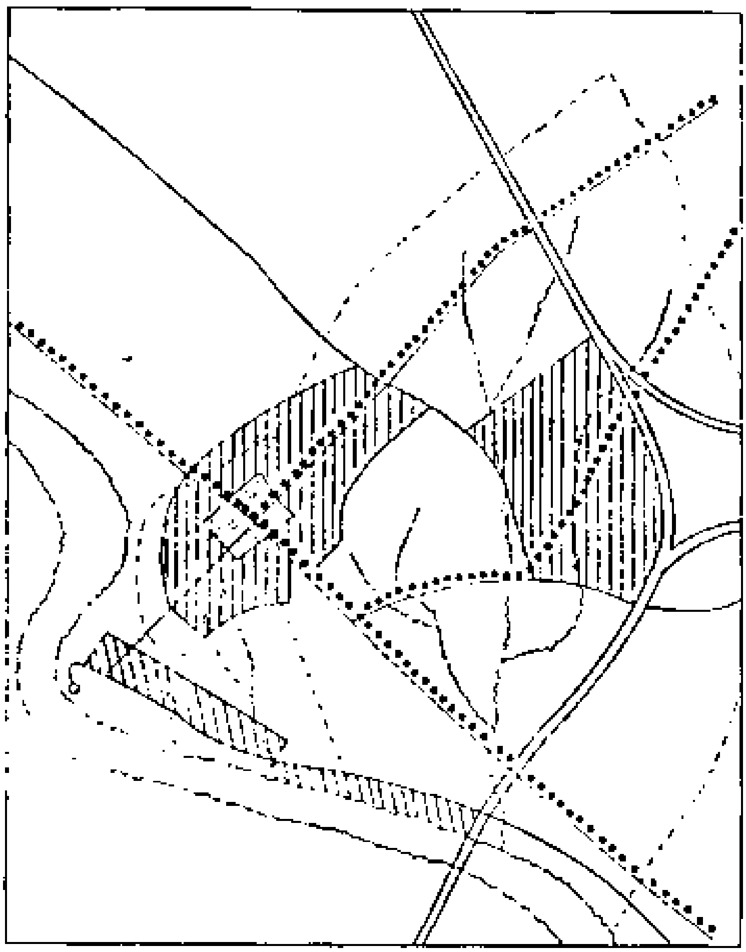


Figura 4. SOBREPUESTA DE LOS LIMITES ADMINISTRATIVOS

Llevando el problema un paso más adelante, esta geografía puede relacionarse con otros archivos de datos, como archivos de permisos de construcción, archivos de casos de incendio, policiacos, etc., para lograr un análisis más preciso de la situación. Para este problema en particular, se saca del archivo de predios, una lista de predios vacantes. Los predios vacantes se relacionan con las cuencas de drenaje y límites de zona y se hace un proyecto del potencial de construcción. El número y tipo de construcciones propuestas llevan a un proyecto preciso de la capacidad potencial de alcantarillado requerida para cada cuenca de drenaje. El impacto del retraso del alcantarillado se podrá calcular con precisión.

(Un análisis diferente podría ser el impacto sobre la inscripción escolar proyectada, utilizando límites de zonas escolares en lugar de los límites de cuencas de drenaje).

Manualmente esta aplicación, podría consumir varios cientos de horas-hombre. Muchas dependencias hacen análisis de este tipo, únicamente para problemas de rutina, y no están relacionados con proyectos especiales. Este procedimiento completo, y muchos otros semejantes, pueden automatizarse utilizando un sistema de información geográfica urbana.

La figura 5 muestra un modelo simple de un sistema de procesamiento geográfico. Los mapas alimentados al sistema son los sobrepuestos ya mencionados. Las características físicas, obras de infraestructura, límites políticos y áreas administrativas. El procesador geográfico combina estas entradas para producir reportes o mapas que apoyen al proceso de toma de decisiones.

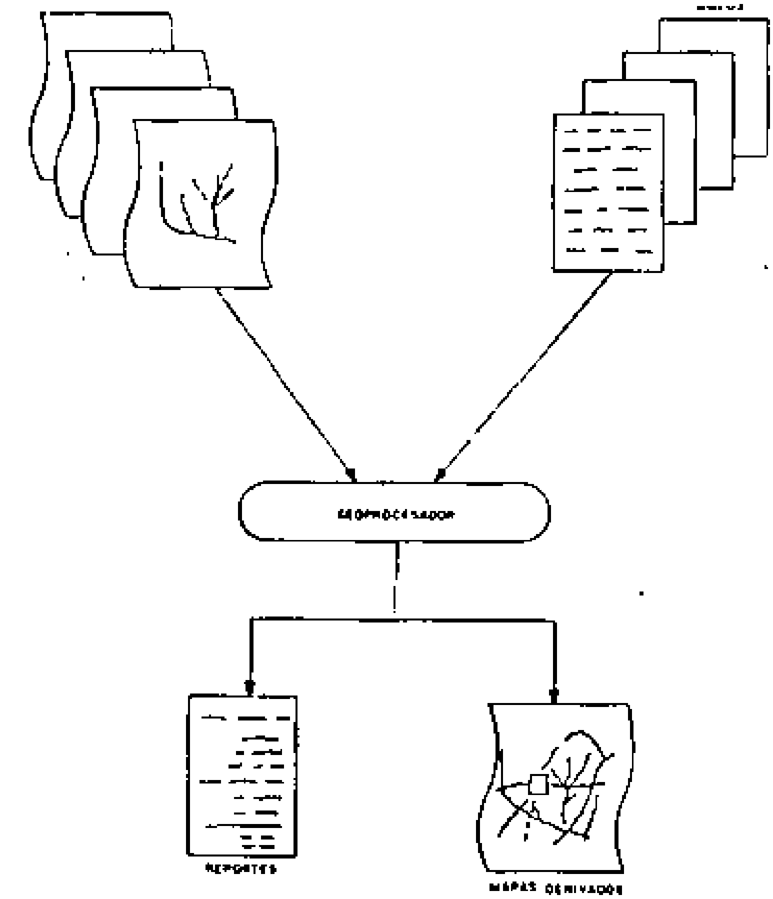


Figura 5 MODELO SIMPLE DE UN SISTEMA DE INFORMACION URBANA

CAPITULO IV.-

DESCRIPCION DEL SISTEMA

Un sistema de geoprocesamiento se puede dividir en tres fases distintas: Construcción/Mantenimiento, Selección y Proceso (ver figura 6).

CONSTRUCCION/MANTENIMIENTO.-

La construcción/mantenimiento, tiene la función de construir, editar y actualizar el archivo geográfico urbano(AGU). Este AGU es una descripción digitalizada de la geografía de un área específica, junto con sus índices asociados (incluyendo el número de calle y/o parcela). El AGU es un modelo de computación de un área geográfica, casi del mismo modo que un mapa es un modelo gráfico.

DIGITALIZAR un mapa es poner los datos en una forma legible de máquina, con lo cual se crea un archivo de procesamiento de datos del mapa. Esto se logra asignando coordenadas X, Y, a los puntos predeterminados en el mapa. Por ejemplo, se les pondrían coordenadas X, Y a las intersecciones de calles, así como a otros rasgos, como localizaciones de hidrantes para incendios, cementerios, puentes y carreteras. Entonces se le da un nombre a cada uno de estos puntos. Esta lista de nombres forma el índice de calles que se asocia a el AGU y se puede considerar como un "diccionario de datos". Cada nombre muestra la información - disponible para cada punto y dónde se puede encontrar esa información en la base de datos.

SELECCION, la Selección busca datos apropiados en el archivo geográfico urbano, y los correlaciona con los archivos de datos existentes (departamento de policía, consejo de planeación, asesoría, etc.) Por ejemplo, en el AGU se puede correlacionar un inventario de carreteras, un archivo de escuelas primarias, y una base de datos de parcelas, para analizar los sitios adecuados para construir una nueva escuela. La correlación se realiza haciendo coincidir los identificadores de localización que aparecen en el AGU y en las bases de datos operacionales.

PROCESO, el Proceso organiza los datos en el formato deseado y despliega el resultado. La produccción puede ser gráfica (mapas), alfanumérica (tabulación estadística o de terminal interactiva). Esta producción se puede hacer en impresoras, graficadores, terminales remotas, o terminales gráficas de vectores. El modelo se puede manejar en tiempo real.

Los mapas se pueden producir en una impresora de líneas, un graficador o un tubo de rayos catódicos (pantalla de video).

Para el público se pueden hacer mapas con graficadores de alta calidad, mientras que para otros mapas que no necesitan ser tan refinados se - puede usar impresoras electrostáticas.

El proceso puede contener un modelo para preguntas: de "qué pasaría si". Por ejemplo:

- El modelo de análisis de tráfico evalúa el nivel adicional de tráfico resultante de un nuevo conjunto comercial en el lugar. Se usa un modelo interactivo por medio de una terminal, donde se pueden fácilmente añadir, suprimir o cambiar datos. (¿Qué pasaría si se construyeran 13 tiendas en lugar de 8? ¿Cuál sería el impacto?).

- El modelo de contaminación del aire computa las concentraciones de contaminantes gaseosos (hidrocarbonos, monóxidos de carbono, etc.), que resultan de los equipos móviles y estacionarios que contaminan el ambiente. (¿Qué pasaría si hubiera 400 automóviles en lugar de 50? ¿Cuáles serían los niveles de contaminación?).

- El modelo de ordenamiento territorial mide el impacto de nuevos fraccionamientos sobre los servicios públicos, escuelas, facilidades recreativas, de salubridad y facilidades de proyección contra incendios, etc. (¿Qué pasaría si se constuyeran habitaciones para 15 familias adicionales? ¿Cuál sería el impacto?).

Estos tres modelos utilizan un archivo geográfico urbano que se correlacionan con las bases de datos para un sistema interactivo que posibilita a los administradores y planificadores resolver los problemas actuales y asegurar las necesidades futuras. Se puede añadir, cambiar o suprimir cualquiera de las partes de la información por medio de una terminal, y el programa se puede volver a correr para las determinaciones del último minuto.

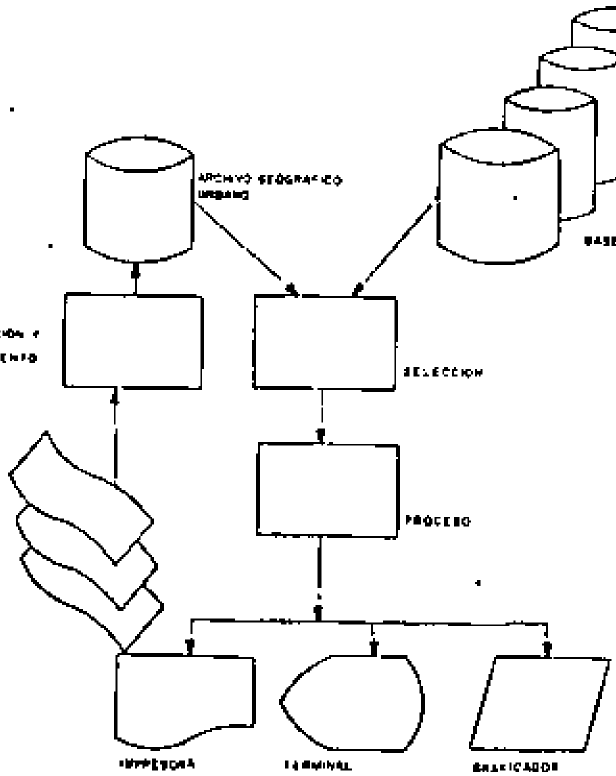


Figura 6. UN SISTEMA DE GEOPROCESAMIENTO

CAPITULO V.-

MANEJO DE LA BASE DE DATOS

El Sistema de Información Geográfica Urbana correlaciona los datos de las bases institucionales, con el archivo geográfico urbano (figura 7).

Los archivos geográficos urbanos se pueden construir en cuatro niveles de complejidad; explícito, estadístico, de límites, y de ingeniería. A medida que se procede desde el básico hasta el más complejo, se pueden manejar una variedad mayor de aplicaciones; también se incrementa el costo y los requerimientos de mantenimiento del sistema.

El nivel de complejidad explícito, es el acceso básico al procesamiento geográfico (figura 8). En este nivel, cada registro de datos contiene el geocódigo. Por ejemplo, el distrito de bomberos está contenido en cada reporte de incidencia de incendios; o la cuenca de drenaje está contenida en cada registro de predio. Con este nivel, se puede hacer un procesamiento geográfico simple, sin el auxilio de un sistema de computación especial. Empero, existen los siguientes inconvenientes:

1.- No es posible cruzar la información de diferentes límites funcionales, a menos que todas las bases de datos estén geocodificadas.

2.- Es virtualmente imposible actualizar los archivos geográficos cuando se cambian los límites administrativos por una nueva zonificación; división, etc.

3.- Las preguntas de "qué pasaría si", no pueden ser económicas porque las fronteras geográficas propuestas no están en el archivo. Por estas razones, el nivel de complejidad explícito no se utiliza tan ampliamente en los sistemas de procesamiento geográfico.

ENFOQUE MULTIDISCIPLINARIO

A las tres distintas fases de un sistema determinado de información urbana (Construcción/Mantenimiento, Selección y Proceso) se les puede denominar el enfoque multidisciplinario. Existen tres niveles de complejidad, (en realidad existen cuatro, pero no se incluye el nivel explícito por su simplicidad) por localización (direcciones y geocodificación simple), por límites (administrativos, políticos o debidos a la malla urbana) y el de facilidades, que defieren entre sí, principalmente en el nivel de detalles geográficos en los archivos geográficos urbanos.

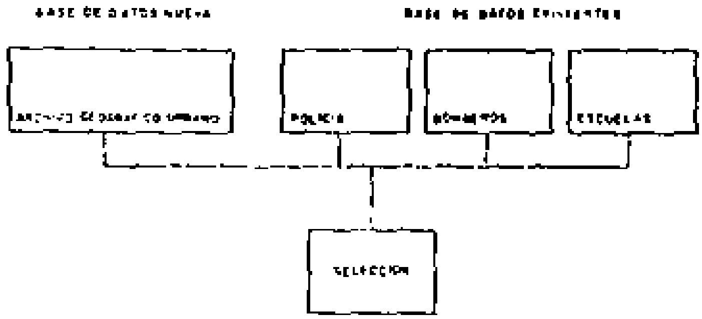


Figura 7. CORRELACION DE INFORMACION FUNCIONAL

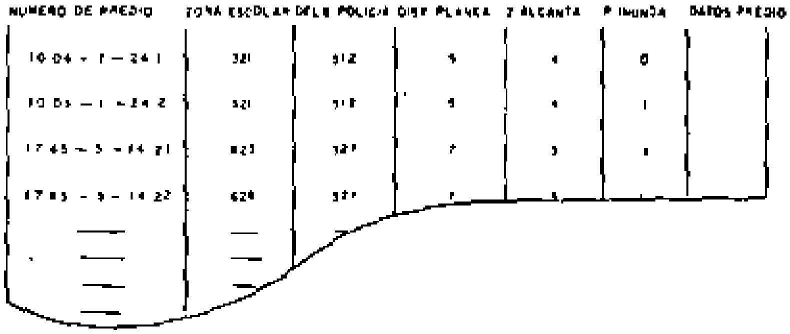


Figura 8. EJEMPLO DE UN METODO DE GEOPROCESAMIENTO

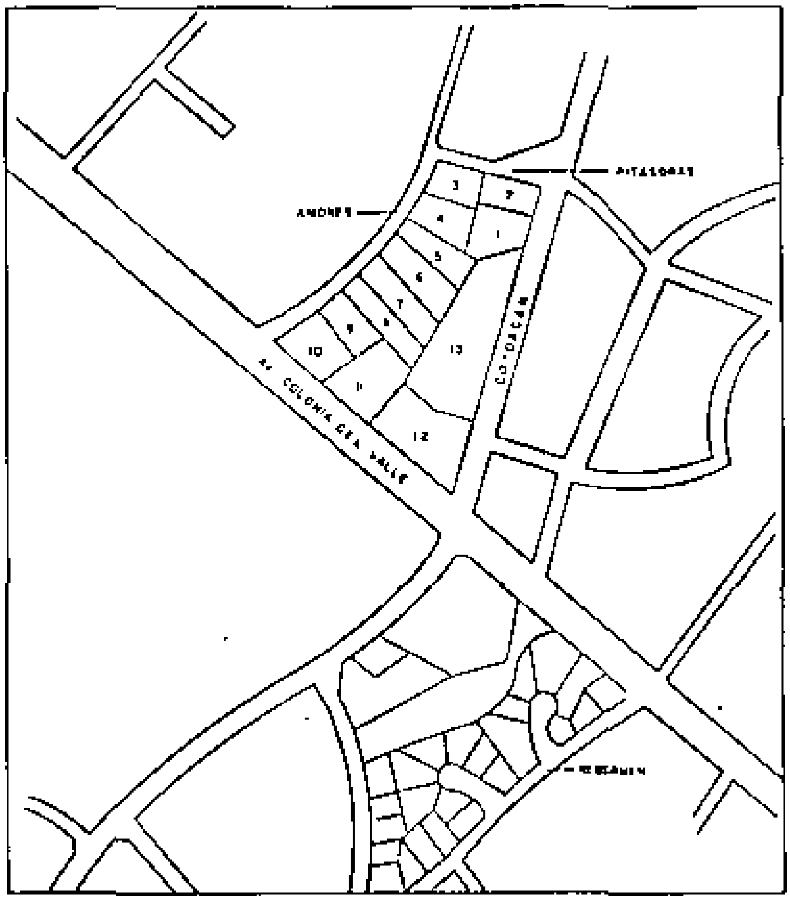


Figura 9.   EJEMPLO DE UN MAPA PREDIAL

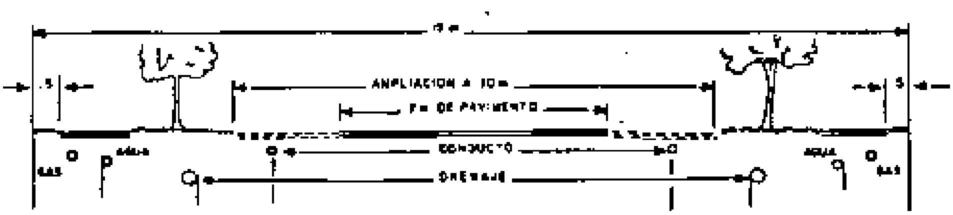


Figura 10.   EJEMPLO DE UN DISEÑO DE INGENIERIA DETALLADA

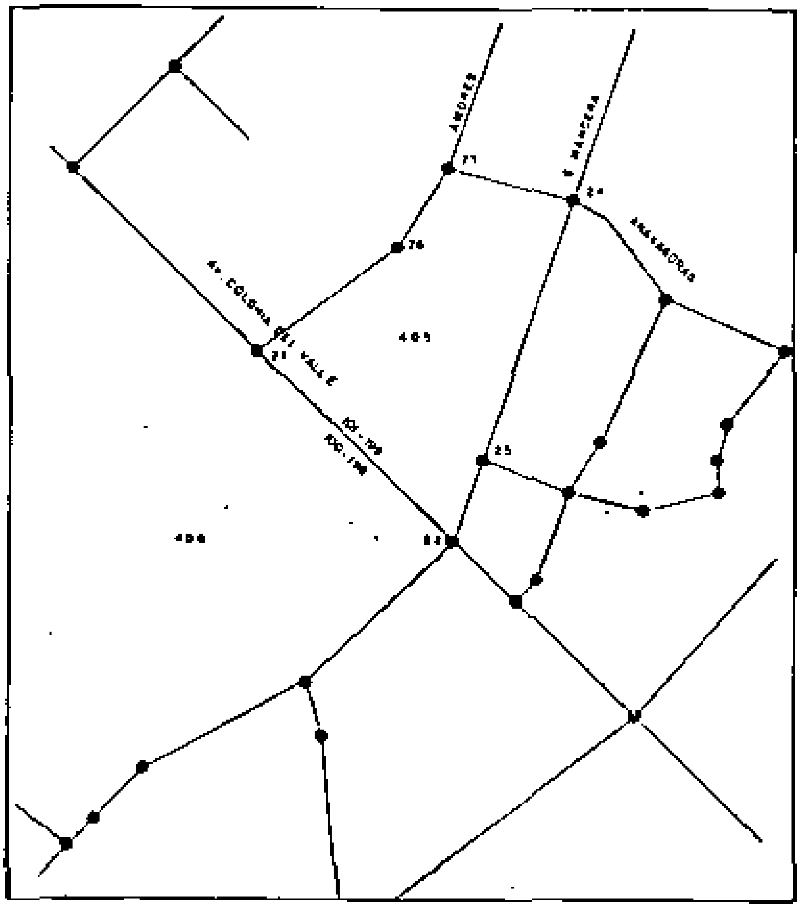


Figure II. EJEMPLO DE UN MAPA AGU/CDMU

1.- El nivel de localización simple resuelve la ubicación de acontecimientos en áreas geográficas (por ejemplo, en el distrito de bomberos 14 ocurrió un incendio en Ave. Taxqueña 181, o en el área de planeación 5 ocurrió una subdivisión del predio 10-1-24). Responde a la cuestión básica: "¿En qué áreas geográficas ocurrieron los hechos?. Tiene la posibilidad de producir reportes estadísticos que sirven para el análisis o respuestas interactivas para una acción inmediata. Este nivel también puede apoyar la producción de mapas de incidencia o de densidad.

2.- El de límites resuelve la geometría de los acontecimientos, en otras palabras, las intersecciones actuales de los polígonos. (Por ejemplo, en la figura 9. ¿Qué porción de qué predio cruzará exactamente el trazo propuesto para una nueva calle o carretera?.) El nivel estadístico listaría solamente los predios afectados. El sistema de límites da una respuesta geométrica más que un sumario estadístico. Este nivel sería útil para el valuador catastral; por ejemplo, podría pedirse contribución especial a todos los predios a 50 metros de una nueva avenida?. Se podrían preparar planos catastrales, para aquellos predios que estén incluídos, aunque sea parcialmente.

3.- El nivel de facilidades (o Ingeniería) resuelve los detalles a nivel de ingeniería (por ejemplo, porporciona trazos de ingeniería sin requerir de un levantamiento preliminar). Ver figura 10.

Todos estos niveles se pueden usar en el Enfoque Multidisciplinario, y son compatibles en nivel ascendente. Cada nivel más alto permite una mejor visión, pero es más complejo, y por consiguiente más costoso en su construcción y mantenimiento. Generalmente es más práctico empezar con el nivel de direcciones (localización) y más tarde extenderse hacia arriba de acuerdo con las demandas que se presenten. El Enfoque Multidisciplinario apoya las aplicaciones en tiempo real, como los despachos de emergencia, así como las aplicaciones de planeación.

ARCHIVO GEOGRAFICO URBANO/CODIFICACION DUAL INDEPENDIENTE PARA MAPAS URBANOS.-

Ya son varios los países que han implementado un sistema de información para áreas urbanas cuyas características principales son:

Una retícula de canevá en proyección cónica de Lambert para el caso de Suecia, sirve de base a la incorporación de información en la base de datos (FRIS).

En Canadá la Unidad Básica de Información está constituida por elementos lineales representado un costo del bloque de manzana (G.R.D.S.R.) y en el caso de los países escandinavos (NIMS) E.U.A. (DIME) y Francia (R.G.U.) la Unidad Básica es el segmento vial limitado por dos nodos o cruceros.

La Oficina de Levantamiento Censal de E.U.A. ha creado un archivo geográfico urbano para las áreas metropolitanas más grandes del país. Estos archivos se utilizarán para el Censo de 1980 y algunos del Censo de 1970, ya están disponibles. Ver figura 11. Sin embargo, algo más importante es que estos archivos (AGU/CDIMU) tienen los datos básicos para apoyar un sistema de procesamiento geográfico en el nivel de localización. La existencia de un archivo AGU/CDIMU para un área en particular, puede reducir bastante el tiempo y gastos necesarios para construir un sistema de procesamiento geográfico.

Los usuarios de estos sistemas serán incontables y ayudarán a enriquecer las bases de información de datos urbanos multidisciplinarios que existan.

CAPITULO VI.-

DESARROLLO DEL SISTEMA

El desarrollo de un sistema de información urbana es una empresa compleja. Es absolutamente esencial un apoyo a nivel directivo. Ya que el procesamiento geográfico cruza los límites funcionales, debe existir un apoyo a alto nivel, para cuando las decisiones crucen estos límites.

Se debe organizar un grupo con representantes de las dependencias que vayan a usar el sistema. Estos representantes participarían en la planeación de todo el sistema, con objeto de asegurar la satisfacción expedita de las necesidades y requerimientos de todas ellas. Se debe consultar a los usuarios potenciales durante el diseño del sistema, con el fin de conocer si aceptarán el producto terminado.

Este grupo de representantes de cada área debe llevar a cabo un estudio de lo siguiente:

- Aplicaciones específicas deseadas para cada dependencia (incluyendo los beneficios potenciales).

- Bases de datos disponibles y las que se tendrán que construir para apoyar las aplicaciones de cada unidad.

- La investigación y la transferencia de códigos o técnicas de potencial aplicación al sistema.

- Los recursos disponibles tanto locales, estatales o federales.

Entonces se procede a la elaboración de un plan de implementación basado en las aplicaciones requeridas por cada área y los recursos disponibles. Se podrían añadir al sistema las capacidades y aplicaciones, de manera modular, estableciendo un programa de implementación.

CAPITULO VII.-

JUSTIFICACION ECONOMICA

El valor real de un sistema de información urbana, se debe medir en términos del aumento de productividad en todas sus aplicaciones.

Se puede analizar la productividad desde tres puntos de vista:

1.- Reducción de costos.- Eliminación de algún desembolso de capital en el futuro; (Por ejemplo, evitar la construcción de una nueva estación de bomberos, porque el equipo actual y los recursos humanos se aprovechen más eficientemente).

2.- Redistribución de costos, recursos humanos, o equipo.- A través de una asignación más eficiente.

3.- Valor agregado.- Resultado de las posibilidades adicionales que antes eran muy costosas o muy difíciles de realizar. La posibilidad de establecer una regionalización nueva cae en esta categoria; frecuentemente, los requerimientos federales y estatales demandan informes sobre el impacto en el medio ambiente para nuevos proyectos, y éstos pueden ser muy complejos. Las horas-hombre empleadas en la investigación manual, podría ser astronómicas.

APLICACIONES POTENCIALES DEL PROCESAMIENTO GEOGRAFICO

En toda administración municipal existen aplicaciones del procesamiento geográfico. Continuamente se hacen algunas aplicaciones (como despachos de emergencia de bomberos o policía). Otras, como la regionalización se hacen sólo ocasionalmente como una función de la planeación. Todavía otras, como las inspecciones y permisos de construcción, se hacen rutinariamente. A continuación se presenta una lista de las aplicaciones potenciales del sistema de información urbana para poblaciones de 100,000 habitantes en adelante. No pretende ser completa, únicamente indicativa.

1.- Despacho de policía.- Despacho de recursos policiacos basados en la asignación geográfica y la historia local.

2.- Despacho de bomberos.- Despacho de recursos de protección contra incendios, basado en la localización geográfica, condiciones locales, y la historia del caso.

3.- Zonificación escolar.- Planeación de la utilización óptima de las facilidades educacionales, basada en la geografía de la población escolar.

4.- Transporte escolar.- Planeación de las rutas de autobuses más eficientes, basada en la población escolar y la localización.

5.- Planeación urbana.- Análisis del impacto de las decisiones urbanas sobre todas las dependencias del gobierno local.

6.- Planeación de transporte.- Planeación del transporte colectivo más eficiente, modificando las rutas y destinos de los transporres alimentadores.

7.- Recreación.- Localización de las mejores áreas recreativas, basada en la localización geográfica de los sitios y usuarios.

8.- Análisis de delincuencia.- Asistencia en la delimitación de áreas de alta incidencia de delitos para optimizar la protección policiaca.

9.- Cuidado de parques públicos.- Planeación del cuidado de zonas verdes dentro de la ciudad, basada en la localización de estas zonas.

10.- Colecta de basura.- Planeación de rutas, basada en la geografía del uso del suelo.

11.- Impacto en el medio ambiente.- Análisis del impacto de las urbanizaciones propuestas, sobre la ecología y las dependencias municipales.

12.- Listas de empadronamiento.- Producción de listas de electores por área geográfica.

13.- Localización de servicios públicos.- Planeación de reparaciones y nuevas construcciones de líneas eléctricas, telefónicas, de agua potable, alcantarillado, etc.

14.- Uso del Suelo.- Mantenimiento de archivos exactos de uso del suelo.

15.- Monitores del crecimiento.- Análisis contínuo de los cambios de localidad, basado en los análisis geográficos de licencias y permisos de construcción.

16.- Inspecciones de construcción.- Planeación de programas de inspección, basada en la distribución geográfica de permisos y licencias.

17.- Mapas base para Catastro Urbano.- Determinación de los impuestos prediales.

18.- Valuaciones especiales.- Asistencia en el trazo de áreas candidatas a impuestos especiales.

19.- Mapa base (Ingeniería).- Mantenimiento de mapas de ingeniería exactos para eliminar la necesidad de estudios preliminares.

No todas las aplicaciones se usarán en todas las organizaciones; de cualquier modo cada aplicación sirve para, por lo menos, dos dependencias. Cada aplicación tiene un cierto potencial de productividad. La suma total de la productividad justificará un sistema de información geográfica urbana como el que se plantea.

CAPITULO VIII.-

CONCLUSION

La implementación de un sistema de información geográfica urbana puede dar muy buenos resultados para los gobiernos estatales y locales. Como con la implementación de cualquier sistema computarizado sofisticado, se necesita un apoyo completo y una gran confianza por parte de los altos niveles gubernamentales. La geocodificación integra información a través de límites funcionales (dependencias) y jurisdiccionales (políticos); el procesamiento geográfico no puede justificarse en base a una sola dependencia. Por tanto, la construcción, mantenimiento y uso del sistema, requieren de la completa cooperación y compromiso de todos los funcionarios, además del coordinador del proyecto. Sólo entonces se pueden obtener los recursos necesarios para tener éxito, facilidades, dinero y personal. Se debe consultar al funcionario de nivel más alto durante todas las fases de la planeación e instalación de la base de datos del sistema geográfico urbano.

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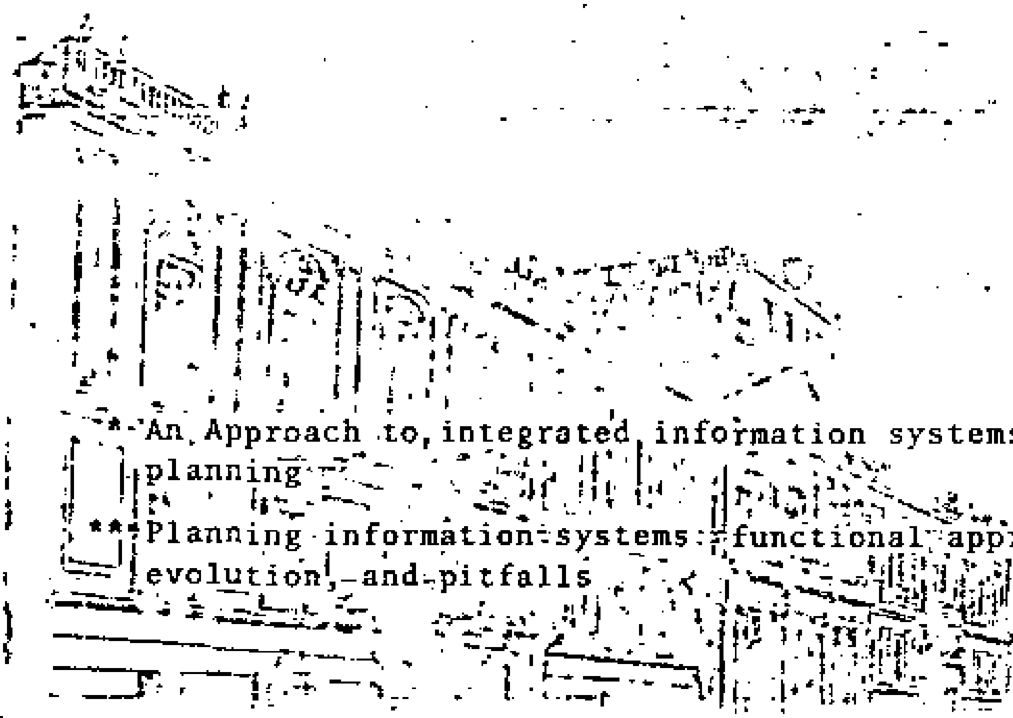
COMPUTACION APLICADA A LA PLANEACION URBANA



* An Approach to integrated information systems for planning

** Planning information systems: functional approches, evolution, and pitfalls

Agosto, 1981

AN APPROACH TO INTEGRATED INFORMATION SYSTEMS FOR PLANNING

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INTRODUCTION TO URBAN INFORMATION SYSTEMS

Requirements for urban information systems

An integrated information system for urban and regional planning requires a data base that can describe the urban system in abstract terms and from which data pertaining to planning issues can be automatically selected and analyzed. These requirements and others must be addressed when applying information systems technology to urban planning.

This article surveys conceptual, rational, and incremental model designs that are used for urban and regional planning. Using the rational model for planning and decision making, the article describes the conceptualization and stratification of data requirements by level of government and by the size and number of areal units. This article also discusses the use of information systems for urban and regional planning, describing and analyzing data requirements for different types of information systems. Finally, a methodology for conducting the planning process and designing urban and regional information systems is also outlined.

TYPES OF INFORMATION SYSTEMS

Four subsystems make up an information system

An urban information system is a special type of geographic information system; its data base consists of observations on population, street segments, land parcels, statistical or jurisdictional areas, transactions, and events. This data is then used for planning and management activities that are, for the most part, nonroutine.

The elements of an information system can be described in terms of four subsystems (see Figure 1):

- Management Subsystem — This subsystem is made up of the organization, staff, and procedures and rules for determining the direction of one or more of the other three subsystems. The management subsystem is largely noncomputerized; staff and procedures are available to facilitate access to the data base and other subsystems. The staff's major function is to translate user questions regarding retrieval queries and analysis tasks.
- Data Processing Subsystem — This subsystem handles data acquisition, input, storage, and retrieval by means of a sequence of operations utilizing various automated and nonautomated procedures. The data base (the major element of an information system) and the various data capture processes that generate the data base are found in this subsystem.
- Data Analysis Subsystem — This subsystem handles such data manipulations as summarization, statistical analyses, or modeling. This subsystem also prepares data for output in various forms. The data analysis subsystem enables selective retrieval of data so that data

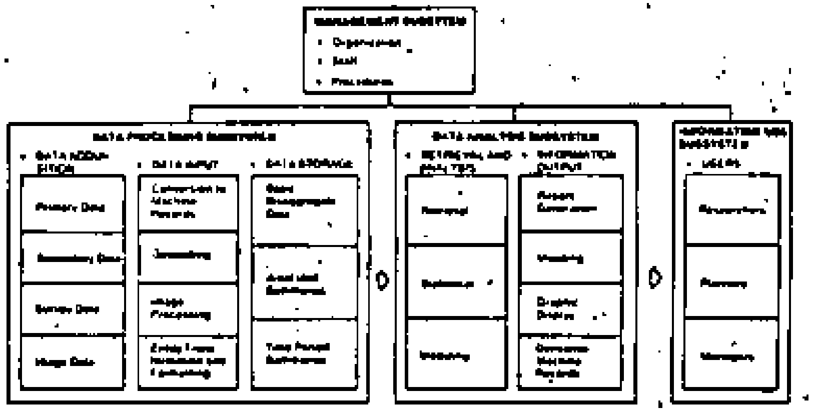

Figure 1. Information System Subsystems

analyses can be performed. These analyses range from the formatting of selected data in report form to the sophisticated modeling of urban systems using various policy options and map output to depict the spatial incidence of policy effects.

- Information Use Subsystem — This subsystem serves as the user's decision-making system where the information is brought to bear on a particular problem. Although the information use subsystem performs noncomputerized activities, it is still considered a subsystem.

Information systems should consist of at least a data processing subsystem and a management subsystem; however, to date, few information systems have paid much attention to a separate management function. The inclusion of part or all of the data analysis subsystem varies considerably, depending on the goals and objectives of the information system. Although the information use subsystem generally is external to the information system, it should be considered as an integral part of the system.

Urban Information Systems

Urban information systems monitor physical, social, and economic subsystems

An urban system is made up of physical, social, and economic subsystems. An urban information system provides a means for discerning changes in the urban system by monitoring the status of these physical, social, and economic processes. To perform this monitoring function, data from maps, surveys, and administrative record-keeping systems serve as vital input to urban information systems. If an urban information system is to be used primarily for intra-urban area surveillance and planning, the system must be linked to local or metropolitan record-keeping functions.

Information needs of planners — supply and demand data

Urban and regional planners and managers have had a long-standing and, for the most part, unmet need for small-area data on population, employment, and similar activity-related data. The principal need of the urban planner and manager is current information on the demand for, and supply of, facilities and services. Although, in the past, supply and demand data by traffic zones and census tracts has been useful, experience has proven that basic land use data is often aggregated in several ways (e.g., school and police districts); therefore, a smaller observational entity, such as a city block or block face, can provide more desirable flexibility.

Population and employment data

Information regarding population and employment is probably the most needed small-area data; therefore, better accounting methods for population and employment changes should be devised. For example, an elaborate record-keeping system or a system for estimating population and employment (by measuring such variables as housing units) should be established.

By monitoring urban change, small-area data regarding the current status of urban activities is always available. The monitoring function can occur in various time cycles (e.g., annually, semiannually, monthly, or daily). In general, in order to maintain the current status of urban activities, urban transactions should be recorded and tabulated as they occur.

DATA REQUIREMENTS FOR URBAN AND REGIONAL PLANNING

Factors affecting urban and regional data requirements

Data requirements for urban and regional planning depend on the type of data (e.g., socioeconomic, physical, or property), the type and number of areal units, and the type of account (e.g., current status, historical data, or flows between areas). Data requirements also depend on how the data will be used. Some data is used exclusively by planners while other data (e.g., land ownership records) is used by planners and administrators. Several factors should be considered when determining data requirements: data volume, differences between subareas, and supply and demand relationships. These factors are discussed in the following sections.

Data Volume. The most important factor for determining information systems requirements is data volume. In planning, data volume is a function of the spatial and attribute resolution of the data. The division of a study region into few (less than 100) subareas is considered coarse-grained or low spatial resolution. Low spatial resolution systems are needed for planning at all levels of government and are easily accommodated by manual systems or conventional computer systems. On the other hand, high spatial resolution systems are needed for more detailed planning and management, such as natural resource analysis, land parcel systems, and street segment-based systems. Since these systems require high spatial resolution data, specialized hardware and software are also required for digitizing and mapping geographic data.

Differences Between Subareas. At all levels of government, jurisdictions analyze differences between subareas and/or allocate resources to subareas. For example, the federal government is concerned with states and functional areas that make up the country. On the other hand, city governments are concerned with neighborhoods and activity nodes that make up the city. In either case, the governmental unit needs data on the socioeconomic and resource status of its subunits. The number of subareas in any jurisdiction usually ranges from 10 to 1,000. Too few subareas make comparisons too general; too many make comparisons too complex.

Supply and Demand Relationships. There are governmental planning functions that require detailed data relating not to program planning or resource allocation questions between subareas, but to project planning or specific supply and demand relationships for specific sites. Analyses of site suitability for development, stream water quality, and the condition of street and highway networks require site specific and link specific data, and, consequently, an information system whose units of observation are sites, links, or other entities under study. For example, when planning a public transportation system, data on ridership and transit vehicles is needed as well as socioeconomic data for the population by subareas of the city. At this more detailed level of planning, the data base for planning is often drawn from, or is the same as, the data base used in the operations or management phases of the information system. For example, the highway network data and land ownership records used in planning are obtained from the operating agencies using the same data for daily administration of those activities. Natural resources planners integrate computerized map data for land capability and suitability analyses. Natural resources managers utilize the same data, perhaps at a different resolution, for forest or wildlife management.

Another category of data for planning is sample survey data that can be based on transit riders, occupants of housing, or users of recreation or health facilities. The number of observations for these kinds of data usually ranges from 100 to 10,000. To perform analyses with such data volumes requires a general-purpose computer and generally available statistical packages.

Analyzing Data Requirements

Data requirements are stratified by level of government

Table 1 illustrates data requirements stratified by level of government. At each level of government there is a need for subarea data and sample survey data. Similarly, at each level there is a need to handle detailed data for small spatial entities, such as land ownerships, small homogeneous natural resources regions (sometimes represented in grid form), and highway, street, stream, and rail networks.

Method for stratifying and analyzing data requirements

Specifically, Table 1 illustrates, by level of government, the kinds of areal units for which planners at that level typically need data for allocative or locational planning and the order of magnitude estimate of the number of areal units. The system user column indicates the users of the data. It is important to note that planning agencies can afford to keep small data sets, while larger data sets must be maintained in conjunction with operating agencies charged with the administration of a particular function. The type of unit column denotes whether the

Table 1. Data Requirements for Planning

Level of Government	Areal Units (no.)	System Users	Type of Unit	Type of Account	Type of Data
State/Regional	Substate districts (10–100)	PL	AR	S H F	SE, PH
	Cities/Towns, Rural districts (100–1,000)	PL AD	PT	S H F	SE
	Rural Land Ownership (10,000–100,000)	AD PL	AR	S	PR
	Natural Resources (All) (1,000,000 – 100x100 m grids per 100x100 km²)	PL	AR	S	PH
	Natural Resources (Selected Study Areas) (100,000,000 – 10x10 m grids per 100x100 km²)	PL	AR	S	PH
	Highway, Rail, Stream Networks (1,000–100,000)	AD PL	LN	S F	EC
Large Urban	Tract (50–500)	PL	PT AR	S H	SE PH
	Block (1,000–10,000)	PL	PT	S H	SE
	Public Facilities (100–1,000)	PL	PT	S F	EC
	Street Segment (5,000–50,000)	PL AD	LN	S F	SE
	Parcel (10,000–100,000)	AD PL	AR	S	PR, SE

Key

System Users: PL Planning; AD Administration

Type of Unit: PT Point; LN Line; AR Area

Type of Account: S Status summary; H Historical or time series; F Flows

Type of Data: SE Socioeconomic; PH Physical; EC Economic; PR Property-oriented

unit of observation is represented as a point, line, or area. The type of account signifies whether current status of values are maintained, whether historical or time series data is important, and whether flows between locations are needed. Where current status is important, a major data issue is a mechanism to update or monitor current status. Finally, the type of data column specifies for each type of areal unit whether the data type is predominantly socioeconomic, physical, economic, or property-oriented.

Types of planning and types of data

The data requirements analysis described in Table 1 does not attempt to stratify planning by sector, but distinguishes between allocation (program) and locational (project) planning and spans socioeconomic data (constituting the demand side for public facilities and services) and natural resources and physical landscape data (constituting limitations on the location or supply of public facilities and services).

Analyzing data in terms of supply and demand

Table 1 also implies the capability to analyze separately collected data in terms of supply and demand. For example, planners analyzing access to emergency health care in terms of the location of hospitals with emergency rooms and ambulance service as compared to where people live and where accidents are likely to occur, require age-stratified population data and traffic and industrial accident data that is geocoded to city blocks. This data serves as demand points for emergency health care services. In this instance, supply data consists of locations of existing hospitals and ambulances and their care and response capabilities. Travel times between points of supply and demand are also needed to determine adequacy of spatial access to health care.

What is missing in Table 1 is the need for sample survey data in planning. Individuals, households, and firms are often surveyed with respect to planning problems. When the results are stratified by location (or areal unit), the data is converted to current status values for small areas and is then treated as socioeconomic data for areal units in the same way as socioeconomic data from secondary sources.

Problems with manipulating large volumes of data

In summary, the list of data requirements for planning illustrated in Table 1 identifies problems with respect to computer processing for both small and large volumes of data. Although the small data sets do not require computerization, their manipulation can be facilitated by creating computer files. The large-volume data sets require specialized hardware and software configurations, including digitizers, plotters, high resolution cathode-ray tubes (CRTs), disk and tape storage, and, most important, software to process geographic data. Large data volumes derived from sample surveys also constitute a problem in that location is coded to larger areas to avoid sample variability problems. Because location must be coded to larger areas, statistical programs that are generally available at university computer centers and large planning agency computer centers can be utilized.

THE URBAN AND REGIONAL PLANNING PROCESS

Urban and regional planning is based, in part, on the evaluation of alternatives, a process that requires considerable data and information systems support. The term "support" defines the information system as a means for establishing a foundation for the planning process.

Steps involved in the systems approach to planning

Traditionally, the planning process used in urban and regional planning has been conducted scientifically using a systems approach. This approach involves a sequence of steps:

- Defining the problem
- Determining objectives
- Inventing alternative solutions
- Evaluating alternatives
- Selecting the best alternative
- Implementing the system or plan
- Monitoring the results

Considerations for evaluating alternatives

When evaluating alternatives, the following considerations need to be assessed:

- Purpose — ideals, goals, objectives and standards
- Measure of performance — efficiency, effectiveness, and impacts
- Components — resources and manpower
- Environment — constraints and assumptions
- Clients — individuals or groups for whom planning is conducted

- Planners — individuals responsible for producing plans
- Decision makers — individuals in a position to make plans operational
- Implementation — establishing connections between planners and decision makers

The preceding considerations are highly interrelated. For example, the client group influences the purpose of the plan, and, if they participate significantly in the process, they influence the decisions. Meanwhile, planners attempt to measure how well an alternative can perform and achieve its purpose with available resources and manpower.

Systems approach can pose problems in long-range planning

Yet, the systems approach has severe limitations and is rarely applied successfully, especially in long-range planning where the system is open-ended and the purpose of the plan is general and vaguely identified. Even if the assumption that better information leads to better decision making is accepted, planning, particularly the long-range planning of an urban system, is fraught with measurement and estimation problems.

Secondary impacts can affect long-range planning

Long-range planning should incorporate the ability to forecast conditionally; it presumes methodology suitable for analysis of secondary impacts and far-reaching consequences. Unfortunately, a methodology for estimating and forecasting long-lasting, pervasive, secondary impacts is not well developed. Yet it is these secondary impacts that are the most important in the long run.

The effects of secondary impacts are often cumulative, having a minor effect in the short run and being difficult to detect and measure (e.g., the effect of thermal pollution on the food chain or the effect of a gas tax). Consequently, existing planning procedures tend to ignore the slow cumulative effects of secondary impacts resulting from established or projected plans and policies.

Planning takes place within this difficult context. The ambition and comprehensiveness of urban and regional planning in the 1960s has been replaced by policy analyses that rely more heavily on aspatial economic models. This transition is discussed in the following section.

Using Information Systems for Comprehensive Land Use/Transportation Planning

Land use/transportation studies of the 1960s emphasized modeling travel demand

The large-scale, comprehensive land use/transportation studies conducted in the 1960s and early 1970s illustrate the information system inputs used for long-range planning. For transportation planning, the emphasis of these studies was on modeling travel demand. Consequently, processing and aggregating massive amounts of origin- and destination-related data was required to provide input to trip generation, distribution, and assignment models. Thus, a major concern was not with ongoing information systems but with data processing and data requirements for modeling.

While working on transportation planning systems, modelers complained about the lack of data and the lack of empirical relationships between hypothetical causal relationships (e.g., the effect of transportation investments on the economic growth of a region). At the same time, data and information system people decried the lack of direction from modelers and inadequate specifications of data requirements. This concern was partly attributable to the one-shot nature of transportation planning at that time. The model orientation and the emphasis on the transportation plan as the product made it inappropriate to try to construct an information system as one of the products of the urban transportation planning process.

Conflict Between Land Use and Transportation Planning

Efforts to interrelate transportation and land use planning were unsuccessful

Land use planners were poor country cousins to the transportation planning process and were tolerated because of irrefutable arguments for transportation/land use interrelatedness. Caught and constrained within the local political process, land use planners often could not deliver on their plans designed to stem urban sprawl. Thus, a major question during the 1960s and early 1970s was whether to use transportation planning to shape desired land use arrangements or whether transportation planning should serve land use under the assumption that land use could not be controlled.[1]

Land use planners, who did not understand at the time that land use models only need to allocate region totals to small areas, wasted enormous energy and resources in collecting and processing land parcel data, very little of which was used in the transportation planning process. Similarly, the Community Renewal Plans (CRP) of this era consumed enormous amounts of resources in processing land parcel data that proved to be essentially useless in actual planning.

Reevaluating the Planning Process

Need for an improved planning process

New information systems technology has encouraged the development of on-line systems and a new planning environment with new data requirements. In an article written by Prof. Douglass B. Lee (University of Iowa) for the Department of Transportation, Lee argues that the technical side of the planning process has not kept pace with the needs of the political side and that the environmental impact statement process collects and displays volumes of data, but with no normative basis for using the statement. Lee also argues for

improved communication among planning professionals, researchers, and policymakers, although "more information is not an unmitigated good, and may serve instead to muddle or distract from the main issue . . . and inadequate or poorly presented information is extremely frustrating."[2]

Scales of data and analysis should be detailed and consistent

A major problem encountered in designing information systems to aid in planning analyses involves the consistency and detail of scales of data and analysis. Although these scales should be consistent and detailed, in practice they are inconsistent and coarse in scale. A zone level of detail is more appropriate for most analyses than planners are capable of accomplishing. Investment in small-area data accounts, manually derived and manipulated, are probably more advisable than large files of detailed data that are inconsistent with the kinds of analyses undertaken.

Comprehensive land use/transportation planning illustrates the difficulty involved in establishing concise objectives for planning information systems. The planning process itself is constantly shifting and, given the complexity and/or controversy in the planning decision, the scale of analysis is subject to considerable debate and change. Thus, the design of information systems for planning cannot be considered a well-structured process. Because of imprecise data requirements and ambiguous objectives, the design of information systems for planning is more of an art than a science.

URBAN AND REGIONAL INFORMATION SYSTEMS DESIGN

Systematic systems design is difficult to achieve

As previously stated, information systems design requires a systematic process consisting of problem definition, analysis of existing systems, evaluation of alternative designs, and system development and implementation. In practice, systematic design is difficult to achieve, particularly when pressing problems and technological gaps exist, or when there are poorly specified purposes and when poorly understood processes are modeled.

Incremental approach to systems design

A more pragmatic, incremental approach to information systems design involves assembling partial systems from specific applications, methodology developments, program needs, and developments in response to hardware acquisition. By necessity, the incremental approach is employed by many planning agencies in developing information systems because project funding gaps and acquisition of new hardware have precluded a more comprehensive design strategy. If a comprehensive design approach is not possible because of resource limitations and an inability to conceptualize the whole system, an incremental and evolutionary design process is appropriate.

Comprehensive versus Incremental Systems Design

Evaluating comprehensive and incremental systems design

Comprehensive information systems design is intended to be flexible and generalized; however, the development histories of such systems are often frustrated by institutional and technical problems. The system objectives are often overly ambitious, and time and budget overruns occur, particularly when cost and time estimates are deliberately optimistic in order to achieve funding support. Yet, partial and narrow systems design objectives are not a virtue. Broad classes of applications must be developed, and sound principles of data base management must be followed. Incremental systems design calling for modular software and clear data structure definitions must be implemented.

Various approaches to systems design emphasize the design process, tool development, or applications development

Despite some of the problems associated with the incremental approach, it offers great flexibility. The lack of specificity of purpose and data requirements forces systems designers to accept certain givens, with respect to information system choices. Systems designers must help to narrow the choices so that a feasible system design can be developed. The following choices can be helpful in systems design:

- Emphasize the process — The process approach focuses on improving the efficiency of a particular function or operation. This approach is exemplified by the efforts of the Urban Information Systems Interagency Committee (USAC), a federal sponsor of pilot municipal information systems development projects designed expressly for subsequent transfer to other cities.
- Emphasize tool development — The tool development approach deals with developing a capability to handle a class of problems. This approach is represented by geocoding efforts, particularly the Dual Independent Map Encoding (DIME) program. The DIME approach involved *a priori* decisions regarding classes or problems to be addressed by the developed system.
- Emphasize specific applications development — The applications development approach deals with a particular problem of analysis. Typical of this focus is the development of transportation planning systems that support trip generation, distribution and mode choice, land use, and travel demand forecasting models. This highly specialized user-oriented system approach lacks features that would encourage the development of more general applications. It also lacks features that encourage the development of applications in areas for which different data, collected to different units (e.g., Census), are needed.

Consequently, information systems responding to one or the other of these approaches will differ considerably. The

Problems associated with each systems design approach

focus or orientation of each approach creates different types of problems. For example, the USAC program encountered failures in subsystem development and in transferability capabilities. DIME has evolved as a system that lacks comprehensiveness from the viewpoint of integrated system goals and lacks flexibility for specific planning needs. The systems approach associated with transportation planning is too specialized to be widely useful in urban and regional management and planning.

FINAL SUGGESTIONS FOR INFORMATION SYSTEMS DESIGN

To precisely state data requirements, the type of data, level of detail, and data volume must be identified

The scope and diversity of urban and regional planning make it difficult to precisely state all data requirements. An added complication is the general lack of knowledge and understanding regarding urban system operations. In an urban system, the type of data, its level of detail, and the data volume must be identified.

The detail of planning for which information systems support is needed determines the spatial and attribute resolution of data. Information systems design seeks to provide a high degree of correspondence between the detail of questions or analyses and the resolution of data describing the urban system.

Information systems should be designed to keep up with dynamic nature of the planning process

Incremental designs of information systems for planning are deemed necessary to keep abreast of the fast-changing planning process. Systems designers, however, should be able to limit debates and options regarding systems design, even if it means risking the development of an ideal, comprehensive system. The main concern should be for a workable system that addresses current and pressing problems, while maintaining the capability to address other problems of the same type or class.

Notes

[1] See paper by Henry Fagin entitled, "Transportation Systems Planning as an Influence on Urban Land Uses," and subsequent transcript of discussion between Fagin and Douglas Carroll in *The Dynamics of Urban Transportation*, published by the Automobile Manufacturers Association in 1962.

[2] See Douglass B. *Improving Communications Among Researchers, Professionals, and Policy Makers in Transportation and Land Use Planning*. Office of the Assistant Secretary for Policy, Plans, and International Affairs, United States Department of Transportation, 1977.

PLANNING INFORMATION SYSTEMS: FUNCTIONAL APPROACHES, EVOLUTION, AND PITFALLS

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INFORMATION SYSTEMS AND URBAN AND REGIONAL PLANNING FUNCTIONS

Urban and regional planning is conducted within a variety of organizational frameworks in the various entities of state and local government as well as within metropolitan or regional planning bodies. The size of the various entities, their location within the metropolitan complex, and their opportunities to design, commission, or otherwise acquire information systems is highly variable.

Planning is carried out within a complex framework

Federal, state, local, and newly emerging forms of metropolitan government also play different roles in collecting and surveying data relating to the planning function. In addition, the private sector also contributes information to local planning data bases. This complex scheme of organizations and data sources makes it difficult to bring the subject of computers in local government urban and regional planning into focus without a unifying theme involving the philosophy of planning itself. Without a unifying theme there is a tendency

to fall back on a discussion of computing techniques that relate to important but limited tasks such as computer graphics, geocoding, census tape processing, or remote sensing. *Computers in Local Government: Urban and Regional Planning* will deal with such themes.

Five generic planning functions

This article deals broadly with the role of information and information systems in the planning process. To this end Martin Meyerson's 1956 classic work, "Building the Middle-Range Bridge for Comprehensive Planning,"[1] provides an excellent framework for linking the subject of urban and regional information systems with metropolitan and local planning. He identifies five generic planning functions as follows:

- Central intelligence function — To facilitate market operations for housing, commerce, industry, and other community activities through the regular issuance of market analysis
- Pulse-taking function — To alert the community through quarterly or other periodic reports to danger signs in blight formation, in economic changes, population movements, and other shifts
- Policy clarification function — To help frame and regularly revise development objectives of local government
- Detailed development plan function — To phase specific private and public programs as part of a comprehensive course of action covering not more than 10 years
- Feedback and review function — To analyze through careful research the consequences of program and project activities as a guide to future action

Central Intelligence Function

Need to assemble internal and external data

The central intelligence function requires assembling information from a variety of data files that are found both within and outside of the planning entity itself. In fact, in a large metropolitan area no single entity could economically assemble the quantity and range of data bearing on this function because of the number of externalities in the system. For example, it is relatively easy for any one unit of government to assemble summary data from its own building permit operation, but it is quite difficult for it to bring together urban region housing market data, such as real estate sales information, that has a bearing on its own housing stock. This task requires both the assembly of relevant internal data bases and the knowledge of external data that will have a direct bearing on the activities important to the planning entity.

Census data is the most important type of external data

The most noteworthy externally collected data is the census data. Although externally assembled, a subset of the census data pertaining to the planning entity itself can be developed, usually by census tracts, census blocks, and census block groups. Similarly, summary subfiles of externally collected assessment data can be assembled where the data is obtainable in automated form. Other sources of externally collected data include commercial banks, lending institutions, school districts, and utility districts or companies. Typical sources of internally collected data include building department records, police department crime files, and traffic counts. The central intelligence function should develop the logic for combining and analyzing variables from the internal and external files.

Pre-automation tasks for assembling data

In the preautomation era the central intelligence planning function was, and for that matter still is, carried out by the assembly of hard-copy material. Integration of the various data bases was a difficult manual process performed with the aid of a stapler, slide rule, and mechanical calculator. Formats and definitions of the data bases were fixed within the confines of each reporting system.

Automated data processing

Automated data processing has made the task of combining variables from different files easier, but the task of searching out files and evaluating the data bases has grown complex as the data base has burgeoned. Planners have moved from hand-produced simplicity to machine-produced complexity.

Skills needed to administer the central intelligence function

The skills demanded of those concerned with the central intelligence function include broad knowledge of the information typically included in municipal files, census files, and other externally developed documents of importance; some general knowledge of data base management systems; a knowledge of geocoding and geoprocessing; and, above all, the operational methods to promote integration of both internal and external files economically. Without such skills and knowledge, the central intelligence function will not be cost-effective and will be subject to the whims of budget curtailment.

Pulse-Taking Function

The role of an early warning system

This function implies alerting top management — the city manager or mayor, commissioners, council, or policy and planning boards — to incipient changes, trouble spots, or danger signs. In the absence of this function there inevitably will be policy development under crisis. According to Meyerson, the pulse-taking function should be an early warning system to alert the administration and provide sufficient time for advance policy study, clarification, and development. While some may argue that policy is not born until crisis appears, the rational model of information use suggests at least an effort at pulse taking.

Need for the planning function to project and forecast conditions

Unlike the central intelligence function, which is designed to produce information "for whom it may concern" either in the local public or private sector, the pulse-taking function must stem from an effort within the planning entity to project and forecast evolving conditions. For example, will a housing rental crunch develop because of a high rate of conversion from apartment buildings to condominiums?

The pulse-taking probe may be initiated by data browsing without knowledge of impending problems. This probe also may be initiated by hypotheses arising out of external events. An example of the latter condition would be an assumed relationship between local housing starts and the changing rates of long-term mortgage money.

Use of interactive computing for data browsing

Data browsing capabilities have been substantially advanced by interactive computing, particularly when assisted by video response and conversational mode access to data bases through either video or printer terminals. For example, for any particular data base, the statistical parameters on any variable can be queried by means of the Statistical Package for the Social Sciences (SPSS) or MINITAB queries on condescriptives; either can yield the minimum and maximum values of the variable, the mean value, the standard deviations, the variance, kurtosis, and other statistical values. From these values the observer can acquire a knowledge of the skewness of the distribution of values of any variable, or combination of variables if a compute command is introduced.

Browsing query is particularly useful if the geography of a data base is known, such as the U.S. Bureau of the Census geography or a file of locally constructed spatial polygons (e.g., relating to school attendance areas).[3] Under these circumstances, the Synagraphic Mapping (SYMAP) System distributed by the Harvard Laboratory for Computer Graphics and Spatial Analysis or the Choropleth Map (CMAP) routine developed for the U.S. Bureau of the Census may be used with great economy to map selected ranges of the variables of interest in the data base. If the data base contains spatial identifiers such as street addresses or coordinates obtained from geoprocessing or digitizing, either cluster analysis or point-in-polygon retrieval is opportune.

Cluster analysis and point-in-polygon retrieval

The cluster analysis yields spatial statistics, including centroid, standard circle, standard ellipse, and the orientation of the major and minor axes, thus allowing statistical comparisons between the clusters of two spatially identified variables. The point-in-polygon retrieval permits data summarization by any polygon or set of polygons superimposed spatially over the data set. For example, census tracts may be represented as spatial polygons if the vertices are digitized to obtain their coordinates. The point-in-polygon summarization would then be used to allocate the points of the data set to the appropriate tracts in which they reside.

Interactive data browsing is not common in local government planning applications

To date, interactive data browsing is still exotic for local governmental planning applications. The field is still wedded to batch mode computing; interactive computing is used primarily in operational matters rather than in planning affairs. Two conditions will change this situation. First, interactive data browsing is now common in major universities and will filter down into local government as trained professionals effect the technology transfer. Second, the advent of economical microcomputers permits almost any enterprising person to operate interactively with selected data bases.

The Policy Clarification Function

Developing and studying policy alternatives

This function logically should precede the development of detailed plan making. The need for policy clarification may arise from the pulse-taking function or in response to unanticipated events or climatological phenomena. Policy clarification implies the evolution of policy alternatives, the study of the impacts of policy alternatives, the weighing of one policy against the others, and the ultimate selection of a policy.

Application of models to planning functions

An information system can be used in policy clarification, and to the extent that it can play a role, it is required to perform computing operations usually involving the application of algorithms or models. For example, assume that in a growing city there have been a number of recent incidents in which fire equipment has responded to calls for service within a reasonable time, yet considerable property has been lost. Policy alternatives costs must be studied. The policy question to be answered is: how much does it cost to provide fire protection service within 16, 13, or 10 minutes of an emergency call?

Let us also assume that in the preceding hypothetical city there is an automated street network file including address ranges, either the U.S. Bureau of the Census DIME (Dual-Independent Map Encoding) file or one similar to it. The analytical task is then to study deployment of the equipment and manpower with regard to existing stations and the street network, so that all property is within the established time limits. To accomplish this, a tree-building algorithm or formula is needed that automatically computes the distance of an address from its nearest fire service center.

Detailed Development Plan Function

Planning agencies' unique responsibility is technical plan preparation. Specific development plans characteristically deal with physical growth or change of the particular plan-

ning jurisdiction, whether it is the city, metropolitan area, or special-purpose district.

Computers can be used to expand the number of policy alternatives evaluated

The development plan function, whether it deals with spatial or nonspatial contexts, invariably represents the selection of one (among many) alternative, and herein lies the importance of the computer in not only expanding these alternatives, but in expediting the preparation of materials for scrutiny and decision-making by both local decision-makers and the public.

Steps in the detailed development plan process

The detailed development plan function traditionally has commenced with the amassing of mapped information at a common scale representing topography, geography, demography, and the current indicators of social, economic, transport, and other activities. This is followed by an analytical planning process involving superposing transparent overlays of the various mapped phenomena over a base map to show spatially how each mapped variable relates to the others. In the overlay analysis, ground and slope conditions are indicated by one color, current land use classifications by other colors or symbols, and the location of economic activities by still other shades or symbols. Based on this overlay information, a sketch planning stage follows; some future desired physical arrangement emerges from the application of land use planning principles to the mass of information in the overlay system. At the most, only a few alternate schemes can be created in this traditional, overlay planning analysis process.

Spatial analysis using the computer

Spatial analysis using the computer can by-pass much of the timeconsuming preparation work in the traditional process. Computer-produced maps can reflect the various information layers previously drawn by hand in the overlay system, and the computer can combine variables that simulate the results of the hand overlay system. The amount of analytical information that can be brought to bear on the detailed development plan function can be increased by many orders of magnitude. Although more analytical information may not make decision-making any easier, it should add dimensions that were hitherto impossible and assure consideration of a greater range of variables.

Automated overlay systems

An overlay system views the variables comprehensively in a spatial context, but it does not respond to another type of planning analysis need, the query. The answer to a query may aid in designing a solution to meet very specific programmatic criteria. For example, in most states local improvement districts for what is termed street front improvements (e.g., paving, water supply, and sewers) cannot be initiated if the value of the improvements are greater than the assessed value of the property, or some multiplier thereof. Assuming certain estimates of the property frontage costs of such improvements, the needed query then becomes: show the locations of all city blocks in a given perimeter where assessed valuation is at least *X* dollars per unit length of block perimeter. This kind of a query can be carried out easily if the assessment file is automated and a geocoding system is available to display block images.

Feedback and Review Function

Closing the loop in the planning process through feedback and review has been the most important missing element of local and regional planning systems. Because of the many private sector decisions that implement, or fail to implement, adopted plans, reviewing the efficacy of the detailed development plans in a timely manner has been difficult.

As an example, areas of the city may show up on the comprehensive plan as predominately single family residences; however, in the same areas there may be a multitude of nonconforming uses and zoning variances that, if superimposed on the plan map, would disclose that a substantially different physical environment actually exists. In fact, recent judgments rendered by courts define "comprehensive plan" as not what is on the comprehensive plan map, but what really emerges from the day-to-day administration of the plan.

Day-to-day administrative changes affecting the comprehensive plan need to be tracked by computer

The analysis required to keep abreast of day-to-day administrative changes impacting the plan can only be performed efficiently by using geoprocessing systems that operate on assessment records, zoning administration records, building department permit records, and other inputs that can disclose conditions that change over time.

Feedback and review technology must be built into planning system

Because planning is a future-oriented activity, there is a tendency for planners to avoid such questions as: what went wrong with the current plan, and why did it go wrong? Relatively little attention has been devoted to this question in urban planning circles and in the literature. Organizations typically hesitate to allocate resources for feedback and review work. The feedback and review function is likely to reach maturity when the data base systems can be more easily queried. To be meaningful, the feedback and review technology must be built into the planning system itself.

EVOLUTION OF INFORMATION SYSTEMS IN URBAN AND REGIONAL PLANNING

Three stages in planning information systems = pre-, para-, proto-automation

The three stages in the evolution of the field can be distinguished by systems levels rather than applications. The first stage, pre-automation, provides a sense of history. Although fairly sophisticated information was produced by the Chicago Area Transportation Study in the late 1950s, the technology was actually not broadly used until the 1960s. References to it,

therefore, are included in the next stage, para-automation, which describes the transition between the very beginning of information automation in the urban planning field and the systems that are becoming operational in the 1980s. The third stage, proto-automation, takes its name from the sense of the word "proto" as leading or prototypical. The third state includes some forecasting of the field from a 25-year perspective.

Pre-Automation Stage: Before 1960

Pre-1960s marked by the electronic accounting machines

The 1960s marked the introduction of the large-scale use of high-level computer programming languages with English-like vocabulary. Although demonstrated in the early 1950s and put into operation later in the decade, the expansion of programming resources burgeoned in the 1960s, largely because of the growth of academic computing facilities and instructional programs.

Detroit and Chicago regional transportation studies were notable exceptions in pre-1960s planning analyses

Before 1960, local and regional planning information was visually descriptive, stemming from on-the-ground "windshield survey" and hand-constructed map overlays. Mapping was supported by tabular information hand copied from U.S. Bureau of the Census decennial reports and other locally enumerated data. This laboriously constructed and hand-gathered information base supported a planning rationale resting mainly on doctrinaire principles, such as the superblock of Clarence Stein and the integral residential neighborhood scheme of Clarence Perry, both institutionalized in the planning vocabulary of the 1920s. With a few notable exceptions, such as Detroit and Chicago, where large-scale regional transportation studies originated, there is a quantum leap between the pre-1960 level of planning analysis and the emerging practices of the 1980s.

Para-Automation Stage: 1960 to 1980

The term para-automation is used to denote a transitional stage between the pre-1960 and post-1980 eras. Several independent thrusts of information automation with differing orientations have developed during this period. The disjointed nature of developments during this period stems partially from local governments' relative unfamiliarity with computing concepts for planning analysis, if not for general local government functions as well.

Automation of urban transportation studies

From an historical viewpoint, the first and most important of these independent information automation thrusts is related to the advent of the urban area transportation study, characterized by the prototype Detroit Area Transportation Study in the late 1950s. This monumental effort represented a federal-state-county funding partnership designed to evolve a comprehensive urban transportation plan through the creation of an independent, publicly supported study team.

Use of gravity-type computerized transportation models

The automation features of this planning effort largely took the form of an automated data base created from a regionwide travel study (based on a sample household survey). The data collected in the study was used in a gravity-type computerized transportation model.

Where early transportation efforts failed — lessons to be learned

The most successful outcome of these travel studies, conducted in all of the major U.S. urban areas in the 1960s, was the detailed design of the traffic flow elements of the urban freeway systems, including ramp and interchange configurations, merging sections, and number of lanes. The studies also furnished traffic flow expectations with future urban growth. Where these efforts failed was in the information system's inability to produce a consensus of goals and actions by various levels of governments for future patterns of urban development and in the lack of providing a methodology for data update. The lesson to be learned is that the information system did not have political support. The information systems for urban transportation planning were the province of an ad hoc board of appointed officials who lacked political authority.

Early transportation efforts introduced data bases and graphic output of urban information

From an information systems development standpoint, these early transportation efforts advanced the state-of-the-art by producing relatively organized data bases of information relating to urban activities. They introduced elementary data base management systems and computer graphics output, and trained a cadre of professionals, many of whom assumed leadership positions in demonstrating the scope of opportunities for urban and regional information systems. These efforts continue in the work undertaken by the federally recognized Metropolitan Planning Organizations (MPO) in U.S. metropolitan areas.

Use of automated census products

The second most important thrust in the para-automation stage is the growing use of the automated products of the U.S. Bureau of the Census. The Bureau had not contemplated user operations other than its own internal system for the use of the 1960 Census of Population and Housing summary tapes, but, through the initiative and cooperation of John C. Beresford (then on the staff of the Bureau of the Census), a handful of external users implemented automated applications using the 1960 Census tapes.

Development of geographic base files

A third significant thrust in the para-automation stage was the development of geographical base files (GBFs). The work of Robert B. Dial and Hugh W. Calkins in 1964 and 1965 at the University of Washington had demonstrated the technical and operational feasibility of a street address geoprocessing system operating off an automated GBF consisting of urban street segments and their address ranges, again under sponsorship of the NSF. Although Statistics Canada had developed an automated address coding guide for its 1961 census, it remained for the New Haven-based U.S. Census Use Study to give national attention to geocoding through its development of the dual independent map encoded (DIME) GBF system in 1967. The New Haven Census Use Study not only laid the foundation for a national system of urban region GBF but it established considerable literature on file construction procedures, address-matching software, editing procedures, and applications.

SYMAP automated mapping system

A fourth important thrust of this period was the development of the SYMAP automated mapping system by Howard T. Fisher and others, commencing in 1963 at Northwestern University and continuing afterwards at the Harvard Computer Graphics Laboratory. SYMAP went extensively beyond the distribution analysis and relatively crude mapping capabilities of the University of Washington's ROMTRAN system, and produced a well-documented and universally accepted printer mapping technology. The system produces both contour and conformal (i.e., area shaded) maps of variables representing data for areal units. Later adaptions of the SYMAP system include three-dimensional pictorial output (Simulated View [SIMVU]). The great advantage of the system is that it is available for lease and is operational in computer centers all over the world. Combined with the computing and analytical capabilities of SPSS, it is a powerful tool for the creation of printer graphics for urban and regional analysis.

Software for accessing Census summary tapes

The early 1970s saw the advent of software systems developed by both the nongovernmental DUALab of Arlington, Virginia, and the Census Bureau's DUALab to access the 1970 Census summary tapes. In addition, the R.L. Polk Company developed data delivery capability from its extensive annual city directory files, with small area data aggregation as needed. The past few years have also seen the growth of U.S. Summary Tape Processing centers in state agencies, on university campuses, and in the private sector.

Proto-Automation Stage: Post 1980

The 1980s will mark a departure from planning systems of the 1960s and 1970s

The 1980s will no doubt mark a general point of departure for urban planning information systems from the past for two main reasons: the rapidly growing automation of day-to-day administrative records, and the advent of economical microcomputer systems.

The automated planning analysis methodologies developed for urban planning systems are leading the data base and data management state-of-the-art by at least a decade. For example, good geographical base file construction techniques are available for the development of geocoding systems, but poorly organized and standardized address files still plague local government geoprocessing applications. Excellent computer mapping capabilities are available, but the organizational framework that will allow such systems to operate with automated assessment records and building permit files is lacking.

Local government data bases have not been developed within a consistent framework

Automated record-keeping (e.g., assessment and building records) in the city halls and county court houses across the nation is in a form that fulfills the originating departments' functional requirements, but not in a form available for analytical work outside of that department. Local government data bases also lack uniformity of definition from one department to another and even within departments. Data entities are not clearly defined, value codes are inconsistent for the same variable from one file to another and address components are not standardized or complete. These inconsistencies reflect both the parochial manner in which data bases are developed and the lack of data base management input. In Seattle, for example, the city light department address records are configured for input to a billing and internal information management package. They are, however, inconsistent with the Bureau of the Census' Zip Code Standardization (ZIPSTAN) program for geoprocessing.

The 1980s will be a decade of data base and data management development for multipurpose use. The state that we have been in is similar to having a high-powered locomotive available, but few railroad tracks.

The availability of microcomputer systems and their continuing reduction in cost and increase in capability presents new opportunities in local government computing. Independent processing systems operating on particularized applications will be more common; for example, a census data analysis package could be mounted on a microcomputer with floppy disks and video output to produce on-line color graphic analysis of census data.

Microcomputer system applications in planning departments

Independent microcomputer systems for special departmental uses can be entirely independent of centralized data processing, bypassing potential limitations of the central processing system (e.g., lack of colorgraphics or graphics-oriented terminals). Or the two systems, the central computer and the remote microcomputer, can be connected in order to obtain the best of two worlds.

PITFALLS AND CAUTIONS

Important considerations for information systems in planning

Information automation in urban and regional planning is important and significant; however, care should be taken when considering the role of information and information automation in human interaction and governmental systems.

A number of points are set forth for consideration.

- Information as an Independent Force of Change — Information is an independent force of change operating on both leaders and nonleaders. Its potential impact rivals decisions arising out of formal policy-making processes. In other words, the availability of information to nonleaders allows them to challenge leaders.
- The Institutionalization of Information Systems Increases Social Overhead — Whether or not automated, the institutionalization of information systems creates new roles, new interactions among organizational parts, new user expectations, and new inertia of both personal and organizational tenure. These costs can overwhelm the cost of automation itself.
- Information Systems Lead to Organizational Change — If at all successful, the institutionalization of information systems redefines roles and relationships, and changes the organizational structure to the detriment of some and advantage of others. There are some significant sociopolitical impacts as a consequence. In addition, the span of control of officials and decision makers may change.
- Information Systems Tend to Make Decision-Making More Difficult — Information does not lead to better or easier decision-making. Again, if relatively successful, information systems tend to introduce more variables, more impacts, more checks and balances, and more opportunities for alternative actions.
- Information Systems Expose the Frailties of Goals — Goals tend to be expressed in broad generalities; systems to meet the goals soon disclose the unavailability of information, difficulties of monitoring policy outcomes, or externalities that obscure the measure of goal realization.
- Information Systems Contribute to an Understanding of System Complexities — Information system development aids in understanding system complexities and gaining a more fundamental view of the problem addressed.
- To be Credible, Planning Must Be Cast in an Information System Context — Planning accomplishments and the outcome of planning decisions can only be judged through feedback monitors.

Notes

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COMPUTACION APLICADA A LA PLANEACION URBANA

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CADD SYSTEMS: CAPABILITIES AND SELECTION CRITERIA

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I. INTRODUCTION

This paper focuses on how to evaluate organizational needs in light of computer aided design and drafting (CADD). Secondly, it will look at subject areas needed for the development of a request for proposal (RFP) that will eventually be to perspective vendors. Finally, the paper will take a brief look at existing and future (within the next two years) capabilities of CADD systems.

II. BACKGROUND AND DEFINITION

Turnkey CADD systems are stand alone, complete and integrated hardware and software tools for automating design, drafting, engineering applications and manufacturing tasks. Support, service, hardware and software are all offered by a single vendor. CAD systems consist of several functional components, including:

- o a central processing unit (micro, mini, or maxi) for data manipulation, systems control, etc.;
- o an interactive graphic work station usually accompanied by a keyboard and digitizing tablet for menuing operations and for interacting with the graphic and textural data;
- o random access and/or serial storage devices associated with a CPU and other types of work stations;
- o a manual or automatic digitalizer for encoding graphical (coordinate) data;
- o a variety of hard copy output devices associated with either the graphic work station or with the CPU for producing final drawings;

o systems and applications software to serve a number of application areas.

Prices for CADD systems normally range from $40,000 (for micro-ed systems) to over $1,000,000. Surprisingly, the average price of a mini-based CADD system (which currently dominate the market), are approximately $350,000 and have remained constant over the last five or six years, despite decreasing hardware costs. This decreasing hardware cost, on the other hand, is balanced by increasing people costs for software development and a relatively stable price structure for graphic input and output devices. Within the same time frame, however, mini-based turnkey CADD systems are offering increasing amounts of application software including traditional applications, such as engineering software for primarily aerospace, automotive, electrical (semi-conductor and integrated circuit), petrochemical, and utility industries, to newer design disciplines such as building and construction.

III. SELECTION CRITERIA

If a firm were to engage a CADD consultant, they would find a number of relatively typical tasks performed in an organized sequence. It would be necessary for example to develop a list of desired functional capabilities, procure computer hardware, and install, maintain and operate that hardware over time. Specifically, these tasks would consist of the following:

3.1 o preliminary study design

3.2 o site visit

3.3 o summary report of findings

3.4 o prioritization of functional capabilities and finalization of action plan

3.5 o development of preliminary request for proposal (RFP)

3.6 o evaluation of RFPs and selection of vendor

3.7 o graphic evaluation of system including benchmarking

3.8 o system start-up

3.9 o training

3.10 o system management, including job tracking and operating procedures

This paper will only discuss the initial five functional tasks through the development of the RFP.

3.1 Preliminary Study Design:

This task as a number of objectives. Primary among them are the selection of a CADD evaluation group, consisting of management and technical staff, that will have responsibility for system selection. Other objectives include the determination and evaluation of management objectives and the development of a list of desired system features. The type of systems analysis performed by a consultant or done in-house would include the determination of a number of micro and macro issues: Examples of macro issues might include:

o total scope of the problem

o functional areas of company

o current decision-making procedures regarding technology

o expectations regarding automation

- goals and objectives regarding CADD (i.e., increase production or save money)
- kind of payback desired
- organization of company
- growth objectives
- in-house expertise (skill groups)

Examples of micro issues related to CADD might include the following:

- differentiation of draftspersons or other skill group tasks
- coordination of work tasks
- output formats
- nature of work
- work flows
- dispensation of data base
- numbers, kinds, magnitude, importance and frequency of revisions and updates
- frequency, types, priorities of work tasks
- potential interface areas
- potential adaptation of existing facilities

3.2 Site Visit

The purpose of the site visit is to both educate the potential procurrer regarding similar case studies and relevant applications of CADD systems; and secondarly, to gather all of the information needs defined above. Once the information is gathered, it is possible to explore trade-offs of mini, micro or maxi-based systems, look at alternative hardware configurations, technologies for CRT displays, soft and hard copy work stations and CADD organizations, and questions.

The outcome of the site visit will be, in part, the determination of a features list which will be incorporated into the summary report of findings. The site visit should normally take from three to ten days depending on the CADD sophistication of the user; and secondarily, the number of orientation or educational meetings necessary.

If at all possible, the summary report should be written in outline or draft form while the consultant is still at the offices to expedite communication and to obtain additional needed input about the user's company. It is also worthwhile to make a presentation for key management personnel and the CADD evaluation group related to a summary of findings related to the site visit.

Another important objective of the site visit is to evaluate senior management objectives in terms of CAD. These types of discussions focus on corporate structure and integration of CADD systems in the firm and, if relevant, its associated offices. It is important to get management ideas regarding applications, projected work flow, key financial issues, capital equipment planning, personnel selection and training, installation procedures, and management objectives related to CADD implementation.

3.3 Summary Report

The summary report is a written document consisting of results and implications of the site visit. It represents an initial benchmark whereby the consultant or the evaluation group specifies the implications of objectives in terms of management and technical needs and makes a preliminary analysis as how to meet these needs. It represents a common basis of understanding as to how to proceed with the development of functional capabilities for the CADD system and how these will be reflected in the development of the preliminary request for proposal.

This report should also contain alternative hardware and work station configurations as well as an applications feature list.

3.4 Prioritization of Functional Capabilities and Determination of Action Plan

Once the summary report is accepted, it is possible to develop an action plan for development of an RFP. Responses from senior management, and from the heads of the various functional departments and from the evaluation team will determine priorities based on need and desired potential productivity increases for the various CADD application areas. The consultant and evaluation team has by this time converted the application task list into a prioritized features list to be incorporated into the turnkey CADD system.

Most significantly, the features list will serve as criteria against which candidate systems can be tested and benchmarked. In addition, it will help determine a short list of vendors to which the RFP is sent. It is even possible to do some preliminary analysis in preparing vendor lists by preparing vendor capabilities and the features list. You will often find, for example, that vendors offer capabilities well in excess of your own features list. Some of these might not be needed, but others might, in turn, be added to your own list. Finally, the prioritization of the features list means that you are sure to not exclude any features that are deemed as critical to your desired CADD

applications.

At this point, it is also desirable to perform a preliminary cost/benefit analysis using management cost structures and both internal and industry standard costing routines, projected productivity increase ratios and projected utilization schemes for the various applications.

3.5 The Request for Proposal (RFP)

A request for proposal can be from five to five hundred pages, depending upon the depth in which the total information needs for the user have been defined. At the very least, however, and in light of the features list, vendors should have enough data to address the following issues:

- o general systems capabilities and how they respond to user's needs
- o detailed hardware recommendations and operating systems software
- o application software recommendations
- o support and maintenance
- o education, training and documentation
- o benchmarking
- o acceptance/inspection testing
- o installation/environmental requirements
- o shipment and delivery
- o warranty
- o terms and conditions
- o names of relevant users
- o policy regarding future enhancements
- o contractual arrangements.

In order for the vendor to appropriately respond, the RFP must be as clear, concise and as specific as possible. Secondly, the RFP should not make unnecessary demands on vendors or they will simply not respond.

If detailed information needs are not specified within the RFP, it is possible to request the vendor to specify how he performs certain functional tasks. For example, you can either ask the vendor to describe how he provides the capability of defining the location of the point; or by specifying, for example, that a point must be defined by methods such digitizing, explicit coordinates, end of an entity, origin of an entity, intersection of two entities, delta displacement, on a grid point, on a surface, projected along a vector and dropped onto a surface, normal to a surface, etc. That is, the RFP can contain as much or as little detail as necessary. Finally, the RFP should contain examples of typical drawings.

Examples of major sections of a typical CADD RFP would include the following:

1. <u>Introduction</u>. This section of the RFP contains general background information, objectives of the CADD system, structure of the user organization, motivation for CADD, projected growth of the CADD system, user experience, selection procedures and criteria, minimum requirements and projected workload.
2. <u>User Groups</u>. This section of the RFP should define which departments will be using the CADD system and describe the work tasks. Information on location (to determine communications needs), work loads, organizational structure, etc. should be presented.

3. <u>Hardware</u>. This section of the RFP covers performance specifications for the various hardware devices. Hardware to be specified includes the processor, disc and/or magnetic tape drives, graphic CRT work stations, alpha-numerical display, pen and tablet or other types of digitizers, hard copy devices, line printers, etc. Operating system software should also be specified in terms of desired system security, file management, text editors, and response time under various work loads.
4. <u>Applications Software</u>. Applications software contains specifications for application areas of interest. For example, mechanical design and drafting would contain data relevant to geometric primitives and non-primitives, dimensioning, properties, associativity, data input mode, display aids, multiple views, grids, labelling, symbols, text, surface data, measurement, finite element modeling, bill of materials and graphics construction language.

For generation of printed circuit/electrical schematics, the RFP might contain data on data base representation, analytic features, and post processing capabilities. For numerical control data on tool path creation capabilities, associativity, and other desired features would be listed.

For mapping data related to input, line fonts, analytic capabilities, editing, output capabilities, data base specifications, etc. would be specified. For piping, information on the operation, data base structure, dimensioning would be included.

For wiring diagram application, data on diagram creation and editing, parts library, diagram construction and editing, report generation and verification should be specified and so forth.

In summary, the RFP can either contain detailed information needs of the company which determine precisely how the features are to be performed or simply leave the onus of how the features are to be performed on the vendor. The former approach requires an extremely sophisticated user group and a great deal of time and money to generate the appropriate RFP. The former approach also mandates the use of bench marks to be used for systems comparison.

On the other hand, most RFPs can be written without detailed information needs and letting vendors respond by stating how features are accomplished within their particular system.

Finally, depending upon the size, number of workstations, response time, etc., vendor supplied capabilities such as education, training and documentation can become as important as the actual hardware and software itself. Visits to relevant vendor sites and talks with other users are obviously critical as well.

IV. FUTURE TRENDS

There are a number of interesting trends taking place in the CADD area. Perhaps foremost among them is the entry of micro-based systems into the turnkey marketplace. At present, there are over 30 suppliers of micro-based systems costing under $100,000 that support most of the functions contained in mini- and maxi-based systems. Within the next

six months, announcements will made from micro-based suppliers offering three-dimensional geometric modelling capabilities and color raster scan work stations. Most of the micro systems currently support one or two users and have very limited applications software. This will obviously change in the near future.

Another emerging development in CADD is the current effort to network mini-computers to be more competitive with large main frame systems. Small stand alone systems are starting to be linked together to create stand alone networks that can be connected, via telecommunications, to large main frame computers in order to access data bases and other application software.

A third trend in CADD is for the more traditional hardware companies to develop joint marketing and support relationships with CADD software systems. IBM's relationship with Lockheed and the emergence CADAM system is such an example, as is PRIME's support of the MEDUSA CADD software.

A few hardware developments taking place include touch and speech input, the rasterization of both input and output devices, and the increasing use of color for all aspects for CADD systems. In terms of software, you will see increased specificity related to applications and turnkey systems being developed for very specialized applications. You will also see the integration of CADD with other types of software such as wordprocessing, management graphics, project control and the like.

V. SUMMARY

By offering applications software, software support, customer training, systems installation, etc., turnkey systems will offer a viable approach to CADD for many years to come. It is very important to spend a great deal of effort planning for the technical and management changes that result from the implementation of CADD systems. Of the thirteen or so years that turnkey systems have been present, there have indeed been documented benefits such as productivity enhancement, time savings in drafting, improved product lead times, improved drawing quality, and significant time savings for engineering analysis.

All of these give the user a potential competitive advantage over firms employing traditional manual drafting methods and should make CADD a serious area of investigation for most firms that are involved in engineering and drafting operations.

Market analysists are extraordinarily optomistic about the growth of CADD. In a recent industry CADD review prepared by L.F. Rothschild, Unterberg, Tobin (New York, New York) it was estimated that there were sales in 1979 of $325,000,000 for turnkey CAD/CAM systems. They further projected close to a 1.9 billion dollar turnkey market for 1984, yielding a compound growth rate of 42%. It is hoped that this paper will provide for a successful planning and utilization of CADD systems for some of these firms.

#11 - TUESDAY

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COMPUTER GRAPHICS HARDWARE: LEARNING TO MATCH YOUR NEEDS WITH CURRENT HARDWARE CAPABILITIES

GRAPHIC DISPLAYS

Presented at Harvard Computer Graphics Week '81
July 26-31, 1981

1. INTRODUCTION

A number of factors can be used to match the technology profile of a display system to the requirements profile of an application. Today, a potential user can draw upon a wide-range of technology, including:

- Storage tubes which draw images as a series of lines or vectors, include some capability for refresh, and most recently include a capability for a second color.
- Refresh (stroke writing) displays which, in some versions, are price competitive and, in some cases, less expensive than the storage tube, while new high performance units draw almost four times as many short vectors as were possible just a few years ago, and
- the explosion of Raster (refresh) technology which offers a wide range of products...from those that are less expensive than the other technology, to those which are high resolution, high image quality with a rainbow of colors at prices comparable to the most sophisticated stroke/refresh displays.

In addition to this cathode ray tube technology, the prospective users today can also select from existing as well as promising new flat panel (matrix) technology.

This paper will discuss the various commercially available products, in terms of the selection factors which the user will probably want to consider, based on his or her application requirement.

The prospective user will want to consider some, or all, of the following factors:

1. Data content
2. Resolution/picture quality
3. Color vs. Black & White
4. Dynamic capability
5. Software availability/capability with existing softw[are]
6. Intelligent vs. Dumb
7. Facility for hard copy and possible compatibility with large screen projection displays
8. Human factors consideration, including brightness, contrast, glare, real estate required, noise
9. Other considerations
10. Price

2. DATA CONTENT

The application will determine how much information needs to be put on the display surface, flicker free. Some business applications may require fewer than 10,000 line segments, while some computer-aided-design, seismic and other data analysis applications may require in excess of 100,000 line segments.

The storage tube display is the only display technology in which the display will not flicker regardless of the data density.

In the conventional bit map raster display, the frame rate is independent of data content. Whether one raster element or all raster elements are turned, will not effect the refresh rate. A typical 512 x 512 system for example, can have potentially about 250,000 elements turned on and off in any combination, while a typical 1000 x 1000 line display could have any combination of a million elements turned off and on.

However, that does not mean that a raster system might not flicker. Present technology limits high resolution (1000 x 1000) color refresh displays to thirty frames per second refresh rate. If short persistent phosphors are used in such a system, (in fact, with any thirty frame per second or less interlaced system) many observers will see flicker regardless of picture content. So the use of raster display does not automatically prevent flicker...it only means that the flicker is independent of data content.

Flat panel displays, such as the plasma display and the liquid crystal display are essentially storage devices. Therefore, the picture remains constant regardless of data content.

Stroke writing refresh displays have traditionally been plagued with flicker as the amount of data displayed increases. Over the past few years, extremely high performance systems have been announced. Vector Automation has a product which sells for about $26,000 that reportedly displays 66,000, 0.1 inch vectors at thirty frames a second. Recently, Evans & Sutherland announced a new system (PS300), selling for about $70,000, which reportedly puts up more than 95,000, 0.1 inch vectors at thirty frames a second.

However, more commonly, the stroke writing systems that sell in the $35-100,000 range, display on the order of 15,000-32,000 vectors at thirty frames a second. These mid-range and high-range products include units sold by Adage, Vector General, Evans & Sutherland, IBM, Sanders, Megatek, Interactive Machines, Inc. and Lundy.

2. Data Content (con't...)

Lower cost stroke writers, such as products made by IMLAC and Hewlett Packard, in the $10,000 range, typically can draw about 4,000-8,000 vectors at thirty frames per second.

Typical storage tubes feature not only storage capability, but a write-through, refresh mode. The earlier versions of these Tektronix displays were limited to displaying about 1,000 inches of lines at thirty frames a second. However, the recent GM 107 series, and the new 4114 unit, feature refresh capability in the 3,000-7,000 inches of line per frame.

In stroke refresh systems, users are often also concerned with the number of characters which can be written, flicker free. Assuming that the hardware, or firmware character generators are used, characters that can be written at thirty frames a second, range from about 1,200 in the lower cost units to about 6,000 in the mid-range to high-priced units.

3. RESOLUTION/PICTURE QUALITY

Technically, resolution when related to display, describes the diameter of the writing element. However, for the purposes of this discussion, resolution will be used as a "catch-all" term, to describe apparent image quality. It will include the analog characteristics of the display as represented by beam diameter and the digital characteristics of the display as represented by addressibility. Resolution, as used here, is a qualitative term to describe the available smoothness of lines and arcs.

The storage tube and stroke/refresh displays are capable of drawing smooth straight lines between any two addressible points on the display. Currently available storage tubes provide either between 800 x 1000 addressible points or 3000 x 4000 addressible points. Currently available stroke writers provide eith 1024 x 1024, 2048 x 2048, or 4096 x 4096 addressible points.

Smooth arcs are a function of whether or not the device incoudes an analog arc or circle generator, or whether the arcs are drawn by short line segments. Some commercial stroke/refresh displays do use analog arc and circle generators. However, the typical storage tube display and other stroke/refresh displays, use software or firmware to form arcs and circles as a series of short lines. Under these circumstances, full screen diameter circles require somewhere on the order of 128 to 256 line segments before they appear "satisfactorily" smooth. Small diameter circles can be satisfactorily drawn with about 16 line segments.

The use of small lines is critical on raster systems and flat panel matrix displays. The issue is the "jaggies" or aliasing. That is, lines at small angles off the vertical or horizontal show discontinuity, or steps. Certainly if the picture consists only of horizontal, vertical, and 45 degree lines, the problem does not arise. However, for other angles, discontinuities will be severe, depending on the number of scanning lines in the image. About 2000 scanning lines would be needed before the "jaggies" disappear (when viewed at the distant consistent with the size of the image). NO commercial direct view raster system or matrix display system offers that resolution at the time this article is being written. And, in fact, none is expected before the end of 1982. Further, a 2000 line interlaced image may have the same apparent picture quality as a 1000 line non-interlaced image.

There are a number of film recording systems (such as those manufactured by Celco, Dicomed, and III) which can produce between 2000-8000 line images. These are used very commonly in presentation quality slide-making systems. Slides produced by these systems do not show "jaggies".

There are other techniques for reducing the picture discontinuities...some involve a slight beam motion, others involve beam defocussing...other involve bandwidth limiting. Finally, there are some analytic techniques called anti-aliasing, which can significantly improve the apparent quality of a low-resolution image.

4. COLOR VS. BLACK & WHITE

Up to about a decade ago, the only way to produce color with a cathode ray tube was to use a conventional color mask CRT. For a variety of technical reasons, that implied a raster display. Ten years ago, most raster systems were much too expensive because of the bit map requirements. It was possible to build raster systems based on alphanumeric techniques and, in fact, the early color systems (used extensively in process control) were adaptations of alphanumeric systems with special graphics symbols added.

However, over the past decade, a variety of technology improvements have been made and now <u>all</u> cathode ray tube technology, can produce some range of color. The color mask tubes still offer the broadest spectrum of colors. A few years ago, color mask could only be used with raster because of conversion problems. However, since color systems were available over a price range of less than $2,000 to $100,000

or more, products of varying resolution and dynamic capability were available for a number of applications.

Because of the resolution issue, it was still an effort to provide color for stroke writers. The first practical solution to that problem was the use of the penetration tube...a dual layer phosphor in which the color was a function of the anode potential. This tube provides a useful range of colors from red to orange to yellow to green. Shades of these colors are available, but generally are not used because of the difficulty in controlling them. While in theory, a third layer of blue phosphor could be added to complete the color spectrum, no commercial systems using tri-level phosphors have been produced.

Penetration tubes product an extremely high quality image since the phosphors are similar to those used on a conventional stroke writing CRT. However, because the color change is a function of anode potential, the changing of anode potential affects a number of other parameters on the tube (such as focus, brightness, and deflection sensitivity) resulting in a fairly complex monitor. The incremental cost for commercially available large screen penetration tubes provided by several suppliers including, Kratos, Raytheon and Sanders is in the order of $10,000-$15,000. Hewlett Packard makes a small rack mounted penetration tube display (with a five inch diagonal CRT) for about $5,000.

About two years ago, Evans and Sutherland produced the first high-speed stroke monitor using the color mask CRT. This system, which can operate at speeds compatible with their normal stroke writers, allow the full range of color. However, the incremental cost of this monitor was $40,000. Twenty years ago, similar monitors were available from IT&T, but writing rates were much to slow (because of the dynamic convergence problem) to be of significant use.

Recently, Electronic Systems Laboratory in Dayton, Ohio, has announced a stroke writer monitor using a color mask and the incremental cost seems to be about $20,000. Also, a Westlake Village, California manufacturer, Interactive Machines, Inc., has announced a $10,000 stroke writing color mask monitor for its product line.

Finally, there is some indication that low-cost color stroke writer monitors would become available from a Canadian company which currently builds the units for arcade game applications. That monitor may be in the $5,000 range.

The storage tube was blocked from applications requiring color since there was no apparent way in which a color image could

4. Color vs. Black & White (con't...)

be obtained with the storage tube. However, in Spring of 1981, when Tektronix announced the new storage tube system 4114, Tek also announced a $2,000 option of a second color in the write-through mode. With that option in place, the refresh rate is in orange, providing a strong contrast to the normal green. In fact, as the beam writes, the image appears orange and reverts to green if the image is stored. Although, technical information about this technology is scarce, the author understands that the color technique is similar to the penetration system described earlier.

While experimental flat panel displays have been produced in color, none are commercially available at this point. Nor have there been any product announcements which would indicate that a color flat panel display will be available within the next few years.

5. DYNAMIC CAPABILITY

The user may need to decide what level of dynamic capability is required for that user's application. In the least severe instance, the dynamic capability simply means the speed with which one image could be replaced by another. Intermediate requirements may be needed for selectively updating portions of the image. In a more severe requirement, some or all portions of the image must translate or rotate in either two or three dimensions.

The traditional scale of dynamic capability would have storage tubes as being least dynamic, the raster having intermediate dynamic capability, and the stroke/refresh being the most dynamic. However, in view of recent developments this scale needs to be reexamined, and in fact, there may be overlap among the various technologies.

In a storage tube, the image appearing on the screen can only be modified by either completely erasing the image, and rewriting it, or by adding new data. An element already drawn on the screen could not be selectively erased. If the image needed to be erased, it usually took about a fifth of a second for that erasure to be accomplished (accompanied by a bright green flash, about one to two seconds before the screen re-settled, and then the new data could be written on the screen at about 5,000 inches per second. Under these circumstances it is unlikely one would attempt to change a storage image more than about once every ten or fifteen seconds...and considerably longer if the image were quite complex.

In the last years, however, a number of operating parameters have been changed in the tube which allows somewhat faster operation. For example, the storage tubes are now available so at least a portion of the picture can be written as a refresh image and therefore selectively erased and moved as

with a conventional stroke refresh display. As the display became larger, Tektronix was faced with issue of blinding "bright green flashes". In the last couple of years, the erase technique has been modified by using two shorter but higher-intensity pulses rather than one longer but lower intensity pulse for erase. The result has been that to the user, the "green flash" is of apparent lower intensity. Further, by introducing some new channels, the rewrite time on the tubes have been considerably reduced. In the 4114 for example, Tektronix suggests that 30,000 line segments can be drawn on the screen in a matter of a second or so. Incidentally, this high-speed rewrite mode was utilized by IBM in the graphic attachment 3277. The associated 618 storage tube could be rewritten with impressive speed.

None of the commercially available storage tube terminals offer any hardware features for translation and rotation (with the exception of the cursor).

Conventional bit map raster displays offer improved dynamic capability because the bit maps can be purged and rewritten in about a tenth of a second, which means that the image can be changed dynamically at about ten frames a second. Furthe the individual elements can be selectively erased, based on a pixel erase and update time of between a half a microsecon to one microsecond per pixel on most of the commercially available units.

There are however, some ways of getting faster apparent upda motion with bit map type systems. It is possible to have a bit map whose area of addressibility is much larger than the screen area. For example, on the Tektronix 4112, the bit ma has an addressibility of 4096 x 4096, even though the image area is approximately 480 x 640. This allows the internal microprocessor to either roam among the larger area (which means that real-time pan and scrolling is achieved) or to do real-time scaling. There are some alternate raster architectures which also permit highly dynamic displays. One technique called, "On the Fly" digital TV generates a raster of real-time without needing a bit map...very much the way a stroke/refresh system generates an image. However, the lo requirements are extremely severe for such a system, and to date, only a few such systems have been implemented... primarily for military applications. An alternate method for eliminating the bit map is to use a technique called "run length encoding" so that if the picture has few transitions, the data compression can be an order of magnitude o better.

Of course, the alphanumeric and character graphics systems a essentially on a fly digital, but the problem is much simpli fied in those systems because of the character block orient

Most commercially available digital TV systems do not provide for 2D or 3D image manipulation. An exception to this are the several systems which have been developed by traditional stroke writing manufacturers. The Megatek 7250, which shares a common front end with the stroke writer 7200, and the Sanders Graphic 8, which shares a common front end with the Sanders Graphic 7, do provide for faster picture manipulation since the picture manipulation circuitry precedes the scan conversion and development of the bit map. These systems sell in the order of $35,000 a channel.

There are extremely expensive simulator systems which provide for real-time picture manipulation as well as hidden line removal and shaded images, but these systems sell in the several million dollar range. Such products are manufactured by Evans and Sutherland, General Electric, Singer Link and MAC Auto. Potentially lower-cost products are being developed by the Advanced Technology Corp., Division of Austin Company.

Normally, when extremely high dynamic images are required, a stroke/refresh system is indicated. Pictures are generated "on the fly" at rates of 30 to 60 times a second and can readily animate wire frame images. A number of the units include provision for hardware 3D rotation. These products, manufactured by companies such as Evans and Sutherland, Adage, Vector General, Megatek, Sanders, Lundy and Image Magnification, Inc., can smoothly rotate images containing several thousand line segments. Other systems can also rotate images by using software, but the number of lines are limited to about 200 before the images appear to sprocket as they rotate. It is interesting to note that the difference in smooth rotation is so pronounced between commercially available raster and stroke writers, that one of the most successful arcade games uses a stroke writing display in order to achieve smooth rotation. This product is expected to have a stroke writing refresh color monitor available in the near future.

AC plasma displays are also capable of selected areas, and the image can be updated as frequently as sixty times a second. Some of the liquid crystal display systems can also be updated at thirty to sixty times a second in order to provide real-time displays.

6. SOFTWARE

Very often the user wishes to choose a terminal based on that terminals ability to be driven from existing software. One approach is to standardize on the so-called ACM core package now offered commercially by several companies (including Precision Visuals and Bell Northern) and then write simple device drivers to convert from that package to the specific displays. On the other hand, at least one manufacturer,

Vector Automation, now offers a stroke writer which accepts standard Core input.

Many organizations use a variety of Tektronix software packages called PLOT 10 and many manufacturers who wish their products to be accepted in that environment now offer Plot 10 compatibility. This includes stroke writers made by IMLAC, raster systems made by Genesco, and plasma displays made by Magnavox (although Magnavox has just announced they are withdrawing their system, the Orion, from the market.

At least one personal computer, the Apple, offers an option made by Tekain which makes the Apple program compatible with the Plot 10.

One other defacto standard has been the IBM 2250. Several manufacturers, including Adage and Vector General, offer stroke writing refresh systems which are 2250/3250 compatible. Such compatibility may not always be desireable. Two years ago, Evans and Sutherland convinced McDonnell that it was more important to take advantage of the superior features of their system, than it was to maintain program compatibility. McDonnell agreed, and over the past two years has been replacing IBM 2250's with Evans and Sutherland Picture II systems even though extensive software modification was required.

7. INTELLIGENT VS. DUMB

As the cost of micro-processors goes down, the presence of these new units in a terminal become much more common. If the selection criteria includes the need to support remote operation, certainly a micro-processor based system or a system with a number of special function generators, might be indicated. These systems would allow much more compact messages to be send across the communication line and the images would then be reconstructed by means of a local micro-processor, or the more sophisticated function generators. Almost all commercial terminals available today provide some level of intelligence or sophistication.

8. EASE OF PRODUCING HARD COPY/LARGE SCREEN DISPLAY

One selection criteria often is the ease with which a copy of the information appearing on the screen can be produced. Assuming that some kind of a vector description appears somewhere in the computer display system, a software conversion can be made to that vector description in order to drive a conventional plotter, microfilm recorder or other hard copy device.

However, very often a user wishes to obtain a copy of the information appearing on the screen without going through the host computer to reformat the data. Initially, about the only technology which allowed that to be done economically was the storage tube technology making use of the ability of the storage tube to also act as a scan converter and to drive the $5,000 dry silver hard copy unit sold by Tektronix.

As raster systems became common, several offered interfaces which allowed the output of the bit map to drive the dry silver hard copier. As the cost per copy of dry silver began to increase, and as users were looking for hard copy with more archival quality, interest evolved in using various electrostatic printer plotters as hard copy devices. These became available as outputs from the storage tube and as outputs from a number of the raster displays.

Interfaces also became available between various raster display systems and a variety of black & white and color impact printers such as Trilog, Ramtek and IBM. Generally, Chromatics, Ramtek and Tektronix have either provided interfaces for such units or the manufacturer of the hard copy devices provided interfaces.

The raster systems were also able to conveniently output to the Xerox color graphic recorder, and the various fast film units such as those made by Dunn, Matrix and Image Resources.

However, relatively low-cost quick hard copy for stroke writing refresh displays, have only become available recently. Sanders was probably the first manufacturer to make such a unit available, adapting the Tektronix dry silver unit to accept an output from the Graphic 7. Recently, several manufacturers such as Megatek, and Adage, have provided scan converters so that the picture or vector description contained in the display file can be used to drive an electrostatic plotter.

If color hard copy is a requirement however, some kind of raster technology is indicated at this point.

Sometimes another selection factor is the ability of the image on the terminal to be reproduced by a large screen (projection) display system. In some cases the easiest technique might simply be to point a TV camera at the terminal and then connect the output of the camera to a conventional TV projector. This would certainly be the approach if one wanted to project the image on a storage tube.

It is possible to obtain a large screen RT projector which is compatible with a stroke writing refresh system. However, these are generally quite expensive...typically in the $50-$100,000 range (products manufactured by Aydin and General Dynamics for example). But, the use of the TV camera may be

an adequate solution.

Generally, however, if one is looking for a large screen slave, the selection of a raster technology would probably be indicated. Color large screen projectors are available for as little as $2-3,000, although extremely high quality images require projectors such as the GE light valve and Eidophor products which are in the $100,000 range.

9. HUMAN FACTORS

There are a variety of human factors issues that might impact terminal selection. There are the physical issues of range and placement of operator input devices, the physical locations of screens, the adjustability for tilt and height of the screens, the ability to control for brightness, contrast, and so forth.

The physical adjustment of the terminals is not generally available in most of the graphics systems today. Some alphanumeric terminals, such as the Datasaab Alphaskop are designed to provide a wide range of display positions.

Most technologies require the user to specify a contrast enhancing filter, with some loss in brightness. The raster and stroke writer displays have had about ten times the absolute brightness available from storage tubes. However, the new line of Tektronix storage tubes, including the 4114, have increased the storage tube brightness by a factor of two or three.

One current trend needs to be noted. In a effort to get better quality higher resolution color images, several manufacturers have reduced the brightness of their raster systems. In subdued light, the colors are intense, but in normal room illuminations the images appear to be washed out.

The choice of operator input devices is not really dependent on the display technology with the exception that light pens can not be used with a storage tube.

At one time, only raster and stroke writing refresh displays offered a full range of screen sizes from about 12" diagonal up to 25" diagonal. However, over the past three years, a range of screen sizes is also available from the storage tube displays and this issue would probably no longer be a selection criteria.

10. OTHER CONSIDERATIONS

Sometimes the user already has determined the computer and would like to add a terminal device with minimum effort. Sometimes this will dictate the choice of those terminals manufactured by the computer supplier. Fore example, the intergration of the IBM 3279 in the IBM environment is a convenient, relatively low risk, operation as is the use of the IBM 3277 graphic attachment with IBM computers.

Hewlett Packard provides support for a broad range of its graphic terminals, such as the Hewlett Packard 2647 and 2648. DEC offers their own raster systems such as the VT105, VS11, and VSV11 that are DEC compatible.

Other computer manufacturers, such as Honeywell, Control Data Corp., and Prime, have made a decision to support one or more display systems. And where the display requirements are not severe, a decision to use that manufacturer's recommended terminal may be the lowest risk decision.

Of course, many computer manufacturers will drive RS232 or equal interfaces and many terminals provide that kind of a hardware interface. In that sense, the hardware interface problem is not severe. However, there still is the data handling communication issue which is unique to the individual host system.

Finally, as indicated previously, there are a number of products that are software compatible with widely used terminals such as the IBM 2250/3250, Tek 4014 and DEC VT100/VT105. Several units compatible with the IBM 3279 have recently been announced.

The user may also wish to consider environmental implications. High performance stroke/refresh displays may consume an order of magnitude more power than is consumed by a storage tube or raster display.

Some displays produce high noise levels (often from internal fans).

For desk top operation, the user may want to consider the surface "real estate" consumed by the terminal.

And, like any other selection, reliability, serviceability, portability and other factors may be considered.

11. PRICE

Although, in this paper, the author has put price as the last item, many times selection within a price category is the first decision made by the potential buyer. At one time, low price automatically meant storage tube and higher prices meant stroke/refresh.

11. Price (con't...)

Today, products of varying performance overlap all price ranges. For example, storage tube displays range from about $3,000 for the Tektronix 4006 to about $24,000 for the Tektronix 4114. Raster systems range from under $2,000 for a character-oriented display like the Intelligent Systems Corporation series 8000, to $60,000 or more for the high performance systems such as the Ramtek 9400. Complete stroke writing refresh systems range in price from about $9,000 for products such as the Imlac Dynagraphic II system, to about $100,000 for the high performance stroke writing refresh systems such as the Evans and Sutherland PC300.

And, of course, there are other considerations as well... delivery, service, reliability, power requirements, other environmental issues, noise generated by the terminal, real estate occupied by the terminal, responsiveness of the manufacturer, weight, just to mention some. Generally, the decision should be made by some kind of a matrix scoring technique. The user assigns a relative value to the various parameters and application factors, and then judges on a numeric scale how all each of the vendors meets that criteria. An example of such a scoring technique is given in the article "Interactive CRT Terminal Selection" by Carl Machover, SID Journal, November/December 1972. Similar scoring techniques are described in the book "The Rational Manager", by Charles H. Kepner and Benjamin B. Tregor, published by McGraw Hill Book Company, 1965.

For convenience, a list of most display manufacturers, together with the technologies that they offer, is attached to this paper (MAC data sheets 509-680 and 566-681).

	RAN/REF *	STORAGE	TV DIGITAL	TV CONV. **	PLASMA	PROJ.
Adage 1 Fortune Drive Billerica, Mass. 01821 (617) 667-7070	X					
Advanced Technology Sys. 17-01 Pollitt Drive Fair Lawn, N.J. 07410 (201) 794-0200			X			
Advanced Electronics Design, Inc. 440 Potrero Avenue Sunnyvale, Ca. 94086 (408) 773-3555			X			
Advent 195 Albany Street Cambridge, Mass. 02139 (617) 661-9500						X
Am Comp 686 W. Maude Avenue Sunnyvale, Ca. 94086 (408) 732-7330			X			
Applications Group, Inc. 26561 Eckel Road Perrysburg, Ohio 43551 (419) 874-3057					X	
Applied Dynamics Intl. 3800 Stone School Rd. Ann Arbor, Mich. 48104 (313) 973-1300			X			

* RAN/REF - Random/Refresh (stroke writing)
** TV/CONV. - TV Scan Converter

REPRESENTATIVE SUPPLIERS - INTERACTIVE GRAPHIC DISPLAYS

	RAN/REF *	STORAGE	TV DIGITAL	TV CONV. **	PLASMA	PROJ.
Aydin Controls 414 Commerce Drive Ft. Washington, Pa. 19034 (215) 542-7800	X		X			X
Calif. Computer Products 2411 W. LaPalma Ave. Anaheim, Ca. 92801 (714) 821-2271			X			
Carroll Manufacturing 4 Hensen Champagne, Il. 61820 (217) 352-5438					X	
Chromatics, Inc. 3923 Oakcliff Industrial Court Atlanta, Ga. 30340 (404) 447-8797			X			
Comtal Corp. 169 North Halstead Pasadena, Ca. 91107 (213) 793-2134			X			
Conrac Corp. Instrument & Controls 3600 S. Mountain Ave. Duarte, Ca. 91010 (213) 359-9141			X			
Control Data Corp. 2401 N. Fairview Ave. Roseville, Mn. 55113 (612) 633-0371	X		X			

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STATE OF THE ART GRAPHICS PRESENTATION - GIMMS RELEASE 4

INTRODUCTION

This paper seeks to overview the GIMMS geographic information system and in particular to review the new capabilities of Release 4 of the system, due Fall 1981.

OVERVIEW

GIMMS is a user orientated, general purpose, geographic processing system for use in a wide variety of applications. It is primarily of use in analysis of geographic data by providing maps, graphs and tabular information of a thematic kind. Figures 1 and 2 show examples of this output.

The system is general purpose in that it is not designed for a specific purpose and can deal with different types of geographic entities and related data. Point, line, and area geographic zones can be processed, and numeric and alphanumeric data relating to them. The most developed functions are thematic mapping and graph production, but the structure of the data used in

the system is of a form that can be utilized by other programs or systems. The addition of extra programs to the system is easily achieved.

The system is user orientated and is controlled by a language using keyword commands with subsidiary parameters and other information. All input is in a relatively free format, thereby not restricting the user in where his commands or data are placed on a line (or card). The user need have no knowledge of computers to operate the system although a general knowledge of computers is a distinct asset. All the permanent files created by the system present a common interface to the operating system, thus reducing the job control knowledge required to be known by the user.

The design of the system allows it to be run in either a batch mode or an interactive mode. There are some parts of the system, however, that are not usefully done by interactive working (e.g. *FILEIN for bulk input) and there are some that are relatively meaningless in batch mode (e.g. *COMPILE for interactive design). Some parts that would be both useful and suitable to run in interactive mode require too many resources (e.g. CPU time) to be effectively used in that mode.

GIMMS is an integrated system since it covers all the aspects of a geographic processing system (input, storage, manipulation, and display) and achieves these with a linked structure and not a set of individual programs. The normal user has no knowledge of how his data is held, nor does he need to know, as the system provides a large proportion of the basic manipulation and display facilities that are often used. For users with more complex data, or who require more complex manipulations than the system provides, there are standard programming or file interfaces to allow users to access data from and to enter data into, the system. It can be used as a pre- or post-processor to other systems. For example, the plotting program could be used to plot data collected by, or for, another system.

At the input stage for geographic data, points are input as points, lines are input as lines in a network and areas are input as boundary segments (which separate two areas). Various checks are done on area data by a group of checking programs (based on topological checks of the node-segment-area planar graph) to ensure geographic completeness, correctness, and consistency. After the checks indicate that the segment descriptions of the areas are correct, then area descriptions of the areas are created to provide input to the application systems.

Complete area descriptions may also be input (i.e. the complete boundary for an area is described). In that case, however, it is the user's responsibility to ensure that common boundaries between areas match correctly.

One of the major developed application of the system is thematic mapping and point, line and area maps can be produced (Figure 1 is a fairly simple example). Data to be mapped can be represented by a wide variety of symbolism using point and area symbolism particularly. There is great flexibility in compilation of maps, allowing overlay of different distributions, multi-map sheets, and a range of multi-component facilities. In addition, there are a wide range of auxiliary facilities such as text placement, and special compilation features such as drawing symbols to represent the direction of north. To assist in the compilation of maps, there is an interactive compilation system using graphic displays.

In Release 4 of the system there are several major new facilities, in particular the decision graphics subsystem and the geographical searching, subsetting and aggregation facilities. These will be described later below.

GIMMS can thus be a very effective tool for the analysis and display of geographic information for research, teaching, or production purposes, and in particular can produce high quality thematic maps by automatic means.

FACILITIES

Map Capabilities

GIMMS has a wide variety of display facilities. It can produce point, line and area maps including multi-component maps and multi-map sheets. The generic type of map symbolism that can be produced are choropleth maps, dot maps and label maps (isopleth is also planned) but within this a great variety of symbolism may be produced.

In addition to the value symbolism produced, GIMMS also has extensive facilities to produce map cosmetics such as text, north arrows, any linear descriptions, legends of various kinds, grids, boxes, flow arrows and much more.

Decision Graphics Subsystem

To provide additional graphics capabilities to users the Release 4 version of the system will provide the user with the capability to produce line graphs, bar and pie charts, and scattergrams as an aid to decision making. These

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A COMPUTER GRAPHICS TECHNIQUE FOR STUDYING THREE-DIMENSIONAL DEMOGRAPHY AND EPIDEMIOLOGY

ABSTRACT

A computer graphics technique to study three-dimensional demography and epidemiology is presented. Contour maps of population abundance, mortality, and fertility on the age-time plane are generated using SYMAP, a packaged computer graphics program. As the Lexis diagram forms the basis for understanding this technique, these contour maps are referred to as modified Lexis diagrams. The examples used to illustrate the effectiveness of this technique are the United States male and female populations from 1940-1975, and their mortality, fertility, and illegitimacy rates.

INTRODUCTION

Age, sex, race, time, and space are the important characteristic variables of demography and epidemiology. Changes in population abundance, morbidity, mortality, and natality occur in a six-dimensional matrix, the final dimension being the dependent variable. However, the six-dimensional problem is complex and difficult to analyze. Consequently, analysis usually focuses on a two-dimensional problem, while holding the other independent variables constant. In this paper, I present a computer graphics technique to study three-dimensional problems defined by the age-time plane. The examples used to illustrate the technique are the U.S. male and female populations from

1940 to 1975, and their mortality, fertility, and illegitimacy rates. These particular examples have been chosen because excellent historical data exist in a readily accessible form and the important demographic events occurring during this time period are well understood.

The two variables, age and time, are related to each other in a special way. For an individual to advance one unit in age, he must also advance one unit in time. Three approaches to studying age-time changes have been used: cross-sectional studies, longitudinal studies, and cohort studies. Cross-sectional studies, based on one-time sampling, are easy to conduct but only provide information on the age distribution. Longitudinal studies provide information about temporal changes, but require an extended data collection effort, as do cohort studies which follow selected age groups as they shift both in age and time. To move from a two-dimensional to a three-dimensional problem, one must combine several sets of cross-sectional, longitudinal or cohort data.

Age distributions of populations are represented graphically in two dimensions as population pyramids. The 1940 and 1975 pyramids for the U.S. male and female populations are presented in Figure 1. The 1940 pyramid is a classic triangle, except for an indentation in the youngest age groups reflecting a reduction in fertility through the 1930's. The number of men is slightly greater in the younger ages while women outnumber men beyond age 65. The indentation in the 1940 pyramid becomes more apparent in the 1975 pyramid by the subsequent bulge resulting from the post-World War II baby boom. This baby boom will continue to appear as a bulge in subsequent pyramids, and because of its size, the associated cohort will influence many aspects of American life (Keyfitz 1972).

Temporal variations in the U.S. total fertility rate and the total number of live births, presented as time series in Figure 2, show the depression in births in the 1930's and the American post-World War II baby boom. The fertility curve closely follows the curve for the total number of live births, with the peaks and troughs slightly damped. As we move forward from 1940, the distance between the two curves increases. This spreading effect is the result of an increasing number of potential mothers producing fewer children. The total number of live births is maintained, but the fertility rate has decreased until women average fewer than two births each in their reproductive lives.

THE LEXIS DIAGRAM AND CONTOUR MAPPING

Lexis (1875) developed a diagrammatic method of studying a population as it shifts in age and time. The axes of a Lexis diagram define the initial age distribution (P(a,0)), and the birth time series (P(0,t)) (Figure 3). Individual life lines starting at age zero (birth) move across the diagram at a 45 degree angle until the person dies. For the three types of studies mentioned above, cross-sectional data would appear aligned with the horizontal axis, longitudinal data with the vertical axis, and cohort data with the life lines. A Lexis diagram is a useful tool in understanding demographic theory and in studies of small populations, but in studies of large populations it becomes cluttered with life lines.

The Lexis diagram forms the basis for the present technique. Rather than plotting life lines, I suggest plotting lines of equal abundance, or contour lines, thus creating a contour map, hereafter referred to as a modified Lexis diagram (MLD). Constructing a contour map from raw data involves a process of interpolation to generate a regular grid of data points. The size of the grid

will depend on the size of the contour map desired. Most methods of calculating grid values involve a weighted average of a limited number of neighbors. Several packaged programs for contour mapping, primarily developed by cartographers, are available and offer a choice of interpolation methods and display options. Some plot contour lines while others shade, either in black and white or color, the regions between contour lines. Most packages offer the option of fitting a polynomial to the surface. While polynomial equations are not useful for making long-term projections, they may prove extremely useful in estimating missing data points and identifying surface trends. The package chosen for use in this paper is SYMAP version 5.2, produced by the Harvard Laboratory for Computer Graphics and Spatial Analysis (Dougenik and Sheehan, 1975).

An alternative method for displaying three-dimensional data is to construct a three-dimensional perspective drawing, a method introduced in demography by Lavasseur (1885) and recently applied by Pullum (1980). Hanson et al. (1980a,b) apply this technique to epidemiological data. The major disadvantage of this approach is that 'valleys' hidden from view by ridge lines are not drawn, making it necessary to provide more than one view to display all the intricacies of the surface. In contrast, contour maps allow one to visualize all parameters at once.

The data presented in this paper are annual cross-sectional data by five- and ten-year age groups. When constructing a contour map, the spatial arrangement of the data on the age-time plane is important. The distances between the data points should be equivalent in each dimension. SYMAP's interpolation procedure belongs to the family of weighted average distance measures, described by Shepard (1968). As demographic data is only available in five- and ten-year age groups. I divided the age axis by the length of the size class to make the data appear as if they were available in single-year age groups. Then I expanded the axis, during the printing process, so that scales were approximately equivalent. For purposes of interpolation, it is necessary to assume a continuous variable. Since population abundance is not a continuous variable I divided the population data by five to obtain estimates of single-year, age-group abundance, then fitted this value to the midpoint of the age group. The axes of the MLD's presented are rotated 90 degrees relative to those of the Lexis diagram shown in Figure 3.

DISCUSSION OF RESULTS

The data were collected and published by the U.S. Bureau of the Census and the Public Health Service. In all, 2410 data points were used in preparing the diagrams. The results that follow are only as valid as the data used. For a detailed discussion of census enumeration errors see Coale and Zelnik (1963).

Population Abundance

MLD's for the U.S. male and female population abundance, including overseas personnel, are shown in Figure 4a and 4b. Population data for Alaska and Hawaii are included from 1950. The data are annual estimates of the population from the U.S. Bureau of the Census (1965, 1974, 1975b).

The two population MLD's together comprise a series of population pyramids, of which Figure 1 is a subset. If there were no mortality and births increased uniformly, each MLD would contain bands parallel to the life lines (drawn at 20-year intervals). However, as cohorts age, mortality takes its toll and reduces cohort populations, thus the contour lines become concave

upwards. Mortality is most severe in the oldest ages causing a flattening of the contour lines. Migration into the population adds to the cohort populations and increases the angle of the contour lines. The opposite is true for out-migration. If in-migration exceeds losses due to mortality and out-migration, the contour lines will become convex upwards. In Figure 4a and 4b, population abundance differentials between sexes are clear at most ages. For the cohort born in 1940, the life line crosses into increasing rather than decreasing population levels, implying net migration into the U.S. Two baby booms are apparent on each map--the post-World War II baby boom indicated by the closely packed contour lines and darkest shading along a ridge line in the upper right corner of each diagram (labelled A-A'), and the post-World War I baby boom starting at about age 15 in 1940 (labelled B-B'). For both sexes there is a break in the ridge lines between 1944 and 1945 (labelled C), which may be associated with the dip in births that occurred in 1919. This gap occurs slightly earlier for women. There is also a gap in the female post-World War II baby boom associated with girls born in 1959. In all three cases the abundance levels in the gaps are just below the levels of the neighboring contour lines and, therefore, are of little significance. Finally, the inclusion of Alaska and Hawaii after 1950 has very little effect on the MLD's, due to the small populations of these two states.

Mortality

MLD's for the U.S. male and female age-specific mortality rates are shown in Figure 5a and 5b. Data for Alaska and Hawaii are included from 1950. Annual cross-sectional data from the U.S. Bureau of the Census (1975a) and the U.S. Public Health Service (1970-1975), are used.

Mortality age distributions are generally presented as U-shaped functions resulting from high infant mortality, low mortality through the childhood and early adult years, and increasing mortality in later years. This is observed in both MLD's. The contour lines for women occur at slightly older ages reflecting the higher life expectancy of U.S. women. There is one important difference between the two diagrams. The contour lines for men are essentially parallel to the time axis, implying that there has been very little reduction in male mortality and, therefore, little improvement in life expectancy. In contrast, the contour lines for women are slightly curved, implying increasing life expectancy (U.S. Bureau of the Census 1975a). This broadening of the U-shaped curve, observed in the female mortality MLD, would be difficult to diagram other than through the concept of contour mapping.

In both the male and female mortality MLD's, there are patterns of peaks, spaced every 3.3 years, along the various contour lines. The regularity of these peaks suggests that a moving average process is being used either in the generation of the data or during the construction of the MLD's. The mapping interpolation algorithm is a smoothing process; however, if one studies the raw data, while the general trend in mortality for any given age group is downward, there are oscillations in these trend lines. SYMAP accentuates the oscillations, or peaks, in the raw data, but why and how they appear is unclear.

Fertility and Illegitimacy

MLD's for U.S. fertility and illegitimacy are shown in Figures 6 and 7. The data, from the U.S. Bureau of the Census (1975a) and the U.S. Public Health Service (1970-1975), are available annually by five-year age groups. The available fertility data spanned the ages 10-50, while the illegitimacy

data spanned the ages 15-44.

If fertility patterns remained unchanged, one would expect a ridge line, spanning the high fertility years, running parallel to the time axis. In Figure 6, there is a ridge line for women in their mid-twenties, parallel to the time axis (labelled A-A'); however, this is obscured by the American baby boom. The excess fertility associated with the boom extends from the late 1940's to the early 1960's. From Figure 2 it was observed that the main thrust of the boom was preceded by two peaks in 1943 and 1947, both of which are apparent in Figure 6. The baby boom falls on top of the expected ridge, but it also spreads into older and younger ages. Not only women in their mid-twenties but also women in their late teens and thirties were having more children. Finally, if the reader focuses on the contour line representing 20 births/1000 women which starts at age 41 in 1940 (labelled B-B'), one observes that this contour line runs parallel to the age axis until 1965. From 1965 to 1975 it decreases to age 37. A similar movement from 1965-1975 is noted for the 40 and 60 births/1000 women contour lines. A possible explanation for this reduction is that older women are increasingly able to control their fertility as a consequence of the introduction of improved contraceptive devices and heightened awareness of the risk of congenital defects associated with late births. This reduction is observed in the cohorts responsible for the baby boom; therefore, an alternative explanation is that those women who already had large families avoided additional births. A shadow effect along cohort lines is the result of this phenomenon.

Figure 7 shows illegitimacy, defined as a birth to a mother whose declared present martial status is single. A peak in illegitimacy associated with the baby boom is observed (labelled A), but it occurs at the end of the baby boom and in a slightly older group. Illegitimacy among teenagers, indicated by contour lines perpendicular to the time axis (labelled B), was increasing steeply. Illegitimacy in all other ages increased through the 1960's, but has since dropped. Compared to the illegitimacy problem experienced in the 1940's the problem in 1975 was more severe. The 1940 level for age 25 was 5-10 illegitimate births/1000 women, but in 1975 the level was 30--a more than threefold increase. It should be noted that among this age group total fertility was higher in 1940 than in 1975. Some of the observed changes might have resulted from increased willingness to report illegitimacy.

CONCLUSION

A computer graphics technique to picture three-dimensional demographic and epidemiological data has been developed. Modified Lexis diagrams of the U.S. male and female populations, and their corresponding mortality, fertility and illegitimacy rates from 1940-1975 are presented. The advantages of MLD's are that they allow the researcher to comprehend three-dimensional changes and to observe variations that occur off the principal axes and the diagonal. Since large amounts of data are included in one diagram, an MLD is an efficient method of presenting tabular data. The ease of visualizing historical data, obtained by constructing an MLD, should aid in the understanding of trends in population and health statistics. This technique should find application in the fields of demography, epidemiology and ecology.

ABBREVIATIONS AND NOTATION

MLD = Modified Lexis Diagram

a = Age

t = Time

P(a,t) = Population at age a and time t.

ACKNOWLEDGMENTS

This work was supported by a grant from the Rockefeller Foundation.

FIGURE TITLES

Figure 1. Population pyramids for the U.S. male and female population, including overseas personnel, for 1940 and 1975. The 1940 pyramid does not include Alaska and Hawaii. Source: U.S. Bureau of the Census (1965, 1975b).

Figure 2. Time series of the U.S. total annual fertility rate and the total annual number of live births. Source: U.S. Bureau of the Census (1975a) and U.S. Public Health Service (1970-1975).

Figure 3. Lexis diagram with arbitrary life lines drawn.

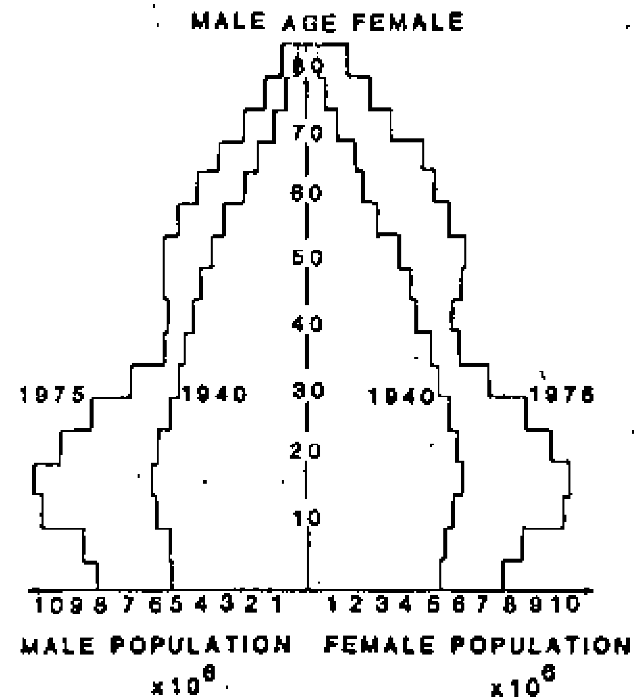
Figure 4a and 4b. MLD's for the U.S. male (a) and female (b) populations (numbers in thousands for single-year age-groups). Time: 1940-1975. Age: 0-85. The data are annual estimates of the population for the age groups 0-4 and in 5-year intervals up to 80-84. Continuous life lines have been drawn at 20-year intervals. A-A' indicates the post-World War II baby boom. B-B' indicates the post-World War I baby boom. C indicates the drop in births that occurred in 1919. Source: U.S. Bureau of the Census (1965, 1974, 1975b).

Figure 5a and 5b. MLD's for the U.S. male (a) and female (b) mortality rates (per 1,000 population). Time: 1940-1975. Age: 0-90. The data are annual rates for the age groups 0, 1-4, 5-14 and in 10-year intervals up to 85+. Source: U.S. Public Health Service (1970-1975) and the U.S. Bureau of the Census (1975a).

Figure 6. MLD of the U.S. live birth rate by age of mother (per 1000 women). Time: 1940-1975. Age: 10-50. Data are annual rates by 5-year age groups from 10-14 to 45-49. A-A' indicates the high fertility ridge. B-B' is the 20 births/1000 women contour line. Source: U.S. Public Health Service (1970-1975) and the U.S. Bureau of the Census (1975a).

Figure 7. MLD of the U.S. illegitimate live birth rate by mother's age (per 1000 women). Time: 1940-1975. Age: 15-44. Data are annual rates by 5-year age groups from 15-19 to 40-44. A indicates the peak in illegitimacy. B's indicate increasing teenage illigitimacy. Source: U.S. Public Health Service (1970-1975) and the U.S. Bureau of the Census (1975a).

Figure 1.



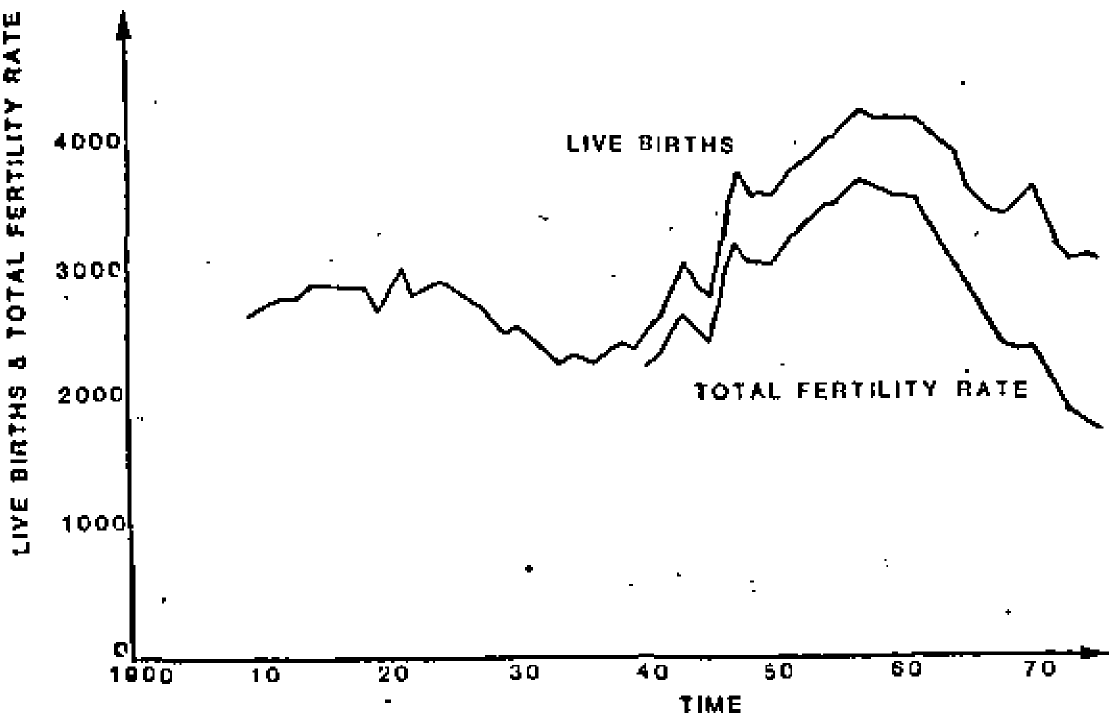


Figure 2.

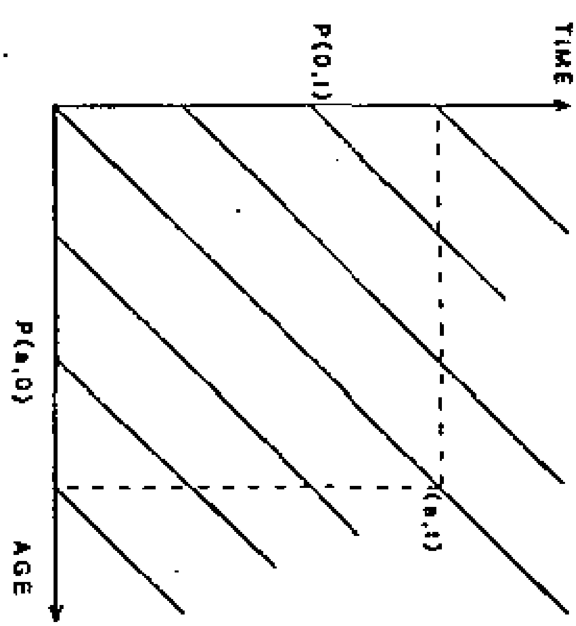


Figure 3.

Figure 4.

Figure 5.

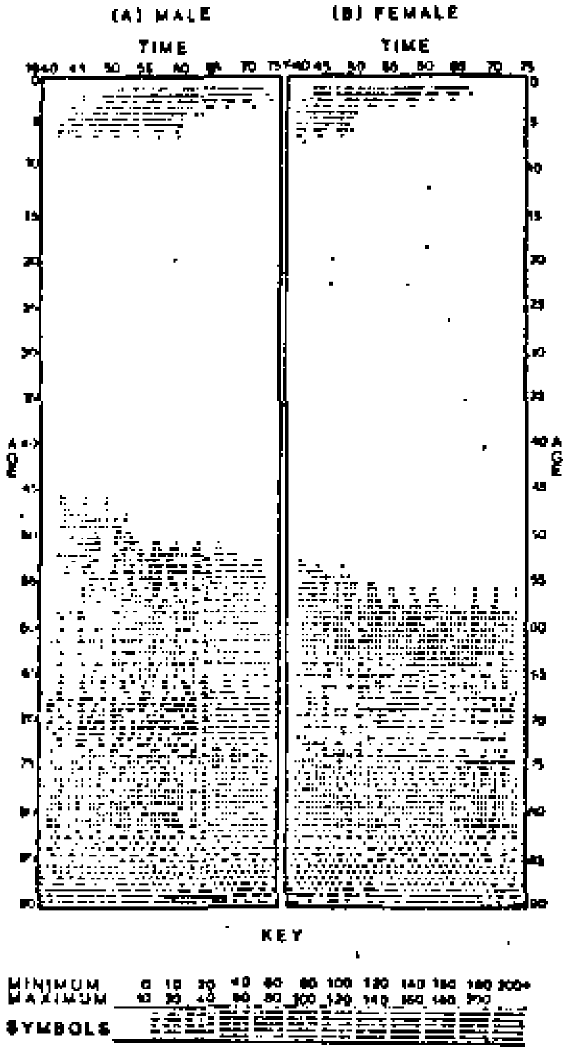


Figure 6.

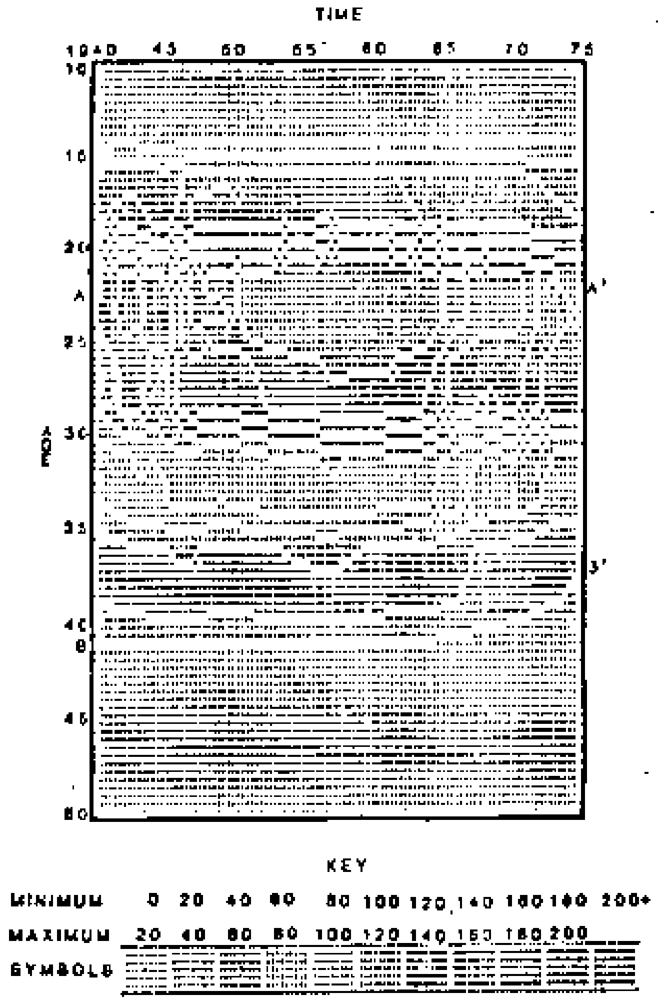
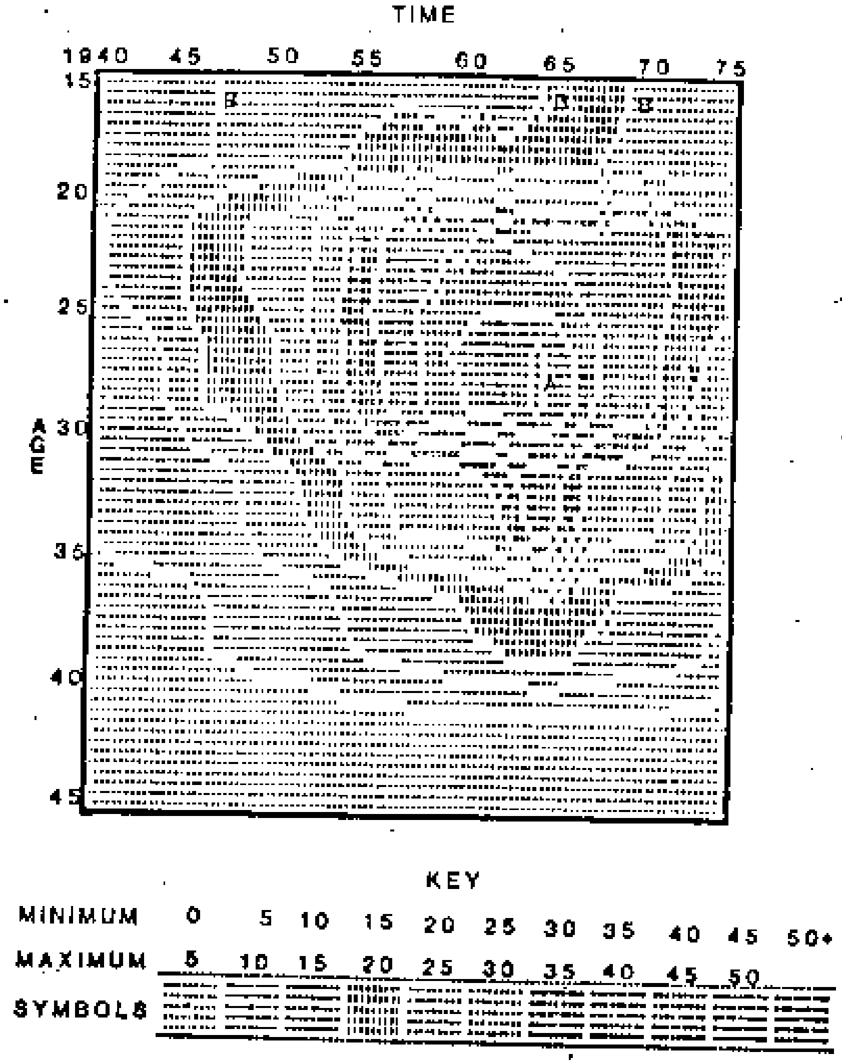


Figure 7.



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COMPUTACION APLICADA A LA PLANEACION URBANA

APENDICE BIBLIOGRAFICO

II

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**** Mapping seismically hazardous housing in urban areas: a case study in the case of the odyssey system

Agosto, 1981

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THE APPLICATION OF COMPUTER MAPPING IN CORRECTING OLD AND SELECTING NEW SOLID WASTE DISPOSAL SITES USING A GEOGRAPHIC INFORMATION SYSTEM

PROBLEM DESCRIPTION

The protection of groundwater resources from the possible adverse effects of solid waste disposal sites is becoming an increasingly important environmental concern. The Love Canal catastrophe in New York has heightened the public's awareness of this issue. In New Castle County, an aquifer contamination problem associated with an old landfill was discovered in 1972. Since then, considerable time and money (over 1.5 million dollars) have been expended for monitoring, investigating alternatives to correct the situation, and containing the problem until such time as corrective actions can be taken.

One task of the Water Resources Agency (WRA) is to develop programs to aid in the control of sources of water pollution. Among the principal non-point sources are landfills and open dumps. In the past, landfills were sited with little regard to water quality, and they were operated and designed with practices we would rarely use today. A nefarious legacy remains which is demanding attention. Limited funds are and will be allocated to correct problems in accord with problem severity and with cost-effective principles.

Solid waste disposal in New Castle County was first examined in a

site inventory by the WRA in 1975 as part of initial work in developing a water quality management plan under Section 208 of Public Law 92-500, The Federal Water Pollution Control Act Amendments of 1972. At that time, few data existed and the inventory relied heavily on the cooperation of site operators. Acreage, volume, and waste constituents were the data provided. After analyzing geologic data, available water quality data, and other information, the survey concluded that of the twenty-five sites identified, three sites already affected water quality and six had a high potential to do so.

Since that time, solid waste disposal has received a considerable amount of national attention. Congress responded with the 1976 Resource Conservation and Recovery (RCRA) Act, which required that states set up solid waste management plans in order to receive federal aid. The states must identify environmentally unacceptable dumps and upgrade or phase them out within five years of the date of identification. The RCRA and the Clean Water Act of 1977 both proposed criteria to be used in identifying waste disposal facilities in terms of effects on surface and groundwater quality, air quality, and public safety, in addition to the use of a cover material. Facilities that allow open burning or facilities sited in wetlands, floodplains, habitats of endangered species, or recharge zones of principal sources of local drinking water are generally defined as unacceptable under these regulations and will have to be phased out.

Since any action the State would take needed to be governed by a system of priorities, the Water Resources Agency elected to reexamine its consequences, more costly to correct, more difficult to prevent, and more difficult to detect. Thus, the classification of lands gives precedence to lands with natural characteristics that would serve as a second line of defense in the event that the leachate control system breaks down. None of these site characteristics is of such value in leachate control that a proper system would be precluded because the value of a leachate control system is equally high with respect to the protection of surface water quality.

The primary analytical objective was to provide a suitability map showing areas where the effect on water quality would be minimal, areas of possible effect on water quality and areas which would most likely affect water quality. This map would be used to analyze potential sites. After the map was produced, the output file was saved. A software package was written which would take the coordinates of existing landfill sites and produce a list of environmental characteristics for each site. Then a priority system based on each sites's potential to affect water quality would be developed.

RESOURCES REQUIRED

The AERI system has been operational for five years on a Burroughs 7700 computer located at the University of Delaware, five miles from the WRA offices. The system--software and data base--was developed and installed over a one year and three month period of time by the Environmental Systems Research Institute (ESRI) of Redlands, California, at a cost of $134,000. Work is done in a timesharing mode with access to the B7700 through a Digital Equipment Corporation LA120 Decwriter III

located in the Agency's office. The Decwriter III provides an advantage over the University's terminal in that by varying the vertical and horizontal pitch selections, maps can be produced at scales of 1:24000, 1:36000, 1:48000, and 1:72000.

The AERI system itself is of the grid cell type. New Castle County, excluding the Delaware River, is approximately 435 square miles in size (Figure 1). The grid cells are square, five hundred feet to a side; thus, each cell covers 5.7 acres. At this scale, a grid matrix of 400 rows by 217 columns is required for countywide coverage, including the Delaware River.

Map output from the system may be directed to a terminal, a line printer, or a plotter. While the Agency has done some color plots of small areas on a Tektronix 4662 plotter, it is too small (10" x 15") to be used for countywide analysis. Draft or working maps are sent to the University for output on a line printer. The maps herein were produced at a scale of 1:72000 and photographically reduced to report size. The cost to print and reduce a map ranges from $10 to $15.

The original data base contained data on thirty-eight variables, among them soils, land cover, geology, hydrology, floodplains, recharge potential, and groundwater elevation. Through the overlay capability of the system, the WRA has developed information for over sixty more variables including runoff and infiltration, erodibility, agricultural capability, annual erosion, septic system suitability, etc. The first step in the analysis was to decide which variables would be used and how would they be used to provide the best possible

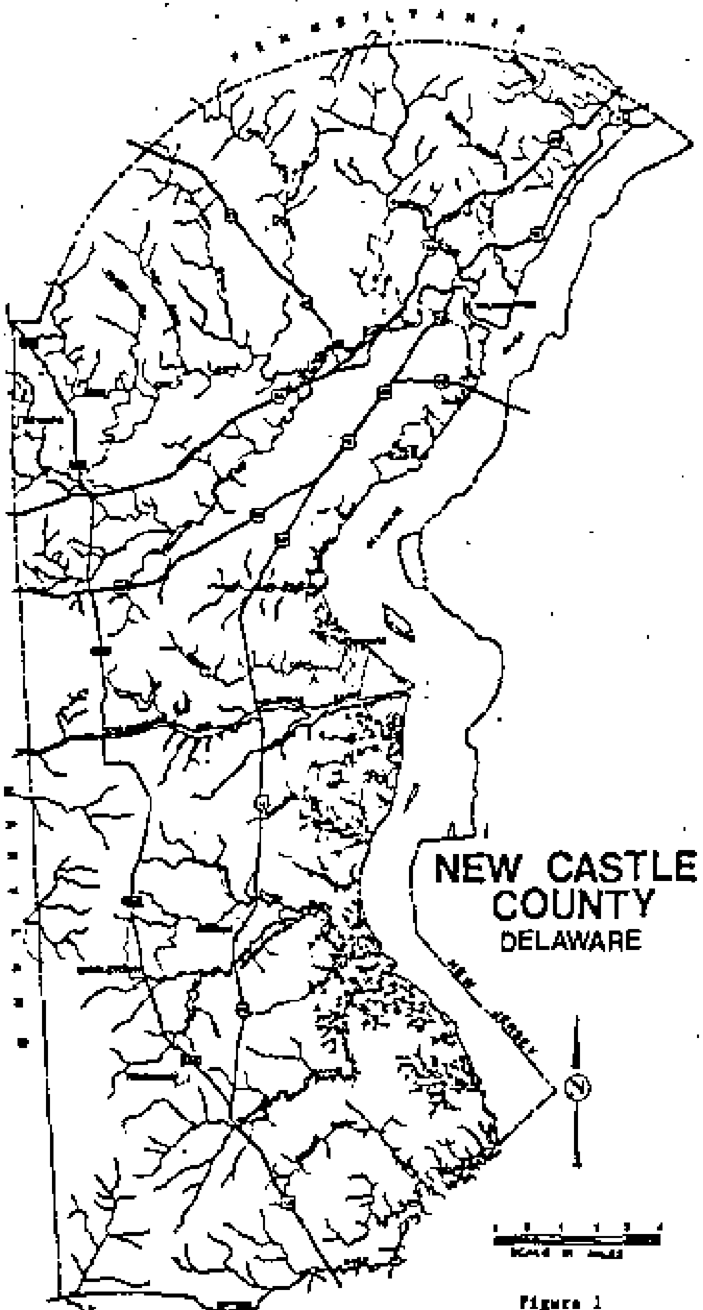


Figure 1

information. Off and on over a period of a year and a half, the suitability model was constantly being refined as new approaches and new data were examined.

PROBLEM ENCOUNTERED

The two major obstacles to performing a satisfactory analysis were both data related. The Piedmont area in the County, the northern quarter, is geologically much more complex than the Coastal Plain. Data on depth to groundwater and aquifer recharge potential were unavailable. The Delaware Geological Survey (DGS), under a contract with the WRA, is currently working to provide these data. This problem could not be overcome. Once data are available, they will be coded and become part of the data base and the suitability data file will be updated.

The second obstacle was that our data on aquifer recharge potential for the Coastal Plain, while it provided much valuable data for this analysis, identified the thickness of the geologic overburden only as greater or less than forty feet. This data file was coded from maps developed by the DGS in 1975. These data classify the Coastal Plain in terms of four measures of recharge:

1. Possibility for recharge to the deeper artesian aquifer.

   I Good - Hydraulic Conductivity 100-250 ft/day
   II Fair - Hydraulic Conductivity 50-75 ft/day
   III Poor - Hydraulic Conductivity 1-20 ft/day

2. Possibility for recharge to the upper water table aquifer, largely the Columbia Formation which consists of gravels, sands, silts, and clays of highly variable character.

   A Good - Hydraulic Conductivity 100-250 ft/day

B Fair - Hydraulic Conductivity 50-75 ft/day
C Poor - Hydraulic Conductivity 3-20 ft/day

3. Thickness of Columbia Formation which determines the potential for the use of these sediments as an aquifer.

   1 Greater than 40 feet--Potentially useful as an aquifer
   2 Less than 40 feet--Useful as an aquifer only for low yield, domestic wells

4. Present flow direction of groundwater.

   a Presently a potential recharge area
   b Presently a discharge area

Each cell could have a value of 1 to 36 depending on the combination of factors. For example, a value of 10 corresponds to 1C1b which indicates good recharge potential to the artesian aquifer (1), poor recharge to the upper aquifer or Columbia formation (C); the latter is greater than forty feet thick (1), and it is a discharge area (b).

A more accurate estimate of the thickness of the Columbia formation was needed. A thickness of less than forty feet would range from 0-39 feet and a thickness greater than forty feet would be anywhere between 40 and 117 feet. Thirty-nine feet of Columbia Formation with "poor" hydraulic conductivity over an artesian aquifer classified as "good" would provide much more protection for the artesian aquifer in the event of leakage from a landfill than would one foot of Columbia formation.

Fortunately, the working maps used by the DGS did have sufficient point data on elevation of the overburden above sea level that contours could be drawn similar to contours showing topographic elevation. Once this was done, the gridded mylar map could be overlaid on the contour map and the elevation of the overburden in the Coastal Plain could be

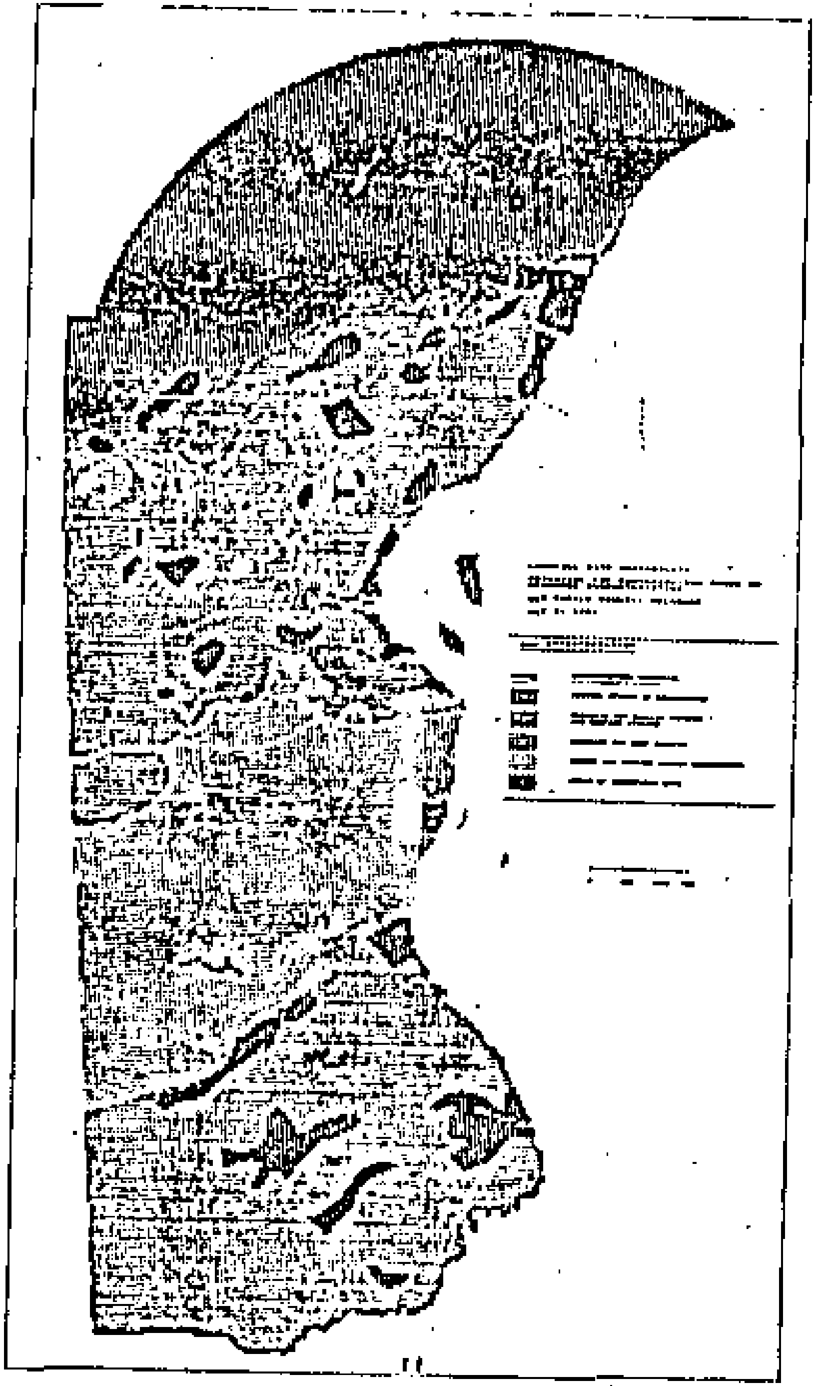
coded. A student was hired to perform this tedious task which took about three months with another three months to check, correct, and verify the data. Once this data file was complete, the AERI system could be used to provide data on the thickness of overburden by subtracting the elevation of the overburden, if it were above sea level, from the topographic elevation or adding it to the topographic elevation if it were below sea level. Thus, data on thickness of overburden was created and used as a variable in the suitability for landfill site analysis. In the future, these data will be used in analyses covering groundwater storage capacity and an assessment of recoverable sands and gravels.

GRAPHICS EXAMPLES

This paper documents the Agency's ongoing solid waste disposal work program which will result in the priority ranking of existing solid waste disposal sites based on their potential to adversely affect water quality. The analysis will also be used to provide information to the Delaware Solid Waste Authority as an aid in its search for a solid waste disposal site. The following explication provides information on the preparation on resulting analysis of the maps used in the study.

Map 1: Landfill Site Suitability
Potential for Contamination Based on Recharge Potential

This map is a first cut and shows the county classified in terms of effect on water quality if leachate from a solid waste disposal site were to enter the ground. It does not take into account the thickness of the Columbia Formation.



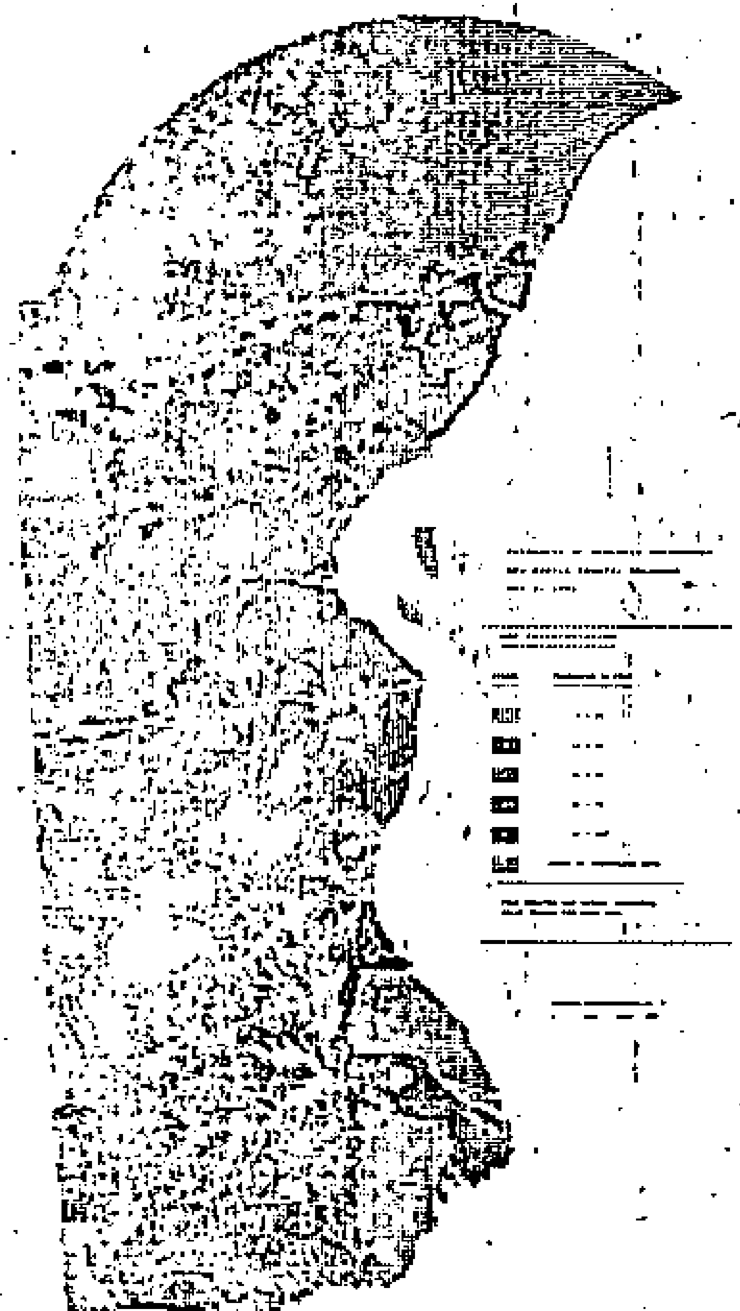
Those cells identified as having a minimum effect are areas classified as IIIC, poor recharge to both the Columbia formation and the deeper aquifer. The second category identifies cells classified as IIIA or IIIB. They have fair to good recharge to the Columbia formation but poor to the deeper aquifer. The third category has poor recharge to the Columbia formation and poor to fair to the deeper aquifer. However, since the thickness of the Columbia formation is not considered, its effect on leachate dispersion cannot be gauged.

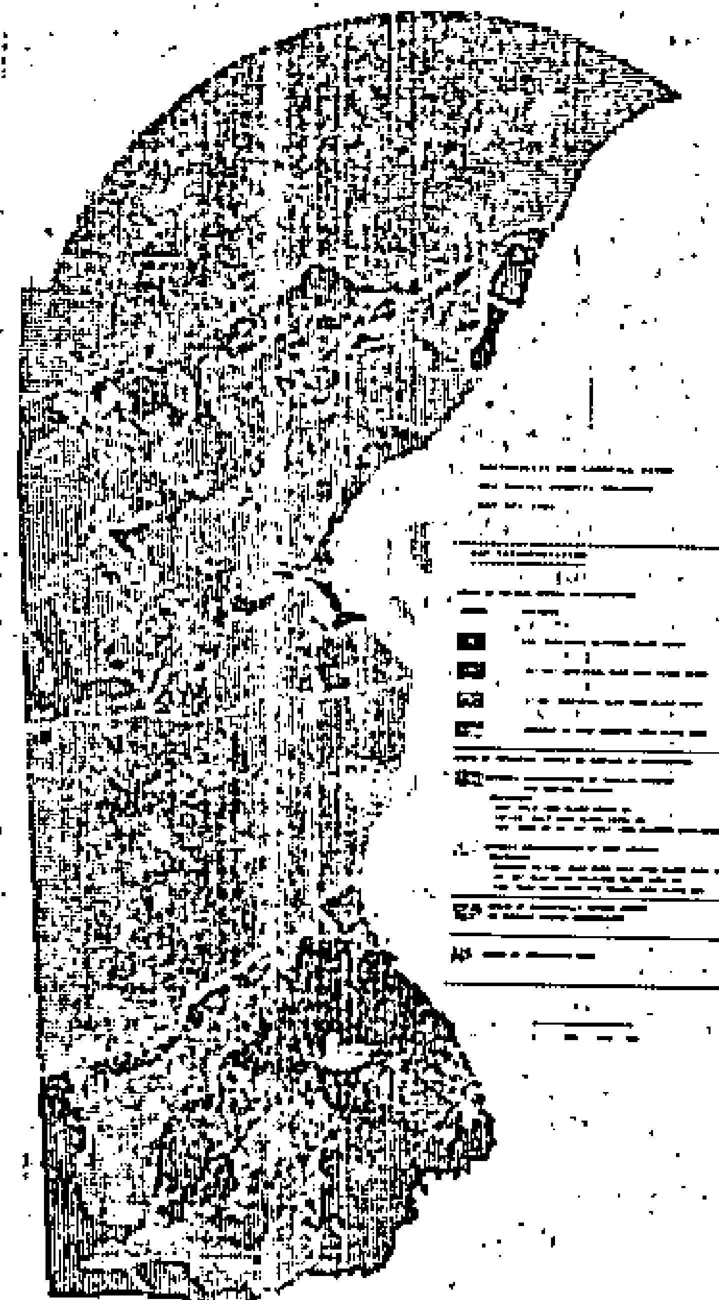
Map 2: Thickness of Geological Overburden

The data portrayed on this map were created for use with the recharge potential data in order to develop a final solid waste disposal site suitability map and file. Each cell in the file has a value for thickness which ranges from 0 (no overburden or the outcrop of the subcropping formation) to 117 feet. The recharge data tell us whether the Columbia formation is primarily sand (A) with good hydraulic conductivity; (B) with average hydraulic conductivity; or (C) essentially clay with low hydraulic conductivity. When combined with thickness data, more accurate assessments of potential for contamination are possible. For example, an area classified a "I" (good recharge potential) would provide much more protection if it were thirty feet thick than if it were two feet thick. The third map displays this information.

Map 3: Suitability for Landfill Sites

A series of levels were devised which characterize suitability in terms of minimal, potential, and severe effects. These levels are basically dependent on clay thickness. Areas identified as having potential effects would require special engineering techniques if considered





as a site. The potential problems in these areas also described.

This map shows that approximately 27,300 acres of land, if used as a solid waste disposal site, should pose minimal problems for water quality. Another 61,800 acres are identified as having a potential to affect water quality. This map and data file were then used as the basis to evaluate existing and proposed solid waste disposal sites.

A comparison between the acreage involved in the various categories on Map 1, which relies only on recharge potential, with that on Map 3, which incorporates the thickness factor shows the following:

	Map 1		Map 3		
	Cells	Acres	Cells	Acres	Change
Minimal Effect	2,945	16,875	4,943	27,323	+10,448
Potential Contamination of Shallow Aquifer and Surface Streams	21,749	134,622	10,144	38,125	+46,497
Potential Contamination of Deep Aquifer	1,054	6,039	645	3,696	-2,343
Potentially Severe Effect	9,417	53,959	19,387	111,087	+57,128

It is obvious that the data with regard to geologic overburden thickness is a major factor in the analysis. Not only does an additional 10,000 acres become suitable for a site, but more importantly, 57,000 acres are added to the areas with a potential to severely affect water quality, which is the predominant concern.

RESULTS

Proposed Sites

Sites proposed by DSWA during the past year and a half have met heavy opposition from neighboring residents. The WRA had analyzed these sites with data available at the time such as land cover, depth to groundwater, soil types, and recharge potential. However, it did not have the data required to look at a combination of characteristics—thickness of overburden together with lithologic structure until the new data file was created.

Also, as stated earlier, the WRA had objected to the method apparently being used by the DSWA to locate a site. The DSWA has proposed a PVC liner beneath the site with a system to collect and treat the leachate before releasing it to a stream. The WRA's position was that if that liner should leak, it would be best to have that site in an area where least environmental damage could occur.

Presently, the WRA has presented its findings on potential solid waste disposal sites to the Agency's Policy Board, which consists of the County Executive and the Mayors of Wilmington and Newark; to the City of Wilmington, where one proposed site is located; and to the County Executive's office. As a result of this last presentation, it was decided to arrange a meeting with the Governor's staff to present this information. Meanwhile, the DSWA has hired a consulting engineering firm to do in-depth site analysis of these potential sites. This is to be completed late in 1981.

Existing Sites

The creation of a solid waste disposal site suitability map and a file permitted the WRA to provide a listing of relevant environmental factors by accessing the data base (Table 1). By analyzing the information provided, especially that in column 17—the overall suitability ranking—it is possible to identify those sites which pose the greatest threats to water quality.

The table shows the data for the Army Creek site, which is the site mentioned early on in this paper, to be an existing site which seriously affected surface water and both the upper and lower aquifer. Every cell but three has a suitability value of 7 which correspond to the classification of "Potentially Severe Effect on Surface and/or Groundwater." The data show that the recharge potential is "A" (Column 10) throughout the site. This indicates good hydraulic conductivity which allows leachate from the landfill to percolate through the ground quite easily to contaminate groundwater. Other factors considered helped to distinguish what quality problems, and the contamination observed tends to confirm the mapping assessment. The WRA is in the process of documenting the rating methodology and will submit its findings to State Department of Natural Resources and Environmental Control and to the Environmental Protection Agency at the end of July.

SUMMARY

The solid waste "problem" is said to have been created by increased competition among land uses of all types, public opposition to new sites, and improved siting criteria. This problem was compounded by rapid

Table 1

INTEGRATED ENVIRONMENTAL RESOURCE INFORMATION SYSTEM
NEW CASTLE COUNTY, DELAWARE
LANDFILL SITING DATA

SITE: ARMY CREEK
TYPE: INDUSTRIAL/MUNICIPAL
NUMBER: 113

DATA DESCRIPTION:

1 = CELL ROW NUMBER
2 = CELL COLUMN NUMBER
3 = PRIMARY LAND COVER
4 = PRIMARY SOIL TYPE
5 = SOIL HYDROLOGIC GROUP
6 = STREAM TYPE
7 = FLOODPLAIN
8 = GEOLOGY
9 = TOPOGRAPHIC ELEVATION
10 = COLUMBIA FORMATION LITHOLOGY
11 = SUBCROPPING FORMATION LITHOLOGY
12 = RECHARGE/DISCHARGE AREA
13 = WATER TABLE ELEVATION
14 = ELEVATION OF BASE OF QUATERNARY SEDIMENTS
15 = UNSATURATED THICKNESS IN COLUMBIA FORMATION
16 = SATURATED THICKNESS OF COLUMBIA FORMATION
17 = LANDFILL SITE SUITABILITY

* AND INDICATES NO DATA FOR THAT VARIABLE.

END OF REQUESTED DATA FOR SITE: ARMY CREEK increases in population and in the volume of wastes, changes in production and consumption practices which influenced the composition of wastes, and, of course, the generation of air and water pollution residuals.

The problem appears to have been the attitude that wastes were nuisances deserving no better fate than dumping on "worthless" land. This attitude permitted environmental impacts to get out of hand, and this simple fact finally caught up with us all of a sudden. In our siting decisions, for example, we took pains that any nuisances would not be experienced locally and, thus, we could not relate to or perceive any problem with our practices until too late. We now know that problems develop in stages. First came odor and vermin; second, open burning posed the new problem of air pollution; groundwater pollution slowly emerged as a third problem; and now, as a result of indiscriminate dumping, economic costs to correct these problems is the major concern.

We tolerated poor waste disposal practices by government and industry. When the consequences caught up with us, they overwhelmed local jurisdictions because local jurisdictional resources were inadequate for correcting them. Through this array of circumstances, we see how there was no local experience with solid waste management's environmental impacts to compare with air and water quality management and, thus, comparable grass-roots design and regulatory improvement were much slower to develop.

We can no longer do this. In fact, if we sited our 25 landfills according to the 1976 Resource Conservation and Recovery Act and the 1977 Clean Water Act proposed siting criteria, most of them would not

be there in the first place. Most are in wetlands; some in riverine floodplains and in abandoned sand and gravel pits; and one is in a major recharge area. Of the two that meet the proposed criteria, neither is well designed (both sites consist of filled trenches). The Delaware Solid Waste Authority proposed siting criteria embrace the RCRA and the 1977 Clean Water Act criteria and, thus, would also not permit them to be sited in these locations.

Hindsight can be foresight, provided that we learned the lessons that past teaches. What remains? If not wetlands and quarries, where? On agricultural land, far from people? Prime agricultural land is an asset too. How can we deal with the land use and political issues today. There seems to be no alternatives but to deal with the management issues.

As far as it is conceivable, landfills must become more acceptable neighbors. This means not only that odors, dust, traffic, and other short-term nuisances must be closely controlled, but that site design and siting--the best combination thereof--should adequately protect against long-term effects on the environment, especially on groundwater, and allow for a re-use of the site that is benefical locally.

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#5 Monday

REDISTRICTING USING COMPUTER GRAPHICS

The release of the results of each Decennial Census is a time for planners, legislators, marketers and managers to rethink their present districts and the start of a frantic period of drawing new district lines. This year's release of Census data will be different in that computer graphics will play a major role in many redistricting projects. The planner, legislator, marketer or manager will now have the option of using computer mapping techniques and will have to be able to evaluate whether computer graphics aids them in their task.

Redistricting at the simplest level is the drawing of new district lines. At the very least, it involves the creation of a permanent record, a map, of what constitutes the new district. Using a computer to draw the new map creates a useful but limited tool. But redistricting is rarely such a simple impressionistic process. More likely it involves an extensive period of analysis and scrutiny of several potential versions of the new districts. Decision makers are assessing the extent to which the proposed districts meet some criteria or goals. In this light, redistricting is the drawing of new district lines in such a way as to maximize the goals of the decision maker. Unfortunately, those goals are rarely defined in such a way as to be clear guidance for the plan drawer.

Redistricting can thus be thought of as a creative process subject to a multitude of constraints. The exact constraints are a function of the redistricting problem. The redistricting problem is usually defined by the type of districts to be created. School districts have different constraints than sales districts. Congressional districts have different constraints than delivery districts. Councilmanic districts have different constraints than air traffic control districts. In almost any redistricting problem having a proposed map is not enough. The designer of the proposed map must know how the proposed districts relate to the constraints imposed by the problem; he must be able to say whether the districts meet the goals of the decision makers. Redistricting almost always involves the evaluation of the proposed districts relative to the decision making constraints. If computer graphics is to be useful in redistricting, the computer graphics system must be able to access and manipulate data in the form of a database with a variety of levels of information. The map by itself is not enough.

Perhaps all of these concepts will be better understood with an example. Political redistricting is the drawing of district lines delineating an area for the election of representatives to legislative bodies. The most important of these in the United States are the Congress and the fifty state legislatures. We will look at redistricting and the role of computer graphics with this particular problem area in mind.

PROBLEM DESCRIPTION

The problem is to draw new Congressional districts for a state. The responsibility for this usually lies with the state legislature, although in some states a special commission is created just for redistricting. All designated bodies work with a similar starting date -- when the Census Bureau releases the needed information. The deadlines vary but normally are within six months. At the outside the process must conclude in time for the next Congressional election and the primaries that precede it. This time the Congress mandated the Census Bureau to make available the maps and population data needed for redistricting by April 1, 1981. The Census Bureau met this deadline, thus setting the redistricting clock in motion. The first official step was actually completed on December 31, 1980 when the Census Bureau released to the President the final 1980 population totals for each state and the resulting apportionment of Congressional seats among the fifty states. This is the point at which state finds out how many districts need to be created. Those states that gain seats are ecstatic as it means increased influence in Congress; those that lose are not pleased.

The period between January 1 and April 1 is frustrating because although the problem has been set forth, the solution cannot be sought until the data are available. It is in this period that the state makes sure it has the technical support for the decision makers. This is the period when programs are tested with hypothetical data and database construction begins. The Supreme Court has established some constraints that the decision makers begin to interpret in their own way. The court has said that districts must be made up of contiguous areas but that areas are not really the important elements of redistricting, people

are. The overriding constraint must always be "one man, one vote."[1]

In theory, this means that the redistricting decision makers must take the state's population and divide that by the number of Congressional seats. This gives them the ideal district population. What the Court has not told them is how far from that ideal a district can deviate before the Court will reject a plan as being inherently unequal. While in most states this implies a goal of being within a few <u>percent</u> of ideal size in some instances Courts have chosen between plans on the basis of which plan had fewer <u>people</u> deviate from the ideal (implying accuracy to six digits).

The practical implications of this are two. First it limits the drawing of district lines to be along boundaries recognized by the Census Bureau. If the population of the districts must be defended in Court, only districts which are described in terms of Census counts will be accepted. This has great implications for database construction. Second, it implies that plans with more equal districts will be preferred over plans with less equal districts, <u>but</u> only up to a point. Beyond that ill defined point other criteria will not only become important but probably dominant. The little understood fact of redistricting is that there is probably an infinite set of equal population districts. The man on the street believes that the Court's equal population rule is sufficiently binding and that all that is needed is to let a computer loose and it will produce the one true set of districts. This is just not the case. There are other criteria beyond equal population which are important and this usually implies that analysis of districts will go beyond evaluating population size and require additional information.

[1] See <u>Reapportionment Law and Technology</u>, NCSL/Publications, (1980).

The additional information is usually of three types. First, the minority population of each district is usually reviewed for the plan impact on minority representation. Second, the past electoral data is reviewed for plan impact on partisan representation. And last, but not at all least, the location of individuals especially incumbents and possible challengers, is reviewed for impact.

Once we realize that establishing equal population alone is not sufficient strict guidance, it is clear that people will differ as to what they consider a better plan on the basis of their own interest. In political situations, there are at least two different versions of what people consider good -- a Democratic and a Republican version. In redistricting, there is almost always a Democratic plan and a Republican plan. In any particular state, only one party is the majority. The majority party's plan is most likely to be the one accepted if the majority party is able to maintain party loyalty on the vote in each house of the state legislature or commission. If one believes the stories of the evils of Gerrymandering, one would think this happens all of the time. In reality, this is difficult to accomplish because any redistricting plan is likely to help some members of the majority party at the expense of others. Those legislators who feel their new district is not as "good" as their old district are likely to break ranks from the majority. A compromise plan becomes a strong competitor for the two partisan plans. The compromise plan usually favors more of the incumbents than the partisan plans. This happens more often in redistricting the state legislature than on the plans for Congressional districts.

We can now see that redistricting Congressional and state legislative districts is a highly political process involving many competing interests going far beyond the simple "one man, one vote" criterion. In some states the process is even more confused in that the state constitution may add additional criteria, such as observance of county or municipal boundaries, compactness, or interlocking of State House and State Senate districts. These additional constraints are specified almost as a wish list rather than as a requirement. They include such phrases as "wherever possible." The priority of one criteria over another is almost never specified.

METHOD DESCRIPTION

The amount of Census data involved in redistricting virtually requires a computer. In the past, desk calculators were the rule. The Court battles involving disputed population totals were the legacy of that inadequate methodology. A computer can not only be programmed to add up a district population, but also to determine whether any Census unit has been left out (underrepresented) or counted more than once (overrepresented). This will not end Court disputes over population but it will make them more informed and focused. Nor will this preclude the exchanging of possible district maps drawn on the back of cocktail napkins. The computer will be used to evaluate the final plan in every state. Whether the computer will take a role in plan generation will depend on how easy and fast one may use the computer to generate evaluations. Decision makers can make many plan decisions (specified only at the broadest level of detail) very quickly.

A computer can very quickly evaluate these decisions once the plan is put in the computer. The bottleneck is clearly the time required to input the plan. If it needs to be keyed at a terminal it will never be fast enough to hold the decision maker in place long enough. The answer to this problem is interactive computer graphics.

Redistricting is almost always a geographic problem. It is possible to point at a map and define a district. If the computer can be made to understand the pointing act then listing is not necessary. By using a computer graphics terminal with graphic input mode it is possible to do just this. A map can be drawn on a terminal screen and the user can describe a district by pointing to the boundaries of the area. This is much quicker than listing all the areas by their geographic identification codes. Once the plan is input, getting a quick evaluation of a plan is a function of how fast the computer is and how efficient the software is. It is definitely possible to evaluate a plan in a matter of moments.

Once the decision is made to use computer graphics, the decision must be made as to which of the various mapping techniques is appropriate for redistricting. Political redistricting is always the building of districts from Census units. This implies that the techniques of statistical cartography are appropriate; they use building blocks rather than arbitrary lines to define areas. A redistricting system using computer graphics should be able to assemble Census units to some intermediary building block level and then provide for the creation of districts from those building blocks. In political redistricting the natural building block is the precinct. For a variety of reasons it is sometimes necessary to use some other building block such as the Census tract.

It is possible to consider using the computer not only to evaluate districts, but also to generate them.[2] To the extent that the number of building blocks is limited, this is a viable option. However, an important caveat is that the constraints on district design must be quantifiable. Computers can create equal population districts within a specified tolerance. These will not necessarily be the most equal districts possible, but at least they will be within the decision makers' definition of equality. These algorithms begin to lose their utility when the constraints are ill-defined. It produces a district plan which is quickly rejected with the comment -- "It split my county when it didn't have to." Unless the algorithm is given these constraints in a form it can understand, it will continue to produce plans that are rejected. It is extremely rare that plans generated by the computer are accepted by decision makers (especially politicians) without extreme modification. A redistricter should consider the limitations of such algorithms before requiring that they be part of their redistricting system.

[2] See Stuart Nagel, "Simplified Bipartisan Computer Redistricting," Stanford Law Review, Volume 17, No. 5, May, 1965, pp. 863-899 and James B. Weaver, Fair and Equal Districts: A How-To-Do-It Manual On Computer Use, National Municipal League, New York (1970).

RESOURCES REQUIRED

Software is the most important resource needed for a redistricting system; hardware is a secondary consideration. There are several basic functions which the software must be able to handle. Among these are the following:

1. Access and manipulate the Census data at all levels inherent in its hierarchical structure.

2. Access other data and associate it with the Census data via a correspondence mechanism.

3. Display information from the database at varying levels of aggregation.

4. Draw district lines and other geographic areas.

5. Assess the extent to which districts meet the decision makers goals to the extent that those goals are quantifiable.

6. Create non-graphic descriptions of districts.

7. Provide flexibility to handle unanticipated analysis.

And these are just the basic functions. There must also be software for creating and updating the database. If the computer is to draw maps there must be software to drive the digitizer and store the data. If there are to be multiple users there must be software to provide security.

A review by Market Opinion Research of the software presented at the Harvard Graphics Weeks of 1978 and 1979 found no software package meeting all the requirements for an adequate political redistricting system. The solution for Market Opinion Research was to commission custom redistricting software from Daniel Fox of the Statistical Research Laboratory at the University of Michigan. This provided an elegant answer to the most important requirement -- flexibility. By

imbedding the custom software in an extensible statistical system -- MIDAS[3] (Michigan Interactive Data Analysis System) we achieved both the flexibility inherent in a general purpose package and the specificity of custom software.

The hardware requirements were easier to resolve than the software requirements. The decision was made to use a large general purpose mainframe computer in a timesharing mode. The size of the database and the necessity for quick response argued for this type of a system. Market Opinion Research chose to utilize Wayne State University's Computing Services Center because it offered a state of the art operating system, Michigan Terminal System, running on a state of the art mainframe, an Amdahl 470/V6. This system provided the computing power. The remaining hardware were input/output devices for building the database and for accessing and manipulating the database.

The basic user work station was a Tektronix 4014-1 graphics terminal with a Tektronix 4631 hard copy unit. These are connected to the mainframe via a 9600 baud digital phone line. The complexity of the images virtually necessitates a high speed line of 4800 baud or greater. Storage tube technology was chosen over raster because the maps require the accuracy inherent in the greater resolution of the storage tube. Color was rejected because of the slow speed of color devices. Most users also have access to a printing terminal. Some users have chosen to add desk top plotters to the basic work station.

The only additional hardware which has been necessary is a digitizer (Tektronix 4954). This was needed in our home office for

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[3]See Fox and Guire, Documentation for MIDAS, Statistical Research Laboratory, Third Edition, The University of Michigan, Ann Arbor, Michigan (1976).

the thousands of Census maps underlying the database. The user work station did not need to have a digitizer.

The last resource required was personnel. Staff needed to be trained in Census geography concepts, digitizing software and hardware process, election data techniques and the basic software. Some of the training took place at Census Bureau User Training Workshops. The personnel requirements should not be underestimated

PROBLEMS ENCOUNTERED

The major problems in any redistricting project will always be the heavy reliance on outside sources of information. The scheduling will be heavily dependent on the timely delivery of Census data and maps. The accuracy of the database will be beyond the control of the database builder. If there is an error in the Census map it is often difficult to recover from or patch around. The Census Bureau will at least be organized. The other data sources are less likely to be as organized. For example, election returns in a state are sometimes centralized in a Secretary of State's office and sometimes machine readable. Often one must collect the information from numerous county clerks in varying formats. The only solution here is diligence and perseverance.

Other major problems developed because of success. With several state databases on one mainframe the storage limits of the system were being pushed. With several user stations around the country it became

clear that more than a few redistricting users would begin to tax the response time of even a large capacity system. Fortunately, the states wound up doing their active redistricting at slightly different times.

The other major problem was also the result of success. With several users we found that each user wanted something different that we had not anticipated. The system proved to be quickly expandable but unfortunately the user always waited until the last minute and then wanted it immediately. Again, diligence and perseverance.

DOCUMENTATION

It is always helpful to look at the documentation as to how redistricting was done in the past. Unfortunately, because political redistricting happens only once a decade, it is rarely the case that the documentation can be located. Even if it can be found, it is likely to be of little use because the computing environment has changed dramatically in the past decade. For backgound material on redistricting, professional organizations like National Conference of State Legislatures were the most useful.[4]

Because we decided to create custom software and to design that software as user oriented, documentation was our responsibility. A user manual had to be written describing the concepts of redistricting and the operation of the software package.[5] Each state needed to have

[4] Reapportionment Law and Technology.

[5] Computer Assisted Redistricting Evaluation System: User Manual, Market Opinion Research, (1980).

documentation on the variable in its database. This described what election statistics were available to the user. Most users received two weeks training. They had to be familiarized with the redistricting software, the statistical package in which it was embedded, and the operating system. Fortunately all prove sufficiently easy to learn that users were able to operate the system on their own after only two weeks of training.

EXAMPLES

CARES was designed to facilitate the drawing of political districts through the use of computer graphics. It is capable of displaying maps of various levels of Census Geography as well as maps of various types of districts. The most important feature of the system is that the user can interact with the map and with the database through the map.

The CARES Connecticut database contains the entire Census PL94-171 data, election data for each election district (precinct) in the state, and a digitized version of every Census unit in the state. Every block and enumeration district has been digitized and is potentially viewable on the graphics terminal, hard copy unit or plotter. Putting every boundary of every unit on the screen at once would produce a useless display. The working assumption is that the user may want to see the entire state, but only want some relevant subset of boundaries.

Figures 1 and 2 show the result of the user selecting high level Census units for display. In Figure 1 we see the outline of each county in Connecticut. The counties are labeled with their FIPS code (Federal Information Processing Standard). In addition, a background map has also been drawn using dotted lines. These delineate the towns. In Connecticut, as in most of New England, counties are merely a statistical area; towns are the more relevant geographic units. In Figure 2 the user has used the towns as their basic display.

In Figure 3 we see the present Congressional districts again with a background of the towns. In Figure 4 we see an evaluation produced by CARES of the present Congressional districts. It shows the ideal popu-

Figure 1 Connecticut Counties

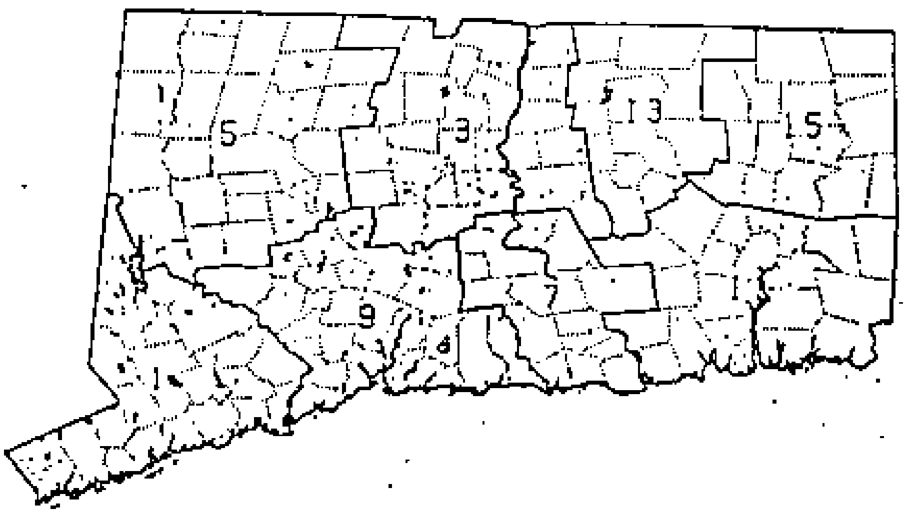


Figure 2 Connecticut Towns

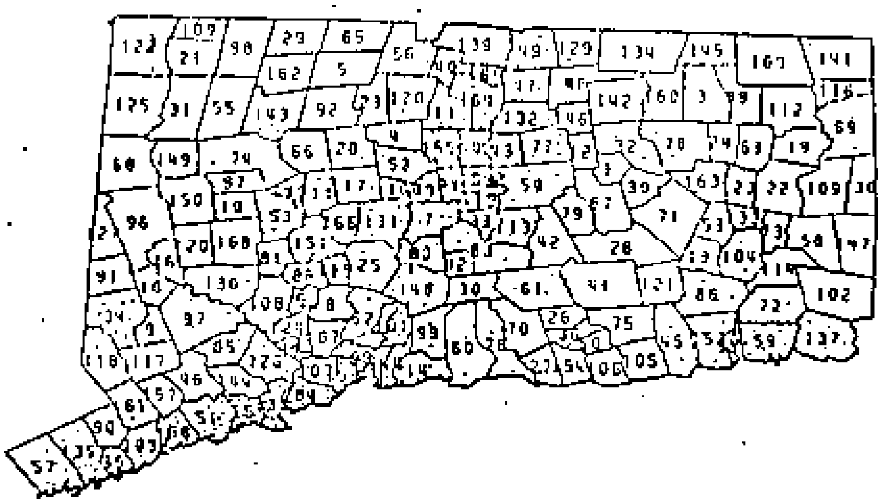


Figure 3 Connecticut Congressional

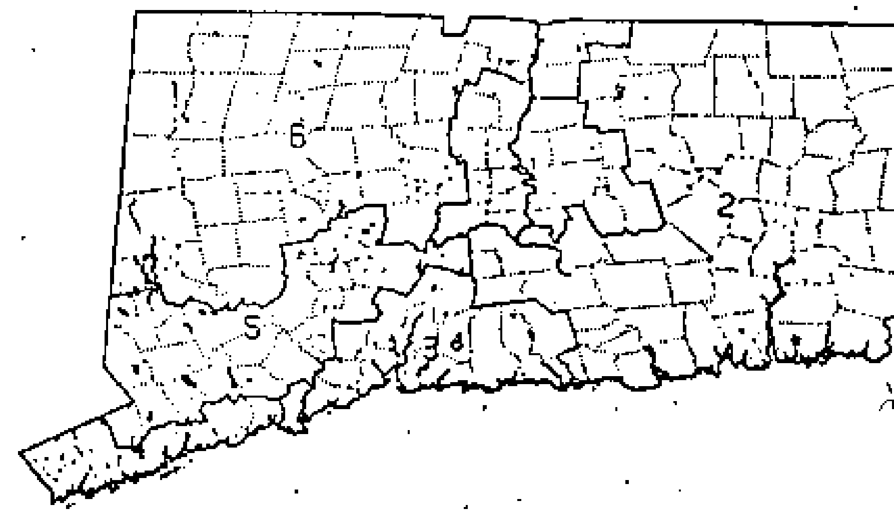


Figure 4 Congressional District Evaluation:

Analysis of CD

Ideal population size=517929 maximum deviation=1.00%

Dist #	Pop.	Dev.	Dev%	BLACK%	Compact.	Neighboring Districts
1	496060	-21869	-4.22%	11.9	.023%	2 4 5 6
2	537510	19581	3.78%	2.9	.022	1 3 5 6
3	513258	-4671	-.90	10.5	.018%	2 4 5
4	477833	-40096	-7.74%	12.1	.006	1 3 5
5	542327	24398	4.71%	4.8	.017	1 2 3 4 6
6	540588	22659	4.37%	1.7	.025	1 2 5

Average compactness=.017 Weighted compactness=.014
Extreme dev%=-7.74, 4.71 Deviation range=12.45

Hit RETURN for map or enter 'C' to continue or 'S' to stop lation size based on the 1980 Census data. For each district it displays the total population and the absolute and percentage deviation from the ideal district size. This is flagged with an asterisk whenever it exceeds a user specified maximum. It also displays a subpopulation percentage, in this case, percent Black. This could be any population count in the database including election returns. The next two columns in the table provide a geographic analysis of each district. The compactness is measured by a ratio of perimeter and area and flagged with an asterisk whenever there is a contiguity problem such as a district in two pieces. This flag can be triggered if a river runs through an entire district. It is the decision-makers job to decide whether this is a sufficient violation of contiguity to cause concern. CARES is merely alerting the user to potential problems. The list of Neighboring Districts is a touch list which tells the user which districts are possible partners for population or area exchange without causing contiguity problems. For instance, we see that District 1 is 21369 below the ideal and District 6 is 22659 above it. This list tells us that District 6 touches District 1. The user could decide to look for possible units along their common border to move from 6 to 1.

The remainder of the table presents summary statistics for the entire district plan. These figures or other calculatable from these have been used by the Courts to decide whether the "one man, one vote" criterion has been observed. In a sense, this table presents the basic problem for the redistricter. They must improve these measure of fit by moving areas and their population from one district to another. This tabular display and the map it is analyzing are displayed over and over again by the CARES user to see if the last set of changes has improved their districts.

Figure 5 Connecticut State Senate Districts

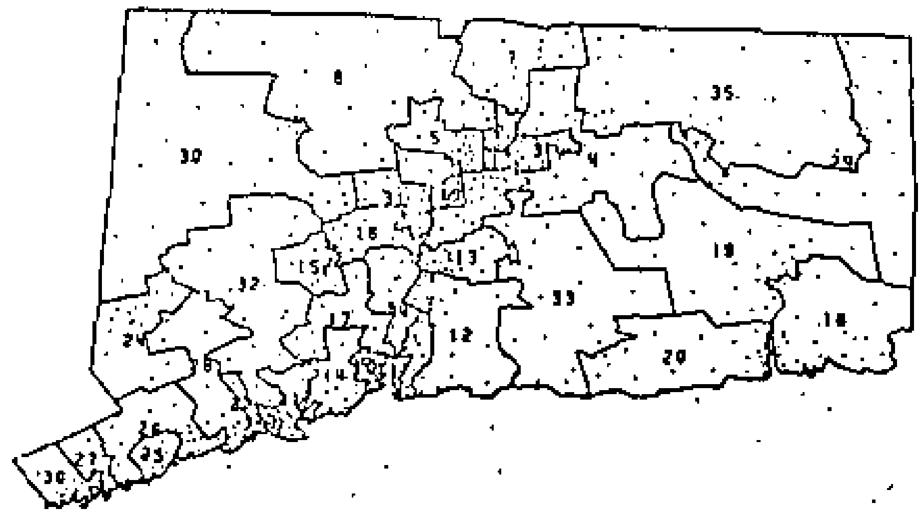
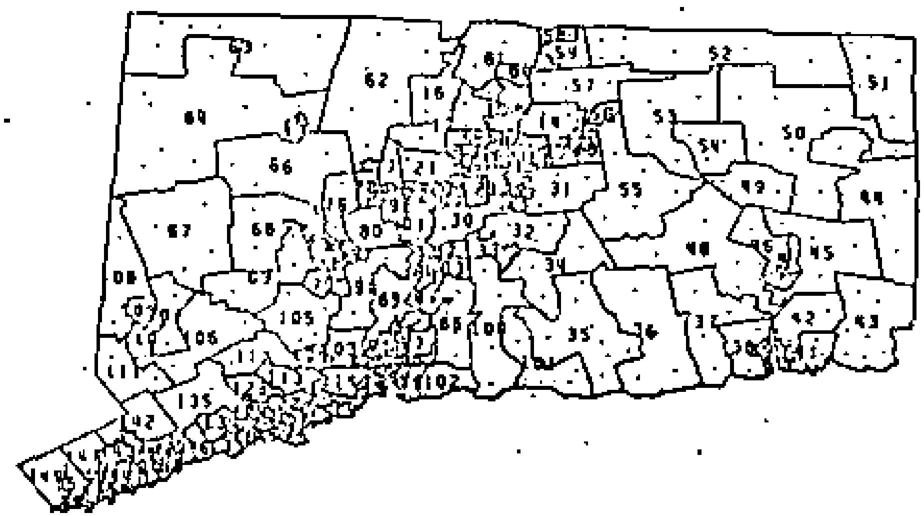


Figure 6 Connecticut State House Districts



In figures 5 and 6 the user is displaying the districts in the Connecticut General Assembly. As the number of districts becomes larger, the state map becomes less clear in the dense urban areas. The user will want to increase the level of magnification to see the finer grain detail in these areas. CARES provides several mechanisms for doing this. One is a windowing function where the user defines a rectangle to be redrawn to as a large a scale as is viewable on the terminal. The second is a zooming function where the user defines a point on the map to use as a center and a level of magnification. The third method is selection of a subset of the state's districts or precincts.

In figure 7 we see the finer grain detail. The solid lines show the precinct boundaries, the dashed lines show the block boundaries. The precincts are labelled with the code used in PL94-171 data. Figure 7 also shows the menu which the user points to in order to control the program. The menu includes the INFO, CODE and BUILD item which are the most important for redistricting. The CODE item allows the user to point at a precinct and code it (redistrict it) into a district. The BUILD item allows the user to point at a block and assign it to a different precinct. The INFO item is the user's access point to the information in the database. In Figure 8 the user has pointed to a block and is informed as to the identity of the block and that it has no population. All the information in the database is viewable in this manner.

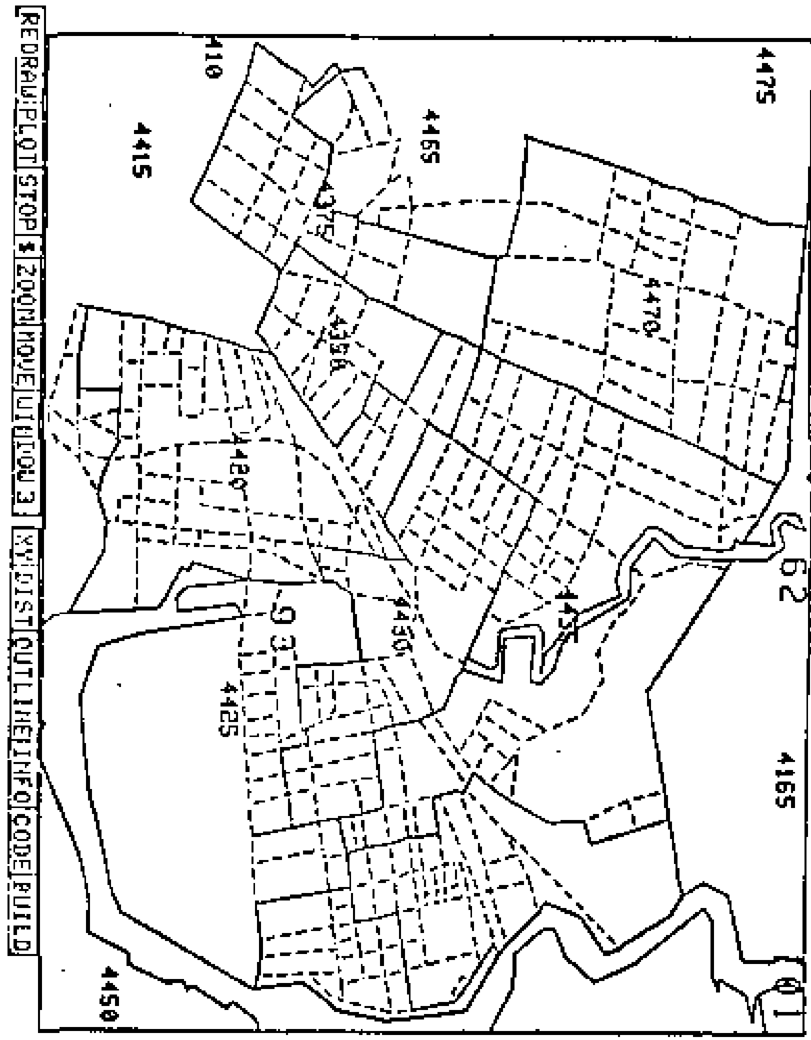


Figure 7 Blocks Within Precincts

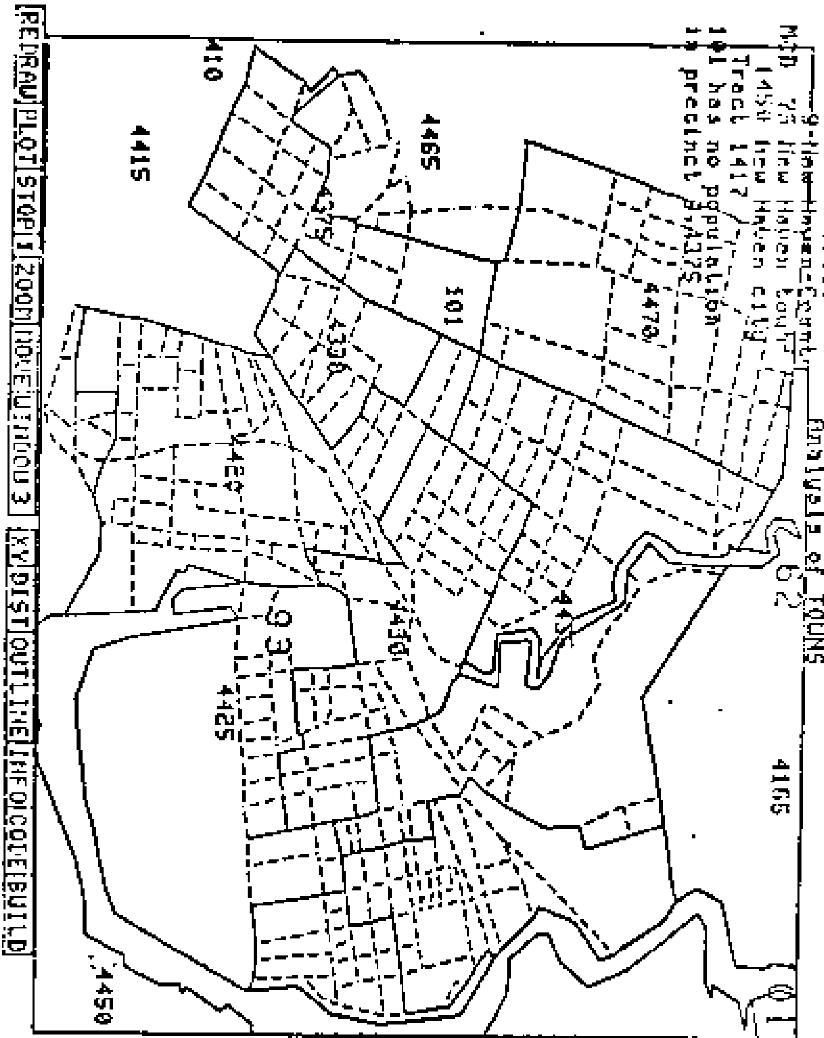


Figure 8 Block Retrieval

In Figure 9 the user has selected a particular district for display. The precinct boundaries are drawn with dashed lines as well as their centroids. The user has located two individuals in the display. This type of display is useful for showing decision makers the extent of a new district. Incumbents everywhere want to see just their district to see how it has changed. A graphic report of a district is useful during the redistricting process, but a nongraphic report is needed at the end of that process. A political redistricting plan must be formalized into law via a legal description of the districts. In Figure 10 we see a report of the highest levels of Census geography contained within a district. This report can be used to create a legal description.

In Figures 11, 12 and 13 we see a typical redistricting sequence. Two districts are displayed. Four precincts along their common border have been selected with the outline function. Through the use of the INFO item the user has determined that the four precincts have a total population approximating the number of people needed to be moved from District 5 to District 4. This is accomplished by pointing to the CODE item and to the precinct and typing the district number to move the precinct into. By pointing to the REDRAW menu item the improved districts are drawn and all information in the database is immediately updated. The mechanics of redistricting in CARES is just that simple.

Figure 9 Graphic District Report

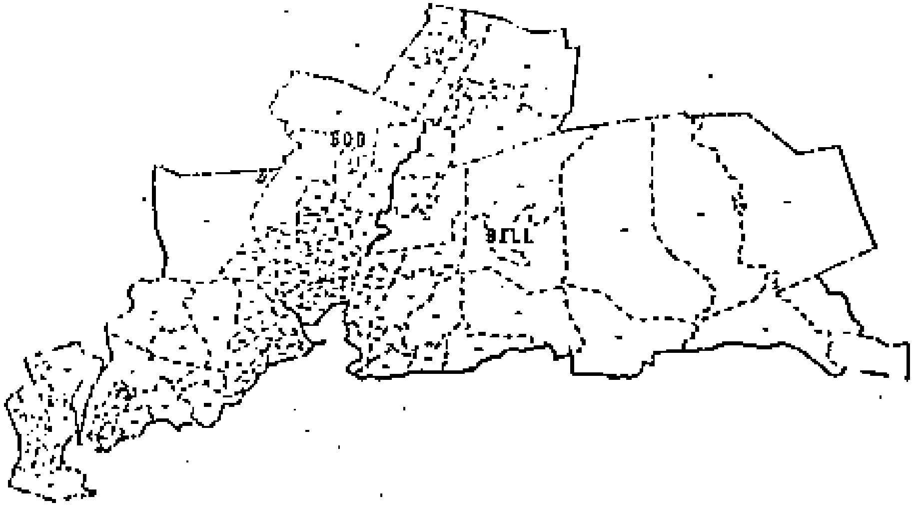


Figure 10 Non-graphic District Report

Demographic Analysis of Connecticut - District 4

	TOTAL	WHITE	BLACK	INDIAN	ASIAN	OTHER	SPANISH
1 Fairfield County							
MCD 18 Bridgeport town	142546	50196	29838	280	778	13316	26677
MCD 25 Darien town	18852	18718	87	11	98	48	431
MCD 36 Fairfield town	54841	53062	482	28	875	178	756
MCD 40 Greenwich town	59578	57464	1104	22	648	304	1235
MCD 65 Norwalk town	77767	64271	10832	80	674	2504	4621
MCD 90 Stamford town	102453	83478	15341	73	1354	4210	5762
MCD 110 Westport town							
Tract 501							
102	378	355	9	0	14	4	12
103	1171	1153	7	0	5	0	10
706	487	466	6	0	14	1	4
Tract 502	3781	3581	41	2	48	31	47
Tract 503							
102	2222	2192	20	1	7	2	20
103	1266	1246	8	0	7	0	5
104	1787	1760	7	3	8	0	16
105	732	723	9	0	4	0	14
Tract 504	2454	2397	29	3	17	8	62
Tract 505	4356	4260	41	6	34	28	101
Tract 506	3625	2078	24	1	20	6	49
Totals	476266	397774	67910	517	3953	18181	35552

4

Figure 11 District Selection

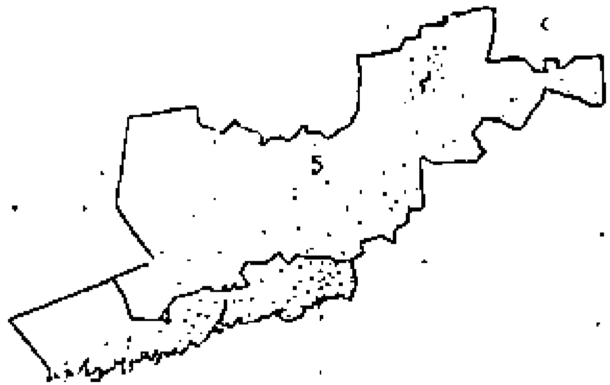


Figure 12 Redistricting Four Precincts into District 4

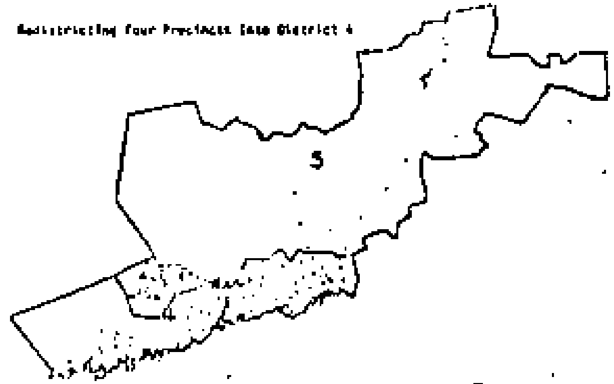
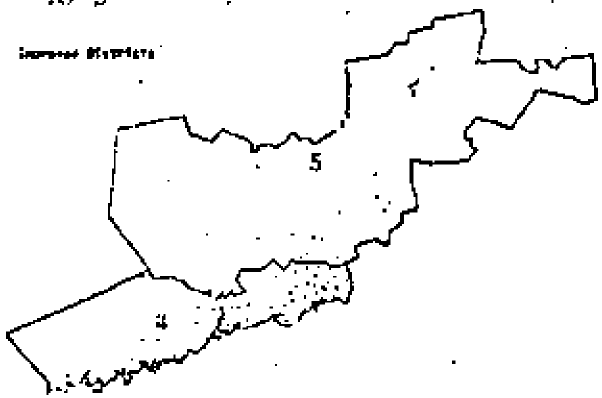


Figure 13 Improved Districts



RESULTS

It is too early in the political redistricting cycle to gauge the impact which computer graphics has had. As of this date, only a few of the states have completed the process. At this very moment redistricting plans are still being worked on in most states. One of the states using the CARES software completed the process within six weeks after the data were released by the Census Bureau. Indiana adopted its plans before the legislature adjourned on April 30. This required a monumental effort to complete the database and a massive effort to draw and redraw plans until the goals could be accomplished. The work station was operated twenty-four hours a day. The use of computer graphics probably allowed the plan drawers to create more equal population districts and more compact districts in a short amount of time and assess quickly the implications of their line drawing decisions and have maps.

A second state is close to completing its redistricting. The General Assembly of the State of Connecticut was farsighted enough to realize that both sides of the legislative aisle could share a common database and could develop their own plans with complete security. They have two user work stations and share the common database. This sharing arrangement is likely to become more common as legislators begin to develop a greater understanding of computers. Building a database does not bias the plans that are adopted. The computer is not guiding the process; it is controlled by the user.

Both the Indiana and the Connecticut experience have been similar. The computer graphics greatly aided them in understanding the results of their decisions. In both cases, users were frustrated until the database was complete, annoyed when they would hit bugs in the software or the database, and overjoyed as they finished their monumental task in record time. Without question, more plans were considered more completely using interactive computer graphics than could have ever been attempted without the facility for instant evaluation.

REACTIONS

The management of Market Opinion Research has reacted very positively to the use of computer graphics. Except for startup problems and problems resulting from outside data, all redistricting projects have proceeded relatively smoothly. There have been problems which have caused considerable uneasiness for periods of time, but no state has abandoned use of CARES. As a major new service, our redistricting has been extremely successful. It has given us great visibility with coverage by both national (New York Times, Newsweek, Washington Post) and local media in each state.

Management is also farsighted enough to realize that the software, hardware and expertise that we have developed for political redistricting will be transformed easily into a more general redistricting capability. As soon as the political redistricting is completed we will begin redistricting sales districts, delivery districts, etc.

The reaction of the technical staff has been very positive. They enjoyed learning new skills and having access to state of the art software and hardware. Their major problem has been the unrealistic time frame in which they had to operate.

HINDSIGHT GAINED

Experience is the best teacher. We learned many things the hard way. Software must be completed long before it is needed and tested and tested. Staff should be trained early. Clients should be listened to for their needs, but also are desperately in need of guidance. Too often we had to give in to their wishes when our guidance was unpersuasive. Users always demand more detailed information than they could possibly use. The databases were always larger than needed.

Our major system design decisions have proven to be good ones. We would still recommend using interactive computer graphics on a large time sharing system. We would also recommend using extensible statistical packages.

POTENTIAL FOR TRANSFER

Redistricting is going to be a high priority task for planners, legislators, marketers and managers for the next few years. Our experience lead us to recommend very strongly that they consider interactive computer graphics as an aid in their decision-making process. It was proven invaluable in political redistricting. Political redistricting has its own set of constraints, but in many ways is similar to our forms of redistricting. The decisions made are important. They must be well thought out. A lot of information must be considered. The data have a natural spatial orientation. Computer graphics will aid the decision maker.

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COLOR ISSUES IN COMPUTER GRAPHICS: A NON-TECHNICAL DISCUSSION

INTRODUCTION

> "Doctrines and theories are best for weaker moments. In moments of strength, problems are solved intuitively, as if of themselves."
>
> Johannes Itten

This quote comes from the Swiss artist and Bauhaus teacher's book, *The Art of Color*, a treatise filled with insights toward an informed use of color.

The trouble is that the user, seated in front of a color graphics system offering a theoretical palette of 8.8 *million* colors (such as the GE Genigraphics system for producing color slides), may very well experience a moment of weakness, and long for the tonic of succinct doctrines and theories to restore, not only his or her strength, but a coherent color image.

The trouble with *that* is that color, in our perception, definition and reproduction of it, traverses too many pathways to lend itself to neat sorting out in reasoned principles. What we have instead is the traditional rat's nest, to borrow an image from CADD applications.

The purpose of this short paper is not to trace the filaments of color perception and production, whether through the optical rods, cones and ganglion cells or through electron guns, phosphors and shadow masks, but to identify some of the dilemmas confronted by the unschooled user in applying color to a graphic image.

Some of the approaches to harmonious use of color articulated by Itten as early as 1919 (derived from study of paintings by artists such as Rembrandt, Titian and El Greco) are news to computer scientists or users composing a color graphic on a display terminal or programming output to a plotter, camera system, or color copier.

Since color is a relatively new "toy" in the industry, that is becoming more available and more sophisticated in palettes offered, a review of some basic ideas that have been developed on the subject may be salutary.

COLOR FAUX PAS

First, let's take inventory of what commonly can go wrong with color in computer graphics as it is now used. (I'm sure you can add to this list with disasters you have personally witnessed):

1. A color key dividing continuous data into groups (such as percentage of population having a certain characteristic) assigns a different hue to each incremental level, obscuring the continuous nature of the data and rendering the color graphic much less effective than a simple grayscale progression would have been.

2. Color choice does not relate to the data or classification scheme, so attention is drawn to a characteristic or area when no special concentration on that aspect is intended. For example, in a map showing the distribution of product sales, product #3 is keyed to bright red, whereas products #1, #2 and #4 are shown in muted shades of green, blue and purple. Product #3 data appears more compelling for no reason. (The opposite problem occurs where an aspect of the data that is equally important to other information being shown fills a very small area. In this case, the small data group must have a more conspicuous color in order to be seen.)

3. Color is overused. For example, there is a type of map (sometimes called a "pillar map") which combines a choropleth 3-d shaded base map with divided columns placed at polygon centroids. Logically, color is

important in distinguishing variables for the divided columns. If it is also used to differentiate areas of the base map, and further, to provide a 3-d shading effect for the base, the information shown in the columns is obfuscated. (The same problem arises in a 3-d column chart, where the shading of the columns may command as much attention as the sections representing information, and be confused with them.)

4. Colors are insufficiently differentiable. This is often related to problems of reproduction, whereby colors that are clearly dissimilar on a CRT display almost match each other in hard copy. This can also be due to metamerism; colors may look different under one lighting condition and alike under another.

5. Colors with specific associations are used without regard for their logical interpretation, e.g. when red is used to show profit, while we normally associate it with loss.

6. Saturated complementary colors are placed adjacent to each other, causing flicker, a sensation that the colors are vibrating. In addition to being distracting, this can cause eye fatigue and make it unnecessarily hard to read borders of colored areas.

7. Background color of the graphic is too close to one of the colors used to show data, so the image fails to stand out. Even if borders of the background and similar color are not adjacent, it can be confusing, as in the case of a white background where white also represents a data classification. The viewer is apt to interpret the white within the graphic as missing data.

8. Adjacent colors viewed at a certain distance appear to fuse together to form a third color, instead of maintaining their individuality. This is sometimes referred to as the "mosaic effect," and is likely to occur in a graphic with many small areas grouped together. (This is the principle on which color half-tone reproduction relies.)

9. Colors chosen do not anticipate the reproduction process, as when a color graphic will be photocopied in black and white or shown on a monochrome monitor.

10. Colors are simply garish, consummately ugly, or unpleasant in combination, repelling the viewer instead of inviting analysis.

DILEMMAS OF COLOR SELECTION

These are a few of the most obvious failures of use of color in computer graphics. The sheer quantity of color choice becoming available in computer graphics equipment can only make matters worse. Typical documentation explains how to specify color gamuts which range up to millions of shades, with precious little information on how to construct meaningful or effective color keys. For example, The Applicon Color Plotting System Basic Software User's Manual (March, 1980) details color codes, shading and scales which can produce 15,625 different color combinations. (This system omits black, but

otherwise operates in a similar fashion to four-color process printing, enabling the user to specify 24 different percentages of each of three primary colors.) Hints on how to harness the mind-boggling versatility of this range of color and pattern are nowhere present in the manual. Even the Hewlett-Packard System 45 color graphics manual, which makes a valiant effort to discuss color theory and terminology (far beyond what is normally to be found in equipment documentation), stops short of mentioning how these elements -- hue, saturation and luminosity, additive and subtractive primaries -- can be manipulated to form satisfying (or even legible) combinations. This system can generate 4,913 colors. The extent of the predicament is shown in the case of the AED 512 Color Graphics/Imaging Terminal, which can display 256 colors at one time, and is capable of designating some 16 million colors total. The basic manual (3/81 version) contains one page called "Color Setup" as the only escort through this vivid empire.

In the technical literature, there is ample discussion of color models and color solids, the physics of color measurement and specification, fine points of color terminology, color systems as approached in hardware and software, and reproduction methodologies. Here again, there is little one can glean that actually helps in making color choices for a graphic image.

Why the reluctance to suggest orderly approaches to application of color in computer graphics? Is color choice too individual? Is it too dependent on the particular application? Does each industry have its own guidelines or color preferences? Are we disinclined to write down anything so elusive when even the science of trichromatic vision has not been sorted out? Are we uncomfortable advancing the intuitive vocabulary and theories of art in a population of scientists and business people?

Once we venture from the quantitative to the qualitative aspects of color, the way is murky. Guidelines set down to make color choices more rational often contain their own inherent problems. This is evident in a recent article in <u>Computer</u> magazine (July, 1981), in which Lee Metrick is cited as suggesting that complementary hues display well together. He does not note the unpleasant vibrating effect produced by certain complementary pairs adjoining one another. He also proposes that viewing colors under tinted light can draw them together "by introducing a mellow tone." However, we see the color of an object because it reflects certain wavelengths of the light illuminating it (absorbing the remaining wavelengths). So, if red paper, which absorbs all the spectrum but red, is illuminated with a green light, the paper will appear black, because the green light contains no red to be reflected. A blue object illuminated with orange light will also look black because the orange contains no blue wavelength to be reflected. Obviously, the color and intensity of the incident light can have a drastic effect on the perception of the color image.

BASIC OBSERVATIONS ON COLOR EFFECTS

Sticking to the pragmatic, rather than the theoretical, there <u>are</u> some color observations advanced by Itten and others which we can review with a few notes on how they might apply to computer graphics color manipulation.

All visual communication, including that which employs color, depends first on contrast. Itten enumerates seven types of contrast in color work:

1. <u>Contrast of hue</u>. Hue refers to the colors of the spectrum, determined by wavelength. Continuous data is frequently shown by a key employing one hue in varying degrees of saturation (also called purity, and defined as difference of the hue from grey). Contrasts of hue are accentuated if color areas are bounded by black or white lines.

2. <u>Light-dark contrast</u>. Pure, saturated hues differ in brilliance, or light to dark value. E.g. pure, saturated yellow is a very light color, whereas saturated blue and violet are very dark. So a graphic using a range of hues at maximum saturation may not match in value. This is one of the reasons it is difficult to construct a color solid based on equal steps of saturation in color space; each hue will not reach maximum saturation in an equal distance or at the same plane of value. The Xerox 6500 color graphics printer only produces hues at 100% saturation, so yellow will always jump out much more brightly than, say, blue or green.

3. <u>Cool-warm contrast</u>. The yellow to red portion of the spectrum is considered warm, the green to violet portion cool. Conservative color

schemes often keep to either the cool or the warm side, since we are familiar with that progression of tones.

4. Complementary contrast. In light, which is based on additive primary colors of red, green and blue, each spectral hue is the complement of the mixture of all the other spectral hues. Complementary pairs in light (additive color mixing) yield white light when they are combined in equal intensity. Complements are opposite each other on the color wheel (which shows the spectral hues in sequence, joined in a circle at red and violet). In subtractive color mixing (referring to pigment, dyes or inks and based on primary colors of yellow, magenta and cyan) complementary pairs yield neutral greys when combined in equal proportions. (This will also occur as a result of optical fusion if complements are alternated in a small color pattern). Each complementary pair has its own peculiarities; for instance, yellow and violet form an extreme light-dark contrast. Red-orange and blue-green together form a warm-cool contrast. Cyan and orange in equal proportions will produce flicker when combined in the same saturation and lightness.

Subtractive primaries absorb or subtract their complement from the incident light. Cyan absorbs red light, and reflects green and blue. Magenta absorbs green, reflecting blue and red. Yellow absorbs blue, reflecting red and green.

Colors and their complements exhibit another phenomenon which is known as "after-image." If you stare at a color for a few seconds, then focus on a white sheet of paper, the after-image of the color will appear. This will be its complement. Orange is the after-image of blue; green is the after-image of red, etc. This effect can be important when

displaying large areas of saturated color, especially if shown in succession.

5. Simultaneous contrast. Areas of color that are juxtaposed can have a strong effect on one another. Grey takes on a complementary tinge to the hue it appears with, e.g. yellow next to grey makes the grey look purplish. Black placed on a red background can look green. This impression can be intensified or cancelled with addition of the hue or its complement. For example, a grey square on an orange ground will tend to look blue. If blue is mixed with the grey, the effect is even more pronounced. If orange is mixed with the grey, it will appear neutral.

Saturated hues bordering each other will seem to shift one another toward their complements.

6. Contrast of saturation. A saturated hue can be altered by mixing it with white, with black, with grey, or with its complement. In additive color mixing, the resulting color is always brighter than any of the contributing colors, whereas in subtractive color mixing, the result can only be darker than the lightest contributing color (since pigments subtract colors from the light falling on them). Because saturated colors always stand out more than greyed tones, it is important to match saturation to the level of attention the data deserves. It may be better to use a saturated hue to represent cumulative figures, deficits or projections if these should be seen above the component variables.

In reproduction, subtractive colors can never appear as saturated as their additive counterparts. Also, the same hue will look darker and more saturated when reflected from a glossy surface than from a matte.

ones. Slides, microfiche and 8x10 transparencies provide hard copy facsimiles of the saturated quality of colors on a color graphics terminal.

F. Contrast of extension. The amount of surface area occupied by a color is vital in calculating all other contrast effects. Itten remarked that "Attention to color areas in composition is at least as important as the actual choice of colors." Since most saturated hues do not have the same value, they must be used in certain proportions to maintain balance in a color image. Otherwise, certain colors will dominate, which may not be desirable if this does not reflect the data values.

A final area of accepted color effects that may be useful in designing color computer graphics is that of spatial perception. In the absence of light-dark or warm-cool contrasts, saturated colors will tend to seem nearer relative to desaturated ones. Generally, light colors and warm colors appear to advance, while dark or cool colors recede. A light object will seem larger than a dark one of the same size. Colors also change with the distance from which they are viewed. Bright orange and red are the most stable in this regard. An example of spatial distortion was reported in a paper presented at Harvard Computer Graphics Week '80 by William S. Cleveland and Robert McGill of Bell Labs. In a map showing equal areas of saturated red and green, subjects judged the red area to be larger. This effect did not occur when pastel colors were used.

CONCLUSION

The above remarks by no means exhaust the generalizations which have been published concerning color mixing and perception. However, they are intended (without totally exhausting the reader) to address pragmatic issues of color selection, such as those pointed out in the earlier list of "faux pas," which are not usually treated in the technical literature and manuals. Some references to issues I have skirted, along with citations for sources which expand on the information given here, are recorded in the bibliography.[3]

But, if you find yourself getting too stymied by the complexity of color issues, I recommend a relaxing read with the U.S. Department of Commerce National Bureau of Standards tome, COLOR--Universal Language and Dictionary of Names." If reading about colors referred to by names such as "Snowshoe," "National School Bus Chrome," "Deep Mouse Gray," or "Illusion" doesn't brighten you up, I can only suggest a vacation in the land of black and white.

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MAPPING SEISMICALLY HAZARDOUS HOUSING IN URBAN AREAS: A CASE STUDY IN THE USE OF THE ODYSSEY SYSTEM

INTRODUCTION

A considerable amount of housing exists in earthquake prone areas. In many regions of this kind, much of the existing housing stock was not specifically designed and constructed to resist the forces introduced by earthquakes. To planners, code officials, architects, engineers, disaster planning agencies, insurance companies and others concerned with the threat of natural hazards, the question of how these structures would fare during an earthquake is critical.

Of particular importance to these groups is the question of probable extent and geographic distribution of the damage that could be expected in a hazard prone area in terms of both the actual damage levels possible, e.g., light, moderate, heavy, severe, or collapse, and the probable number and location of housing structures experiencing each of these different damage levels. Of comparable importance is data on the relation between the total number of housing structures in an urban area exposed to an earthquake and the number which would actually experience damage. (Due to local variations in soil or geological conditions in an area and different inherent structural resistivities of different housing types, it can be expected that only a portion of the total population of housing structures in a stricken area would experience significant damage.)

Research was undertaken to establish a method for providing data of the type generally described above to interested users. The specific goals of the research were as follows:

A. to provide a method for identifying the range of different housing types (from single family units through various types of multifamily structures) that exist in any seismically hazardous urban area, for quantifying the numbers of the different types identified, and for mapping their relative geographic distribution;

B. to provide a qualitative assessment of the relative seismic vulnerability of a series of selected housing types found to be prevalent in hazardous areas, but whose seismic performances are largely unknown. Probable damage states as a function of varying seismic intensity levels were identified;

C. to provide a method for mapping potential housing damage distribution patterns in a hazard-prone urban area on the basis of mapped distributions of different housing types, a knowledge of their relative seismic vulnerabilities, and known mapped distributions of seismic intensity levels, geological conditions or soil types.

In order to accomplish the goals noted above, the research method required the gathering, manipulation, and analysis of large amounts of data defining the types and distributions of housing found present in hazard prone areas. The ODYSSEY system was developed for these purposes.

The ODYSSEY system is an extendible group of program modules for the creation, manipulation and display of geographic data. The scope of each module in the ODYSSEY system is functionally defined, embracing one particular type of data transformation. All modules communicate with one another using external media, typically sequential data files representing either polygons, chains, segments, data points, or data values. The system facilitates the manipulation of spatial data. Data overlays and selections are easily accomplished.

Following sections describe the use of the ODYSSEY system in connection with assessing probable damage distribution patterns in hazard prone urban areas. The first section outlines in more detail the methodology of the overall project and the points at which ODYSSEY was utilized. Subsequent sections detail specific applications of ODYSSEY and describe results.

DESCRIPTION OF STUDY

A section of Boston, Massachusetts (known to be earthquake hazard prone) was selected as the primary study area for purposes of developing the methodology. The research consisted of several major phases which are briefly described as follows:[1]

[1] The study is described in detail in the following report: Schodek, D.L. and Gauchat, U.P., "Patterns of Housing Type and Density: A a for Analyzing Earthquake Resistance," National Science Foundation, September, 1981.

1. Development of Data Bases. The primary method for determining the nature of the housing stock present in an urban area was through the analysis of readily available aerial photographs. Census, tax assessment, and other data bases, however, were used as well.

2. Housing Type Identification. Although communities normally contain many housing forms, a closer examination of the housing in a given community reveal the existence of recurring generic types (particularly in the medium to low density range). Some prevalent types can be isolated. Among them are single family detached and semi-detached houses, various kinds of row housing, triple-deckers, and high- and low-rise structures with single- or double-loaded corridors or point access circulation networks. A range of concomitant variants have evolved for each generic housing type due to the differences in contextual constraints and local building methods. Standard photogrammetric techniques were used to analyze aerial photographs with the intent of identifying the types and distributions of types present in the study area. This analysis was made possible through the development of a special housing typology which facilitated the classification of different aerial images. The typology was largely based on the type of dwelling unit access network present. Dimensional and feature analysis techniques were then used to identify different aerial images (see Figure 1).

3. Mapped Distributions of Housing Types. Data obtained from the photogrammetric analysis of aerial photographs was next mapped. Aerial information was digitized using a component of the ODYSSEY system. The digitized housing base map and the completed housing distribution maps are shown in Figures 2 and 3.

4. Analysis of Housing Type Construction. In order to later assess their relative seismic vulnerabilities, a general study of the construction of the different types of housing found to exist was made. Several selected examples were documented in detail (see Figure 1--Analysis of Construction).

5. Seismic Vulnerability Analysis. Based on the previously obtained construction documentation, assessments were made of the probable seismic performance of a series of selected housing types by a group of professional engineers with experience in the field. A questionnaire technique was used. Specifically addressed was the relation between specially defined "damage states" and varying seismic intensity levels for each of the housing types studies. The "damage states" used are briefly described as follows: "None to minor," "Light," "Moderate," "Heavy," "Severe to Collapse." Extensive definitions were associated with each of these brief descriptors which described the damage levels in terms of type and extent, costs to repair, effects on habitability of structure, etc. (see Figure 1--Seismic Vulnerability Analysis).

6. Mapped Distributions of Seismic Intensity Levels. For the selected study area, known distributions of probable seismic intensity levels, geological conditions, or soil types (depending on the type of available information) were mapped. A component of the ODYSSEY system was again used for the mapping (see Figure 4).

7. Damage Distribution Patterns. For the selected study area, potential housing damage distribution patterns were determined from the information gained from steps 3, 4, 5, & 6. Typical outputs include maps showing the approximate location on the ground of all housing which might be expected to experience the various damage states previously defined. Composite maps showing the expected distribution of damage states were developed (see Figure 5 through 8). The development of these maps were made possible through the overlay capabilities of the ODYSSEY system and is further described in the following section.

Associated with the mapped distributions illustrated, quantitative data describing the number of residential structures experiencing each of the different damage states was obtained based on ODYSSEY area calculations and density information.

THE ODYSSEY SYSTEM

The ODYSSEY system itself is a family of geographic information processing modules. Common file structure, language processor and other programming utilities provide ease of data transfer from one process

COYSSEY Cartographic Data Base Creation

Allows creation, verification, and modification of CDBs.

HOMER--The CDB file editor. Has abilities to do comprehensive error location and correction.

CYCLONE--Verifies CDB topological correctness or produces error reports.

PENELOPE--Automatic CDB chain file creation from digitizer or other line-file source input.

The use of ODYSSEY modules rarely follows a prescribed sequence. The order of their utilization varies with problem applications. This application of ODYSSEY to earthquake hazard mapping used only partial system capabilities. Descriptions of the processes utilized follow.

APPLICATION OF THE ODYSSEY SYSTEM

Task 3, the housing distribution mapping, involved use of HOMER, PENELOPE, and POLYPS to create, edit, and display the map. The housing type classification areas (based on the aerial photos and housing type analysis) were digitized for the Boston study area. The HOMER module facilitated this operation by echoing digitizer input, maintaining source controlpoints, and creating the ODYSSEY geographic files. Two companion files were input with HOMER: a "line" file containing source map coordinates without any labels to identify node, chains, or polygons; and a "point" file that associated polygon names with a digitized point within each polygon.

These two files then were input to PENELOPE which composed a topological (one that contained nodes, chains and polygons) file of the housing polygons. Minor digitizing errors were eliminated through PENELOPE's point coalescing process. (Two points that are closer than a specified tolerance distance are merged into a single point.) PENELOPE thus removed minor digitizer overshoots and undershoots; double digitized lines; and extraneous detail. Major digitizing errors remained, but were identified in a report file. This information was used as a guide for further error correction with HOMER. Continued processing with HOMER and PENELOPE continued until PENELOPE verified that the file was topologically error-free. The resultant CDB is shown as Figure 3.

The housing CDB was then related to a nominal values file that cross-referenced the CDB polygon names to 7 housing groups in POLYPS (see Figure 3).

The same processes of digitizing, file creation, editing, verifying, and display were used to map distributions of probable seismic intensity based on soil groups in Boston (task 6, see Figure 4).

With these two maps, (Figures 3-4) the distribution of seismic risk can be intuitively understood. However, risk information from the housing construction analysis and from the seismic vulnerability questionnaire were gathered to quantify severity of damage. In order to understand the effects of both of these factors in the study area, it was necessary to overlay the variables and their associated CDBs. This was accomplished with the WHIRLPOOL module.

to another. The philosophy of the ODYSSEY system is the use of sequential files for the processing of geographic data structured on a topological model. The topological approach allows for internal consistency checks on the data as well as advantages in performing necessary operations. The sequential file approach arises from a a concept of a "local processor," i.e., an algorithm which requires only local information to solve a problem in a band-sweep fashion. The file system organizes and processes the locality data piecemeal, reducing the amount of searching and main storage required. For certain applications, such as polygon overlay, the locality of the processor is a band of the coordinate space created by sorting the lines on one coordinate axis.

Analytic work in ODYSSEY is performed on a topological network structure of boundary intersections (nodes), polygon boundaries, (chains), and the polygons themselves. This topology defines complete cartographic characteristics of the map base.

Thematic map displays available through ODYSSEY include three-dimensional choropleth representations of polygon surfaces and two-dimensional shaded choropleth maps output on black-and-white display terminals and plotters; or on color raster or vector emulating terminals and plotters. Tabular outputs such as area calculations of polygons can be produced.

The functional descriptions of the ODYSSEY module capability are listed below. These descriptions are for the most part paraphrased from the ODYSSEY User's Manual.[3]

[3]Scott Morehouse, Martin Broekhuysen, and Bonnie J. Johnson,

ODYSSEY Mapping

POLYPS--Combines a cartographic data base (CDB) with a values file to draw a two-dimensional shaded "polygon" map of a geographic region. It allows flexibility in design through composition and placement of map elements.

PRISM--Draws three-dimensional perspective representation "polygon" maps.

PROTEUS--Performs standard modifications including line generalization, selecting a CDB subset, polygon aggregation, and map projection.

ODYSSEY Geographic Analysis

"Polygon overlay" is the most advanced analytic ODYSSEY capability. Two CDBs of a geographic region are overlayed to create a new CDB of the resulting areas. The analysis creates report files that, with further processing, allow the system to make complex decisions about new representations of the geographic region.

WHIRLPOOL--Performs the CDB overlay and writes report files.

CALYPSO--Performs values file aggregation, disaggregation and overlays based on the WHIRLPOOL report.

ODYSSEY User's Manual, Laboratory for Computer Graphics and Spatial Analysis, Graduate School of Design, Harvard University, Cambridge, Mass., 1981.

When PENELOPE evaluates a line file it identifies points where lines cross one-another and designates them as nodes. Similarly, WHIRLPOOL discovers the points where chains from the input overlay files are intersecting and gives them node designations in the WHIRLPOOL output file. These new nodes define a completely new chain boundary structure. The critical topological characteristic that WHIRLPOOL retains however, is the polygon names of the input file. Each output chain has 2-input polygon "ancestors", in this application, a soil and housing polygon ancestor.

Figure 5 demonstrates the overlap of a small portion of the study area file. In Figure 5, the housing polygons are labelled 3 and 4. A soil polygon boundary between soil types 1 and 2 crosses the sample area and then creates housing-soil geographic units from the original five in the housing CDB. WHIRLPOOL assigns 3-digit names to the new polygons in the overlay CDB of 103, 104, 203, and 204, but the relationship to the ancestor files is maintained : (1 and 3 yield 103, 1 and 4 yield 104, etc.).

The WHIRLPOOL creation of the housing-soil overlay CDB allowed the mapping of the seismic vulnerability data. Figures 6 through 8 thus represent a damage severity estimate based on two variables. The maps directly answer questions such as: "Is a single family unit located in the soft soil region at greater or lesser risk than a row house on firm soil? How much? What is the expected distribution of the worst damage based on these two variables? What proportion of the study area will be inhabitable after an earthquake of Modified Mercalli Intensity 7? After an Intensity - 9 earthquake?

Further research is being conducted concerning the quantification of damage using the ODYSSEY system. WHIRLPOOL and CALYPSO are being used to overlay a census tract map with the housing-soil CDB. This will allow the disaggregation of a variety of census variables to the damage classification base. From this process results for these questions will be obtained:

How many housing units are classified with moderate, heavy and severe damage?

What is the value of the destroyed or damaged housing?

How many people live in affected housing?

How many would lose their lives and, most importantly,

How can these deaths and costs be reduced?

SUMMARY

The final damage distribution maps (Figures 6 through 8) that resulted from the application of the ODYSSEY system can now form the basis for making policy decisions for mitigating earthquake effects or planning for aftermaths. These measures, for example, would include targeted seismic strengthening/retrofit programs by building code officials. They are also useful for specific "life line" planning by disaster planning agencies, i.e., what is the probable extent of aid required and where is it needed.

Without the ODYSSEY system, it would have been infeasible to develop these maps due to the large amounts of data involved. The

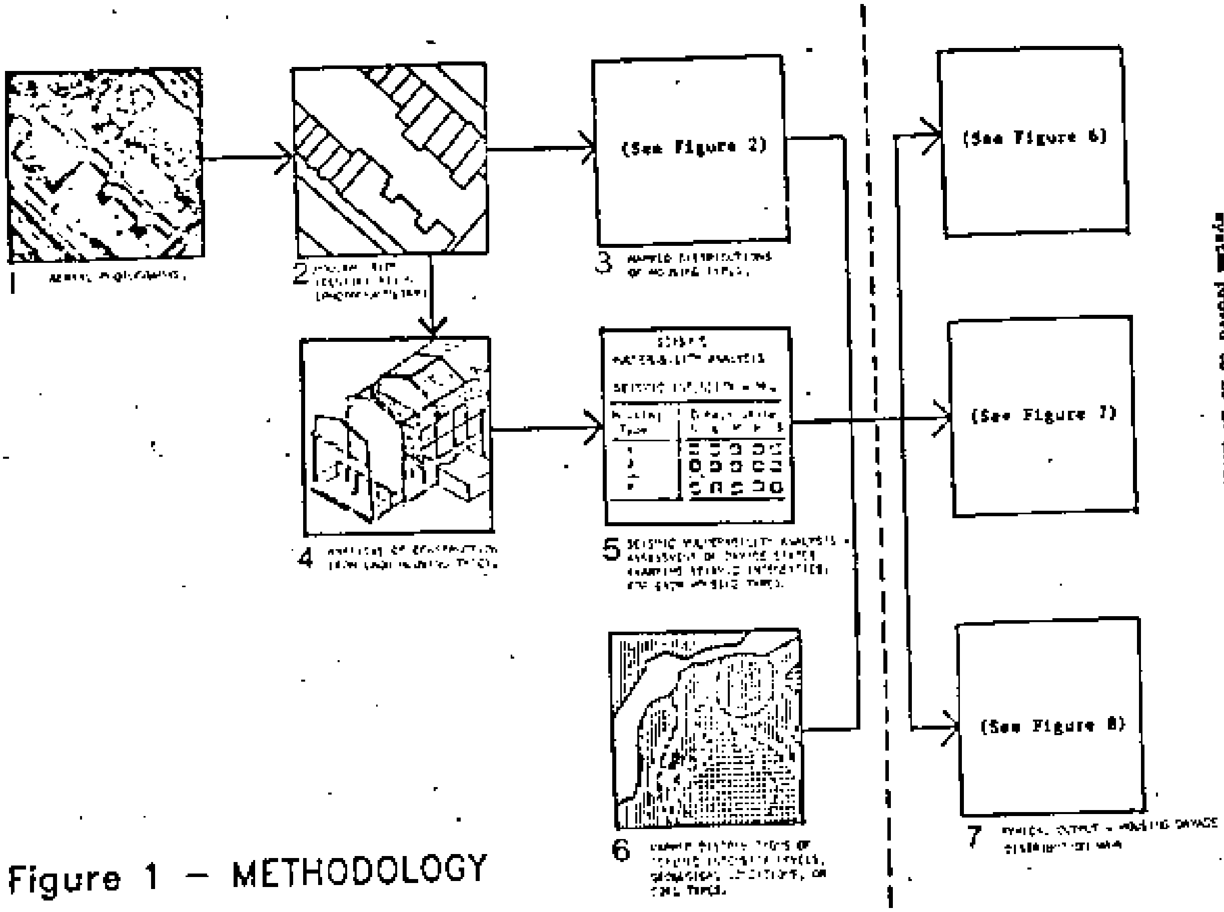


Figure 1 — METHODOLOGY

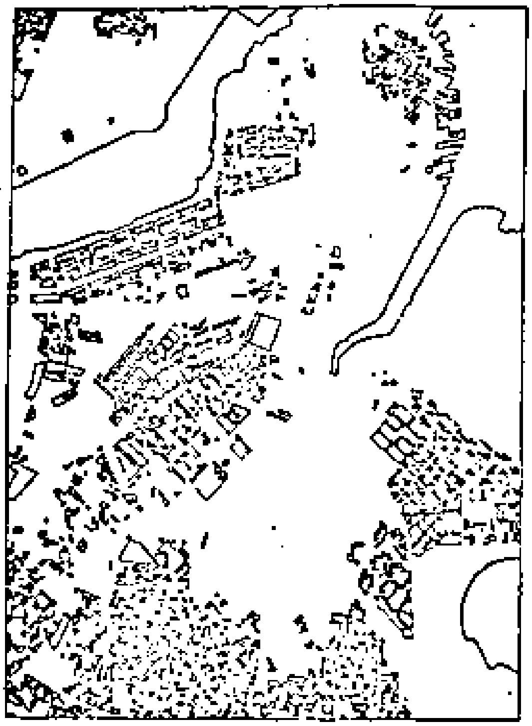


Figure 2 — CARTOGRAPHIC DATA BASE (HOUSING)

system proved to be an invaluable tool.

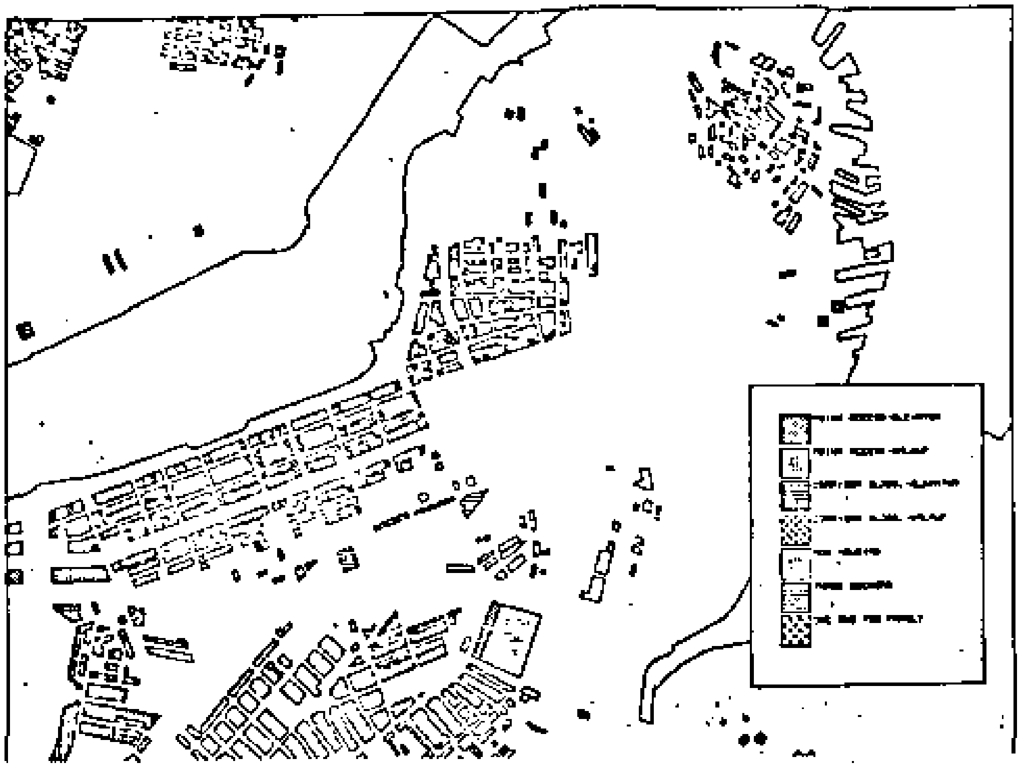


Figure 3 – HOUSING GROUPS (north half)

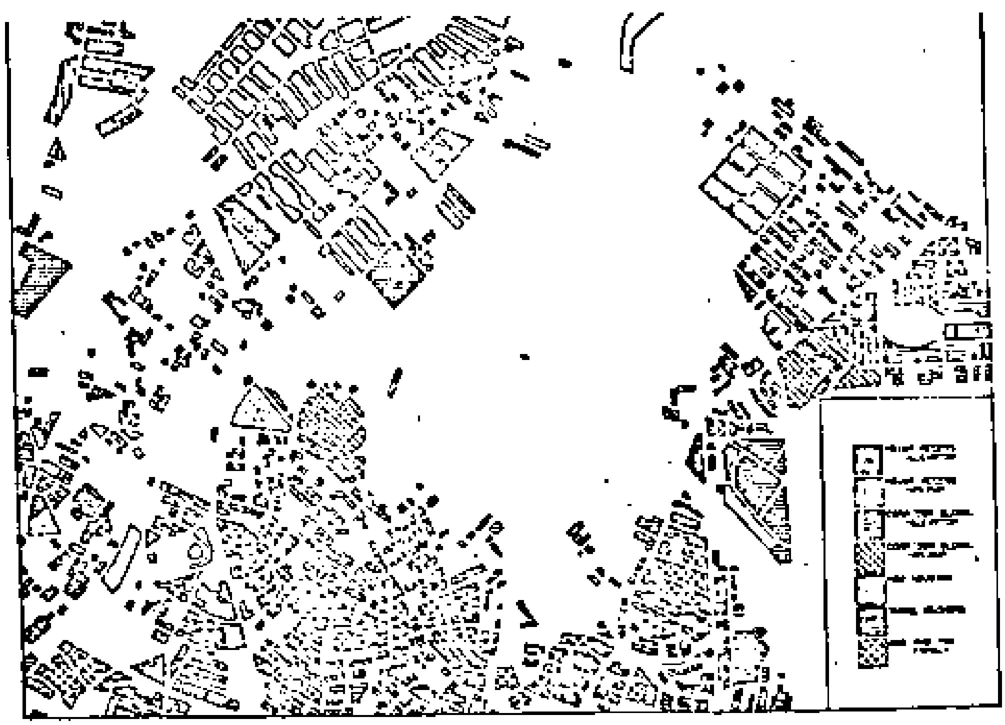


Figure 3 – HOUSING GROUPS (south half)

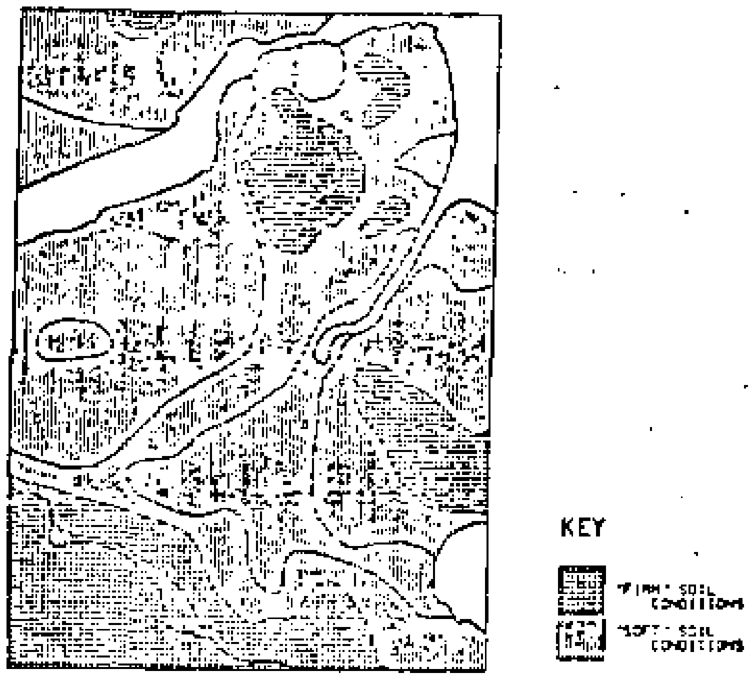


Figure 4 – SOIL CONDITIONS

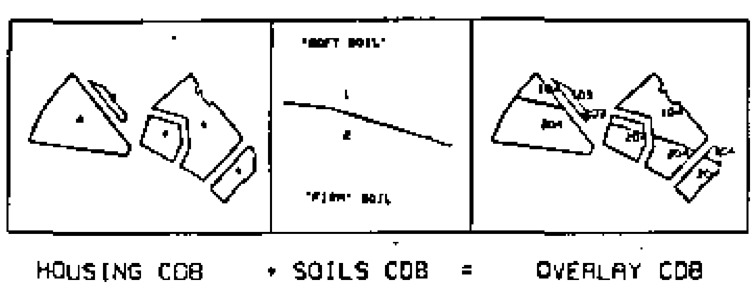


Figure 5 – ODYSSEY GEOGRAPHIC ANALYSIS

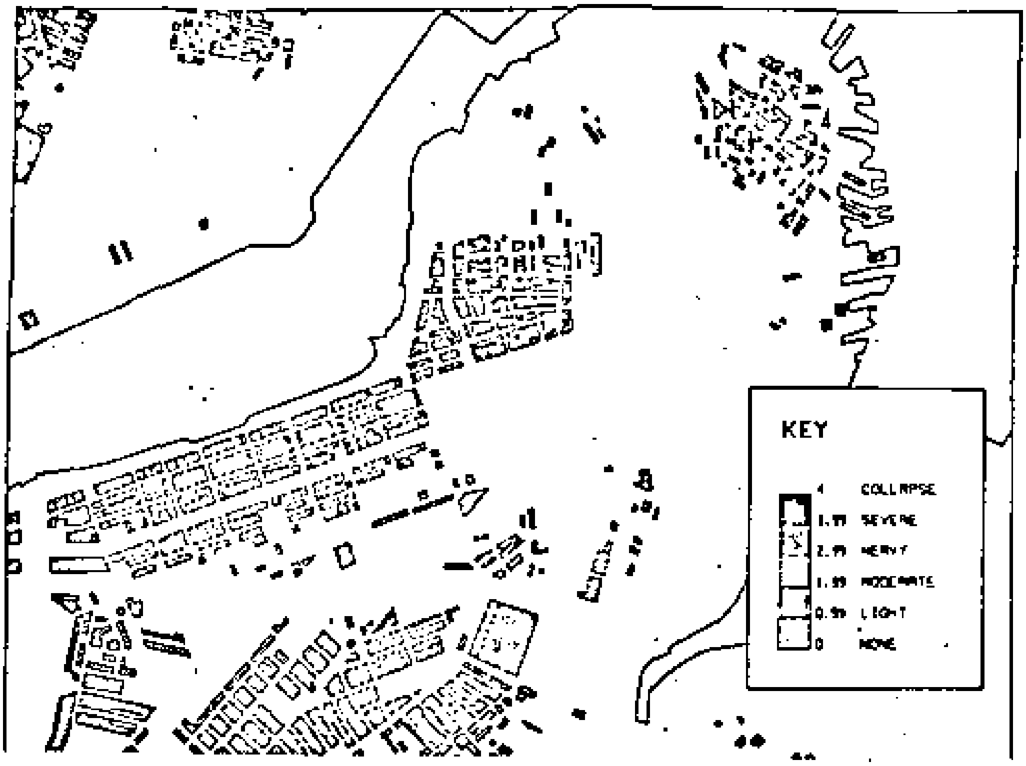
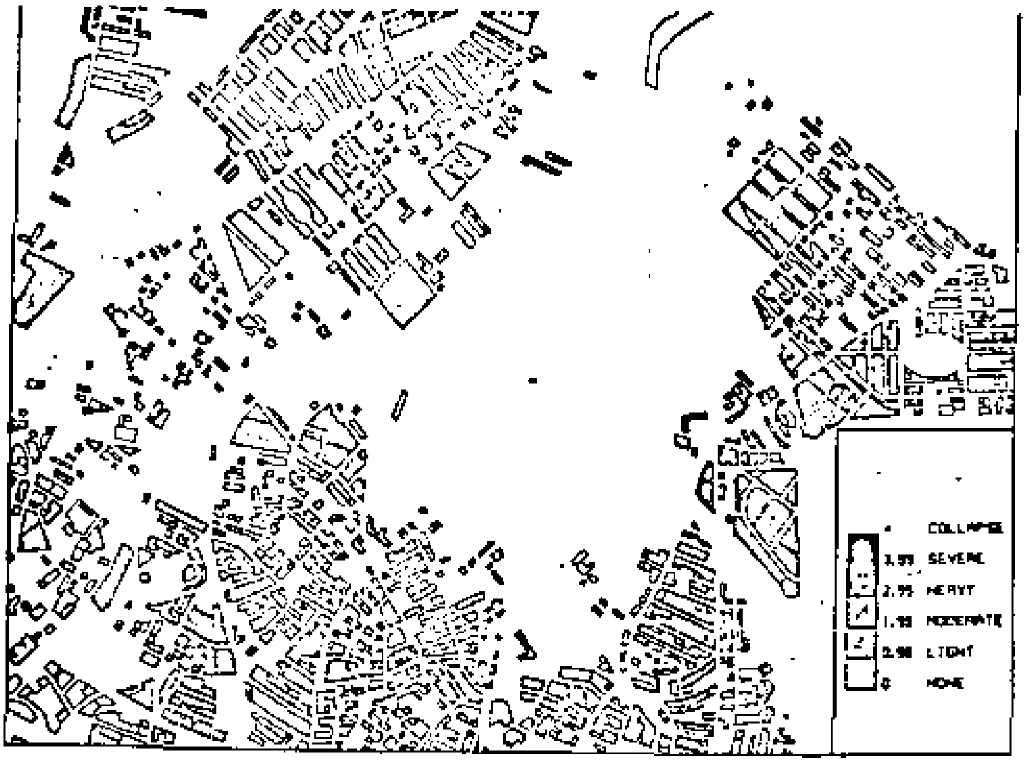


Figure 6 – PROBABLE DAMAGE STATES
Modified Mercalli Intensity = 7 (north half)



Figu 6 – PROBABLE DAMAGE STATES
"fied calli Intensity = 7 th half)

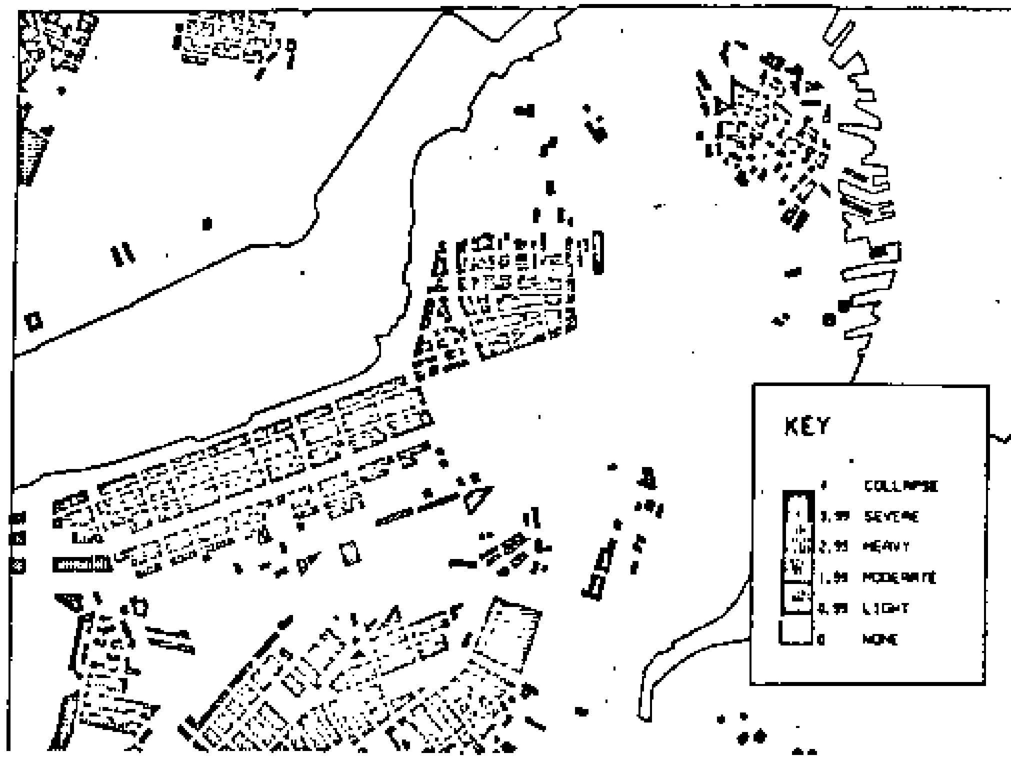


Figure 7 – PROBABLE DAMAGE STATES
Modified Mercalli Intensity = 8 (north half)

Figure 7 – PROBABLE DAMAGE STATES
Modified Mercalli Intensity = 8 (south half)

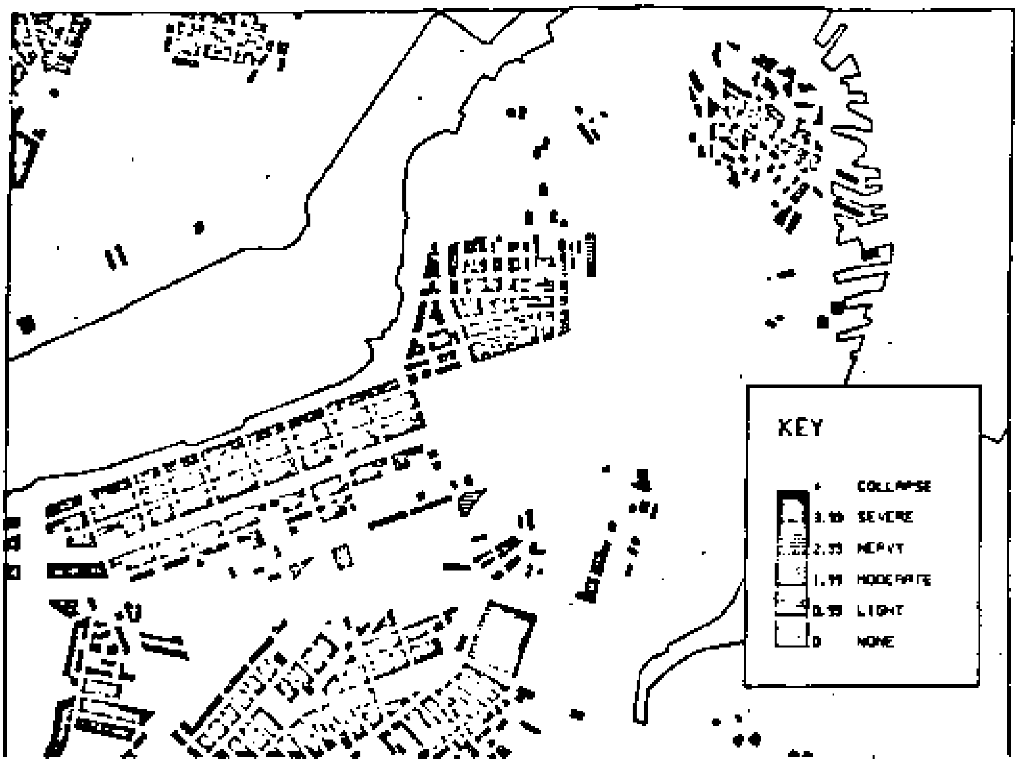


Figure 8 – PROBABLE DAMAGE STATES
Modified Mercalli Intensity = 9

(north half)

Figure 8 – PROBABLE DAMAGE STATES
Modified Mercalli Intensity = 9

(south half)

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COMPUTACION APLICADA A LA PLANEACION URBANA

APENDICE BIBLIOGRAFICO

III

* Land use and transportacion models: structural comparison

** Land use and transportation models: an overview

*** Analyzing urban development issues using sequential land use data and a geodatabase: a case study from limburg, the netherlands

**** A written description of the network software product

***** Geographic information systems the ODYSSEY proyect

****** Zipmap^{tm}: an automated system for mapping 5-digit zip codes

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LAND USE AND TRANSPORTATION MODELS: STRUCTURAL COMPARISON

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Charles D. Laidlaw, CONSAD Research Corp

MODEL STRUCTURE

Either land use or transportation models can be used to illustrate a model's structure; however, the primary emphasis of this article is on the structure of land use (activity allocation) models. A burgeoning body of literature is available for reviewing past, current, and prospective land use models. The interested reader should consult these references for a fuller understanding of these models.[1] There are several ways to classify and categorize land use and transportation models; their structure, both design and construction, is one important way.

The urban land market defined in the context of land use models

The structure of a land use model must help the user to determine the marketplace for urban land, so that if changes take place external to that marketplace, it will be possible to use the model to forecast the likely land use consequences. Ira S. Lowry, one of the founders of land use modeling, explains the market for urban land (in the context of land use models) in these terms:[2]

> Urban spatial organization is the outcome of a process which allocates activities to sites. In our society, the process is mainly one of transactions between owners of real estate and those who wish to rent or purchase space for their homes and businesses. These transactions are freely entered contracts, neither party having a legal obligation to accept the other's offer. These elements suffice to define a "market". . . . The market process of transactions between willing buyers and willing sellers determines the spatial organization of urban activities in a very immediate sense. . . . Models of urban development must reflect the institutional arrangements of our society if they are to reproduce the results . . . .
>
> [Given] the dynamics of the land market, . . . each period's market-clearing solution is examined by landowners for clues to profitable investments in site-improvements. As improvements are installed on particular sites, establishments reevaluate these sites. The matrix of demand prices is thus altered, and a new market-clearing solution is in the making. . . .
>
> The passage of time also brings changes in the number and types of establishments seeking locations. Existing establishments also change in their characteristics, households change in size, manufacturers acquire new production methods, retailers shift product-lines. . . .

Land use models must reflect behavioral attitudes and market supply and demand

A land use model must deal, in some way, with both existing land uses as well as the succession of land uses created by dynamic market forces. Land use models must represent the location and migration behavior of both households and firms that seek to locate, work, and produce at specific places. Land use models also should deal with market supply and market demand, reflecting which land users are more willing than others to relocate or even emigrate from their current locations.

Not surprisingly, none of the land use models currently in use handle all of the preceding market phenomena. Some models are more explicit and more realistically reflect human behavior than others. The Lowry-type models discussed in the next section are probably some of the most behaviorally realistic and understandable land use models.

TYPES OF LAND USE MODELS

Types of projection methodology for land use models

Land use models fall into categories based on their projection methodology:

- Simulation forecasting models
- Controlled variation of independent variables models
- Analytic mathematical models

Some of the models described in this article fit into a combination of categories; they will be classified, however, by their primary use. Moreover, the statistical techniques used for describing relationships between model variables in each of the model systems (e.g., factor analysis and multiple regression), are not necessarily related to the projection methodology and can be discussed independently.

Table 1 compares the characteristics, advantages, and disadvantages of major, operational land use models.

Simulation Forecasting/Lowry-type Models

Simulation forecasting models — projections are based on theoretical frameworks for urban activities

Simulation forecasting models integrate the results of statistical data analyses with various theories concerning urban growth, decline, and/or development to forecast urban development. Statistical methods used include standard regression techniques, time series analysis, equations based on the probability of occurrence of various phenomena based on empirical evidence, or any combination thereof. These models joined with, and in some cases constrained by, judgments of experts are then combined into a sequence of equations that take input data, evaluate the interrelationships, and produce output data updated to the end of the forecasting period. This approach, compared with that of controlled variations of independent variables (discussed in the next section), features the simultaneous development and interaction of submodels and a structure for integrating their outputs. In simulation forecasting models, the conditional projections of the future are based on predominant theoretical concepts accounting for urban activities and representing them as theoretical frameworks for the relevant urban characteristics under study.

Description of the Lowry model

The most well-known and widely used example of a simulation forecasting model is the Lowry model.[1] The Lowry model is comprehensive in that it deals with all activities that consume land, although a number of predictable variables are taken from outside the model system, particularly the spatial distribution of basic employment. "Basic" defines those parts of the economy that are not dependent on the local population; essentially, the industrial or exporting sectors. The nonbasic sectors are broadly defined as service sectors.

Assumptions involving activity rates and economic base are used in the Lowry model

The Lowry model is ingeniously constructed based on a few simple assumptions. Given total basic employment by industrial/employment sector, the equivalent population supported by these jobs is calculated, making an assumption about an activity rate. Given a further assumption about population demand for services, a multiplier is calculated that leads to an estimate of total service employment and total population. In effect, two simple sets of assumptions, involving activity rates and an economic base, are used to replace the extended sector models used in other types of models.

Table 1. Comparison of Operational Land Use Models

Spatial distribution of activities in the Lowry model

The spatial distribution of activities in the Lowry model are produced using simple gravity equations that are linked through an iterative mechanism that also involves land use accounting. Initially, the spatial distribution of basic employment is assumed to be given, and workers and their families are assigned to residences in a gravity-like way around workplaces. The demand for services, measured in units of service employment, is then distributed in a gravity-like way around these populations. At each stage of the iteration, land use constraints (given maximum density service and minimum size constraints) must be satisfied.

Basic employment assumptions

The first assumption made in the Lowry-type model is that basic employment opportunities are directly or indirectly responsible for most development decisions. They are the driving force behind the model and trigger all later calculations within the model. The other major determinants are independent population growth and development projects. The initial step in the Lowry model is to project basic employment for the region, county, and city for several employment categories. These projections are then examined for probable labor force participation and patterns of journeys to work, which are then exploded into an estimate of total population of the city. This population estimate is then compared with an independently derived set of small area projections by age, sex, and race. The employment estimate dominates the assumption, but the relative proportion of the distribution of population by age, sex, and race as projected independently remains the same.

Site-oriented employment assumptions

The second assumption distributes site-oriented employment opportunities throughout the surface of the city and assumes that various types of the site-oriented employment will gravitate to specified areas of the city according to several locational criteria (e.g., present employment clusters, land use policies, access by various transportation modes, and assessment patterns). Future employment is also evaluated in terms of minimum (empirically determined) size of firm, capacity for each Standard Industrial Classification (SIC) grouping in each small area unit, and sites available for new firms. Locational characteristics are manipulated until this portion of total employment is distributed across land uses. If no satisfactory sites are found, the location constraints may be relaxed or public policy changed to accommodate the new employment; the alternative implies that employment will leave the city.

The effect of employment upon the location of households assumptions

The third assumption allocates employment, which is not site oriented but residentially oriented, and calculates the effect of all employment upon the location of households. Households tend to locate at prescribed distances from work, and commercial service employment tends to cluster at locations within prescribed distances from households. Ethnic, occupational, and economic characteristics of households also determine household location. In addition, the types of housing offered by the area serve as constraints on the location of households. In other words, given the attributes of previously located employment, households of a certain size are located within a specified distance and at predetermined locations, thus creating service employment at specified distances from the households. The new employment generates new households that produce additional service employment, and so on. The process is constrained by present residential and commercial settlement and land use policies.

Wingo-type model framework

Other Lowry-based models have used a mechanism similar to the preceding one to allocate housing demands to housing supplies — one of these models is the Wingo scheme.[4] The Wingo model framework focuses on the major spatial interdependencies of the housing market's supply and demand as follows:

- Housing supply — data pertaining to the stock of housing units. There are two important aspects of housing unit data: spatial distribution and the functional characteristics of relevant housing units. Both dimensions can be entered as follows:

  $_kS_i$ = number of housing units of class k located in subarea i. The letter k refers to the classification of housing stock into qualitative and functional groupings so that each class may behave ideally as a homogenous good on the market. Qualitative differences refer to age, condition, and internal services of the structure (e.g., plumbing, hot water). The functional differences pertain to size and character of construction (e.g., elevator apartment). Thus every group k is distinct from all other groups either in terms of character or quality of the unit. Subscript i refers to the analytical area (e.g., planning area, tract, zone). Ideally, areas should be defined so they are homogenous with respect to k.

- Housing demand — Two characteristics are relevant to the consumption patterns of housing. One refers to the household characteristics and its consumption patterns. The other pertains to the primary locational constraint of the household in the Wingo scheme.

  $_hD_j$ = number of households of class h that are based in area j.

  Here h is based on socioeconomic and demographic characteristics (e.g., household size, composition, income, race). The letter j represents the subarea exerting the primary locational constraint on the household. In many cases, j refers to the area where the household's employment site is located. The assumption here is that the choice of a residential location area will be sensitive to the location of employment (at j). Other examples of j may be university area for students or medical facilities area for the aged. At this point, we have a spatial distribution of the housing units by market classes ($_kS_i$) and on the demand side of the market ($_hD_j$) specified by consumption aspects (h) and spatially (j, the area with the dominant activity relevant to households).

Occupancy and vacancy variables

The supply and demand functions can be utilized to define two variables: occupancy and vacancy.

- Occupancy — $_{hk}W_{ij}$ = that part of $_kS_i$ occupied by $_hD_j$ (i.e., the number of class h households based in area j occupying k class housing in area i).

  In this expression, ij may refer to the journey to work relationship, while hk represents the households of class h interested in class k housing units. In other words, the underlying idea is that the h class household whose head may have a job in subarea j has chosen to live in a house class k in subarea i, weighing in the spatial relationships between i and j.

- Vacancy — $_kE_i = \dfrac{_kS_i - {_kW_i}}{_kS_i}$ where:

  $_kE_i$ = the vacancy rate in housing class k in area i.

  $_kW_i$ = the housing units of class k occupied by all households "based" on all subareas or

$$_kW_i = \sum_h \sum_j {_{hk}W_{ij}}$$

  $_kS_i$ = number of housing units of class k in area i.

All of the above formulations refer to housing stock by location and class of housing.

Housing policy analysis

Having developed the concepts of housing supply and demand, the Wingo construct helps its users perform the following type of housing analysis.

- Housing policy — Housing policy is concerned with the succession of changes in the following variable.

  $_{hk}W_{ij}$ (the occupancy variable).

  This variable reflects the outcome of housing market processes with or without various public policies. It also suggests the appropriate form of housing policy objectives. Thus, one may identify one set of values for $_{hk}W_{ij}$, say $_{hk}W'_{ij}$, which is the desired set of the city's housing units for type k for a particular household (h — say the client group of interest) in area i. Then the policy objectives emerge quite directly. They are the actions intended to close the gap between $_{hk}W_{ij}$ and $_{hk}W'_{ij}$.

  The values of $_{hk}W'_{ij}$ may be (in practice) derived from a variety of more general analyses. The ij relationship is influenced by the transportation network planned. It may depend on a host of other institutional relationships. The h values are largely influenced by regional and national conditions (e.g., economic growth, industrial mix, immigration, etc.).

  The value of k or housing types is influenced by the existing stock of housing as well as by the public policy view of what constitutes a desirable improvement in the level of housing welfare. In other words, the type and number of housing types recommended for household type h will be influenced by the nature of the current housing stock and certain standards suggested by welfare considerations.

Controlled Variation of Independent Variables

Statistical relationships significant in controlled variation of independent variables models

This second class of land use models depends more on straightforward statistical relationships and less on the theoretical concepts used in the Lowry model systems. Distinctions of basic and service employment, household types, and access differentials that are crucial to the Lowry models, are less significant in the controlled variation of independent variables models.

The process behind the controlled variation of independent models is described in the following scenario. Suppose that a plan is proposed and its outcome is forecasted. The question then arises — suppose certain inputs and independent variables (i.e., those outside the control of the planner or decision-maker) are changed? Answers can be provided by the technique of alternatives testing. Further, experimental design (a technique that determines how the greatest amount of information about the impacts of alternatives can be selected for a given amount of experimentation) can be used to test the impacts of a multitude of alternative plans. A prime example of the controlled variation of independent variables methodology is the EMPIRIC model, used in dozens of planning studies over the last 10 to 15 years.

EMPIRIC. In the EMPIRIC activity allocation model, dependent variable values (those partially under control of the planner or decision-maker) are treated as indicators of growth or change and are used to prorate exogenously (beyond the control of the urban/region in question) estimated growth for each major land use activity. EMPIRIC rationale is as follows: the development of land for population and employment is highly interrelated, and the development of land for various uses is influenced by many external causal factors. The EMPIRIC model extensively uses the statistical method known as indirect least squares, a commonly utilized statistical technique.

EMPIRIC allocates population and employment activity to changes in land use

EMPIRIC allocates projected increases or declines in regional population and employment to a set of smaller subregions or districts.[3] These allocations of future activity are then translated into equivalent changes in land use for each subregion. The allocation process is designed to reflect the impact of major regional policy decisions on the future pattern of urban development. Policies concerning the provision of improved transportation and public utilities services, zoning and density controls, and the availability of land for development are emphasized.

Functions of EMPIRIC

EMPIRIC is intended to fulfill three major functions:

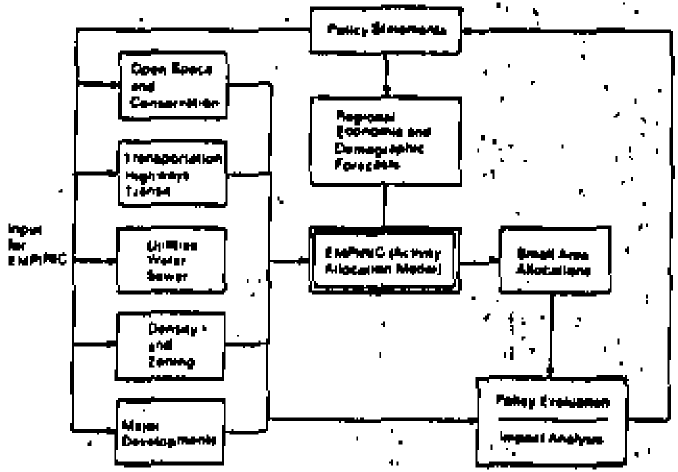
- Generate subregional forecasts of the future distribution of population, employment, and land use set in a format appropriate for subsequent input to more detailed transportation, environmental, and related functional planning activities.
- Provide a way for assessing the probable impact of major regional policy decisions on the future distribution of regional activity.
- Provide a quantitative framework for the coordination of regional policy decisions in a variety of functional areas.

Figure 1 shows how EMPIRIC draws on several sets of urban development conditions in order to produce projections for subsequent policy evaluation and impact analysis.

Components of EMPIRIC

The EMPIRIC model consists of four basic operational components:

- Simultaneous Equations Module — uses data on urban development conditions as reflected by an extensive array of variables dealing with activity levels, land usage, and policy conditions, in order to generate statistically derived estimating equations. These equations are used in allocating zone-by-zone shares of regional population and employment change to subareas of the metropolitan area.
- Forecast Monitoring Module — compares zone-by-zone totals of existing and projected activities with policy limits in order to determine where overages exist. Such overages can be reallocated to other zones.



Source: Puget Sound Council of Governments, PSCOG Facilities Plan Evaluation Test, 1976

Figure 1. Use of EMPIRIC to Produce Projections for Policy Evaluation and Impact Analysis

- Land Use Consumption Module — utilizes data on present and desired development characteristics to convert activity allocations into estimates of actual land usage by allocated activities.
- Supplementary Submodels — perform calculations necessary to provide estimates of households by size, population by age, automobile ownership, and similar factors of concern.

Specific requirements for the simultaneous equations module

Development and use of the EMPIRIC simultaneous equations module requires statistical, regression-based calibration of a set of simultaneous estimating equations intended to generate data on households, stratified by income group, and employment change by industrial sector. More specifically, the household categories projected by the module are low income households, low-middle income households, upper-middle income households, upper income households, and unrelated individual households. The employment equations project data for the following employment groups: retail employment change, service employment change, manufacturing employment change, government and education employment change, and wholesale, transportation, communication, and utility employment change.

Statistical calibration of the simultaneous equation module identifies sets of effective projection variables, and the estimating coefficients to be associated with them, for use in projecting zone-by-zone shares of geographical activity changes. The estimating equations are estimated interdependently (a dependent variable to be estimated by one equation may well be treated as independent in one or more other equations). For example, the zonal share of upper income households is estimated by one equation, but it is also used to help estimate the share of upper-middle income households generated by another EMPIRIC equation. This means that the variables used in EMPIRIC are somewhat more interdependent than in statistical regression models that do not utilize the simulated regression approach characterizing EMPIRIC.

The data required for parameter estimation of the simultaneous equations module is of several types: base year shares of households/employment, various measures of land use, and several transportation access variables. The simultaneous equations module also requires input of data on such urban/regional policy reflectors as extent of sewer service, location of renewal projects, and existence of amenities.

Sample requirements for the land consumption module

Data requirements for the EMPIRIC land consumption module are as follows: existing land use acreages classified by type, existing and projected changes in population and employment by whatever classification available data permits, designation of land use/activity combinations, definition of types of development in terms of the degree of urbanization of the area, and nominal development densities for each land use/activity combination and each development type.

The four operational components of EMPIRIC require data generated by the simultaneous equation module on household breakdown by income category. In addition, the components require base year, future year, and temporal changes in the household size and population by age variables.

EMPIRIC district-level forecasts

When the EMPIRIC statistical relationships are determined, the model system is capable of making district-level forecasts of households by income group, employment by industrial sector, land use acreages by type within each district, households by structure type, households by size, population by age, and automobile ownership. The model system can use these district-level forecasts to make small area forecasts to model the impact of alternative policy schemes. For example, the system can be employed to address questions relating to transportation systems planning, evaluation of major regional developments, evaluation of alternative regional settlement policies, and similar metropolitan development inquiries.

Mathematical Optimizing Models

Mathematical optimizing models are oriented to strategy calculating

As opposed to simulation forecasting models, mathematical optimizing models are oriented to strategy calculating. For example, assuming that various urban growth developments have been forecasted, how can development be effected to best cope with undesirable outcomes? In the case of industrial blight, analysis may have revealed that there are a few key factors causing the blight, and the problem then becomes one of eliminating the negative factors. Deciding among the alternative ways of accomplishing this task is a problem of deciding upon the best policy/planning method. Various techniques from the field of operations research and analytical decision theory are applicable. The results of these techniques will be satisfactory strategy, in terms of time or cost, for accomplishing the stated objectives.

Few continuously operating mathematical optimizing models exist, although there have been several one-time applications.[5]

TRANSPORTATION MODELS

The system of models used in transportation planning

Six types of analytical land use and transportation models make up the system of models used in urban planning. Figure 2 illustrates the sequence of use and flow of information among the following models.

1. Regional Socioeconomic Forecasts — Estimation of control totals for economic and demographic activity for the region.
2. Land Use Allocation Model — Allocation of regional totals for economic and demographic activity to analysis zones within the region.
3. Traffic Generation Model — Estimation of total originated traffic and terminated traffic (e.g., measures of traffic outflow and inflow for each analysis zone).
4. Traffic Distribution Model — Allocation of each zone's originated traffic to specific destination zones (e.g., other analysis zones and the zone under consideration) and the allocation of each zone's terminated traffic to specific origin zones.
5. Modal Split Model — Allocation of total origination/destination flows to individual modes serving each given origination/destination.
6. Traffic Assignment Model — Allocation of mode-specific origination/destination flows to specific network links, superimposed for all origination/destination pairs to obtain total link flows.

The design behind the four transportation models (items 3 through 6) is derived from the proposition that travel behav-

LAND USE AND TRANSPORTATION MODELS: AN OVERVIEW

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THE EVOLUTION OF LAND USE/TRANSPORTATION MODELS

Since the late 1950s, mathematical computer models have been used to assist in the analysis of urban problems and to pull together many diverse elements that, taken together, represent what analysts know as urban areas. The focus of these mathematical computer models has been on urban transportation ground systems (automobile and transit) and urban land uses (more simply referred to as urban activity allocation modeling), both of which are core functional elements of cities and metropolitan areas.[1] This article presents a discussion of how these models work and how they help urban analysts make better decisions about preferred land use mixes and transportation system investments and operations.

Traditional urban transportation and land use modeling systems

Most urban transportation and land use modeling/planning systems are descendants from the late 1950s Detroit and Chicago Metropolitan Area Traffic Studies. Figure 1[2] depicts the elements in the traditional urban transportation and land use modeling/planning process. The process was initiated with the forecasting of growth in socioeconomic activity (e.g., population, employment, and personal income) for the

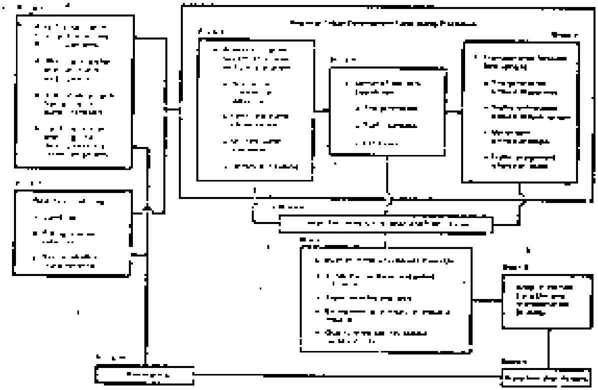

Figure 1. Comprehensive Urban Transportation/Land Use Allocation Analysis and Planning Process: An Overview

entire urban or regional area, based on a prorating of national or regional trends or some other such projection strategy (see Block 1 in Figure 1). In addition, other "givens," including alternative ground transportation systems under investigation and policies (e.g., zoning regulations) guiding land use development, were taken into account in the growth forecasting.

Activity allocation systems

Growth is typically measured as changes in population and employment (socioeconomic characteristics), land uses, and transportation networks for a specific base year referred to as a base-year inventory (see Block 2 in Figure 1). These overall urban- or regional-area population, employment, and income growth totals were then allocated to small subareas within the total urban or regional area by using some strategy that was initially devoid of any explicit sensitivity to transportation. This strategy is sometimes called a land use model or activity allocation model (see Block 3 in Figure 1), since it determined projected land consumption associated with the socioeconomic activity forecasted for each subarea.

Trip generation, distribution, modal split, and assignment

Based on these land use forecasts, volumes of traffic origination and of traffic termination were then estimated by a trip generation transportation model (see Block 4 in Figure 1). Existing utilization patterns were concurrently reviewed to identify major congestion problems. Planners would then specify alternative "skeleton" transportation systems for the future. These skeletons were fashioned to cover a range of systemwide alternatives, but they left considerable freedom for detailed location and design decisions for individual components of the skeletons. Given these skeleton specifications and the small-area trip generation forecasts, demand forecasts were then created to estimate the equilibrium pattern of network utilization for each hypothesized skeleton (see Block 5 in Figure 1). The demand forecasts were derived by the series of models (see Block 4 in Figure 1) that characterize trip, traffic, and land use direct effects as a function of hypothesized transportation policy variables and socioeconomic variables.

Summary of changes to the urban land use planning process

The preceding planning process was continued extensively into the mid-1960's as a trip forecasting tool. Changes to the process as it was practiced evolved in the following manner:

- Change 1 (1952-1962) — Initially (late 1950's to early 1960's), land use planners speculated on qualitative notions of future land use patterns and used these alternative land use hypotheses to generate alternative transportation flows. Planners in these early years would visualize, however crudely, how dispersed regional settlement patterns would lead to vastly different urban and corridor traffic flows from those of either a centralized or a multinucleated land use pattern. Land use patterns, however, did not change as a result of transportation system change.
- Change 2 (1963-1969) — Later, planners/modelers incorporated transportation accessibility into the subarea land use forecasts (see Block 3 in Figure 1), which in turn gave more meaning to the demand forecasts. For the first time, the land use (or activity allocation) models were rendered sensitive to transportation by means of an accessibility variable, a measure that weighted the socioeconomic attractiveness of other subareas by the difficulty of traveling to that subarea (i.e., intermodal impedance). These impact models characterized indirect effects as a function of transportation policy variables.
- Change 3 (1970-present) — In the most current approach, the results of the land use allocation model are fed directly to the evaluation stage (see Block 7 in Figure 1), since such estimates of impacts (indirect effects) are increasingly valuable information for decision makers; that is, the consideration of larger and larger scales of transportation investments as well as alternative land use policies have led to a consciousness of indirect effects — economic, traffic-related, environmental, and quality of life.

Using a variety of objectives, criteria, and analyses, a preferred land use and transportation strategy (see Block 8 in Figure 1) is adopted. Through explicit implementation actions (see Block 9 in Figure 1) and feedback (see Block 10 in Figure 1), the initial sets of concepts and policies are revised and the base-year inventories are updated (or at least reviewed).

Four parts of an overall urban and regional transportation/land use models system

Typically, the battery of computerized models used in the urban and regional transportation/land use planning processes is complex. The overall model system(s) can be seen as having four interrelated parts, as illustrated in Figure 2.

- Economic-Demographic Model — uses economic base concepts, statistical estimating equations, cohort-survival population dynamics, and informed opinion to project urban/regional population and activity totals in response to economic and social factors impinging upon the region and its future.
- Activity Allocation Model or Land Use Model — uses economic-demographic outputs and statistically derived estimating relationships in order to distribute households and employment to subareas of the geographic area in response to development factors, policy variables, and activity indicators, in addition to determining evident departures from desired results and calculating likely future land usage amounts.
- Transportation Planning Models — draw on activity allocation model outputs to determine trip generation, trip distribution, modal split, and trip assignment patterns for an urban/regional transportation system serving an array of transportation planning zones.
- Data Base — provides input data for the models and other planning purposes, serves as a sequential data source for successive models in the planning model series, and absorbs planning model outputs as data for use in other urban or regional planning activities.

In addition, planners must input to the modelling system alternative versions of land use sketch plans as well as potential transportation supply alternatives. These land use and transportation plans can be changed as often as the planner wishes to examine alternatives.

Compared with activity allocation models, transportation models are typically better documented and are already part of a well-articulated planning process formally mandated by legislation and regulation. Activity allocation models have progressed in the last two decades; however, a great deal of leeway still remains in how the land use/activity allocation subsystem fits into the total planning and analysis process.

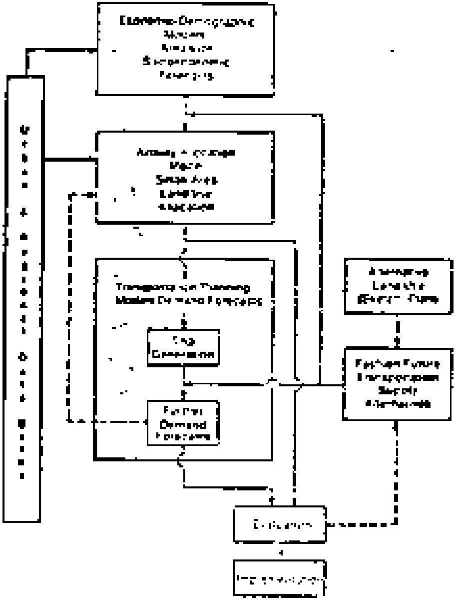

Figure 2 The Modeling System Urban Transportation/Land Use Allocation

INTERACTION BETWEEN MODELING AND PLANNING FUNCTIONS

Model building must be placed in the context of policy analysis

In carrying out a planning process in which planning models are being used, those involved — planners, systems analysts, economists, and public administration specialists — have stressed the need to move from the process and mechanics of model building to the development of a product meeting user needs and providing users with information they want.

Interaction of modeling and planning

If properly integrated into the overall planning structure, modeling allows decision making to drive planning and, in turn, planning to drive modeling. The interaction of both modeling and planning functions is shown in Figure 3, which also indicates some of the lessons learned in model building:

- Models are designed to assist in the planning policy formulation and reformulation process. To be useful, models need to deal with those decisions and strategies most important to the planners and others who will be using them.
- Data is gathered and hypotheses to be tested in the model system are formulated after the entire model system is conceptualized. Data that is not useful in the model-assisted decision process is less useful to the entire planning process, and hypotheses that cannot be analyzed in the model system cannot be formally tested.
- All steps in the model development process must relate to uses in planning policy formulation, evaluation, implementation, and reformulation. The quality of decisions concerning how (or whether) a certain land use or a specific segment of the transportation system is to be altered can be considerably improved by a relevant model system that estimates what the economic, travel, environmental, and quality of life implications are likely to be.
- Public input at the five stages indicated in Figure 3 is becoming increasingly important to successful planning policy making. Effective model design and usage, therefore, must also include provision for public participation in model use and model system design, testing, and implementation. In some jurisdictions, the public is encouraged to use the model system and is trained in all facets of its design, structure, strengths, and weaknesses.
- There are many steps in planning policy making (several of which are noted in Figure 3): policies (to be tested) must be formulated, once models are tested, then planning policies can be evaluated, and with public input, the selected policy is implemented. Policies must be reevaluated, and, finally, policy can be reformulated and alternatives generated for further testing, analyses, and policy redesign and improvement.

A major thrust of today's urban and regional planning is seen as surveying prospective users of planning policy in order to determine how their concerns can be combined in a practical planning context and to encourage these users to enter the process at as many decision points as indicated in Figure 3.

What Models Can Do

Computerized land use and transportation planning models can be (and have been) used to serve a wide variety of

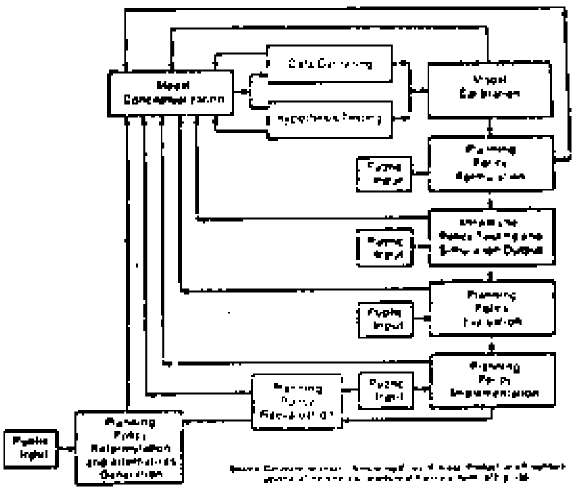

Figure 3. Interaction of Modeling and Planning Functions

Models can produce data for a broad range of areas

planning purposes. Given the available techniques, a battery of planning models can be designed to produce either generalized regional development patterns (e.g., Standard Metropolitan Statistical Area (SMSA), multicounty, or city council) or detailed local area allocations for zones suited to whatever specific planning assignment is at hand (e.g., within a city or a group of neighborhoods). A compact modeling system can readily and inexpensively generate overall patterns that are likely to be relevant to almost any urban or regional situation. In similar fashion, subregional systems designed to fit the development dynamics and geographies of specific counties, cities, or even neighborhood groupings can generate individualized patterns of land use socioeconomic activity. Finally, detailed small-zone allocations tailored to the particular zone-by-zone characteristics relevant to transportation planning, housing concerns, environmental considerations, or even fiscal implications can be generated as follow-on output.[4]

What Models Cannot Do

Underlying the generalization about what models can do is an equal realization that models cannot do everything expected of them. They cannot generate reliable and sensible results at the extremely fine-grained detail often called for in a particular planning application (e.g., the desirability of zoning one high-value land use versus another one immediately adjacent to it for a specific high-rise building project). In addition, traditional models are ineffective at anticipating types of behavior that have seldom occurred, such as the impact of high energy prices on automobile travel and housing search patterns.

State-of-the-art models may be able to deal with situations where traditional models fail

State-of-the-art models do exist for dealing with the preceding specialized issues, and the results of these models can then be used in the standard models under consideration in this article. Even the state-of-the-art models are suspect when pushed to generate extremely minute detail from gross and highly conditional regional control totals. In addition, state-of-the-art models do not function well when applied to areas of concern in which generalized uncertainty exists; examples include social patterns affecting behavior, the impacts of a Proposition 13 type of fiscal reform, or the introduction of new and reliable electric-battery-energized passenger cars.

Multilevel Models

Applications for multilevel models

Although few planning organizations have yet done so, it is possible to design a two-tiered activity allocation system (a system, in this case, can be defined as a combination of models) in which successive levels of areal detail are determined from a preceding higher level (larger area), with feedback between the levels to ensure feasibility and consistency.[5] Multilevel models can serve a wide array of functional planning applications because they can be tailored to both the substance and the detailed geography of the problem at hand. Potential applications for multilevel models include:

- Development of generalized regional development patterns for land use and transportation alternatives, followed by more detailed allocations of particular alternatives.
- Development of particularized transportation planning (or test system alternatives) at the detailed transportation zone level for purposes of program certification and evaluation of planning opportunities.
- Development of functionally oriented, detailed planning that produces general regional and countywide activity allocations, which are then distributed to small-scale functional areas for examination as generalized patterns.
- Selective impact evaluation of major public and private development proposals to serve A-95 review needs and to generate indications of emerging regional issues.[6]

- Imaginative assessment of regional strategy alternatives in order to maintain regional initiative in metropolitan-area development planning and growth management.
- Annualized regional and countywide updates of regional economic and population projections accompanied by activity allocation model two-level allocation of employment and households in order to monitor or anticipate changing patterns and trends on a year-by-year adjustment basis.

What the preceding examples suggest is that where models are available and suitably structured, they can be used to test more planning alternatives in terms of a larger span of consistent measures than would otherwise be possible.

Applicability and Utility of Models

Model applications in planning

Transportation planning and other functional planning models can be used in planning applications in the following ways:

- Transportation planning can be done without models, but present-day models can be used to effectively process large volumes of data and trace the implications of widely varied alternatives.
- Population models show the prospective effects of alternative patterns of population dynamics.
- Economic models indicate patterns of output and employment.
- Land use models sketch out likely subarea patterns of urban development.
- Trip generation models indicate patterns of traffic demand.
- Trip distribution models reveal variations in patterns of movement.
- Modal split models suggest allocations of trips under differing transit availability conditions.

Quality of the data used in the model is crucial

Model builders and users need to exercise substantial caution in extending usage of the models beyond what was originally intended. A model adequately structured to indicate modal split patterns in a metropolitan area with a bus-only transit system can hardly respond well to prospective usage patterns of an improved highway network versus an all-rail high-speed transit system. Two considerations are suggested concerning the applicability and utility of models. First, the overall applicability of a model is more closely related to the quality of the data used than it is to the model's internal structure.

The problem of statistically precise vs. behaviorally appropriate models

Second, calibrating models (i.e., fitting data through regression and other statistical techniques) to high levels of statistical reliability may doom a model to poor projective performance. High statistical accuracy may guarantee that a model

is good for predicting the past but quite useless for anticipating the future. These contrary options pose a dilemma for model builders. One possible solution may be found in asking decision makers what they want from models and how they think the metropolitan complex functions now as well as how they believe it may function in the future. Armed with that kind of information, model builders can turn — cautiously, of course — to less statistically precise but more behaviorally appropriate modeling procedures.

Experience indicates planning models need a clientele — they must deal with questions which are of interest to decision makers. While easily said, this suggestion is hard to implement. Decision makers can have difficulties using models and often need model builders to help them. Successful planning/modeling applications are [illegible] and implemented based on effective two-way communication.

Land use models are gaining wide acceptance with policy analysts because of their potential for providing rapid insight into such topical issues as dealing with growth, assessing new housing programs, evaluating market-oriented land use incentive systems and/or new approaches to tax base and revenue sharing and property tax reform, and a host of other urban challenges. Transportation models have become well accepted for a variety of investment and traffic flow uses, including a choice of transportation investments and the selection of desired traffic patterns.

CHECKLIST FOR MODEL EVALUATION

Steps for assessing the value of a planning model

In assessing the value of specific planning models, the following steps should be considered:

- Review published material and assess the requirements for an effective, understandable, and reliable computerized planning model within the regional planning process.
- Analyze how planning requirements are being met relative to specific regional planning issues.
- Examine such specific applications of computerized planning models as impact testing and urban boundary definition in order to determine patterns of acceptance or rejection of model outputs.
- Evaluate the theoretical bases, technical structure, operational characteristics, and practical applicability of potential models.
- Examine the organizational, operational, and functional requirements for continued (and enhanced) use of computerized models in ongoing planning work.
- Develop recommendations for step-by-step enhancement of computerized models and data base capabilities.

Specific Model Evaluation Techniques

Structural analysis, sensitivity testing, and flowcharting

There are several technical ways to examine the structure of computerized models being used in planning applications including the following methods:

- Structural Analysis — involves comparing the initial theoretical design, algorithm specifications, and program design standards in order to determine how closely they match each other and how closely they relate to stated user requirements.
- Sensitivity Testing — involves comparing the patterns of model output with different data sets, alternative operating assumptions, or changed parameters. Sensitivity testing helps in assessing the range of conditions within which a model is reliably applicable. Sensitivity testing also helps indicate the patterns of variation that can be expected to emerge under differing model usage scenarios.
- Flowcharting of Computer Model Programs — helps determine whether a program is actually operating in the way it was designed.

Nontechnical analyses

Even more important, several nontechnical analyses can be used to examine computerized planning models, including the following techniques:

- User evaluation can help build an organized body of information about how models are perceived relative to planning requirements. Users should include both technical user operators and decision makers who utilize the outputs of models. The two groups may have very different evaluations of the model.
- Consensus techniques and orderly disagreement techniques can be used to provide model assessments. A consensus technique allows several rounds of question-and-response feedback until a general group opinion is established as a benchmark. Alternatively, an orderly disagreement technique such as dialectic debate allows the debate of two disparate views of a commonly accepted set of facts and data. Both techniques may have selective applicability to model evaluation.
- Scenario testing of models on alternative sets of assumptions can determine ranges of applicability and expose decision makers to the uses of the models. This exercise can establish a practical context for using technically correct models in an operational planning context.

Existing model users can select a combination of the preceding technical and nontechnical techniques in order to develop a better picture of the benefits and costs of their model systems. New and prospective models should make an effort

to incorporate lessons learned by those who have experience with models.

EVALUATION: WHERE DO WE STAND?

Urban model users are becoming more realistic

In a recent review of where transportation and land use models stand in the overall scheme of planning activities and developments during the last decade or two, one of the authors of this article concluded that policy analysts using urban models have become less romantic and optimistic and more realistic:[7]

- They have disabused themselves of the notion that it is simple to make analytic system inputs to policies.
- They have learned a great deal about what it takes to make inputs to policies — increased understanding of decision making, early information system development, and user feedback.
- They have learned to accept the long start-up time required by the model-building activity.

Planning models must stand the scrutiny of cost-benefit analyses

Because model use more or less derives from the demands of planners, those who seek to develop performance measures for modeling must work with the demand, not the ultimate solutions to the planning issues. Information gained from modeling can be viewed like any resource that planners find useful in achieving their objectives, including educational resources. Model-produced information, including the new levels of understanding generated by developing the modeling approach, should be assessed using the same cost-benefit terms (when possible) that are used to evaluate other methods for producing planning information.

Notes

[1] Whenever "urban" is used in this discussion, the reader can substitute city, county, or urbanized region. "Region," more appropriately, denotes cities and their surrounding suburban areas, metropolitan areas, groupings of counties, or contiguous clusters of several cities and counties tied closely by economic and transportation relationships. "Area" or "areal" refers to any or all of these geographic units for model analysis. The models described here have been and are being used in all of these geographic and jurisdictional contexts.

[2] Adapted from The Governor's Committee for Transportation Final Report, [illegible] Framework for Comprehensive Transportation Planning, Pennsylvania Transportation and Traffic Safety Center, Pennsylvania State University, 1967.

[3] Lakshmanan, T.R. and Steger, W.A., *Plan Evaluation Methodologies: Some Aspects of Decision Requirements and Analytical Response*, a paper presented to Highway Research Board Conference on Urban Development Models, Dartmouth College, Hanover, NH, June 1967, summarizes criticisms of the "traditional" planning process.

[4] Such results can be produced by means of an extensively operated zonal allocation procedure (ZAP) designed essentially to rearrange basic planning procedures in order to achieve particular planning requirements.

[5] [illegible] Research Corporation, *Review of PSCOG Computerized Planning Models and Data Bases*. Prepared for the Puget Sound Council of Governments, 1978.

[6] U.S. Office of Management and Budget Circular A-95 on procedures for metropolitan area planning.

[7] Steger, W.A., "Urban Models I Have Known," TIMS/ORSA Conference, 1978, and [illegible], 1979.

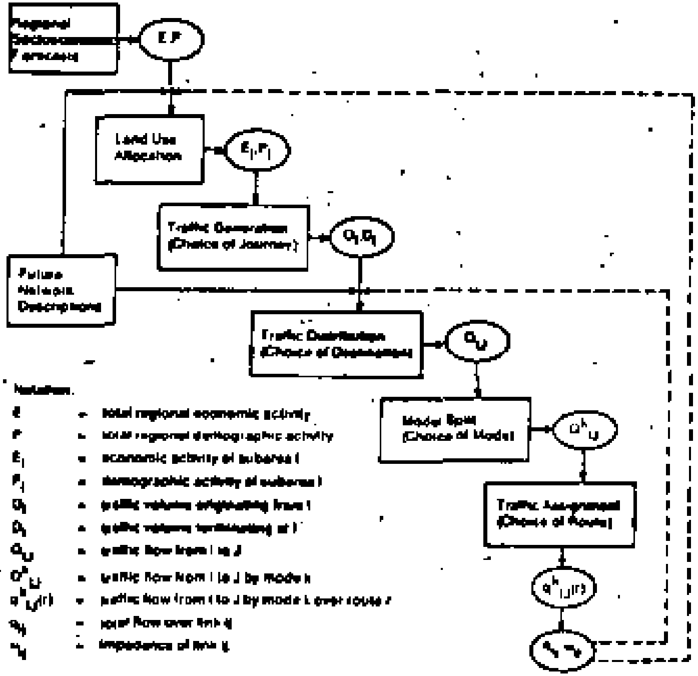

Figure 2. Sequence of Models Used in the Urban Transportation Model System

ior, given a fixed location for a firm or household, involves four fundamental decisions: the choice of whether to journey, the choice of a destination, the choice of mode, and the choice of route.

Evaluation of Current Model Systems

Some operational transportation models

A list of current transportation model systems includes the following models, organized by type:

Demand Models
Trip Generation Model
Gravity Model
Intervening Opportunity Model
TRC Modal Split Model
Pratt Marginal Utility Model
Llaco Probit Model
n-Dimensional Logit Model
Economic Demand Model

Network Models
Federal Highway Administration (FHWA) Network Programs
Urban Mass Transportation Administration (UMTA) Transportation Planning System (UTPS) Network Programs
DCO/TRANPLAN Network Programs
Dial Stochastic Assignment Model

Cost-Benefit/Impact Models
DODOTRANS
Transportation Resource Allocation Study (TRANS)
SRI Network Analysis Program (SNAP)

Tables 2, 3, and 4 list and compare the characteristics, resource requirements, advantages, and disadvantages of the models.

Use of sketch planning models

Current urban transportation planning techniques usually require an extensive data base, coding of detailed networks, and use of a costly set of computer programs.[7] Approximately 70 percent of urban planning funds are devoted to data and model preparation, with less than 20 percent devoted to plan evaluation and testing. Because of the complex nature of the transportation planning techniques, the analysis of an urban transportation plan requires from 12 to 24 calendar months. Logically, therefore, the most meaningful development direction for analytical techniques would be toward sketch planning models that require less data base development than current models. The sketch planning models would facilitate faster turnaround for analysis, resulting in procedures more responsive to issues and problems and enabling planners to explore and evaluate a larger number of alternatives.

Methods for streamlining the transportation planning process

Other methods for streamlining the transportation planning process include:

- Aggregate, instead of detailed, modeling approaches that place less demand on data bases or the coding of detailed networks, and in general would cut down on the analysis resources devoted to model preparation.
- Interactive planning techniques using graphic terminals could be an effective way of interfacing the analyst and the decision-maker with the model.

There are a significant number of transportation modeling systems available; however, what is really needed for transportation planning is a method for applying transportation sketch planning model approaches to regional alternatives, and then using more detailed transportation projection and analysis techniques for detailed system planning, corridor evaluation, or localized transportation analysis. This proposed improvement is one of approach rather than of additional cost; it involves the reallocation of planning and anal-

Table 2. Comparison of Operational Demand Transportation Models

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Adapted from U.S. Department of Transportation, *A Review of Operational Urban Transportation Models*

Table 3. Comparison of Operational Network Transportation Models

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 4. Comparison of Operational Cost/Benefit Impact Transportation Models

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ysis effort rather than additional staffing or project funds. It can offer potential savings. The suggested change implies the use of generalized models that may be less expensive to run, initially, and reserves the use of detailed models for high-potential transportation system planning tests.

Recommendations for Transportation Modeling Systems

Checklist of capabilities and features for transportation modeling

Following is a checklist of desirable capabilities and features for transportation modeling systems. Some transportation/land use systems already incorporate these features and capabilities, but many do not. In many instances, models and data bases require substantial revision, and staff retraining is required to support the changes. Transportation modeling systems should be capable of:

- Analyzing different modes of transportation adequately.
- Analyzing mass transportation programs being considered for suburban areas. Examples of these programs include cross-county transportation service, Dial-A-Ride service, and alternative forms of feeder service to regional mass transportation facilities.
- Deriving accessibility measures from the transportation forms being considered. These should include both weighted (e.g., those produced as a by-product of gravity model operation) and unweighted (e.g., opportunities within certain travel times). They should also be modular so that different kinds of access measures can be computed (e.g., opportunities for employment for different income groups, opportunities for retail sales).
- Incorporating data collected and maintained by different geographic analysis units. These include the zones and districts, census tracts, and the half- and one-mile square grid systems.
- Supporting analytic procedures compatible with the transportation system programs being analyzed. For example, in urbanized portions of the county moderate highway improvements such as lane widening, intersection improvement and different mass transportation alternatives can be considered feasible from an implementation aspect. In the more rural sections of the county, major highway construction may still be considered feasible.
- Determining congestion and the level thereof in any transportation system alternative being examined.

QUESTIONS TO ASK ABOUT MODELING

Before making decisions about model development, the following questions should be asked in order to initiate an

It is important to have an agencywide discussion of the goals and directions for planning models

agencywide discussion of planning models:

- What are the theoretical and practical capabilities of the existing models in terms of structure, applicability, and data reliability?
- How can the agency's planning process be better reflected within the modeling process for improved support of planning decisions reached amid uncertainty and with the aid of partial data?
- Are the agency's present modeling efforts providing worthwhile information in terms of the costs and intended purposes?
- Can the agency's present models be improved to better meet identified needs at reasonable cost?
- What would be the likely effects of abandoning the present computer modeling efforts?
- What additional modeling capabilities might be useful to meet identified needs at reasonable cost?
- Can present or prospective models provide an adequate basis for urban and/or regional transportation planning and, perhaps, for other functional planning purposes such as those related to environmental concerns, fiscal matters, and housing?
- Are the models structured to answer the questions being asked now, or likely to be asked later, within reasonable cost and confidence limits?
- How can the models be accommodated to localized changes and better deal with uncertainties and policy concerns at a suitable level of detail?
- How can the models be administered, interpreted, and controlled in order to make them an operational part of the metropolitan decision-making process?

To each of these questions, there is a positive answer. Precisely how a planning agency, along with its councils and local governments, decides to respond is a matter of political and technical choice.

Notes

[illegible] "The Lowry Model Heritage," *Journal of the American Institute of Planners* (March 1971) [illegible]-110. Harris, Britton. A paper prepared for the Committee on Urban Economics, Analytical and Policy Issues, January 1967. Hemmens, "Planning Agency Experience with Urban Development Models and Data Processing," *Journal of the American Institute of Planners* (September 1968) 323-327. House, Peter. "What's Really New About Policy Analysis?" *Journal of Policy Analysis* (May 1974). Kilbridge, Maurice. *Urban Planning Models*. Graduate School of Business Administration, Harvard University (August 1967). Krueckeberg, D. et al. *Urban Analysis*. [illegible] 1970. 1-34. Lamb, Donald D. "Research on Existing Land Use Models" [illegible] 1965). Lakshmanan, T.R., and Siegel, R.A. "Plan Evaluation Methodologies: Some Aspects of Decision Requirements and Analytical Response," op. cit. Lowry, Ira S. "Seven Models of Urban Development: A Structural Comparison," RAND paper P-3673, September 1967. Lowry, "A Short Course in Model Design," *Journal of the American Institute of Planners* (May 1965) 158-165. [illegible] "Scale and Purpose in Urban Simulation Models," Discussion paper prepared for the Conference on Strategy for Regional Growth, October 1964. Putman, Steven. "Intraurban Employment Fore-

casting Models," *Journal of the American Institute of Planners* (July 1972) 216-230. Putman, "Urban Land Use and Transportation Models," *Transportation Research* 9, 1975; Steger, W.A., "The Pittsburgh Urban Simulation Exercise for City Planning," a paper delivered before the New York City Chapter of the American Statistical Association, September 1964; [illegible] on Simulation in Business and Public Health; Steger, "Review of Analytic Techniques for the CRP," *Journal of the American Institute of Planners* (July 1965); Steger, "Urban Models Have Known: A Fifteen Year Assessment" [illegible] Conference, 1978, and [illegible], 1979; Steger, "Urban Simulation: Taking Stock of the Recent Past," Center for Regional Studies, University of Kansas, 1965; Traffic Research Corporation, "Review of Existing Land Use Forecasting Techniques," Boston Regional Planning Project, Massachusetts Transportation Commission, July 1963; U.S. Department of Transportation, *A Review of Operational Urban Transportation Models*, Transportation Systems Center, 1973; A.G. Wilson, et al., *Models of Cities and Regions*, New York: John Wiley & Sons, 1978.

[illegible]Lowry, "Seven Models of Urban Development," op. cit., pp. 121-127.

[illegible]Lowry, "Eleven Models of Urban Development," op. cit.; also Lowry, "A Short Course in Model Design," op. cit.; and Lowry, *A Model of Metropolis*, The RAND Corporation, 1964; also Wilson, *Models of Cities and Regions*, op. cit. The mathematical formulation of the basis of the Lowry model is a gravity allocation function of the following form:

$$T_{ij} = a_i \left[n_j e^{-\alpha c_{ij}} \Big/ \sum_j n_j e^{-\alpha c_{ij}} \right]$$

where T_{ij} = the amount of interaction between activities of type i in zone i and activities of type j in zone j

a_i = the total amount of activity of type i in zone i

n_j = the total amount of activity of type j in zone j

c_{ij} = the generalized travel cost between zones i and j, and

α = a parameter that reflects the influence that travel costs have on destination decisions for the particular interactivity interaction being considered.

From Hutchinson, B.G., et al., "Applications of Land Use Models to Strategic Transport Planning," *Transportation Research Record 654*, *Transportation Development and Land Use Planning*, Transportation Research Board, National Academy of Sciences.

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ANALYZING URBAN DEVELOPMENT ISSUES USING SEQUENTIAL LAND USE DATA AND A GEODATABASE: A CASE STUDY FROM LIMBURG, THE NETHERLANDS

1. PROBLEM DESCRIPTION

1.1 Background

One of the major issues concerning the future of geoinformation systems is how and when they will be accepted by the planners. Pilot projects where planners may get hands-on experience with geoinformation systems and geodata processing are therefore essential to guide the direction of future development. This paper discusses some aspects of such a project carried out by the Dutch National Agency for Physical Planning (RPD) and the International Institute for Aerial Survey and Earth Sciences (ITC). The project was founded by the RPD as a research contract. It involves datacollection and data processing for an area in the south of the Netherlands and addressed a highly actual planning issue in the Netherlands: the "bufferzone" concept.

1.2 The "Bufferzone" concept in Dutch Physical Planning

One of the objectives of the national physical planning policy in the Netherlands is to achieve a balanced and well structured urbanization pattern with a clear distinction between urban and rural areas, avoiding amorphous urban sprawl. In this concept remaining rural areas between neighbouring cities are very important. A special policy has been designed to maintain such areas as so called "bufferzones" and to prevent their gradual urbanization. These bufferzones should not be seen as large regional parks, they are supposed to be normal functioning rural areas with some emphasis on their recreational function to the adjoining cities. Bufferzones have formed an element of the Dutch Physical Planning policy since the mid sixties and a number has already been established. In view of further practical implementation of this policy (designation of actual areas, attribution of subsidies etc.) there is a need for more empirical knowledge on the actual land use change process going on in portential bufferzones. Existing urban fringe theories were felt to be maybe not fully applicable to the Netherlands due to differences in scale and planning system.

1.3 The Actual Project

In 1979 the National Agency for Physical Planning (RPD) started an investigation to prepare the delineation and designation of 2 possible bufferzones in the south of the Netherlands. The study was to be based on two surveys: one on the development of the agricultural situation from 1965 - 1979 to be carried out by the Dutch Agricultural Economics Research Institute (LEI) and one survey based on air photo interpretation of the land use of the same area in 1965, 1975 and 1979 by ITC. The ITC was to set up a computer database for the land use data and this was also to contain other thematic data which could be supplied by the Planning Agency and which could be accessed and used by the planners themselves.

2. METHOD

2.1 Airphoto Interpretation

The land use data for the study were obtained by interpretation of air photos according to a classification specially designed for this purpose by the RPD. There were 7 mainclasses and in total 32 subclasses. (table 1.) Besides data on land use, data had to be obtained for dispersed houses, farms and other relatively small phenomena (in total 10 types of "point" data). The historical land use was "reconstructed" by using copies of archivephotos of the Dutch Topographical Service

that had been used in the past for topographical mapping. Those photos were not optimal for this purpose (mapping specifications differ from interpretation specifications with regard to time of the year and desired scale) but they were usable and formed the only possible source. For the present situation, however, special aerial photography has been flown by ITC in 1979. Characteristics of the various coverages are given in table 2. All photos were black & white pancromatic.

The land use interpretation was carried out stereoscopically and the results were registered on transparant overlays over each photo. The minimum classifiable area was 1.2 ha. The interpretation was complemented with various fieldchecks.

2.2. Computer Processing

For computerprocessing of those data the ITC USEMAP/DDP software package has been used, a package for geodata processing with gridcell databases developed from 1973 onwards (DE BRUIJN 1974, 1978). Apart from the usual routines found in most geodata processing packages, USEMAP has a number of specially designed routines for input of photo interpretation data and for digitally backed photo interpretation (DBP) enabling direct digitizing of interpretation results during interpretation (DE BRUIJN 1979). The land use was digitized directly from the interpreted photographs. As the area is mostly gently sloping, digital rectification was sufficiently accurate for the subsequent land use sampling process. Rectification was based on 6 well spaced, well identifiable tiepoints to be digitized both on the photo and the topographical map. The computer would report the residual error per point after transformation. If this error would be more than 5 metres on any tiepoint, a new rectification would be made by the operator. Land use digitizing was carried out with line samples for the west-east centre lines of the gridcells in the eventual database. Line sampling was preferred to polygon or segmentdigitizing, as it was found much quicker and virtually eliminated the necessity of later editing. Digitizing was carried out

TABLE 1 LANDUSE CLASSIFICATION

Code	Rural I (agricultural)
11	Orchards low trees
12	Orchards high trees
13	Grassland
14	Arable land
15	Orchards high tree dressing
	Rural II (not agricultural, no buildings)
21	Estates
22	Forest
23	Water
	Intermediate I (recreation)
31	Allotment gardens
32	Camping
33	(Summer bungalows)
34	Main Recreational Attractions
35	Manegen (Riding schools)
36	Urban recreation (Parks, Sport)
37	Swimming Pools
	Intermediate II (infrastructure)
41	Rivers, canals
42	Airport
43	Motorways
44	Marshalling yards (railways)
	Intermediate III (others)
51	Garden Centres
52	Sandpits, garbage & car dumps
53	Vacant
54	Others
	Urban I (residential & services)
61	Residential
62	Commercial/institutional/offices
63	Building Sites
	Urban II (industrial)
71	(Greenhouses)
72	Industrial
73	Harbour area & storage
74	Mining
75	Mining dumps & coal mountains

TABLE 2 OVERVIEW AIR PHOTO COVERAGE

Year	1965	1975	1979
Scale	1:20 000	1:15 500	1:12 500
Date	march 11	feb 23	may 15
Size (in cm)	18 x 18	23 x 23	23 x 23
Interpreted photos	27	25	44

TABLE 3 THEMATIC MAPS FOR THE STUDY AREA

Nature and landscape conservation, regional plan 1975
Ecologically important areas, regional plan 1975
Registered areas (landscape and nature) 1969
Nature and landscape conservation 1970 and 1978
Road accessibility per km2 (all roads/paved roads only) 1965
Road accessibility per 25ha near natural areas 1965
Settlements with basic services (1km radius)
Location of complexes for recreation, campings etc. (1km radius)
"Scale of the landscape" per km2
Relief per km2
Limits of areas of LEI study
Plan for the open air recreation (recreation authorities)
Municipal zoning plans for the "rural" areas
Municipal boundaries
Reallotmentschemes
Urban fringe areas

interactive with results displayed on a graphic screen and with various software controlled acoustic signals. The line samples were stored in separate files for each digitized photo and were later converted into gridcell values. After the land use interpretation the 1965 & 1979 photos were interpreted again for pointdata. They were digitized directly during interpretation as centroids stored in centroid files and later converted into gridcell values (number of occurencies per gridcell). The thematic data supplied by the Planning Agency (table 3), were digitized as polygons or entered as numerical codes for KM squares.

3. RESOURCES REQUIRED

3.1 Hardware

The basic USEMAP package runs in batch on a PDP 11/45 with a lineprinter but the extended version USEMAP/DBP uses a VAX 11/780 and operates in a semi-interactive mode. The configuration includes now various perpherals grouped together in what is called a "Digital Interpretation Unit". Such a unit specially designed for photo interpretation tasks consists of a graphic screen (Tektronix 4010 of 4054), a digitizer (Summagraphics 30" x 40"), a keypad, an ITC developed digital parallax-bar (to measure height in photographs and to work in areas with a lot of relief). At present there are three such units in operation, sharing a hardcopy unit (Tektronix 4631), a small flatbed plotter (Tektronix 4663) and a COLORPLOT 100 line printer. In future the units equipped with 4054's will carry out most of the interpretation related task locally.

3.2 Database and Data Accuracy

The database for the study is formed by a 210 x 105 cell matrix with cells of 100 x 166 m. To assist the planners in selecting a suitable gridcell size, a representative area was interpreted and computerprocessed with four different gridcellsizes: 75 x 125, 100 x 166, 150 x 250, and 200 x 333 (all in meters). For each gridcellsize maps and tables of land use changes have been made to show the amount of detail that could still be perceived. Eventually the planners selected the 100 x 100 m cell as being sufficient for their needs. For each cell 35 items of information were stored and used for further analysis.

Various checks were carried out to assess the reliability of the data with regard to:

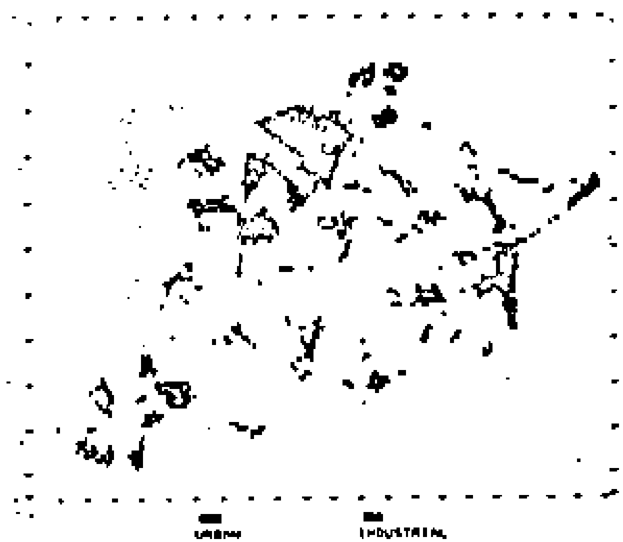
a) the accuracy of the photo interpretation and

b) the accuracy of the digital rectification and encoding of the data.

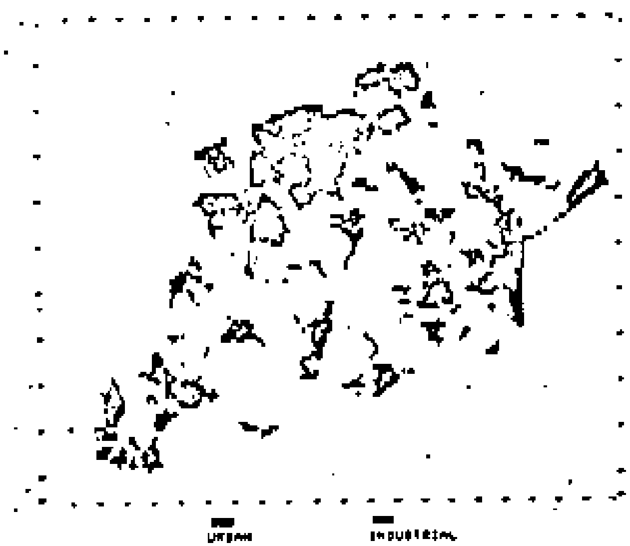
As the emphasis of the project was on changes, it was decided to check in the field the land use changes 65/79 obtained after computer processing of the data. If the land use changes were found correct, both the photo interpretations of 65 and 79 and the rectification/digitizing procedure would be sufficiently accurate for the purpose.

In total there were 316 areas with 2 or more cells that had undergone land use changes. Of these areas 192 (61%) were checked in the field. Together they represented 47% of the total acreage affected by changes. Only 28 areas proved wrong (14% of the total number of checked areas, but they were generally small, only 9% of the checked acreage). Most errors were related to photo interpretation (18 areas); the other errors were due to coding mistakes (5) and rectification errors (5). To obtain another indication on the accuracy of rectification and digitizing all 3 independently created land use maps for 1965, 1975 and 1979 were overlaid by the computer and a frequency count was made for the linear features rivers and motorways. If a motorway or a river is in continuous existence since 1965, it should occur in the same position (= the same gridcell) on the maps for all 3 years. A cell belonging to such a feature should have a frequency 3 (occuring on all 3 maps) when there are no problems with the metric accuracy. A lower frequency indicates that in one of the years rectification/digitizing must have been inaccurate. For rivers only 2 out of 50 cells were inaccurate (4%) and for motorways this was 11 out of 149 (7%).

MAP 5 URBAN LANDUSE 1965



MAP 6 URBAN LANDUSE 1979



4. GRAPHICS AND TABLES

In all phases of the study, extensive use was made of the mapping facilities of the programme. Most of the maps used were for cost reasons produced as straightforward "lineprinter" maps on paper or on the Tektronix screen for interim checking. In editing and verification phases, anomalies were mapped and then corrected, based on local knowledge, along with renewed study of the photographs and/or the use of logical sequences. For the first raw analysis, straightforward data display maps showing land use in mainclasses, or specially selected subclasses, were studied. In this phase the use of colour output became important. The first coloured land use maps (for mainclasses) from the area in 1965, 1975 and 1979 showed with much more impact than their black & white counterparts how the urbanization in the study area had progressed, also in areas that were supposed to remain rural (map 1 and 2). We found that many professionals who had been merely looking politely at the line printer maps, showed suddenly a real interest when the same maps became available in colour. In the endphase, several analytical maps were made to indicate the resistance of the various areas against urbanization (stability maps). Those will be described in more detail below. Based on different assumptions and tested out on the 1965 - 1979 development, they showed which areas would be most sensitive to further urbanization. But in geodata processing, maps are only half of the story. They are used in combination with tabular quantitative data so that "where" and "how much" can be analysed together. It is precisely this combination of manipulating maps and numbers together that makes applied geodata processing such a powerful tool for planners and other people involved in the analysis of spatial patterns.

In total, during the project, well over ± 1000 computer maps and tables have been produced, partly only in ephemeral format (display on the graphic screen) and most of them only for interim use during the analysis. They are, however, essential steps in the difficult process of coming to grips with the dynamic spatial behaviour of a region.

5. PROBLEMS

The study was the first of its kind undertaken in the Netherlands and the planners involved in the study had no previous experience with geodataprocessing or with land use inventories. Due to the system of pilot interpretation those problems were minimized but they had their influence on the total duration of the project and they created substantial additional work (recoding etc.) A more severe problem, however, was the delay in obtaining new photographs, due to unfavourable weather conditions. For this reason it was necessary to start interpretation with the old photos. That was of course interesting from a research point of view, since independent interpretations were made which could be checked against each other. From an operational point of view, however, it necessitated in an unnecessary large amount of editing. As the region has boundaries with Belgium and Germany, photographs showing part of foreign territory were not available without special clearance. When the photos finally arrived after a lot of "red tape" they could no longer be incorporated in the workflow and were only partly processed.

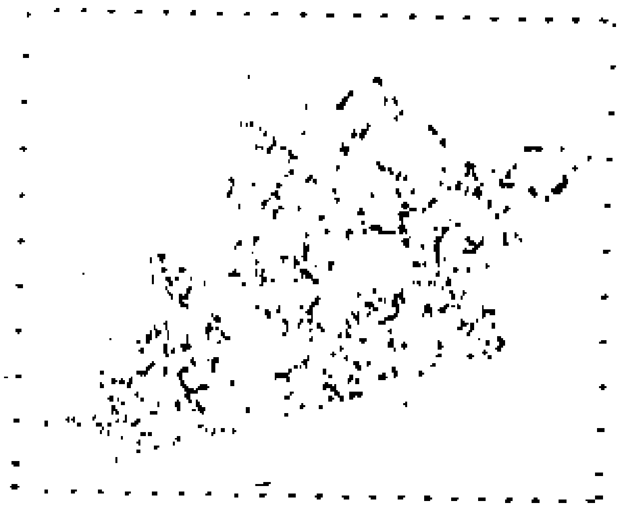
The delineation of the study area was chosen arbitrarily for the subject of the study and coincided neither with the photographs nor with administrative boundaries. Later comparison with municipality based statistical data, like population was only partly possible. Computer processing created no special problems, except for the usual ones hardly worth mentioning like the 2 successive changes of the computer (with different operating systems) that was allocated to the project and the incorporation of new peripherals like the COLORPLOT 100. There were of course the predictable amount of hardware difficulties and delay in applicationsoftware development which made the contention that computer processing is much faster than conventional procedures more an article of faith. But as this seems to be the actual state of the art nobody noted such problems except for the novice first time users who were the planners.

6. SOME MAJOR RESULTS

The project obtained most of its objectives. The planners did get hands-on experience with geodataprocessing and computer mapping and now have a much better idea on how these tools can be used in the future. The data collected enabled a succesful analysis of the land use dynamics in the studyregion. The efficiency of digitally backed photo interpretation methods for datacollection has been clearly established. The introduction of colourmaps that could be produced cheap and fast on a colour lineprinter improved substantially as anticipated, acceptance and understandability of the computer results (even with the present somewhat disappointing quality due to not yet solved problems with the colourribbon.) A detailed discussion of results of the analysis itself is not possible in this context since it will demand much explanation about the region itself.
However, some of the major findings can be summarized as follows.

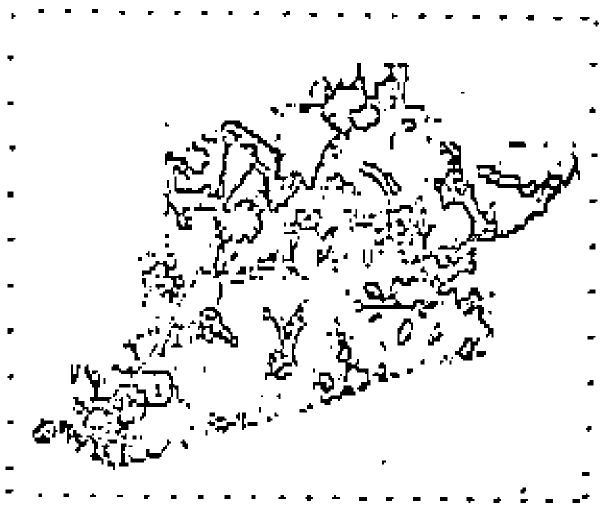
a) Some "generally held" ideas on the development of the area proved wrong after analysis of the data. The region in question has for example a substantial amount of apple orchards. Traditionally, these were high tree orchards, but with increased labour cost they were replaced by low tree orchards enabling mechanized farming. High tree orchards became an economically weak land use and as the region is close to a main tourist area, the idea was that they would be converted for fringe activities especially related to recreation. The study proved this completely wrong. Decaying orchards were either used for planned urban extension, if located close to the villages, or were taking part in the agricultural land use change cycle. Conversions to other uses were highly exceptional. There are several more examples along these lines. (Such "negative" findings, however, are often not remembered as results of the study because on afterthought they seem so selfevident that people involved in the study are inclined to forget their original ideas).

MAP 3 CELLS WITH DISPERSED BUILDINGS 1969



3-9 BUILDINGS / 1-2 BUILDINGS /

MAP 4 STABILITY AGAINST RURAL > URBAN CONVERSIONS IN 1983



UNSTABLE RATHER UNSTABLE

b) The "stability" of each area with regard to urban/rural land use changes was mapped. The changes in land use were analyzed by the planning agency in relation to the various thematic maps made for this study. This was done mainly with numerical data. (Cross tables of land use/or landuse changes versus the thematic item under consideration). From this analysis it was found that "stable" areas (i.e. areas without urban/rural land use changes) were characterized by

1) presence of forest landscape type
2) presence of nature conservation areas at all levels of legal protection
3) areas with high landscape value indicated in the regional plan
4) areas zoned as natural areas or as areas with high landscape value (at the municipal level)
5) high number of contourlines/sq. km (much relief)

Instability was indicated by location close to the built-up urban areas, high accessibility (number of road-entrances/sq. km), high tree orchard landscape type and a low number of contour lines (flat areas). The influence of the other indicators on stability was neutral or incertain.

Based on this analysis, two new maps were made as linear combinations of the thematic maps, one for stability and one for instability. The map for stability (with a scale from 1 - 5 according to the number of favourable factors that is present) was composed of the factors described above. It gave the following result when confronted with the 65/79 changes.

stable areas	area in HA (%)	rural decrease	% loss
1-5 factors	4657 (36)	316 (16)	7
2-5 factors	606 (5)	23 (1)	4
total rural area 1965	12800 (100)	1940 (100)	15

Over the past 14 years, any combination of two of these factors produced indeed rather stable results. It shows that planning control over those valuable areas is functioning rather well.

The map for instability (scale 1 - 4) was made in the same way with the results below

instable areas	area in HA (%)	rural decrease	% loss
1-4 factors	8100 (63)	1578 (81)	19
2-4 factors	2700 (21)	831 (43)	31
total rural area 1965	12800 (100)	1940 (100)	15

Any combination of 2 or more factors gave about twice as much changes as the overall % for the region.

In this stage, the data on dispersed buildings had not yet been used (map 3). Also more use could be made of the available land use map of 1965:

- to analyse what was happening in the cells immediately neighbouring cells with an urban land use
- to see if there was a relation between the average size of a homogeneous land use area and its sensitivity to change.

The USEMAP package contains software for such analysis. The programme PERIM will generate the surrounding area for any land use, while the programme CONCID will compute for each cell the "concentration index", that is how much of the 8 immediately surrounding cells have the same land use. The cell itself is added to that number, so the concentration index runs from 1 (no surrounding cell has the same land use, so it is a small isolated land use island) to 9 (all surrounding cells have the same land use, so the cell is somewhere in the middle of a relatively large land use unit).

By combining the 3 maps on dispersed buildings, cells neighbouring directly urban land, and cells with a concentration index of 5 - 7 it was possible to achieve much better results for instability. To obtain a complete picture, this new map should be merged with the stability map. But the 2 maps had overlapping areas (i.e. areas that got both indications for stability or instability) and it should be decided what to do in such cases. When the mixed cells were rated as stable, the results in the instable classes improved slightly, but the stable class still contained 7% rural landuse losses. When the mixed cells were considered instable, results for the stable class improved to only 2% rural land losses.
It demonstrates that stability indicators are of limited value, when an area is at the same time potentially unstable. For example, an area with high landscape value far away from the city is much more stable than one at the urban fringe, at a location suitable for urban expansion.

For the final map (map 4) stability was treated as a penalty point for the instability score. The indicator was composed as follows:

D + F + CI - S + 2

D = 1 if a cell contains dispersed buildings, else Ø
F = 1 if a cell is directly neighbouring urban land, else Ø
CI = 1 if a cell has a concentration index between 5 and 7, else Ø
S = 1 if a cell has a stability score between 1 and 5, else Ø
The constant 2 enables to differentiate between stable areas from the stability map and other areas that are "not unstable".

stability score		area in HA	(%)	rural decrease	(%)	%loss
(1)	stable	2763	(21)	55	(3)	2
(2)		5945	(46)	495	(25)	8
(3)	rather unstable	2508	(19)	678	(34)	27
(4)	unstable	1416	(12)	618	(32)	44
(5)		180	(2)	93	(5)	52
TOTAL RURAL AREA 1965		12812	(100)	1940	(100)	15

From this map it follows that the areas most sensitive to urbanization in the past 14 years were
- located very close to existing urban land uses
- relatively small land use units or areas at the edge of larger units.
- areas where dispersed buildings existed already.

This is typical of the type of urbanization in this region, where many villages are built along existing roads (long linear building patterns) and where the expansion of the villages is a continuous "slow but steady" process. Because of this gradual aspect, this type of urbanisation is subjectively underestimated and one of the advantages of a study of this type is to show the situation in its "true" proportions.

c) The loss of rural land is not due so much to suburbanization as to the lowering of densities at the village level.
The startling increase in urban land uses in the region is not so much a result of suburbanization, but of an increased space use by the existing population, especially for recreation and residential areas. For the complete municipalities included in the study area, the data are as follows.

	tot.pop.	res.area	res.area/ inh.	recr.area	recr.area/ inh.	res.+rec. inh.
1965	95294	1367	144 m2	47	5 m2	149 m2
1979	107738	2007	186 m2	149	14 m2	200 m2
Index	114	147	129	317	281	134

Data by municipality, however, show marked differences that may give clues to the planners for future policy.

d) The scattered pattern of urbanization still dominates the area but under the influence of planning it becomes more concentrated. This could be quantified in various ways. First by comparing the "ring" area created with PERIN with the actual urban area. If the pattern continues in the same dispersed way the ringarea should increase more than the core area. But the reverse happened, showing more concentration and fill-in of areas already in the urban sphere of influence.

	1965	1979	index 1979/1965
urban land uses	1447	2266	157
urban land uses + ring	3585	4539	126
core/ring	40%	50%	

Another indication is the reduction of dispersed buildings outside the urban area. In 1965 the rural area had 720 cells (10%) with d dispersed buildings, in 1979 this had decreased to 490 cells (8%). The apparent incorporation of dispersed houses in 1979 urban area was not followed by a new growth of dispersed houses. So in these aspects planning control proved rather effective.

The overall conclusion can be drawn that the control at the lowest level has been relatively effective (concentration at the village level) and that control of obvious planning targets like nature conservation areas of high landscape value has also been quite effective. The same, however can not be said of the overall urbanization pattern, the buffer-zone concept should become much more concrete before it is likely to become really effective. By analyzing the "sensitivity maps" from this study and by comparing them with the desired planning policy, it should be possible to formulate a feasible strategic approach for the coming decade.

7. CONCLUSION

The project can be considered highly successful. A fully operational

procedure has been worked out for the collection and analysis of sequential land use data including the use of land use derived indications such as "surrounding area" and "concentration index". The results of the study are appreciated by the planners and it is likely that the study will be repeated for several more bufferzone areas. The lessons learned, can be deduced from the description of the problems given earlier in this paper. In the next study such problems should not occur again.

In general it can be stated that sequential land uses analysis made possible by the combination of photo interpretation techniques and applied geodataprocessing, is a very effective approach to obtain valuable empirical knowledge about certain critical planning issues. Working with sequential data of the past, planners may obtain a better idea on the future potential of a geo information system and about the type of items which should be stored in such systems.

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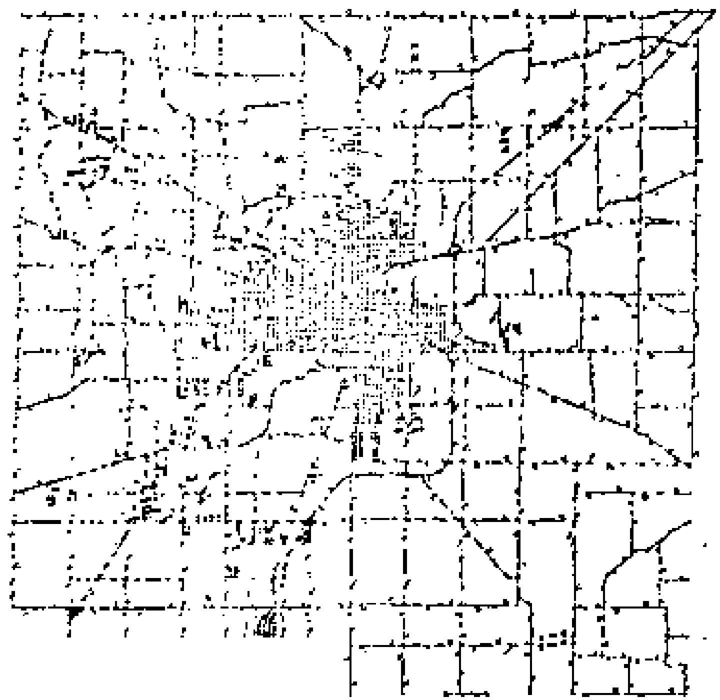
A WRITTEN DESCRIPTION OF THE NETWORK SOFTWARE PRODUCT



The NETWORK program was originally written by Kelvio Nelson with the aid of Nick Chrisman during 1978 and major enhancements were undertaken by John Albert Fehr with the aid of numerous Laboratory staff programmers including Scott Morehouse, Jim Dougenick, and Bruce Donald during 1980. The address of the Laboratory is:

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48 Quincy Street
Cambridge, Massachusetts 02138
USA

NETWORK is a companion interactive graphic program to the FRETOP program series designed to facilitate the definition of activity zones and their associated links. NETWORK is a geometric definition and editting program. It allows the user to create a topological and geometric database describing a network, be it a network describing a circulation pattern within a building or the circulation patterns of a city or a region or a country.

A session allows the user to dynamically create and/or edit the topological data structure made up of zones, their centroids, gates (entry points or sources of sinks), and transshipment nodes describing his/her area of interest; to perform minimum path calculations based upon distance or travel time by creating minimum path spanning trees; and to compute specific distances or zone areas. For the model formulation, any flow leaving or arriving to a zone is directed/assigned to its centroid.

Several years ago, the then-associate director of the Laboratory, Eric Teicholz, contacted the CSIRO group in Australia for information on their allocation model called TOPAZ which is a program based upon solution approximation of quadratic assignment problems optimizing the allocation of activities into zones based upon topologic and flow constrained data structures. At that time, their model was computationally batch-oriented, that is to simply say that execution of the program occurred in a non-interactive setting, and the input/output process was entirely card associated. The user would prepare and later interpret the processed output data via numeric fields, the input consisting of punched cards and the output consisting of formatted printout. Modifications to the topology and/or geometry were possible only with a thorough understanding by the user of both the original data and the program's internal data representation. TOPAZ was acquired by the laboratory from the CSIRO group in Australia almost four years ago. Little modification has occurred to that program at Harvard. TOPAZ originally was executed under a CDC batch-run environment and has since been modified to operate in a DEC environment and adapted to run interactively and, thus, read files interactively. It was written in FORTRAN, incidentally.

The program NETWORK evolved to provide the user with a simple interactive and graphic environment in which the input data could be easily introduced and modified as necessary. Databases created by NETWORK were destined for ultimate submission to a TOPAZ run or series of TOPAZ runs. NETWORK was originally developed on a DEC-10. This initial evolutionary period also included the development of a data structure capable of dynamic reallocation of direct access core memory or online mass storage as data elements were added or deleted without having to increase computational resource overhead, the development of raw coordinate input interfaces to massage data collected from external sources such as rough DIME file post-processors or blind digitizer sessions, and the incorporation of algorithms for minimum path calculation.

Since the program was originally developed and written by Melvin Mation, I have endeavoured to enhance its visual presentation, its command/request language and dialect structure, its computational efficiency, its source language independence from any one host computer, its ability to support a wide variety of graphical input and display peripherals, its internal data structure, and its internal/external documentation. NETWORK is also written in FORTRAN. Some of the input/output handlers are written in assembler.

In terms of the network, any zone is represented by its centroid; which is automatically calculated and is considered as a special type of node. NETWORK deals with only two dimensional topologies and geometries at this time.

NETWORK works well with one type of circulatory system, one can't mix systems easily. For example, one can't use it to monitor fresh water versus raw sewage circulatory patterns. It's instead used to monitor flow within the network and the cost of transporting items across the network. Interfaces have since been provided that will allow on-line digitizing or conversion of coordinates from an external source, such as a blind or unchecked digitizing session, to be converted to a coordinate system NETWORK standard. These external coordinates may be world coordinates, such as latitude/longitude, or a

user-defined coordinate base, as long as it's integer precise to five places.

Actual applications include (with the addition of a minimum path determining algorithm) the ability to, based upon the actual cost derived from the geometric data or from costs that are tacked-on or attributed to a particular link within the database, estimate optimal paths. This cost attribute might represent a speed limit or a dollar cost of using that link or some other abstract attribute that's not wholly geometrically related, or when combined with the geometric data can derive a new cost such as given a speed limit of miles per hour and a certain distance, one can calculate the amount of time that it takes to travel that particular link.

Given this minimum path algorithm, one can determine the minimum paths from a given point in the network to points that may have meaning to the user. An example would be, from one subway entrance to entrances of surrounding buildings, maybe within a micro-network in the neighborhood.

NETWORK should not be confused with NP-complete problems, such as the traveling salesman problem. NETWORK does not solve this type of problem but merely, in terms of minimum paths, selects the optimum paths from a certain point to all other points in the network.

A potential purpose for NETWORK would be in the mapping of 3d or three dimensional networks and, such as high-rise structures, or another might be flows within a power plant, or any other circulatory network that has components stacked upon one another as well as horizontally laid out. Being able to minimize piping runs would be a potential application in three dimensions. Another application might be the study of the circulation of people within a urban table structure with several buildings sticking out of it; while trying to optimize the paths through that structure. Another might be the study of a factory layout and attempting to optimize the movement of parts and products through it.

To some extent, the factory application is already possible in the present NETWORK given that the factory setup exists and the number of gates are known, such the vertical contact areas such as elevator shafts or stairwells or loading docks within the structure; the flows might easily be determined and then recalculated as a series of slices through the structure, rather than trying to treat it as one three dimensional object encompassing a network.

NETWORK was originally developed to run on a large storage tube device. Its display support now includes all the Tektronix storage tube devices and their color terminal, the Advance Electronic Devices (or AED) 512 raster terminal.

Plotted output can be written onto a Calcomp-type plotter, a Houston Instruments plotter, or a Servigor BBC 281 plotter. Color output on these plotters isn't yet supported but it would be a minor enhancement or easily implemented. The form of output on a storage tube is probably the best, given the interactive nature of NETWORK for rapid input and viewing of data. Using thumbwheel or cursor control, the user can overlay new coordinate data onto existing display data. It's generally true that the larger the display device, the better the resolution; although it's easier to pick points with the cursor input using a raster device.

One can have 8.5 by 11 inch thermal hardcopy from a storage tube device or up to 34 inches from a plotting device such as the Houston Instruments. This large format output is recommended for networks having a high density, such as a regional network or a large structure for error checking and viewing pertinent data.

The data is sequential for input. The links are designated by the operator during the execution of the program and then a series of coordinates are input and are interpreted to be the sequential nodes of the link or of the segment. The segment being made up of a set of small links; a curve segment is represented by a series of short vectors, for example.

Each link of a network has ascribed to it two costs, one being calculated from the distance between the two endpoints describing the link, given the scale of the overall image. That primary cost is known as a geometric cost. The secondary cost is known as an optional or auxiliary cost, such as speed limit or monetary costs of transversing a particular link. This second cost is associated within the database to each link. One might logically imagine that it is tagged on the end of the record for that link description.

Since NETWORK is a front-end for TOPAZ (and in effect serves as a data preprocessor for TOPAZ), it is concerned not only with networks but their associated zones, because of the ultimate data integration with TOPAZ. There are three sets of points that are associated with networks and/or these zones of activity. The normal nodes (which are network related only), the gates (which are network related only), and the zones and the centroids of the zones (which are network and zone related). A centroid is a means of connecting a network to an associated zone and is a x/y coordinate not determined by the user directly but by the user's coordinate description of the zone. As the user creates a zone, for example, a rectangle, a centroid is created based upon the area and shape of the zone and is usually (or often) the dead center of the zone. It's a simple matter of computing delta x, delta y and halving those figures and adding them to the minimum x, minimum y of the zone to create a centroid.

Zones can be created and deleted at will, points describing the network can be moved, gates be moved, centroids cannot be moved unless the zone is somehow modified, if the edges of the zone are shifted about; of course, a new centroid will be calculated and a new link would have to be computed as well.

The data record structure presently one record per link or node. One would rather be able to delimit each record not by a carriage return/line feed but by a control character and then be able to add as much cost of other relevant data as necessary so one would not be limited to a certain field width.

From an external digitizing source, if the original data has not been created during an on-line NETWORK session (which is frequently the case because there are so many data bases existing (largely in DIME file format), a little massaging or error checking data can readily integrate the data into NETWORK), the data is organized into two files. One file is called a coordinate file, which is a listing of coordinates. Each coordinate simply has a code id, or an identification number, a x, and a y coordinate; thus three values for each coordinate. Each node can be defined as being a gate (a sink of flow or a source of flow within the network), a normal node (a node

that is merely a change in vector within a linkage segment, such as a portion of a curve), or a centroid. The second file takes these coordinates, the coordinate identities, and creates a linkage file or consists of a linkage file which explains to the program the connectivity of the points. The first file can be likened to a set of dots on a page and the second file is the description of how to connect the dots. This second file consists of a linkage id, which is for optional later use by the user for error checking, a coordinate id (or identification number) for the coordinate that the linkage is proceeding from and finally a coordinate or identification number for the endpoint or the termination of that particular point. Once the files are read into NETWORK and processed, a single binary file may be written containing the network data.

In a city with maybe only its major arteries described; typically one may have two or three thousand coordinate identifiers and thus, depending upon how many streets are one-way and the sets of linkages, there may be four to six thousand links describing the network.

All zones have to be created while running NETWORK, either on a storage tube or raster display device, or else digitized from probably an overlay on a digitizer of plotted output. The present version of NETWORK does not allow the input of zone descriptions or zone files from external sources.

If one is running the program on a virtual machine, the data quantity limits are very large. This has yet to be decidedly proven, however, but in a future study to be undertaken will be the analysis of a network describing Los Angeles. I think that may be a credible test.. The computational efficiency has yet to be quantified. Everything, from a minimum path computation standpoint however, has led me to believe that the calculational complexity of the equation is linear, that is, as one introduces more and more links into a data structure or into a network structure, the amount the computation increases linearly and not exponentially.

From a display standpoint, since the program has been written in a easily transportable language, certain input/output functions have been clustered to simplify installation and thus, during the course of execution, a moderately optimized number of subroutine calls are made. This course of moderation may somewhat increase the computational load, but is offset by the ease of modular support of the program.

From a data structure standpoint, the data structure might be called "dynamic star-out." It allows modifications in the network by using backward and forward pointers linking all endpoints of links starting at the same node. The structure consists of a set of vectors for the nodes and another set of vectors for the links. Thus, operations like insertions and deletions of nodes and links become very efficient with the dynamic star-out representation. Another feature of this data structure is that the number of lines used in the link and node lists is always minimum; this is a consequence of the fact that the deletion of any link creates a space which is used by the next inserted link. This benefits core utilization. A similar strategy is used for the insertion and deletions of nodes.

NETWORK uses a command language structure common to most of the Laboratory's programs. This structure has proven to be a viable means of communicating with an individual program while providing, to an

extent, a measure of support to the new user. A keyword vocabulary contains a relative coding scheme to allow the user to communicate requests to the program in an informal yet exacting manner. The language is largely based upon verb-object constructions with simple punctuation rules. Modifiers such as WITH or BY are used to distinguish special conditions or environmental/parameter changes. There are three types of data which the language handler respects: integer values, floating point values and alphanumeric characters. These value types associate with variable types commonly known as integers, reals, and strings, respectively. The NETWORK language will accept data entered as part of a request, however the user should be aware that the ultimate processing of the data will be with respect to one of these three data types. For the inexperienced user's convenience, an online help utility explaining the meanings and features of the major verbs of the request language is supported within the program. Help is presented to the user following the request HELP [verb].

There are two types of interactive session environments. One can work under a viewing format, in which one is examining the data and looking at the results of minimum path calculations or the integrity of the network. Alternately, one might be operating under a creation/editting type of environment in which new geometric or topologic descriptors are introduced into the database and/or editting those elements; moving them around, deleting them and/or creating additional elements. Commands for the former operation would be 'draw network,' or 'draw zones;' these would be very English-like commands. A scaling grid may be overlaid the network with commands such as 'draw grid with interval:100' which would mean having a tick mark drawn every one hundred feet if the scale is known to represent, say, 500 feet or 5000 feet to the inch, or whatever. The latter operations are the greater portion of the command language and those include 'move point' or 'delete link' or 'delete one way link' or 'delete two way link,' at which point the program will present the display device with a set of crosshairs and ask for the user to input the endpoints of the link that is desired for modification or deletion.

There are four sets of alphanumeric reports that are optionally switched on or off during a NETWORK session. The first report is simply a summary of the node attributes for each coordinate identity. The second report is a summary of the minimum path/times between the network entrances and user-selected gates, provided that the user has chosen to calculate the minimum path spanning trees within the network (based upon or rooted from a user-designated set of gates). The third report is a report of the minimum path/times between all nodes within the network; from each root to every branch of the network, be it a gate or not. This report lists the minimum path sums from all entrances to all normal nodes within the network. The fourth report is connectivity analysis of the minimum path spanning tree. This is an error report which tells the user if any gaps exist within the network; if there are any segments that are not reached by any path within the network. This report might indicate a data situation analogous to a 'bridge-out' syndrome.

During an interactive session, there are many graphic presentations available to the user. One can request a network to be drawn, a network and its zones to be drawn, or the zones by themselves; as well as (when the user requests minimum path spanning calculation), the program will dynamically exhibit the growth of the

tree from each rooted entrance. And as it, the tree, grows or radiates from the entrance (and this is most effective on a color display), the selected paths are drawn. The resulting graphic represents a minimum path spanning tree overlaying the original network. The tree can be based upon the geometric costs or the optional (or auxiliary costs) associated with the network, such as travel time.

The program is a licensed distribution Laboratory product. Within the Laboratory, Bruce Donald is responsible for program support and distribution. The NETWORK is being licensed for US$10K initial fee for a one year non-exclusive license, with an option to renew the license at $1K per year. The program has been implemented only on certain hardware. Presently, there is only a supported DEC VAX version, there is not a supported IBM version; and any other distribution/installation would be at the user's risk.

The software was initially distributed earlier this month, July of 1981. As of today, it is in use here at Harvard and at a corporation in Ohio. Documentation is in a final writing stage.

ABSTRACT

The paper defines the background and current use of Geographic Information Systems (GIS). Specifically, it describes and illustrates a computer based interactive graphics GIS developed at Harvard University, called The ODYSSEY Project.

Geographic Information Systems: The ODYSSEY Project

by
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data base (along with its associated attributes), performing analytic tasks on the data, such as polygon overlay, and displaying the results as colored or black and white thematic maps.

BACKGROUND

For the last several years, there has been a tremendous growth in the acquisition and use of environmental data. This has come about because of satellite and airborne data collection systems, such as LANDSAT, and a generally increased need on the part of federal, state and local government agencies for the use of this data. The availability of this data obviously resulted in the need for computers to store, analyze and display the data and for the development of sophisticated geographic information systems (GIS).

As the information systems become more sophisticated, and the man/machine interfaces more facile (higher level languages, the use of color display devices, etc.), an increasing number of users are becoming interested in the use of such systems. These new users might include corporate managers wanting to, for example, generate demographic analyses related to a new product's market penetration, a paper company that might want to compare LANDSAT coverage of a geographic area of interest with their traditional paper maps, a utility company wanting to see what type of equipment is already underground before starting excavation for a new sewer line and other applications.

There are a number of approaches for designing and evaluating a particular geographic information system. The figure below from Tomlinson et al. (1976) depicts a three-stage process for designing and evaluating a GIS. These include the determination of the system's objectives and resource assessment (stage 1), the generation and evaluation of various system designs (stage 2) and their evaluation in terms of meeting systems specifications determined during stage 1 (stage 3).

A number of individuals have assessed the proliferating number of geographic information systems and compared them in terms of a number of characteristics. Some of the better surveys that have been conducted include (listed chronologically) Power's "Computerized Geographic Information Systems," (1975), the International Geographic Union's "Inventory of Computer

GEOGRAPHIC INFORMATION SYSTEMS: THE ODYSSEY PROJECT

by Eric Teicholz [1]

1 June 1980

There are numerous public and private agencies that are currently creating geographic (location specific) data. These agencies include the Census Bureau (County DIME, Urban Atlas, DIME files), the United States Geological Survey (Land Use Series), the Central Intelligence Agency (World Data Banks I and II), NASA (LANDSAT), the Soil Conservation Service (soil surveys) and others. In addition, there are an increasing number of commercial service bureaus offering geographically referenced data. A major problem facing planners, resource analysts, marketing analysts, mathematical geographers and others is the ability to combine these different coverages into a common data base (population, land use, sales areas, zoning districts, etc.), and the ability to compare these irregular coverages by means of the analytical process of polygon overlay in order to create a composite coverage. This latter task would give the analyst the ability to display a map of, for example, employed persons between the ages of 40 and 50, paying between $2000 and $3000 in real estate taxes and aggregated to congressional districts.

The ODYSSEY project of the Harvard Geographic Information System was designed to respond to these problems. ODYSSEY is an open-ended series of program modules that interactively create, manipulate, edit and display geographic data. More specifically, the ODYSSEY programs create data bases by integrating data from a variety of sources, enabling the manipulation of a

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Software for Spatial Data Handling." (1976), Tomlinson's et al. "Computer Handling of Geographical Data," (op cit.), Salmen's et al. "Comparison of Selected Capabilities of Fifty-Four Geographic Information Systems." (1977), Cowen's "Coastal Plains Regional Resource Information System Study." (1978) and Knapp and Rider's "Automated Geographic Information Systems and Landsat Data: A Survey." (1979).

A geographic information system, as opposed to a management, or any other type of information system, has as its input geographic or location specific data (X,Y coordinates, a street address, latitude/longitude, etc.). Figure 2, from Knapp and Rider (op. cit., p. 58), graphically depicts the essential components of an idealized geographic information system.

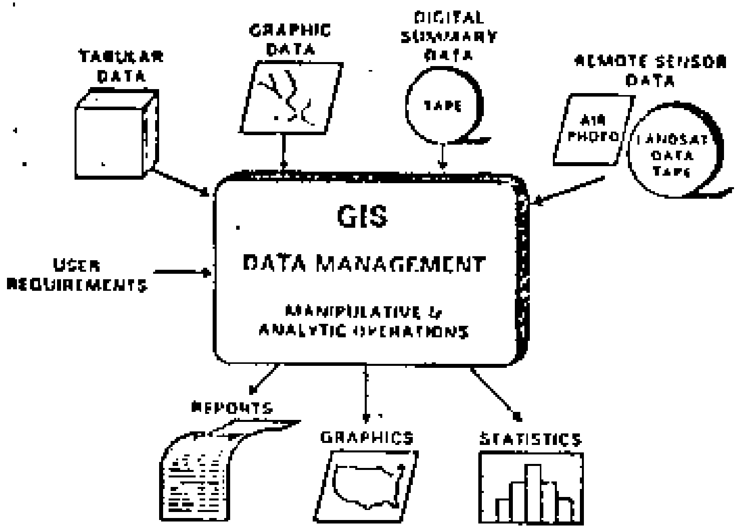

Figure 2: Graphic Representation of a GIS (from Knapp and Rider, p.58)

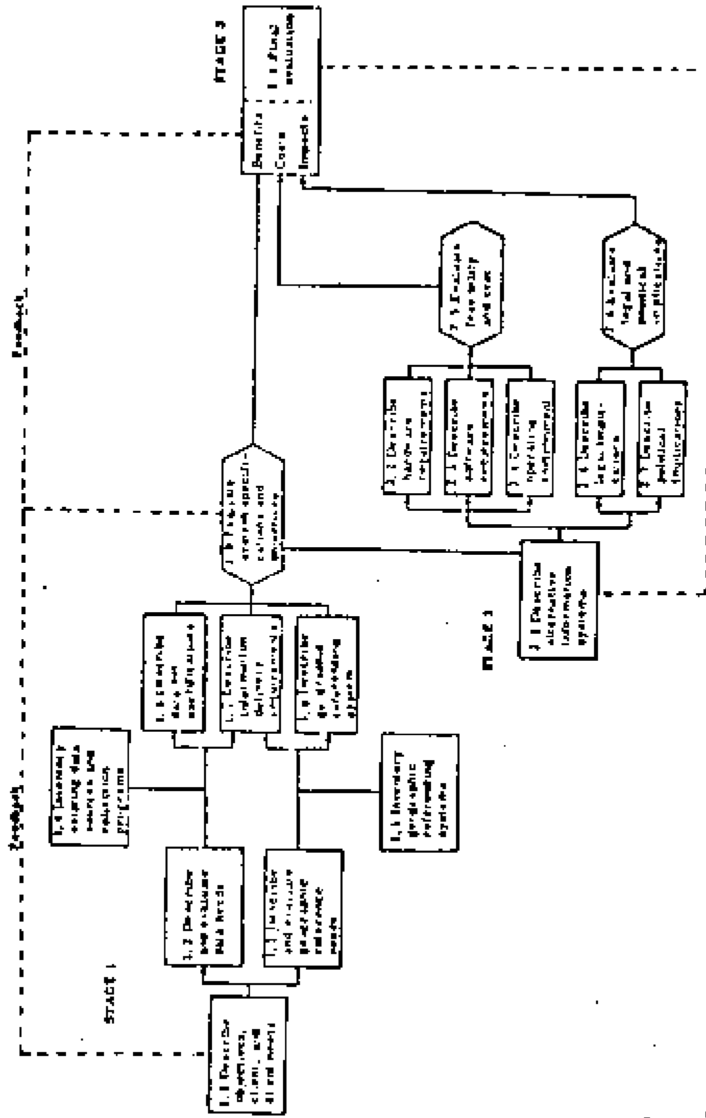

Figure 1: (from Tomlinson et al., 1976, p. 16) Information System Design and Evaluation Model

Knapp and Rider (op.cit. p. 57), describe 5 subsystems that would make up such an ideal GIS. These include subsystems for data encoding and input processing, data management, data manipulation and analytic operation, and data display.

Data Acquisition concerns itself with graphic and statistical data encoding and input processing. Data structures must encompass points, lines, surfaces and polygons. Encoding structures include grids and polygonal types (see Peucker and Chrisman, 1975). The merit of each type is discussed in detail by Kennedy and Meyers (1977). Data Management applies to both graphic and attribute data and deals with capabilities such as report generation, security, data integrity, and a variety of statistical reporting functions. The Data Manipulation and Analytic Operation subsystem applies both to the graphic data base and the statistics that relate to the geographic areas of interest. Operations here might include projections, transformations, combining different types of data, polygon overlay, statistical analysis on the data, etc. Data display obviously relates to the ability to output maps, graphs and tabular information on a variety of output media.

THE ODYSSEY PROJECT

The process modules of ODYSSEY operate independently with a common file structure from a single language processor without the use of directories. For purposes of simplicity, ODYSSEY's functional components (Table 1) can be divided into: (I) Sources; (II) Management; (III) Analysis and Display; and (IV) Converted Geographic Output.

DATA SOURCES

ODYSSEY, as a general purpose, open-ended GIS, can operate on a variety of data types. Some of the data input will be topological in nature. These data include the Census Bureau's DIME files and other readily available topological data files such as the Harvard Laboratory's version of World Data Bank I and the U.S.G.S.'s land use data files. Other data that might be input include polygon-formatted data such as those generated by the Census Bureau's Urban Atlas Files. A generalized grid/raster interface exists for entering classified raster images (such as those from the LANDSAT satellites) or from raster-scanned digitizers.

Finally, ODYSSEY has the ability to handle unstructured digitized "spaghetti-type" data, consisting of lines with no topological information. This data is automatically converted to a topologically consistent output file that is subsequently merged with user-specified polygon identifiers. This module also includes the capability of identifying common digitizing errors such as under- and over-shooting nodes and checking for topological consistency.

Among projected sources of attributes for geographic units are census data containing a variety of economic, agricultural, demographic and housing data variables; data generated from statistical packages such as SPSS or SAS; and nominally classed data from image sources.

DATA MANAGEMENT CAPABILITIES

The analytic power of ODYSSEY lies in its ability to interactively process both network (cartographic) and attribute data. None of the capabilities described below is unique, but the broad spectrum of analytical capabilities embodied under a single geoprocessing information system distinguishes ODYSSEY from other information systems.

Verification and correction capabilities may be performed in either manual or automated mode. Chains* can

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* A continuous line of any shape, containing any number of coordinates, which represents a boundary between two adjacent polygons or between a zone and the background polygon.

be updated in terms of replacing, inserting and deleting single or groups of coordinates or entire chains. Most topological inconsistencies are automatically identified and corrected. Digitizing errors such as under- and over-shoots or lines are detected and also corrected automatically. Other inconsistencies are just identified and require (manual) correction.

Splicing (or quilting) refers to the merging of multiple data files such as those from different map sheets. Data can, and often should, be maintained as separate files. It might be desirable, however, to combine files, particularly when performing global operations on the data. One might want to merge, for example, state-referenced data with other data that cross state boundaries (such as sales, health zones or land use polygons). Splicing performs the function of fitting together adjacent areas.

Network or geographic overlays are one of the most powerful analytical capabilities performed by ODYSSEY. An analyst will often want to query the resultant network created by overlaying two or more networks. Cellular output is possible but true polygon overlay with complete identification of intersections exists within ODYSSEY. A planner might want to overlay land use data with flood plains. A business analyst might want a demographic profile of his sales districts that can be achieved by overlaying census enumeration districts with sales zones. A forester might want to compare his tree inventory regions with soils maps.

Geographic aggregation relates to the building of small units into successively larger units such as streets into blocks into tracts into townships into counties into states into regions into countries into worlds into galaxies - although some cosmological problems might be encountered within ODYSSEY in the merging of streets into galaxies.

Both line and area generalization are performed by ODYSSEY. The line generalization routine searches for "trend lines" in chains and appends a detail tolerance level value to all coordinate values. A user can then ask for any level of detail desired for a particular display (Figure 3).

Table 1: ODYSSEY Functional Components

I. SOURCES

- A. GEOGRAPHIC
  1. TOPOLOGICAL NETWORKS SUCH AS GBF/DIME, WORLD DATA BANK I, COUNTY DIME, U.S.G.S. LAND USE DATA FILES
  2. DIGITIZED INPUT WITHOUT TOPOLOGY
  3. POLYGON FORMATTED DATA SUCH AS THE CENSUS BUREAU'S URBAN ATLAS FILES
  4. GENERAL GRID AND RASTER DATA
- B. ATTRIBUTE
  1. CENSUS DATA
  2. STATISTICS PROCESSORS SUCH AS SPSS
  3. NOMINAL DATA

II. MANAGEMENT

- A. GEOGRAPHIC
  1. VERIFICATION AND CORRECTION
  2. SPLICING
  3. OVERLAY
  4. AGGREGATION
  5. GENERALIZATION
  6. CARTOGRAPHIC PROJECTIONS
  7. POINT-IN-POLYGON
- B. ATTRIBUTE
  1. AGGREGATION/DISAGGREGATION
  2. CLASSIFICATION
  3. MERGING
  4. CORRECTION

III. ANALYSIS AND DISPLAY

- A. NETWORK MEASUREMENTS
- B. BASE MAPS
- C. 2-D CHOROPLETH SHADED AND COLOR MAPS
- D. 3-D PRISM MAPS
- E. INPUT FOR LINE PRINTER MAPS
- F. NON-GRAPHIC TABULAR REPORTS SUCH AS AREA, PERIMETER CALCULATIONS

IV. CONVERTED GEOGRAPHIC OUTPUT

- A. POLYGON FORMATTED FILES
- B. GRID/RASTER FORMATTED FILES

Point-in-polygon calculations refer to the ability to automatically identify a point that lies within one coverage set (land use, school zones, etc.) with another coverage set. For example, a natural resource analyst might identify a data point source from a Census map (i.e., a street name) and want to know the soil conditions that exist under that street (obtained from a U.S.G.S. soils map) or in what congressional district a land use category lies (derived perhaps from a LANDSAT satellite image) without performing the computationally demanding operation of polygon overlay. The point-in-polygon routine provides the analyst with this capability.

Attribute management consists of aggregation, classification, merging and correction of the appropriate statistical data. Aggregation of attributes is directly related to network or area aggregation (i.e., if areas are to be aggregated, then area data attributes may need to be aggregated). ODYSSEY will aggregate attributes in a "natural" way. That is, numerical data such as absolute counts of population distribution might be simply added while population densities would be automatically recomputed based on population counts and the area or zones of interest. Nominally valued (class) data, on the other hand, would be aggregated by simple concatenation, predominant type or according to specific priorities. Land use data for small areas, for example, would be concatenated as a result of the aggregated network of land use polygons.

Attribute disaggregation involves certain assumptions. Nominal data is easily broken down whereas more complex data such as population counts require an assumption about the spatial distribution. For example, if you have population density for regions and want to know density by zones within a particular region, ODYSSEY can either take the counts per zone and zone areas to calculate new values or, if zone counts aren't available, assume a uniform population distribution for the region and disaggregate the data using this total value.

Attribute classification represents a functional transformation of the attributes. This transformation is usually from larger to smaller groups which could (in certain instances) involve the conversion of nominally-classed data into ordinal data. An analyst might start with land use classifications and want to rank the data into suitability categories according to certain criteria.

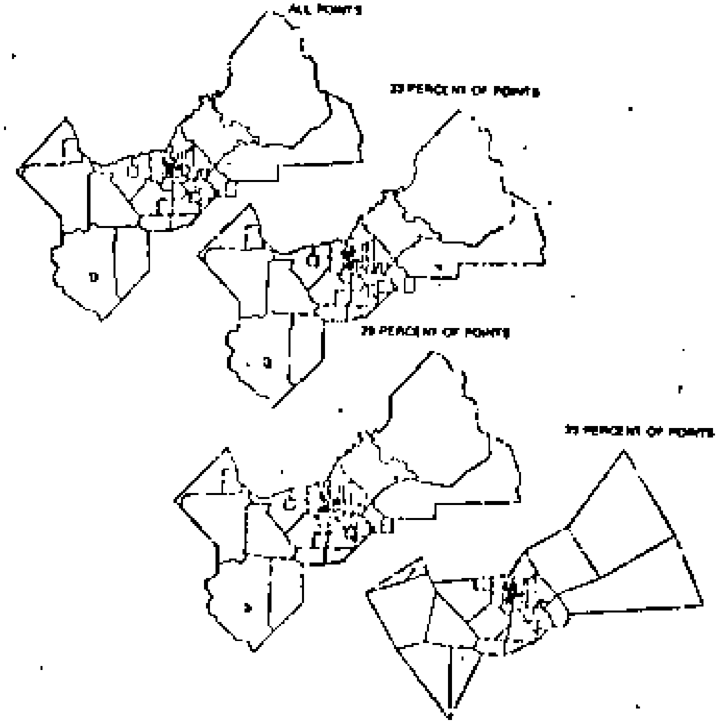

Figure 3: Line Generalization (Fresno SMSA 1970 Census Tracts)

Line generalization starts by collapsing coincident lines at user specific localities. This ensures that line generalization will not introduce topological inconsistencies. Furthermore, features such as deltas or bays will be simplified. Area generalization results in the deleting of polygons that are inconsistent with either the current scale of the data being used by the analyst or the resolution of the display device being used for output.

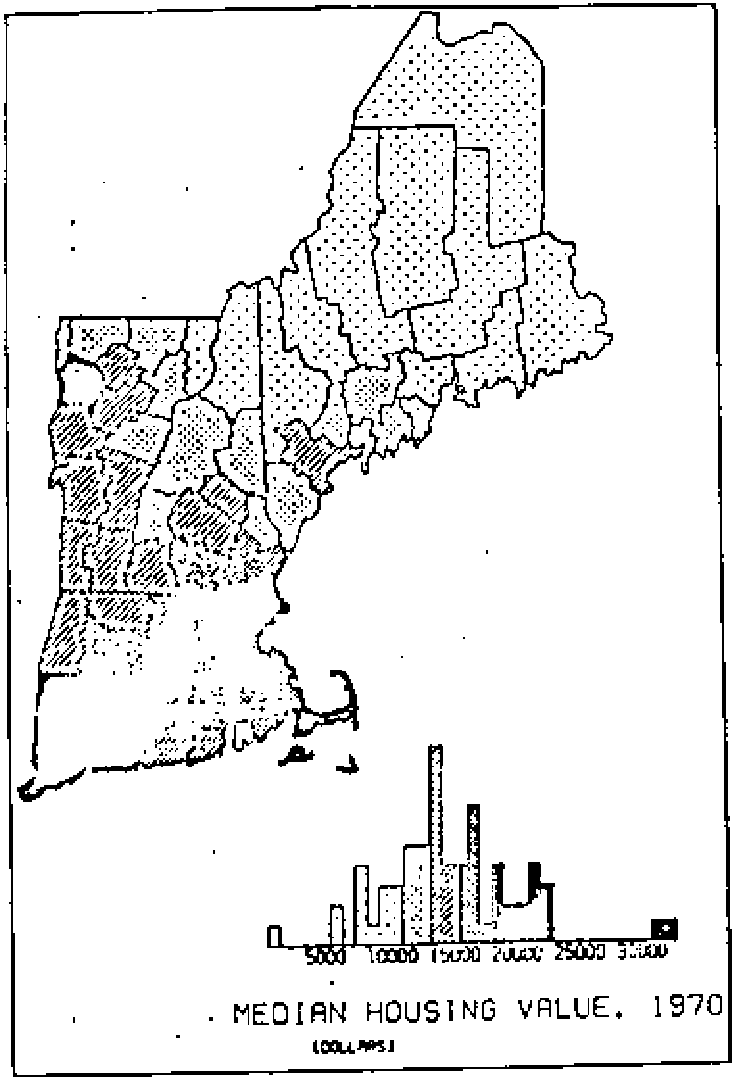

Figure 4: POLYPS Output

attribute merging corresponds to network splicing or quilting. As data from different map sheets or different files are merged, attribute data corresponding to the different files are automatically merged.

Attribute correction is an editing function. ODYSSEY can edit globally as well as locally (i.e., functions can be applied to all or part of the data). Analysts can therefore change all instances of the category "red" to the category "black" or add a number calculated as the fertility index times the number of women from 18-45 years of age times a magic constant to all population counts within a particular region.

ANALYSIS AND DISPLAY CAPABILITIES

It is difficult to incorporate ODYSSEY's analytic capabilities into a single section. Analysis is involved in all aspects of manual, semiautomatic and automatic data capture and network and attribute management. Besides capabilities associated with data capture and management are facilities to perform first-order geometric measurements on the data such as length, area and perimeter calculations and the ability to derive topological properties of the network such as finding all areas that are contiguous to a certain zone.

In terms of display, ODYSSEY can display base maps, shaded black and white or colored choropleth maps, three-dimensional representations of polygon surfaces and line printer maps.

POLYPS (figure 4) is the 2-D display module of ODYSSEY. It draws shaded or colored choropleth maps offering the user a great deal of flexibility in classifying and representing the distribution of a spatial variable. The program is capable of automatically classifying a continuous variable (i.e., percent of children bussed to school) by any one of five methods including: equal intervals, rank intervals, deviations, quantiles and F-ratio. A user can manually specify the class intervals and number of levels. Grey-scale symbolisms include crosshatch, dot, halftone, and random dot. Parameters affecting the perception of the symbolisms, such as the range of lightness to darkness or the colors (if being displayed on a color CRT), can also be controlled by the user. Nominal data such as soil types or land use categories which involve discrete types, as opposed to continuous values, may also be mapped.

(Continued page 16)

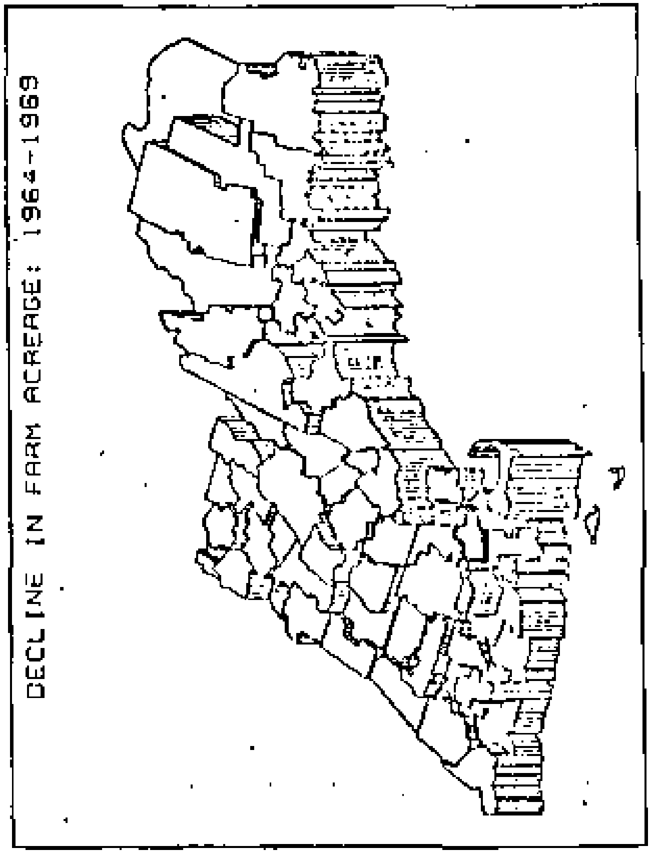

Figure 5: PRISM Output

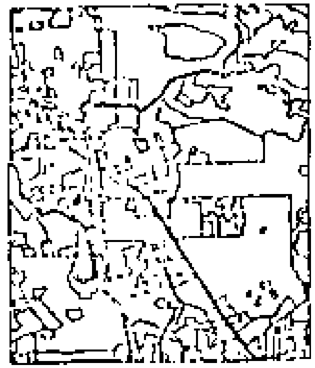

Figure 6: Land Use Coverage

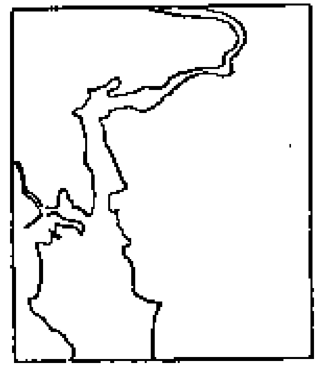

Figure 7: Flood Plain Coverage

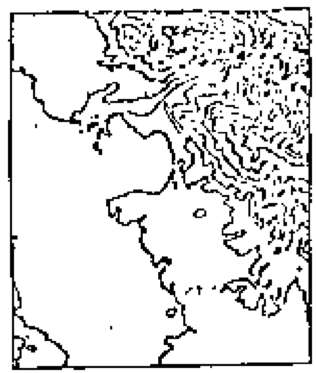

Figure 8: Elevation Coverage

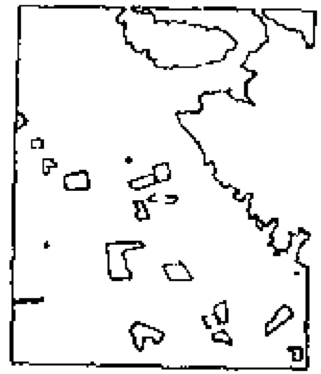

Figure 9:
Set Landuse: (ACC)
Set Elevation (E0,E100,E200)
Select LANDUSE or ELEVATION

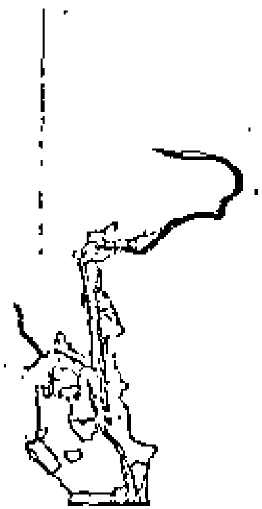

Figure 10:
Set Floodplain: WET
Set Elevation: (E0)
Select FLOODPLAIN AND ELEVATION
Form Detailed Landuse

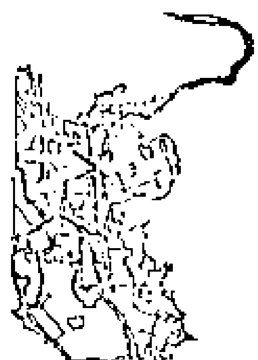

Figure 11:
Union of Floodplain and Elevation Data
Set Floodplain: (WET)
Set Elevation: (E0)
Select FLOODPLAIN OR ELEVATION
Form Detailed Landuse

PRISM (Figure 5) is ODYSSEY's program for displaying 3-D scenes of discrete, spatially-varying surfaces. PRISM plots 3-D scenes with hidden lines removed and the visible prism sides shaded. Options include viewpoint modification (azimuth, altitude, scale), shading parameters (angle that the light source is coming from, minimum and maximum spacing of crosshatch lines) and annotation parameters (box around plot, title).

Reports generated by ODYSSEY include tabular outputs such as names of areas or attributes within a particular region and other local or global characteristics associated with the data set of interest.

CONVERTED GEOGRAPHIC OUTPUT

It is often desirable, for purposes of archival storage or if subsequent processing is to be done on the data, to output binary or ASCII files of ODYSSEY-processed data. Both polygon and gridded data files can be output.

ANNOTATED EXAMPLES

This section of the paper contains descriptions of two examples of ODYSSEY use. The first relates to land use and illustrates Boolean set notation on various coverages, and the second is taken from a forestry project and illustrates polygon overlay analysis. In the first example, an analyst starts with three files containing geographic data on land use, flood plain and elevation coverages (Figures 6,7, and 8).

Using Boolean set notation, the analyst then specifies subsets of each coverage to be selected. The inclusion sets can be chosen using union, intersection and complementation operators, for use in later selection expressions. The total area of interest is described in a selection statement which uses the operators AND and OR to combine features from one or more overlaid coverages. In our example, regions for LAND USE, ELEVATION and FLOODPLAIN may be retreated individually, or all three coverages may be mentioned in making a selection.

After defining areas of interest, the analyst uses commands to specify a level of detail desired <u>within</u> that area. Each coverage may be chosen to be aggregated or presented in detail. When detail for a coverage is specified, all codes for that coverage which are present in the area of interest are displayed as separate regions and are tabulated as subtotalled areas. The effect is that of showing the original map for a particular coverage, within the outlines of the selected region.

Figure 9 depicts regions of cropland and the 300-foot contour line. Figure 10 shows the intersection of the WET area of the floodplain and the elevation zone 0 to 100 feet (Land Use Coverage presented in detail). Figure 11 illustrates the <u>union</u> of the WET area of the floodplain and the elevation zone 0 to 100 feet.

FORESTRY PROJECT EXAMPLE

This example demonstrates the use of ODYSSEY on a forestry project undertaken for a large paper company. The objectives of the study were first to evaluate the feasibility of plotting forestry stand maps (derived from aerial photographs) with ODYSSEY, and secondly, to test the utility of using LANDSAT satellite images to update the forest company's data base for inventory purposes. Figure 12 depicts a LANDSAT derived forest classification map (done at Purdue University) that was automatically converted to the ODYSSEY chain file format. Input consisted of the classified LANDSAT image in a grid format. Figure 13 represents a typical forest stand map that was encoded with a line-following digitizer.

The next step was to overlay these two images to produce a composite map. The values associated with each of the polygon files were then compared by calculating a cross tabulation between the measured and the LANDSAT-derived forest types. Discrepancies (measured in terms of hundreds of acres) could then be automatically calculated. Figure 14 depicts the composite (overlayed) map, and Figure 15 shows (in black) the correspondence between the LANDSAT-derived and the aerial survey-derived data. Discrepancies could then be depicted by forest/category or classification and results depicted graphically (Figures 16 and 17) or by area tables.

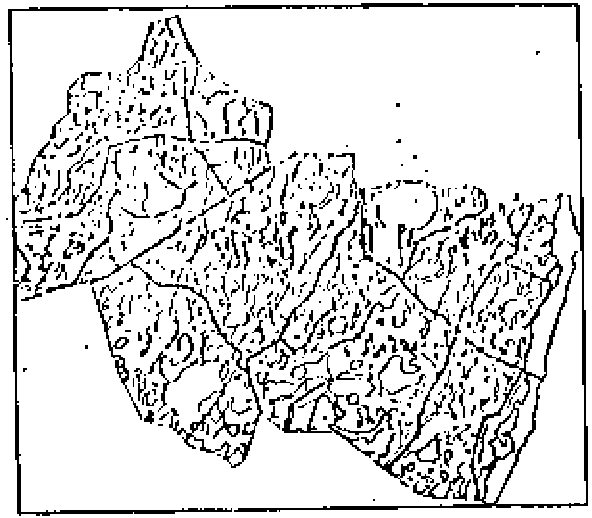

Figure 13: Digitized Forest Stand Map

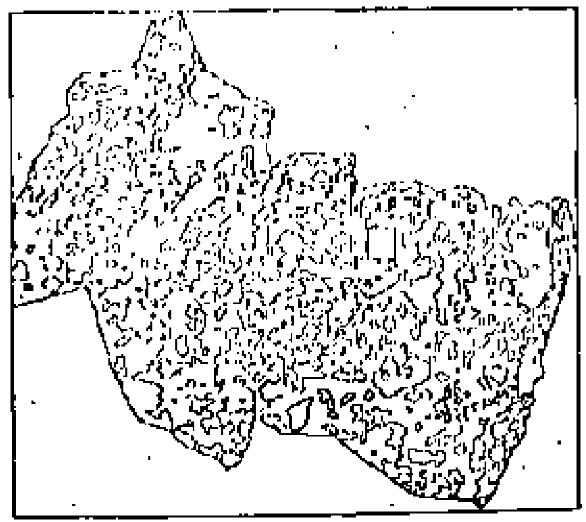

Figure 12: LANDSAT derived Forest Classification

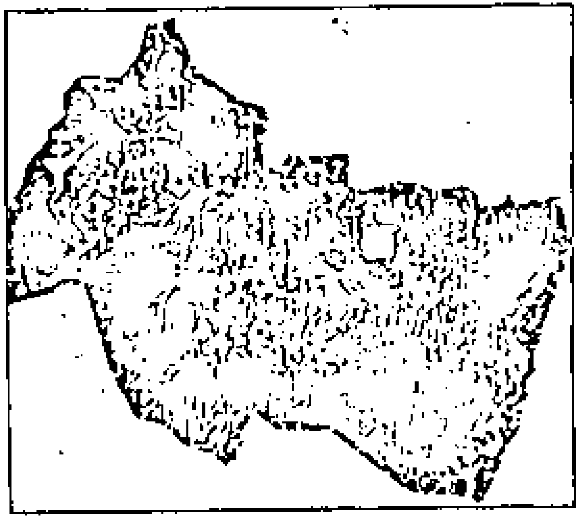

Figure 15: Agreement (shown in black) between LANDSAT and Survey Data

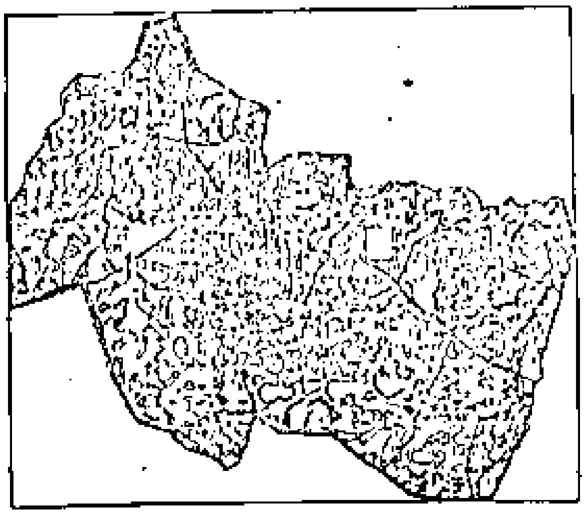

Figure 14: Overlayed Map

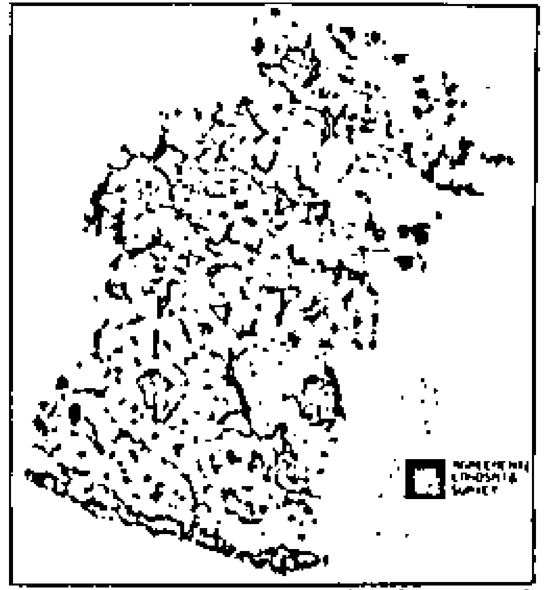

Figure 16: Hardwood Agreement

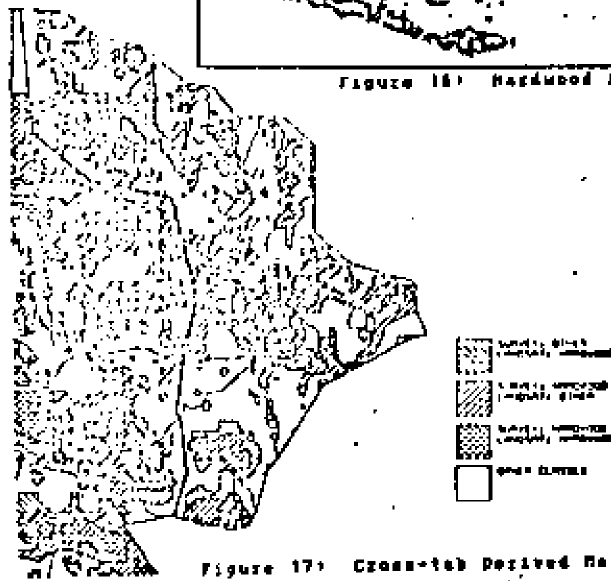

Figure 17: Cross-tab Derived Map

THE FUTURE

In terms of hardware, ODYSSEY currently operates on 32-bit and larger word machines. At Harvard University, VAX 11/780 and PDP-10 versions are maintained and IBM S/370 and CDC 6000 series versions exist. Program modules take from 40 to 60K (DEC 10) words. All software is written in ANSI Fortran IV. Peripherals include disks and, optionally, tapes, digitizers, plotters, color camera hard copy devices, and other graphic I/O equipment.

Future hardware developments will include dedicated turnkey systems with all or a subset of the current program modules. For example, there might be a natural resource management version of ODYSSEY that operates on a 16-bit word microprocessor or a Census Bureau version on a mini-VAX.

Related to applications, work is currently underway regarding network analysis and the merging of network and polygon data bases. Point and linear display modules are being developed and network analysis capabilities are being designed for integration into ODYSSEY. In this manner, a query such as the selection of the shortest route between Boston and San Francisco (network) that does not go through a city of greater than 100,000 people (polygon) might be made.

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ZIPMAP™: AN AUTOMATED SYSTEM FOR MAPPING 5-DIGIT ZIP CODES

INTRODUCTION

Why hasn't someone developed an automated ZIP Code mapping system? This is a question that has many answers, but the basic reason is because nobody has digitized the boundaries of all ZIP Code areas. A further complication is that ZIP Code boundaries often change. To make matters even worse, the U.S. Postal Service does not possess nor support any cartographic base files, maps, or boundary information on 5-digit ZIP Code areas.

Until ZIPMAP™ the best a market researcher could do was map centroids of ZIP Code areas using a commercially available centroid file from Rand McNally, Donnelley Marketing, or List Processing Company. In special cases companies such as Geographic Systems and Demographic Research would digitize ZIP Code boundaries from telephone books, the Rand McNally ZIP Code atlas, or from maps available from small local map publishers. Generally, these mapping efforts were performed under contract for a limited number of metropolitan areas. No complete, national coverage of the approximately 37,000 ZIP Codes existed. In addition, the costs for these custom mapping efforts were relatively large and well out of reach for most marketers.

One alternative to mapping ZIP Codes is to map census tracts. Census tracts have defined boundaries, and digitized cartographic base files have been available for 1970 census geography. The availability of 1980 tract boundary files, however, is currently a major concern to the demographic and business data mapping community, since the Census Bureau has decided not to digitize tract boundaries. One commercial vendor, Geographic Data Technology, Inc., is publicizing that they will make available digitized 1980 tract files over the next several years on a roll-out basis. No doubt other vendors, including Geographic Systems, will offer digitized tract boundaries on a contract basis.

Unavailability of 1980 tract files is a problem that can be solved. Another problem for many companies is the high cost to meet the need to geocode all their customer address data to census tracts. A major benefit of ZIP Code mapping is that most inhouse customer files already have the 5-digit ZIP Code so that tract geocoding is not necessary.

For some purposes the ZIP Code may be too large an area, and the census tract or block group level of analysis is more appropriate. Census tracts, however, are but one geographic level in the census geography hierarchy. They are not territorially exhaustive, nor are they a consistent geographic unit in urban and rural areas. The ZIP Code is territorially exhaustive, coast to coast, and provides areal resolution at the smallest practical geographic unit consistent for both urban and rural areas. Since ZIP Code areas reflect the level of economic activity within an area, in terms of mail volume, the areal size of ZIP Codes generally corresponds to the density of economic activity.

This paper briefly describes a solution to the problem of ZIP Code mapping using a mapping system that portrays proximal ZIP Code boundaries, especially created for the thematic mapping of ZIP Coded data. The paper first describes the procedure for creating the ZIPMAP™ cartographic file. Several case study applications are described next, followed by a few observations on the pros and cons of ZIP Codes versus census tracts for map display and analysis.

PROXIMAL ZIP CODE BOUNDARIES

In researching the problem of establishing a national, uniform system for automated ZIP Code mapping, CSI discovered that for most market

research applications the precise boundary of a ZIP Code is not required. What the market researcher does require is a graphic that will show the relative positions of ZIP Code areas in relation to one another. A proximal, or approximate, boundary meets this requirement.

We also found that there were generally two types of needs corresponding to two levels of scale and resolution for mapping proximal ZIP Codes. One need was for a market overview, or assessment, of trends in a state or group of states. The second need was for detailed trade area analysis within a metro area. We are accommodating the needs for both regional and metro area geography by creating state level cartographic files that can be either combined to form multi-state regions or used to extract metro area ZIP Codes.

The approach we have taken to create ZIPMAP™ cartography utilizes the classical Thiessen polygon technique. We begin with a latitude/longitude centroid coordinate file of ZIP Code areas (see Figure 1) and convert them to an Albers Equal Area projection. We extract ZIP centroids on a state by state basis and draw perpendicular bisectors between neighboring centroids (see Figure 2). The resulting polygons are called Thiessen polygons, with each polygon edge defining the locus of all points (or people) equidistant from two centroids and not closer to any other centroid in the state. Line segments and polygons are cropped at state boundaries which are at the same scale and projection as the centroids (see Figure 3).

Proximal ZIP Codes have not been created for U.S. trust territories, APO and FPO military ZIP Codes, and certain ZIP Codes assigned to local firms within a given community. For places with a single ZIP Code, the ZIPMAP™ polygon represents the approximate areal extent of mail delivery to that place. For U.S. cities having more than one ZIP Code (multi-coded), polygons approximate the delivery area for a local Post Office branch or station or the proximal area of a ZIP Code. Proximal ZIP Code areas which correspond to a Post Office Box, Postmaster, or General Delivery of a multi-ZIP-Coded city are created for the main post office or geographic center of the city. In highly urbanized multi-ZIP Coded areas where ZIP Codes share a common proximal area, a single proximal ZIPMAP™ polygon represents several ZIP Codes and is specially coded to indicate a multi-ZIP range.

The ZIPMAP™ polygon roster of ZIP Codes has been cross-referenced with the Claritas REZIDE™ and Donnelley ZIProfile℠ ZIP Code rosters. Cross-referencing with the ZIP Coded data bases such as the Dun's Marketing DMI file and the Economic Information System I/MARKET file is planned. The task to keep the ZIP roster files cross-referenced

and polygon boundary files up-to-date will be a large but manageable annual project. The GSI Service Bureau will be responsible for maintaining and updating the ZIPMAP™ cartography and mapping system.

ZIP CODE MAPPING APPLICATIONS

The ZIP Code proximal polygon method is both time and cost efficient and provides a boundary file suitable for displaying and analyzing thematic ZIP Coded data from the multi-state level down to the SMSA, or metro, level.

An example of ZIP Code mapping at the multi-state level is represented by a company which was interested in evaluating the effectiveness of its sales promotion campaign, the efficiency of its sales territory force location, and alignments for following through on the sales campaign. Map #1 (on the green sheet) shows the spatial distribution of direct mail response to the firm's promotional campaign. The map shows where the campaign was effective or ineffective in terms of response rate. Map #2 (on the green sheet) shows the distribution of an index of income. The firm assumed areas of high income would produce high response rates and, therefore, can use this map to identify areas where response rates should have been high. Map #3 (on the green sheet) shows the correlation or association between response rate and the income index. From this map the firm can identify those areas where high response was expected, but did not occur, as well as where response exceeded or met expectations. Clusters of ZIP Code areas possessing similar characteristics are easily identified. Management action, such as focusing follow-up efforts into areas where high response should have occurred, can be directed easily and efficiently. Figure 4 portrays the present sales territory configuration. From this map the firm can see where its sales territories are discontinuous and overlapping, and can use it to coordinate future sales follow-up by each local office or to help realign sales territories in a more efficient manner.

At the state level an insurance company wanted to find out and understand the pattern of cross-selling of its product lines by different sales agents in Ohio. Who was selling how much of what product line or lines and where was it being sold? Where were there areas where a high percent of multiple product lines were being sold by one agent and a low percent by another agent? By mapping the percent share of sales of single versus multiple product lines for each sales agent, and then overlapping each agent's map and correlating the percent share of single versus multiple product lines, a complex analysis problem was reduced to a single graphic.

When the corporate market research analyst was asked by the company's regional sales manager at the inception of the project, "How else can we evaluate 1,357 ZIP Codes at a glance to determine areas of cross-selling opportunities missed and areas where we have high sales but high losses also?" The answer was quite succinct: "There is no other way."

CONCLUDING OBSERVATIONS

- We have found that both ZIP Codes and census tracts are valuable, commonly used, geographic units of analysis.
- Census tracts have been used more often in automated mapping applications than have ZIP Codes.
- ZIP Codes are found more often on customer and inhouse proprietary files than are census tract codes.
- Census tracts are used by the Bureau of the Census to tabulate demographic data.
- Zip Coded demographic data can be obtained through commercial data vendors who cross-reference ZIP Codes with Census geography.
- Census tracts have precisely defined boundaries that can be superimposed to overlay on a city or metro street map.

- The major obstacle to ZIP Code mapping has been the lack of a cartographic boundary file.
- The availability of ZIPMAP™ reduces the cost and makes available the automated graphic display of ZIP Coded data.
- With the increasing use of ZIP Coded demographic, industrial, retail, and inhouse data, ZIP Code mapping can now be expected to play a significant role in the analysis of this enormous data resource.

Figure 1. Connecticut 5-digit ZIP Code Centroids.

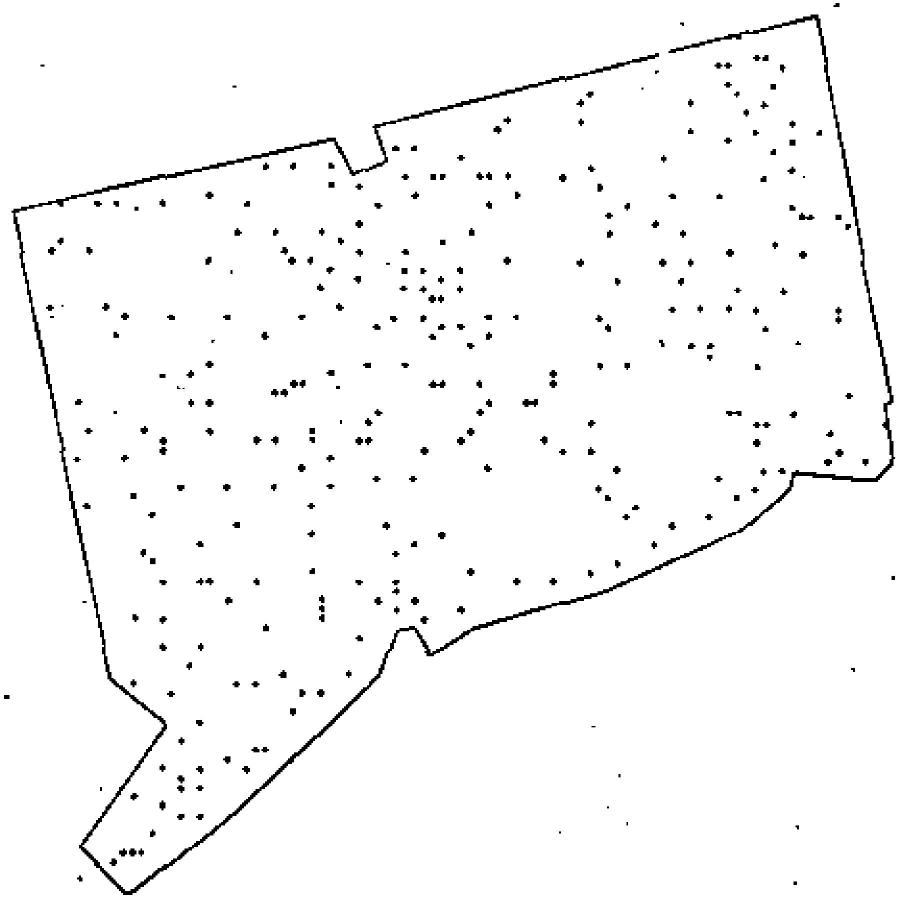


Figure 2. Thiessen Polygons Approximating 5-digit ZIP Code Areas.

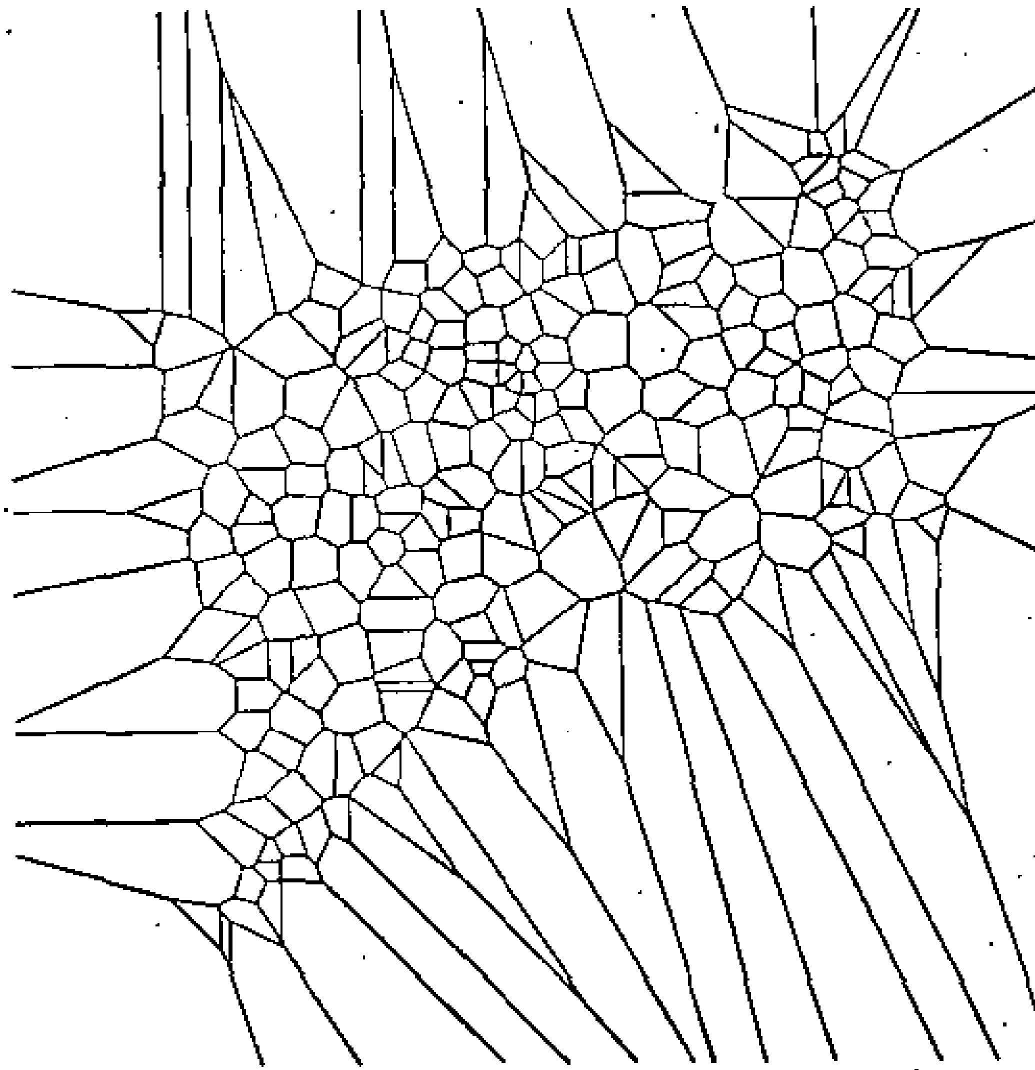
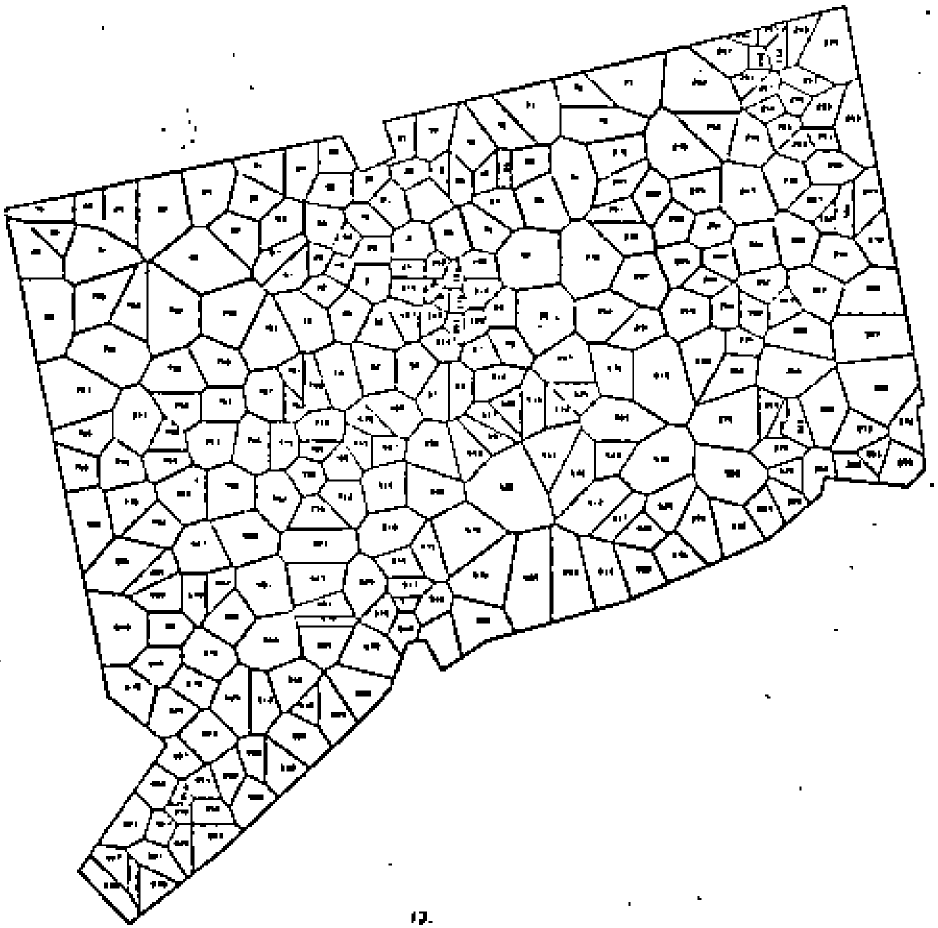


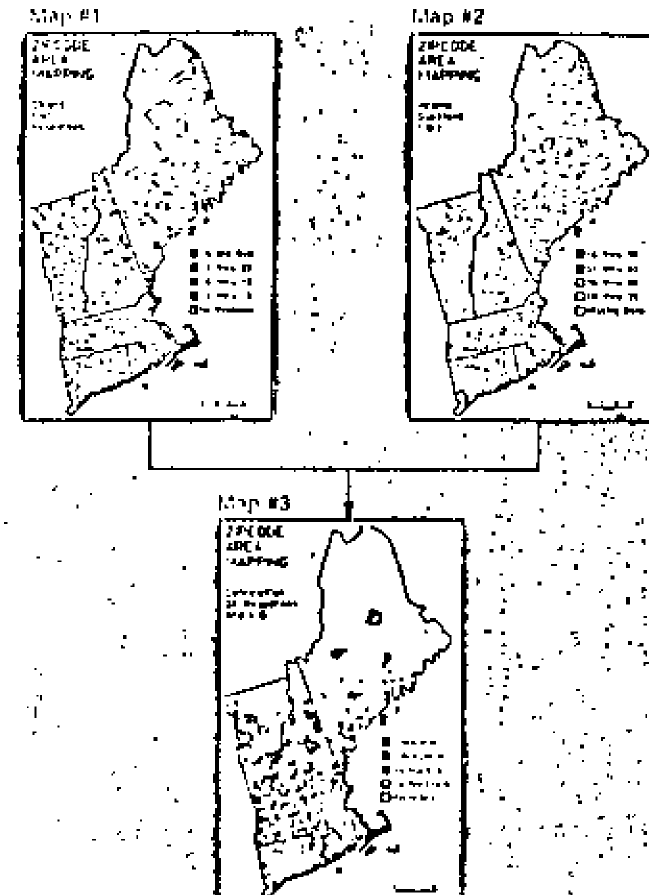
Figure 3. 5-digit ZIP Code Proximal Polygons with ZIP Code Labels.



ZIP MAP™ GRAPHICS

Example Application

The three maps shown below illustrate the use of ZIPMAP™ graphics for identifying specific geographic markets to allocate sales and promotional resources. Sales developed from direct mail is shown in Map #1. Household income, in the form of an income quotient, is shown in Map #2. The correlation between direct mail sales response and income is shown in Map #3. Sales territories were realigned, branch offices relocated, and sales efforts targeted using these and other ZIPMAP™ graphics.



DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

COMPUTACION APLICADA A LA PLANEACION URBANA

MODELOS DINAMICOS DE SIMULACION URBANA Y REGIONAL

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AGOSTO, 1981

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CURSO DE PLANIFICACION URBANA.

C O N T E N I D O

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I. INTRODUCCION

La impartición del curso Dinámica de Sistemas Sociales, en la Sección de Planeación de la División de Estudios de Posgrado de la Facultad de Ingeniería de la UNAM, dió origen a este trabajo, mismo que a partir de 1978 se ha ido complementando para utilizarlo como ayuda a este curso.

Para la realización de este trabajo se tomó como base el "DYNAMO USER'S MANUAL, BURROUGHS 1972 , al cual se le -- añadieron varios ejemplos diferentes a los que contiene el manual original, dichos ejemplos son modificaciones de algunos modelos tomados de la bibliografía y otros son originales del autor.

El estudio de estos modelos permite adiestrar a los alumnos en la producción de modelos mucho más complejos y elaborados que resuelven un sinnúmero de problemas de Planeación.

Por este medio quiero expresar mi agradecimiento a mis alumnos de la División de Estudios de Posgrado de Ingeniería de la Sección de Planeación y a los de la División de Estudios de Posgrado de Arquitectura del Area de Tecnología, que se encargaron de procesar algunos modelos que aquí se incluyen y cuya colaboración me fue sumamente valiosa.

II MODELOS

La palabra "modelo" se usa como un sustantivo,un adjetivo y un verbo,en cada caso tiene distinto significado. Como sustantivo, modelo es una representación en el sentido en el cual un arquitecto construye un modelo a escala o la maqueta de un edificio. Al usarlo como adjetivo modelo, implica un grado de perfección o idealización; el alumno modelo. Cuando se usa como verbo modelar significa demostrar, revelar, indicar cómo es una cosa.

Todos los modelos representan estados,objetos y eventos. Se idealizan en el sentido de que son menos complicados que la realidad y por lo tanto más fáciles para usarlos en investigación. Su simplicidad radica en el hecho de que sólo los aspectos relevantes de la realidad se representan, como el caso de un mapa de carreteras que es un modelo de la superficie terrestre y ahí no se contemplan los habitantes,las casas, los cultivos,etc, pues no son relevantes respecto al uso del mapa.

Los modelos se usan para acumular y relacionar nuestro conocimiento de diferentes aspectos de la realidad, y más que esto, sirven como instrumentos para explicar el pasado y el presente y para predecir el futuro.

Existen tres tipos básicos de modelos:

ICONICOS. Son representaciones de la realidad a escala ;vgr. un avión a escala, una maqueta de un edificio, etc.

ANALOGICOS. Utilizan otras propiedades diferentes de la realidad, o sea que se usa una propiedad para representar a otra; por ejemplo en un mapa para representar los usos del suelo usamos colores; la regla de cálculo es un modelo analógico en el cual las cantidades se representan por distancias proporcionales a sus logaritmos; las gráficas donde se representan propiedades tales como costos, tiempo, población, porcentajes, también son modelos analógicos.

SIMBOLICOS. Representan las propiedades de la realidad simbólicamente. Una relación mostrada en una gráfica también se puede representar en una ecuación; la ecuación es un modelo simbólico.
Los modelos donde los símbolos empleados representan cantidades se llaman modelos matemáticos. Dentro de los modelos matemáticos tenemos los modelos de simulación dinámica que se clasifican en modelos de tiempo continuo y modelos de eventos discretos o discontinuos.
Los modelos de eventos discretos cambian de estado cuando ocurre algún evento determinado. Este cambio ocurre generalmente en intervalos de tiempo irregulares. El modelo así construído describe actividades o entidades y eventos, y su interrelación, disparándose así, diferentes acciones que simulan la realidad que cambia según mecanismos lógicos prestablecidos. Dentro de este tipo de modelos tenemos a SIMSCRIPT, GASP, GPSS, SIMULA, algunos usos son: Simulación de un sistema telefónico, de una tienda de autoservicio, de una fábrica, de la avenida de un río, de un crucero urbano con semáforos, etc.

Los modelos continuos; DYNAMO, CSSL, SAS II (*) se llaman así porque el tiempo que es una variable independiente del sistema avanza en pequeños incrementos uniformes finitos. En este tipo de lenguajes todo el sistema se revalúa (digital o analógicamente) en cada intervalo de tiempo transcurrido. Desde este punto de vista la simulación continua se parece a la simulación analógica que resuelve sistemas de ecuaciones diferenciales. Al modelar, las ecuaciones expresan: la teoría de operación del sistema y una visión panorámica completa de las interrelaciones causa-efecto durante el tiempo transcurrido

de las variables que intervienen.
Generalmente estos modelos requieren menos información que los discretos pero necesitan de un estudio muy profundo de los mecanismos actuantes.

* Simulador Analógico desarrollado en el Instituto de Ingeniería, codificado en ALGOL para la Burroughs 6700.

III. EL COMPILADOR "DYNAMO"

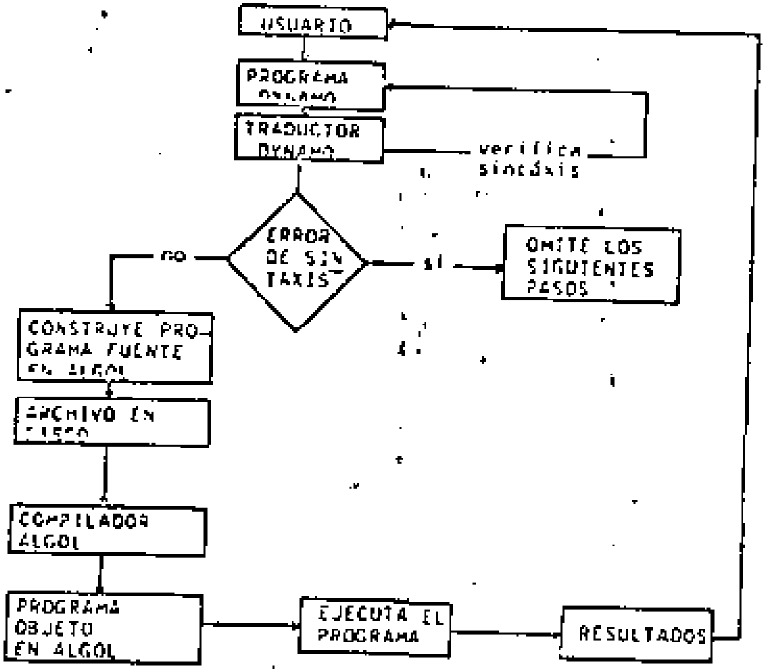
DYNAMO es un compilador para traducir y correr modelos continuos que han sido descritos por un conjunto de ecuaciones diferenciales. El compilador fue desarrollado por el grupo de dinámica industrial en el Instituto Tecnológico de Massachussets para realizar simulaciones de negocios, modelos económicos y modelos de sistemas sociales y actualmente se usa para simular cualquier sistema continuo.

DYNAMO se diseñó para personas cuya principal actividad es la de resolver problemas, dirigiendo sus esfuerzos básicamente a esta actividad evitando distracciones en complejos requerimientos computacionales.

DYNAMO aparece originalmente según Alexander L. Pugh III como un programa llamado SIMPLE (Simulation of Industrial Management Problems) fue escrito por Richard K. Bennet en 1958 para una IBM 704. El modelo evolucionó en 1959 apareciendo como DYNAMO de DYNamic MOdels y fue escrito por el Sr. Phyllis Fox y la Sra. George Sternlieb y el Sr. Alexander L. Pugh III.
En 1962 el Sr. Jay W. Forrester modificó el paquete haciéndolo compatible para operar en tiempo compartido; esto hizo posible crear, corregir y correr el modelo en pocas horas.
En 1965 se escribió otra vez DYNAMO eligiendo como lenguaje fuente el ALGOL AED (Algol Extended for Design) pues en ese entonces era uno de los lenguajes suficientemente poderoso y disponible en el Tecnológico de Mass. DYNAMO II se diseñó para aceptar modelos escritos con DYNAMO I con muy pocos cambios.
Como respuesta a la demanda en 1971 se desarrolló una versión de DYNAMO interactiva; durante la simulación, el usuario puede examinar el estado del sistema simulado y decidir acciones que él considere apropiadas, se conoce como GAMING DYNAMO.
Para responder al creciente número de modelos que tienen sectores que se repiten varias veces con objeto de representar la realidad de una manera más desagregada se le añadió la capacidad de manejar arreglos vectoriales. Este lenguaje se conoce como DYNAMO III.
En 1976 se comenzó a desarrollar DYNAMO para implementarlo en minicomputadoras.

IV PROCESAMIENTO DYNAMO

El programa DYNAMO que el usuario diseña es leído por el traductor DYNAMO que verifica la sintáxis y construye un programa fuente en ALGOL creando un archivo en disco. Después de terminar el trabajo anterior el traductor DYNAMO se conecta (ZIP) al compilador ALGOL para realizar la compilacion del código emitido. El compilador ALGOL compila el programa fuente resultando un código o programa objeto que al ejecutarse nos presenta los resultados.



Para el uso de DYNAMO se requieren de dos elementos básicos, el que llamaremos teórico y el que llamaremos mecánico.

El teórico se refiere a cómo realizar la investigación para resolver problemas, cómo plantear los problemas, cómo concebir el modelo, cómo calcular los parámetros, cómo elegir las variables, cómo realizar los análisis de sensibilidad, etc.

El otro aspecto, el mecánico, se refiere a cómo introducir los datos a la computadora para simular el problema.

Analizaremos brevemente el elemento teórico:

En la solución de problemas generalmente se tienen dos aspectos, solución a problemas no sociales y solución a problemas sociales. La solución a problemas no sociales se realiza planteando ecuaciones con incógnitas, que al ser resueltas y encontradas las incógnitas queda resuelto el problema. En estos casos la simulación se usa cuando las condiciones para las que se obtuvieron las ecuaciones cambian con el tiempo y el problema requiere de una solución dinámica, encontrándose una gama de valores que resuelven el problema en el tiempo.

Cuando los problemas son sociales la técnica varía y lo que se requiere como solución es realizar el planteamiento siendo éste la solución. Estos casos también pueden ser resueltos por simulación, pués la estructura del modelo se va formando con el sistema causa-efecto hasta llegar a modelar o formar a la medida del problema una estructura DYNAMO o sea un modelo dinámico de simulación que nos represente la realidad, y que nos permita estudiarla haciendo experimentos determinados según las necesidades.

Ya sea que se trate de problemas sociales o no sociales en general se sigue la siguiente secuencia:

1. Modelo Anecdótico. Es una descripción verbal sintetizada del problema, donde se destacan los principales mecanismos, las variables, los parámetros, etc.

2. Diagrama Causal. Es un diagrama donde se interrelacionan las principales variables usando flechas y un signo + o - que indica si las variables interrelacionadas crecen o decrecen en el contexto del modelo.

3. Diagrama de Flujo DYNAMO. Se forma con la nomenclatura DYNAMO como se verá posteriormente. Permite observar claramente el camino que siguen los flujos dentro del sistema ilustrando las tasas, los niveles, los canales de información, los flujos de insumos o productos o personas o dinero etc. El diagrama permite realizar una rápida verificación de la lógica del sistema y apreciarlo globalmente.

4. Ecuaciones DYNAMO. Son las ecuaciones que forman el programa DYNAMO y que se deducen con ayuda del diagrama anterior.

5. Variación de Parámetros o Análisis de Sensibilidad. Generalmente se puede realizar en una misma corrida dando instrucciones que indiquen que al terminar la primera corrida continúe corriendo una segunda o tercera vez o más pero con algunos parámetros modificados.

6. Modificaciones al Modelo y Ajustes de Escalas. El modelo puede modificarse una vez hechas las primeras corridas para lograr algún objetivo, el rango de las escalas puede ajustarse para que las gráficas queden acotadas según nuestros deseos y/o agrupadas en las mismas escalas.

7. Validación del Modelo. Se refiere a hacer que el modelo repase valores históricos conocidos que sabemos ocurrieron, esto con una corrida simulando el período histórico; la validación o calibración consiste en adecuar el modelo de tal forma que represente el período histórico. Este aspecto no siempre se realiza, pues al tratar de pronosticar el futuro si la historia del fenómeno no se conoce difícilmente podrá realizarse la calibración o validación.

Veamos ahora el elemento mecánico. Una herramienta básica de la simulación es el proceso de integración. La integración aparece en toda la naturaleza y es esencial para representar el proceso de cambio en los sistemas. Es el proceso que relaciona una cantidad con su tasa de cambio temporal. Se puede pensar que la distancia recorrida por un vehículo en un cierto tiempo es la integral en todo el intervalo de la función que represente la tasa de cambio de posición del vehículo. Veamos un ejemplo: Si un automóvil se mueve a una velocidad constante de 60 km/hora en 4 horas habrá recorrido 240 km. Esto podemos calcularlo así:

$$\frac{ds}{dt} = 60 \; ; \quad ds = 60\,dt \quad ; \quad S = \int_0^4 60\,dt.$$

$$S = 60\,(t)\Big|_0^4 = 240$$

DYNAMO usa otra forma para resolver el mismo problema: La ecuación computacional que usa llamada de nivel es del tipo:

RECORRIDO ACTUAL = RECORRIDO ANTERIOR + TIEMPO TRANSC. X TASA DE CAMBIO

Para la primera hora tenemos:

$S = 0 + (1\text{ hora}) \times 60 = 60$

Para la segunda hora:

$S = 60 + (1\text{ hora}) \times 60 = 120$

Para la tercera hora:

$S = 120 + (1\text{ hora}) \times 60 = 180$

Para la cuarta hora:

$S = 180 + (1 \text{ hora}) \times 60 = 240$ km.

Esta forma de resolver el problema es más elaborada para este caso donde la tasa es constante. Si la tasa fuera variable, primero habría que encontrar la función que la represente en el tiempo y después integrarla para obtener el resultado. Si esta función no es sencilla el proceso de integración se dificulta y caeremos en lo que hace DYNAMO . Para cada intervalo de tiempo escogido considerará que la tasa es constante durante el intervalo e integrará . Si reducimos este intervalo lo suficiente tendremos una buena presición.

Para manejar el tiempo DYNAMO usa índices, J,K y L para indicar:

K. Hoy,este momento,este segundo, etc.

J. Ayer,el momento anterior,el segundo anterior,etc.

L. Mañana,el momento siguiente,el próximo segundo,etc.

JK Intervalo de tiempo de ayer a hoy,etc.

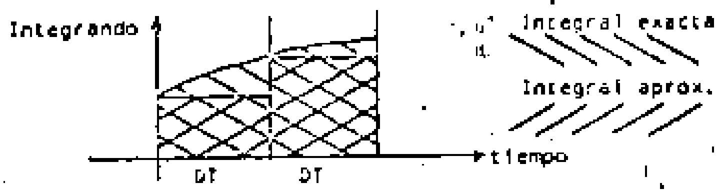
KL Intervalo de tiempo de hoy a mañana,etc.

Estos intervalos de tiempo tienen una medida que se llama DT (delta time). Usando esta notación la ecuación anterior queda de la siguiente forma:

S.K=S.J+(DT)(V.JK)

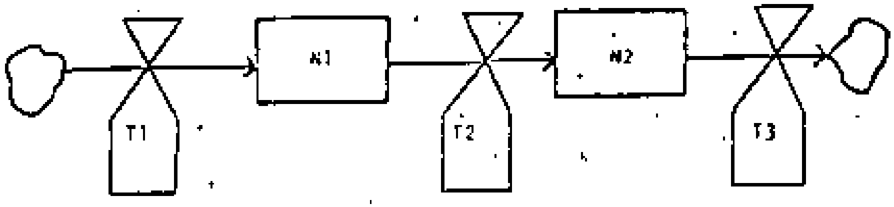
donde V.JK = 60

V.JK es la tasa que en este caso la consideramos constante,si la tasa varía muy aprisa para tener cierta exactitud debemos operar la ecuación digamos cada minuto o cada segundo depende de que tan aprisa varíe V.Y consideraremos constante la tasa en el intervalo reducido, se puede resolver con la exactitud que se quiera basta escoger a DT muy pequeño.



Tasa de sistemas donde el flujo se conserva:

El ejemplo del automóvil es típico,así como el caso del flujo de algún líquido a un tanque,el flujo de personas a una población,el flujo de corriente eléctrica a un condesador,el flujo de tareas en una fábrica,etc. En cada caso existe un flujo que se mueve sin ser creado o destruido en el proceso. Las partes de nuestros modelos que tienen esta característica las identificaremos como subsistemas que se conservan y llamaremos a estos flujos tasas. En estos sistemas las tasas de cambio de los niveles toman la forma de simples sumas o diferencias de tasas. Hay una forma típica en que aparecen dos niveles que son controlados por tasas. El nivel N1 es alimentado por la tasa T1,pero a la vez la tasa T2 le quita y alimenta a N2 que a su vez es disminuido por la tasa T3. En estos casos en que la tasa siempre se añade,pero nunca se resta,se considera que la tasa fluye hacia dentro del sistema desde una fuente exterior que podemos considerar como el límite de nuestro sistema. Si la tasa siempre se resta y nunca se añade entonces esta fluyendo a un sumidero exterior que también marca una frontera del sistema. Veamos la representación gráfica.



Las ecuaciones correspondientes son:

N1.K=N1.J+(DT)(T1.JK-T2.JK)

N2.K=N2.J+(DT)(T2.JK-T3.JK)

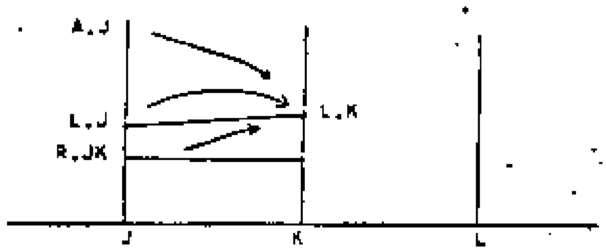
Las tasas se calculan en el instante K para usarse en el intervalo KL . Este cálculo se realiza con una expresión algebraica de variables en el mismo instante K.

Sistemas en donde no se conserva el flujo: Contiene relaciones integrales y algebraicas. Las integrales se calculan con las ecuaciones de nivel pero las tasas de cambio de los niveles son más complicadas que la suma de varias tasas.

En los subsistemas, donde no se conservan los flujos, las relaciones algebraicas simples se calculan con ecuaciones auxiliares. Estas se calculan en el instante K a partir de los niveles y otras ecuaciones auxiliares. Como DYNAMO no acepta ecuaciones simultáneas es necesario ordenar los cálculos de las ecuaciones auxiliares de tal forma que un auxiliar se calcule antes de ser requerido en otra ecuación auxiliar, si DYNAMO no encuentra un orden para hacer esto, manda un mensaje de error que dice ECUACIONES SIMULTANEAS.

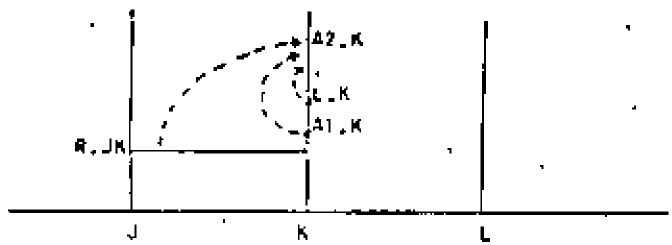
V. SECUENCIA COMPUTACIONAL

En el instante K se calculan primero todos los niveles, los que a su vez dependen de su valor previo en el instante anterior J y de las tasas calculadas para el intervalo JK. Como ya se hicieron los cálculos para J y JK no hay problemas para calcular los niveles.



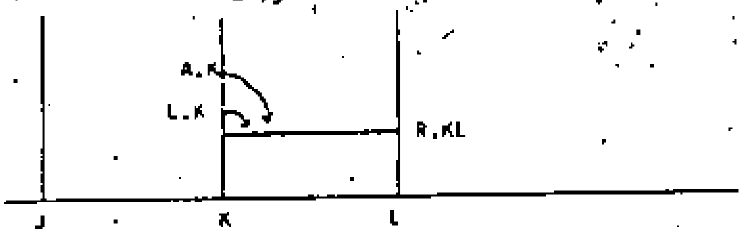
L.K=L.J+(DT)(R.JK-A.J)

Auxiliares: En seguida las ecuaciones auxiliares ordenadas automáticamente por DYNAMO se calculan para el instante K a partir de los niveles en K y otras auxiliares calculadas primero en K.



A2.K=(L.K)(A1.K)

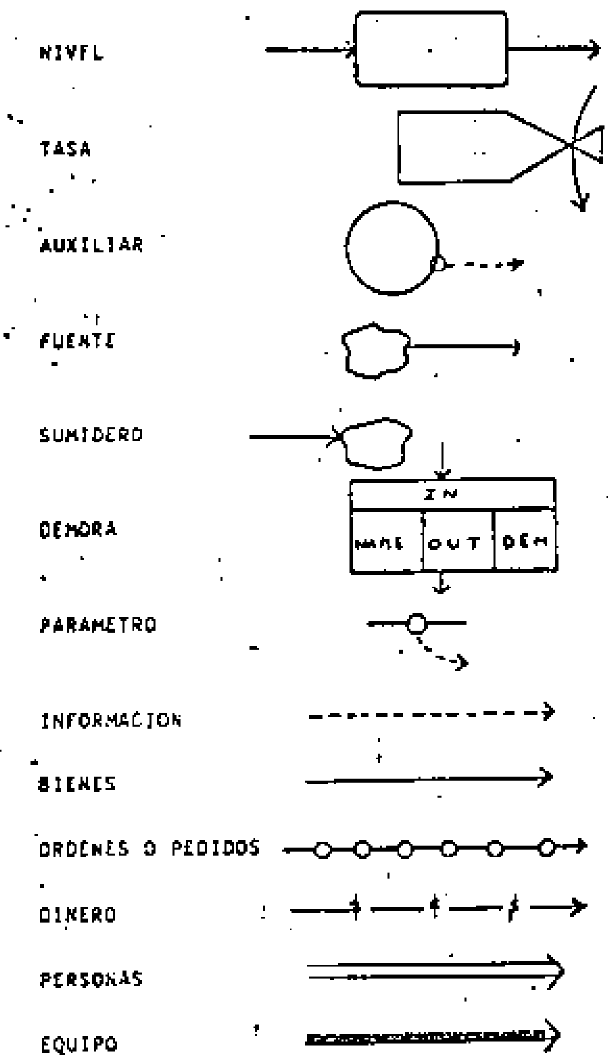
Tasas : Finalmente se calculan las tasas para el intervalo próximo KL a partir de los niveles y las auxiliares en el momento K.



R.KL= L.K+A.K

En este momento cuando las tasas ya se han calculado el tiempo actual se avanza automáticamente DT unidades. Todas las cantidades que se calcularon para el tiempo K ahora se considera que son valores en el tiempo J y las tasas calculadas para el intervalo KL ahora son tratadas como si fueran valores en el intervalo JK. Aquí se repite el ciclo comenzando de nuevo con los niveles.

VI. NOMENCLATURA DE LOS DIAGRAMAS DE FLUJO



VII. ESCRITURA DE ECUACIONES

Las reglas para formar una ecuación son las usuales del álgebra, la forma básica es :
tipo de ec.   cant=expresión (a partir de la col. 7)
Los tipos de ecuaciones pueden ser :

Tipo	Símbolo
De Nivel	L
Auxiliares	A
De Tasa	R
De Valor Inicial	N
Constante	C
Tabla	T
Suplementaria	S

En DYNAMO I era necesario indicar el tipo de ecuación, pero en el sistema implantado actualmente no es necesario. "cant" es el nombre de la cantidad que esta siendo definida por la ecuación. El nombre debe cumplir las reglas para formar nombres y debe tener el índice apropiado de tiempo . Todo nombre de una cantidad debe comenzar con un carácter alfabético, y puede ser seguido por hasta cinco caracteres alfábeticos o numéricos,(en la versión actual se permiten hasta 63 caracteres,pero al imprimir sólo aparecerán los seis primeros,sólo deben usarse dígitos de hasta seis cifras). "expresión" puede ser cualquier cosa desde un simple número hasta una combinación de factores y términos que involucren funciones.
Las operaciones de suma,resta,multiplicación y división se indican por + , - , ( ) , / , se usan las jerarquías comunes: multiplicación y división se realizan primero que suma y resta.Los paréntesis significan que la expresión dentro de ellos debe calcularse y sustituirse por ellos.

A+BXC implica A+((B)(C))

Si las operaciones son del mismo valor jerárquico se realizan en orden de izquierda a derecha:

A-B+C implica (A-B)+C

Debe tenerse cuidado en el caso de la multiplicación y la división. Si se desea dividir X entre el producto de Y y Z debe escribirse:

X/Y/Z

DYNAMO interpreta X/(Y)(Z) como (X/Y)(Z)

Los valores numéricos se escriben en la forma usual. Se pueden usar hasta seis dígitos significativos. Números muy grandes o muy pequeños se pueden escribir indicando potencias de 10 multiplicadas por el número con la letra E: 10 000 000 = 10E6 = 1E7
.001 = 1E-3

En DYNAMO es posible crear subrutinas llamadas MACROS cuando se tienen sectores del modelo que son repetitivos. Esto evita tener que escribir un conjunto de ecuaciones varias veces para cada sector ,basta declararlo una vez definirlo y cuando se necesite introducir los valores en la función MACROS,esto equivale a volver a escribir las ecuaciones del sector con sus nuevos valores.
Existen varias funciones y macros ya creadas dentro de DYNAMO que corresponden a las siguientes categorías:

a) Intrínsecas que modelan curvas llamadas DELAYN
b) Intrínsecas computacionales que son: SIN,COS,SQRT, LOGN,EXP y SUMN.
c) Intrínsecas controladas por el tiempo: BOXLIN,BOXCYC, PULSE,RAMP,SAMPLE,STEP.
d) Intrínsecas de selección de valores: CLIP,MAX,MIN, SWITCH y TABLE.
e) Intrínsecas aleatorias: NOISE y NORMRN.

Ecuaciones de Nivel: Matemáticamente indican integración. Una ecuación típica de nivel es de la siguiente forma:

L.K=L.J+(DT)(R1.JK-R2.JK)

L.K es el nombre,el índice K indica que el valor es leído en el presente. El lado derecho de la ecuación usa el mismo valor L, pero con el índice J para indicar que se trata del valor de L en el periodo anterior, más el intervalo de tiempo transcurrido, DT desde la última evaluación multiplicado por una expresión que considera el valor del cambio del nivel en el lapso DT o sea la tasa.

REGLAS PARA COLOCAR INDICES EN LAS ECUACIONES DYNAMO								
LADO IZQUIERDO			INDICE DE LA CANTIDAD DEL LADO DERECHO SI EL TIPO ES:					
TIPO	CANTIDAD	INDICE	L	A	R	S	C	N
L	NIVEL	K	J	J	JK	-	-	-
A	AUX.	K	K	K	JK	-	-	-
R	TASA	KL	K	K	JK	-	-	-
S	SUPL.	K	K	K	JK	K	-	-
C	CTE.	-	-	-	-	-	-	-
N	VAL. INIC.	-	-	-	-	-	-	-

Ecuaciones de tasa: Esta ecuación define el tamaño del flujo entre variables de nivel y una fuente, un sumidero u otra variable de nivel. Una ecuación típica de una tasa es:

R.KL=(L.K-R.JK)/L2.K

R.KL es el nombre de la tasa con índice KL para el intervalo de tiempo entre el presente y el futuro. El lado derecho es una expresión aritmética de variables de nivel, variables de tasa, variables DYNAMO o constantes. Las variables de nivel tienen el índice K o J, las variables de tasa del lado derecho tienen índice JK.
Ecuaciones Auxiliares: Al modelar puede querérsele dar un nombre a una expresión que se use en otra ecuación. La ecuación que asigna el nombre a la expresión se llama ecuación auxiliar. El índice usado es K. Un ejemplo de una ecuación auxiliar:

HAZTIB.K=AM.K/DT

Ecuaciones Suplementarias: Como en el caso de la ecuación auxiliar la ecuación suplementaria le da nombre a una expresión, pero para usarla en valores de salida como listado o gráficas por ejemplo:

H.K=VALOR.K-L15

Ecuaciones constantes: Es una cantidad sin índice;
AB=1638
Ecuaciones de Valor Inicial: Si la ecuación tiene la forma de una ecuación constante, pero el nombre de la cantidad aparece en otro lugar del programa, se llama ecuación de valor inicial. Los valores iniciales sólo se requieren para las variables de nivel, sin embargo se pueden dar valores iniciales a otras variables. Se pueden realizar varias corridas con un mismo programa cambiando cada vez el valor inicial, por lo que se puede realizar diseño experimental en una corrida.

Sistema de tiempo y unidades: Al calcular los valores del programa se usan unidades tales como unid/mes o u/sem etc, las unidades no se dan en unid/DT. Es recomendable hacer la unidad de tiempo del sistema un múltiplo del intervalo de solución DT. Si DT no es un múltiplo de la unidad de tiempo del sistema, hay problemas para elegir el valor de DT para imprimir o graficar, DYNAMO lo resuelve usando el valor que tenga la variable justo antes y dentro de un intervalo de DT/2 del tiempo transcurrido.
Los tiempos de impresión o graficación PRTPER y PLTPER se expresan en unidades de tiempo del sistema así mismo LENGTH.
EJEMPLO: las siguientes instrucciones quieren decir:
columna
1 7
SPEC DT=1/LENGTH=10/PRTPER=2/PLTPER=3
La unidad de tiempo del sistema es 1, la simulación se realizará durante 10 unidades de tiempo, las variables que

se grafiquen serán cada 2 unidades de tiempo y las gráficas tendrán un punto cada 3 periodos.

SI DT=0.2, LENGTH=10 , PLTPER=.2 y PRTPER=0

Quiere decir: Se harán cálculos cada .2 unidades de tiempo simulándose durante 10 unidades de tiempo se graficará cada .2 unidades de tiempo y no habrá lista (PRTPER=0).

O sea, si la unidad del sistema es el segundo:

DT=.1 segundos, LENGTH=10 segundos, etc.

Es conveniente elegir a DT en un intervalo práctico que va de 1/3 a 1/5 del valor del tiempo más pequeño dentro del modelo. Una vez que el modelo se ha probado y está corriendo se puede aumentar el valor de DT para ahorrar tiempo de procesamiento.

Símbolos de Graficación: Las escalas tienen un rango de 10^{-33} a 10^{33} los siguientes símbolos se usan en las escalas que DYNAMO automáticamente escoge para graficar.

SIMBOLO	K	Y	W	U	L	J	M
MULTIPLO	$<10^{-30}$	10^{-30}	10^{-27}	10^{-24}	10^{-21}	10^{-18}	10^{-15}

SIMBOLO	G	F	E	A	X	T	M
MULTIPLO	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{0}	10^{3}	10^{6}

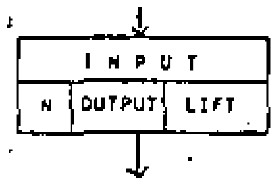
SIMBOLO	B	R	Q	V	S	P	C
MULTIPLO	10^{9}	10^{12}	10^{15}	10^{18}	10^{21}	10^{24}	10^{27}

SIMBOLO	N	O	Z
MULTIPLO	10^{30}	10^{33}	$>10^{33}$

VIII FUNCIONES INTRINSECAS

DELAYN.

Alteran la tasa de flujo que se mueve en el sistema, no añaden ni restan nada sólo retardan el flujo, las demoras pueden ser de varios ordenes de 1 a 5, DELAY1 a DELAY5 el orden de la demora coincide aproximadamente con la pendiente, cuando se aplica la demora a una función escalón al aumentar el orden la demora es menor. El símbolo para la demora es:



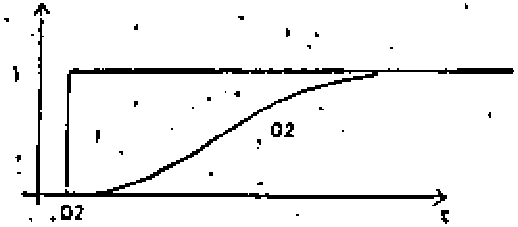
Una demora de orden N significa que la demora promedio LIFT se reparte en N intervalos consecutivos del sistema cuando este es estable. EJEMPLO:

Demora de primer orden:

```
O1.KL=O1.JK+(DT)(N.JK-O1.JK)/DEM
DEM=5
N.KL=STEP(1,0.02)
```

Demora de segundo orden:

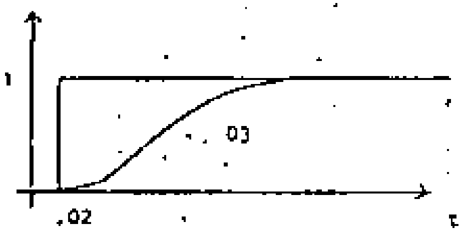
```
O2.KL=O2.JK+(DT)(R.JK-O2.JK)/DEM
R.KL=R.JK+(DT)(N.JK-R.JK)(2)/DEM
```



Demora de tercer orden:

D3.KL=DELAY3(N,JK,DEM)

De la demora de tercer orden hasta la de quinto orden se pueden escribir como la anterior ya que DYNAMO tiene definida interiormente esta función.



SIN,COS,SQRT,LOGN,EXP,SUMN.

SIN.

Calcula la función seno; se introduce a la máquina como:

VALOR=(AMPLITUD)(SIN((2PI)(TIME.K)/PERIOD))

Por ejemplo para representar la función con una amplitud de 30 y un periodo de 20:

I.KL=(30)(SIN((2PI)(TIME.K)/P))

P=20

COS.

Es igual que SIN, pero se usa COS

SQRT.

VALOR=SQRT(ARG)

El valor del ARG debe ser mayor o igual a cero.

LOGN.

VALOR=LOGN(± ARG)

Si se trata de logaritmos base 10:

VALOR10=(COEF)((LOGN(ARG))

COEF=0.434

EXP.

VALOR=(COEF)(EXP(±ARG))

Se refiere a potencias de e.

SUMN (N=1,2,3)

Esta intrínseca se refiere a operaciones semejantes al producto interior que se ve en álgebra vectorial es muy útil para dar peso a las variables.

VALOR=SUM1(ENTERO,NOMBRE)

Esta función da el siguiente valor:

$$\sum_{i=1}^{N} P_i$$

NOMBRE es una secuencia de valores que se da de la siguiente manera:

NOMBRE*=6/8/7/3

V.K=SUM1(4,NOMBRE)

V.K=24.

La forma de SUM2(N,P,Q) es:

VALOR=SUM2(ENTERO,N1,N2)

y arroja el valor:

$$\sum_{i=1}^{N} P_i Q_i$$

La forma de SUM3(N,P,Q,R) es:

VALOR=SUM3(ENTERO,N1,N2,N3)

y arroja el valor:

$$\sum_{i=1}^{N} P_i Q_i R_i$$

por ejemplo:

$N1{*}{*}x_1/x_2/x_3/x_4$

$N2{*}{*}y_1/y_2/y_3/y_4$

$N3{*}{*}z_1/z_2/z_3/z_4$ entonces VALOR será :

$VALOR{=}x_1y_1z_1{+}x_2y_2z_2{+}x_3y_3z_3{+}x_4y_4z_4$

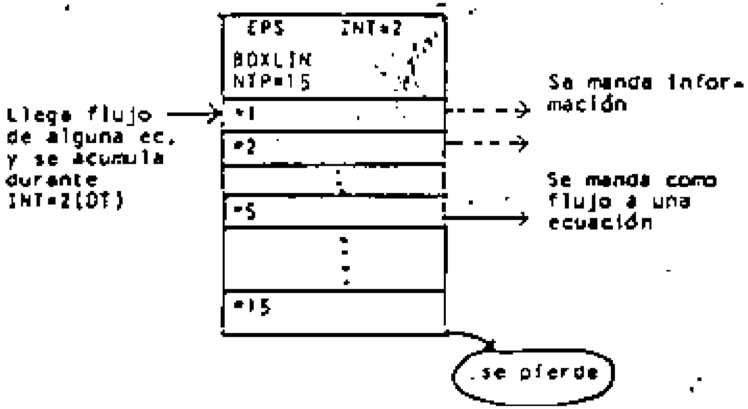
BOXLIN,BOXCYC,PULSE,RAMP,SAMPLE,STEP

BOXLIN.

Especifica una progresión lineal descartando el último término:

EPS=BOXLIN(NTP,INT)

EPS es el nombre que se le da a la progresión.
NTP es el número de términos de la progresión.
INT es el intervalo después del cual la progresión se corre, descartando el último valor.



Cada celda se identifica como:

EPS*1 , EPS*2 .... EPS*15

También puede dársele valor a las celdas con:
EPS**N1/N2/..... /NM

o con:

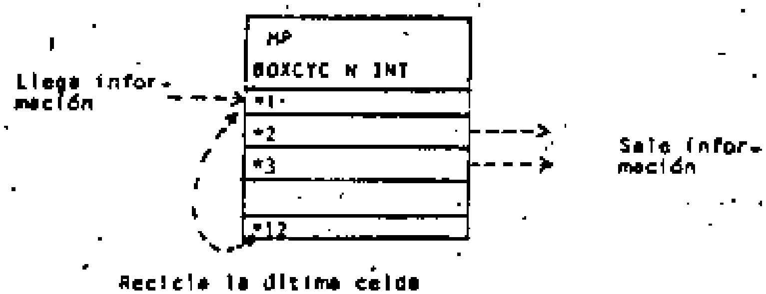
EPS=BOXLOAD(VAR1,VAR2)

Esta última ecuación ocasiona que todas las celdas se carguen con el producto de VAR1 * VAR2 , si queremos cargar una celda en especial por ejemplo la 5,usamos:

EPS*5.K=EXPRESION.

BOXCYC.

Es análoga a BOXLIN salvo que en lugar de descartar el último valor de la progresión,lo recircula de la última celda a la primera. Se carga igual que BOXLIN



MP=BOXCY(N,INT)

PULSE.

VALOR=PULSE(±HEIGHT,FIRST,INTERVAL)

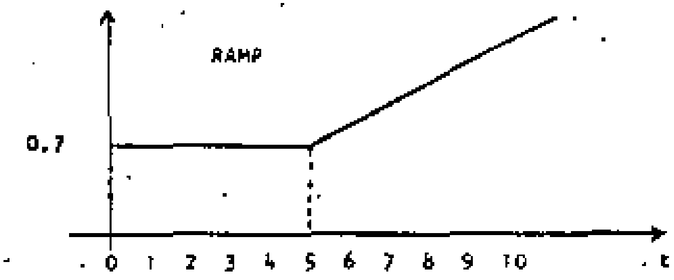
Esta intrínseca hace que VALOR cambie súbitamente de cero a (±HEIGTH)(DT) y otra vez a cero comenzando en el instante FIRST y cada periodo de tiempo INTERVAL. HEIGTH, FIRST y INTERVAL pueden ser constantes o variables.

RAMP

VALOR=RAMP(±SLOPE,STARTTIME)

RAMP tiene un valor constante hasta el momento STARTTIME en el que empieza a crecer ±SLOPE cada DT.
En el caso de que se quiera que tenga un valor inicial de 0.7 y que en el tiempo 5 empiece a crecer se tendrá:

RMP.K=0.7+RP.K
RP.K=RAMP(1,5)



SAMPLE.

VALOR=SAMPLE(SUB,INT)

Se puede dar valor inicial a SAMPLE de otra forma vale cero hasta que el tiempo de simulación llega a INT en ese momento toma el valor de SUB.

Ejemplo:

S=SAMPLE(R,10)

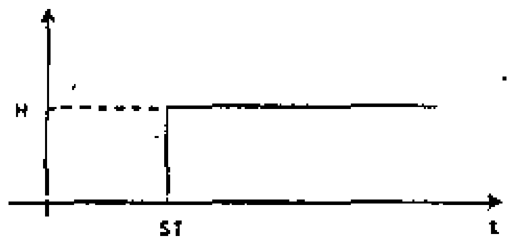
R,K=RAMP(0,1,10)

Cuando el tiempo =0, S=0 durante 10 periodos, cuando t=10 S= al valor que tenga R en el instante t=10, y este valor lo conserva durante 10 periodos de tiempo al final de estos 10 periodos S toma el valor que tenga R en ese instante y lo conserva 10 periodos, etc, etc.

STEP.

VALOR=STEP($\pm$H,ST)

VALOR adquiere el valor $\pm$H en el momento ST y lo conserva hasta finalizar la simulación.



CLIP, MAX, MIN, SWITCH, TABLE

CLIP.

VALOR=CLIP(V2,V1,A2,A1)

VALOR=V1 si A1 > A2

VALOR=V2 si A1 ≤ A2

MAX.

VALOR=MAX(A1,A2)

Elige el valor máximo A1 o A2 si A1=-A2 :

VALOR=valor absoluto.

MIN.

VALOR=MIN(A1,A2)

Elige el valor mínimo.

SWITCH.

VALOR=SWITCH(VAR1,VAR2,ARG)

VALOR=VAR1 si ARG=0

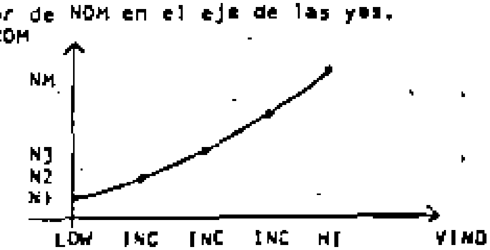
VALOR=VAR2 si ARG≠0

TABLE.

VALOR=TABLE(NOM,VINO,LOW,HI,INC)

NOM*=N1/N2/......./NM

Esta intrínseca permite hacer una gráfica NOM Y VINO en donde VINO tiene un valor mínimo de LOW y un valor máximo de HI y la escala (eje de las x) tiene valores de incremento de INC en INC. A cada valor de VINO corresponde un valor de NOM en el eje de las yes.



Para valores intermedios la máquina interpola linealmente.

Los valores con los que se entra a la tabla son los de VIND y sale con valores de NOM.

NOISE, NORMRN

NOISE.

Es una función uniformemente distribuida que puede usarse como muestra de ruido blanco.

```
VALOR=(RANGO)NOISE
```

Da un valor pseudoaleatorio en el rango de -RANGO/2 a +RANGO/2 .

Ejemplo: UNIFORM=(10)NOISE

Esta ecuación da variables aleatorias en el intervalo -5,5 para generar estos valores existe un método standar congruente, siempre que se invoque esta función dará los mismos números aleatorios si queremos que los cambie usamos: NOISE=N N es un número entero menor que: 549755813888.

NORMRN.

Genera variantes pseudoaleatorias a partir de la distribución de Gauss con una media= MEAN y una desviación estandar=ST y tiene la forma:

```
VALOR=NORMRN(-MEAN,ST).
```

IX. FUNCIONES MACRO

Cuando al modelar se encuentra un patrón en la forma de las ecuaciones, o sea que se encuentran varios conjuntos de ecuaciones exactamente del mismo tipo, pero con diferentes valores, entonces es conveniente declarar una función MACRO y sólo definir los diferentes valores cada vez que se necesite. Una declaración MACRO requiere de tres elementos básicos: la palabra MACRO y después de dejar un espacio la función, ejemplo:

```
COLUMNA
1     7
MACRO SMOOTH(IN,DEL)
```

A continuación el conjunto de ecuaciones y al final la palabra MEND a partir de la primera columna; las variables que se encuentran en la función se escriben igual en la declaración MACRO; pero si aparecen otras variables en el conjunto de ecuaciones (llamadas variables locales) deben empezar con el signo $. Veamos un ejemplo:

```
MACRO DELAY(IN,DEL,L1,L2,L3)
      L1.K=L1.J+(DT)(IN.JK-$R1.JK)
      $R1.KL=L1.K/$OLY.K
      L2.K=L2.J-(DT)($R1.JK-$R2.JK)
      $R2.KL=L2.K/$OLY.K
      DELAY.K=$R3.JK)
      $OLY.K=DEL.K/3
      L1=($OLY)(IN)
      L2=L1
      L3=L1
MEND
```

para llamar a una función MACRO y encontrar su valor para poder usarlo en algún otro lado;

```
V.K=DELAY(IN,DEL,L1,L2,L3)
```

pero ya con los valores numéricos de IN,DEL,L1,L2,L3 .

X INSTRUCCIONES Y TARJETAS DE CONTROL PARA PROCESAR DYNAMO.

1. Para procesar a través de tarjetas:

A Tarjetas de control 1a. parte.

B Programa DYNAMO

C Tarjetas de control 2a. parte.

A:

```
COLUMNAS
1     7
?JOB CUALQNOMBR;USER=FM98/CL;CLASS=3;BEGIN
?EXECUTE *DYNAMO/DISK;
?EBCDIC DYNAMOINPUT
```

B: Programa DYNAMO:

La primera tarjeta es el nombre de un archivo de referencia del programa fuente en ALGOL CON SIETE CARACTERES o menos:

```
COLUMNA
1     7
PREFIJO/SUFIJO1                          tarjeta 1.
```

La siguiente tarjeta tiene las opciones DYNAMO

```
COLUMNA
1     7
DYNAMO NOZIP OPCION OPCION OPCION        tarjeta 2.
```

Las opciones que maneja DYNAMO son:

NARROW.

Las gráficas de salida y las listas se imprimen en un formato angosto de 72 columnas, esto limita el número de columnas en las listas a 8.

WIDE.

Da una impresión de 120 columnas y se pueden usar hasta 14 columnas de listas. Puede graficarse hasta 10 variables por gráfica.

OLIST.

Esta opción hace que aparezcan impresas las ecuaciones del modelo cuando se procesa por terminal.

CODE.

Enlista el programa fuente que DYNAMO creó en ALGOL

DUMP.

Imprime la estructura de información que maneja DYNAMO para el programa en cuestión.

NOZIP.

Nada más se usa en BATCH inicia un ZIP (conecta) al compilador ALGOL siempre y cuando no se hayan detectado errores.

Las opciones se pueden colocar en las columnas de la 7 a la 72, cuando se use más de una opción se pueden colocar en la misma tarjeta separadas por un espacio en blanco, las tarjetas o tarjeta de opciones pueden colocarse en cualquier lugar del programa.

La siguiente tarjeta tiene RUN en las primeras tres columnas y a partir de la séptima un nombre que empiece con carácter alfabético y de hasta 72 caracteres, en las impresiones sólo aparecen los 6 primeros caracteres.

```
COLUMNAS                          tarjeta 3:
1     7
RUN   CUALQUIERNOMBRECON72CARACTERESSOLOIMP6
```

Después del RUN comienzan las ecuaciones DYNAMO.

NOTA. Para introducir comentarios en las ecuaciones basta dejar un espacio después del último carácter y escribir cualquier comentario, número o símbolo hasta la columna 72 inclusive o escribir una tarjeta con los caracteres NOTE a partir de la primera columna y escribir lo que se quiera a partir de la séptima columna, si no se escribe nada en los listados aparece un renglón en blanco, o sea que las ecuaciones correspondientes a la tarjeta anterior y posterior a la que tiene NOTE aparecen separadas por un renglón en blanco.

Si se quiere realizar pruebas con el modelo cambiando el valor de los parámetros, esto puede hacerse colocando otro RUN con otro nombre al final del programa DYNAMO anterior y a continuación tarjetas con los valores de los parámetros nuevos, no se permite cambiar variables ni tablas en estas corridas sucesivas, resumiendo:

```
PREFIJO/SUFIJO1
DYNAMO NOZIP NARROW
RUN   PROGRAMA  PARA EL CURSO QUE SE IMPARTIRA ..
NOTE
NOTE
          Aquí se inserta el programa con sus ecuaciones.

RUN   OTRACORRIDA  VAMOS A MODIFICAR PARAMETROS.
NOTE
      PARAMETRO=8
RUN   OTRADIFERENTE
      PARAMETRO=15
```

C. Tarjetas de control 2a. parte.

```
COLUMNA
1       7
?COMPILE NOMBCUALQ   ALGOL;
ALGOL PROCESS=200;ALGOL IO=200;
PROCESS=200;IO=200;
?EBCDIC CARD
  $SET BCL MERGE FORMAT
TARJETA EN BLANCO
TARJETA EN BLANCO
?REMOVE PREFIJO/SUFIJO1
?END.JOB
```

NOTA. Después de JOB y COMPILE puede aparecer cualquier cosa de uno a diez caracteres, el nombre del listado que sale por la impresora en letras grandes es el que se haya colocado después de JOB.

- -

2. Para procesar por terminal:

Existen dos formas:

A. Introducir el programa con tarjetas perforadas y mandar a ejecutarlo desde la terminal.

B. Escribir el programa directamente en el teletipo.

Para introducir las tarjetas según A hay dos formas.

La primera consiste en introducir las tarjetas para que sean leídas, ir a la terminal y mandar ejecutar el programa con la instrucción:

```
EXECUTE *DYNAMO/DISK
```

Una vez realizada esta instrucción se espera en la impresora de línea los resultados.

La segunda consiste en usar las siguientes tarjetas de control para que se forme un archivo en disco (DATA)

```
COLUMNA
1       7
?JOB INF   ;USER=AP82/PN;CLASS=3;BEGIN
?RUN *SYSTEM/DUMPALL("CRDDSK N1 N2");
DATA N1
      :
      :
?END JOB
```

Al procesar el programa por terminal debe usarse la instrucción REMOTE a partir de la primera columna en una sola tarjeta en lugar de PREFIJO/SUFIJO1 .

Una vez leídas las tarjetas anteriores o escritas directamente en el teletipo se procede como sigue:

Se forma un archivo que se llame DYNAMOINPUT con las instrucciones CANDE siguientes: MAKE DYNAMOINPUT SEQ , se escriben las ecuaciones del programa en este archivo y se guarda con la instrucción SAVE.

Si se usan las tarjetas el archivo aparece con el nombre N2 y se le cambia el nombre de la siguiente manera:

```
TITLE N2 TO DYNAMOINPUT
```

Después de esto se guarda (SAVE) y cuando la computadora contesta:

```
# DYNAMOINPUT SAVED
```

Damos la siguiente instrucción:

EXECUTE *DYNAMO/DISK

y la máquina contesta:

#RUNNING

después de poco tiempo aparece en la pantalla:

#?

ENTER IN COLUMNS 1-25 THE NAME OF THE DISK FILE YOU WISH DYNAMO TO CREATE TO WRITE YOUR ALGOL SOURCE CODE. IF OUTUT IS DESIRED ON THE LINE PRINTER ENTER C IN COLUMN 1 FOLLOWED BY FILENAME.

Entonces se escribe el nombre de este archivo:

PREFIJO/25 o lo que se quiera.La máquina contesta:

OK

(Si en las opciones DYNAMO colocamos DLIST aparece un listado de nuestras ecuaciones corregido por DYNAMO si es que encontró errores si no hubo errores aparece sólo la lista)

BURROUGHS B6700/B7700 DYNAMO LEVEL DYN 454: la fecha

INPUT PHASE BEGIN AT la hora.

Después de un cierto tiempo aparece el listado del programa DYNAMO,el primer renglón es la tarjeta DYNAMO.

Aún cuando no se haya especificado DLIST y haya o no errores DYNAMO contesta:

INPUT PHASE BEGAN AT ....
GENERATION PHASE BEGAN AT ......
RUN PHASE GENERATED AT ....
PRINT PHASE GENERATED AT ....
PLOT PHASE GENERATED AT ....
ELAPSED COMPILATION TIME ....

Si hay errores aparece un aviso diciendo que las siguientes fases serán omitidas.

Si se colocó la letra "C" antes del nombre del archivo aparece el letrero:

PLEASE RECEIVE YOUR OUTPUT AT THE LINE PRINTER
ET= _____ PT= _____ IO= _____

Si no se puso la letra "C" aparece el siguiente mensaje:

PLEASE ENTER COMPILE (el nombre del archivo) WITH ALGOL. THEN WAIT UNTIL YOUR TERMINAL REPORTS THAT YOUR COMPILATION IS COMPLETE,AFTER GOOD COMPILATION,ENTER EXECUTE(EL NOMBRE DEL ARCHIVO)
ET=_____ PT=_____ IO=_____

entonces uno escribe en el teletipo:

COMPILE PREFIJO/SUFIJO1 WITH ALGOL y la máquina contesta:

#COMPILING

si no hubo errores aparece:

ET=..... PT=..... IO=.......

Entonces vuelve uno a escribir:

EXECUTE PREFIJO/SUFIJO1 y la máquina contesta:

#RUNNING

Después de un cierto tiempo aparece todo el programa en pantalla,esto si se usó DLIST si no sólo aparecen las listas y las gráficas. Si está uno en una terminal de rayos catódicos después de que se llena la pantalla aparece la leyenda PAGE que quiere decir que hay que apretar el RETURN del teletipo para que continúe,si está uno en un DECWRITER los resultados se irán escribiendo directamente.

Si estamos en una terminal de pantalla y una vez obtenida la salida deseamos una impresión por la impresora de línea,damos la siguiente instrucción:

EXECUTE PREFIJO/SUFIJO1;FILE W9900(PRINTER),esto imprime sólo la salida,para imprimir el programa:

WRITE DYNAMOINPUT

XI. DESARROLLO DE UN EJEMPLO

Vamos a describir un proceso físico que consiste en el enfriamiento de agua caliente que se tiene en un calentador que está apagado, dicho calentador se encuentra en un cuarto a temperatura constante. Al enfriarse el agua se transfiere calor al cuarto a una rapidez que depende de la temperatura del agua, de su volumen y del material aislante que tiene el calentador. Este proceso continúa hasta que la diferencia entre la temperatura del cuarto y del agua sean iguales. Veamos como queda el modelo anecdótico:

MODELO ANECDOTICO.

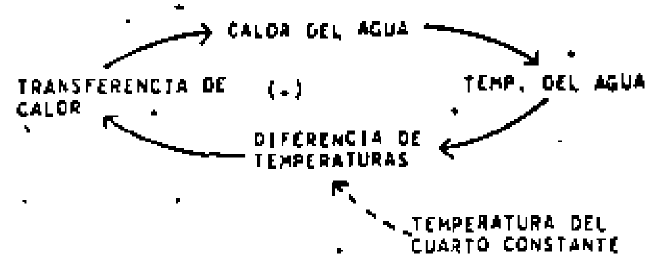
Existe un flujo de calor entre el medio ambiente del cuarto donde se encuentra un calentador con agua caliente apagado.
La temperatura del agua indica la cantidad de calor almacenado.
La transferencia de calor es proporcional a la diferencia entre la temperatura ambiente del cuarto y la temperatura del agua.
La constante de proporcionalidad depende de las propiedades físicas del calentador de su volumen y de su material aislante.

Elección de variables :

Calor del agua.................................CA	(calorías)
Tasa de transferencia de calor........TTC	(calorías/min)
Cte. de conversión calor-temp..........C1	(C°/caloría)
Cte. de transferencia de calor........C2	(cal./C°/min)
Diferencia de temp. del agua y el cto. TC	(C°)
Temperatura del cuarto...................TC	(C°)
Temperatura del agua......................T	(C°)

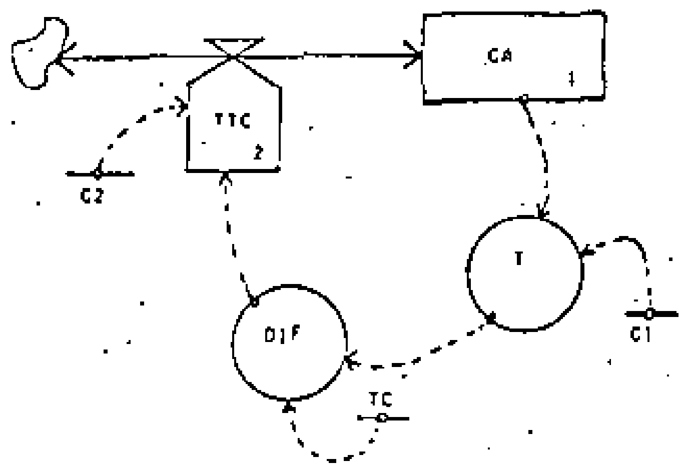
Para obtener el diagrama causal se procede así:
¿Al aumentar el calor del agua, qué le pasa a la temperatura del agua? Aumenta, luego el signo junto a TEMP. DEL AGUA es +. En caso de que para diferentes etapas del modelo las variables cambién de signo pondremos ±. Usando las reglas de los signos determinamos el signo del circuito, en este caso es (-).

DIAGRAMA CAUSAL:



Los circuitos negativos se caracterizan por tender a una me o límite que puede ser fijo o variable. Los circuitos posit vos se caracterizan por crecer sin límite (explosivamente) decaer a cero.
En todos los casos se trata de circuitos de retroalimentaci positiva o negativa los que toman el control del sistema se gún las circunstancias de la simulación.

A continuación dibujamos el
DIAGRAMA DYNAMO:



La tasa de flujo TTC es controlada por C" y por DIF que reciben información de T, TC y estos a su vez CA.

ECUACIONES DYNAMO.

```
CA.K=CA.J+(DT)(TTC.JK)                                   1
CA=TI/C1
TI=200
C1=1
CA        CALOR DEL AGUA
TTC       TASA DE TRANSFERENCIA DE CALOR
TI        TEMPERATURA INICIAL
C1        CONSTANTE DE CONVERSION DE CALOR A TEMP.
TTC.KL=(C2)(DIF.K)                                       2
C2=0.1
C2        CONSTANTE DE TRANSFERENCIA DE CALOR
DIF       DIFERENCIA DE TEMP. ENTRE EL CUARTO Y EL AGUA
T.K=(C1)(CA.K)                                           3
T         TEMPERATURA DEL AGUA
DIF.K=TC-T.K                                             4
TC=78
TC        TEMPERATURA DEL CUARTO
```

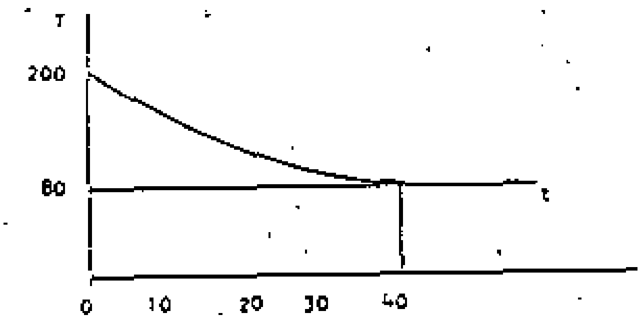
Veamos como queda el programa para procesarlo en BATCH:

```
COLUMNA
1     7
?JOB AGUACAL1 ; USER=F483/CL;CLASS=4;BEGIN
?EXECUTE =DYNAMO/DISK;
?EBCDIC DYNAMOINPUT
MANUAL/OCT80
DYNAMO NOZIP
RUN   AGUA FRIA
NOTE
      CA.K=CA.J+(DT)(TTC.JK)                             1
      CA=TI/C1
      TI=200
      C1=1
NOTE
      TTC.KL=(C2)(DIF.K)  TASA DE TRANSF. DE CALOR       2
      C2=.1
NOTE
      T.K=(C1)(CA.K)  TEMP. DEL AGUA                     3
NOTE
      DIF.K=TC-T.K  DIFERENCIA DE TEMP.                  4
      TC=78
NOTE
NOTE  TARJETAS DE CONTROL DE IMPRESION Y GRAFICACION
NOTE
PRINT 1)T/2)TTC,CA/3)*/4)*/5)D
PLOT  T=T,TTC=H,DIF=C,CA=3
SPEC  DT=1/LENGTH=40/PRTPER=1,PLTPER=1
```



```
RUN   ENFRIA2 CUARTO MAS CALIENTE
      TC=88
RUN   ENFRIA3  CUARTO MUCHO MAS FRIO
      TC=50
NOTE  LE HEMOS AÑADIDO AL MODELO ORIGINAL ESTAS DOS
NOTE  CORRIDAS DONDE CAMBIAMOS LAS TEMPERATURAS DEL CUARTO.
?COMPILE EXPER ALGOL;
ALGOL PROCESS=200; IO=200;
?EBCDIC CARD
  $SET BCL MERGE FORMAT
TARJETA EN BLANCO
TARJETA EN BLANCO
?REMOVE MANUAL/OCT80
?END JOB
```

RESULTADOS DE LA SIMULACION.



TIEMPO	CA	T	DIF	TTC
0	200	200	-122	-12.2
1	187.8	187.8	-109.8	-10.98
2	176.82	176.82	-98.82	-9.88
3	166.94	166.94	-88.94	-8.89
.	.	.		
.	.	.		
.	.	.		
40	80	80		

NOTA:

Los resultados de la simulación se obtienen en el listado y contienen en primer lugar una lista de las variables con su referencia de tiempo y cada variable lleva una indicación sobre la potencia a la que hay que elevar el número que aparece abajo de la variable, esta indicación consiste en una letra E seguida del signo (+) o (-) y el número al que hay que elevar en potencias de diez, los números que aparecen en las columnas.

Después imprime las gráficas y vuelve a empezar con ENFRIAR2 hace otras listas y otras gráficas y sigue con ENFRIA3.

XII. ANALISIS DE SENSIBILIDAD

El análisis consiste en revisar para ver si existen algunos valores de las variables o de los parámetros que al variar un rango pequeño, hagan variar fuertemente el comportamiento del sistema. En algunos casos se busca evitar las oscilaciones del sistema haciéndolo estable mediante la reducción o aumento de los parámetros para lo cual el análisis de sensibilidad es inminente.

XIII. DESARROLLO DE OTROS EJEMPLOS

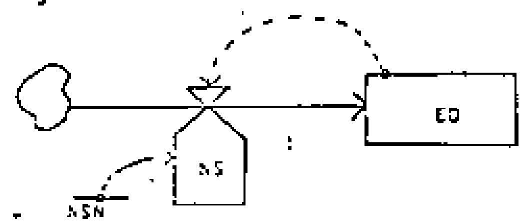
MODELO DINAMICO DE SIMULACION DEL DESARROLLO URBANO I

Este modelo se refiere al inicio de los estudios de los mecanismos existentes en el ámbito urbano. Nos referiremos al mecanismo que existe entre la construcción de edificios (NS) y los edificios ya construidos (ED).

Veamos el diagrama causal:

O sea que al aumentar el número de edificios también aumenta la construcción de los mismos.

El diagrama DYNAMO es :



ECUACIONES DYNAMO:
Los edificios actuales son iguales al número que había el año pasado más los que se construyeron durante el período de tiempo DT (un año).

ED.K=ED.J+(DT)(NS.JK)

Supondremos que ya existen ciertos edificios ED digamos que sean 1000 de valor inicial.

NS.KL=(ED.K)(NSN)

Se presenta a continuación una copia realizada en la terminal .

```
#B6700:126 CANDE 30.1AO: YOU ARE DESPT 11(24)
#TA ACIS ECEACODE SYNTAX; ENTER USERCODE PLEASE.
FADS/IL
# DEFAULT PRINT DESTINATION=SITE
RECIBE MIUS PROXIMOS SEMINARIOS
#SESSION 1241  10:44:34  10/27/80
MAKE DYNAMOINPUT
#WORKFILE DYNAMOINPUT: SEQ
SEQ
100 REMOTE
200 DYNAMO OUTPUT NARROW CODE
300 RUN   ESALGI
400 NOTE
500 NOTE  MECANISMOS DEL ANDITO URBANO,CONSTRUCCION DE EDIFICIOS
600 NOTE  NS,EDIFICIOS CONSTRUIDOS*ED,TASA NORMAL DE CONST=NON
700 NOTE
800         ED.K=ED.J+(DT)(NS.JK)
900         ED=EDI
1000         EDI=1000
1100         NS.KL=(ED.K)(NON)
1200         NON=.07
1300 PRINT 1)ED/2)NS
1400 PLOT  ED=E(0,8000)/NS=N(0,800)
1500 SPEC  DT=.5/LENGTH=30/PRTPER=2/PLTPER=1
#
SA
#WORKSOURCE DYNAMOINPUT SAVED; OLD SOURCE REMOVED
EXECUTE #DYNAMO/DIGA
#RUNNING 1347
#?

ENTER IN COLUMNS 1-15 THE NAME OF THE DISK FILE YOU WISH
DYNAMO TO CREATE TO WRITE YOUR ALGOL SOURCE CODE.  IF OUTPUT
IS DESIRED ON THE LINE PRINTER ENTER C IN COLUMN 1 FOLLOWED
BY FILENAME


UNS/IBO

OK

BURROUGHS B6700/B7700 DYNAMO LEVEL DYNA54:10/20/80

INPUT PHASE BEGIN AT 10:43  4


DYNAMO OUTPUT NARROW CODE
RUN   ESALGI

      MECANISMOS DEL ANDITO URBANO,CONSTRUCCION DE EDIFICIOS=
      NS,EDIFICIOS CONSTRUIDOS*ED,TASA NORMAL DE CONST=NON

      ED.K=ED.J+(DT)(NS.JK)
      ED=EDI
      EDI=1000
      NS.KL=(ED.K)(NON)
      NON=.07
PRINT 1)ED/2)NS
PLOT  ED=E(0,8000)/NS=N(0,800)
SPEC  DT=.5/LENGTH=30/PRTPER=2/PLTPER=1
```



```
INPUT PHASE CONCLUDED AT  10:43 40


GENERATION PHASE BEGAN AT 10:43 43
#SET DCL RESET LIST
BEGIN   INTEGER W3000,W3001,W3002,W3003,W3004,W3005,W3006,W3007,W3009,W3
010,W3011,W3012,W3000;BOOLEAN W3500;ALPHA W3500,W3501,W3502,W3503,W3504,
W3505,W3506,W3507,W3508,W3509,W3510,W3511,W3521,W3522,W3523;      FILE W9
900(MYUSE=2,INTMODE=3,KIND=3,BUFFERS=2,MAXRECSIZE=9     );FORMAT W9910(/
X10,"STARTED TO RUN CODE AT ",5A6/),W9915(2006),W9913(//X2,"FINISHED RUN
 NUMBER ",A6," AT ",5A6),W9921("PAGE ",I2,X4,A6/)         ,W9925(A20,5A6);
LABEL W6654;    FILE W9901(MYUSE=2, INTMODE=3, KIND=1, BUFFERS=2, AREAS=
20, AREASIZE=1000, TITLE=        "DYNAMO/DIAGRAM.",           SAVEFACTOR=1,
MAXRECSIZE=         4);DEFINE MAX=SPACE 1;REAL LENGTH,DT,NON,PLTPER,P,N
SMAX0,NSMIN0,ED+EDMAX0,EDMIN0,PRTPER,EDI,         TIMEX,W3701,W3700; REAL
 ARRAY  NSE0:1],W3499[0:4];     DEFINE W1111TIME=TIMEX#; LIST W9921(DR
W3005)=0          STEP 1UNTIL 400 W3499[W3005]);    PROCEDURE W2990();VALUE
 T;REAL T;BEGIN INTEGER A,B,C,D;PROCEDURE CLOCK(W,B,C,D);VALUE W;INTEGER
 B,C,D;POINTER W;BEGIN POINTER DI,SI;ARRAY LOCAL[0:0];REPLACE DI:POINTER
(LOCAL[0])BY B FOR 2DIGITS,        C FOR 2DIGITS,                  D
FOR 4DIGITS;IF SI:=       POINTER(LOCAL[0])="0"THEN BEGIN REPLACE DI:
DI BY" ";SI:=       SI+1;END ELSE REPLACE DI:    W BY DI:DI FOR 1;REPLAC
E DI:DI BY SI:SI FOR 1,                ":",                 SI:SI FOR 2
,        ,           ".";REPLACE       DI:DI BY      SI FOR 4,       ".";END CLOCK
;A:=      ENTIER(T);D:=        A DIV 60;D:=A MOD 60;D:=(         A);D:=0;
CLOCK(POINTER(W3499[0]),B,C,D);END W2990;PROCEDURE W2997();VALUE T;ALPH
A T;BEGIN LABEL X;INTEGER L,M,N;;ALPHA ARRAY A,B[0:0];PROCEDURE LINEPL
ACE,DAY,L,MONTH,M,YEAR,N);VALUE PLACE,DAY,L,MONTH,M,YEAR,N;INTEGER L,M,N
;POINTER YEAR,MONTH,DAY,PLACE;BEGIN POINTER DI;REPLACE PLACE BY DAY FOR L
, FOR L, SI:MONTH+1 FOR 7,           .        SI:1 FOR M,YEAR FOR 2,
 "  "    FOR N  . END;                                        PROCEDURE LI:I
A);VALUE A;POINTER A;BEGIN POINTER SI,DI;ARRAY LOCAL[0:2];DI:=        A;D
I:=       POINTER(LOCAL[0]);THRU 300 BEGIN REPLACE DI:     DI:DI BY SI:SI FO
R 6END;REPLACE        A BY        POINTER(LOCAL[0])FOR 300 WORDS END LI;FALP
HA ,     ARRAY MNC[0:11,0:1],DAYS[0:11];FILL DAYS WITH"000","031","059",
"090","120","150","181","212","243","273","304","334","365";FILL MNC[0,*]
WITH" JANUAR","Y 19  4";FILL MNC[1,*]WITH" FEBRUA","RY 19 5";FILL MNC[2,*]
WITH" MARCH ","19    5";FILL MNC[3,*]WITH" APRIL ","19    2";FILL MNC[4,*]
WITH"  MAY 1","9      1";FILL MNC[5,*]WITH" JUNE 1","9     1";FILL MNC[6,*]
WITH" JULY 1","9      1";FILL MNC[7,*]WITH" AUGUST",", 19   2";FILL MNC[8,*]
WITH" SEPTEM","BER 19";FILL MNC[9,*]WITH" OCTOBE","R 19   4";FILL MNC[10,*
]WITH" NOVEMB","ER 19 5";FILL MNC[11,*]WITH" DECEMB","ER 19 5";B[0]:=
   TIME(2);A[0]:=         TIME(1);IF  INTEGER(POINTER(B[0]),2)MOD 4=0AN
D INTEGER(POINTER(A[0]),3)>31THEN FOR N :=       STEP 1UNTIL 1200 DAYSEN
]:=       DAYS[N]+1;FOR N:=       STEP 1UNTIL 1200 IF A[0] LEQ      DAYS
[N]THEN GO TO X;X:REPLACE POINTER(A[0],6) BY (INTEGER(POINTER(A[0]+3)),
3) - INTEGER(POINTER(DAYS[N-1],6),3)) FOR 3 DIGITS; IF INTEGER(POINTE
R(A[0],6)),3)>9 THEN L :=2 ELSE L:=1; M:=MNC[N-1,1].[47:6];LINEPLAC
(POINTER(W3499[0]),POINTER(A[0]),L,POINTER(MNC[N-1,0]),M,POINTER(B[0]),N)
;LI(POINTER(W3499[0]))END W2997;                      REAL PROCEDURE LOG(A);VALUE
A;REAL A;IF A>0THEN LOG :=      LN(A)/2.30258509299;ELSE LOG:=0;  REAL PRO
CEDURE CLIP(G,L,N,C);REAL G,L,N,C;BEGIN IF N>C THEN CLIP:=L ELSE CLIP:=
G      END;      PROCEDURE BOXCYC(N,T,B);VALUE N;INTEGER N,T;ARRAY B[0]
;BEGIN   IF B[0]=OTHEN B[0]:=T   ;IF TIMEX LEQ       B[0] DIV2THEN BEGIN RE
AL S;S:=       B[N];FOR D[N]:=        N STEP 1UNTIL(N-1) LEQ      1;B[1]:=S
;B[0]:=        B[0]+T END;END;      PROCEDURE BOXLIN(N,T,B);VALUE N;INTEGE
R N,T;ARRAY B[0];BEGIN    IF B[0]=OTHEN B[0]:=T   ;IF TIMEX LEQ      B[0] D
IV2THEN BEGIN DO B[N]:=          B[N-1] LEQ 1;B[1]:=   B[1]+
B[0]+T END;      END;    PROCEDURE BOXLUA (N,D,T,N);VALUE N,D,N;ARRAY B[0
```

```
3;REAL P,Q;INTEGER K;BEGIN DO FIN;I:=G UNTIL  NIN    ;I:=0 END
F       BOOLEAN WVVNOISE,W77NOISV;REAL PROCEDURE RANDOM NOISE ;=REAL(UV
9NOISE:=       BOOLEAN(DC45 REAL(W77NOISE)*2:5271:9)AND BOOLEAN (2**27 1
)) OR WVVNOISV)-0.5;     REAL PROCEDURE NORMAN(A,S);VALUE A,S;REAL A,S;BE
GIN INTEGER I;REAL K;K:=0;FOR I :=1       STEP 1UNTIL 12 DO K := K+NOISE;
NORMAN := K*S+A END NORMAN;             REAL PROCEDURE PULSE(P,Q,R,T);VA
LUE P,Q,R;REAL P,Q,R,T;BEGIN IF TIMEX   NEQ 0  THEN IF TIMEX GEQ     T-D
T/2THEN BEGIN PULSE:=P; T:=T+R        END ELSE PULSE:=0 ELSE IF T :=0 NEQ
0 THEN PULSE:=P ELSE PULSE:=P END;       REAL PROCEDURE SAMPLE(P,Q,T,V);V
ALUE P,Q;REAL P,Q,T,V;BEGIN IF TIMEX NEQ 0    THEN BEGIN IF TIMEX GEQ T-
DT/2      THEN BEGIN V:=P;T:=T+Q          END END ELSE T:=0;SAMPLE:=V END;
REAL PROCEDURE WVSTEP(P,Q,V);VALUE P,Q,V;REAL P,Q,V;IF  TIMEX    GEQ  Q-
DT/2THEN WVVSTEP:=P ELSE WVVSTEP:=V;     REAL PROCEDURE RAMP(P,Q,V);VALUE
 P,Q,V;REAL P,Q,V;IF TIMEX GEQ Q-DT/2THEN RAMP:=      P+V ELSE RAMP:=V;
REAL PROCEDURE SWITC(G,L,N);REAL G,L,N;BEGIN IF N=0THEN SWITC:=G ELSE SW
ITC:=L   END   ;        REAL PROCEDURE TABLE(N,P,I,C,R);REAL P,I,C,R;REA
L ARRAY N[*];BEGIN INTEGER I,J;REAL Q;IF P LEQ I  THEN TABLE:=N[1]ELSE IF
(I:=  ENTIER((Q:=(P-I)/R)+1)) GEQ (J:=  ENTIER(C-I)/R)+1)THEN TABLE:=N[J
]ELSE      TABLE:=(N[I] TIMES (N[I+1]-N[I]))+N[I]END;  REAL PROCEDURE S
UM(N,P);VALUE N  ;INTEGER N;ARRAY P[*];BEGIN INTEGER I;REAL R;FOR R:=R+P[
I]:=I+1 UNTIL I GEQ    N;SUM:=R END;   REAL PROCEDURE SUMSQ(N,P,Q);VALUE
 N    ;INTEGER N;ARRAY P[*],Q[*];BEGIN INTEGER I;REAL R;FOR R:=R+P[I]*Q[I
-1]     DO I:=I UNTIL I GEQ      N;SUMSQ:=R      END;REAL PROCEDURE SUM3(N,
P,Q,R);VALUE N      ;INTEGER N;ARRAY P[*],Q[*],R[*];BEGIN INTEGER I;REAL
 S;DO S :=       S+P[I]*Q[I]*R[I] UNTIL I GEQ      N;SUM3:=S
END;   REAL PROCEDURE RAMP1(P,Q,V);VALUE P,Q,V;REAL P,Q,V;IF TIMEX GEQ
Q-DT/2 THEN RAMP1:=  (TIMEX Q)*P+V ELSE RAMP1:=V;       W3004:=TIME(2)/
TIME(0)         ;WRITE(WV900[SKIP 1]); W3500:=    "EORLOG";       WRITE(WV
900     ,WV921,W3004,W3500);W3004:=W3004+1         ;W7V2:=TIME(1)/3600;WRI
TE(W9900,WV925,WV75V);
                     FOR W3003:=1STEP 1UNTIL   110     BEGIN LABEL W401
2;LIST WV740(TIMEX,         ACL[W3003],E[3]);  BEGIN LABEL W4005,W3003;
WC06:=W3V00:=TIMEX:=0;DT:=DT/2;       W7V00:=1;W77NOISE:=TRUE;W77NOISV:=BOOLEA
N      (016+V0+4&:1071)));      PRIPER:=2;PLIPER:=1;T:=-12       W3V05:=
IF PLTPER GTR      PRIPER AND PRIPER NEQ 0 OR    PLTPER=0 THEN PRIPER ELSE
 PLTPER;BEGIN LABEL W4444;
                                         FORMAT OUT WV750(X3,A6,X14,A3,X11,A2
);LABEL
     W6001,W6002;      SWITCH W6000:=  W6001;  GO TO W6000[W3003];

W6001:PLTPER:=1;PRTPER:=2;LENGTH:=30;DT:=.5;NOHAX:=,B;ILOD:=1000;ED:=ED(N
C(3]:=E[3]:(CO));GO TO W6002;W6002:
                                     NOMAXD:=NOMIND:=NOLD[3];EDMAXD:=EDMIND:
=ED;      W4444:END;WV900[TIME(1)/3600;WRITE(WV900,WV910,WV75V)];FOR TIMEX
:=0 STEP DT UNTIL 1 +    LENGTH DO BEGIN IF  TIMEX:=0 THEN GO W4005;IF BOO
LEAN(W3003)THEN BEGIN W3003:=0;W3000:=1          END ELSE BEGIN W3001:=1+W3
000:=0  END;     ED:=ED+(DT)*(NOL[W3003]);

                                     NOL[W3003]:=(ED+(NOH)); 
                                                                  W4005:W400
3:      IF TIMEX GEQ W3V00-DT/2      OR TIMEX:=0  THEN BEGIN LABEL W4443;W
3V00:=W3V00+        W3V01;         WRITE (WV701,*,WV740);  IF NO     [W3003]
NOMAXD THEN NOMAXD:=NO  [W3003] ELSE IF NO        [W3003]:NOMIND THEN NOMI
ND:=NO  [W3003]);IF EDMAXD THEN EDMAXD:=ED ELSE IF ED LEQ EDMIND THEN EDMI
ND:= PHASE  GENERATED AT  10:40 30
AD:=ED;W4444:   END END;REWIND(WV701);W3005:=       W3001:=0LR0;
                                                                  BEGIN IN
TEGER LFR;       FORMAT OUT WV711(X10,"STARTED PRINTING AT ",5A6/),WV71(
```



```
X1,F7.4,X1,F7.4,X1,F7.4,/)         ,WV723(" "    TIME        ED         NO "/)
,W9922( X3,A4,X4,A4,X4,A4/))       INTEGER ARRAY A1[0:         2     ];ARRAY
A2[0:       2      ];ALPHA ARRAY SC[0:            2];LIST WV741(          FOR W300
0:=0STEP 1UNTIL      2     DO A1[W3000],A2[W3000]] );          LABEL W4000,W4
001,W4002;        PROCEDURE W0077(MAX,SCALE,ORDINAL,EXPONENT,DECIMALPLACE
S);VALUE IMAX;REAL IMAX,SCALE;INTEGER ORDINAL;ALPHA ARRAY EXPONENT[0];IN
TEGER ARRAY DECIMALPLACES[0];BEGIN INTEGER I1,I2;ARRAY LOCAL[0:1];IF  I1
:=ENTIER(LOG(MAX)/  GEQ 0 THEN   I2:=0 ELSE I2:=1        ;LOCAL[0]:=SCALE:=3
*((I1:=       I1-2+I2)DIV 3);DECIMALPLACES[ORDINAL-1]:=      ABS(I1 MOD 3-2-
I2);REPLACE POINTER(LOCAL[1])+6 BY LOCAL[0] FOR 2DIGITS;EXPONENT[ORDINAL-
1]:=0;  "E"       [3:5:6];IF  SCALE LSS 0THEN "-"ELSE"+"[11:5:6];LOCAL[1][1
1:11:2];SCALE:=10**SCALE END W0077;      REAL W7001,W7002,W7003,W7004;
      IF PRIPER=0THEN GO TO W4002;W350V :=        "       "+W3510:="  - "
;        W0077(EDMAX-W7001,  1,SC,A1);W0077(MAX(ABS(EDMAXD),ABS(EDMIND))
,W7002,  2,SC,A1);W0077(MAX(ABS(NOMAXD),ABS(NOMIND))-W7003,  3,SC,A1);
      W2500:=          TRUE;W4000:W3007:= 0;WRITE(WV900  [SKIP 1  ]);WRITE
(W9900       ,WV921,W3004,W3500);W3004:=       W3004+1;IF  W2500 THEN BEGIN
W7V90(TIME(1)/3600);WRITE(WV900,WV711,WV75V)END ELSE WRITE(WV900[DBL],WV
915);WRITE(W9900,WV923            );IF W2500 THEN BEGIN W2500:=        FALS
E;W3007 :=        2        ;WRITE(WV900,WV922,FOR W3003:=0 STEP 1 UNTIL
   2      DO SC[W3003]       ));END;W4001:       FOR W3007:=        W3007 STEP  DO
WHILE W3007+ 4 LEQ 52        DO BEGIN LABEL W4003,W4004;READ(WV701,*,WV740)[W
4003];IF LENGTH/W3V01-TEMP:=ENTIER LEQ 2 THEN GO W4003;A2[    W1]:=W1;[1]:=A
E/W7001;A2[     1]:=ED/W7002;A2[    2]:=NOL[3]/W7004;       WRITE(WV900,WV71
6,WV741);        IF PRTPER: W3V01 THEN SPACE(WV701,ENTIER(PRTPER  W3V01)
/ W3V01));[W4003];GO TO W4004;W4003:REWIND(WV701);GO TO W4002;W4004:END;G
PRINT PHASE GENERATED AT  10:47 30
O TO W4000;W4002:END;
                                 BEGIN    ALPHA ARRAY W3501[0:100],W3502[0:140],W3
520[-11:12];  FORMAT OUT WV912(X10,"BEGAN PLOTTING AT ",5A6/),WV917(X1,
A1,X8,F8.1,A1,X11,F8.1,A1,X1,A6,A1),WV916(A5, 31A1,X1, 3A1);
REAL  W0038, W0039,W0040,W0041,W0042,W0043,W0044,W0045; ALPHA PROCEDURE
W3596(P);ALPHA P;BEGIN POINTER P1,P2;ARRAY LOCAL[0:0];LOCAL[0]:=       P
;SCAN P2:P1:=        POINTER(LOCAL[0])FOR 6 WHILE=       "0"; W3596:=W6 "
   " [35:35:6]DELTA(P1,P2);END W3596;ALPHA PROCEDURE W3597(P);INTEGER
W;BEGIN          ARRAY LOCAL[0:0];REPLACE POINTER(LOCAL[0])BY W FOR
6DIGITS;W3597:=      LOCAL[0]END W3597;       PROCEDURE W3598(W3000,W3502,
W3503,W3504);VALUE W1000;INTEGER W3000;ALPHA W3501,W3503;ALPHA ARRAY W35
02[0];BEGIN INTEGER W3001,W3002;LABEL W4000;W3002:=0;FOR W3001:=       W3
000 STEP-1UNTIL 100 BEGIN IF W3502[W3002]:=" "THEN BEGIN W3502[W3002]:=
 W3503;W3502[W3002][3]:=       W3503;GO TO W4000 END ELSE IF W3502[W3
002]:=W3506 THEN FOR W3000:=2STEP 1 UNTIL        W3001 DO IF  W3502[W3002]
W3000]:=" "THEN BEGIN W3501[W3002]W3000] :=        W3504;GO TO W4000 END;W3
002:=W3002;W3001 END    SEARCH;W4000:END OF  W3598;PROCEDURE W3599(W3502,W
3012);VALUE W3012;INTEGER W3012;ALPHA ARRAY W3502[0];BEGIN INTEGER W3000
,W3001,W3002;BOOLEAN W2500;LABEL  W4000,W4001,W4002;W3000:=W3002 :=0;FOR
W3012:=       W3012 STEP-1UNTIL 100 DO BEGIN W2500:=TRUE;FOR W3001:=0     STEP
1 UNTIL   W3012-100 IF W3502[W3000][W3001]:=" "THEN IF W2500 THEN GO TO W40
01 ELSE GO TO W4000 ELSE BEGIN W2500:=          FALSE;W3502[W3002] :=W3502[
W3000+W3001]:=W3002:=          W3002]FILL;W3002:=W3002+1;GO TO W4001;  W4000:
W3502[W3002]:=  " ";            [W3002]:=W3002];W3000:=  ;     W3000:W3012 END;W40
01:FOR W3002:=IF  W3002    NEQ 0 THEN W3002 ELSE 0STEP 1UNTIL 1400 W3502[
W3002]:=" "W4002:END;          FILL W3520[*]WITH"X","Y","Z","W","U","T","S","R","Q",
"P","O","N","M","L","K","J","I","H","G","F","E","D","C","B","A";IF P
LTPER=0THEN GO TO W4012;BEGIN LABEL W4007;INTEGER LFR;  FORMAT WV733 ( "
      ED=E, NO=N        "/);LIST WV742 (ED,NOL[3]);ARRAY W1010,W1000,W102
```

```
OEO; 2];ALPHA ARRAY W3504[1: 3];FILL W3504[*] WITH "2"," ","*";                 W
RITE(W9900[SKIP 1]);WRITE(W9900 ,W9921,W3004,W3509);W3004:=         W3004
+1;W9996(TIME(1)/3600);WRITE(W9900,W9912,W9959);WRITE(W9900,W9923);
BEGIN LABEL L;W10000[ 1]:=         0                              ;W10201[ 1]:=
8500                 ;BEGIN W0030:=W10000[ 1];W0039:=W10201[ 1]END;W100
00[ 1]:=W0030+W10201[ 1]:=W0039;  IF ABS(W3007)= [illegible]   (ABS(W0039)) GE
O     THEN BEGIN W0039 :=W0039/10*( [illegible] W3007:=3×ENTIER [illegible]
[illegible] W3500[W3007]/3 END ELSE W35
[illegible]
,W3521,W0041:=W0040:=     (W0039 W0030]/3);W0030,W3521
               ,W0043:=      W0039 W0040,W3521,W0039,W3522,W3522,W35
23);    L:END;BEGIN LABEL L;W10000[ 2]:= 0                          ;W10201
2]:=   600                    ;BEGIN W0030:=W10000[ 2];W0039:=W10201[ 2]
END;W10000[ 2]:=W0030/W10201[ 2]:=W0039;  IF ABS(W3007)= LOG       (ABS(W00
39)) GEQ     THEN BEGIN W0039 :=W0039/10*(       W3007:=3×ENTIER(
 (LOG(W0039)/3))W0030:=W0030/10*W3007;W3521:=         W3520[W3007/3]END
ELSE W3521:=" ";          W3522:="N        ";W3523:="        ";WRITE(W9900,W99
19,W0030,W3521,W0041:=W0040:=       (W0039 W0030]/3);W0030,W3521
                         ,W0043:=       W0039 W0040,W3521,W0039,W3522,W
3522,W3523);     L:END;  W3010:=10700 BEGIN     READ(W9909,[illegible]W0097]
;       FOR W3000:=0 STEP 1 UNTIL 10000 W3501[W3000]:=      " "; FOR  W3000:=
0,20,40,60     DO W3501[W3000]:=".";W3505:="    [illegible] W3010=0 THEN BEGIN W
3010:=0;     W3000:=        ENTIER(TIME(1,5)[illegible]W3505:=
     W3596(W3523)[illegible] FOR W3000:=0         STEP UNTIL 10000 W350
1[W3000]:=        "=";END;W3010:=W3010+1; FOR      W3000:= STEP UNTIL 140
DO [illegible] W3000] :=      [illegible] FOR W300
0:=STEP UNTIL  2         DO BEGIN LABEL W401;W3007:=;          [illegible]
[illegible] IF W3007 [illegible] W30
07> 60 THEN GO TO W401;W3506:=W3502       [illegible] W3506:=" FOR W3506
=".",OR W3506="" THEN W3501[W3007]:=W3504[W3000]ELSE W3570[       3
 ,W3502,W3506,W3504[W3000]);W401:;END;W3577(W3502,          3        );WRIT
E(W9905,W9914,W3505,FOR W3000:=0  STEP 1       UNTIL  6000 W3501[W3000]);FO
R W3007 :=0 STEP 1     UNTIL  200 [illegible] THEN GO
[illegible]                           END UNTIL
[illegible] GENERATED AT  10:52 26
[illegible]
W3996(TIME(1)/3600);WRITE(W9900,W9913,W3505,FOR W3005:=0 STEP 1          UNT
IL 400 W3499[W3005]);    ENDTLAB.
```

ELAPSED COMPILATION TIME   10 2

PLEASE ENTER COMPILE URB/100   WITH ALGOL. THEN
WAIT UNTIL YOUR TERMINAL REPORTS THAT YOUR COMPILATION
IS COMPLETE. AFTER GOOD COMPILATION ENTER EXECUTE
URB/100

COMPILE URB/100 WITH ALGOL
#COMPILING 1476
#SET DCL RESET LIST
66051000 WARNING-DCL PROGRAMS ARE NOT PORTABLE TO ECLIPSE MACHINES.
#ET=26.9 PT=10.0 IO=7.0

EXECUTE URB/100
#RUNNING 1502

PAGE 1   EDNEO1

11:01.6103, 20 OCTOBER 1980

STARTED TO RUN CODE AT 11:01.6203, 20 OCTOBER 1980

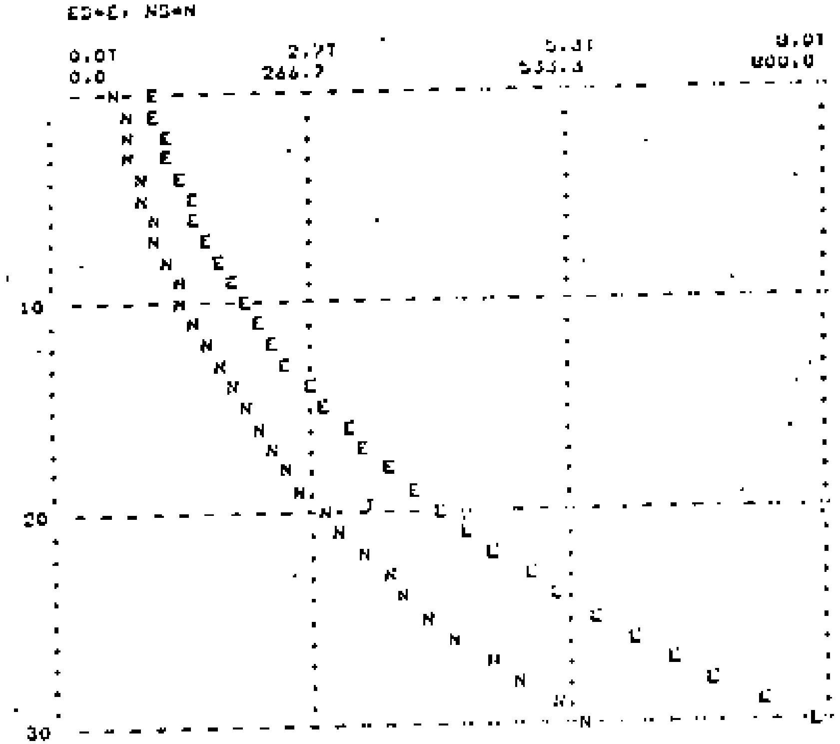
PAGE 2   EDNEO1

STARTED PRINTING AT 11:01.7050, 20 OCTOBER 1980

TIME	EO	NS
E+00	E+00	E+00
0.000	1000.0	70.00
2.000	1147.5	80.33
4.000	1316.8	92.18
6.000	1511.1	105.77
8.000	1734.0	121.38
10.000	1989.8	139.29
12.000	2283.3	159.83
14.000	2620.2	183.41
16.000	3006.7	210.47
18.000	3450.3	241.52
20.000	3959.3	277.15
22.000	4543.3	318.03
24.000	5213.6	364.95
26.000	5982.7	418.79
28.000	6865.3	480.57
30.000	7878.1	551.47

PAGE 3 CONEG1

BEGAN PLOTTING AT 11:02.10V4, 20 OCTOBER 1980



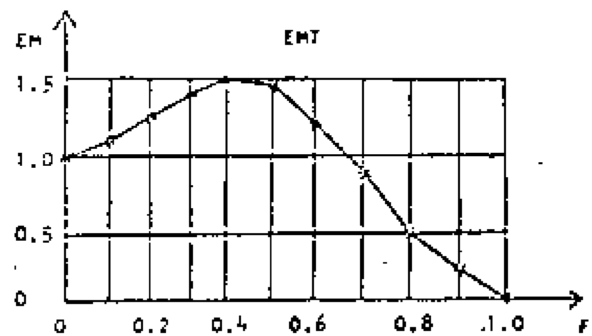
FINISHED RUN NUMBER EDNEG1 AT 11:03.56?? 20 OCTOBER 1980
#CT=2:06.V PT=2.2 IO=2.1
EXECUTE DRB/1BOJ FILE DYVOO(PRINTER)
WARNING 1032
#CT=19.1 PT=2.5 IO=2.6
WRITE DYNAMOINPUT

MODELO DINAMICO DE SIMULACION DEL DESARROLLO URBANO II

Complicaremos el modelo anterior añadiéndole lo siguiente: La tasa de construcción NS se verá afectada por un efecto multiplicador que tome en cuenta que mientras más construcciones haya al inicio del desarrollo habrá más alicientes para que se construya más, pues se establecen servicios que pueden ser aprovechados. Se abren restoranes cerca de los edificios, se instala energía eléctrica, gas, agua potable, telefonos, etc. Este efecto dura hasta que la densidad de edificios aumenta, o sea, cuando aumenta la ocupación del suelo el fenómeno se invierte y el efecto tiende a disminuir la tasa de construcción.

DIAGRAMA CAUSAL:

Para poder introducir el efecto multiplicador, tendremos que relacionarlo con la densidad, y lo haremos mediante una tabla:



Cuya ecuación es:

EM.K=TABLE(EMT,FSO.K,0,1,.1)

EMT*=1/1.15/1.3/1.4/1.45/1.4/1.3/.9/.5/.25/0

O sea que entrando con un valor FSO, refiriéndolo a la gráfica y luego al eje EM nos dará el valor del multiplicador según sea la forma de la curva experimental. Esta cualidad permite introducir a la computadora elementos subjetivos como corazonadas dándole diversas formas a las curvas según nuestra intuición y luego revisando y verificando o cambiando los resultados.

Veamos como se forma la ecuación FSO:

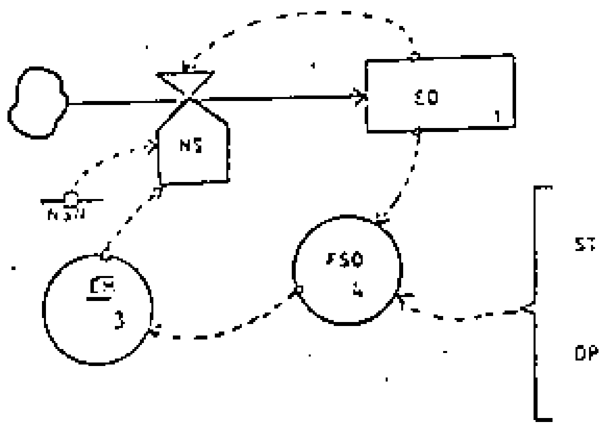
FSO va a ser la fracción de suelo ocupado por los edificios por lo que intervendrá en su ecuación, los edificios ED, la superficie total del ámbito urbano o sistema considerado, y la densidad media dada en hectáreas por edificio:

FSO.K=(ED.K)(DP)/ST

ST=1000

DP=0.2

Veamos como se modificó nuestro diagrama DYNAMO:



Las ecuaciones DYNAMO quedan:

ED.K=ED.J+(DT)(NS.JK)
ED=1000

ED	edificios	(unidades)
NS	tasa de construcción	(unids/año)

NS.KL=(ED.K)(NSN)(EM.K)
NSN=0.7

NS	tasa de construcción	(unids/año)
ED	edificios	(unidades)
NSN	valor normal de la tasa NS	(fracción/año)

EM.K=TABLE(EMT,FSO.K,0,1,.1)
EMT*=1/1.15/1.3/1.4/1.45/1.4/1.3/.9/.5/.25/0

EM	efecto multiplicador	(adimensional)
EMT	nombre de la tabla	
FSO	fracción de suelo ocupado	(fracción)

FSO.K=(ED.K)(DP)/ST
ST=1000
DP=.2

ST	superficie total en estudio	(Hectáreas)
DP	densidad promedi	(Ha/unid.)

```
100 REMOTE
200 DYNAMO DLIST NARROW
300 RUN    EDNLG2
400 NOTE
500 NOTE   MECANISMOS DEL AMBITO URBANO,CONSTRUCCION DE EDIFICIOS=
600 NOTE   NS,EDIFICIOS CONSTRUIDOS=ED,TASA NORMAL DE CONST=NSN
700 NOTE    AL MODELO ANTERIOR SE LE AGREGA EL EFECTO MULTIPLICADOR
800 NOTE   POR LA FRACCION DE SUELO OCUPADO POR LOS EDIFICIOS(FSO)
900 NOTE   TOMANDOSE EN CUENTA LA SUPERFICIE TOTAL(ST) Y LA DENSIDAD
1000 NOTE  PROMEDIO DE SUELO OCUPADO POR EDIFICIO (DP)
1100 NOTE
1200          ED.K=ED.J+(DT)(NS.JK)
1300          ED=EDI
1400          EDI=1000
1500          NS.KL=(ED.K)(NSN)(EM.K)
1600          NSN=.07
1700          EM.K=TABLE(EMT,FSO.K,0,1,.1)
1800          EMT=1/1.15/1.3/1.4/1.45/1.4/1.3/.9/.5/.25/0
1900 NOTE
2000          FSO.K=(ED.K)(DP)/ST
2100          ST=1000 HECTAREAS
2200          DP=.2 HECTAREAS POR EDIFICI
2300 PRINT 1)ED/2)NS/3)FSO
2400 PLOT  ED=E/NS=N/FSO=F
2500 SPEC  DT=.5/LENGTH=30/PRTPER=2/PLTPER=1
*
800NOTE  (EM) POR LA FRACCION DESUELO DEL
800NOTE  (EM) POR LA FRACCION DE SUELO OCUPADO POR LOS EDIFICIOS(FSO)
RES
UPDATING
*
L 800
800 NOTE  (EM) POR LA FRACCION DE SUELO OCUPADO POR LOS EDIFICIOS(FSO)
C
2200         DP=.2 HECTAREAS POR EDIFICIO
RES
UPDATING
*
L
100 REMOTE
200 DYNAMO DLIST NARROW
300 RUN    EDNLG2
400 NOTE
500 NOTE   MECANISMOS DEL AMBITO URBANO,CONSTRUCCION DE EDIFICIOS=
600 NOTE   NS,EDIFICIOS CONSTRUIDOS=ED,TASA NORMAL DE CONST=NSN
700 NOTE    AL MODELO ANTERIOR SE LE AGREGA EL EFECTO MULTIPLICADOR
800 NOTE   (EM) POR LA FRACCION DE SUELO OCUPADO POR LOS EDIFICIOS(FSO)
900 NOTE   TOMANDOSE EN CUENTA LA SUPERFICIE TOTAL(ST) Y LA DENSIDAD
1000 NOTE  PROMEDIO DE SUELO OCUPADO POR EDIFICIO (DP)
1100 NOTE
1200          ED.K=ED.J+(DT)(NS.JK)
1300          ED=EDI
1400          EDI=1000
1500          NS.KL=(ED.K)(NSN)(EM.K)
1600          NSN=.07
1700          EM.K=TABLE(EMT,FSO.K,0,1,.1)
1800          EMT=1/1.15/1.3/1.4/1.45/1.4/1.3/.9/.5/.25/0
```



```
1900 NOTE
2000          FSO.K=(ED.K)(DP)/ST
2100          ST=1000 HECTAREAS
2200          DP=.2 HECTAREAS POR EDIFICIO
2300 PRINT 1)ED/2)NS/3)FSO
2400 PLOT  ED=E/NS=N/FSO=F
2500 SPEC  DT=.5/LENGTH=30/PRTPER=2/PLTPER=1
*
SA
#WORKSOURCE DYNAMOINPUT SAVED; OLD SOURCE REMOVED
EXECUTE *DYNAMO/DISK
#RUNNING 1681
#?

ENTER IN COLUMNS 1-15 THE NAME OF THE DISK FILE YOU WISH
DYNAMO TO CREATE TO WRITE YOUR ALGOL SOURCE CODE.  IF OUTPUT
IS DESIRED ON THE LINE PRINTER ENTER C IN COLUMN 1 FOLLOWED
BY FILENAME

UKD/200

OK

BURROUGHS B6700/B7700 DYNAMO LEVEL DYN454:10/20/80

INPUT PHASE BEGIN AT 11:39 55

DYNAMO DLIST NARROW
RUN    EDNLG2

       MECANISMOS DEL AMBITO URBANO,CONSTRUCCION DE EDIFICIOS=
       NS,EDIFICIOS CONSTRUIDOS=ED,TASA NORMAL DE CONST=NSN
        AL MODELO ANTERIOR SE LE AGREGA EL EFECTO MULTIPLICADOR
       (EM) POR LA FRACCION DE SUELO OCUPADO POR LOS EDIFICIOS(FSO)
       TOMANDOSE EN CUENTA LA SUPERFICIE TOTAL(ST) Y LA DENSIDAD
       PROMEDIO DE SUELO OCUPADO POR EDIFICIO (DP)

       ED.K=ED.J+(DT)(NS.JK)
       ED=EDI
       EDI=1000
       NS.KL=(ED.K)(NSN)(EM.K)
       NSN=.07
       EM.K=TABLE(EMT,FSO.K,0,1,.1)
       EMT=1/1.15/1.3/1.4/1.45/1.4/1.3/.9/.5/.25/0

       FSO.K=(ED.K)(DP)/ST
       ST=1000 HECTAREAS
       DP=.2 HECTAREAS POR EDIFICIO
PRINT  1)ED/2)NS/3)FSO
PLOT   ED=E/NS=N/FSO=F
SPEC   DT=.5/LENGTH=30/PRTPER=2/PLTPER=1

INPUT PHASE CONCLUDED AT  11:40 41
```

```
GENERATION PHASE BEGAN AT 11:40 42
RUN PHASE GENERATED AT 11:40 53
PRINT PHASE GENERATED AT 11:40 55
PLOT PHASES GENERATED AT 11:40 57

ELAPSED COMPILATION TIME 1 43

PLEASE ENTER COMPILE DRB/200 WITH ALGOL. THEN
WAIT UNTIL YOUR TERMINAL REPORTS THAT YOUR COMPILATION
IS COMPLETE. AFTER GOOD COMPILATION ENTER EXECUTE
DRB/200

#ET=1:50.8 PT=6.1 IO=7.2
COMPILE DRB/200 WITH ALGOL
#COMPILING 1906
$SET DCL RESET LIST
00001000 WARNING-DCL PROGRAMS ARE NOT PORTABLE TO DIGITAL MACHINES.
#ET=44.0 PT=12.1 IO=9.1
EXECUTE DRB/200
#RUNNING 1917
```

PAGE 1 EDNEG2

11:42.5578, 20 OCTOBER 19[illegible]

STARTED TO RUN CODE AT 11:42.5600, 20 OCTOBER 19[illegible]

PAGE 2 EDNEG2

STARTED PRINTING AT 11:42.6347, 20 OCTOBER 19[illegible]

TIME	ED	NS	FSO
E+00	E+00	E+00	E+00
0.000	1000.0	91.00 0.20000	
2.000	1197.1	112.24	0.23941
4.000	1441.2	140.05	0.28024
6.000	1745.9	174.11	0.34919
8.000	2124.6	213.79	0.42492
10.000	2579.9	249.94	0.51597
12.000	3101.4	264.62	0.62027
14.000	3590.3	208.03	0.71004
16.000	3960.2	147.44	0.79204
18.000	4227.3	114.32	0.84547

20.000	4435.4	87.65	0.88707
22.000	4593.2	65.37	0.91865
24.000	4710.1	47.79	0.94202
26.000	4795.0	34.40	0.95901
28.000	4855.9	24.49	0.97118
30.000	4899.1	17.30	0.97983

PAGE 3 EDNEG2

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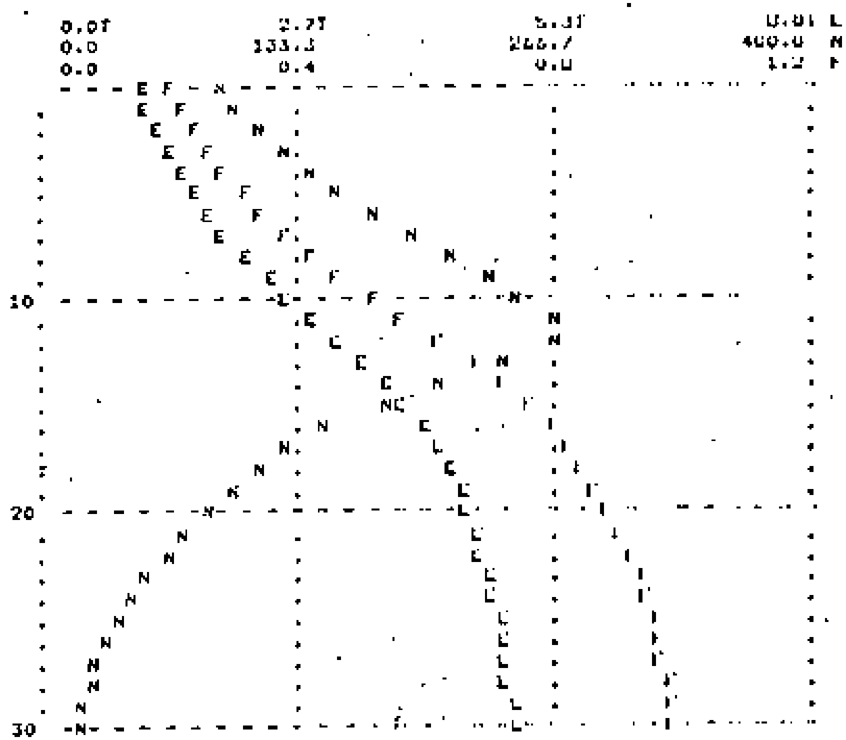
ED=E, NS=N, FSO=F

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INTRODUCCION A UN MODELO GRAVITACIONAL.

Plantearemos cómo realizar la simulación del fenómeno de la atracción entre dos polos de masa M1 y M2 a una distancia D uno de otro y con las siguientes condiciones:

- M1 tiene un crecimiento exponencial determinado por condiciones propias.
- M2 Crece proporcionalmente a la fuerza de atracción F
- La distancia D entre los polos disminuye proporcionalmente al valor de F.

Si usamos la Ley de Keppler que dice: "La atracción de los cuerpos es directamente proporcional a sus masas e inversamente proporcional al cuadrado de las distancias de los cuerpos", usando la siguiente formula:

$$F = G\ M1\ M2/D^{N}$$

Tenemos las siguientes ecuaciones DYNAMO:

```
M1.K=M1.J+(DT)(TM1.JK)
M1=
TM1.KL=(M1.K)(TNM1)
TNM1=
F.K=(G)(M1.K)(M2.K)/D1.K
G=
D1.K=EXP(C)
C=(N)(LOGN(D2.K)
N=
D2.K=D2.J+(DT)(TD.JK)
TD.KL=(TNA)(F.K)
TNA=
M2.K=M2.J+(DT)(TM2.JK)
M2=
TM2.KL=(TAM2)(M2.K)(F.K)
TNM2=
```

Se sugiere al usuario revisar el modelo anterior, formular el diagrama causal y el diagrama DYNAMO y procesarlo, determinando los rangos de valores congruentes con la realidad.

XIV OTRAS APLICACIONES

Los modelos de simulación permiten resolver una gran cantidad de problemas , donde otros métodos resultan muy difíciles o no aplicables.

Al realizar el proceso de la creación del modelo de simulación, lo que se hace es identificar las variables que son relevantes en el contexto del problema, dándoles su valor real. Se investiga el porcentaje de crecimiento o variación de estas variables, su relación entre ellas y los parámetros que las controlan. Al hacer variar la variable tiempo, las variables actuan según los valores preestablecidos en el modelo y nos permiten ver su comportamiento. Al estudiar este comportamiento podemos cambiar algunos datos iniciales con objeto de lograr que el valor de las variables oscile entre valores deseados o que tienda a ciertos límites.

Si fuera el caso que estuviéramos modelando un sistema cuyo comportamiento histórico es conocido, estos valores nos servirán para adecuar el valor de los parámetros de tal manera, que el modelo al ser procesado en la computadora repita el proceso histórico, extrapolando su comportamiento para un número futuro de años. Este trabajo se conoce como calibración del modelo.

Veamos a grandes razgos los campos de aplicación que tienen los modelos de simulación dinámica:

En la Industria:

Existe desde hace aproximadamente unos 15 años un campo conocido como la "Dinámica Industrial" en donde se simula todo el proceso industrial, desde la producción y formación de inventarios hasta su distribución y comercialización. Se contemplan también los principales flujos de caja y diversos impactos en la industria como son los efectos de la publicidad en las ventas, el aumento o disminución en los inventarios, etc. La simulación permite a los directores de la industria tomar decisiones anticipadas a la ocurrencia de los eventos,"probándolas" en los modelos de simulación.

En Planeación: Desde hace algunos años se usa la simulación para resolver problemas de Planeación , basta con que se identifique algún problema, se determinen sus variables relevantes y se cree el modelo de simulación para que puedan probarse políticas que de no probarse en un modelo de simulación, en la realidad, además de ser mucho muy caras, crean efectos sociales irreversibles.

En Planeación Urbana: Se han creado modelos urbanos de grandes ciudades y pequeños poblados para la prueba de políticas.

En la Planeación Regional: Se han modelado las principales variables regionales para cuestionar la Economía Regional como en el caso del Estudio del Vaso del Río Susquehanna en Estados Unidos-en los Estados de Maryland, Pennsylvania del Centro y el sur del Estado de Nueva York en 1962.

En Ecología: Las componentes de los sistemas ecológicos se han estudiado aisladamente y apenas hace pocos años se ha iniciado el estudio global de todo el sistema . Los modelos de simulación permiten controlar el comportamiento del sistema. Existe un modelo clásico de la relación entre Predadores y Presas (conejos y coyotes) de Nathan B. Forrester del Instituto Tecnológico de Massachusetts.

En Ingeniería Sanitaria: Hay varios modelos de simulación que simulan el desarrollo de una epidemia, muestran la propagación de ésta y su posible control. También es posible simular el comportamiento de pozos,desarrollo de bacterias,etc.

En la Física: Se han desarrollado una gran cantidad de modelos para simular suspensiones mecánicas,fenómenos de amortiguación variable,procesos en general,fenómenos de flujo,temperatura,presión, etc. Y en general en todos aquellos fenómenos que tengan una tasa de cambio son susceptibles de simularse.

En Administración: Hay modelos para simular los procesos Administrativos y modelos sobre varios problemas en la Administración.

En Arquitectura: El campo ha sido poco desarrollado pero tiene muchísimos alcances, sobre todo en las áreas de Tecnología, Urbanismo y Restauración.

En Medicina: Se usan mucho los modelos para simular el comportamiento de diversos órganos internos para medir su comportamiento con diferentes estímulos.

En Química: Se pueden simular procesos para control,monitoreo e investigación.

En C. Sociales Hay modelos sobre el uso de narcóticos,sobre sistemas sociológicos,educativos,etc.

En Investigación: La construcción de modelos orienta a la investigación cuando se están creando modelos,pues se requieren verificaciones de hipótesis que a veces sólo son posibles simulando.

Otros Campos: Finanzas,Psicología,Comercio,Biología,Astronomía,Geología,Geografía,Derecho,etc.

XV. BIBLIOGRAFIA

En los siguientes libros y manuales se pueden encontrar más ejemplos y algunas características de diversas versiones.

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M. en I. Francisco José Alvarez Caso

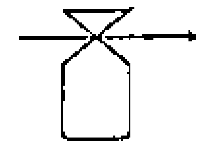
2. CONSTRUCCION DE MODELOS DE SIMULACION

Existe en la actualidad un metalenguaje a nivel agregado que permite realizar análisis, síntesis y comunicación en pocos meses. Este lenguaje consiste en la utilización de símbolos con conceptos bien definidos.

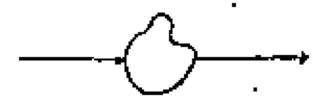
Concepto — **Símbolo**

Nivel: Se refiere a el volumen acumulado originado por un flujo de elementos o unidades durante un cierto tiempo.

Tasa: Especifica la cantidad de flujo que puede pasar en un intervalo de tiempo y controla el flujo.



Fuente o sumidero: La nube intenta representar todo lo que esta fuera del sistema que se estudia.



Auxiliar: Son cálculos que se realizan para ayudar a determinar el valor de las tasas en un intervalo dado.

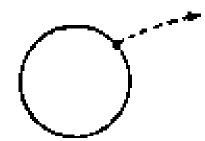
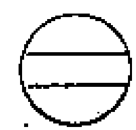


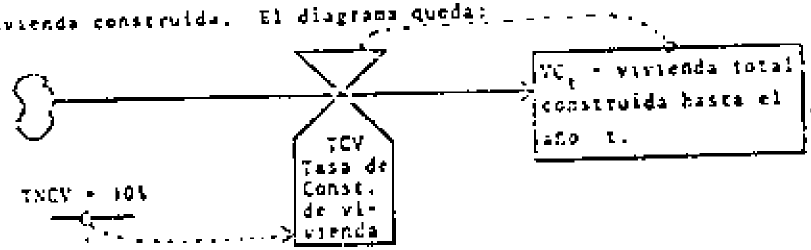
Tabla: Representa un cambio en la variable que le llega este cambio puede ser cualitativo. o cuantitativo.



Concepto	Símbolo
Flujo: Representa flujo de bienes productos, unidades o cosas	
Flujo de Información:	
Parámetro o constante del sistema.	

Veamos algunos ejemplos del uso de este lenguaje gráfico:

Supongamos que en un ámbito urbano se construye vivienda a una tasa histórica normal TNCV al año, y que durante el transcurso de los años el número de viviendas construidas se va acumulando, sea VC la vivienda construida. El diagrama queda:



$VC_t = VC_{t-1} + TCV, \quad TCV = TNCV \times VC_t$.

Veamos como calcular VC con datos supuestos: En el año t=0 tenemos un valor de 600 viviendas y se construyen cada año el 10% más:

t	VC_t	TNCV	TCV
0	600	0.1	60
1	660	0.1	66
2	726	0.1	72.6

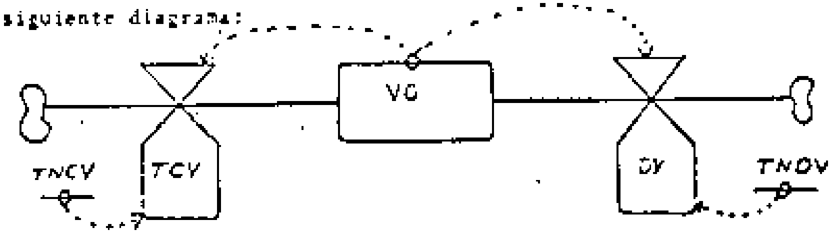
t	VC_t	TNCV	TCV
3	798	0.1	79.86
4	878	0.1	87.85
5	966	0.1	96.63
6	1062	0.1	106.3
7	1169	0.1	117
8	1286	0.1	128.6
9	1414	0.1	141.4
10	1556	0.1	155.6

tomemos como ejemplo el año 6:

$TCV = TNCV \times VC_5 = 0.1 \times 966 = 96.6$

$VC_6 = VC_5 + TCV = 966 + 96.6 = 1062.6$

Modifiquemos el diagrama anterior, para indicar que además de la construcción de vivienda, va a existir la demolición o restauración de vivienda. Sea: DV = restauración o demolición de vivienda y TNDV = tasa normal de demolición o restauración anual. Tendremos el siguiente diagrama:



Supongamos los siguientes datos adicionales al ejemplo anterior.

- TNDV = 2% anual (Implica 50 años de duración)

t	VC_t	TNCV	TCV	TNDV	DV	TCU-DV
0	600	0.1	60	.02	12	48
1	648	0.1	64.8	.02	12.96	51.84
2	699.84	0.1	69.9	.02	13.99	55.90
3	755.74	0.1	75.6	.02	15.11	60.49
4	816.23	.01	81.62	.02	16.32	65.29
5	952.04	.01	88.15	.02	17.63	70.51
6	952.04	.01	95.20	.02	19.04	76.15
7	1028.20	.01	102.82	.02	20.56	82.26
8	1110.46	.01	111.04	.02	22.21	88.85
9	1100.28	.01	119.93	.02	23.98	95.94
10	1295.22	.01		.02		

Tomemos como ejemplo el cálculo del año 8:

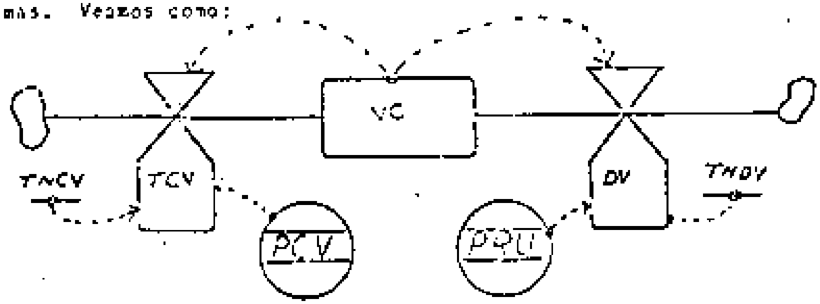
$TCV = TNCV \times VC_7 = .01 \times 1028.20 = 102.82$

$DV = TNDV \times VC_7 = .02 \times 1028.20 = 20.56$

$TCV - DV = 102.82 - 20.56 = 82.26$

$VC_8 = VC_7 + (TCV - DV) = 1028.20 + 82.26 = 1110.46$

Hasta ahora hemos supuesto que las tasas de construcción y de demolición son valores fijos promedio de la realidad. Sin embargo si en un momento dado aparecen programas de construcción de vivienda o de regeneración urbana, estas tasas se alteran de acuerdo a los programas. Veamos como:

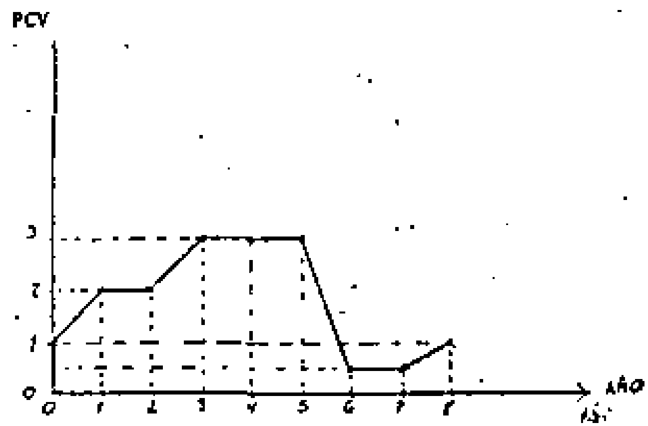


PCV = programa de construcción de vivienda

PRU = programa de regeneración urbana

Descripción del programa de construcción:

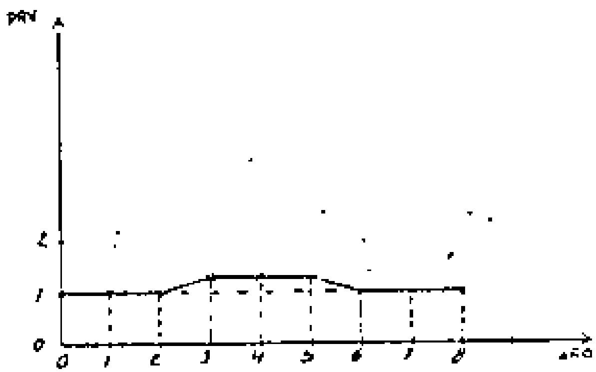
Año	Concepto	TCVM
0	No empieza	0.10
1	se construye el doble	0.20
2	se mantiene el doble	0.20
3	el triple de lo normal	0.30
4	el triple de lo normal	0.30
5	el triple de lo normal	0.30
6	disminuye a un 50% de lo normal	0.05
7	se mantiene igual	0.05
8	se recupera a valor normal	0.10



Programa de Regeneración Urbana:

Año	Concepto	DVM
0-2	Igual	.02
2-3	aumenta 20%	.024
3-5	se mantiene	.024
5-	vuelve a normal	.02

PRV



Los cálculos anteriores se ven modificados por los valores nuevos de TCV y DV debidos a los programas, calculemos estos valores:

t	TCV	DV	Valores Modificados		VC
			TCVM	DVM	
0	0.1	0.02	0.10	0.02	600.00
1	0.1	0.02	0.20	0.02	648.00
2	0.1	0.02	0.20	0.02	764.64
3	0.1	0.02	0.30	0.024	902.27
4	0.1	0.02	0.30	0.024	1151.28
5	0.1	0.02	0.30	0.024	1469.00
6	0.1	0.02	0.05	0.02	1874.50
7	0.1	0.02	0.05	0.02	1930.00
8	0.1	0.02	0.10	0.02	1988.60
9	0.1	0.02	0.10	0.02	2147.70
10	0.1	0.02	0.10	0.02	2310.50

Hemos reflejado el impacto de los programas en el total de la vivienda en el transcurso del tiempo.

Es posible desagregar aún más el modelo anterior descomponiendo los programas en más elementos; por ejemplo: De estudios socioeconómicos puede concluirse que es necesario crear programas, evaluando las condiciones del ámbito urbano como son: Las fuentes de trabajo, la demanda de vivienda, las comunicaciones, la densidad de ocupación del suelo, etc.

Estos elementos forman parte de mecanismos socio-urbanos que es indispensable distinguir y tipificar con objeto de poder decidir eficientemente las acciones necesarias dentro de un marco global y congruente.

P L A N E A C I O N   U R B A N A
M O D E L O   R E S I D E N C I A L

EN UNA ZONA GEOGRAFICA DONDE RESIDE UNA COMUNIDAD, LA DISPONIBILIDAD DE VIVIENDA ES EL FACTOR DETERMINANTE DEL CRECIMIENTO DE LA POBLACION, ADEMAS DE EL ATRACTIVO NATURAL QUE IMPLICA SU CLIMA E INSTALACIONES PARA RECREACION.

SE HA ENCONTRADO QUE LA VIVIENDA DESEADA ES PROPORCIONAL A LA POBLACION EXISTENTE Y QUE MIENTRAS LA VIVIENDA DESEADA SEA - IGUAL A LA VIVIENDA DISPONIBLE, LA GENTE LLEGA A LA COMUNIDAD.

SE HA ENCONTRADO QUE LAS CARACTERISTICAS DE LA COMUNIDAD ATRAEN A LA GENTE A UNA TASA ANUAL DEL 14.5% DE LA POBLACION RESIDENTE SIN EMBARGO ALGUNAS PERSONAS SE VAN A UNA TASA DEL 2 % ANUAL.

LA ABUNDANCIA DE VIVIENDA TIENDE A ATRAER A LA GENTE A UNA TASA MAYOR DEL 14,5 % Y A DISMINUIR EL 2 % DE SALIDAS. ESTO HACE QUE LOS PRECIOS DE COMPRA DE VIVIENDA Y RENTAS BAJEN, PUDIENDO LOS COMPRADORES TENER UN AMPLIO MARGEN DE SELECCION ASI COMO LOS ARRENDATARIOS OBLIGANDO A LOS FRACCIONADORES A REALIZAR PROMOCIONES ESPECIALES PARA LOGRAR VENTAS.

AL CAMBIAR ESTA SITUACION Y HABER CARENCIA DE VIVIENDA LA GENTE YA NO LLEGA A LA COMUNIDAD Y ALGUNOS RESIDENTES AL NO PODERSE - CAMBIAR DE CASA SE VAN DE LA COMUNIDAD.

LOS POSIBLES INMIGRANTES A LA COMUNIDAD PERCIBEN O DETECTAN LOS CAMBIOS EN DISPONIBILIDAD DE VIVIENDA EN 5 AÑOS DEBIDO A QUE NO EXISTE UN PROGRAMA DE PUBLICIDAD .

DEBIDO AL TIPO DE COMUNIDAD QUE CUENTA CON MUCHOS ANCIANOS HAY UNA TASA NETA DE DEFUNCIONES DEL 2.5 % ANUAL.

LA INDUSTRIA DE LA CONSTRUCCION RESPONDE TANTO A LA DISPONIBILIDAD DE SUELO URBANO COMO DE VIVIENDA, O SEA QUE LAS CONSTRUCCIONES NUEVAS CONTINUAN APARECIENDO AL HABER SUELO DISPONIBLE.

BAJO ESTAS CONDICIONES , LA TASA DE CONSTRUCCION ANUAL SERA DEL 12 % ANUAL DE LAS VIVIENDAS EXISTENTES PARA SATISFACER EL CRECIMIENTO NORMAL DE LA POBLACION.

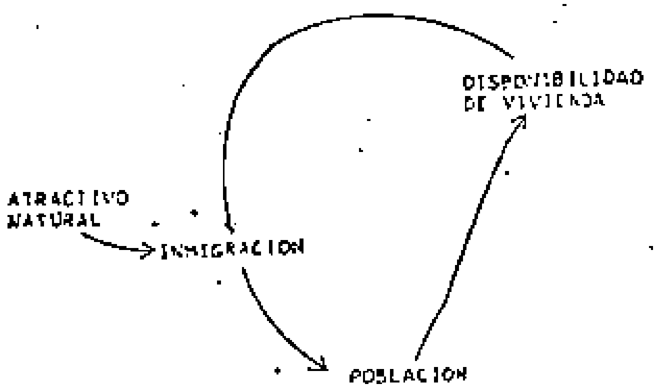
CUANDO EL MERCADO SE SATURA LOS CONSTRUCTORES DEJAN DE CONSTRUIR . CUANDO LA VIVIENDA ESCASEA ,LA TASA DE CONSTRUCCION AUMENTA PARA SATISFACER LA DEMANDA.

AL TERMINARSE EL SUELO DISPONIBLE PARA VIVIENDA LA CONSTRUCCION CESA. COMO LA VIDA PROMEDIO DE LA VIVIENDA SE SUPONE DE 50 AÑOS, LA TASA ANUAL DE DEMOLICION ES DEL 2 %.

La descripción anterior constituye lo que se conoce con el nombre de modelo anecdótico y que es el resultado del diagnóstico de la comunidad. Para lograrlo es necesario realizar estudios que nos determinen el comportamiento de la comunidad y nos permitan cuantificar los porcentajes de crecimiento y variacion de las principales variables que definen el proceso.

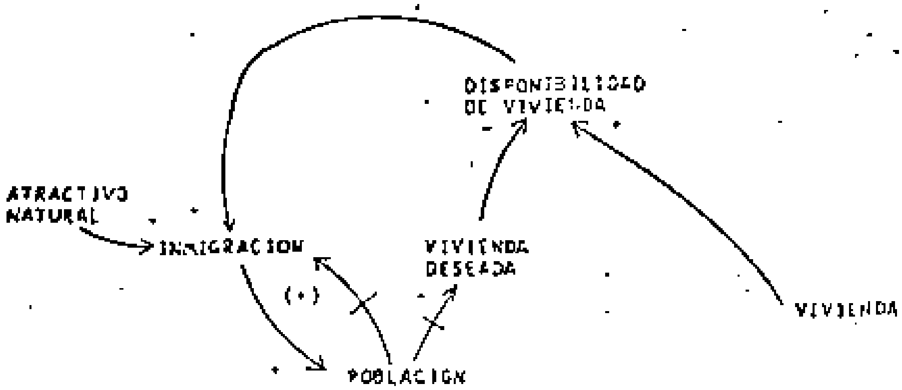
El siguiente paso consiste en construir un diagrama de causalidad que nos interrelacione las principales variables y sus dependencias lógicas.

DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.
1



LA DISPONIBILIDAD DE VIVIENDA ES EL PRINCIPAL FACTOR DETERMINANTE DEL CRECIMIENTO DE LA POBLACION

DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.
2



MIENTRAS LA DISPONIBILIDAD DE VIVIENDA IGUALE A LA VIVIENDA DESEADA, QUE ES PROPORCIONAL A LA POBLACION, LA GENTE LLEGA AL AREA.

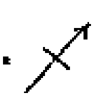
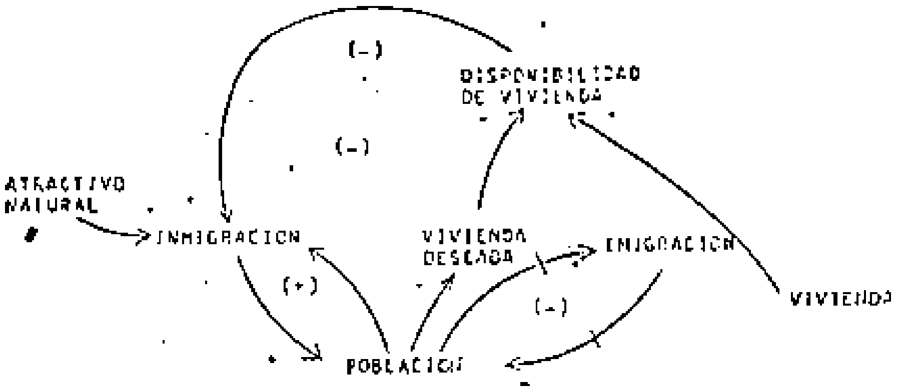
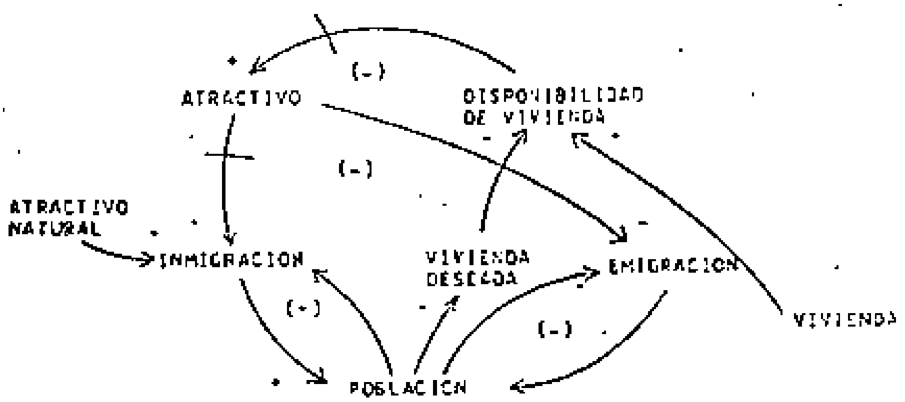
INCREMENTO AL DIAGRAMA: 

DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.



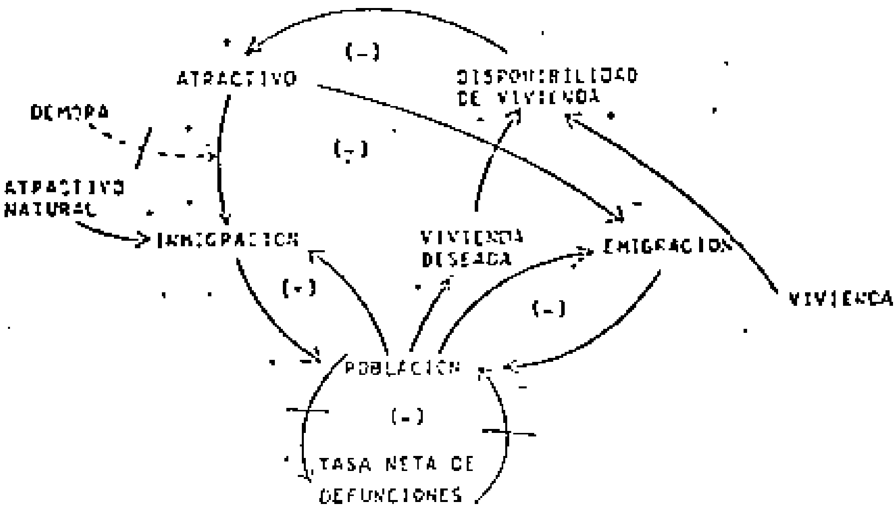
ALGUNOS RESIDENTES SALEN DE LA COMUNIDAD A UNA TASA DEL 2 % ANUAL.

DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.



LA ABUNDANCIA DE VIVIENDA TIENDE A ATRAER A LA GENTE A UNA TASA MAYOR DEL 14.5 % ANUAL Y A DISMINUIR LA SALIDA DEL 2 %.
ESTO TIENDE A QUE LOS PRECIOS DE COMPRA Y LAS RENTAS BAJEN APARECIENDO UNA ALTA SELECTIVIDAD PARA EL COMPRADOR O INQUILINO, LO QUE OBLIGA A LOS FRACCIONADORES A REALIZAR PROMOCIONES PARA PODER VENDER.

DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.
5



EL CAMBIO EN DISPONIBILIDAD DE VIVIENDA ES PERCIBIDO POR LOS POSIBLES INMIGRANTES DESPUES DE UNA DEMORA DE 5 AÑOS , MIENTRAS TANTO LA POBLACION EXPERIMENTA UNA TASA NETA DE DEFUNCIONES DEL 2.5 % ANUAL DEBIDO AL CARACTER DE VEJEZ DE LA POBLACION.

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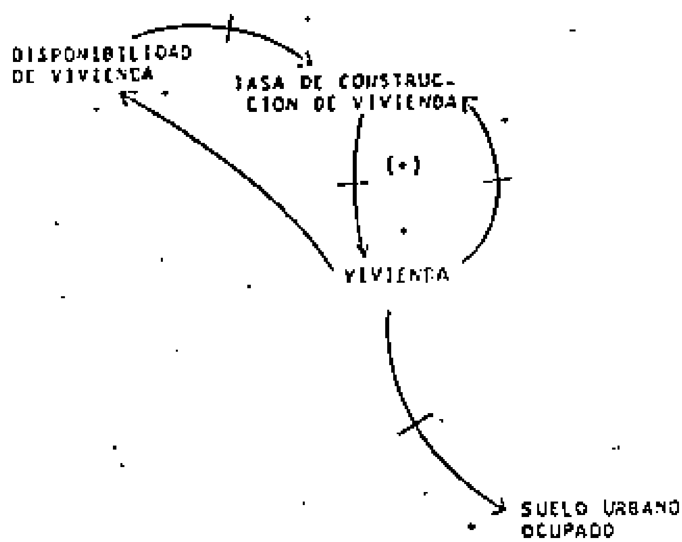
DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.
6



LA INDUSTRIA DE LA CONSTRUCCION RESPONDE TANTO A LA DISPONIBILIDAD DE SUELO URBANO OCUPADO COMO DE VIVIENDA EN LA ZONA.

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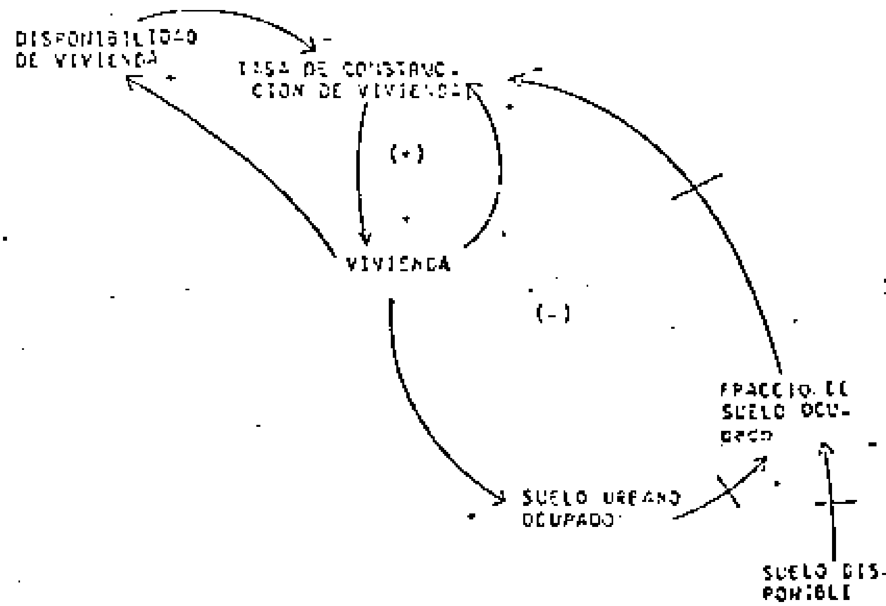
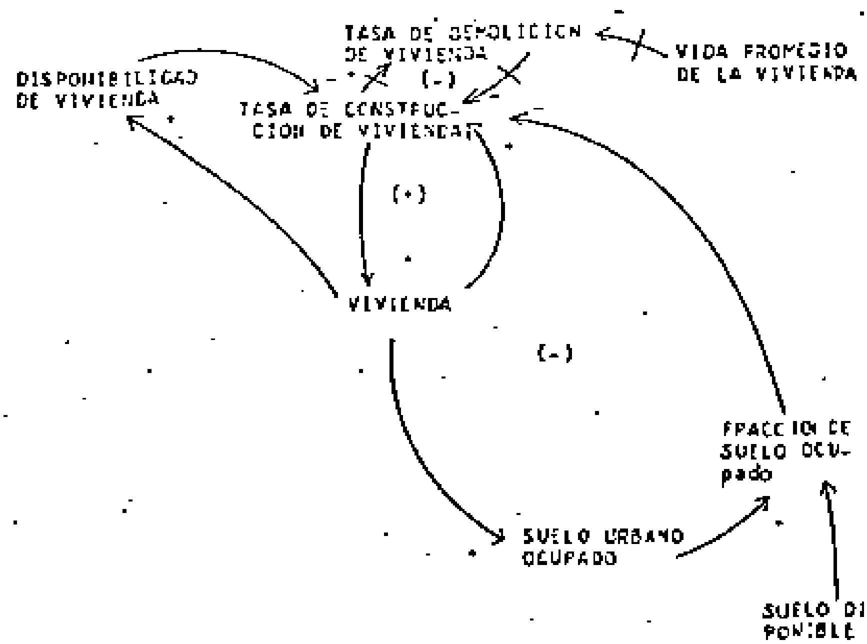
7 DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.



- CUANDO HAY VIVIENDA SIN VENDER NI RENTAR LOS CONSTRUCTORES DEJAN DE CONSTRUIR.
CUANDO EL MERCADO DE VIVIENDA SE VUELVE CRITICO , LA TASA DE CONSTRUCCION AUMENTA PARA SATISFACER LA DEMANDA.
AL TERMINARSE EL SUELO DISPONIBLE PARA VIVIENDA LA CONSTRUCCION CESA.

DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.
8



PUESTO QUE LA VIDA PROMEDIO DE LA VIVIENDA ES DE APROXIMADAMENTE 50 AÑOS LA TASA ANUAL DE DEMOLICION ES DE 2 %.

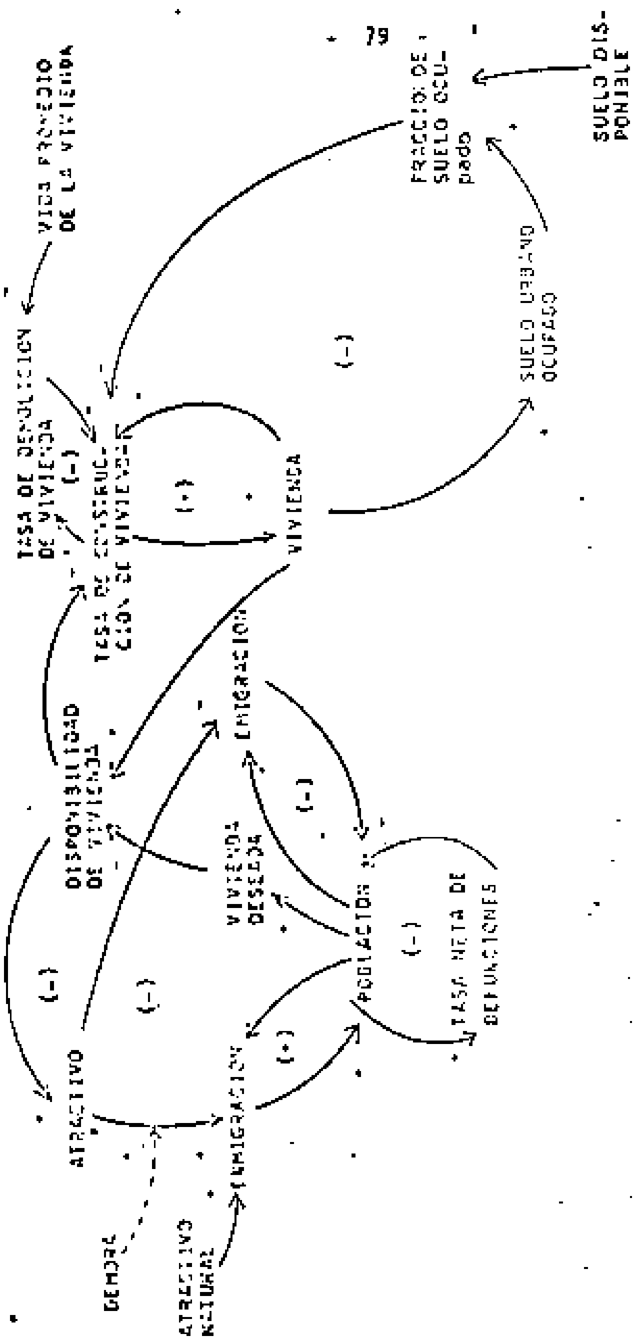


DIAGRAMA CAUSAL DEL MODELO RESIDENCIAL ORIGINAL.

DIAGRAMA CAUSAL INTEGRADO

HASTA ESTE MOMENTO HEMOS DESCRITO LA CAUSALIDAD DE LA COMUNIDAD.

VEAMOS COMO ES POSIBLE SIMULAR EL DESARROLLO DE LA COMUNIDAD, - USANDO LOS DATOS MENCIONADOS ANTES:

USAREMOS UNA ANALOGIA CON LAS REDES DE FLUJO NATURALES, COMO SON LOS RIOS, LAS ARTERIAS, ETC.

IDENTIFICAMOS COMO FLUJOS A LAS SIGUIENTES VARIABLES:

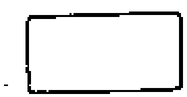
La inmigración y la emigración, las defunciones, la construcción, la demolición de vivienda.

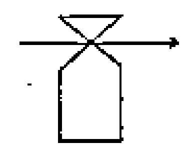
ESTOS FLUJOS SE PUEDEN CUANTIFICAR SI SON VERTIDOS EN UN RECIPIENTE QUE LLAMAREMOS NIVEL. ESTE NIVEL NOS PERMITIRA DETERMINAR LAS CANTIDADES DE FLUJOS QUE HA HABIDO DURANTE EL PERIODO DE ESTUDIO.

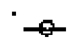
PODEMOS IDENTIFICAR COMO NIVELES A:
La población en un año determinado, el número de viviendas.

PARA ESTABLECER UN DIAGRAMA QUE NOS PERMITA RAPIDAMENTE ESTABLECER EL SISTEMA COMUNIDAD PLANTEADO ANTES USAREMOS LA SIGUIENTE NOMENCLATURA:

FLUJO DE PERSONAS O VIVIENDAS 

NIVEL 

TASA QUE CONTROLA EL FLUJO SEGUN SU VALOR NORMAL Y ALGUN OTRO U OTROS ELEMENTOS. 

PARAMETRO O VALOR NORMAL DE LA TASA 

FLUJO DE INFORMACION 

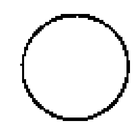
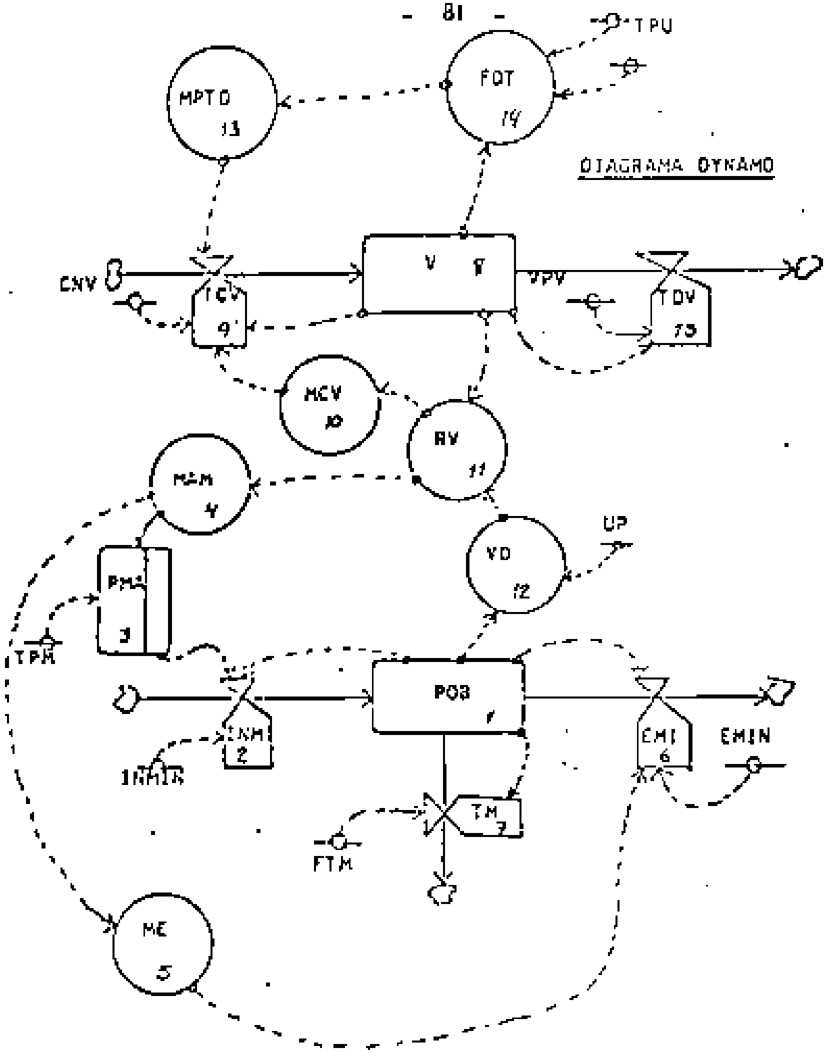
VARIABLE O RELACION AUXILIAR. 

DIAGRAMA DYNAMO



MPTD=Multiplicador por tierra disponible
FOT=Fracción ocupada de tierra ,T=Tot. de suelo,TPU=suelo por viv.
CNV=Const. norm de viv.,TCV=Tasa de const.,TDV=Tasa demolición.
VPV=Vida prom. de vivienda,MCV=Multiplic de const.,RV=Rel de viv.
MAM=Multiplic por atractivo,VD=Viv. deseada,PMA=Tiempo para percep.
de migrantes probables.TPM=Tiempo para percibir la migr.
INMI=Tasa de inmigr.,EMI=Tasa de emigr. TM=Tasa neta de defunciones
ME=Multiplic de emigr.,FTM=valor normal de TM,INMIN=Valor norm de
INMI,EMIN=Valor norm de EMI. UP=Viv. por persona.POB=Población.

DESCRIPCION DEL DIAGRAMA:

EXISTEN DOS LINEAS DE FLUJO PRINCIPAL,LA DE VIVIENDA Y LA DE POBLACION.

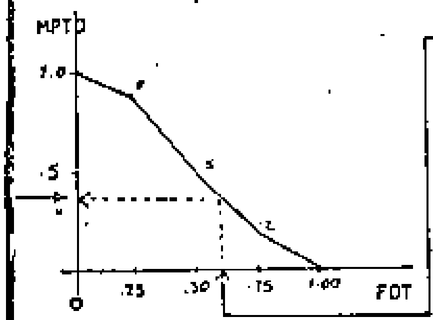
EL NIVEL DE POBLACION POB ES ALIMENTADO POR LA TASA INMI QUE TIENE UN VALOR NORMAL INMIN . POB SE VE DISMINUIDO POR LAS TASAS DE EMIGRACION EMI CON VALOR NORMAL EMIN Y LA TASA NETA DE DEFUNCIONES TM CON VALOR NORMAL FTM.

EL NIVEL DE VIVIENDA SE ALIMENTA CON LA TASA DE CONSTRUCCION TCV CON VALOR NORMAL CNV Y DISMINUYE POR LA TASA DE DEMOLICION TDV CON VALOR NORMAL DADO EN FUNCION DE LA DURACION DE LA VIVIENDA VPV.
TODAS LAS DEMAS AUXILIARES SIRVEN PARA CONTROLAR LOS VALORES DE LAS TASAS,SALVO LA DEMORA PMA QUE ENTRETIENE EL FLUJO 5 AÑOS PARA SIMULAR LA PERCEPCION DEL ATRACTIVO DE LA POBLACION POR LOS POSIBLES INMIGRANTES.

DESCRIPCION DE LAS AUXILIARES:

FOT: RECIBE INFORMACION DEL NUMERO DE VIVIENDAS EXISTENTES EN UN INSTANTE DADO O SEA V,USANDO LOS PARAMETROS T Y TPU QUE SON LA TIERRA DISPONIBLE PARA VIVIENDA Y LA TIERRA PROMEDIO POR UNIDAD DE VIVIENDA PARA CALCULAR LA FRACCION DE TIERRA O SUELO OCUPADO POR LAS VIVIENDAS EXISTENTES,ADEMAS ENVIA UNA SEÑAL DE INFORMACION A MPTD.

MPTD : USA LA INFORMACION DE LA CANTIDAD DE SUELO OCUPADO PARA AFECTAR LA TASA DE CONSTRUCCION DE VIVIENDA TCV SEGUN UNA REGLA QUE HAYAMOS DETERMINADO PREVIAMENTE,ESTA REGLA QUEDA EXPRESADA MEDIANTE UNA TABLA COMO SIGUE:

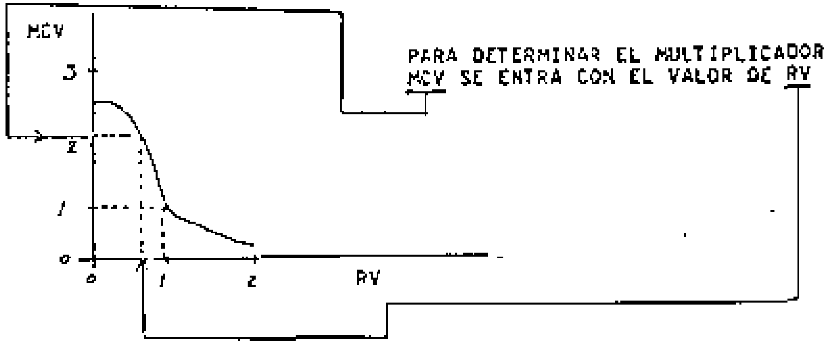


SEGUN EL VALOR DE FOT SE REFIERE UNO A LA GRAFICA Y SE DETERMINA EL VALOR DE MPTD

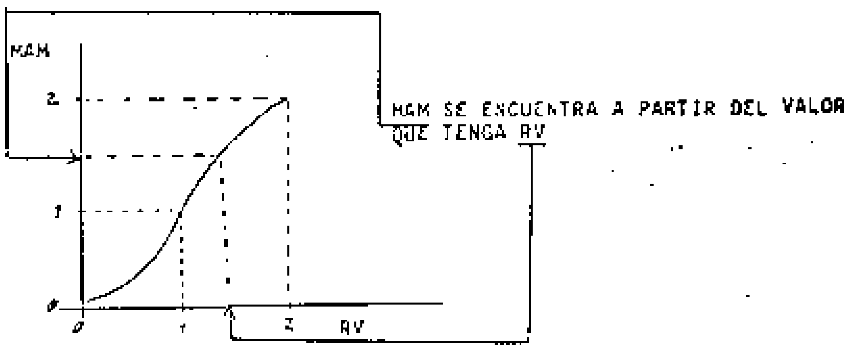
VD: RECIBE INFORMACION DEL TAMAÑO DE LA POBLACION POB EN UN INSTANTE DADO Y LA TRANSFORMA EN NUMERO DE VIVIENDAS DESEADAS POR LA POBLACION USANDO EL PARAMETRO UP QUE ES EL PROMEDIO DE HABITANTES POR VIVIENDA.

RV: RECIBE INFORMACION DE VD O SEA LA DEMANDA DE VIVIENDAS Y DE V O SEA LA OFERTA DE VIVIENDA, ESTABLECIENDO LA RELACION V/VD O SEA LA RELACION OFERTA ENTRE DEMANDA DE VIVIENDA. ESTA RELACION LE ENVIA INFORMACION AL MULTIPLICADOR DE CONSTRUCCION MCV Y AL MULTIPLICADOR DE INMIGRACION POR ATRACTIVO DE VIVIENDA MAM.

MCV: MODIFICA LA TASA DE CONSTRUCCION DE VIVIENDA JUNTO CON HPTO SEGUN SEA EL VALOR DE RV DE ACUERDO A LA SIGUIENTE GRAFICA PROPUESTA:



MAM: TAMBIEN RECIBE INFORMACION DE RV Y SEGUN SU VALOR DETERMINA CUANTO DEBE VALER MAM O SEA EL MULTIPLICADOR DE INMIGRACION POR ATRACTIVO, SEGUN LA SIGUIENTE GRAFICA;



NOTA. LAS CURVAS EN LAS GRAFICAS DEBERAN DETERMINARSE EN CADA CASO MEDIANTE ALGUNA TECNICA DE MEDICION, O SIMPLEMENTE USAR LAS QUE CREAMOS SON CONVENIENTES, VERIFICANDO POSTERIORMENTE SU ELECCION.

ME: ES EL MULTIPLICADOR POR EMIGRACION QUE SE DETERMINA USANDO EL SIGUIENTE POSTULADO: " LAS MISMAS CONDICIONES DE VIVIENDA QUE INDUCEN A LA GENTE A LLEGAR AL AREA EVITAN QUE LA GENTE SE VAYA" POR LO QUE:

$$ME = 1/MAM$$

PMA : ES UN MECANISMO DE DEMORA QUE SE APLICA PARA SIMULAR QUE LA GENTE PERCIBE EL ATRACTIVO DE LA ZONA DESPUES DE 5 AÑOS.

E C U A C I O N E S.

LAS ECUACIONES QUE SE USAN PARA REALIZAR LA SIMULACION DE FLUJOS USAN COMO INDICE DE TIEMPO PRESENTE A LA LETRA "K", TIEMPO PASADO LA LETRA "J" Y FUTURO LETRA "L", ESTO UNICAMENTE PARA LOS NIVELES. LAS TASAS USAN DOS LETRAS "JK" DEL LADO DERECHO DE LA ECUACION Y KL DEL LADO IZQUIERDO, SE SUPONE QUE "KL" ES LA TASA PARA APLICARLA EN EL PROXIMO PERIODO Y QUE SE CALCULA EN ESTE PERIODO "K".

EL TIEMPO TRANSCURRIDO ENTRE CALCULOS SE DESIGNA POR LAS LETRAS "DT" Y SE USA PARA CUANTIFICAR EL VALOR QUE ARROJA LA TASA AL ACTUAR DURANTE ESTE TIEMPO "DT".

AL INTRODUCIR LAS ECUACIONES EN LA COMPUTADORA USANDO EL PAQUETE "DYNAMO" ESTA HACE QUE EL TIEMPO BRINQUE DE "DT" EN "DT".

"DYNAMO" ACTUA DE LA SIGUIENTE MANERA:

1. SE INTRODUCEN LAS ECUACIONES POR TARJETAS, TERMINAL, CINTA, DISCO, ETC.
2. "DYNAMO" REVISA LAS ECUACIONES CHECANDO LA SINTAXIS SI SON CORRECTAS PROSIGUE SINO MANDA UN MENSAJE Y SE DETIENE.
3. "DYNAMO" REALIZA UN PROGRAMA FUENTE EN ALGUN LENGUAJE, LO COMPILA Y LO EJECUTA, ARROJANDO LOS RESULTADOS AUTOMATICAMENTE, EN FORMA DE TABLAS Y GRAFICAS SEGUN DESEOS DEL USUARIO.
4. UNA VEZ QUE SE HA LOGRADO SIMULAR EL PROBLEMA, SE PUEDEN PROBAR DIVERSAS POLITICAS CON EL MODELO PARA EXAMINAR SU COMPORTAMIENTO. ESTO HACE QUE EL MODELO MATEMATICO SE CONVIERTA EN UNA VERDADERA MAQUETA EXPERIMENTAL CUYOS USOS SON MULTIPLES, MEDICION DE IMPACTO URBANO, PRONOSTICOS DE POBLACION, DETERMINACION DE CORRIENTES MIGRATORIAS, MEDICION DE ATRACTIVO, ANALISIS REGIONAL ANALISIS URBANO, MEDICION DE UMBRALES, DISEÑO DE PLANES MAESTROS, ETC, ETC.

A continuación veremos la lista de variables usadas y sus nombres, así como las ecuaciones correspondientes:

Nombre de las variables usadas:

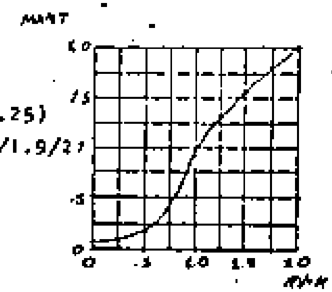
MPTD	=	Multiplicador por tierra disponible
FOT	=	Fracción de tierra ocupada
T	=	Tierra (suelo)
TPU	=	Tierra por unidad
CNV	=	Construcción normal de vivienda
TCV	=	Tasa de construcción de vivienda
MCV	=	Multiplicador de construcción de vivienda
VPV	=	Vida promedio de la vivienda
TDV	=	Tasa de demolición de vivienda
V	=	Vivienda
RV	=	Relación de vivienda
MAM	=	Multiplicador por atractivo por migración
PMA	=	Percepción del atractivo por migración
TPM	=	Tiempo de percepción de migración
INMI	=	Inmigración normal
EMIN	=	Emigración normal
POB	=	Población
ME	=	Multiplicador por emigración
FTM	=	Factor de tasa de defunciones
TM	=	Tasa de defunciones
VD	=	Vivienda deseada
UP	=	Unidades por persona

ECUACIONES.

1. POB.K=POB.J+(DT)(INMI.JK-EMI.JK-TM.JK)
Personas=Personas +(año)(Personas/año-Personas/año-
Personas/año)
POB=30.3 PERSONAS (VALOR INICIAL)

2. INMI.KL=(INMIN)(PMA.K)(POB.K)
Personas/año=(fracción/año)(adimensional)(Personas)
Personas año=Personas/año
INMIN=0.145 /año

3. PMA.KL=DELAY(MAM.K,TPM)
Adimensional=Adimensional
TPM=5 años



4. MAM.K=TABLE(MAMT,RV.K,0,2,0.25)
MAMT*=0.05/.1/.2/.4/1/1.6/1.8/1.9/2

5. ME.K=1/MAM.K
Adimensional=Adimensional

6. EMI.KL=(EMIN)(ME.K)(POB.K)
Personas/año=(fracción/año)(adimensional)(personas)
Personas/año=Personas/año
EMIN=0.07 / año
Fracció/año=Fracción/año

7. TM.KL=(POB.K)(FTM)
Personas/año=(personas)(fracción/año)
Personas/año=Personas/año
FTM=0.025 /año
Fracció/año=Fracción/año

8. V.K=V.J+(DT)(TCV.JK-TDV.JK)
Unidades=Unidades+(años)(unidades/año-unidades/año)

Unidades=Unidades

V=10 unidades

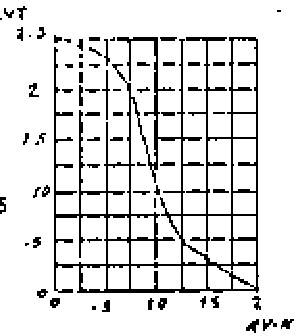
9. TCV.KL=(CNV)(MCV.K)(MPTD.K)(V.K)

Unidades/año=(fracción/año)(adimensional)(adimensional)

(Unidades)

Unidades/año=Unidades/año

CNV=0.12 /año



10. MCV.K=TABLE(MCVT,RV.K,0,2,.25)

MCVT*=2.5/2.4/2.3/2/1/.37/.2/.1/.05

11. RV.K=V.K/VD.K

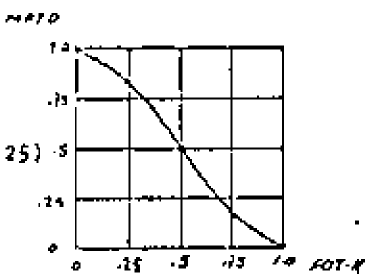
Adimensional=Unidades/Unidades

12. VD.K=(POB.K)(UP)

Unidades=(Personas)(Unidades/Persona)

Unidades=Unidaes

UP=0.33 Unidades/Persona



13. MPTD.K=TABLE(MPTDT,FOT.K,0,1,.25)

MPTDT*=1/.8/.5/.2/0

14. FOT.K=(V.K)(TPU/T)

Adimensional=(Unidades)(Ha/Unidades/Ha)

Adimensional=Adimensional

TPU =1 Ha/Unidad

Ha/Unidad=Ha/Unidad

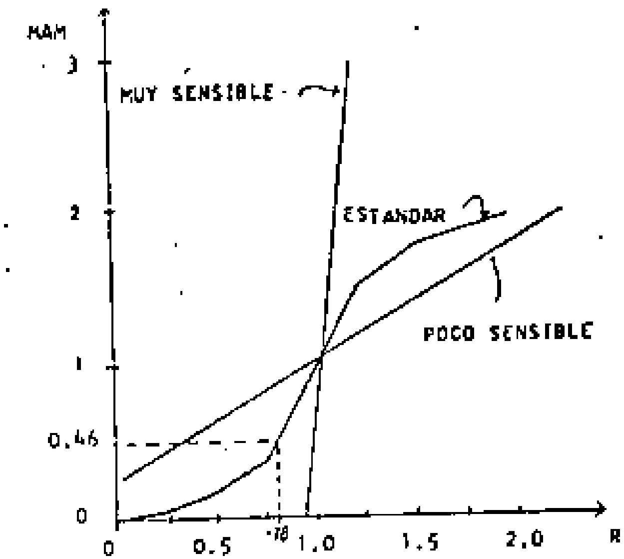
T=1500

15. TDV.KL=V.K/VPV

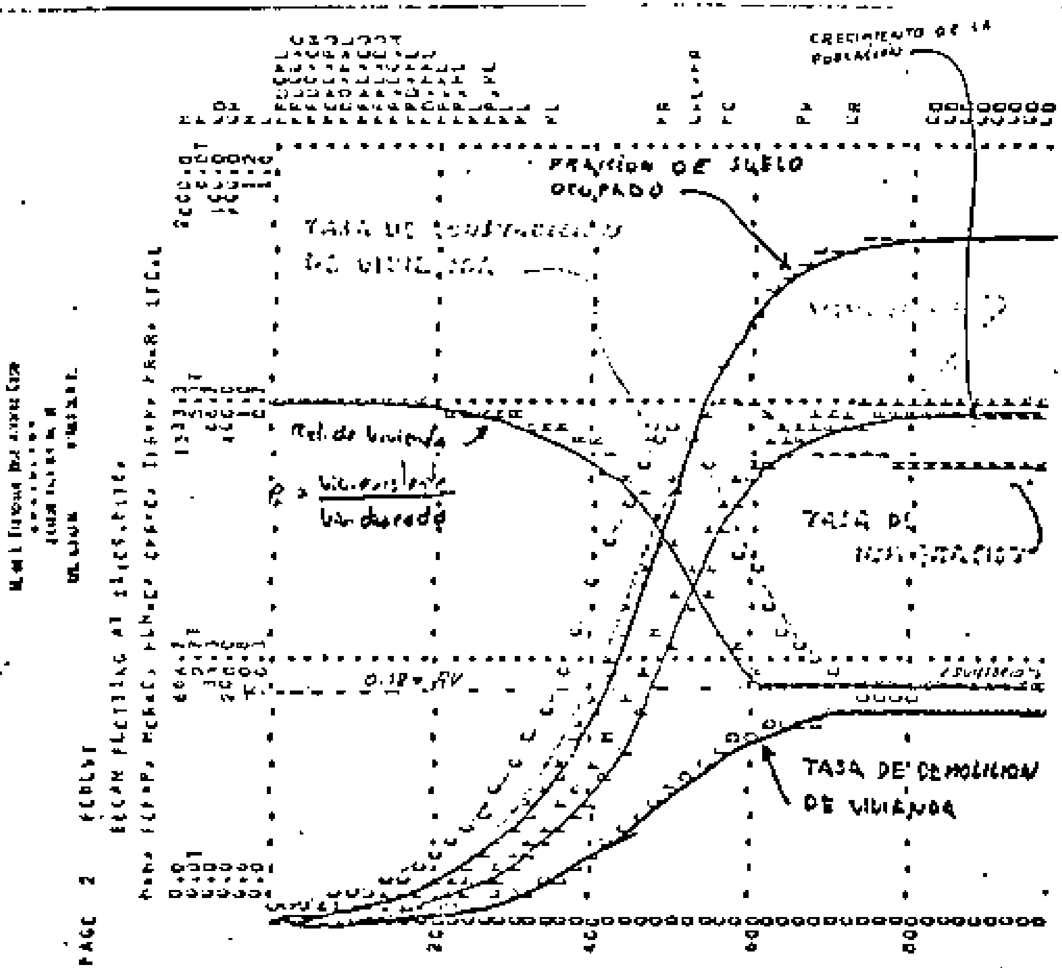
Unidades/año=Unidades/año

VPV=50 años.

ANALISIS DE SENSIBILIDAD:



Para que haya equilibrio, el atractivo deberá valer 0.46 La curva de poco sensible supondría que la disponibilidad de vivienda casi no afecta la inmigración, en este caso la RV sería menor, o sea, 0.30 .



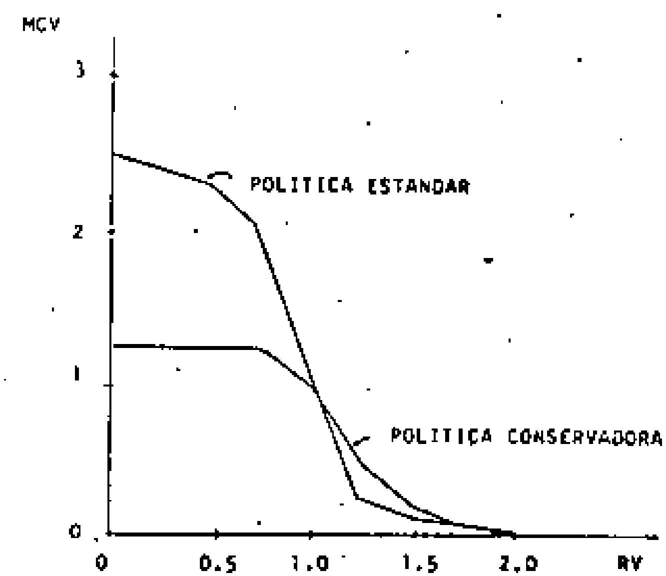
La recta de la figura anterior muy sensible el equilibrio se dá en 0.9. La forma de la función después del punto de definición no afecta el equilibrio del valor dado por RV.

CORRIDA NUMERO DOS.

La construcción normal de vivienda CNV, la cambiamos de 12% al año a 24% al año, esto implica una política especulativa de construcción muy optimista.

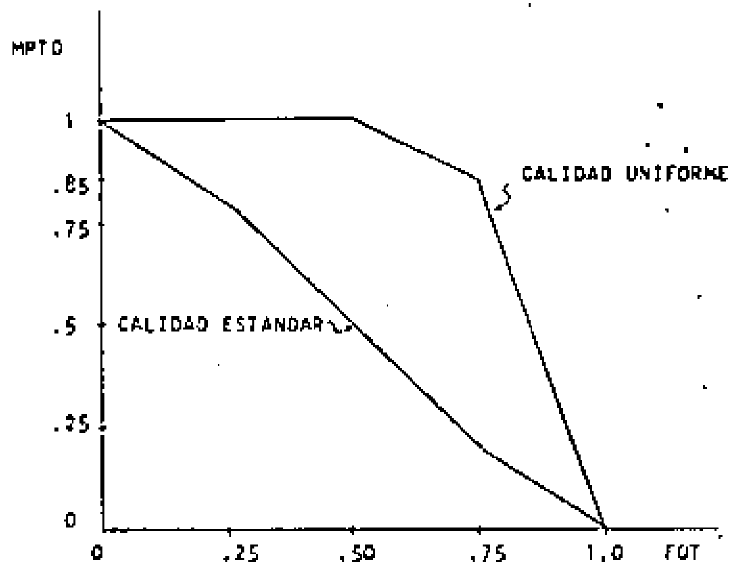
CORRIDA NUMERO TRES.

Para probar el efecto de una tabla conservadora de la variable MCV (multiplicador de construcción de vivienda, cambiamos la tasa original por la siguiente:



CORRIDA NUMERO CUATRO.

Supongamos ahora como última prueba que la tierra tiene una calidad uniforme, o sea que la construcción se detiene sólo cuando escasea la tierra.



MODELO RESIDENCIAL MODIFICADO.

Vamos a realizar una modificación al modelo residencial anterior consistente en agregar las siguientes variables:

C	=	Comida
GC	=	Generación de comida
CPH	=	Comida por habitante
PC	=	Proporción de comida
CCPH	=	Consumo de comida por habitante
CRT	=	Tiempo de regeneración de comida
CCAP	=	Capacidad de comida

Además usaremos algunas variables auxiliares y dejaremos al usuario la interpretación de las siguientes ecuaciones:

```
CPH.K=C.K/POB.K

C.K=C.J+(DT)(GC.JK-CC.JK)

GC.KL=(CCAP-C.K)/CRT.K

CV.K=C.K/CCAP

CRT.K=TABLE(CRTT,CV.K,0,1.5,.25)
CRTT*=1/2/3/8/20

CC.KL=(POB.K)(CCPH.K)

CCPH.K=TABLE(CCPHT,PC.K,0,1.5,0.25)
CCPHT*=0/.25/.5/.75/1/1.12/1.2
```

Con estos nuevos valores realizamos la siguiente corrida.

MODELO RESIDENCIAL MODIFICADO

ANALISIS DE SENSIBILIDAD:

1. En esta corrida, el análisis de sensibilidad nos muestra que en la actualidad la población de un período de cien años presenta un monto de 5349 habitantes, con una producción alimenticia de 3410 unidades de comida. La tendencia de la gráfica nos muestra que para la población existente el número de miembros por familia es de 4 personas, el consumo per cápita es de 0.84 fracción de unidades diarias, con una producción alimenticia superior a las necesidades en los primeros 30 años y con una estabilización en la vivienda a partir de los 50 años.

2. Tenemos que si aumentamos la tasa de crecimiento de construcción normal de vivienda, se produce una disminución de vivienda muy moderada, lo que obliga a que el crecimiento de la población sea también moderado, mientras que el consumo per cápita supera al normal durante los primeros 50 años, estabilizándolo a partir de este año, mientras que la vivienda se estabiliza después de los 60 años.

3. Por otra parte tenemos que acelerando la construcción de vivienda en los primeros años, haciendo variar el multiplicador de construcción de vivienda en la forma expresada, nos encontramos que la población se estabiliza durante los primeros 25 años, debido a que dicha estabilización llegó muy rápido, el consumo per cápita existente será también superior durante los primeros 20 años.

4. De manera inversa, manteniendo casi constante el multiplicador de tierra disponible, la población crecerá muy poco y por lo tanto la comida existente en el lapso de 100 años mantendrá un nivel superior al normal, con un decrecimiento pequeño producto del poco crecimiento existente en la población, la vivienda crecerá muy poco como una consecuencia de la población.

5. Durante los primeros 25 años, el consumo per cápita existente será superior durante ese lapso de tiempo, sucediendo lo mismo con la población y la vivienda, la cual a partir de ese momento tenderá a estabilizarse como consecuencia de los cambios tecnológicos existentes.

6. Estableciendo un consumo per cápita elevado en los primeros 20 años, obliga a una baja grave del mismo, después de dichos 20 años, posterior a ese lapso, la vivienda y la población se afectan y presentan una ligera disminución de crecimiento.

[illegible]


```
PRINT [illegible]
PLOT  [illegible]
PLOT  [illegible]
SPEC  [illegible]
SPEC  [illegible]
SPEC  [illegible]
SPEC  [illegible]

RUN   [illegible]

INPUT PHASE FINISHED AT  [illegible]

GENERATION PHASE BEGAN AT [illegible] 17
RUN   PHASE  GENERATED  AT [illegible]
PRINT PHASE GENERATED  AT [illegible]
PLOT  PHASES GENERATED AT [illegible]

ELAPSED COMPILATION TIME  [illegible]

NO [illegible] TO ALGOL COMPILER ************************************************
```

PAGE 2 [illegible]

[illegible]

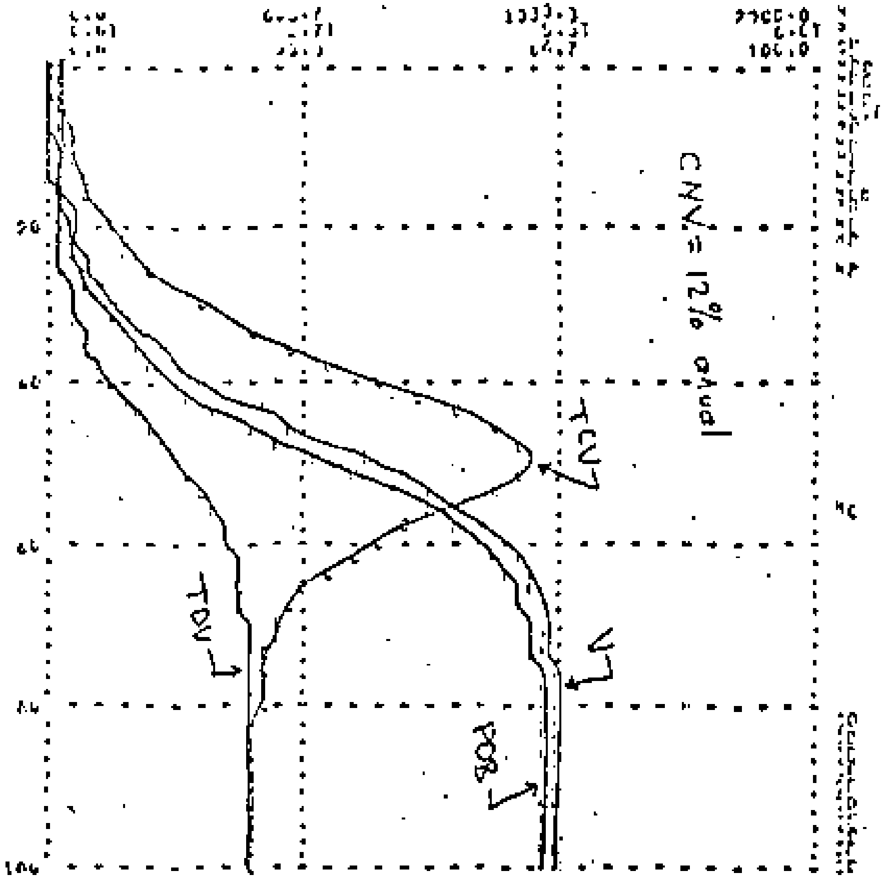
TIME	[illegible]	FCC	[illegible]	[illegible]	[illegible]	[illegible]	FV	FCT
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.66	1.60
0.00	16.6	36.3	1.193	[illegible]	6.41	4.35	1.0001	[illegible]
[illegible]	16.[illegible]	44.4	1.751	[illegible]	6.49	6.43	0.9965	[illegible]
8.00	25.[illegible]	64.9	2.594	[illegible]	1.36	9.16	0.9960	[illegible]
12.00	35.2	[illegible]	3.717	[illegible]	1.91	13.69	0.9576	[illegible]
16.00	[illegible]	132.6	5.059	[illegible]	2.79	15.97	0.9966	[illegible]
20.00	[illegible]	161.2	7.631	1.316	4.09	25.04	0.9949	[illegible]
24.00	9[illegible].5	276.6	11.165	1.926	5.99	[illegible]	0.9926	[illegible]
28.00	139.3	[illegible]	16.142	2.760	6.76	[illegible]	0.9892	[illegible]
32.00	200.5	[illegible]	22.446	4.005	[illegible].65	67.16	0.9841	[illegible]
36.00	2[illegible].1	[illegible]	31.794	[illegible]	[illegible]	126.16	0.9768	[illegible]
40.00	[illegible]	[illegible]	42.735	[illegible]	27.[illegible]	174.04	0.9[illegible]	[illegible]
44.00	[illegible]	[illegible]	53.422	11.[illegible]	[illegible]	236.[illegible]	0.9430	[illegible]
48.00	733.1	[illegible]	61.459	14.[illegible]	[illegible]	311.17	0.9077	[illegible]
52.00	944.5	[illegible]	61.959	[illegible]	[illegible]	373.47	0.8047	[illegible]
56.00	1077.4	[illegible]	52.470	[illegible]	135.76	[illegible]	0.8205	[illegible]
60.00	[illegible]	[illegible]	[illegible]	[illegible]	161.67	392.34	0.7900	[illegible]
64.00	[illegible]	[illegible]	39.511	[illegible]	192.[illegible]	366.97	0.7657	[illegible]
68.00	[illegible]	[illegible]	32.[illegible]	[illegible]	[illegible]	351.[illegible]	0.7662	[illegible]
72.00	1318.[illegible]	[illegible]	27.443	[illegible]	[illegible]	[illegible]	0.7[illegible]	[illegible]
76.00	[illegible]	[illegible]	27.[illegible]	[illegible]	[illegible]	361.75	0.7767	[illegible]
80.00	132[illegible]	5179.[illegible]	27.[illegible]	[illegible]	[illegible].77	354.71	0.7771	[illegible]
84.00	13[illegible]	51[illegible].7	27.[illegible]	24.417	[illegible]	[illegible]	0.7786	[illegible]
88.00	1335.7	[illegible]	25.659	26.555	220.35	351.50	0.7793	[illegible]
92.00	1335.4	5190.[illegible]	26.01[illegible]	26.0[illegible]	221.67	353.76	0.7785	[illegible]

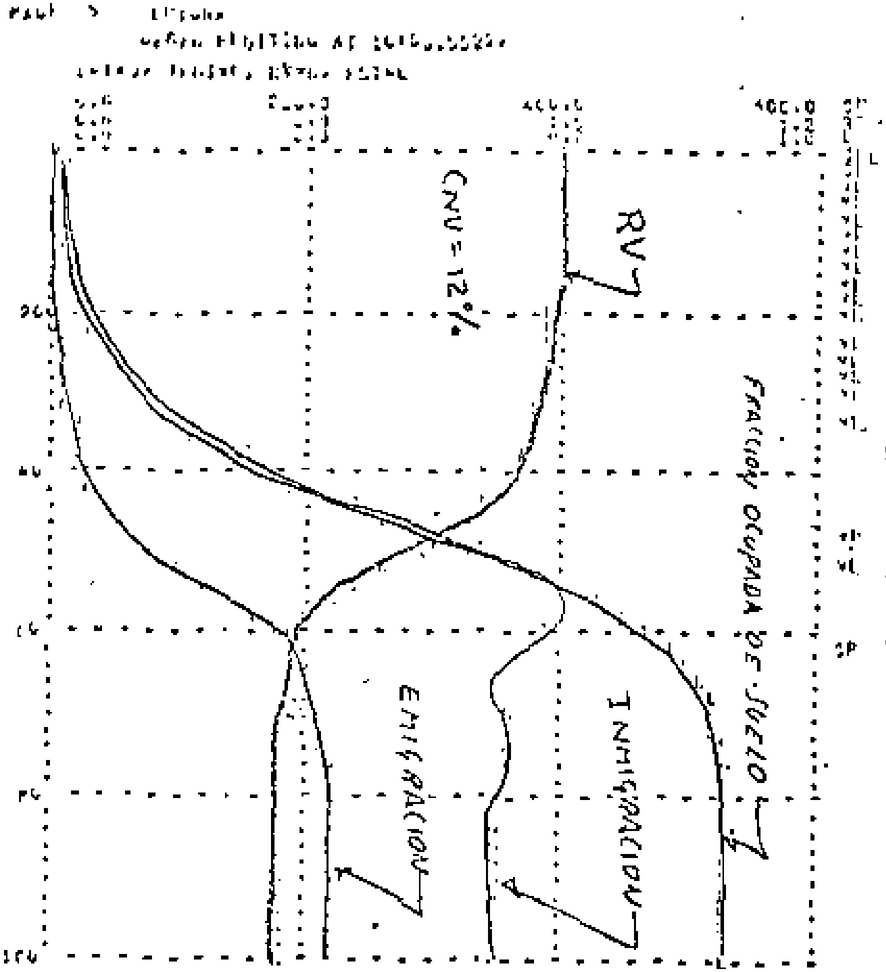
PAGE 3 [illegible]

TIME	Y	FCC	[illegible]	[illegible]	[illegible]	[illegible]	FV	FCT
96.00	133[illegible]	5197.5	25.779	26.579	222.72	353.12	0.7777	[illegible]
100.00	133[illegible]	5197.[illegible]	25.[illegible]	26.[illegible]	222.[illegible]	351.[illegible]	0.7779	[illegible]

PAGE [illegible]

[illegible]





PAGE 6 [illegible]

[illegible]

PAGE 7 [illegible]

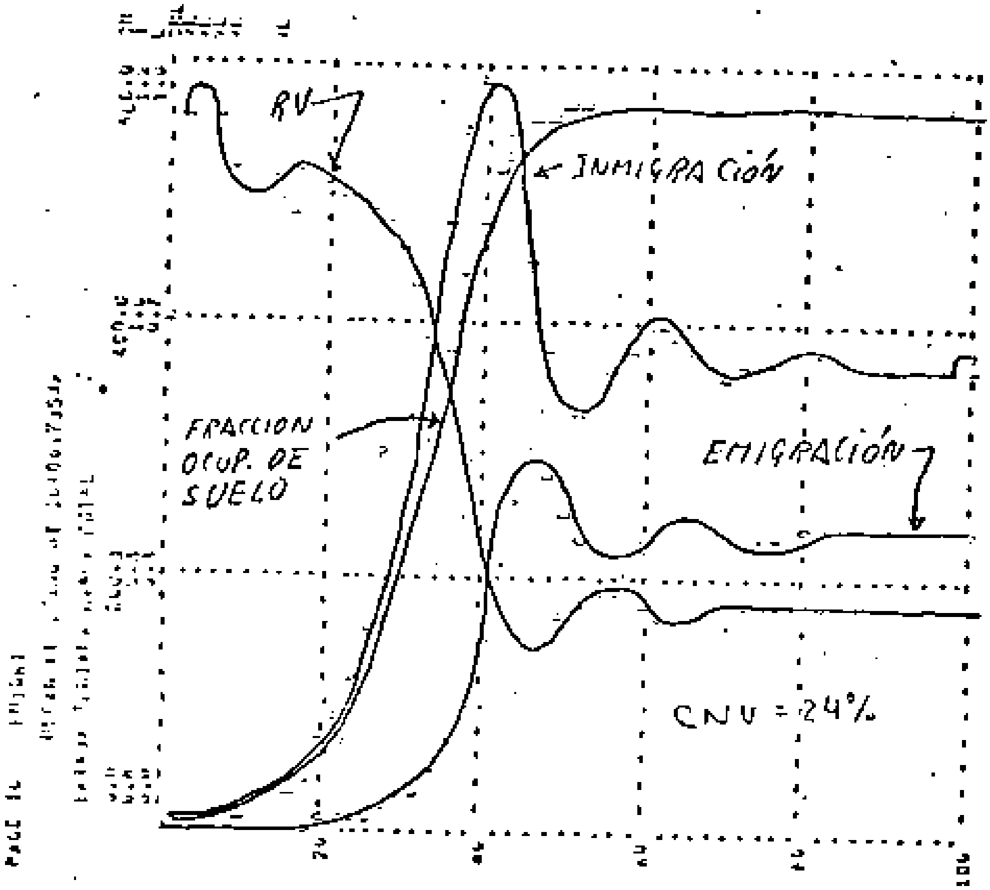
[illegible]

TIME	V	FLO	TVV	TIV	EEI	SEEI	CV	FCT
0.00	[illegible]	[illegible]	2.307	[illegible]	[illegible]	4.35	1.6001	[illegible]
4.00	[illegible]	[illegible]	2.50	[illegible]	[illegible]	[illegible]	1.1630	[illegible]
8.00	27.5	[illegible]	[illegible]	[illegible]	5.15	14.72	1.1224	[illegible]
12.00	[illegible]	[illegible]	4.506	[illegible]	2.16	25.71	1.1587	[illegible]
16.00	[illegible]	[illegible]	11.730	1.697	3.60	41.76	1.1161	[illegible]
20.00	[illegible]	[illegible]	20.25	[illegible]	[illegible]	71.90	1.1118	[illegible]
24.00	[illegible]	[illegible]	31.350	[illegible]	10.66	123.12	1.0554	[illegible]
28.00	403.3	[illegible]	60.513	[illegible]	19.15	263.45	1.0777	[illegible]
32.00	[illegible]	[illegible]	83.132	[illegible]	34.99	326.51	1.0316	[illegible]
36.00	957.6	5069.5	95.550	[illegible]	69.16	451.50	0.9458	[illegible]
40.00	1200.7	[illegible]	75.276	[illegible]	167.17	564.90	0.4325	[illegible]
44.00	1396.6	5460.9	45.665	27.795	263.63	529.76	0.7562	[illegible]
48.00	1413.9	5674.4	31.612	26.139	274.20	366.16	0.7534	[illegible]
52.00	1417.7	5626.7	27.930	26.35	229.44	326.16	0.7527	[illegible]
56.00	1414.5	5411.4	27.577	26.31	235.42	362.96	0.7927	[illegible]
60.00	1415.5	5470.1	25.739	26.41	232.33	392.56	0.7765	[illegible]
64.00	1417.4	5527.7	25.690	26.246	246.67	347.40	0.7714	[illegible]
68.00	1417.1	5565.3	26.263	26.341	241.21	367.90	0.7749	[illegible]
72.00	1417.4	5552.2	26.147	26.240	232.65	365.98	0.7606	[illegible]
76.00	1417.6	5564.0	26.325	23.357	232.44	374.46	0.7665	[illegible]
80.00	1417.0	5511.5	25.482	26.346	236.67	374.96	0.7776	[illegible]
84.00	1417.4	5529.7	25.364	26.347	234.29	375.92	0.7767	[illegible]
88.00	1417.4	5521.0	26.257	26.247	234.42	371.96	0.7779	[illegible]
92.00	1417.7	5514.4	26.212	26.344	235.12	371.99	0.7706	[illegible]

PAGE 8 [illegible]

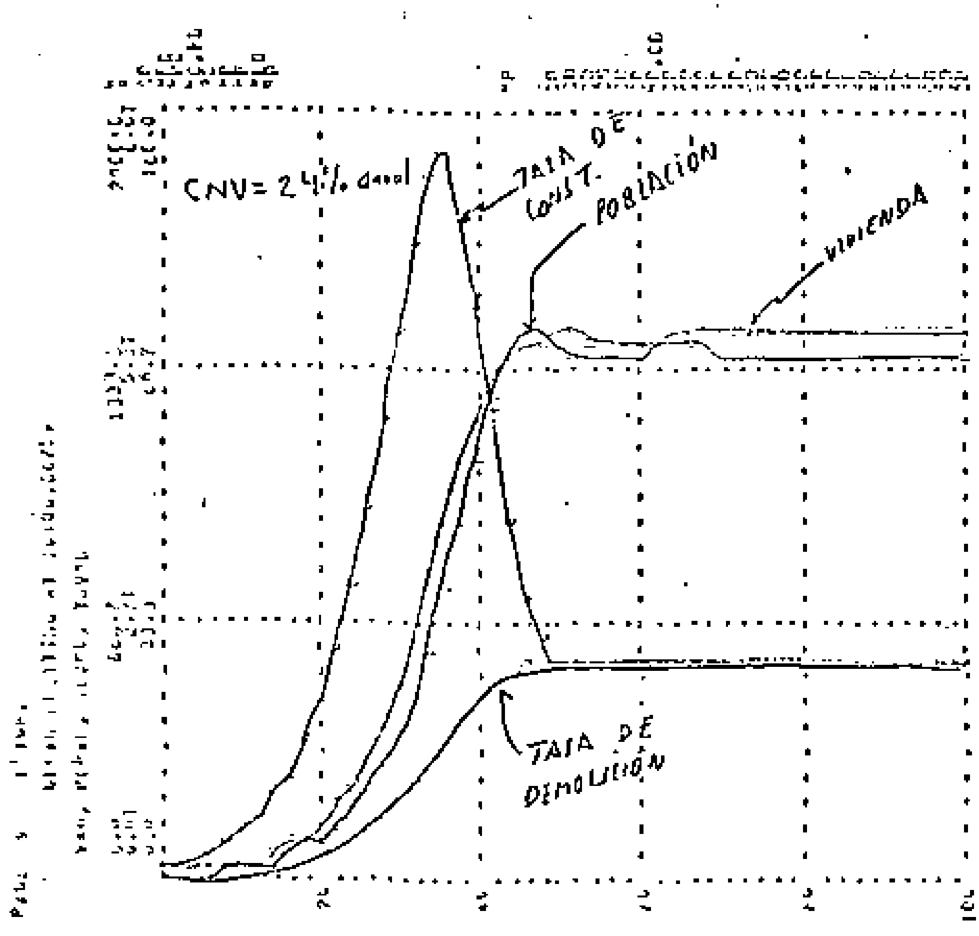
TIME	V	FLO	TVV	TIV	EEI	SEEI	CV	FCT
96.00	1417.1	5516.6	25.356	26.343	235.67	374.93	0.7764	[illegible]
100.00	1417.2	5520.0	26.264	26.344	234.51	374.97	0.7779	[illegible]

102



RV
INMIGRACIÓN
FRACCION OCUP. DE SUELO
EMIGRACIÓN
CNU = 24%

101



CNV= 24% anual
TASA DE CONST.
POBLACIÓN
VIVIENDA
TASA DE DEMOLICIÓN

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DYNAMO [illegible]

MODELO RESIDENCIAL

[illegible]

[illegible] VIVIENDA

[illegible] VIVIENDA

[illegible] MIGRACION

[illegible] MIGRACION

[illegible]

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[illegible]
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PLOT [illegible]
SPEC DT=1 [illegible]
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GENERATION PHASE BEGAN AT [illegible] 47

[illegible]

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AGE 2 [illegible]

STARTED PRINTING AT [illegible]

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0.00	10.0	20.3	[illegible]	[illegible]	0.61	4.39	1.0001	0.00667
4.00	14.6	44.3	[illegible]	[illegible]	0.89	6.43	0.9970	0.00974
8.00	21.3	64.9	2.500	0.427	1.31	9.37	0.9963	0.01422
12.00	31.1	94.6	[illegible]	0.622	1.91	13.61	0.9959	0.02073
16.00	45.2	137.8	5.325	0.905	2.79	19.79	0.9948	0.03016
20.00	65.6	200.4	7.660	1.312	4.09	28.72	0.9917	0.04373
24.00	94.8	293.8	10.933	1.895	6.00	41.41	0.9873	0.06317
28.00	136.1	419.9	15.415	2.721	8.78	59.19	0.9820	0.09071
32.00	193.7	602.1	21.366	3.873	12.82	83.80	0.9747	0.12910
36.00	272.3	855.7	28.920	5.445	18.73	117.68	0.9642	0.18151
40.00	376.4	1201.1	37.962	7.527	27.33	164.24	0.9496	0.25091
44.00	505.7	1655.4	45.338	10.114	46.29	214.05	0.9257	0.33714
48.00	650.8	2210.2	50.263	13.017	66.45	266.89	0.8891	0.43369
52.00	797.7	2837.2	50.756	15.953	86.02	310.60	0.8519	0.53177
56.00	924.0	3412.6	46.029	18.500	114.14	330.04	0.8291	0.61667
60.00	1029.6	3847.5	40.000	20.500	144.57	333.46	0.8063	0.66601
64.00	1099.7	4130.6	35.127	21.975	164.99	331.56	0.7949	0.73249
68.00	1143.4	4399.1	31.629	22.867	179.45	324.32	0.7876	0.76225
72.00	1174.5	4531.0	29.719	23.469	166.80	325.09	0.7855	0.78297
76.00	1196.3	4620.5	28.259	23.927	191.30	325.93	0.7846	0.79755
80.00	1211.5	4691.6	27.231	24.230	196.29	326.99	0.7825	0.80767
84.00	1222.0	4746.0	26.517	24.441	260.81	327.63	0.7803	0.81469
88.00	1229.3	4779.9	25.959	24.585	263.24	326.51	0.7793	0.81952
92.00	1234.2	4799.1	25.631	24.684	204.07	327.71	0.7793	0.82278

AGE 3 [illegible]

TIME	V	PGB	TCV	TDV	CHI	IGHI	RV	FGT
96.00	1237.5	4812.7	25.365	24.749	204.81	326.23	0.7792	0.82497
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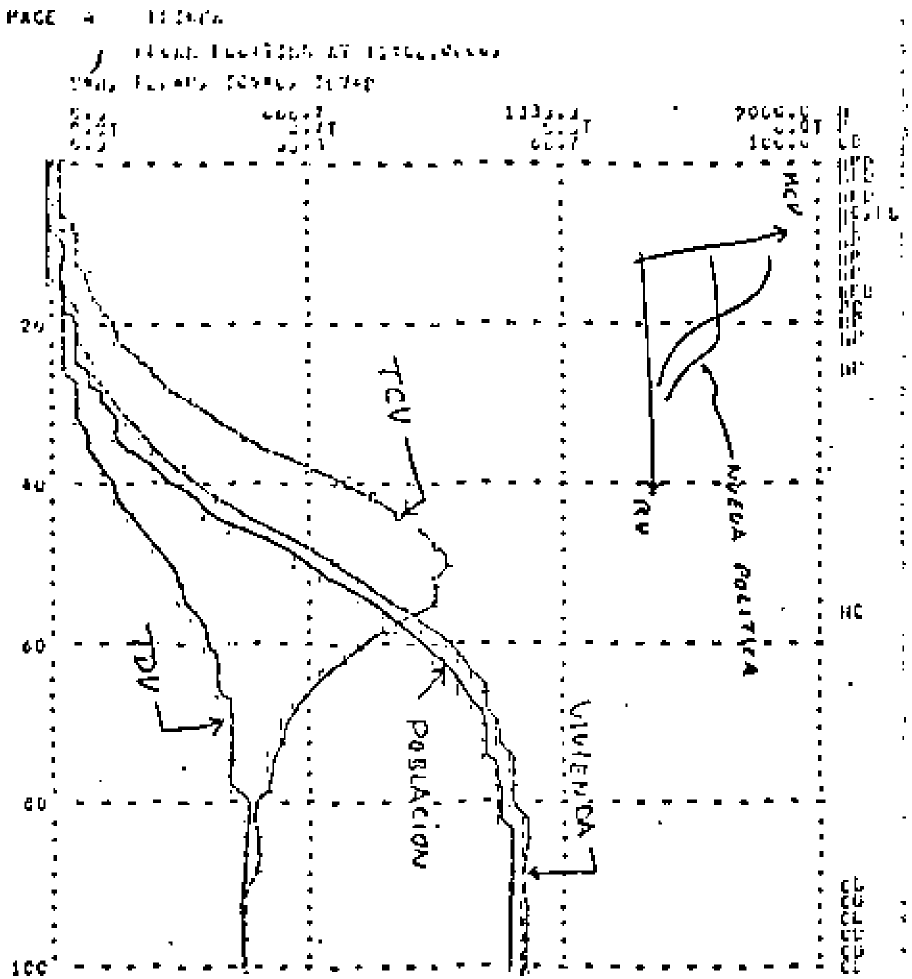
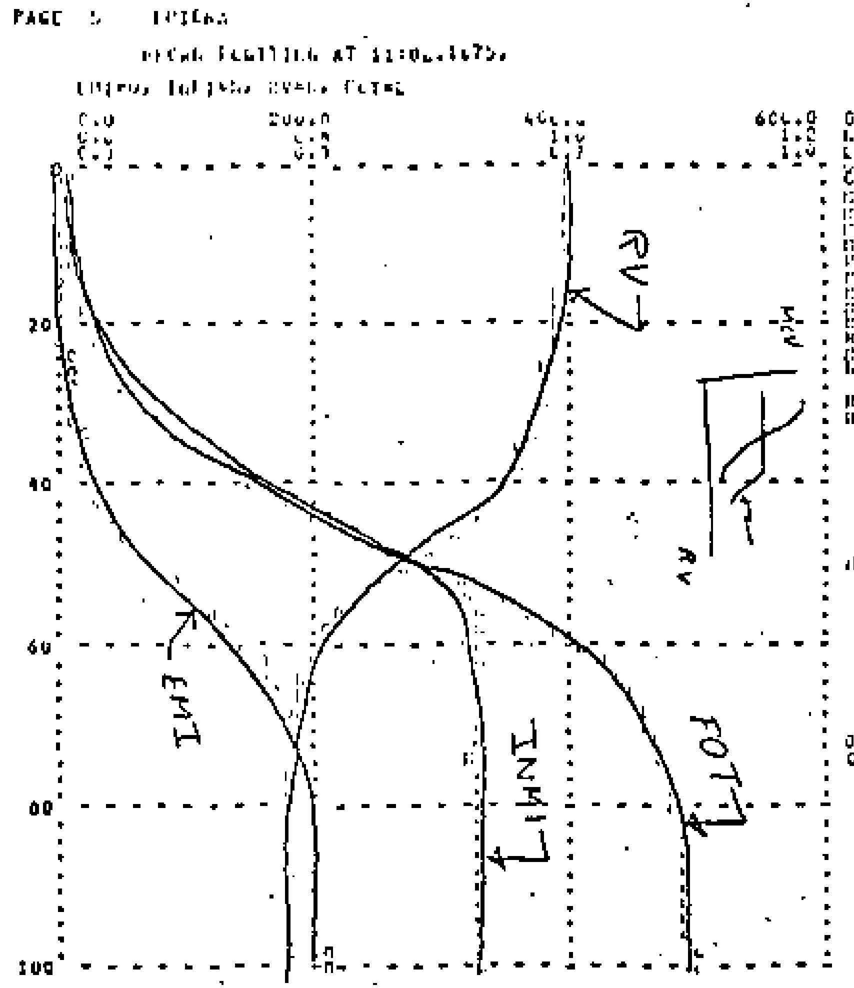

PAGE 4
TCV
TDV
POBLACION
VIVIENDA
NUEVA POLITICA
RV
HCV


PAGE 5
RV
EMI
INMI
FOT
HCV
RV

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INPUT PHASE [illegible]

[illegible]

TIE = TIEMPO
[illegible] = [illegible] DE VIVIENDA
[illegible] = [illegible] DE VIVIENDA
[illegible] = [illegible] POR MIGRACION
[illegible] = [illegible] POR MIGRACION
[illegible] = [illegible] DE MIGRACION
[illegible]

[illegible]

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GENERATION PHASE BEGAN AT [illegible]
[illegible] PHASE GENERATED AT [illegible]
PRINT PHASE GENERATED AT [illegible]
PLOT PHASES GENERATED AT [illegible]

ELAPSED COMPILATION TIME 1 15

NO ZIF TO ALGOL COMPILER ....

PAGE 2 [illegible]

STARTED PRINTING AT [illegible]

TIME	V	FUG	TCV	TDV	LNI	ILLI	AV	FUT
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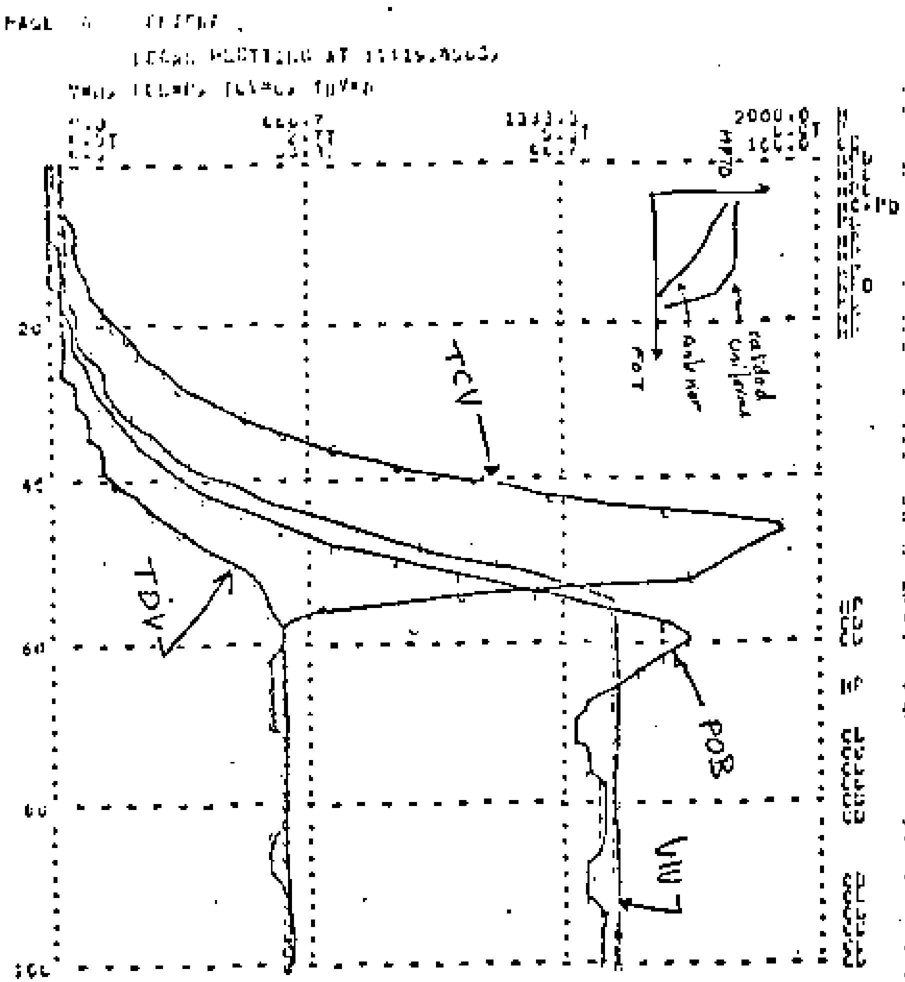
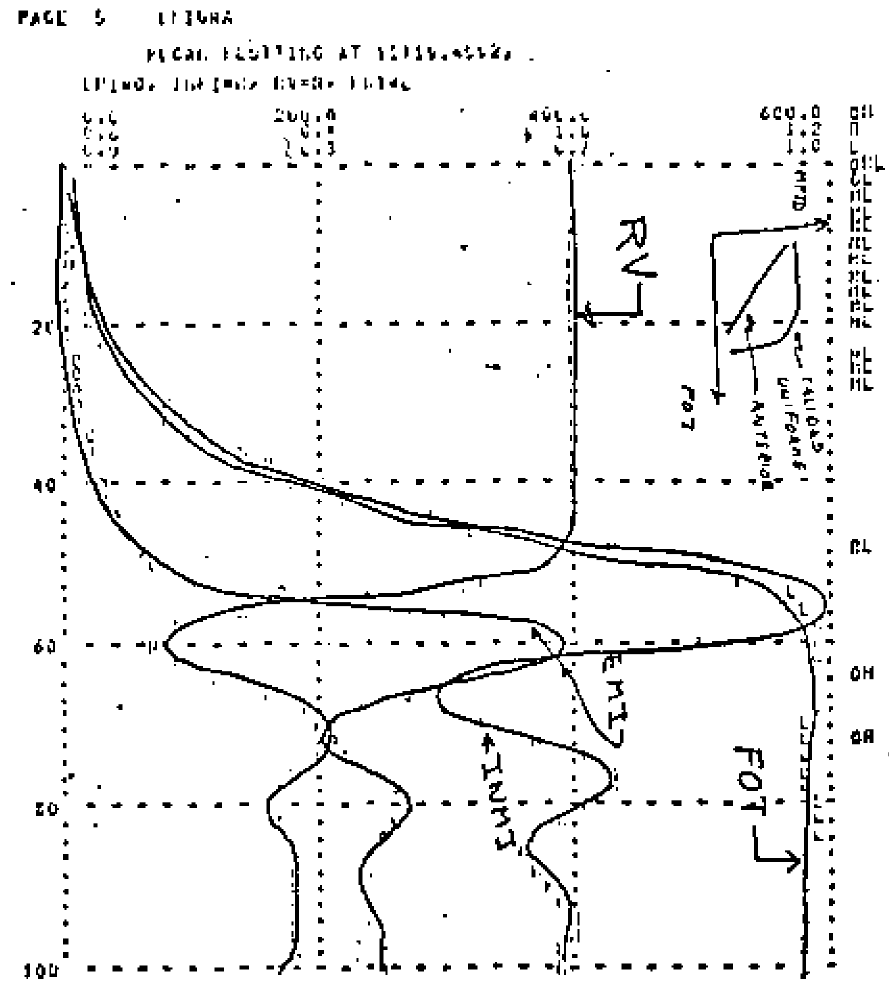
0.00	30.5	50.3	1.10	0.200	0.61	4.30	1.0001	0.00167
4.00	14.6	40.4	1.76	0.193	0.89	6.43	1.0000	0.00976
8.00	21.4	65.0	2.57	0.329	1.30	9.42	1.0000	0.01425
12.00	31.4	95.1	3.77	0.420	1.90	13.79	1.0000	0.02092
16.00	46.0	139.2	5.51	0.919	2.78	20.19	1.0000	0.03063
20.00	67.3	203.9	8.07	1.346	4.08	29.56	1.0000	0.04485
24.00	98.5	298.5	11.82	1.970	5.97	43.26	1.0000	0.06567
28.00	144.2	437.0	17.31	2.884	8.74	63.37	1.0000	0.09615
32.00	211.1	639.8	25.34	4.223	12.80	92.78	1.0000	0.14077
36.00	309.1	936.6	37.10	6.183	18.74	135.84	1.0000	0.20610
40.00	452.6	1371.6	54.31	9.052	27.43	198.88	1.0000	0.30174
44.00	662.7	2008.1	79.52	13.254	40.16	291.18	1.0000	0.44176
48.00	964.6	2939.8	116.54	19.291	59.62	426.28	0.9993	0.64304
52.00	1322.9	4200.5	67.09	26.459	101.60	615.50	0.9348	0.86196
56.00	1456.7	5927.9	35.87	29.133	299.61	755.10	0.7446	0.97113
60.00	1465.8	6019.3	29.40	29.316	393.03	496.24	0.6710	0.97720
64.00	1465.3	6130.6	27.94	29.305	323.16	316.07	0.7243	0.97684
68.00	1462.5	5610.4	28.20	29.251	227.45	361.28	0.7891	0.97501
72.00	1459.9	5492.0	29.17	29.197	206.13	366.03	0.8054	0.97325
76.00	1461.1	5603.0	29.61	29.222	237.73	429.30	0.7616	0.97406
80.00	1463.0	5797.3	29.43	29.260	266.35	412.02	0.7647	0.97532
84.00	1462.9	5742.7	29.63	29.259	253.71	379.96	0.7720	0.97529
88.00	1462.0	5655.1	29.66	29.239	235.56	367.65	0.7834	0.97464
92.00	1461.6	5654.5	29.31	29.232	235.63	366.13	0.7833	0.97443

PAGE 3 CHICHA

TIME	V	FUG	TCV	TDV	LNI	ILLI	AV	FUT
96.00	1462.1	5702.4	29.16	29.242	245.41	390.62	0.7770	0.97473
100.00	1462.4	5716.7	29.25	29.248	248.74	388.44	0.7749	0.97494


TCV
TDV
POB
VW7


RV
EMI
INMI
FOT

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RUN [illegible]

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        T = TIERRA
        TPV = TIERRA POR UNIDAD
        CNV = CONSTRUCCION NORMAL DE VIVIENDA
        TCV = TASA DE CONSTRUCCION DE VIVIENDA
        MCV = MULTIPLICADOR DE CONSTRUCCION DE VIVIENDA
        VPV = VIDA PROMEDIO DE LA VIVIENDA
        TDV = TASA DE DEMOLICION DE VIVIENDA
        V = VIVIENDA
        [illegible] = RELACION DE VIVIENDA
        MAM = MULTIPLICADOR DE ATRACTIVO POR MIGRACION
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        TM = TASA DE MUERTOS
        VR = VIVIENDA REQUERIDA
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        C   = COMIDA
        GC  = GENERACION DE COMIDA
        CPH = COMIDA POR HABITANTE
        PC  = PRODUCCION DE LA COMIDA
        CLPH = [illegible] DE COMIDA POR HABITANTE
        [illegible] = TIEMPO DE [illegible] DE COMIDA
        CCAP = CAPACIDAD DE COMIDA
        [illegible] = FACTOR DE LA TASA DE CRECIMIENTO DE INMIGRACION

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        [illegible]=[illegible].07
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        TDV.KL=V.K/VPV
        VPV=[illegible]
        C.K=C.J+(DT)(GC.JK-CC.JK)
        C=[illegible]
        GC.KL=((CAP-C.K)/CPT.K
        CCAP=[illegible]
        CY.K=C.K/CCAP
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        CPTT=1/[illegible]/[illegible]/[illegible]/20
        CC.KL=(POB.K)(CLPH.K)
        CLPH.K=TABHL(CPHT,FC.K,0,1.5,0.25)
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PLOT    [illegible]/TCV=C,TDV=D(0,100)/[illegible](0,[illegible]00)/[illegible]=0,IMI[illegible]
X       [illegible](0,.005)/[illegible](0.[illegible],1.[illegible])/[illegible](0,1)
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SPEC    LENGTH=100
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SPEC    PRTPER=[illegible]

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GENERATION PHASE BEGAN AT 21:30 46
RUN PHASE GENERATED AT 21:31 13
PRINT PHASE GENERATED AT 21:31 14
PLOT PHASES GENERATED AT 21:31 19

ELAPSED COMPILATION TIME  1 17

NO ZIP TO ALGOL COMPILER ******************************************

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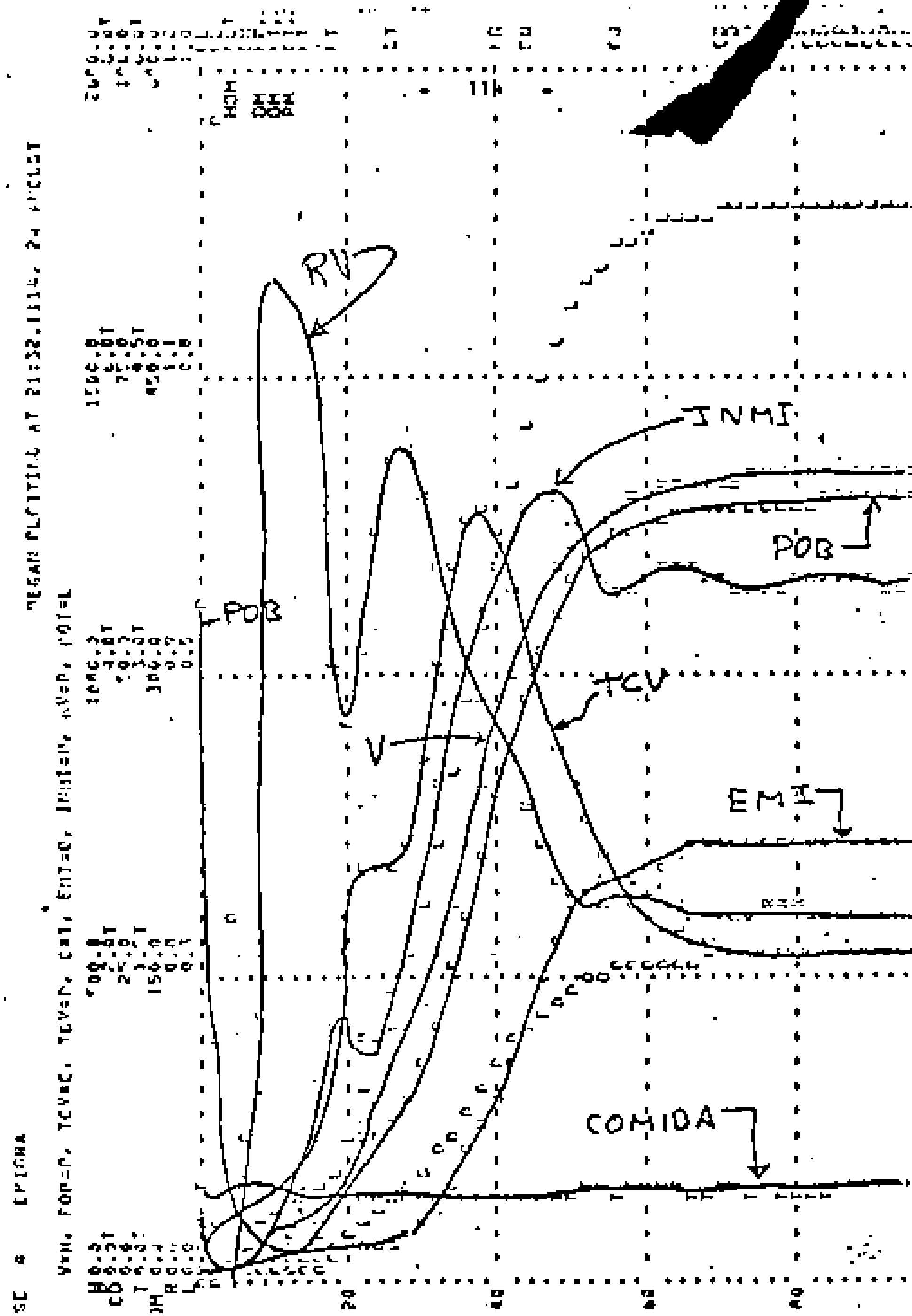
4.00	20.5	648.1	7.005	0.531	450.00
8.00	66.6	276.0	15.505	1.373	261.40
12.00	169.3	293.2	4.222	2.006	265.06
16.00	116.4	339.6	11.614	2.329	305.95
20.00	184.7	648.7	50.847	3.056	406.67
24.00	300.9	980.0	53.959	6.017	416.54
28.00	410.6	1271.1	56.447	8.211	419.70
32.00	579.7	1716.3	51.075	10.754	449.99
36.00	718.7	2416.7	45.155	14.374	450.00
40.00	989.2	3161.9	41.571	10.155	450.00
44.00	1065.2	3659.5	52.397	21.306	450.00
48.00	1171.3	4473.1	04.294	23.425	450.00
52.00	1262.7	4775.0	77.726	24.856	450.00
56.00	1284.9	4924.0	72.576	25.648	450.00
60.00	1306.4	5011.1	26.788	26.120	450.00
64.00	1318.4	5089.7	26.503	26.368	450.00
68.00	1325.5	5158.7	27.776	26.516	450.00
72.00	1329.3	5170.6	27.125	26.597	450.00
76.00	1331.1	5189.7	26.865	26.622	450.00
80.00	1331.6	5153.8	26.770	26.637	450.00
84.00	1332.3	5161.0	26.749	26.637	450.00
88.00	1332.7	5163.8	26.713	26.654	450.00
92.00	1332.8	5162.5	26.673	26.677	450.00

PAGE 3 EPIGNA

TIME	V	POB	TCV	TDV	C
96.00	1332.9	5161.5	26.653	26.677	450.00
100.00	1332.9	5162.2	26.663	26.676	450.00



larly referenced information required by participating city departments.

System development

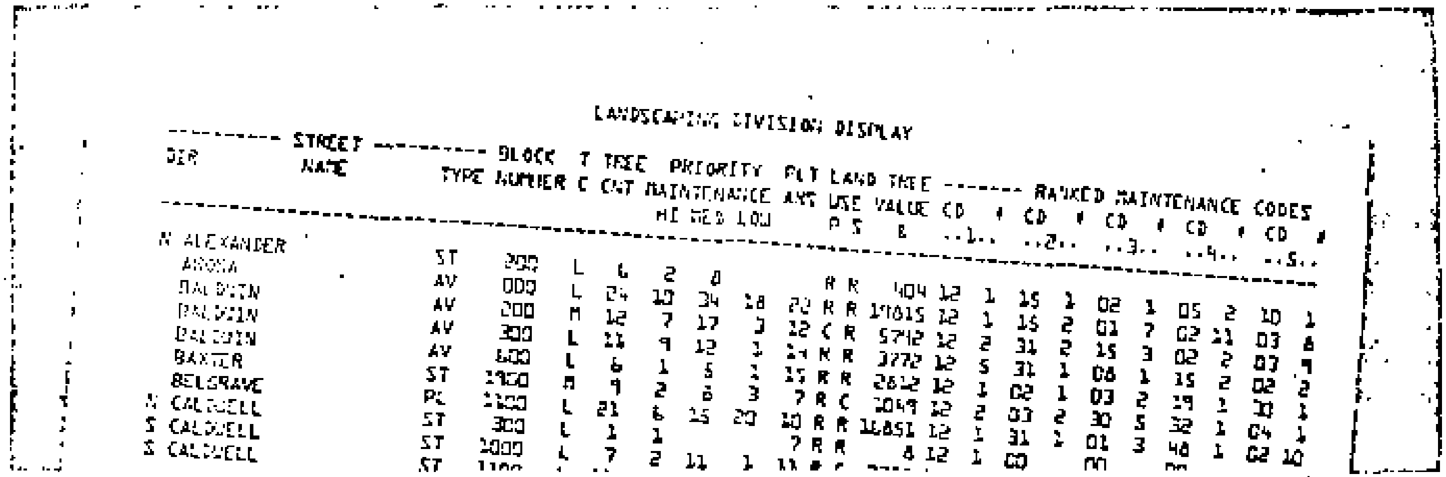
Data necessary to describe the city-maintained parks and trees were coded to street segment and stored in ESIS for management planning and analysis purposes.

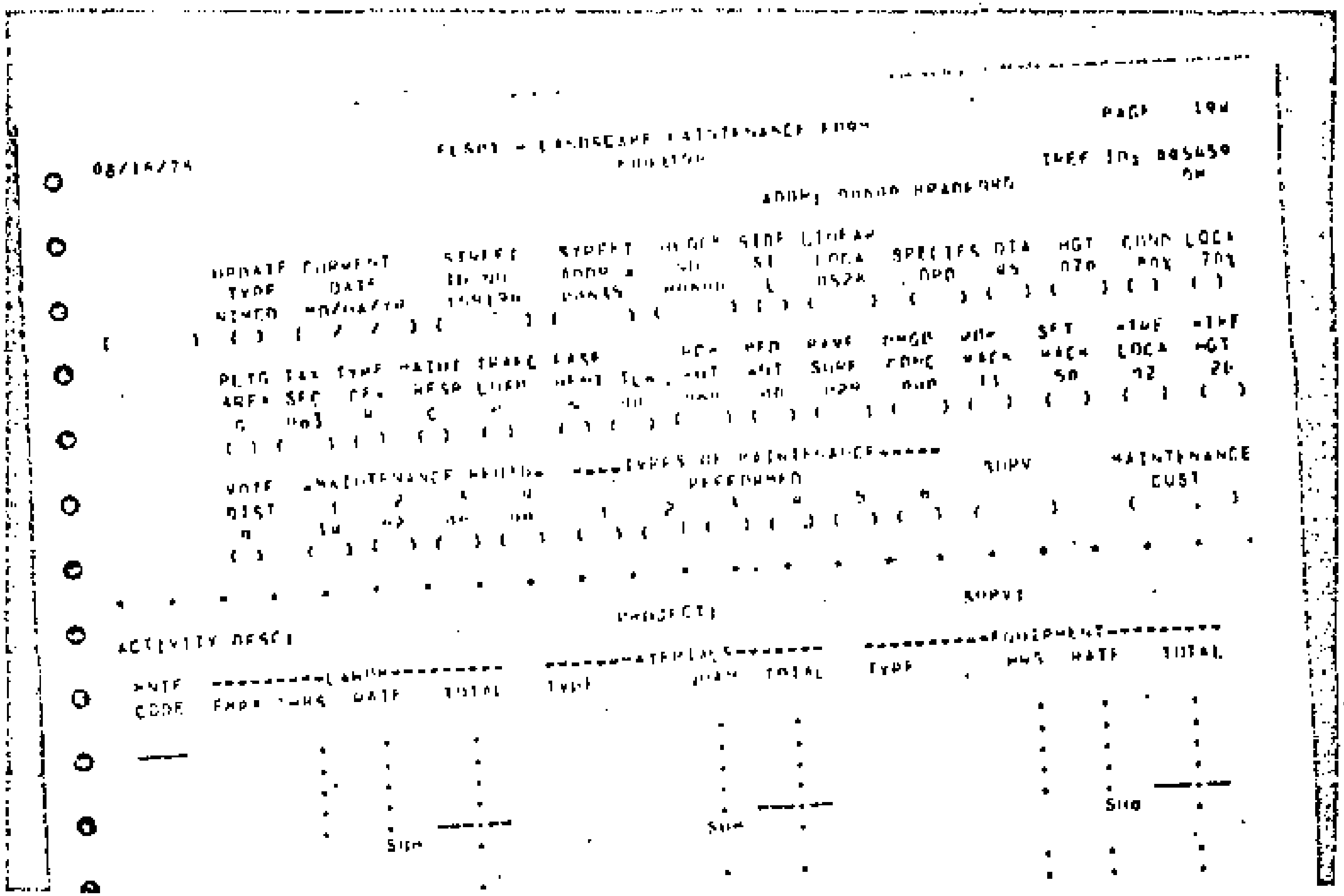
Using personnel hired through the CETA program and trained to identify tree types and maintenance problems, a census was taken over the course of 4 years of the city's 50,000 trees and 150,000 planting areas. Data were keypunched and added to the segment record. Information for each segment includes number of trees, number of trees requiring maintenance by type and priority, number of planting areas, and dollar value of the trees.

Additional data, such as traffic volume (low, medium, or high) and land use, maintained in the ESIS by other city departments, are also used for analysis.

Maintenance problems, identified prior to the tree census, were ranked according to priority—high, medium, or low. Some of these maintenance activities include:

- Prune immediately (high)
- Shape tree (low)
- Clear street lights (high)
- Remove vine (low)
- Remove stump (medium)
- Remove girdling wires (medium)





Information regarding Charlotte's 50,000 trees and 150,000 planting areas is maintained through the city's Engineering Street Index System. Data items required by the city's Landscaping Division include the number of trees and planting areas on the segment, the tree value, and the total number of trees by priority maintenance.

Computer-generated field forms are used to enter additions or removals from the inventory or to record various maintenance activities.

Additions to the inventory, removals, and maintenance activities are logged onto computer-generated field forms and subsequently entered into the computer.

System description

Listings of information in the file are printed out on a regular basis and include the total number of trees per segment requiring maintenance by priority. Other output reports can produce listings sorted by maintenance codes. Upon request, selected field sheets can be generated for a given street or work area, thus permitting the targeting of specific field work, such as tree removals.

The system also has a polygon processing capability that allows the Landscaping Division to draw ad hoc management areas depending upon the need at the time. For example, separate management areas can be described for removals, pruning, spraying, and other such activities. Boundaries can also be changed quickly if a situation changes drastically.

The system allows the Landscaping Division to start with a given maintenance operation in the management area of greatest need and to work through the other areas to ones of lowest need. In addition, the division has an overview of where all real or potential problems are located. For example, if a new disease or insect appears, the city would know the location of the trees that could be affected and could plan for necessary remedial measures.

Houston, Tex.: A Water Main Repair System

The alternate shrinking and swelling of the coastal plain soil, minor seismic faults, and the subsidence resulting from the extraction of water, oil, and natural gas are responsible for the constant ground shifts in Houston that cause major and minor breaks in underground water pipes. During a prolonged dry spell in the fall of 1977, for example, there were about 2,500 reported leaks in the city. In the past, up to 3 days could be required to handle work orders to dispatch a repair crew. This handling time has been reduced to a few minutes by the development of an online reporting system using the GBF/DIME-File.

Previously, when a call for service was received, an operator would fill out a blank work order. A second clerk would later manually code the address to a map-book gridcell reference. The water service area number also had to be determined. Once the address was located, the work orders were hand sorted by service area number and delivered by messenger to the proper maintenance barn location. Often, duplicate work orders were cut. The process was prone to error and could take several days. Additionally, there was no defined process of maintaining permanent records on leak location and frequency for later management analysis.

The Water Division of the Houston Public Works Department, in an effort to expedite maintenance activities, decided to automate and worked with the Planning Department to integrate the existing online DIME System into a new water leaks dispatch system.

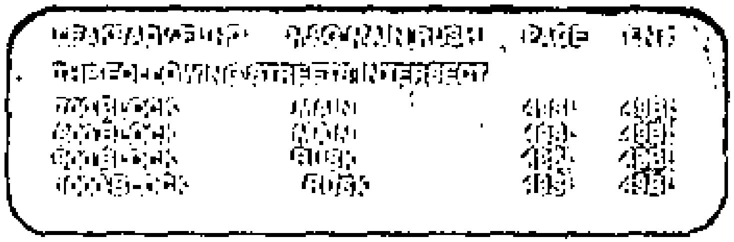
Components of the Houston Online DIME System

The Houston City Planning Department developed and implemented an online system to correct and update the city's DIME file. The system, which operates on a Honeywell computer, consists of eight integrated, indexed sequential files. Different programs can use one or more files as necessary, depending on the particular application. The eight files are described below.

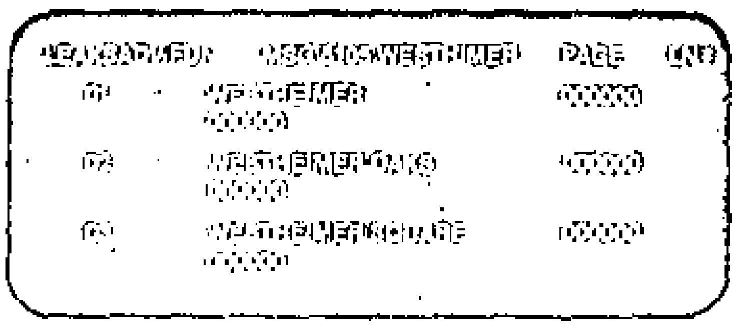
1. The main data file consists of approximately 91,000 DIME file records.
2. The unique feature name file contains the names of streets or other features (about 11,000) included in the DIME file.
3. An equivalent names file contains cross-reference information for street names, building names, common misspellings, churches, hospitals, etc.
4. An ID cross-reference file keys the permanent DIME identification number to its corresponding location in the data file (number 1 above).
5. A node locating file enables a user to retrieve all records for an intersection or to rapidly chain along a particular street.
6. A soundex file contains street names that have been reduced to a phonetic series of letters, usually only

The Houston water main repair system uses an online DIME system to determine the location of a reported water leak. As a call for service is received, an operator enters the address information on a CRT. The entry can be an address with a street name and number, a well-known building, or two intersecting streets.

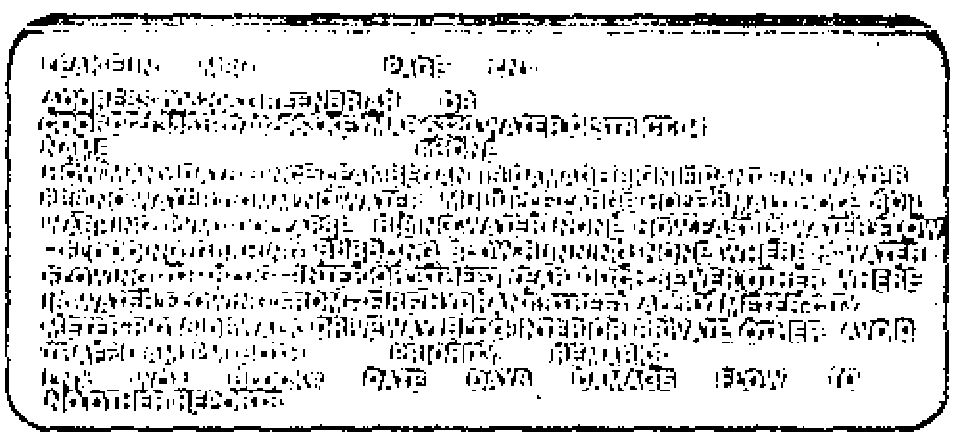
In the case of an intersection, a list of segments that intersect at that point appears on the screen.



The operator must select the segment that actually has the leak. If a street name cannot be found as spelled, a predefined equivalency file or a soundex file is checked. When a street name is soundexed, a list of similarly spelled names appears on the screen and the operator can select the correct name.



A form screen that must be completed is then brought up. It contains coordinate information for the midpoint of the segment, the key map page and gridcell, and the water district number.



After the information about the leak has been taken from the caller, the data are transmitted to the appropriate maintenance barn.

the basic consonants from the original name. When a terminal operator is unable to spell a street name correctly, the name is soundexed and similar sounding names can be rapidly accessed.

7. A tract-block file enables rapid access to the records in any census tract or block.

8. A State plane coordinate file enables access to all records within a gridcell of 2,500 square feet.

System description

The Water Division required that calls for service be located on a key map page and gridcell and referenced to a water maintenance district. The key map is a privately published street map booklet for Harris County (Houston) and is used by almost all delivery and service personnel who must drive in the city. A program was written to add the key map reference to the file based on coordinate information. Water district numbers were added on the basis of tract and block numbers and are now a permanent item in each record of the 91,000-record DIME file.

The city's system is unique in the way it helps telephone operators find the proper address, even if the operator cannot spell the name properly or doesn't know the address of a well-known building. The operator enters the call for service address information on a CRT. The initial request can be entered as either a street address or two intersecting streets. In the latter case, the program will respond with a list of street segments that intersect at that point. The operator must select the segment which actually has the leak. If a street name cannot be found as spelled, the program will attempt to locate the address by checking the equivalent names file. The equivalency file can cross-reference two street names (if a street name is changed, a single entry in this file will permanently relate the two names) or can relate a commonly known building (like the Astrodome) to its address. If the name entered on the terminal cannot be found on this second try, the program soundexes the name, and an array of similar sounding street names is brought up on the terminal screen.

Once the correct segment is located, the program brings up a form screen that contains the caller's address, the correctly spelled street name, coordinates of the DIME segment midpoint, the key map page and gridcell, and the water maintenance district number. The operator must type in the additional information to complete the form screen, including the caller's name, phone number, information on the number of days the leak has been present, the significance of the damage (e.g., soil washing, pavement collapse), the rate of water flow, the source (e.g., hydrant, street, building interior) and destination (e.g., street, yard, ditch) of the water flow. A priority can also be assigned and a notation regarding traffic detours can also be made.

If a leak was reported previously and work orders issued, these orders are listed at the bottom of the form screen, thus reducing the number of duplicate work orders. After the form is completed, the information is transmitted via a message-switching system, keying on the district number, and printed immediately on remote printers at the proper maintenance barn location so that crews can be dispatched.

The new system also allows all work order records to be stored in a history file. Statistics can be tabulated from these records or computer plotted on a street map of the city. Such analysis will be especially useful to pinpoint subdivisions with excessive numbers of leaks and areas that should be covered by new capital improvements programs for the replacement of water mains.

New York, N.Y., and Albany, Ga.: Water Supply Inventory Studies

A private consulting firm was contracted to study the water supply systems in these two cities. The New York City study involved an analysis of water main breaks since 1955. In Albany a detailed water main inventory provided a basis for evaluating the existing system and proposed expansions.

The GBF/DIME-File was used in both studies to geographically reference the water main system. The COBOL version of ADMATCH was used to geocode related information to the water main inventory. All computer work was done on a Hewlett-Packard 3000 System II or III.

New York, N.Y.: Analysis of water main breaks

To study the physical condition of water mains and assess the need for water main replacement in the older urban centers of the Northeast, the Army Corps of Engineers contracted a private consulting firm to design and carry out the analysis. The study examined water main breaks since 1955 in Manhattan to determine if a pattern existed and whether deterioration in the system was due to age or other factors.

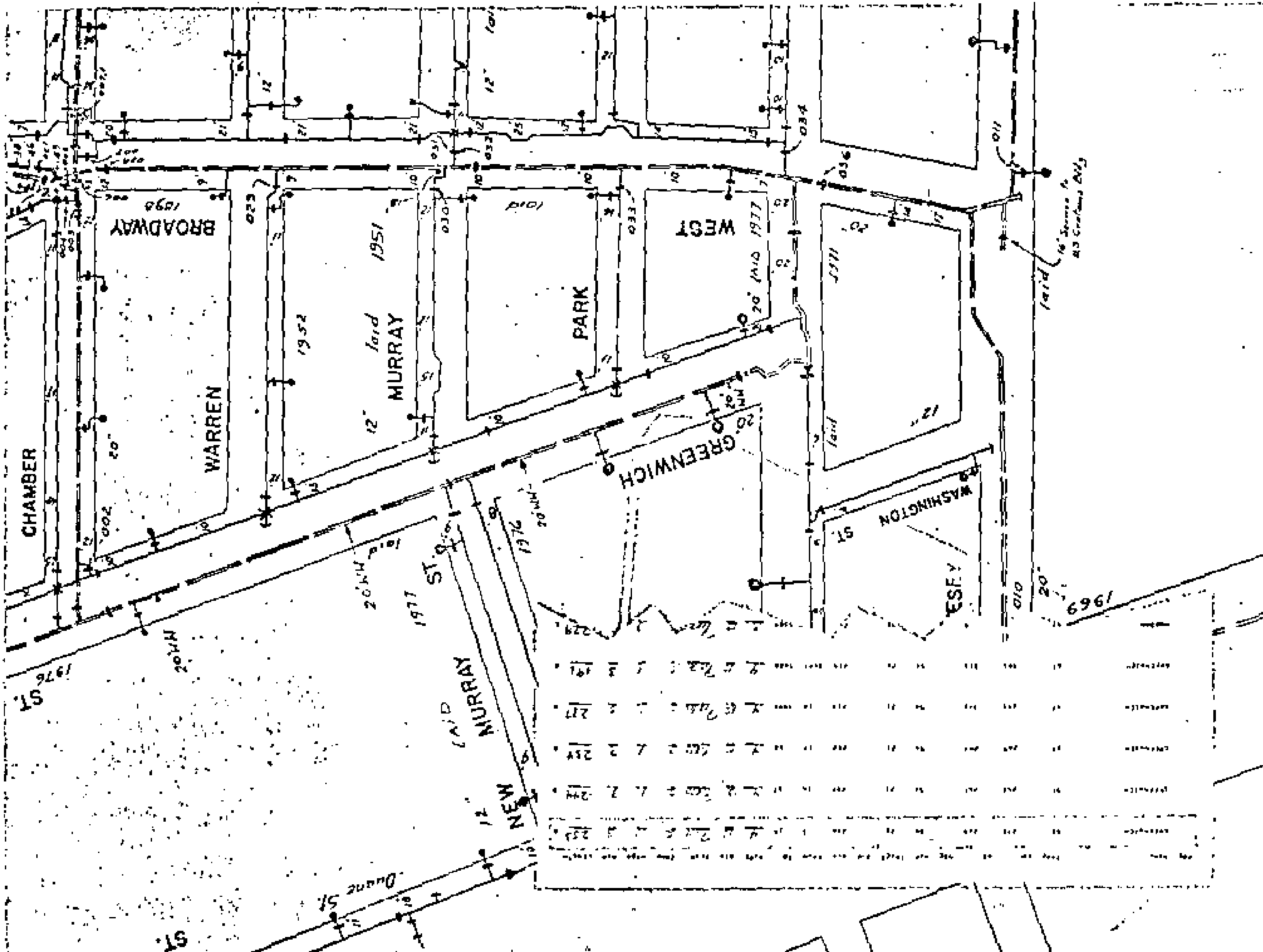
The budget for the project was $70,000; about $25,000 was used for coding and address matching.

A method was needed to geographically reference the water main system and water main breaks within the system. Information about the size and age of the pipes, for example, was also required. Additionally, the study would consider related information, such as traffic flow, to see if there was a relation between traffic volume and water main breaks.

The GBF/DIME-File was used to create a special water inventory coding file containing the tract and block numbers, address ranges, and nodes associated with each segment. Each segment was divided into left and right components and the related geographic information was printed out on special coding sheets.

The water main system, described on maps obtained from the Manhattan Bureau of Water Supply, was then coded to individual street segments. Information included pipe diameter, year laid, number of hydrants connected to the pipe, pipe length, and a map number.

Information taken from water main break reports was then related to street segments in the water inventory file using the ADMATCH program. The 2,500 water main break reports between 1955 and 1978 contained the date, location and type of break,



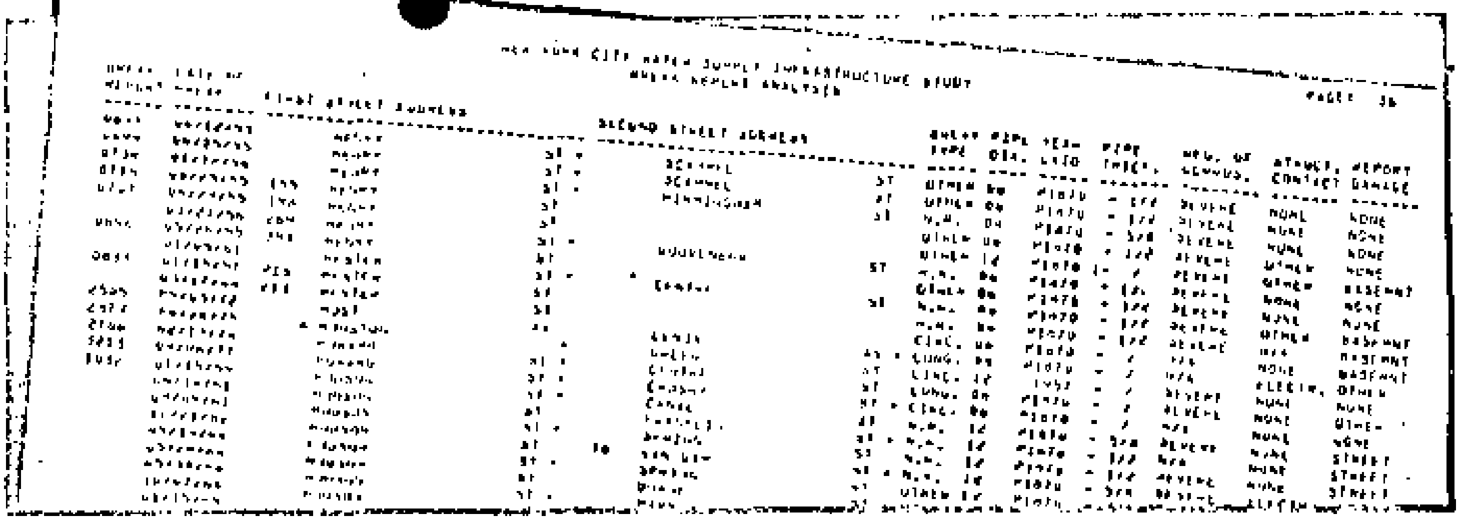
CHAMBER
BROADWAY
WARREN
MURRAY
PARK
WEST
GREENWICH
WASHINGTON
ST.
NEW
MURRAY
Duane St.

pipe diameter, year laid, and type of structure, if any, in contact with the broken main. Such a structure could be a building foundation, subway tunnel, or various utilities.

The Tri-State Regional Planning Commission supplied data on traffic volume, speed, and vehicle weight for 35 selected streets in the city. This information was also related to the appropriate street segments. To find a pattern, the number of breaks per mile of main for each pipe diameter was calculated for each census tract and break incidence was plotted on computer maps.

Some tracts had no breaks; others had several times the average number of breaks per mile. The study determined that older pipes, especially those laid before 1870, were breaking in greater numbers than their representation in the system, but there was no consistent pattern of increasing breaks as pipes got older. Statistical analysis of all the data showed that location may be the single most important factor for predicting water main breaks. High break areas seem to be areas of high activity such as heavy traffic, major reconstruction, subways, and underground utilities.

The DIME file was used to relate the New York City water main system to individual street segments. Information about pipes in the system was obtained from engineering maps and entered onto coding forms generated from the DIME file.



The study showed that although there are some problem areas, the water supply system is generally in good condition. The analysis could be used to pinpoint problem areas so that the city could orient its replacement program more specifically to pipes that were expected to break rather than to only those of a certain age or diameter.

Albany, Ga.: Water Inventory file
In a related application, a water inventory file was created for Albany, Ga. The resulting information provided the city with an accurate, detailed inventory of the existing system and a tool for building a water system master plan.

The water inventory file consists of three subfiles: (1) A node file, containing all nodes (located where there is a change in pipe diameter, where pipes intersect, or at the terminus of a pipe) within the system; nodes were related to the GBF/DIME-File using a methodology similar to that employed in the New York City study. The elevation of these nodes was taken from U.S. Geological Survey topographic maps. (2) A pipe file, containing such information as pipe diameter, length, node numbers, and address ranges, was also created using the New York City study methodology. (3) An assignment file was created by ADMATCHing the node and pipe file to water billing records of actual water consumption for each household. The ADMATCHed file contained water consumption for each segment in the system.

The information from the inventory file was used as input to a water analysis model. The output of the model can be used to analyze the system to determine its adequacy to meet water demands, provide fire protection, and meet peak demand; to determine the effects of peak demands on pressure; and to measure the effects of supply reductions or proposed construction projects. The output analysis can also be used to develop a master plan for system expansion.

The system will be installed on the Albany Water, Gas and Light Commission's computer as a permanent planning tool for the Commission's engineers. The budget for coding data and setting up the model was $30,000.

Reported water main breaks between 1955 and 1978 were geocoded to street segments to determine if a pattern of breaks existed and whether deterioration in the system was due to age or other factors.

Applications of the GBF/DIME-File Relating to Health Care Planning

DIME files are used by many U.S. cities for health care planning. The DIME file enables a locality to geographically locate cases of diseases and other health-related problems. Taking into account the number of inhabitants, disease and mortality rates can be tabulated or mapped for specific geographic areas. These data can aid health systems agencies or other health-related organizations in planning or evaluating proposed or existing health services or facilities. Two specific applications pertaining to health care planning are discussed below.

The Health Systems Agency of San Diego and Imperial Counties, Calif., used the DIME file to geographically code offices of physicians. Computer maps illustrated specific areas within the region that were underserved by physicians.

In Akron, Ohio, researchers used the GBF/DIME-File and the ADMATCH program to geocode reported inci-

period. The spread of the disease was tracked and areas with a high potential for future outbreaks were identified.

San Diego and Imperial Counties, Calif.: Physician Need Study

The Health Systems Agency of San Diego and Imperial Counties wanted to identify areas underserved by physicians and thus recommend locations for new physicians. An identification of areas with shortages of health care services would allow community organizations to apply to the U.S. Department of Health and Human Services for the free services of a National Health Service Corps professional such as a doctor, nurse, or dentist for a 2-year period.

To accomplish these objectives, a private firm conducted a physician manpower study at a cost of $5,000. The 3-month investigation was completed in July 1979. The DIME file provided the reference for the assignment of geographical areas to physicians' office locations.

The basic hardware was two computers, a Burroughs 7800 and an IBM 370, and a pen plotter. The system can also operate on a microcomputer.

System description

The general procedure consists of four steps: Data collection, address matching, aggregation, and analysis and display.

Data collection. Data were collected from five different sources and included physicians associated with the San Diego County Medical Society, the University of California (San Diego) Hospital, the Kaiser Foundation, the military, and the California Department of Consumer Affairs. The resulting lists, containing the office address and primary speciality of each physician, were edited and duplicates were removed. In addition, physicians assumed to be unavailable to the public were eliminated.

Address matching. These lists were then geocoded using the Census Bureau's ADMATCH program with the DIME file as the reference file. Each record that was successfully matched had the census tract number and coordinates of the end nodes of the appropriate street segment appended to it. A match rate of 80 percent was achieved. After manually coding the nonmatches, the data file contained 2,399 physician records with the required information.

Aggregation. The San Diego region was divided into 23,496 gridcells of 2000' × 2000' each, approximately 92 acres.

A software program calculated the approximate coordinates for each office. This process, known as interpolation, considers the address number and its relative position between the low and high address numbers for the street segment. Once the relative locations of the addresses were calculated based on the coordinates of the

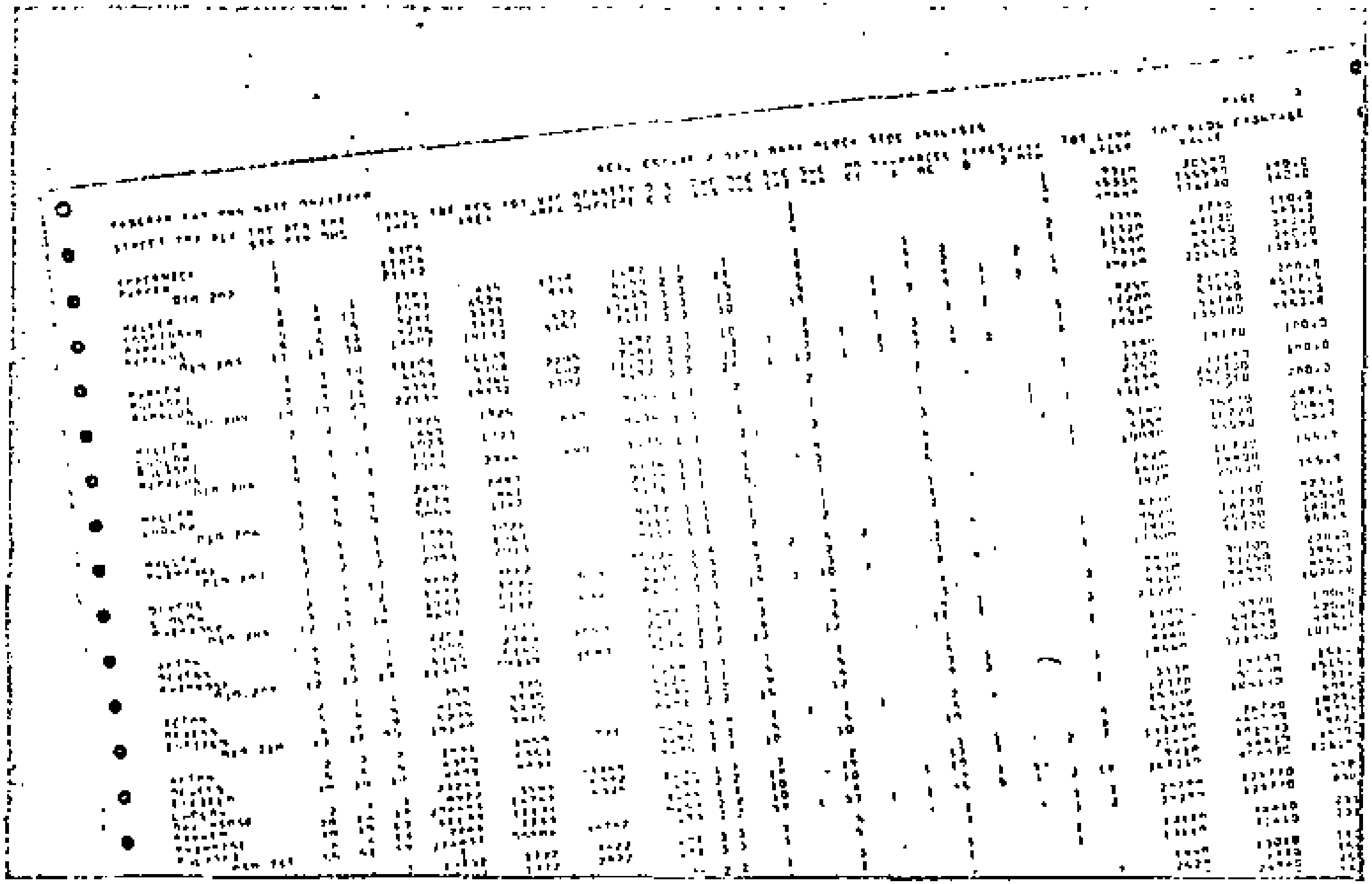
these final coordinates to a particular gridcell. The physician records were then aggregated by gridcell for each primary speciality.

Analysis and display. The accessibility of physicians to the general population was of prime importance in determining which areas were well served or inadequately served. The measure of accessibility chosen in this study was 5 miles. The population of a gridcell was considered to have access to a physician located in another gridcell if the two gridcells were no more than 5 miles apart.

The distance between any two gridcells was calculated by summing the straight-line distances going through the network from the center of one gridcell to the center of an adjacent gridcell, assuming there were no natural barriers between the adjacent gridcells. Distances calculated in this manner, rather than along the actual street network, very closely approximated the actual driving distance, especially for distances of 5 miles or more.

Various types of computer maps were then generated using the 5-mile accessibility criterion:

- Number of physicians by speciality type within 5 miles of each gridcell
- 1975 population per gridcell within 5 miles of at least one physician, by speciality
- 1975 population per gridcell beyond 5 miles of any physician, by speciality



The GBF/DIME-File provides the geographic reference needed to relate data contained in Springfield's master parcel-level file to standard geographic areas. The real estate file, containing information on land use, area, density, and value, can be sorted by census tract, block, and block face.

area. About 100 batch programs are used to prepare various file listings and to produce reports for analysis. All files are online.

Cost and funding

The system was begun in 1969 and operates at an annual cost of about $25,000, representing primarily the staff costs of two to three persons. City funds are used to support the system although some clerical assistance was funded through CETA grants.

Applications

The Springfield Community Development Staff uses data from the system for analysis and for targeting special neighborhood programs such as housing rehabilitation. For example, the number of standard and substandard units by owner and renter occupancy, a data requirement of housing assistance plans needed for funding under the Community Development Block Grant program, was easily retrieved at the block level through the system. In another instance, the staff was able to determine, through the system's various sort and list routines, that a proposed rehabilitation program for older, medium-sized apartment buildings would not be feasible since it would affect only one structure in the city. The business file is used regularly to determine the person to contact in an emergency situation. A record can be called up online by address, business name, or telephone number. In an emergency in a shopping center, a master property identifier record that lists all the businesses in the center can be retrieved if only one address or business is known.

The ambulance trip data are used regularly by physicians, hospital administrators, and the Fire Department to analyze emergency services, to redesign catchment areas, and to place ambulances. In a separate application, the GBF/DIME-File is used by the Springfield Police Department to assist in crime analysis and develop patrol areas.

Cincinnati, Ohio

The Urban Information System (UIS) of Cincinnati was developed in 1977 by the City Planning Commission to organize and manage the data already maintained by various city departments and to make them available to policymakers. Some of the software was developed under contract; however, most of the system was designed in-house by staff members of the Planning and Management Support System (PAMSS), a division of the City Planning Commission.

The PAMSS Division maintains the system and its components. Data are usually provided by various city agencies on a regular basis. Although users may directly access the system, most agencies make requests for information or reports directly to the PAMSS staff. Reports of a general nature are also occasionally generated.

Informational content
The basic concept of UIS is that data items, where possible, are translated into indicators (statistics such as percentages or rates, which lend themselves to analysis). Thus, the system not only stores data, it can manipulate data items to form indicators. These indicators can then be compared to commonly accepted standards or be compared over time. The UIS has five information modules with over 800 data items. A set of indicators has been developed for each module, which corresponds with the task elements of a coordinated city plan. These modules include housing, economics, transportation, social services, and safety.

INDICATOR NAME

1. PHYSICAL CHARACTERISTICS

IH101	Percent of structures which are vacant problem buildings
IH102	Percent of total dollars spent in housing renovation
IH103	Percent of total CDBG dollars
IH104	Percent of structures which have been demolished
IH105	Mean estimated cost of newly constructed dwelling united
IH106	Mean appraised true value per dwelling unit
IH107	Mean orders per building
IH108	Quality point average of auditor's building condition grade

2. AVAILABILITY

IH201	Percent change in the number of dwelling units
IH202	Percent change in the number of people
IH203	Average persons per household
IH204	Vacancy rate-total
IH205	Areas with percent vacant for sale greater than or less than variable standards
IH206	Areas with percent vacant for rent greater than or less than variable standards
IH207	Mobility rate of households

The Cincinnati Urban Information System uses indicators to identify and monitor trends in city and neighborhood conditions. Some of the indicators in the housing module are illustrated.

Major sources of information include local agencies (e.g., Building Department, Fire Department, Health Department, Auditor's Office, Welfare Department), the R.L. Polk Company's *Profiles of Change*, the Multiple Listings Service, savings and loan institutions, utility companies, and a citizen attitude survey. Decennial census data as far back as 1940 are also included.

The GBF/DIME System is used to geocode the data. The primary level of aggregation is usually the block, so that unique neighborhoods or other districts based on blocks can be created. Most data coming into PAMSS have already been geocoded by the particular department.

Capabilities
UIS is written in PL/1 for an IBM computer and can be transferred to any system with that capacity. It has several data manipulation and report-generating capabilities and can retrieve certain data items, manipulate them into indicators, and generate detailed tabulations and summary reports. The system also has mapping capabilities and utilizes the SYMAP mapping program. Information may be retrieved by various geographic levels including census tract, block, neighborhood, and, on a limited basis, voting ward. UIS can also create unique areas based on block aggregates to help fill special data needs. Five different types of reports can be developed by using the system. These deal with the current status or trends in various indicators at city or neighborhood levels.

Cost and funding
The Cincinnati system cost approximately $100,000 to develop. Community Development Block Grant funds paid for about half the staff time and some hardware. Ongoing costs, covered primarily by a regular city budget, involve staff time and a monthly rental charge for a computer terminal. Users of the system are charged only for computer time.

Applications
The system has been used by various city agencies for analysis and planning purposes.

Charlotte, N.C.
Charlotte has implemented a computerized Engineering Street Index System (ESIS), which provides the basic data base for several city departments that require street-related data items in their daily operations.

The shared uses of portions of routine administrative files is an integral feature. The organization of the system, in terms of interagency cooperation, data collection, and dissemination appears to be more formalized than in the other three cities.

Charlotte was the site of several earlier, less successful efforts to build an integrated system. To avoid some of the pitfalls of these earlier attempts, the developers of the ESIS project kept several goals in mind:

- Data elements would be included only if users were committed to the collection and maintenance of the data.
- ESIS data would be shared with as many users as were interested in the data.
- Geographic encoding and report flexibility would be provided.
- The system would be simple to develop and maintain and inexpensive to operate.
- Provision would be made for expansion of applications for future users.

The system was designed by the city and a private contractor and developed in 18 months. Parts of the system have been operational since 1978.

The GBF/DIME-File provides the capability of producing a wide variety of output reports organized around geographic identifiers such as street names, intersections, census statistical areas, or areas defined by coordinates.

DIR	STREET NAME	TYPE	BLOCK NUMBER	M R.	TYPE SUR	BASE MAT	LENG	WIDTH MIN	WIDTH MAX	% MAX	C&G L	C&G R	CB #	TRAV CODE	ONE WAY CODE
S	CHURCH	ST	500	C	A	C	331	32	32	100	V	S	1	S	T
S	CHURCH	ST	600	C	A	C	445	27	31	70	V	S		S	T
S	CHURCH	ST	700	C	A	C	169	27	27	100	V	S		S	T
S	CHURCH	ST	800	C	A	C	241	27	27	100	V	S		S	T
S	CHURCH	ST	820	C	A	C	74	31	31	100	V	V		S	T
S	CHURCH	ST	900	C	A	C	200	30	30	100	V	V	2	S	T
S	CHURCH	ST	1000	C	A	C	244	31	31	100	V	V		R	T
S	CHURCH	ST	1018	C	A	C	192	31	31	100	A	V	2	S	T
S	CHURCH	ST	1100	C	A	C	312	26	100	70	V	V	2	S	T
S	CHURCH	ST	1200	C	A	S	569	23	23	100	N	N	1	R	S
S	CHURCH	ST	1209	C	A	S	289	20	20	100	N	N	1	S	S
S	CHURCH	ST	1400	C	A	S	625	21	28	70	A	A		S	S
S	CHURCH	ST	1500	C	A	S	440	23	23	100	A	N		U	S
	CLEVELAND	AV	1400	C	A		135	28	28	100	S	A		S	S
	CLEVELAND	AV	1508	C	A	C	338	30	30	100	V	V		S	S
	CLEVELAND	AV	1600	C	A	S	430	30	30	100	V	V	2	S	S
	CLEVELAND	AV	1700	C	A	S	432	30	30	100	V	V	2	S	S
	CLEVELAND	CT	400	P	A		201	16	16	100	N	N	[illegible]	[illegible]	[illegible]
	CLIFFWOOD	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

There are three active users of the system: The Landscaping Division, the Street Maintenance Division, and the Traffic Engineering Office. Six agencies (the Planning Commission, the Fire Department, the Engineering Division, the Transit Planning Office, the Sanitation Division, and the Public Information Office) are envisioned as future users.

Informational content
The Engineering Street Index System combines street segment information

The Charlotte Engineering Street Index System (ESIS) combines street segment information from the DIME file with similarly referenced information required by participating city departments. Data elements used by the Engineering Division may include the type of street surface (e.g., asphalt or concrete), maintenance responsibility (e.g., city or private), the length and width of the segment, the type of curb and gutter, the number of catch basins along the segment, and various traffic codes (no left turn, no right turn, dead end, or straight only).

from the GBF/DIME-File with similarly referenced information required by the participating city departments.

For example, the Sanitation Division would require information on the length and width of the street, whether it is one-way, the regular and special pickup days for that street, and the sanitation zone where it is located. The Traffic Engineering Office needs similar information on the length and width of the street as well as data on traffic counts, rights of way, bus routes, and stop signs. For an item to be included in the ESIS, an agency must assume responsibility for its maintenance. Individual data items are collected and maintained by a single user department, but every effort is made to ensure a wide utilization of each item stored in the system. Data sharing is greatly enhanced by the common data base approach of ESIS. New data items have been added since the original system was designed and some elements have been dropped for lack of ongoing support by users.

Data are entered into the system through automation of existing manual files, on-line file maintenance, or a field survey. In this last case, a field survey form is automatically generated for each street segment.

Capabilities

The system, which operates on a Burroughs 6700 computer and uses locally developed software, can generate three basic products: Survey forms, 21 routine reports, and numerous special option reports. The system also has polygon processing capabilities by which boundaries of special areas can be assigned.

Cost and funding

The system cost approximately $50,000 to develop. The Street Maintenance Division saves an estimated 3 staff months per year using the system. No comparable figures are available for the Landscaping Division since the system provides management planning capabilities that were not previously available.

Applications

Most applications of the system have involved ongoing operations and planning activities. For example, the Street Maintenance Division of the Operations Department maintains information on street surfaces and resurfacing histories, which it uses to develop a comprehensive resurfacing program. A specific use of the system by the Landscaping Division is described in the section entitled "Applications of the GBF/DIME-File in Public Works."

Tucson, Ariz.

The Regional Data Exchange (REDEX) Consortium is an organization of some 25 agencies in Tucson and Pima County interested in promoting the exchange of social, physical, and economic data among those who produce or need such data. The consortium, established in 1975, coordinates the use of the GBF/DIME System for the area.

Key persons from participating organizations meet monthly to discuss new data sources or other items of interest to consortium members. Additionally, a newsletter, now in its fourth year, keeps members and other interested parties apprised of upcoming meetings, new data resources available, and other items of interest such as 1980 census developments.

The REDEX Consortium is more broadly based than the other three systems discussed here, drawing upon city and county agencies, as well as other organizations such as the United Way, the research office of the local community college, and several health-related agencies. At the same time, its organization is more informal, and its source of funding and relation with the city government more tenuous than in the other examples. However, it is one of the more successful of several groups in the country that have attempted such an arrangement.

Informational content

Participating agencies submit their records to be processed through the system. Summary records are made available to consortium users.

The master data index system is maintained at the University of Arizona Computing Center. Besides 1970 census data, other items in the tract-level data base include a 1975 special census of Pima County, birth and death records from the city Health Department, unemployment insurance claims and employment service reports from the State Department of Economic Security, and the results of recent community surveys.

Capabilities

The data records of participating agencies are address matched against the Tucson GBF/DIME-File, and census tract codes are appended. The records are then aggregated at varied levels of geography, primarily the census tract. Summary data at the tract level are made available to REDEX users. However, each agency can maintain a private or special data base, containing comparable data of a confidential nature or of no interest to other REDEX users. Summary statistics are made available through computer printouts or maps, on magnetic tape, or at a terminal.

Cost and funding

The cost of automating various files is borne by individual agencies. For example, the development of a manpower planning component was financed by a special CETA grant. The local health systems agency has funded the processing of health data. The University Computing Center provided computer resources for file storage and maintenance.

Applications of the GBF/DIME-File in Public Works

As local governments continue to automate their administrative files, the GBF/DIME System will play an increasingly important role in the day-to-day operations of many city departments. The system permits cities to geographically reference data to such standard areas as tracts and blocks, or to areas of a specialized nature that are useful to a single department. These areas include sanitation districts, maintenance zones, or catchment areas.

The following examples illustrate how the DIME files, in conjunction with automated procedures, have helped several cities deliver public services more effectively and at a lesser cost than was previously possible using manual methods.

An innovative street maintenance system in Kansas City, Mo., maintains information on each street segment in the city. The DIME file provides the geographic reference needed in this application. Additional features enable the city to determine those streets that can be resurfaced within existing funding levels.

A landscape maintenance system, which uses the DIME file as a geographic reference, enables Charlotte, N.C., to process information on the city's 50,000 trees and 150,000 planting areas.

Houston, Tex., has developed an online system for locating water main breaks. The DIME file is used to geographically reference calls for service and to verify addresses.

Two final applications illustrate how the DIME files were used in an analysis of existing water supply systems. The New York City study pinpointed potential problem areas where water mains were likely to break and where pipes should be replaced. The Albany, Ga., study enabled that city to plan for increased demands on the system and for potential system expansions.

Kansas City, Mo.: A Street Inventory System

The Public Works Department of Kansas City, assisted by the City Development Department, uses the GBF/DIME-File as the basis for automating and maintaining an inventory of all street conditions in the city. This inventory has been used since 1977 to determine the best allocation of highway repair funds.

System development

Information on street conditions and characteristics was previously maintained on approximately 25,000 index cards; changes to the inventory were simply handwritten onto the cards and the old information crossed out. The new file contains the following information for each street segment:

- Classification, such as east trafficway, west trafficway, private street, or State maintenance
- Type, such as asphalt, brick, concrete, or dirt
- Rating of quality, with a 1 being the worst condition and a 99 the best
- Length/width of the segment in feet (allowing for calculation of area)
- Maintenance history (whether the street was resurfaced or slurry sealed, and the year of last maintenance)

Information from the GBF/DIME-File includes the street name, type, address ranges, nodes, and tract numbers. Additional geocodes—the maintenance district, the construction district, and the councilmanic district in which the segment is located—were added to the street inventory file.

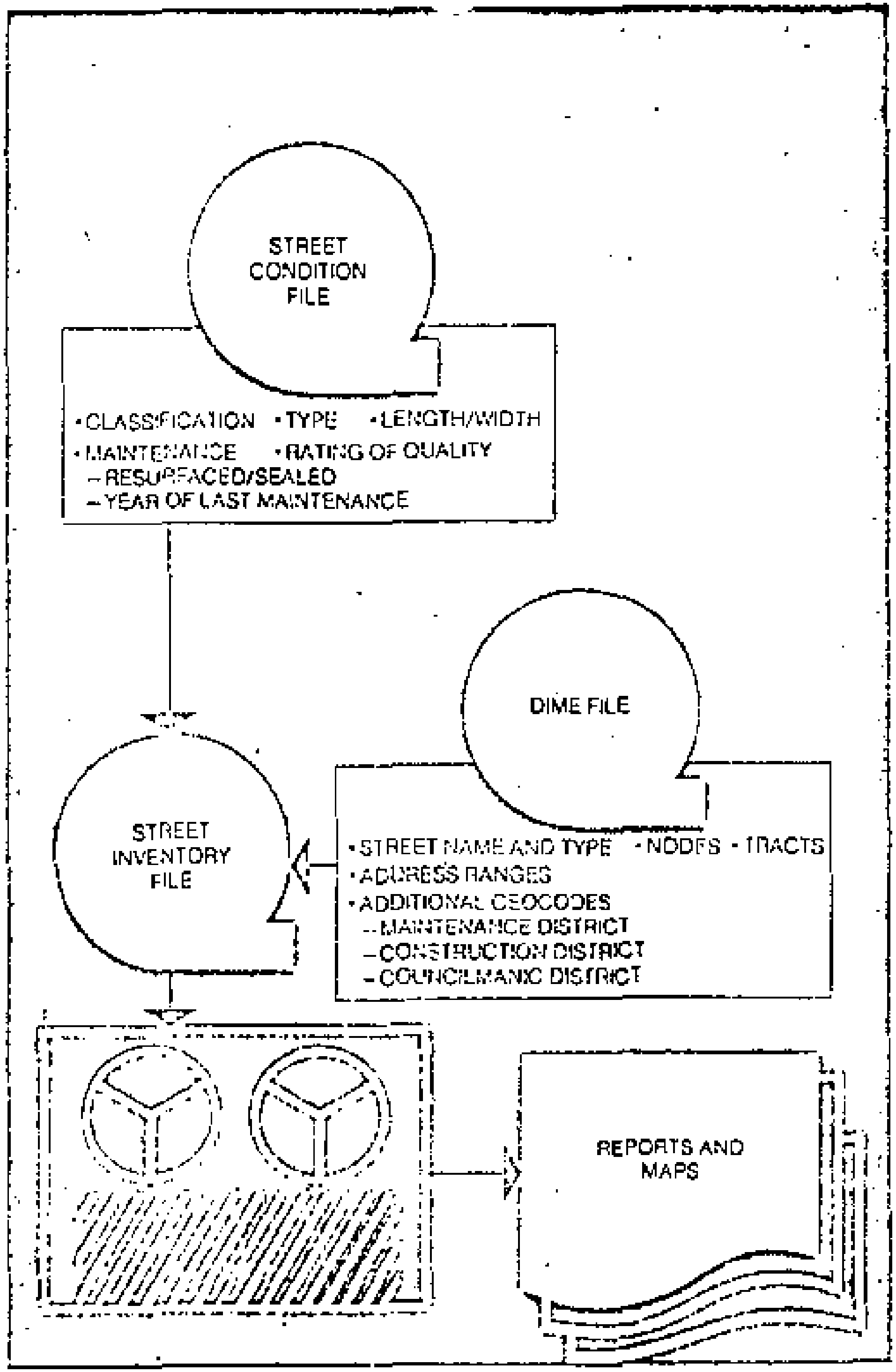
The inventory is updated annually. Coding form sheets with information about each segment are generated by

Applications

The Tucson Water Department had its customer billing file run against the GBF/DIME-File to attach ZIP codes. ZIP codes are needed on the mailing addresses to qualify for presorted bulk mailing rates. This run saved the department approximately $14,400 per year in postage.

A random sample of Tucson library patrons was geocoded to determine whether patrons reside in the city of Tucson or in Pima County. The percentage of city versus county patrons is used to determine the portion of the library's operating budget that is to be paid by the county.

Kansas City, Mo., uses the DIME file to geographically reference information on the city's streets and roadways. The street inventory file combines basic locational information, such as street name, address ranges, and node and tract numbers, from the DIME file with information on street segment conditions and characteristics including the type of paving, the length and width of the segment, and the year and type of last maintenance. Various reports and maps are produced on a regular basis.



the computer for each census tract. Field inspectors, generally with a tape recorder or dictaphone, drive the assigned street and evaluate its condition or note any discrepancies in the information provided. The information is later transcribed and the new information is added to the automated file. The initial programming and keypunching of the file required an estimated 306 staff hours. An additional 40 to 60 hours per year of keypunching is required to maintain the system.

System description

Programs have been developed to sort the file by any number of informational items and to generate the desired information, for example, a listing by census tract of unimproved streets rated 20 and below. The file can also be sorted by year of last maintenance, by councilmanic district, by classification, or by various rating ranges.

The system can also be used to determine the number of streets that can be resurfaced using currently available funds. The Public Works Department supplies information on current funding levels and current prices for street maintenance materials. Since the length and width of each street segment are already in the file, the cost of resurfacing with a 3-inch overlay of new asphalt can easily be determined for specific streets. A program first computes the cost of resurfacing those segments rated 20 and below and then those in better condition until the stipulated funding level is reached.

Map is an integral component he street Inventory system. Pen-plotter maps are produced showing streets below a certain rating or by maintenance history.

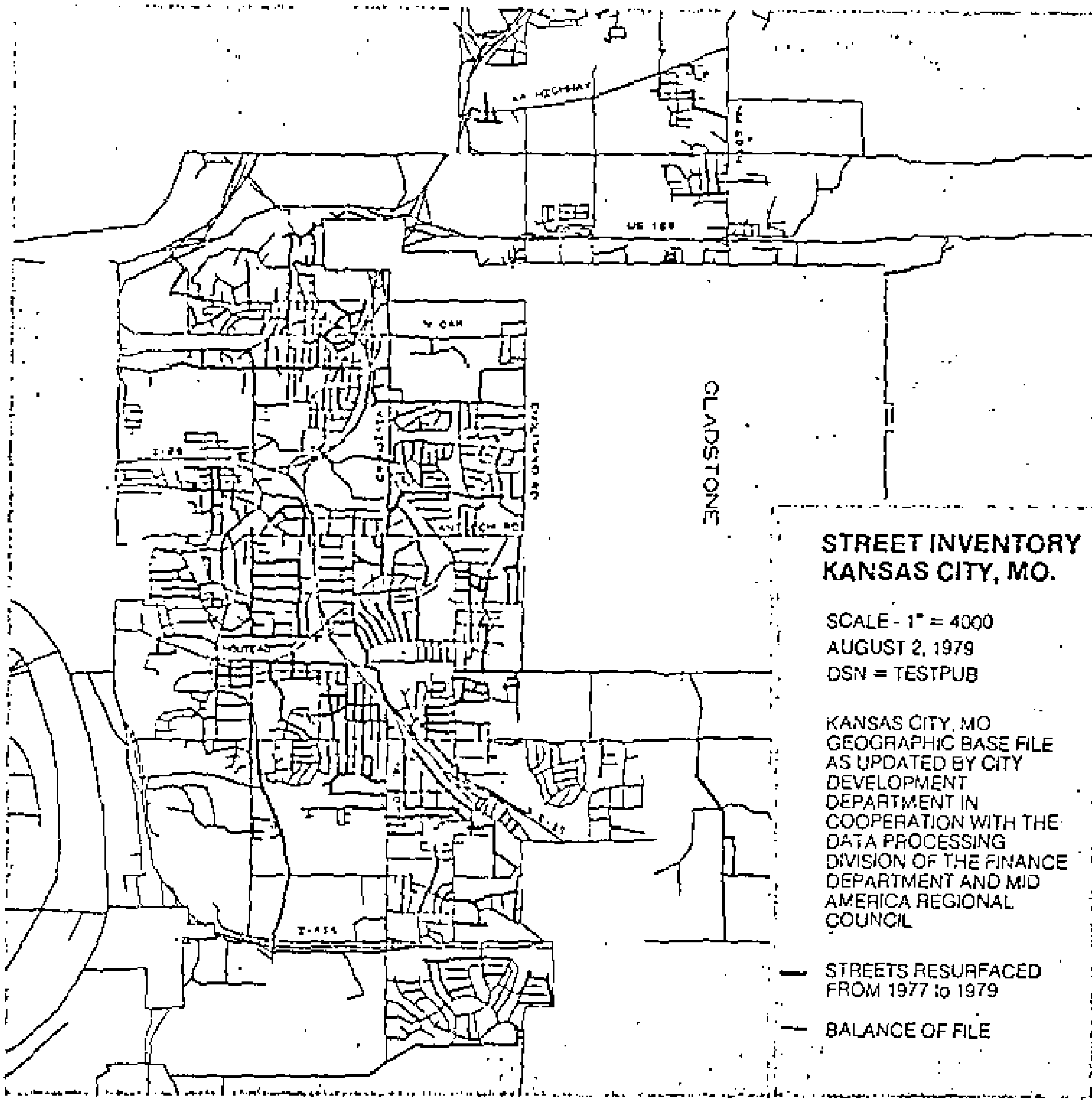
Maps have also been produced on a pen plotter using different colors to show improved or unimproved streets or those below a certain rating. These maps are used for planning purposes or when the entire city street network needs to be reviewed or analyzed.

The system has been used successfully for the past 3 years. The use of the system cut the time required to formulate and maintain street repair and restoration programs in half.

Charlotte, N.C.: A Landscape Maintenance System

Charlotte is using the GBF/DIME-File as part of a landscape maintenance system that enables the city to process information on its trees and planting areas and to determine priority areas and levels of maintenance.

The basis of the landscape maintenance system is the city's Engineering Street Index System (ESIS), which is described in the "Integrated Information Systems" section. The ESIS combines street segment information from the GBF/DIME-File with simi-



Computer Mapping

The display of various data on maps can be especially useful for understanding the geographic implications of data for an area, whether that area be a city, a neighborhood, or an entire metropolitan area. For displaying large amounts of data, maps are visually clearer and more informative than columns of numbers. Maps are particularly useful, not only for planning and analysis, but for administrative and public information purposes as well. Moreover, displaying data by computer mapping can cost substantially less than producing maps manually. The GBF/DIME-File is especially suited for computer mapping since it can be used to geocode the data to be mapped and the coordinates in the file can be used to create the boundaries of the areas to be represented.

Cincinnati, Ohio, regularly uses a commercially available mapping program to produce maps of basic neighborhood indicators such as number of housing units, occupations of family heads, new construction, and number of vacant problem buildings. The maps are used by several city departments for analysis and program planning.

The San Bernardino County, Calif., Environmental Improvement Agency has mapped assessed housing valuations by block. The maps help to define areas of low- and moderate-income households that would be appropriate targets for Community Development Block Grant funding. Housing values as reported in the 1970 census were correlated with 1970 income levels. After adjustment for inflation in specific areas, this housing/income correlation was applied to 1977 housing values, thereby identifying areas with a large number of low- and moderate-income households.

The Denver, Colo., Regional Council of Governments collects burglary data from each jurisdiction within the SMSA on a monthly basis. The data are matched against the GBF/DIME-File, and block codes and State plane coordinates are added to the original records. Data on the number of burglaries per block are then plotted for each police jurisdiction.

Kansas City, Mo., produced a computer-generated map to show ambulance response times for 25,000 calls for service. The map was used to determine areas that could be served best by additional emergency vehicles. Additional information on this application is provided in the "Delivery of Emergency Services" section of this report.

Four basic elements are required to produce maps by computer:

- A data file with data already aggregated to points or geographic areas
- A boundary file in which the boundaries of the areas to be mapped are expressed in coordinates (latitude and longitude) or a point file in which the coordinates of the points, such as the centroids of census tracts, are known. The coordinates for an area or point can be determined from the GBF/DIME-File.[3] Some boundary and point files are already available.[4]
- Appropriate computer hardware and supporting graphic devices
- Appropriate software

Computer Mapping Hardware and Software

Types of maps that can be produced are determined primarily by the type of mapping hardware available to a local agency. There are three basic methods of map production:

- Line printers produce maps by printing and overprinting letters and characters to approximate data values and densities. Aggregated data can be assigned to a point or an entire area can be shaded.
- Pen plotters draw actual lines to represent boundaries or data values. A pen or several pens with different colors of ink move over a piece of paper or other drafting surface to produce a map.
- Cathode ray tubes (CRT's), similar in appearance to a television screen, are used primarily for interactive analysis and are especially suited for computer graphics. Maps can be produced on a screen and altered as necessary. Any permanent output, however, must be photographically processed or plotted on some graphic device.

Computer mapping software has been developed by the Census Bureau, local agencies and organizations, and various commercial and nonprofit sources. Programs available from the Census Bureau include two line-printer programs, GRIDS and EASYMAP, that are described in appendix B.

EASYMAP, an easy to use computer mapping program, is available from the Bureau of the Census. EASYMAP produces shaded-area (choropleth) maps and can display data values and text in the center of each area, and borders and block-letter titles in the map image.

[3] Some additional software is usually required to reformat boundary files before they can be used for mapping purposes. A program known as EASYCORD is available from the Census Bureau for this purpose. (See appendix B.) It can also determine the center point of an area.

[4] The boundaries of all counties in the United States are available on the DIME CO File. The boundaries of 1970 census tracts in major metropolitan areas are provided on the Urban Atlas File. Centroids of 1970 enumeration districts and block groups have been calculated on the MED-LIST; the 1980 version of this file will be known as the Master Area Reference File. The PICADAD file lists coordinate information for several thousand places in the United States.

Computer Mapping Costs

The bulk of the time and effort required for computer mapping is spent in geographically coding the data and manipulating the data to fit the available equipment and programs. Additional time is required to develop a boundary file. In a study conducted by the Census Bureau, it was determined that about 80 percent of the time spent on computer mapping activities was devoted to preparatory stages and only 20 percent spent on actually testing the programs and producing the maps.[2]

Computer mapping is cost effective when an agency needs to produce many maps of the same type. The larger the data file to be mapped and the more files to be processed, the more economical it is to produce maps by computer. An agency that produces only a few maps a year, but needs to display a large quantity of data, or an agency that requires a large quantity of similar maps would probably benefit from computer mapping.

Major cost considerations are the hardware and mapping devices required for the type of map desired. Maps produced by line printers, usually available in most agencies, are not dependent upon additional hardware. Pen plotters may range in price from several thousand dollars to several hundred thousand dollars. CRT's suitable for mapping purposes would cost a minimum of $7,500, including the hardware to produce hard copy.

Although start-up time and costs would not be cost effective for just one map, once the software and the boundary file are installed, the cost per map is generally less than $100. The actual cost would depend upon the method employed. For example, large 4' x 6' line printer maps can be produced in minutes using the EASYMAP program for a little more than $10 each.

[2] U.S. Department of Commerce, Bureau of the Census, *Computer Mapping*, Census Use Study Report No. 2 (Washington, D.C.: 1969), p. 2.

Resource Allocation

The GBF/DIME-File has been used by local governments to determine the distribution of available resources (i.e., resource allocation). One type of resource allocation problem involves the delivery of services. Any analysis of this problem must consider the location of facilities in relation to potential users of the service. In some instances, the consumer travels to the facility for the service (e.g., citizens going to election polling stations to vote). In other cases, the facility's staff travel to consumers to provide the service (e.g., emergency ambulance paramedics driving to a home to render medical services). The analysis does not depend as much on whether the consumers must travel to the facilities or vice versa, but rather on the relationship between the location and number of consumers versus the location and size of the facilities.

The GBF/DIME-File offers several capabilities that can be applied in resource allocation analysis. It can be used to geocode addresses of consumers and facilities, and the coordinates in the file can be used in the calculation of distances. The production of computer maps, which may be required as part of the analysis, can also be facilitated through use of the DIME file. Software to perform most of these tasks is available from the Census Bureau. Additional programs needed to perform various calculations such as minimum path determination and interpolation are available commercially.

In many applications involving resource allocation, the straight-line distance between any two points is sufficient, even though the actual route would be along streets or walkways. This type of distance measurement is the easiest to apply and does not require excessive resources or staff expertise. However, other applications may involve more precise measurement and the actual path to be used would have to be considered. This type of analysis is described in the section entitled "Network Analysis."

Examples of Resource Allocation

Local school districts in Pennsylvania are partially reimbursed by the State for expenditures incurred in busing students who live more than 1½ miles from their schools. To assist the Philadelphia School District in identifying the eligible students, the regional planning commission calculated the coordinates of each school location and the centroid of each block in the city, using the coordinates in the GBF/DIME-File. A computer program was developed to determine the blocks that fell within the 1½-mile radius of each school. Since the school district regularly matched its enrollment file to the DIME file to append census tract and block codes to each pupil record, it was an easy task to list the students in those blocks outside the 1½-mile limit.

The Health Systems Agency of San Diego and Imperial Counties wanted to identify geographic areas that were inadequately served by physicians of different specialties and to locate areas having an abundance of doctors. This information would be used to aid in recommending office locations for new physicians and to identify inadequately served areas so that community organizations located in these areas could apply to the Federal Department of Health and Human Services for free services of a National Health Corps professional for a 2-year period. The DIME system was used to geocode the primary office addresses of available physicians. The coordinates of the nodes of the street segment were appended to each record. Other software interpolated the address, matched the address to a gridcell, and generated the grid network maps that were used for the analysis. More detail is provided in "Physician Need Study" in the section on applications in health care planning.

Los Angeles, San Francisco, Baltimore, Indianapolis, and other cities have used the DIME file and a program known as CARPOL* to print out a list of potential carpoolers for each employee who completed an application form. The program considers whether the applicants live near each other and work similar hours. The DIME system is used to geocode each applicant's address and append the appropriate census tract code to the record. If potential carpoolers do not work at the same site, the place of work would also be geocoded. The program can determine those census tracts that fall within a specified search radius. If the listing of the potential carpoolers residing and/or working in those tracts is below a specified minimum number, the search radius is increased to include applicants residing and/or working in adjacent census tracts.

*Further information on this program is available in appendix B

Local Criteria

In most applications of resource allocation, locally determined criteria must be considered. These criteria include a facility's capacity and accessibility.

Accessibility can be based on many different measurements, such as walking distance, driving time, or number of cross streets to the facility. For example, a local school board might consider a school as being accessible to students if it is less than 1 mile away from their homes. On the other hand, another school board could define accessibility in terms of driving time, e.g. no more than a 20 minute bus ride to the school.

The capacity of each facility may also be a part of a locally determined criterion. For example, in establishing school catchment areas, the number of students in different grade levels is generally considered so that the capacity of a given school and individual grades is not exceeded.

Geographical Level of Detail

The geographical level of detail is an important consideration in any resource allocation problem. In some applications, census tracts, even though they vary in size, are a reasonable choice. Other times, it may be desirable to select a smaller geographical area such as a census block group or block. Other commonly used areas are gridcells, equal-sized, usually square, geographic units which have the advantage of remaining constant over time, and allow the user to select the most appropriate size for a particular analysis. Sometimes, the exact locations of the consumers and facilities must be determined to analyze the problem.

One of the factors involved in deciding the geographical level of detail is the degree of precision needed. In situations involving matters of life and death such as deciding where to house an emergency ambulance, a determination of the exact recommended location would be desirable. In carpooling, census tracts would be of reasonable size to prepare a list of potential carpoolers.

Network Analysis

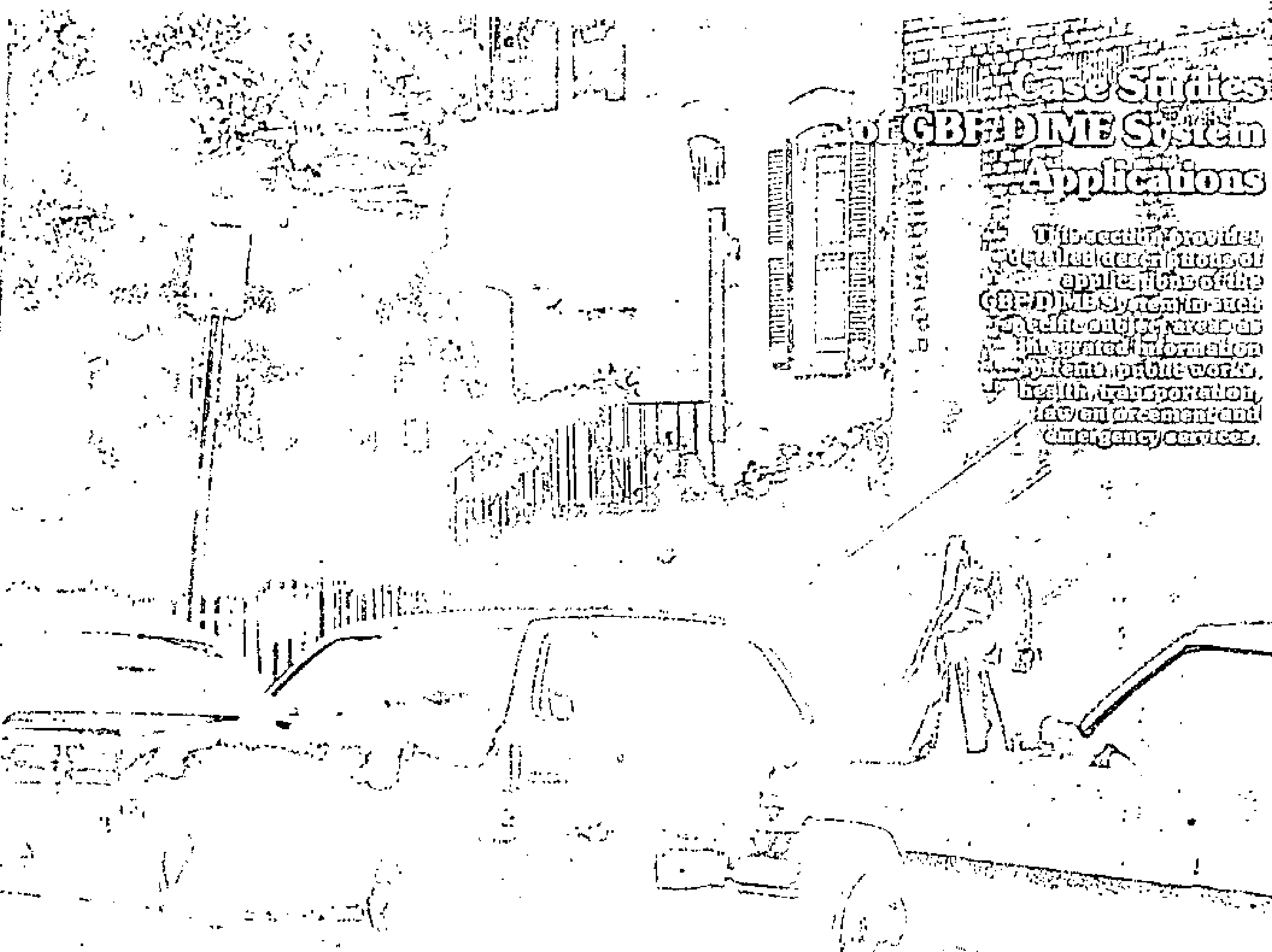
Network analysis, a specialized resource allocation technique, is concerned with actual paths [illegible] along a street or walkway network between consumers and facilities, rather than an imaginary straight-line distance. The DIME file can provide an automated version of the street network required for such analysis. Network analysis can be applied to the same types of problems discussed above; however, the analysis would be more complex and the results more precise. The geographical level of detail would normally be the exact locations or block faces of consumers and facilities.

A basic component of network analysis involves the determination of the minimum path between facilities and consumers. Even though the actual route traveled by a consumer may differ from the minimum path, the difference is assumed to be inconsequential for the analysis. Various measurements could be used to determine the minimum path, e.g., walking or driving distance, walking or driving time, and number of cross streets. The particular type of analysis would determine which measurement is most appropriate. Walking distance may be most appropriate in locating a school facility. On the other hand, driving time would probably be chosen as the measurement to be used in fire company dispatch systems.

Examples of Network Analysis

The San Jose, Calif., Fire Department needed to update and evaluate its fire alarm assignment file. This file had developed in a piecemeal manner over an extended time period. The National Fire Protection Association worked with the San Jose Fire Department to develop a system to perform these tasks in a systematic and timely fashion. The GBF/DIME-File was used to assign coordinates to the street intersections of the travel network and to determine the minimum driving time from the fire stations to each intersection. More information on this application is provided in the section entitled "Delivery of Emergency Services."

The San Diego Transit Corporation analyzed subregional transit areas in terms of existing service, service needs, potential ridership, and social and demographic characteristics of area residents. A transportation network evaluation system (TRANES) developed by the San Diego Comprehensive Planning Organization and a private contractor was used as part of the analysis package. TRANES was used to estimate the loss in potential ridership if certain bus stops were eliminated from a bus route. Potential ridership for alternate bus routes was determined by measuring the walking distance from the far end of each street segment (within specified accessibility limits) to the closest bus stop. To determine the minimum path, the DIME file was used to calculate distances along walkway networks. More information on this application is provided in the section on applications in transportation planning.



Case Studies of GBF/DIME System Applications

This section provides detailed descriptions of applications of the GBF/DIME System in such specific subject areas as integrated information systems, public works, health, transportation, law enforcement and emergency services.

Integrated Information Systems

The GBF/DIME System is used in several cities as an integral component of a city- or area-wide information system. Developments in four cities that have functioning systems—Springfield, Mass.; Cincinnati, Ohio; Charlotte, N.C.; and Tucson, Ariz.—are discussed in this section in terms of general features, informational content, capabilities, funding and costs (if available), and applications.

The information system supported by the GBF/DIME System may be an informal consortium as in Tucson or a fairly structured approach to data base management as in Charlotte. The rationale behind the development of systems in these four cities is that data routinely collected by one municipal department are often useful to other departments with different functions. That maintenance costs can be spread over several departments is an additional consideration.

These systems, while differing somewhat in their approaches, organizations, and capabilities, have several features in common: Regularly collected administrative files are geocoded, the data are tabulated to some small geographic level, and the summarized information is available to one or more agencies.

Springfield, Mass.

The information system in use in Springfield has evolved since 1969 as administrative files have become automated. There are six cooperating agencies—the Housing, Assessor's, and Building Departments, the Historical Commission, the Redevelopment Agency, and the Planning Department, which is responsible for the development and maintenance of the system. The Planning Department also provides information from the data base to public and private agencies and to residents for various purposes and uses. Most Federal grant applications submitted by the city use data derived from the system.

Informational content

The basic geographic unit in the system is the parcel. A master record file created from the assessor's files is geocoded once. As additional information becomes available, it is added to the master record. Each parcel is assigned a unique 9-digit parcel identifier, the first five digits of which identify the street. The GBF/DIME-File provides the geographic reference needed to relate the data contained in the master file to geographic areas such as block, block face, or census tract.

There are three real estate-related subfiles in the system—a real estate file, a property sales file, and a business file. A separate file, also maintained by the Planning Department, contains geocoded ambulance trip data.

The records in the real estate file are created by the Assessor's Department and include information on ownership, square footage, and value. These records are initially geocoded and the parcel identifier and other geographic codes are appended to each record. Historical district code, zoning classification, land use, housing conditions and other data are obtained from other city departments. The master real estate file is maintained through four computer terminals in the Assessor's and Planning Departments.

Data on housing conditions are regularly updated via a windshield survey and entered into the file. Each structure in the city is field checked approximately every 12 months to determine its condition based on eight observable structural characteristics.

The property sales file uses the same parcel identifiers as the real estate file. It is maintained by the Planning Department and contains sales transactions for the preceding 18–24 months recorded at the county Registry of Deeds.

A subfile has been created from the real estate data base for most nonresidential-use properties in the city. Commercial establishments, schools, and churches are included in this business file. Two types of data are recorded for each record: descriptive information such as the type of business, the type of license, and the owner's name; and information such as police and fire district, census tract code, and emergency contact name and phone number. If other information or comments, such as the presence of a guard dog on the property, which might limit investigative activities, is available, it can also be added to each record.

A separate file was created for the Fire Department. The ambulance trip ticket file contains information provided by ambulance drivers on the type of emergency, patient characteristics, care received, departure and arrival times, and the receiving hospital. About 7,700 ambulance runs are completed each year.

Capabilities

The city has developed its own software for matching, mapping, and other processing tasks. Commercially and publicly available software did not suit the particular needs of Springfield at the time, since these programs were not suited to the operational requirements of an online system. For example, the city developed a matching program that uses some ADMATCH logic but it matches parcel number to parcel number or address to address, instead of address to standard geographic

Geocoding

Geocoding costs can be measured in terms of time, money, and personnel; all of these should be considered before selecting the appropriate software. For example, there are three versions of ADMATCH. Two are written in assembly language, the third in COBOL. All are easy to operate and, given basic geocoding applications, will provide cost-effective results. On the other hand, the sophisticated procedures of UNIMATCH can result in even more significant improvements in match rates and computer efficiency when facing complex and difficult geocoding problems. The greater computational power of UNIMATCH can offset any difficulties encountered in learning to operate the system.

Of course, the condition of each GBF/DIME-File and the data files to be geocoded will be an additional major cost factor. For example, numerous errors in either file not only add to the time and expense of geocoding, they also make improved match rates unlikely when multiple geocoding runs are attempted to produce better results. Extra effort to ensure quality of all files is a major way to guard against such unnecessary costs. Finally, staff experience is a crucial factor in reducing overall costs to a minimum, regardless of which software is used.

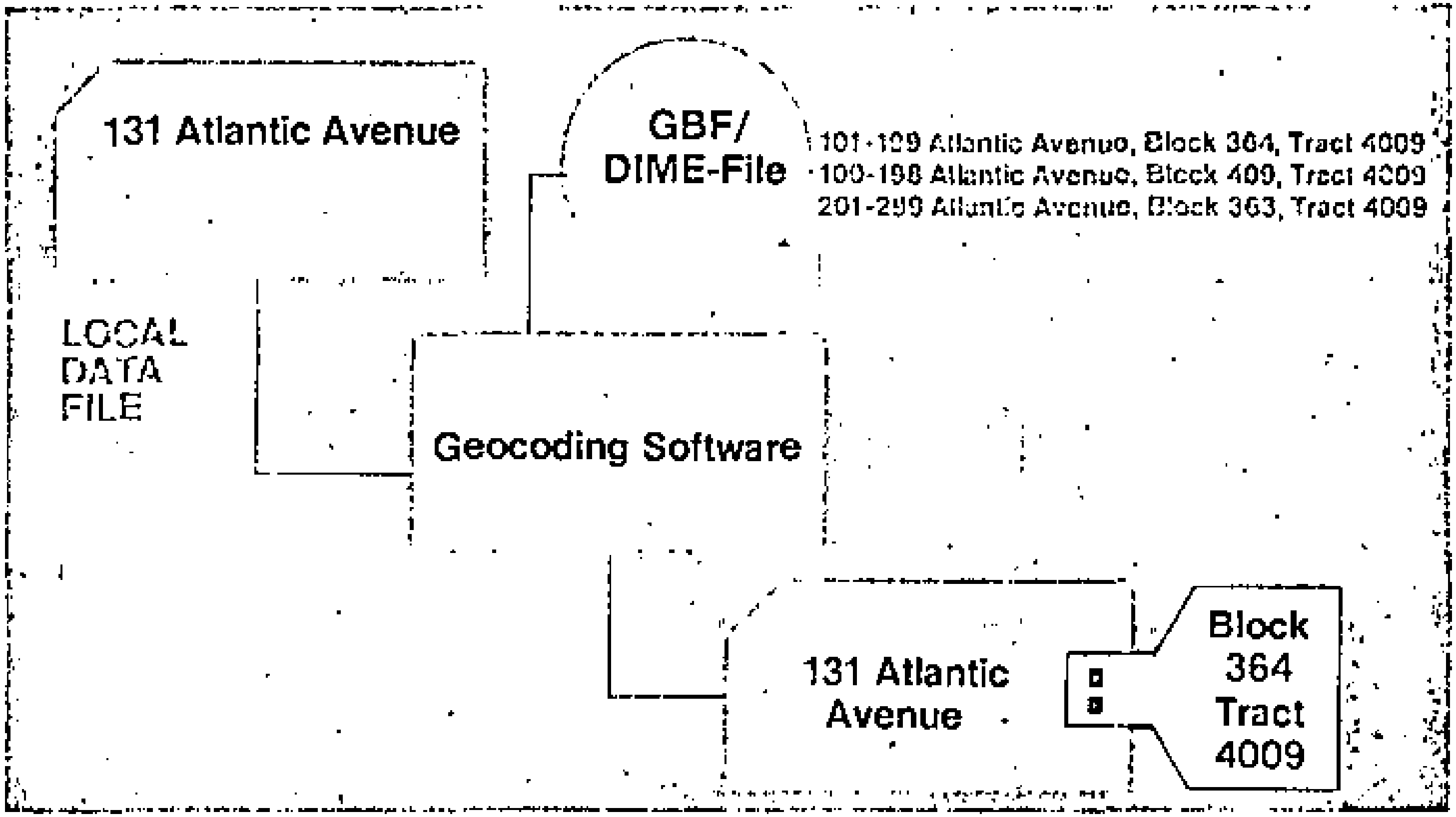
One further consideration is that the data file should be large enough to warrant automated rather than manual geocoding. When the file size reaches 2,500 to 3,000 records, it may be more cost-effective to geocode by computer.

Most agencies doing geocoding are unable to separate geocoding costs from ongoing program costs. However, the Dayton, Ohio, Office of Management and Budget estimated 1¢ per record for geocoding a file of welfare recipients.[2] Orange County, Calif., estimated an average of half a cent per record ($.004 computer time and $.001 staff time) to geocode a 50,000 record file on an RCA computer.[3] The Regional Planning Council of Baltimore calculated approximately 2¢ per record ($.0125 computer time and $.0075 staff time and incidental costs) for geocoding a motor vehicle administration file of 421,740 records using UNIVAC equipment and the COBOL version of ADMATCH.[4]

[2] U.S. Department of Commerce, Bureau of the Census, *GBF/DIME System Description and Uses* (Washington, D.C.: 1976), p. 11.

[3] Telephone conversation with Thomas L. Tousignant, County Administrative Office, Santa Ana, Calif., November 6, 1979.

[4] Regional Planning Council of Baltimore, "Geoprocessing Motor Vehicle Owner Address Records," Technical Service Report No. 20 (Baltimore, Md.: 1977).



The geocoding software compares addresses on the local data file to all possible address ranges on the GBF/DIME-File and adds the appropriate geographic codes from the best match to the original record.

Computer costs vary with the type of computer and the operating environment. CPU (central processing unit) time may offer a better measure for calculating costs. The following table shows the results of geocoding various files using the ADMATCH and the UNIMATCH/ZIPSTAN Systems.

Examples of Geocoding

Geocoding is often the initial step for many related applications. Once records are geocoded to appropriate geographic areas, the records can be tabulated and compared to other information—such as census data—at that level. The geocoded data can also be used as input to more complex applications such as computer mapping or resource allocation. Further examples illustrate the process and the use of geocoding by local governments.

In Rochester, N.Y., the Center for Governmental Research, Inc., a nonprofit research group, used UNIMATCH to geocode the Monroe County Department of Social Services 50,000-record client file using the GBF/DIME-File. The geocoded file was then used by a number of local agencies. Action for a Better Community used the data to determine the distribution of elderly households in planning the location of registration centers for elderly households eligible

Examples of Geocoding Cost Factors

Local File	Omaha, Nebr., Public Schools Census File[1]	Douglas County, Nebr., Real Property File[1]	Connecticut Department of Labor Unemployment Insurance File Extract	Albany, Ga., Water Billing File	Hartford, Conn., Medicare File	San Bernadino County, Calif., Blood Pressure Testing Station Records
Number of records	71,564	78,062	4,400	26,860	15,392	1,434
Match rate[2]	79.7%	91.7%	94.2%	78.0%	89.2%	92.0%
Computer time (CPU minutes)	3.62	6.92	.55	144.89	4.1	.10
Geographic level	Place/county	Place/county	Tract/neighborhood	Block face	Tract/neighborhood	Block
Software	ADMATCH	ADMATCH	ZIPSTAN/ UNIMATCH	COBOL/ ADMATCH	ZIPSTAN/ UNIMATCH	ZIPSTAN/ UNIMATCH
Hardware	IBM 360/70	IBM 360/70	IBM 370/158	HP 3000/System III	IBM 360/65	IBM 370/168
DIME file coverage of area	80%	90%	100%	100%	100%	100%

[1]Taken from Stephen Kinzy, *Geoprocessing in Local Government: A Feasibility Study for the City of Omaha* (Omaha, Nebr.: 1977), p. 74.
[2]Represents the number of records matched divided by the total number of records.

for assistance i payment of winter heating The United Community Chest analyzed client data to aid in the location of multi-service centers, while the Monroe County Planning Department used information about the location of social service assistance recipients to determine the allocation of Community Development Block Grant funds.

The San Bernardino County, Calif., Environmental Improvement Agency uses the GBF/DIME-File to support its residential growth monitoring system. New residential units and other data are geocoded and aggregated to geographic levels, such as tracts, cities, and school districts, using UNIMATCH. Then maps and reports are generated to show growth rates by various geographic areas. The San Bernardino County Health Department used the DIME file and the ADMATCH program to geocode address lists of pet owners who had not renewed their pet licenses; this enabled the agency to develop workloads by geographic area for personal visits by department officials. The Loma Linda University Biostatistics Laboratory used ADMATCH to code information by census tract and block for paramedic response time studies.

The Orange County, Calif., Administrative Office, in cooperation with the State Employment Development Department, developed the Industrial-Commercial Data System (INCOM), which has provided estimates of employment by industry for tracts and other statistical areas in the county since 1966. The Employment Development Department receives quarterly employment and payroll reports from every employer covered by the provisions of the Unemployment Insurance Code. These data are geocoded to the appropriate statistical level using the GBF/DIME-File. Various reports are regularly published on employment by area or by industrial group for the entire county.

In related effort, the Orange County Administrative Office geocodes some three-quarters of a million records annually. Various files from the Health Department, Social Services Department, and the Assessor's Office have been geocoded to census tracts, community analysis areas, places, or specialized districts. This information is presented in the yearly *Report on the State of the County* and is used for ongoing program analysis and evaluation. The maps, charts, and analyses that are produced assist county agencies, departments, and administrators in their annual planning and budgetary process.

Introduction

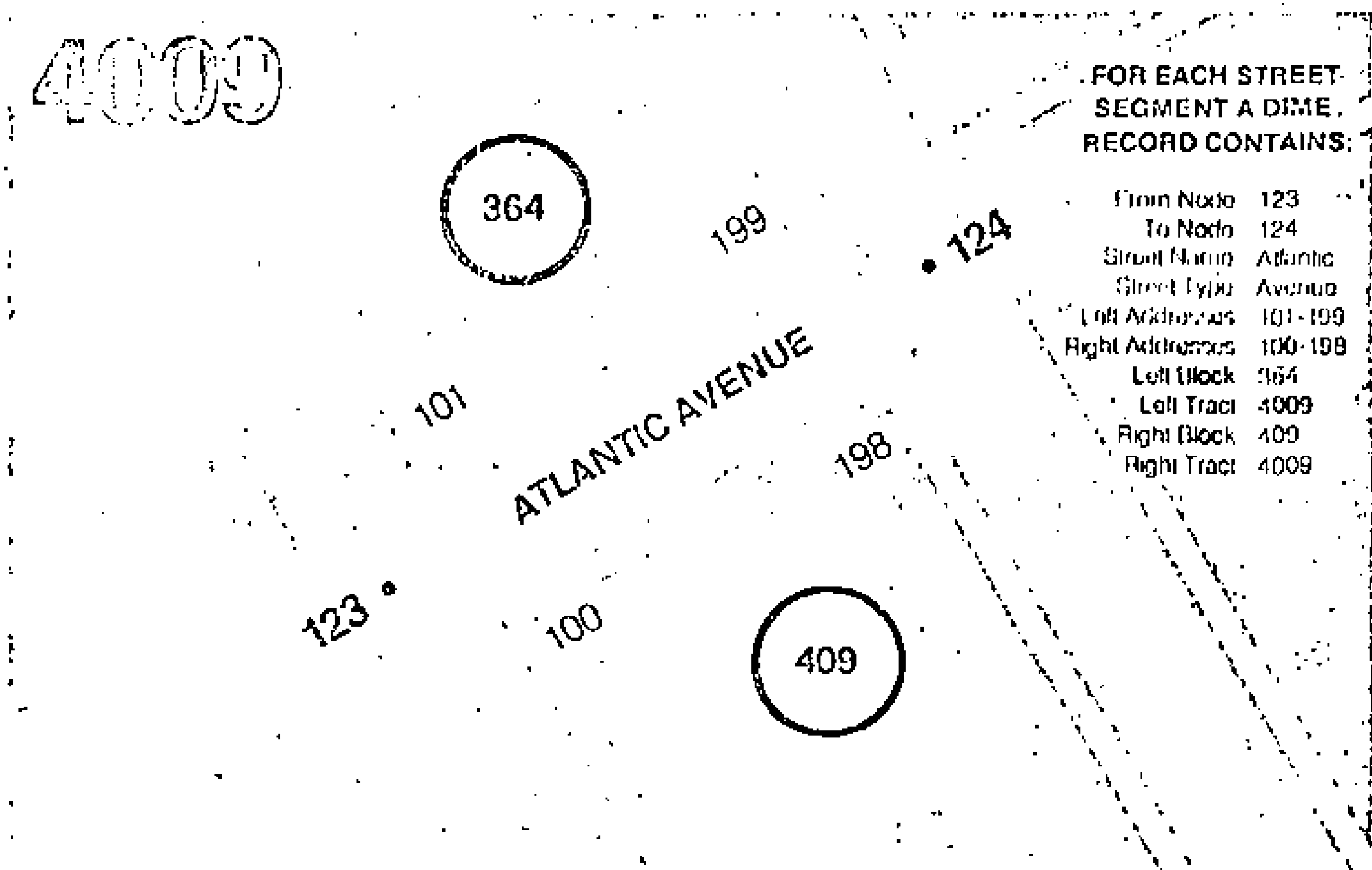
GBF/DIME stands for the geographically based computer files created through a process known as Dual Independent Map Encoding, a means of coding geographic information so that it can be easily edited by computer.

The creation of a DIME file begins with the Census Bureau's Metropolitan Map Series, a group of maps that shows the boundaries of all the political and statistical units in metropolitan areas. Address range information is also required. Information about these boundaries, areas, and address ranges must be clerically coded and entered into the computer.

Each street included in a file is divided into one or more segments, the basic components in the file. Each street segment, usually a length of a street between two intersections, is represented by a record in a DIME file. Each record contains identifiers for the end points (nodes) of the segment, the related low and high address numbers, and appropriate codes for the blocks, census tracts, or other geographic areas associated with the segment. A file can also incorporate records for such nonstreet features as rivers and railroad tracks.

Once all the information has been coded and entered on the computer, a series of computer programs enable a file to be edited for accuracy, consistency, and completeness. After various features of a file have been checked, coordinate values, such as latitude and longitude, are determined for each intersection or node. This process is known as digitizing. The coordinates facilitate computer mapping and other applications that require spatial analysis.

Each record in a DIME file contains identifiers for the end points (nodes) of a segment, the related high and low address numbers, and appropriate codes for blocks, census tracts, and other geographic areas associated with the segment.



The initial GBF IE-Files were created in the 1970's by the Census Bureau in cooperation with local agencies. Later, the Census Bureau worked closely with these agencies, usually regional planning groups or councils of governments, to ensure that each local file was correct and that subsequent changes to the street network and streets added by new housing subdivisions were included in the file. As new metropolitan areas were designated, new files were also created. In this cooperative venture, known as the CUE (Correction, Update, and Extension) Program, the Census Bureau provided the clerical procedures, technical support, and other assistance required to establish and maintain the files.

GBF/DIME System Availability
Files are available for most standard metropolitan statistical areas (SMSA's) and cover at least the urbanized areas, that is, the central city of the SMSA and the densely settled suburbs. In some instances, a file may cover the entire SMSA. These files contain all the statistical boundaries recognized for the 1980 census. Streets, street names, and corporate boundaries represented on the file are those submitted to the Census Bureau by local agencies between 1976 and 1978. Copies of the files are available from the Bureau of the Census, Data User Services Division, telephone (301) 449-1600. The file for an entire SMSA is generally contained on a single reel of computer tape and can be purchased for $80 a reel.

Individual files may also be available from local government agencies in each metropolitan area. The name of the agency and the appropriate person to contact are also available from the Census Bureau, Data User Services Division.

Software is available from the Census Bureau to carry out geocoding, tabulation, and computer mapping. Other applications may require more complex programs that have been developed commercially or by nonprofit organizations.

GBF/DIME System Applications
The Census Bureau used the GBF/DIME-Files as a primary geographic resource for the 1980 census.[1] However, the GBF/DIME-Files are also an important resource for local agencies and organizations at the city, county, or regional levels. These agencies can use the GBF/DIME-Files and related computer software to relate data from any number of local administrative or survey files that contain street addresses to geographic areas and to tabulate, display, and analyze these data.

Relating data to geographic areas, or geocoding, is the process of adding a geographic code, such as a block or census tract number, to records with addresses. The use of a GBF/DIME-File and programs for geocoding allows information from various sources to be compared using standard geographical areas for analysis.

Geocoded records can be tabulated and statistical tables produced for analysis; the data can also be mapped using the coordinates on the DIME file to describe the boundaries of the areas that are to be mapped.

More complex applications involve allocations such as school children to schools and ambulances to accident sites. The allocation could be based on a straight-line distance or could take into consideration the exact path a child or vehicle has to travel. Using the street network system described by the DIME file, the distance between two points can be determined and the appropriate school bus or ambulance assigned.

Applications of the GBF/DIME System involving geocoding, computer mapping, and resource allocation are described in the following sections. Applications of the system in such program areas as health, law enforcement, and transportation are examined in detail in the section entitled "Case Studies of GBF/DIME System Applications."

[1] See Robert A. LaMacchia, "Address Matching at the Bureau of the Census," presented at the International Users' Conference on Computer Hardware, Software, and Data Bases (Cambridge, Mass.: July 18, 1979).

Relating Data to Geographic Areas

The GBF/DIME-File and geocoding software enable a city to relate local files with addresses to geographic areas. Data can then be tabulated or mapped by geographic areas such as census tracts, school districts, or police precincts.

Geocoding usually involves adding some geographic code, such as a block or census tract number, to records with addresses.

For example, a city can geocode its assessor's file by determining which addresses fall into which census tracts and adding the appropriate census tract code to each record. This can be done manually using a map or street index or by computer using a GBF/DIME-File and geocoding software. Once tract codes are on the records, the records can easily be sorted, and information such as the number of homes per tract or the average value of homes in a tract can be tabulated. This information can be shown on a map of the city using different shadings to represent the values in each tract. The i[illegible]nation could also be compared to decennial census data to determine changes in the number of housing units or other factors. The program records of any city or State department can be geocoded in the same way, providing they contain street addresses that can be related to geographic areas.

New Orleans, La., has geocoded various local files such as the State AFDC (Aid to Families with Dependent Children) program file and the city CETA (Comprehensive Employment and Training Act) master file to produce service reports by neighborhood. In Hartford, Conn., the city voter registration file, which contains birth date information, was geocoded; program administrators used the data to estimate the number and location of elderly in the city. In Albuquerque, N. Mex., school enrollment files and building permits are regularly geocoded to data analysis subzones (groups of blocks within census tracts) to update 1970 population figures.

Three basic elements are required to geocode by computer:

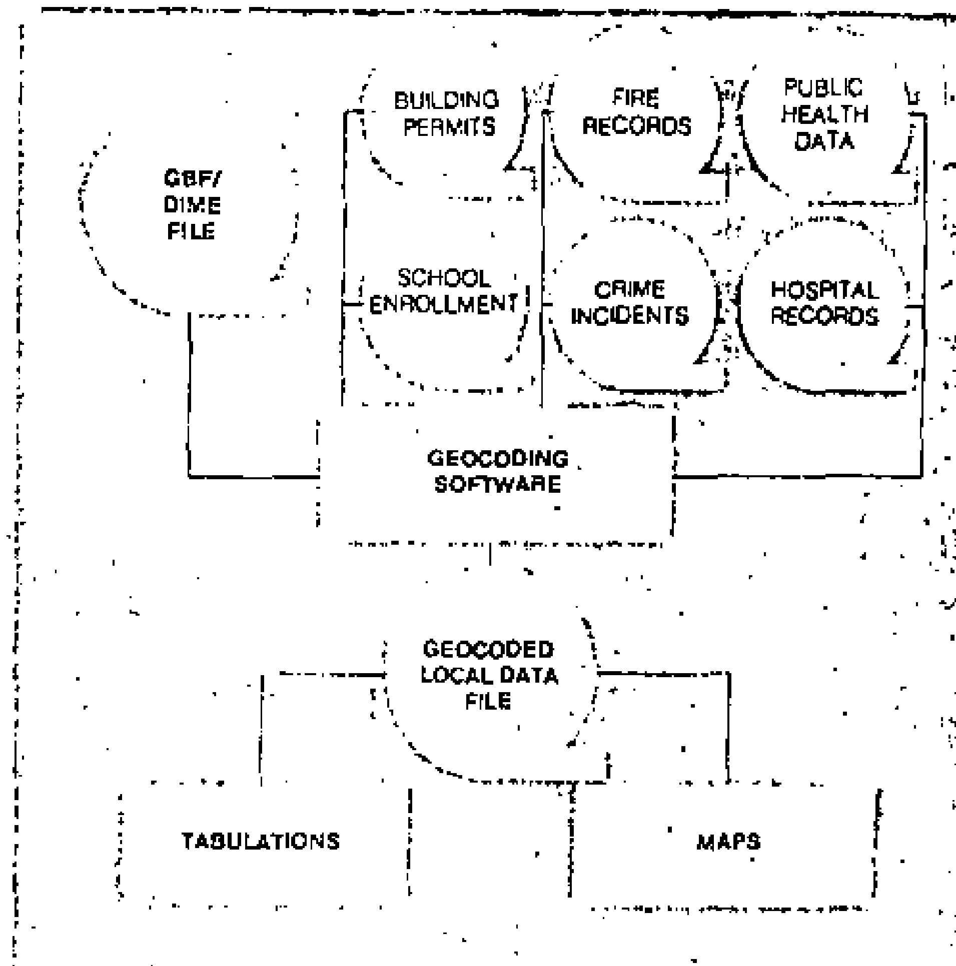
- A data file with addresses
- A reference file (such as the GBF/DIME-File) that contains address ranges and the required geographic codes
- Geocoding software to match the street address on the data file record with the address ranges in the reference file and to add the appropriate geographic codes to the data file record

Geocoding Software

Most local data file records contain street addresses; however, these addresses are frequently in a free-form format with no regard to standard street name spellings or direction or street type abbreviations. The geocoding software develops a standardized format and standardized abbreviations for street type and direction, which allows for more efficient matching. These standardized addresses are then compared to a similarly standardized reference file, in this case the GBF/DIME-File, which contains address ranges and related geographic codes. Once a match is found between the number and street on the data file record and the address range and street on the reference file, the appropriate geographic codes from the reference file are appended to the data record.

The Census Bureau has developed two geocoding programs, ADMATCH and UNIMATCH, which are publicly available and used for this purpose. ADMATCH was developed for the specific purpose of address matching. UNIMATCH was created several years later as a generalized record-linkage system that could be used not only for address matching but also for more complex applications that involve, for example, linking names or serial numbers. When used for address matching, UNIMATCH requires a second program, ZIPSTAN, which standardizes addresses on the reference and the data files.

The ADMATCH System is well documented and relatively simple to use with easily understandable basic logic. However, it is limited in the type of input allowed, the matching it can do, and its ability to handle and diagnose rejected records. UNIMATCH, on the other hand, is much more flexible in these areas and in its ability to handle building names or names that contain spelling errors. However, it is a more sophisticated system and requires more user programming experience.



The GBF/DIME-File and geocoding software enable a city to relate local files with addresses to standard geographic areas. Data can then be tabulated or mapped by such geographic areas as census tracts, school districts, or police precincts.

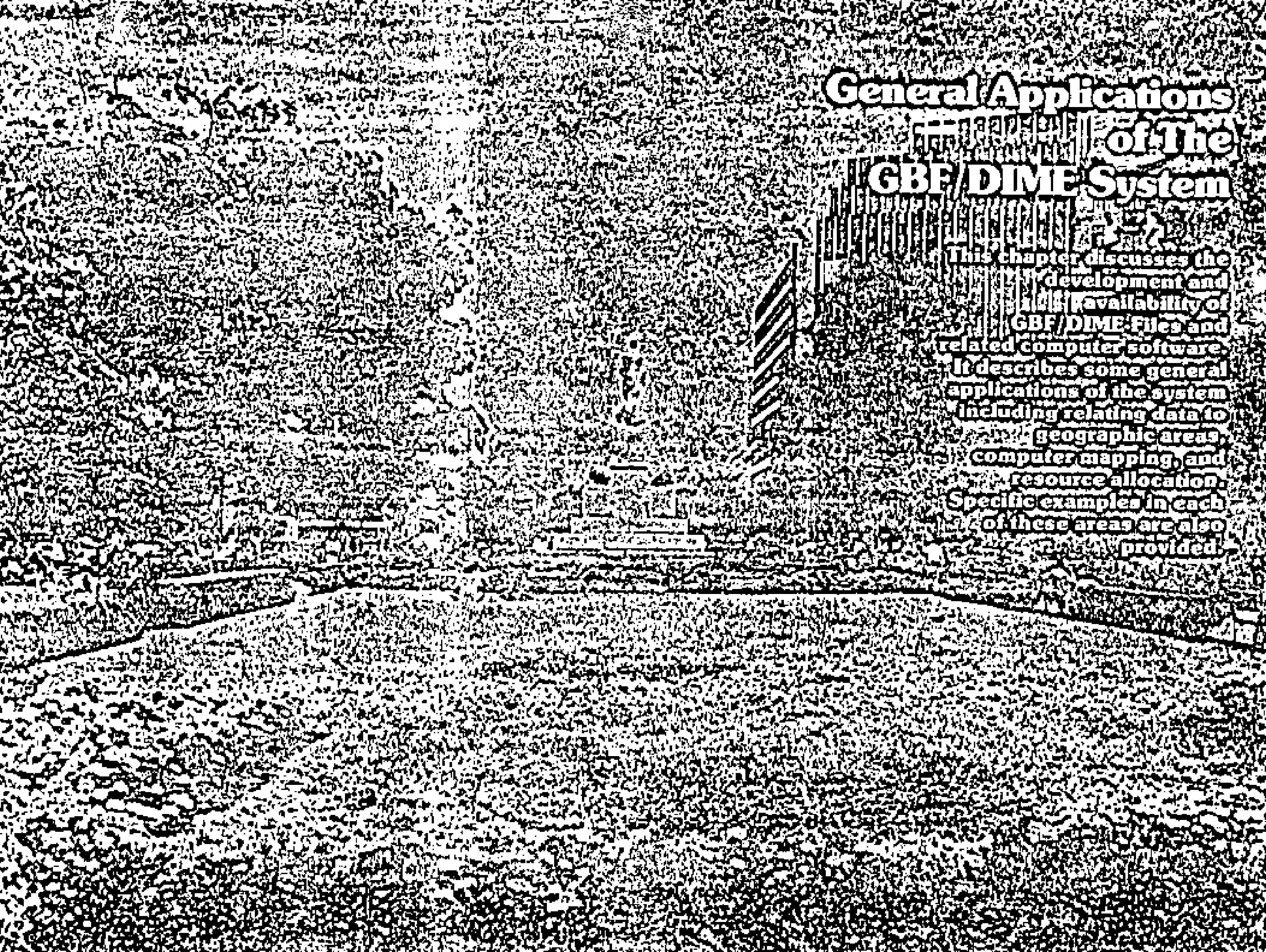
DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

COMPUTACION APLICADA A LA PLANEACION URBANA

THE CENSUS BUREAU'S GBF/DIME System:

A tool for Urban Management and Planning

Agosto, 1981



General Applications of The GBF/DIME System

This chapter discusses the development and availability of GBF/DIME Files and related computer software. It describes some general applications of the system including relating data to geographic areas, computer mapping, and resource allocation. Specific examples in each of these areas are also provided.

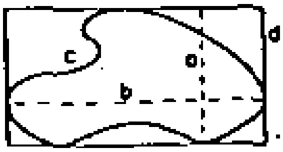


FIGURE 'BASIC RECTANGLE'

a. Minor axis of (c)
b. Major axis of (c)
c. Region.
d. Basic rectangle of (c)

The eccentricity e = b/a is always greater or equal to 1. It is a shape descriptor, although not a good one.

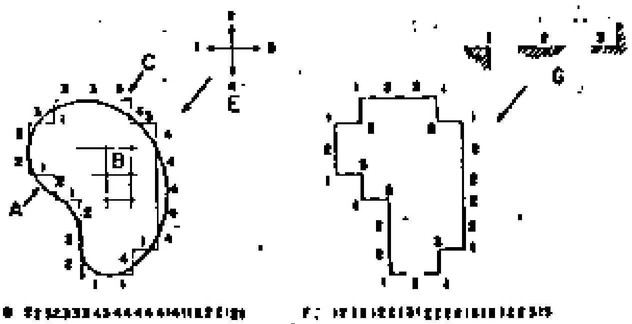


FIGURE 'CHAINS'

A: the region. B: the grid. C: the Freeman chain in four directions. D: its chain number. E: the four directions of (B) used to code (C) into (D). F: the derivative of (C). G: the three types of corners used to code (C) into (F).

1.6 The shape numbers.

This section tells how to obtain our proposed description for the shape of <u>shapes</u> and <u>regions</u>. The procedure to find the shape number of a region is as follows:

1. A grid of arbitrary cell size is overlaid on top of the region. A "black" region is formed with all the cells that fall 50% or more inside the region.

2. The boundary of such black region is the chain sought after. This chain is denoted by its derivative notation (q.v.). We collect these numbers traveling clockwise. Refer to figure 'SHAPE NUMBER'.

Observe that there are several strings of digits 1, 2 and 3 corresponding to the above chain, depending on the starting point (see figure 'SHAPE NUMBER'):

121311312131113	(A)
213111312131131	(B)
131113121311312	(C)
311312131113121	(D)
113121311131213	(E)
131213113121 31	(F)
312131113121311	(G)
121311312131113	(H)
213113121311131	(I)
131113121311312	(J)
311312131113121	(K)
113121311131213	(L)
131213113121 31	(M)
312131113121311	(N)

Observe also that one of them is a minimum, when regarded as a number in base 3: (E) in the above example.

3. Select the chain that is minimum as the chain that represents the region. In the example, it is 1 1 3 1 2 1 3 1 1 3 1 2 1 3. Observe that the minimum chain always starts with a 1, since every discrete shape contains at least four 1's.

<u>What size of grid? What orientation?</u> Unless a procedure is given that normalizes these questions and provides unique answers, a region will have several shape numbers.

The adopted posture is that the orientation of the grid will be normalized, but its size will be a parameter that will allow us to vary the precision of the shape number. Nevertheless, although

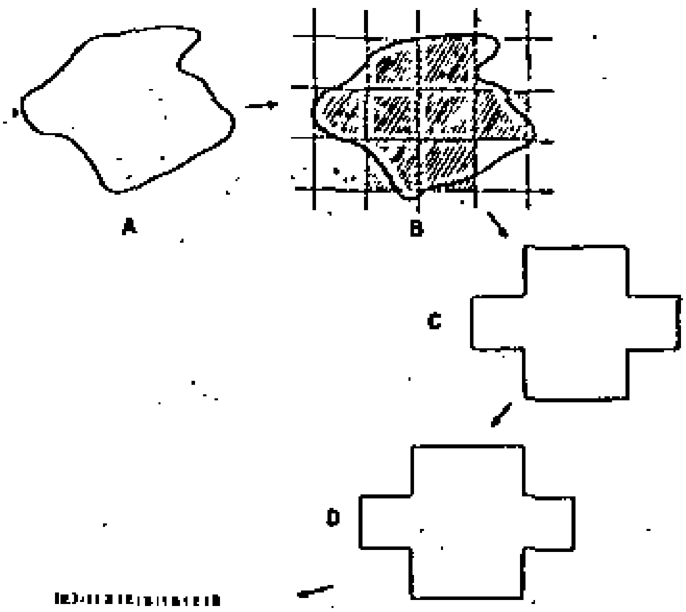


FIGURE 'SHAPE NUMBER'

(A) the continuous shape. (C) the discrete shape.
(E) the shape number.

the size of the cell of the grid varies according to the precision, the number of segments of the grid (sides of each cell) into which the region will be mapped is no longer at user's will, but it is dictated by the precision he specifies.

The orientation of the grid is not arbitrary, but it is made to coincide with the major axis of the region. The reason is clear: each region should carry along with it its own direction of the grid. In this manner, if the region rotates, the grid rotates the same amount and a code is obtained invariant under rotations.

Procedure to achieve a unique shape number. Given a region surounded by its basic rectangle, a grid of a given (fixed) size could be placed on top of the rectangle, in order to extract the unique shape number of the region. Instead, the user is allowed to tell how many digits he wants his shape number to contain. That is known as the order of the shape number.

It is clear that the same shape gives rise to several shape numbers. But, given n, the shape number of order n of that shape is unique.

Shortly a procedure will be shown to find the shape number of order n of a region, for a given n. Before that, however, the families of discrete closed shapes of several orders are presented.

All the shapes of order 4. These are all the regions that can be formed with four sticks of the same size, when they can be placed only collinearly or at 90 degrees with respecto to each other.

There is only one closed shape of order 4, the square: 1 1 1 1.

This is the most primitive or fundamental shape. Imagine you are looking at things very far away; you can not really differentiate much. All objects would look round (square, in this paper) and equal.

All the shapes of order 5. No shape number of odd order represents a closed figure. For a closed figure,

number of corners = number of sticks = order of figure.

This paper does not deal with open figures. Not all ternary numbers with an even number of digits are shape numbers. Most of them do not close.

All the shapes of order 8, 10, 12. See corresponding figures.

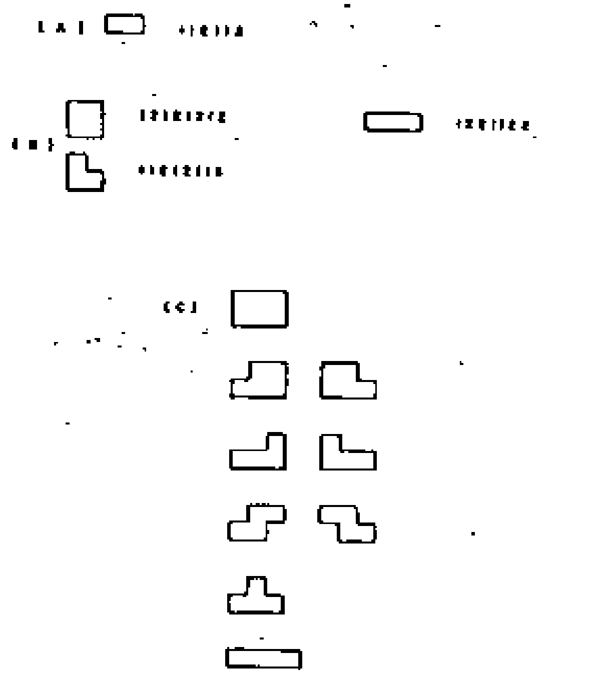


FIGURE 'ALL THE SHAPES OF ORDERS 6, 8, AND 10'
(A) of order 6. (B) of order 8. (C) of order 10.

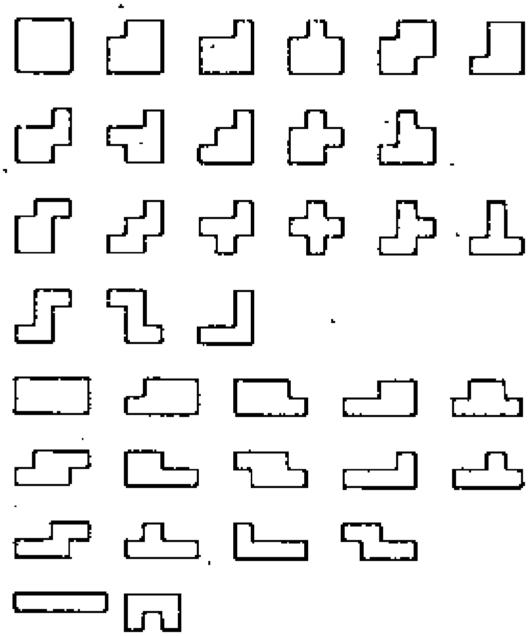


FIGURE 'ALL THE SHAPES OF ORDER 12'

II USING THE SHAPE NUMBERS FOR SHAPE DESCRIPTIONS

.1 The order of a shape number.

The order of a shape number is the number of ternary digits that the shape number contains. It is always even, because the boundary is closed.

II.2 How to find the shape number of order n of a continuous shape.

The procedure is as follows:

1. Find the basic rectangle of the region.

2. From the family of discrete shapes of order n, find the rectangle of order n with eccentricity closest to that of the region. (This is easy. For instance, for n=22, the rectangles of order 22 --those with perimeter equal to 22-- are of sides 6 by 5, 7 by 4, 8 by 3, 9 by 2 and 10 by 1).

In practice, it is better to aproximate the longer side of the rectangle instead of the eccentricity. If e = eccentricity, one can deduce that the longer side is b=(n/2)(e/1+e). Select a rectangle with longest side closest to that quantity. Lay this rectangle, centered, so as to cover the region, and make a grid of a by b square cells ("C", in figure 'FINDING THE SHAPE NUMBER OF ORDER 22').

3. Make black (=1) all those cells falling more than 50% inside the region; leave white (0, outside) all others.

boundary of this black region, expressed in the ivative notation, is the desired shape number.

Remember to write down the digits of the chain traveling clockwise, and selecting as the starting point the corner of type 1 that makes the chain number the smallest of the n possible chain numbers. An example is given in figure 'FINDING THE SHAPE NUMBER OF ORDER 22'.

Notice that the resulting shape number is indeed of order n. This will not be true if the figure has depressions (concavities) in its boundary. The depression in the boundary makes the order bigger. Each depression of depth k increases the order of the shape by 2k.

When, looking for a shape number of order n, if a number of order n+2d results, try next to look for a shape number of order n-2d. Due to the presence of the holes, the shape number n-2d will be increased by an amount equal to the "hole excess" 2d, thus yielding the desired order n. This relation

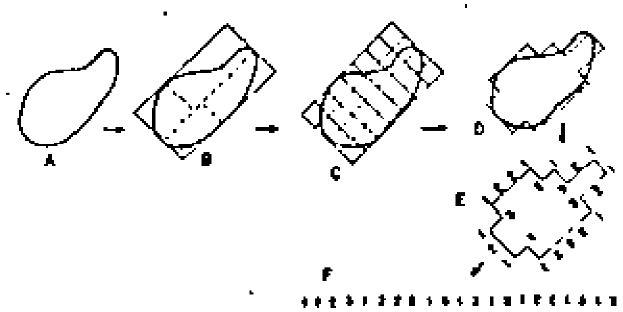


FIGURE 'FINDING THE SHAPE NUMBER OF ORDER 22'

The continuous (A) is encased in its basic rectangle (B). Given n=22, a square grid of appropriate size (see text) is centered (C) on the basic rectangle. A discrete shape (D) is obtained. The "derivative notation" (E) is found. Traveling clockwisely, the chain with the minimum absolute value (F) is the shape number of order 22 digits. (D) has 22 sides, as well as 22 corners.

holds only approximately, since the size of the holes of order n is smaller than those of order n-2d. Thus, in practice, try the basic rectangles of order n-2d, n-2d+2, n-2d+4, ..., n-2, and when we obtain a shape number of order n, that is it. See also Section II.d.

Properties of the shape number. It is insensitive to orientation of the region, to its position, to its size, and to the origin of the chain. It is therefore appropriate to think that the shape number of a region indeed describes its shape (cf. Section I.1).

Also, since it is possible to compute the shape number of a region without reference to a table of stored shapes (canonical shapes), we avoid making correlations or comparisons of shapes or of strings. That is, the shape number of a region can be deduced solely from the region.

In addition, the precision of the resulting shape number can be varied. This is done with the order of the shape number; that is, the size of the sticks (or of the grid) that we use to find it.

II.3 Shapes without shape numbers.

A shape with a thin isthmus (narrower than the size of the grid) will not yield one shape number, since the procedure of Section II.2 will split the continuous shape into several discrete shapes (Part II of figure 'DEPRESSIONS AND DEGENERATE SHAPES'). Some shapes with depressions in their boundaries may not have a shape number. This is discussed in Section III.3.d.

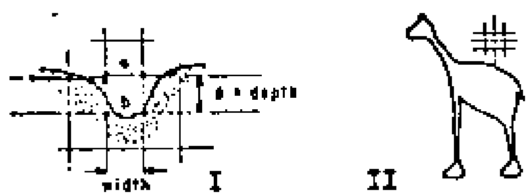


FIGURE 'DEPRESSIONS AND DEGENERATE SHAPES'
I. A depression of depth d increases the shape number by 2d.
II. Degenerate regions split the discrete shape but do not have a shape number.

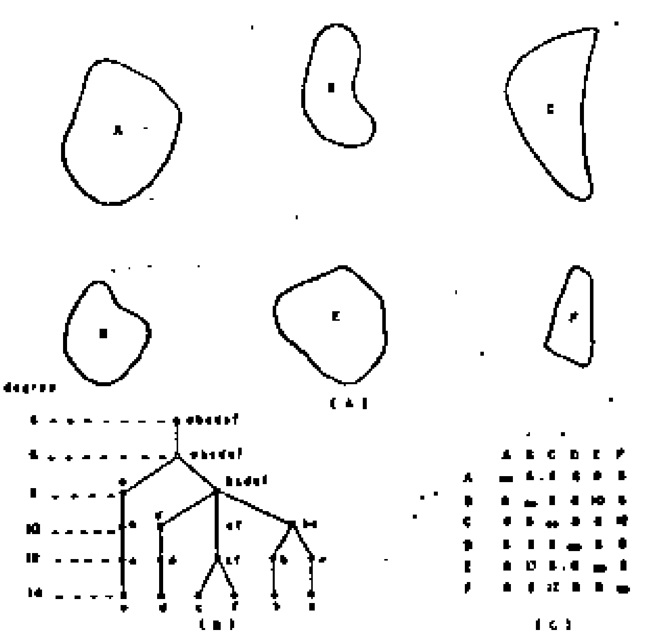


FIGURE 'DEGREE OF SIMILARITY'
(A) regions to be analyzed. (B) Similarity tree for (A).
(C) Similarity matrix for regions (A).
The shapes form a hierarchy, a tree with root at degree = 4.

III USING THE SHAPE NUMBERS TO MEASURE SHAPE SIMILARITY

III.1 The degree of similarity between two shapes.

The shape number of a region enables us to find instances of a given shape, even when distorted by enlargement or rotation. It answers the questions "Have these two regions the same shape?", up to an order n.

In practice, however, a shape rarely repeats itself, due to noise and the allowable variations (for instance, ten silhouettes of apples have similar but not identical shapes). The relevant questions to answer are "How much different are these two forms?", "How much do these two shapes resemble each other?", "Is region A closer in shape to B, or to C?". This section gives a procedure to quantitatively answer these questions.

When the shapes of two regions A and B are compared, we can notice that the shape of order 4 of A, $s_4(A)$, is equal to 1111 (the only shape of order 4), and is therefore equal to $s_4(B)$.

Also $s_6(A) = s_6(B)$; probably $s_8(A) = s_8(B)$. It is likely that their first few shape numbers be identical. The reason is that the discrete shapes are coarse and not varied at low orders, where the "resolution" is low.

Nevertheless, most likely $s_{102}(A) \neq s_{102}(B)$, also $s_{58}(A) \neq s_{58}(B)$, etc. This is expected, because, due to the finer precision at higher orders, there exists a large variety of shapes, thus the discrimination between A and B is more demanding.

Of course, if A and B were very similar (but not identical), one might need to go up to say 170 to find that $s_{170}(A) \neq s_{170}(B)$. Onthe other hand, if they are visibly different (not alike at all), already at order 10 we will find $s_{10}(A) \neq s_{10}(B)$.

Thus, as we increase the order n of the two shape numbers $s_n(A)$ and $s_n(B)$, they begin to be equal but at some order they become different from that point on. How long they remain equal gives us an idea of the similarity between the shapes of A and B.

<u>Degree of similarity</u> k between the shapes of two regions A and B: It is the largest order for which their shape numbers still coincide.

That is, it is the largest m for which $s_m(A) = s_m(B)$, but $s_{m+i}(A) \neq s_{m+i}(B)$ for all i greater than 0.

That is, we have $s_4(A)=s_4(B), s_6(A)=s_6(B), s_8(A)=s_8(B), \ldots, s_k(A)=s_k(B), s_{k+2}(A)\neq s_{k+2}(B), s_{k+4}(A) \neq s_{k+4}(B), \ldots$

If A and B are regions with degree k of similarity we write $a \equiv_k b$.

Example. For the figures of Fig. 'DEGREE OF SIMILARITY' we have for figures A to F:

$s_4(A)=s_4(B)=\ldots=s_4(F)=1111$;

$s_6(A)=s_4(B)=\ldots=s_6(F)=112112$;

$s_8(A)=s_8(D)=s_8(E)=12121212$; $s_8(B)=11212113$;

$s_8(C)=s_8(F)=11221122$;

$s_{10}(A)=1212212122$; $s_{10}(B)=1121221123$; $s_{10}(C)=1122113113$;

$s_{10}(D)=s_{10}(E)=1131212122$; $s_{10}(F)=1122121213$

$s_{12}(D)=113113121213$; $s_{12}(E)=113121221213$

Therefore, A and B have a degree of similarity equal to 6: $A \approx_6 B$. Also, $A \approx_8 E$; $E \approx_6 B$; $D \approx_{10} E$; etc.

This is represented in the figure both as a similarity tree and as a similarity matrix.

The similarity matrix is symmetrical; in fact, it is easily proved that, for arbitrary regions A and B,

(1) (Thm.) The relation "A and B have degree k of similarity" (for a fixed k) is not an equivalence relation.
(2) (Thm.) The relation "A and B have degree of similarity of at least k" (for a fixed k) is an equivalence relation.

In fact, the equivalence classes of (2) for k=10 are nine, since there are only nine discrete shapes of orden 10.

Informally speaking, the size (power) of the magnifying lens that barely confuses two regions gives the degree of similarity between such regions.

The comparison procedure could be visualized as follows: A number (a shape number of high order) is associated to each one of two regions. If the numbers are equal, the regions have identical shape. If not, another pair of numbers (shape numbers of the next lower order) is deduced, and so on until we find that the two numbers coincide. The number of stages needed is an indication of the dissemblance of the two shapes.

III.2 The distance between two shapes.

Distance. (def) The distance between two shapes A and B is defined to be the inverse of their degree of similarity. $d(A,B) \triangleq 1/k$.

Then d is an ultradistance, obeying

$$d(A,A) = 0 \qquad (1)$$
$$d(A,B) \geq 0;\ d(A,B)=0 \text{ if and only if } A=B \qquad (2)$$
$$d(A,C) \leq \operatorname{Sup}(\ d(A,B),\ d(B,C)) \qquad (3)$$

III.3 Comments on this theory of shapes.

a. No parsing is necessary. To find the degree of similarity between A and B, their shape numbers are compared for equality. Two shape numbers of different orders are inconmensurable. Two shape numbers of the same order are either equal or different. If different, that is it. There is no need to compare "how close in shape they are". String matching [2] is not needed.

   To find out the degree of similarity, a binary search is used. First see whether the shape numbers at order 8 are equal or not. Then compare the shape numbers at the highest required accuracy (say, 100). Then at the middle. Then at the middle of the remaining valid half. And so on.

b. Intuitively satisfying. Shape numbers are not invariant under reflexions (mirror images), skewing, or unequal expansion along the X and Y axes. These transformations alter what could be considered the intuitive shape of a figure. At the end of the paper a Theory "B" of shapes is presented, where the last transformation is allowed, i.e., a circle and an ellipse have the same Bshape number.

c. Occassional loop in the similarity tree. Due to noise or the 50% requirement for quantization, and at low orders, a transitory divergence and then convergence in the shapes of two regions is sometimes observed, v.gr.,

$$s_8(A) = s_8(B)$$
$$s_{10}(A) \neq s_{10}(B)$$
$$s_{12}(A) = s_{12}(B)$$
$$s_{14}(A) \neq s_{14}(B)$$
$$s_{16}(A) \neq s_{16}(B)$$
$$\vdots$$

   i.e., they were already different at order 10, but they are again equal at order 12 (however, only to separate soon forever). This still gives a unique number for the shape of a region, but makes the definition of degree of similarity less attractive, and the procedure to find it, unreliable. Only loops of size 2 (such as the example given) have been found, infrequently. These loops disappear in Theory B.

d. Non existent shape numbers. Shape number of order n may ocassionally not exist for a given figure, due for instance to symmetrical holes of type I in figure 'DEPRESSIONS AND DEGENERATE SHAPES'. This does not bother the similarity procedure, but it is a nuisance not to have that shape number.

e. Quantization of the eccentricity. The basic rectangles of order 12 have eccentricities equal to 1 (the square of 3 by 3), 2 (the rectangle of 4 by 2) and 5 (the rectangle of 5 by 1). For an object of eccentricity 1.6, one of these has to be used. An error is going to be commited in any case. There seems to be no way out of this.

A theory is now presented that has none of these problems.

III.4 Theory "B" for Shape description.

To obtain this new theory, the current theory undergoes some changes:

1. Force the eccentricity of any region to be equal to one, by performing an unequal dilation of its axes. The only discrete Bshapes that now exist are those obtained from squares. All the rectangles have disappeared.

2. Do not go into depressions (I in figure 'DEPRESSIONS AND DEGENERATE SHAPES') with width smaller than the size of the side of the cell of the grid. This avoids degenerate shapes.

   That is, if a region is "scratched" by thin lines (thinner than the size of the grid) that belong to the background, either ignore them (act as if they were not there) or else, if they can not be ignored, this theory "B" says that the size of the grid is inappropriate to describe such region, and that its Bshape does not exist at this order. Higher resolution is needed.

3. Let the depressions where the sticks do go in (because they are wider than Part 1 of figure 'DEPRESSIONS AND DEGENERATE SHAPES') generate Bshape numbers having a number of (ternary) digits larger than the expected order. That is, do not correct the anomaly that these depressions cause. The perimeter of the Bshapes no longer tells its order.

4. Eliminate the orders that are not powers of two. The only valid orders for Bshape numbers are 4, 8, 16, 32.... These numbers still indicate the perimeter of the basic square of the region.

The procedure is the following:

How to find the Bshape number of order n.

1. Find the basic rectangle of the region and convert it to a square. Declare that the Bshape number does not exist if the region has necks (isthmus) or depressions (channels, fjords) narrower than 4/n or $_2 2^{-n}$.

2. Make a grid by dividing the side of the basic square into n/4 equal parts.

3. Mark with a 1 each cell of the grid of step 2 that is more than 50% contained in the region. The collection of grid squares containing a 1 form a discrete Bshape.

4. Find the shape number of the discrete Bshape of step 3, and give that as answer (even if it has more than n ternary digits).

The order n of a Bshape number is four times the number of parts into which the side of the basic square was divided. It is also the perimeter (measured by the number of sticks) of the basic square.

It is no longer the perimeter of the discrete Bshape, nor the number of ternary digits of the Bshape number.

Given a shape, it is easy to derive its Bshape number. An example is given in figure 'EXAMPLES OF BSHAPES AND THEIR SIMILARITY'.

The degree of similarity between the Bshapes of two regions is obtained as before. No change in the definition.

Downwards constructability. Given the Bshape number of order n of a region, the Bshape number of order n/2 can be deduced from it, by regroupping appropriate sets of 4 neighboring cells into a cell for the lower order. Therefore, if two regions have the same Bshape number of order n, they will continue to have equal Bshape numbers of smaller order, until they cease to exist. This gets rid of problem III.3.c of the former theory.

Upwards existence. If the Bshape number of order n of a region exists, the existence of numbers for higher order is guaranteed, since the channels or narrow parts that could not split the shape at order n, will also be unable to split it at higher orders. This defeats problem III.3.d of the former theory.

Quantization of the eccentricity. Finally, problem III.3.e of the former theory is not present in theory B because all eccentricities are now equal to 1.

Some examples of similarity comparison using theory B are given in figure 'SIMILARITY TREE FOR THE BSHAPES OR REGIONS A TO F'.

Disadvantage of Theory "B". Squeezing along one axis is now a valid (Bshape preserving) transformation. Thus, either the application does not care about the eccentricity or aspect ratio, or this has to be carried as another parameter, in addition to the Bshape number.

Also, more care needs to be exercised now when selecting the major and minor axis, to avoid noise perturbations. It may pay to use the rectangle suggested in [3].

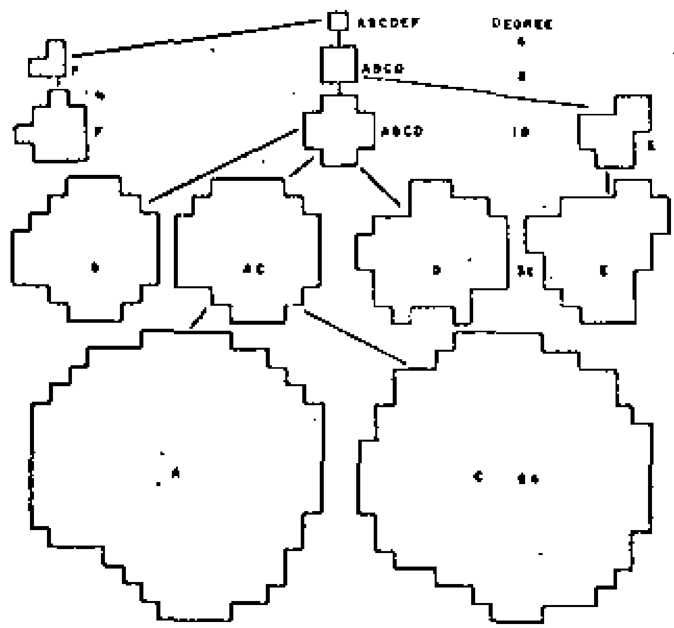
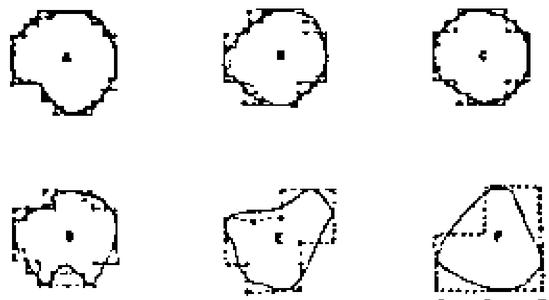


FIGURE 'SIMILARITY TREE FOR THE BSHAPES OF REGIONS A TO F'
The tree shows that the degree of similarity between B and E is 8, but between B and C is 16.



	A	B	C	D	E	F
A	[illegible]					
B	[illegible]	[illegible]				
C	[illegible]	[illegible]	[illegible]			
D	[illegible]	[illegible]	[illegible]	[illegible]		
E	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
F	4	4	4	4	4	[illegible]

TABLE 'SIMILARITY MATRIX FOR THE BSHAPES OF REGIONS A-F'

[illegible]

	A	B	C	D	E	F
A	0	1/16	1/32	1/16	1/8	1/4
B		0	1/16	1/16	1/8	1/4
C			0	1/16	1/8	1/4
D				0	1/8	1/4
E					0	1/4
F						0

TABLE 'DISTANCE MATRIX FOR BSHAPES OF REGIONS A TO F'

A and C are very together (1/32) in Bshapes. The region F is quite dissimilar (1/4) in shape to all others.

FIGURE 'EXAMPLE OF BSHAPES AND THEIR SIMILARITY'

The arrows on the figures signal the beginning of the string of order 32 or 64.

IV THE SHAPE NUMBERS OF SHAPES WITH HOLES

It is possible to assign shape numbers for regions with holes, and to use them for shape comparison and shape similarity measurement. The idea is to use the basic rectangle of the outer boundary for discretization of all the boundaries (both the outer and the inner boundaries). Using the shortest possible vertical or horizontal cuts, join the boundaries among them. Each cut reduces by one the number of boundaries. Finally, a single boundary is found. Then such a boundary can be described by an ordinary shape number. Such a shape number is then associated with the original region.

Notice that no other shape with holes could also be the owner of that shape number, since the new number has "touching edges" (those running along the cut). And since the set of cuts is unique (cf. discussion below), the resulting shape number is also unique. See figure 'SHAPES WITH HOLES'.

The procedure is detailed now for Bshapes. To find the Bshape number of order n of a region with holes, proceed as follows:

1. Find the Bshape number of order n of the outer boundary.
2. Using the grid defined in (1), find the discrete Bshapes of the inner boundaries.
3. Let a "cut" be a sequence of purely vertical or purely horizontal segments of the grid. Find the minimum spanning tree of cuts that connects the boundaries (This tree can be found as follows: (a) find the two boundaries closest to each other; that is, the two boundaries with the shortest cut joining them. That cut belongs to the tree, and these two boundaries are now joined by such cut. (b) Now, find the boundary closest to that new boundary. That defines another cut. This new cut belongs to the tree, and this new boundary is now joined (by such cut) to the former collection of boundaries. (Now we have three boundaries joined by two cuts). (c) Keep iterating (b), each time adding a new boundary (the closest one) to the collection of boundaries, and its corresponding cut to the minimum spanning tree of cuts. When all boundaries are joined, stop).

   The result is a simply connected boundary.
4. Find the Bshape of this simply connected boundary, and give that as answer.

If there are two cuts of equal length, use the cut that minimizes the resulting Bshape number. This favors cuts near the starting point of the Bshape number.

With this tie-breaking rule, the Bshape number is unique.

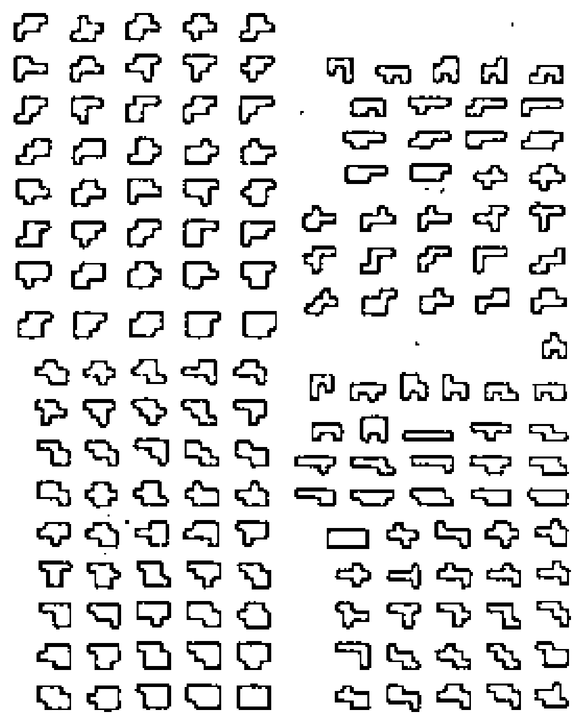
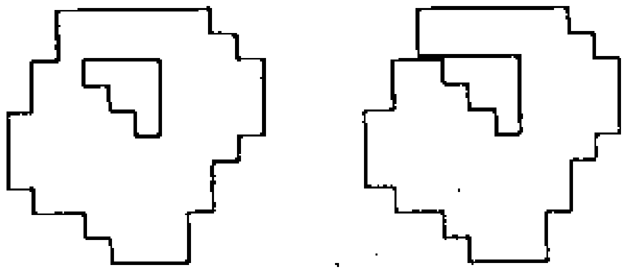


FIGURE 'ALL THE SHAPES OF ORDER 14'



A B

FIGURE 'SHAPES WITH HOLES'

To find the Bshape number of a discrete shape (A) with a hole, cut a channel across the region, so as to have a simply connected region (B); then return the Bshape of (B) as the answer. The text provides more explanation.

Conclusions

For each two-dimensional region, a shape number can be derived. This number depends exclusively on the form of the region.

These shape numbers can be found without table look up or correlation or string matching.

The shape numbers can be of different order; high orders are more accurate for shape description. Informally, the number of ternary digits of a shape number will tell its order.

The degree of similarity between two regions, introduced in this paper, permits to find out how close in shape two regions are. Two regions with shapes that look alike will have a high degree of similarity.

Informally speaking, the degree of similarity between the shapes of two regions is the highest optical resolution (power of the magnifying lens) that still confuses them.

The distance between two shapes is defined and it is found to be an ultradistance or ultrametric.

The Bshape numbers allow additional advantages and overcome some problems of the (ordinary) shape numbers.

The shape numbers of figures with holes are defined.

Suggestion for further work: apply the shape numbers to three-dimensional surfaces enclosing a volume.

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How to describe pure form and how to measure in shapes using

Shape numbers.

Agosto, 1981

HOW TO DESCRIBE PURE FORM AND HOW TO MEASURE DIFFERENCES IN SHAPES USING SHAPE NUMBERS

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The shape number of a curve is derived for two-dimensional non-intersecting closed curves that are the boundary of simply connected regions. This description is independent of their size, orientation and position, but it depends on their shape.

Each curve carries "within it" its own shape number. The order of the shape number indicates the precision with which that number describes the shape of the curve. For a curve, the order of its shape number is the length of the perimeter of a 'discrete shape' (a closed curve formed by vertical and horizontal segments, all of equal length) closely corresponding to the curve.

A procedure is given that deduces, without table look-up, string matching or correlations, the shape number of any order for an arbitrary curve.

To find out how close in shapes two curves are, the degree of similarity between them is introduced; dissimilar regions will have a low degree of similarity, while analogous shapes will have a high degree of similarity. Informally speaking, the degree of similarity between the shapes of two curves tells how deep it is necessary to descend into a list of shapes, before being able to differentiate between the shape of those two curves. Again, a procedure is given to compute it, without need for such list or grammatical parsing or least square curve or area fitting.

The degree of similarity maps the universe of curves into a tree or hierarchy of shapes. The distance between the shapes of any two curves, defined as the inverse of their degree of similarity, is found to be an ultradistance over this tree.

The shape number is a description that changes with skewing, anisotropic dilation and mirror images, as the intuitive psychological concept of "shape" demands. Nevertheless, at the end of the paper a related Theory "B" of shapes is introduced that allows anisotropic changes of scale, thus permitting for instance a rectangle and a square to have the same Bshape.

These definitions and procedures may facilitate a quantitative study of shape.

Introduction

The study of shape is an important part of the field of Pattern Recognition.

As pointed out by Lord Kelvin, a science begins to emerge when it is possible to make measurements of the phenomena that such science seeks to understand, allowing quatitative comparison and mathematical relations among them.

This paper gives a procedure to measure (i.e., to assign a number to) the resemblance between any two shapes.

With the help of procedures like this, a quantitative study of shape may be possible.

Previous Work on Shape.

Shape extraction is an active field. Sequential extraction of shape features [4] can be performed making only one pass over the image. For global shape analysis, several authors have used Freeman chains, medial axis transforms, descomposition into primary convex subsets, polar coordinates [6], decomposition at concave vertices; decomposition by clustering, mirroring axes [7] and stroke detectors. These and other methods are reviewed by Pavlidis [5].

I THE SHAPE NUMBERS

1.1 What is a shape

A region is a simply connected portion of a plane limited by a curve boundary. That is, no holes; no self-intersecting boundary. It is a closed boundary. A given region has a size, a position, and an orientation in the plane. This defines a flat region, which is uniquely defined by the curve it has as boundary. This paper deals with shapes of regions, but the shape numbers used here can also be applied to open curves. In addition, Section IV describes regions with holes.

A shape is what remains of a region after disregarding its size, position and orientation in the plane. That is, two regions have the same shape if we can make them coincide exactly by translation and rotation in the plane, in addition to an uniform change of scale (the x and y coordin-

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ates increase by the same factor).

A region and its mirror images will not have the same shape, in general.

This definition coincides with the intuitive psychological definition of "shape".

If a notation is going to be used to represent the shape of a region, it has to be independent of the position, orientation and size of such region. It should be reproducible: a region, when translated, magnified and rotated should still give the same description as when untransformed. Two regions with different shapes should produce different descriptions. Finally, the shape number should be unique for a given region; for instance, it should not depend on an arbitrary starting point or a particular coordinate system.

If the notation can be deduced exclusively from the region, without comparison with a table of canonical shapes or shape descriptors, for instance, then we can expect savings in memory and computer time for the procedure that computes the shape description.

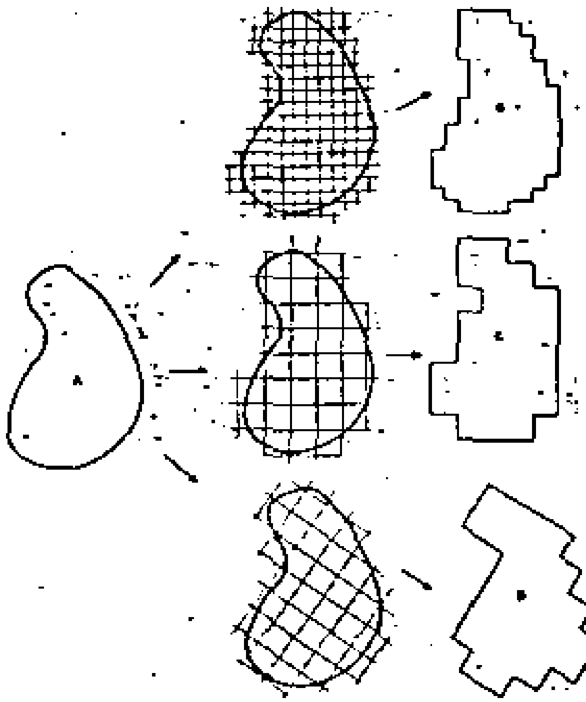


FIGURE 'CONTINUOUS AND DISCRETE SHAPES' Continuous shape A gives rise to several discrete shapes B,C,D. If it is desired to have a unique discrete shape derived from A, then it is necessary to specify the grid size (related to the order of the discrete shape), as well as its orientation and position with respect to the continuous curve A. In this manner, for a given order n, the discrete shape corresponding to A will be unique. This is accomplished in Section 1.6.

1.2 Continuous and discrete shapes.

A shape is discrete if the boundary of the region is formed by segments of a square grid. Otherwise, the shape is continuous.

1.3 Mapping a continuous shape into a discrete shape.

A square grid may be overlaid on top of a continuous shape to obtain a discrete shape. The quantization of the shape is as follows: a square of the grid is "black" (inside the discrete shape) if more than 50% of it is covered by the continuous shape; otherwise it is "white" or outside (Fig. 'CONTINUOUS AND DISCRETE SHAPES'). The size, orientation and position of this grid will influence the resulting discrete shape.

A discrete shape, obtained from a continuous shape in the above manner, can not be a shape descriptor of the continuous shape, because it depends on the size and orientation of the grid. This will be solved in Section 1.6.

Now, some shape descriptors will be given.

1.4 Eccentricity

The eccentricity (ratio of the major to minor axis, Figure 'BASIC RECTANGLE') of a region is a descriptor that depends only on its shape.

The major axis of a region is the line joining the two perimeter points furthest away from each other. The minor axis is perpendicular to the major axis, and of length such that a box could be formed that just encloses the region. This box is called the basic rectangle (Figure 'BASIC RECTANGLE').

Ocassionally, there will be more than one major axis in a region. In that case, select that which gives the shorter minor axis; if necessary, add additional criteria to make the choice of major axis a unique choice.

1.5 Freeman chain and its derivative.

Freeman chain in four directions. For a given region and a given square grid of fixed orientation and size, the Freeman chain in four directions is the curve obtained by walking clockwise on the grid (on its "wires") around and outside the squares that are more than half contained by the region (Figure 'CHAINS').

Derivative of Freeman Chains. It is the chain number obtained by clockwise replacing each convex corner of the Freeman chain by a 1, each straight corner by a 2, and each concave corner by a 3, as Figure 'CHAINS' suggests. The number obtained ("F" in Figure 'CHAINS') will be different if we change the size or orientation of the grid. In the next section a method appears that makes the "derivative of Freeman chain" independent of these changes. This new derivative will be called the shape number.

En las siguientes secciones se describe el modo de consulta al BDC por medio de una terminal con pantalla de CRT.

Se cuenta con las siguientes funciones adaptadas a teleproceso.

PRO (CCCC, (MN, MY, IG), N)

PROP (CCCC, EN, N, M)

UNADE (CCCC, CCCC, (MN, MY, IG), N)

HAYVIA (CCCC, CCCC)

SERPRO (CCCC, N)

PUEBLO (CCCC)

SERPOB (N, (Y, O), S)

HABIT (N, N)

donde:

CCCC indica la clave utilizada según la tabla apropiada.

(MN, MY, IG) significa alguna de las funciones relacionales.

MN=MENORQ

MY=MAYORQ

IG =IGUALQ

Se utiliza sólo una de ellas.

N es un número que varía de 0 a 99999, según la pregunta.

EN=ENTRE

(Y, O) significa alguno de los operadores lógicos.

Y=AND

O=OR

Se utiliza sólo uno de ellos.

S Indica las subdivisiones de los servicios de la población y será un número que incluya a los dígitos 1, 2, 3, 4, 5, 6, 7 sin repetir ninguno según la equivalencia:

a = 1

b = 2

c = 3

d = 4

e = 5

f = 6

g = 7

Creación de una pregunta con base en las funciones anteriores.

- Cada función se construye con base en las especificaciones anteriores, sin incluir espacios intermedios.

PRO (6001, MY, 0) correcto

PRO (6001,   MY, 0) incorrecto

- La posición de cada función no tiene restricción.

- Los espacios en blanco entre funciones no tienen ningún efecto.

- Se utilizan los operadores lógicos Y, O, NO que son equivalentes a:

Y = AND

O = OR

NO = NOT

- Pueden usarse libremente los paréntesis.

- El número máximo de funciones es de 60, inclusive.

- El tamaño máximo de la pregunta es de 10 renglones en la pantalla.

Por medio de las teclas adecuadas se transmite la instrucción al nivel deseado, y se obtiene como resultado una matriz de caracteres donde * = cuadro oscuro y - = cuadro claro con los significados explicados anteriormente.

CAPITULO III

EJEMPLOS INTRODUCTORIOS

En el resto de este manual se usa la 1a. versión del BDC para describir y ejemplificar el lenguaje de usuario, y los programas de aprendizaje. En general, la 2a. versión funciona de igual manera, salvo pequeñas diferencias que se señalan cuando es necesario. Se utilizaron los cinco tipos de cartas (Edafológica, Topográfica, Geológica, Uso del Suelo y Uso Potencial), de cada una de las siguientes zonas; Celaya, Querétaro, Cortázar y Apaseo el Alto. La información que de estas cartas fue vaciada al BDC está descrita en las tablas del apéndice,[9] y corresponde aproximadamente a la información que un usuario extraería guiándose por las leyendas y explicaciones que aparecen en los márgenes de ellas.

Las funciones que dan acceso al BDC permiten describir los sitios (zonas, cuadros o subcuadros), que poseen determinada propiedad o cumplen con cierto predicado.

[9] Véase apéndice pag. 144

Se procede a dar algunos ejemplos sencillos, con el fin de mostrar la simplicidad de su uso. Cualquiera de las dudas que surjan en estos ejemplos, serán aclaradas en secciones posteriores. Por ejemplo, si se desea encontrar, a nivel 3, los cuadros en Celaya que poseen una superficie cultivada mayor del 40%, se define el predicado CULTI[10] mediante el postulado que define a CULTI como todo aquel lugar donde la propiedad 6104 sea mayor de 40, o sea, mayor del 40%. La tabla 1 del apéndice indica que la propiedad 6104 equivale a cultivos:

Una vez hecha esta definición, se procede a buscar CULTI a nivel de cuadro en Celaya, como sigue:

```
CULTI = PRO (6104, MAYORQ, 40)
CALL BUSCA (CULTI, 3, 1)
```

En la segunda versión, la segunda instrucción es como sigue:

```
CALL BUSCAS (CULTI, 1, MICROREG, 2, 3)
```

Las dos instrucciones anteriores, necesitan de ciertas declaraciones e instrucciones adicionales. Los programas completos son: programa que define el predicado CULTI.

```
LOGICAL FUNCTION CULTI (N)
LOGICAL PRO, MAYORQ
```

10 El nombre dado no tiene importancia pero no debe pasar de 6 letras. Es conveniente usar nombres mnemónicos.

```
EXTERNAL MAYORQ
CULTI = PRO (6104, MAYORQ, 40)
RETURN
END
```

y programa principal que busca CULTI a nivel 3 en la zona 1, esto es, cuadros en Celaya, como se muestra en el listado 3.1.

```
LOGICAL CULTI
EXTERNAL CULTI
CALL BUSCA (CULTI, 3, 1)
STOP
END
```

El resultado se muestra en la figura 3.1 en la cual, se observan cuadros oscuros que son los que tienen más del 40% de su superficie cubierta por cultivos.

Observaciones.- Las declaraciones LOGICAL en los programas definen a CULTI, MAYORQ y PRO, como funciones que adquieren valores lógicos que pueden ser verdaderos o falsos. La (N) de CULTI (N) es una variable muda; las declaraciones EXTERNAL definen a CULTI y MAYORQ como nombres de funciones; las RETURN y END en el predicado, y STOP y END en el programa principal, terminan correctamente los programas. El usuario no necesita entender todo esto; sin embargo, es conveniente apuntarlo.

```
LOGICAL FUNCTION CULTI(N)
LOGICAL PRC,MAYORQ
EXTERNAL MAYORQ
SE DESEA SABER QUE CUADROS DE LA ZONA DE CELAYA TIENEN MAS DEL
40 POR CIENTO DE SU SUPERFICIE CULTIVADA
CULTI=PRC(6104,MAYORQ,40)
RETURN
END
```

```
LOGICAL CULTI
EXTERNAL CULTI
CALL BUSCA(CULTI,3,10)
STOP
END
```

LISTADO 3.1 ¿QUE CUADROS DE LA ZONA DE CELAYA TIENEN MAS DEL 40% DE LA SUPERFICIE CULTIVADA?

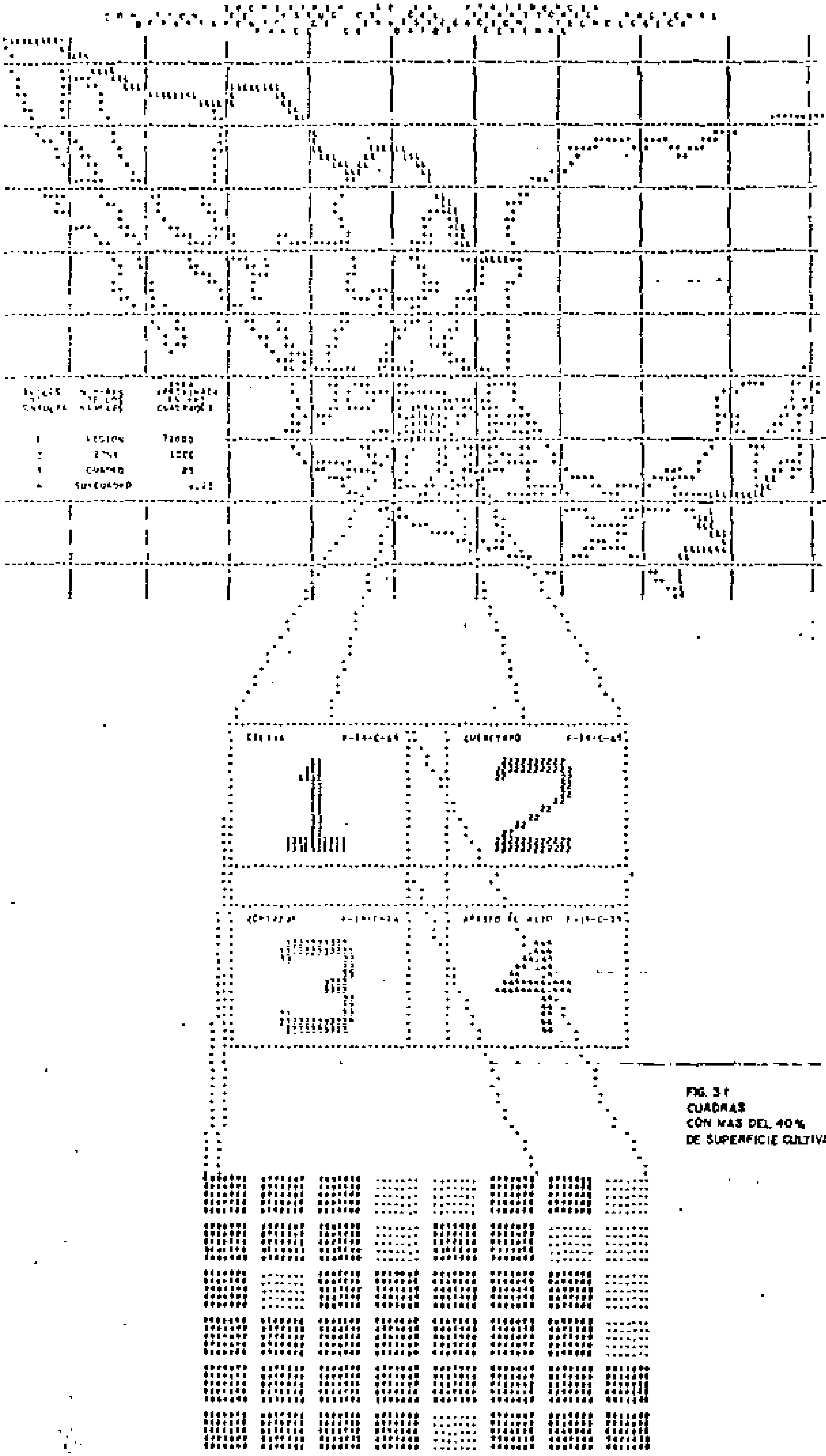


FIG. 31
CUADRAS
CON MAS DEL 40%
DE SUPERFICIE CULTIVADA

Para buscar el mismo predicado CULTI a nivel de subcuadro, se dice la siguiente instrucción en el programa principal:

CALL BUSCA (CULTI, 4, 1)

Si hay interés por zonas en las que más del 60% de su superficie está cultivada o sean pastizales, propiedades 6104 y 6201, respectivamente, se dice:

ZONA = PRO (6104, MAYORQ, 60) .OR. PRO (6201, MAYORQ, 60)

Si se quiere hallar zonas que no tengan chaparrales, propiedad 6509, se dice:

NOCHAP = .NOT. PRO (6509, MAYORQ, 0)

Es decir, PRO (6509, MAYORQ, 0) define lugares donde sí existen chaparrales, y con un .NOT. anterior a la expresión, se niega esta propiedad.

El BDC, puede contestar también preguntas como las siguientes:

. ¿Qué lugares tienen pocos álamos y muchos pirules? Si se conviene en que poco signifique menos del 15%, y muchos signifique más del 70%, la función es:

ALAPIR = PRO (6312, MENORQ, 15) .AND. PRO (6319, MAYORQ, 70)

. ¿Qué lugares están comunicados por cualquier tipo de carretera? Si se usa la tabla 1 del apéndice,[11] se observa que las pro

[11] Véase apéndice pag. 144

piedades de la 801 a la 810 se refieren a diferentes tipos de carreteras. Con una de ellas es suficiente para comunicar el lugar por donde pasan. La función es:

COMUN = UNADE (801, 810, MAYORQ, 0)

Esta función se interpreta de la siguiente forma: al menos una de las propiedades 801 a la 810 debe ser mayor que cero, es decir, debe existir. Si se quieren conocer todos los lugares que están comunicados y que tienen agua almacenada, en presa o bordo, se dice:

COMAGU = UNADE (801, 810, MAYORQ, 0) .AND.
UNADE (401, 408, MAYORQ, 0).

Otras de las preguntas son:

- ¿Qué zonas se encuentran entre 1600 y 1800 metros sobre el nivel del mar?

RESUL = PROP (101, ENTRE, 1600, 1800)

- ¿En qué lugares hay palmares que ocupan el 25% de la superficie, y están a más de mil metros sobre el nivel del mar?

PALMAR = PRO(6501, MAYORQ, 25) .AND. PRO (106, MAYORQ, 1000)

- ¿Crecerán los nopales sobre suelos de tipo Gléyico?

Se define en que: "crecen los nopales" significa que más del 30% del suelo está cubierto de nopalera, propiedad 6507, y que un suelo es de tipo "Gléyico", cuando la superficie ocupada por la propiedad 3319, suelo Gléyico, es mayor de 70%. Entonces:

NOPG = PRO (6507, MAYORQ, 30) .AND.PRO (3319, MAYORQ, 70)

Se pueden hacer preguntas arbitrariamente largas. En el ejemplo que está a continuación, se buscan lugares de atractivo turístico; éstos pueden ser lugares donde haya cataratas, propiedad 601, o bosques, propiedades 6301 y 6302, o ríos, propiedad 503 y que estén en lugares no muy altos, esto es, a menos de 2 500 m snm; o bien aquellos lugares altos y con volcanes propiedad 2553 o lugares en donde haya más de 4 manantiales termales propiedad 2604, que estén bien comunicados por algún tipo de camino o carretera, propiedades 801 a 810 y que se hallen en terrenos no montañosos, propiedades 5802 y 5803.

Se puede proceder por partes y definir:

UNO = PRO (601, MAYORQ, 0) .OR. UNADE (6301, 6302, MAYORQ, 0)
 .OR. PRO (503, MAYORQ, 0) .AND. PRO (105, MENORQ, 2500)

DOS = PRO (106, MAYORQ, 2500) .AND. PRO (2553, MAYORQ, 0)

TRES = PRO (2604, MAYORQ, 4) .AND. UNADE (801, 810, MAYORQ, 0)
 .AND. .NOT. UNADE (5802, 5803, MAYORQ, 0)

Finalmente se dice:

TURIS = UNO. OR. DOS. OR. TRES

Otro ejemplo es el siguiente:

- ¿En qué lugares de Celaya se pueden explotar minas ?

En este ejemplo, se usan las funciones y rutinas de "aprendizaje".

Para proponer las minas que se pueden explotar, se necesitan experiencias anteriores. Los programas pueden adquirir estas experiencias de minas ya existentes en cualquiera de las cuatro zonas.

Se construye la función que busca minas, propiedad 2605, de la siguiente forma:

MINA = PRO (2605, MAYORQ, 0)

También se construye la función de "aprendizaje", en la cual incluye una variable de tolerancia; en este caso del 20%. Puede suceder que los programas de "aprendizaje" no encuentren nada debido a que la variable de tolerancia es muy severa, entonces se puede hacer mayor la tolerancia y así encontrar algunos lugares de los que se buscan.

Para buscar minas en CORTAZAR, se da la siguiente instrucción:

CALL BUSCA (MINAS, 3, 3)

A continuación, el aprendizaje de minas se lleva a cabo con la siguiente instrucción:

CALL LEARN (3, 2605)

Con las muestras (de minas) obtenidas en Cortázar se pueden proponer minas en Celaya como se describió anteriormente.

Según lo que se ha visto, también se puede "aprender" de otras zonas, y así tener mayor confiabilidad en los resultados.

También se puede determinar la confiabilidad con que se está trabajando, es decir, si se comparan las minas propuestas con las minas existentes, y se ve que se proponen 4 minas en lugares en donde existen 5, se está trabajando con una confiabilidad del 80%, y esto se hace en la forma siguiente:

CALL CONFIA (MINAS, 3, 1)

La rutina llamada por la instrucción anterior, dice la confiabilidad con que se está trabajando.

NOMENCLATURA USADA EN LOS EJEMPLOS ANTERIORES.

PREDICADO: Pregunta construida por el usuario.

FUNCIONES RELACIONALES: MENORQ, MAYORQ, DIFERE, IGUALQ, ENTRE, MAYORI, MENORI, NOIGUA.

FUNCIONES LOGICAS: PRO, PROP, UNADE, CERCA, SERPOB, SEPRO, PUEBLO HAYVIA Y APRE11.

CONTENIDO

RESUMEN

Este manual explica el lenguaje de acceso al Banco de Datos CETENAL (BDC) cuyos programas están escritos en el lenguaje FORTRAN IV.

Una característica de este lenguaje es que dentro de las restricciones que otorga, es ilimitado en su construcción de predicados o preguntas. Se le facilita al usuario su rápido aprendizaje, sin tener conocimientos previos de programación o de computación.

El objetivo del BDC es poder contestar preguntas en forma rápida, tales como: ¿En qué lugares de la República Mexicana se cosechará mejor el maíz?, ¿Qué partes de la República Mexicana están a más de 50 km de las redes de caminos y carreteras existentes?, ¿Cuántas carreteras nuevas se deben diseñar y por dónde van a pasar?, ¿Qué lugares son apropiados para el turismo?, ¿En qué lugares se pueden colocar zonas industriales?, ¿Qué pueblos tienen más de 1000 habitantes y no tienen medios de comunicación?, etc. Contestar éstas y otro tipo de preguntas en forma manual, sería muy la-

borioso e implicaría pérdida de tiempo.[3]

En este manual se describen las funciones que constituyen el lenguaje del usuario; se incluyen ejemplos y sus salidas gráficas.

También en este manual, como otra fase del BDC, se describen: una serie de programas de "aprendizaje", que procesan y "memorizan" las experiencias desarrolladas en la solución de problemas muy variados, como por ejemplo, la búsqueda de zonas urbanas; el BDC indica, como respuesta al problema, en qué lugares existen zonas urbanas al nivel deseado. Sobre este estudio, los programas "inteligentes" encuentran los parámetros y factores comunes que existen en estos lugares en un radio determinado y los "aprenden"; con estas experiencias buscan zonas de posible desarrollo urbano.

Entre más zonas urbanas analice, mayor será la correlación de propiedades comunes existentes y más precisa la ubicación de zonas de posible desarrollo urbano.

[3] Véase referencias 5, 10 pags. 180, 181

INTRODUCCION

El Banco de Datos CETENAL (BDC) es una herramienta para manejo masivo de la información (producida por CETENAL y contenida en las diversas cartas), que describe el medio geográfico y socioeconómico.[4]

La información que contiene el BDC es la que un usuario obtendría de las siguientes cartas:

Geológica

Topográfica

Uso del Suelo

Edafológica

Uso Potencial

Se podrían vaciar al BDC otras cartas tales como la Carta Urbana, la de Climas y la Turística, ya que la estructura del mismo acepta gran variedad de información.

El BDC está diseñado para proporcionar varios niveles de consulta. Esto significa que se puede consultar a diferentes tamaños de

[4] Véase referencias 6, 8 pags. 180, 181

área, lo cual activa el acceso a la información.

La información de las cartas se clasifica en tres tipos:

1) Propiedades superficiales. - Comprenden todas las propiedades que están definidas por áreas, por ejemplo: el área que comprende el suelo aluvial, el área urbana, el área de nopalera, etc, están en el BDC como propiedades de este tipo.

2) Propiedades lineales. - Comprenden todas las propiedades que implican uniones entre determinados puntos o comunicación entre ellos, ejemplo: una carretera, vías de energía eléctrica, telegráfica, telefónica, etc.

3) Propiedades puntuales. - Estas propiedades están definidas por su localización, ejemplo: minas, pozos, puntos de verificación, etc.

Las propiedades superficiales están definidas por su clave y por su cantidad, dada como un porcentaje del área del nivel al que pertenecen. Las propiedades lineales y puntuales, están definidas por el número de ellas dentro del nivel al que pertenecen y también por su clave. Hay otras propiedades puntuales, como los servicios de la población y los servicios propuestos para la población en un pueblo, que también están en el BDC.

Como se puede observar, toda la información, ya sea geográfica o socioeconómica, puede ser clasificada dentro de los tres tipos de propiedades anteriores.

El vaciado de la información al BDC se realiza en la Oficina de Bases de Datos del Departamento de Informática de CETENAL con una metodología bien definida.

Las formas de salida son de dos tipos: mensajes escritos por impresora de la computadora, y mensajes por medio de pantallas de CRT, o sea por una terminal remota; esto permitirá tener acceso al BDC, aún estando distante de él. En este manual se describen ambas formas de salida.

Después de definir las funciones del lenguaje de usuario, se describe la forma de combinarlas.

En la parte última del manual se describen los programas de "aprendizaje" del BDC, con una serie de ejemplos para su análisis y conclusiones.

Un aspecto importante del método de "aprendizaje", es el de poder mejorar las experiencias anteriores y agregar nuevos parámetros y factores al BDC.

En los ejemplos de "aprendizaje", también se desarrolló un programa que verifica la confiabilidad del "aprendizaje".

CAPITULO I

DEFINICION DE LOS NIVELES DE CONSULTA

Para establecer los distintos niveles de consulta, se comienza por definir el nivel de regiones. Una región comprende el área dada por un rectángulo de 6° de longitud x 4° de latitud. El territorio nacional está cubierto por 20 regiones aproximadamente. Los siguientes niveles se establecen por subdivisiones sucesivas del rectángulo de menor tamaño que se tenga definido. Así, el nivel de subregiones se forma al subdividir cada región en 12 subregiones que son los elementos de un arreglo matricial de 3 x 4.

Las microregiones constituyen un arreglo matricial de 6 x 4 sobre una subregión. Cada microregión constituye una carta 1:50 000 de las producidas actualmente por CETENAL. La República Mexicana está cubierta por 2336 de estas cartas, aproximadamente. La información vaciada al BDC es extraída actualmente de estas cartas, aunque se vació también una carta urbana escala 1:5 000 y se ha proyectado vaciar las cartas de climas escala 1:500000. Las microregiones se subdividen en 5 x 5 localidades o grupos y éstos en 4 x 3 sublocalidades o celdas. La figura 1.1 aclara los niveles establecidos y la tabla 1.1 re sume estos niveles y sus características.

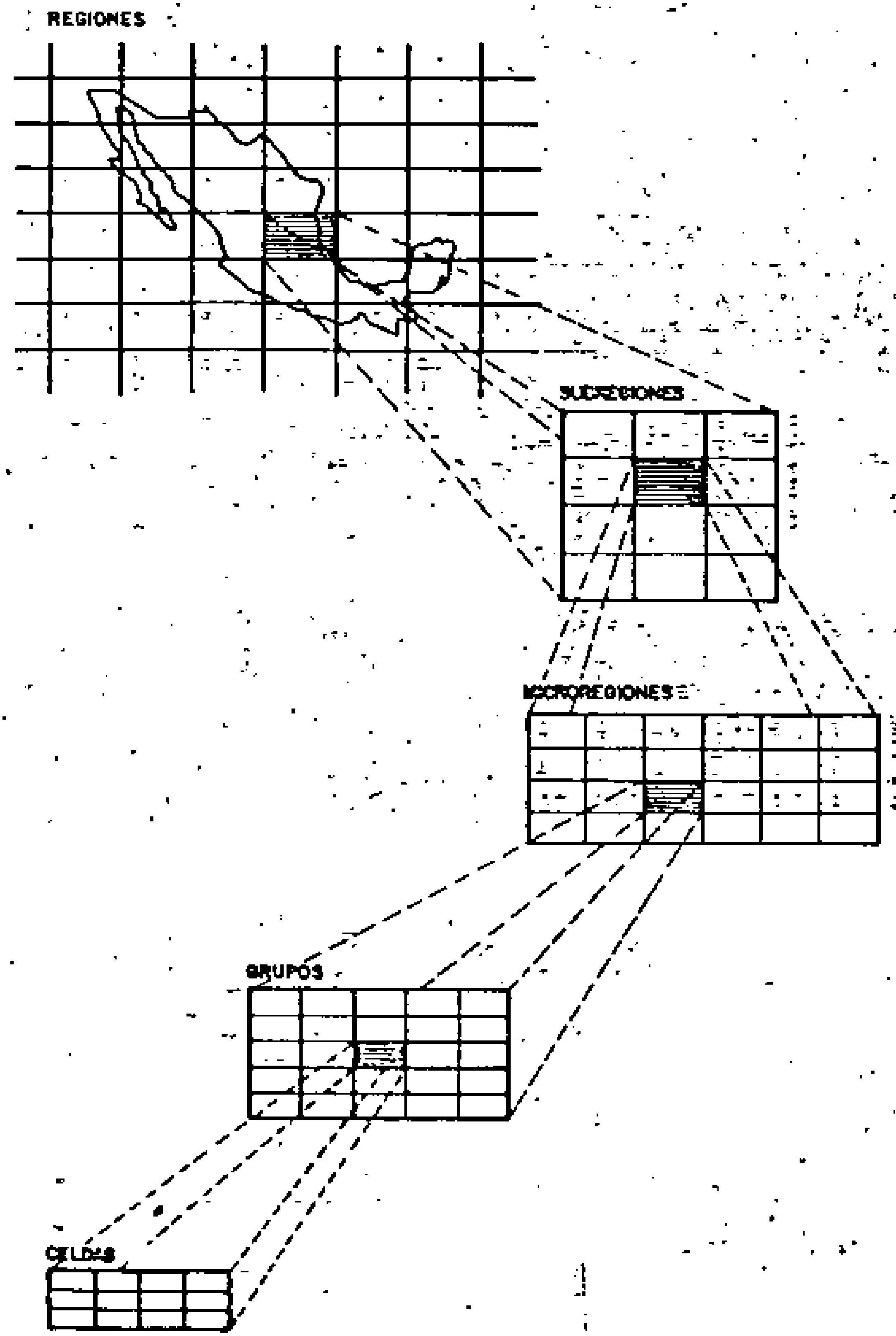


figura 1.1 NIVELES DE CONSULTA (2ª versión)

tabla 1.1 NIVELES DE CONSULTA (2ª versión)

NIVEL	TAMAÑO		AREA APROX. KM²	CONTIENE	EQUIVALE A
	LONG	LAT			
REGIONES	6°	4°	288 000.0	3 X 4 SUBREGIONES	12 CARTAS 1:250000
SUBREGIONES	2°	1°	24 000.0	6 X 4 MICROREGIONES	1 CARTA 1:250 000
MICROREGIONES	20'	15'	1000.0	5 X 5 GRUPOS	1 CARTA 1:50 000
GRUPOS O LOCALIDADES	4'	3'	34.7	4 X 3 CELDAS	
CELDAS O SULOCALIDADES	1'	1'	2.9		

Esta estructura de varios niveles agiliza las consultas y además cada subdivisión aumenta la precisión[5].

Una versión más antigua del BDC y que aún se aplica a las zonas de Celaya, Querétaro, Cortázar, Apaseo el Alto y Ojo Caliente, utiliza los niveles dados en la tabla 1.2 e ilustrados en la fig. 1.2[6].

tabla 1.2 NIVELES DE CONSULTA (1ª versión).

NIVEL	NOMBRE	AREA APROXIMADA	CORRESPONDE A
4	SUBCUADROS	6.25 km²	
3	CUADROS	25 km²	4 SUBCUADROS
2	ZONA	1000 km²	48 CUADROS O, 192 SUBCUADROS
1	REGIONES	72 000 km²	72 ZONAS O, 3456 CUADROS O, 13824 SUBCUADROS
0	REPUBLICA MEXICANA	2 500 000 km²	32 REGIONES O, 2336 ZONAS O, 112128 CUADROS O, 448512 SUBCUADROS

5 Véase referencia 7
6 Véase referencias 9, 11

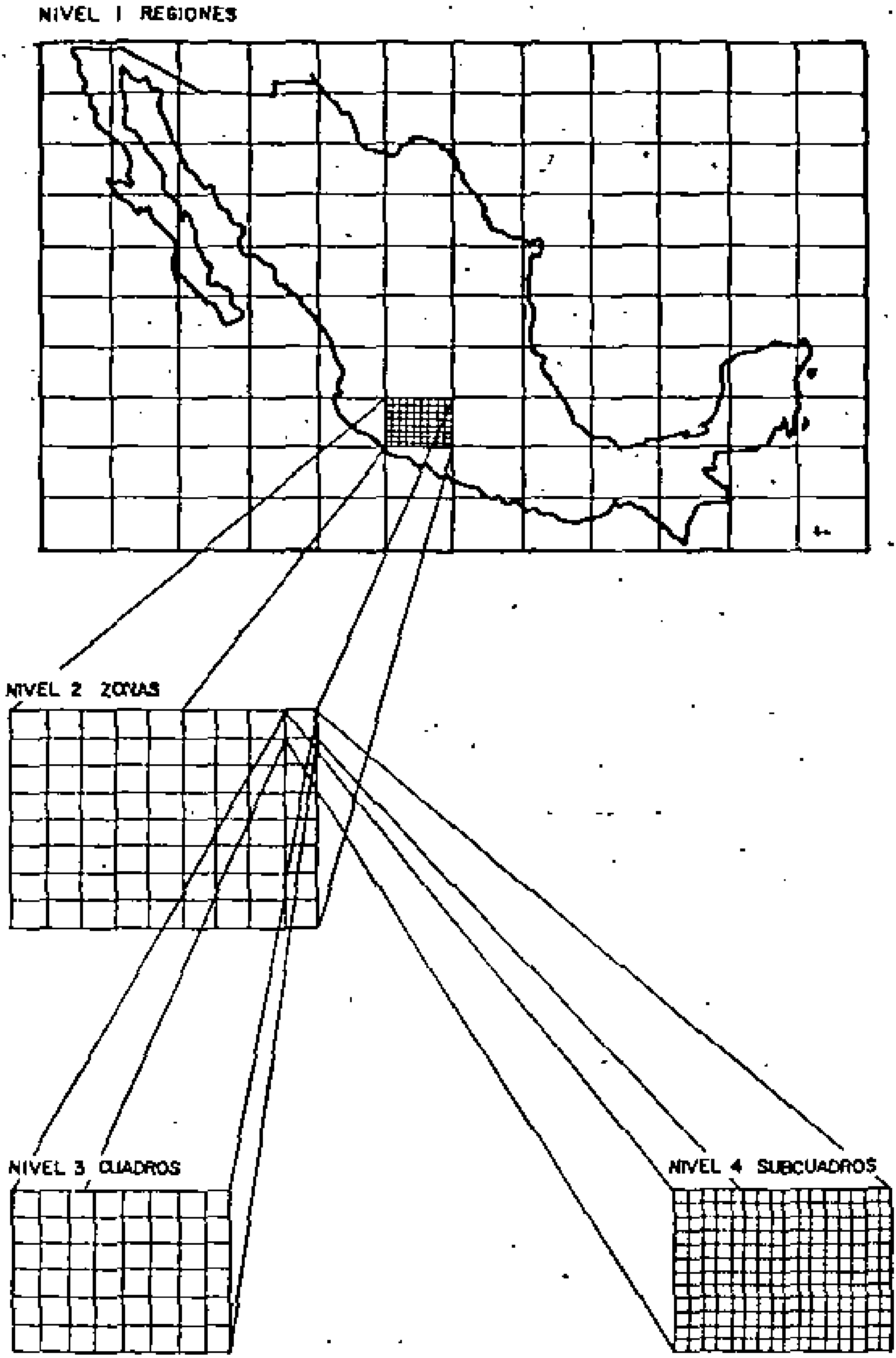


figura 1.2 NIVELES DE CONSULTA (1ª versión)

Dentro del BDC a una carta se le llamó zona. Una zona tiene una área aproximada de 1 000 km^2; un nivel superior a éste, en área, es lo que en el BDC se llamó región y es el área comprendida por 72 zonas en un arreglo matricial de 9 x 8 zonas; esta división también aparece en las cartas de avance de CETENAL; cada región tiene una área aproximada de 72 000 km^2 y corresponde a 2° de latitud y a 3° de longitud. La República Mexicana queda contenida en un arreglo matricial de 12 x 10 regiones. Una zona se dividió en 48 cuadros, y un cuadro tiene una área aproximada de 25 km^2; cada cuadro se dividió en 4 subcuadros y cada subcuadro tiene una área aproximada de 6.25 km^2.

CAPITULO II

FORMAS DE SALIDA DE LOS RESULTADOS

Para explicar la forma de salida de los resultados por impresora, se hace referencia a resultados obtenidos con la primera versión del BDC que utiliza los niveles de zonas, cuadros y subcuadros. El significado de estas explicaciones puede hacerse extensivo a las impresiones de resultados obtenidos con la segunda versión del BDC aplicable al Estado de Aguascalientes, y que utiliza los niveles de microregión, localidad y sublocalidad. La única diferencia está en que los distintos arreglos matriciales de cuadros tienen distintas dimensiones.

Como respuesta a la búsqueda a un nivel determinado, la máquina produce en la impresora arreglos matriciales de cuadros de dos tipos: unos de cuadros claros y oscuros, y otros de diferentes tonos de gris (16 en total). Con el primer tipo de arreglos se puede distinguir en qué cuadros las preguntas son verdaderas y en qué cuadros son falsas[5].

[5] Véase figuras 2.1, 2.2, 2.3 pags. 18, 20

Los cuadros oscuros indican en ese lugar la pregunta se hizo verdadera, y los cuadros claros indican que en ese lugar la pregunta se hizo falsa.

Por ejemplo, con un predicado llamado "FRIJOL" se pregunta al BDC en qué zonas hay FRIJOL. Para esto se define la siguiente instrucción:

CALL, BUSCA (FRIJOL, 2, 79)

Y como respuesta se obtiene el resultado que muestra la figura 2.1 en la cual se ve un arreglo de matriz de 2 x 2 zonas. El área de una zona es igual al área de una carta CETENAL escala 1:50 000; las zonas corresponden a la región # 79.

Las zonas oscuras marcan los lugares en donde hay FRIJOL; en estos casos el predicado FRIJOL se cumple. Las zonas claras indican que en esas zonas no hubo FRIJOL, por lo tanto, el predicado buscado no se cumplió en esos casos: o lo que es lo mismo, que el conjunto de propiedades definido por el predicado FRIJOL no se encuentra en lugares donde aparecen zonas claras, (después se verá cómo definir al predicado FRIJOL). Resumiendo: zona oscura significa que sí hay lo que se busca y zona clara significa que no hay lo buscado.

Al buscar el predicado FRIJOL a nivel 3 (cuadros), se obtienen los resultados que muestra la figura 2.2. Esto permite tener una información más precisa que la del nivel 2, ya que dentro de este nivel, que en este caso es la carta de Celaya, se ve con más exactitud cuáles son los cuadros de esta zona que cumplen con el predicado FRIJOL; así se puede seguir haciendo a un nivel más pequeño, como se muestra en la figura 2.3, que corresponde al nivel 4 (subcuadros).

En síntesis, se resume que el predicado FRIJOL se hace verdadero en la zona 1, correspondiente a Celaya, de la región 79. A nivel de cuadro la función FRIJOL se hace verdadera en los cuadros: 5, 6, 13, 14, 17, 21, 22, 25, 26, 27, 28, 29, 30, 33, 36, 37, 40, 41, 42 y 45; esto permite tener más información que en el nivel anterior. Si se desea ampliar esta información se busca a nivel de subcuadro y se ve en qué subcuadro de cada cuadro se hace verdadero el predicado FRIJOL. Los subcuadros que cumplen la función FRIJOL son: los subcuadros c y d del cuadro 5, los subcuadros b, c y d del cuadro 6, el subcuadro a del cuadro 13, los subcuadros b y d del cuadro 14, los subcuadros c y d del cuadro 17, los subcuadros c y d del cuadro 21, los subcuadros a, b y c del cuadro 22, los subcuadros a, b y c del cuadro 25, los subcuadros a, c y d del cuadro 26, los subcuadros c y d del cuadro 27, los subcuadros c y d del cuadro 28, los subcuadros a, b, c y d del cuadro 29, el subcuadro a del cuadro 30, los subcuadros a y c del cuadro 33, los subcuadros a y b del cuadro 36, los subcuadros a, c y d del cuadro 37, los subcuadros a y b del cuadro 40, los subcuadros a y c del cuadro 41, el subcuadro c del cuadro 42 y el subcuadro a del cuadro 45. La tabla 2.1 explica detalladamente la nomenclatura usada[6].

Es preciso hacer notar la importancia que tienen los niveles de consulta en la estructura del Banco de Datos CETENAL.

Esto es, en el ejemplo de la función FRIJOL se buscó a nivel 4, qué subcuadros cumplieron con esta función.

Si no existieran los diferentes niveles de consulta, se tendría que buscar la función FRIJOL en aproximadamente 448 512 subcuadros, lo cual no sería eficiente ni práctico, aún desde el punto de vista del procesamiento por computadora. En cambio, usando los niveles de consulta, se pueden detectar rápidamente los subcuadros que cumplen la función FRIJOL en la forma siguiente:

1. Se busca a nivel 1 regiones[7] de toda la República Mexicana y los resultados se presentarán en un arreglo de matriz de 12 x 10; supóngase que solamente en la región 79 se cumplió la función.

2. Se busca a nivel 2 (zonas en la región 79) y se obtiene la figura 2.1, que muestra la zona 1 oscura; por lo tanto, la función

[6] Véase tabla 2.1 pag. 24

[7] Este nivel actualmente no se ha establecido debido a que el BDC todavía no cuenta con más de 72 cartas vaciadas para formar una región.

es verdadera en ese lugar.

3. Se busca en la zona 1 a nivel de subcuadro y se obtiene la figura 2.3.

Como se puede observar, con los pasos anteriores se obtuvieron en forma rápida los subcuadros que poseen la función FRIJOL, ya que cada nivel está constituído por su descriptor,[8] y no es necesario buscar en lugares donde no existe FRIJOL.

La figura 2.4 muestra una impresión de resultados para el nivel de sublocalidades de una microregión de Aguascalientes.

El segundo tipo de arreglos, formados por cuadros de diferentes tonos de gris, se describe en el capítulo VI.

[8] Descriptor es el conjunto de información que existe en el BDC para cada nivel, véase referencia 1.

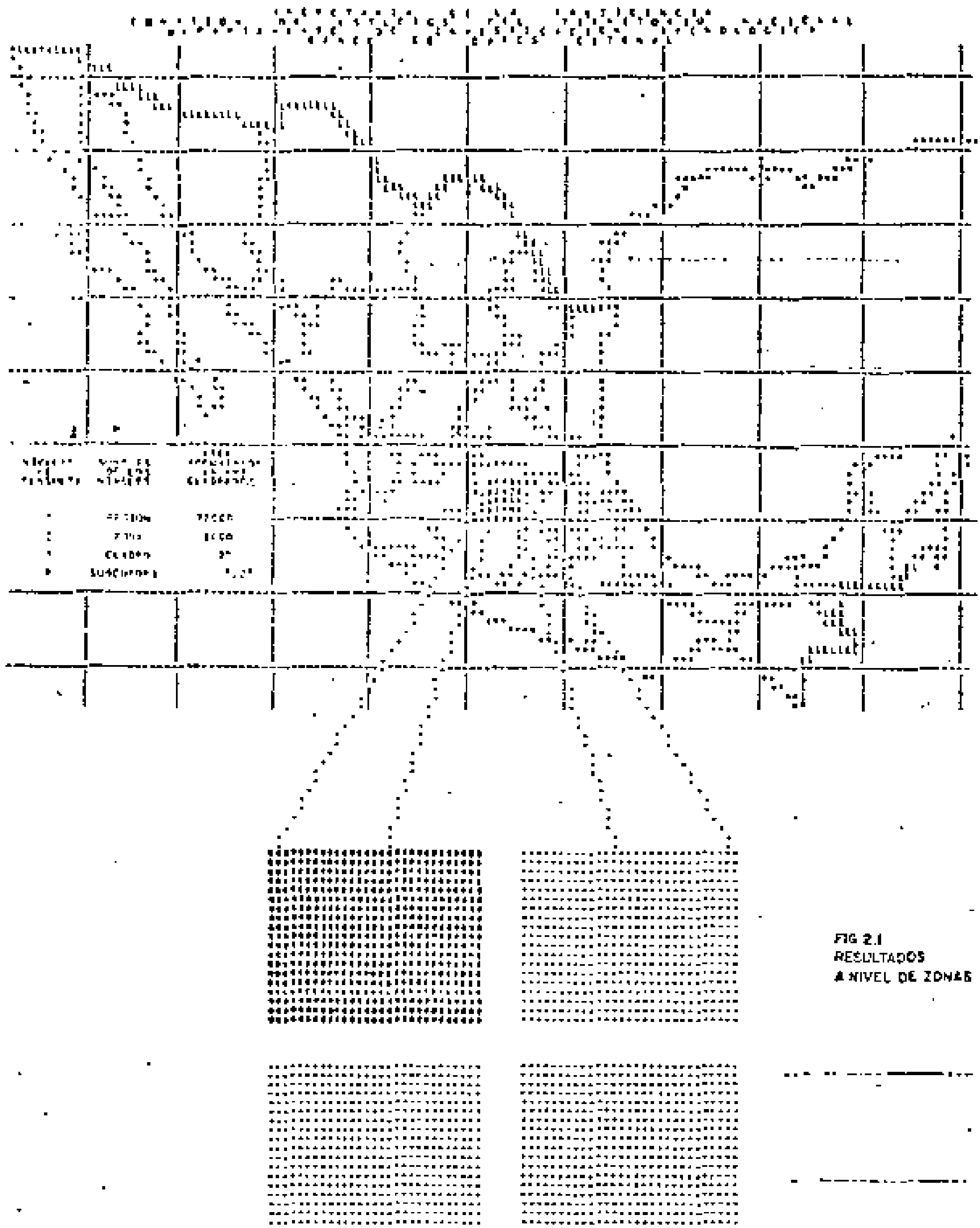


FIG 2.1
RESULTADOS
A NIVEL DE ZONAS

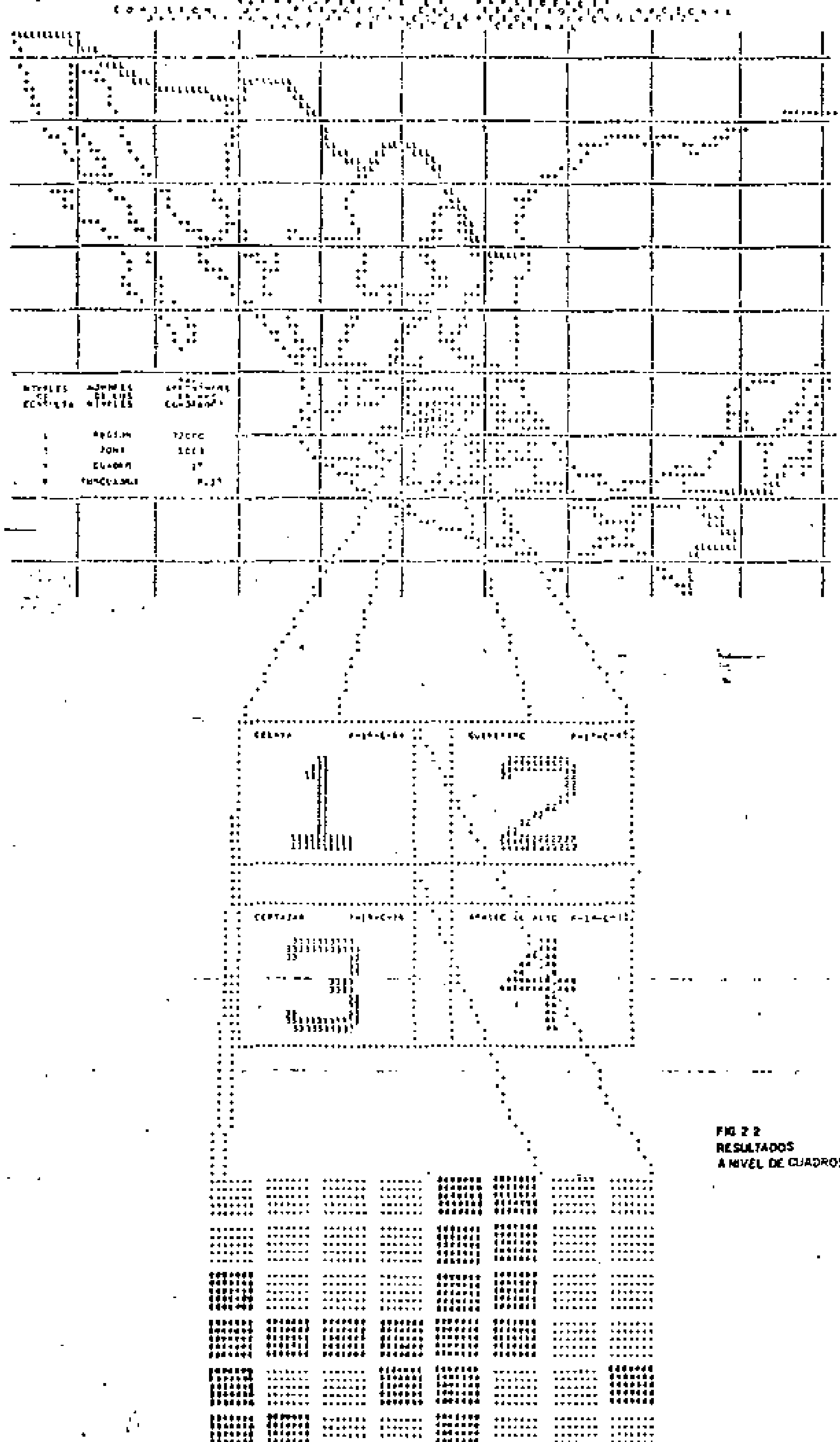


FIG 2 2
RESULTADOS
A NIVEL DE CUADROS

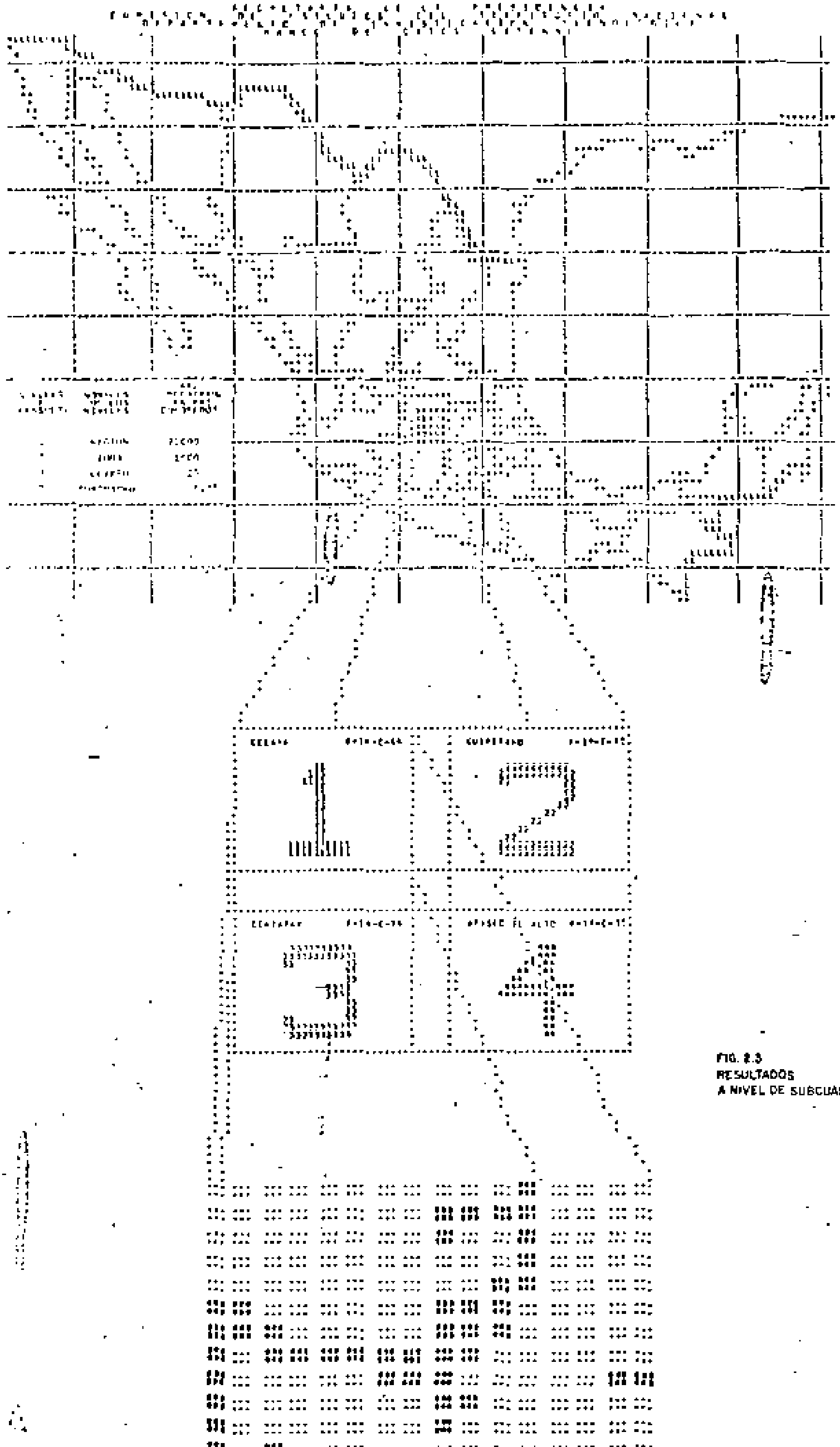


FIG. 2.3
RESULTADOS
A NIVEL DE SUBCUADROS

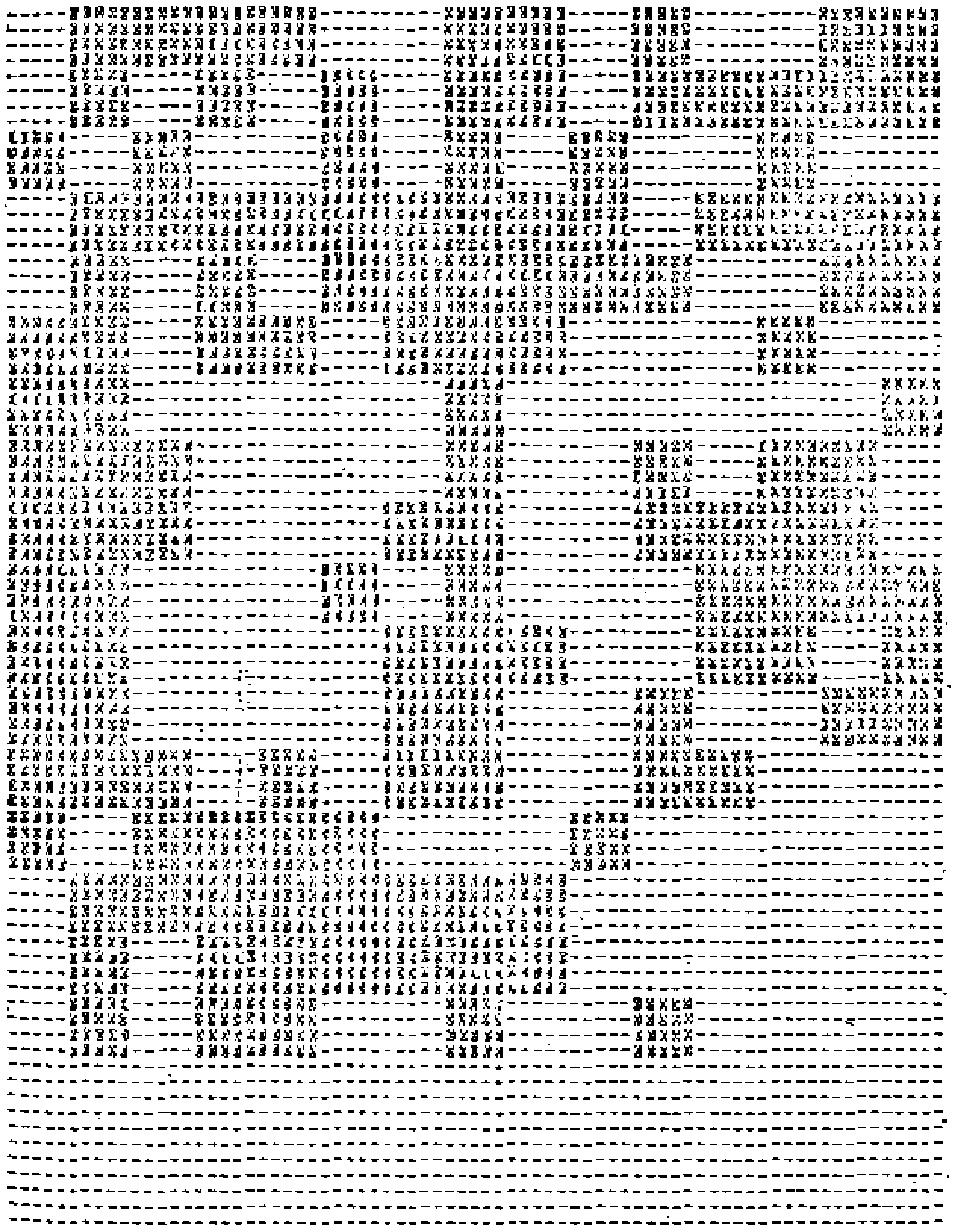


FIG. 24 RESULTADOS A NIVEL DE SUBLOCALIDAD

TABLA 2.1

NOMENCLATURA DE ZONAS, CUADROS Y SUBCUADROS

ZONAS

1	2
3	4

1. Celaya	2. Querétaro
3. Cortázar	4. Apaseo el Alto

CUADROS

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48

SUBCUADROS

ab	ab	ab	ab	ab	ab	ab	ab
cd	cd	cd	cd	cd	cd	cd	cd
ab	ab	ab	ab	ab	ab	ab	ab
cd	cd	cd	cd	cd	cd	cd	cd
ab	ab	ab	ab	ab	ab	ab	ab
cd	cd	cd	cd	cd	cd	cd	cd
ab	ab	ab	ab	ab	ab	ab	ab
cd	cd	cd	cd	cd	cd	cd	cd
ab	ab	ab	ab	ab	ab	ab	ab
cd	cd	cd	cd	cd	cd	cd	cd
ab	ab	ab	ab	ab	ab	ab	ab
cd	cd	cd	cd	cd	cd	cd	cd

DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

COMPUTACION APLICADA A LA PLANEACION URBANA

Manual de utilización del banco de datos cetenal

Agosto, 1981

PREFACIO

El objetivo principal del Banco de Datos CETENAL (BDC), es resolver en forma rápida y confiable, gran cantidad y variedad de problemas sobre el mejor aprovechamiento de los recursos del país, que requieren el manejo de información abundante y compleja.

Actualmente, con la ayuda del BDC, se han localizado cuencas lecheras en el área de Ojo Caliente, Zac.[1] y en las áreas de Celaya, Querétaro, Cortázar, Apaseo el Alto y en el Estado de Aguascalientes se han señalado rutas para carreteras, se han localizado lugares aptos para desarrollar ciertos cultivos específicos, y se han propuesto lugares apropiados para una aplicación dada, con base en soluciones anteriores. Sin embargo, la solución de estos problemas apenas indica el inicio de una serie de aplicaciones en planificación regional, estudios económicos y otros aspectos.

Este manual hace posible el acceso del usuario al BDC, con un lenguaje de fácil aprendizaje y comprensión, que no requiere conocimientos previos en ciencias de la computación.[2]

[1] Véase referencia 2 pag. 180
[2] Véase referencia 1 pag. 180

TITULO DEL MAPA

EVAL DEL IMPACTO DEL PLAN 3 CONTAMINACION DE LA SUP. DE AGUA.

AREA DE ESTUDIO   VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

OPCIONES USADAS PARA ESTE MAPA

10 EL TITULO DEL MAPA ES

LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO I	USO DEL SUELO II	USO DEL SUELO III
ACTIVIDADES DE ESPARC.	ESTACIONAMIENTOS	CABALLERIZAS
CALZADA	ESTRUCTURAS	ESTAC./ TRAILERS
	CAMINOS	
	VIS	

TITULO DEL MAPA

EVALUACION DEL IMPACTO DEL PLAN 3 EN: EROSION

AREA DE ESTUDIO   VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

OPCIONES USADAS PARA ESTE MAPA

10 EL TITULO DEL MAPA ES

LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO I	USO DEL SUELO II	USO DEL SUELO III
ACTIVIDADES DE ESPARC.	CAMINOS	SERVICIO INT. COM
CALZADA	ESTACIONAMIENTOS	CABALLERIZAS
	ESTRUCTURAS	ESTAC./ TRAILERS

TITULO DEL MAPA

EVALUACION DEL IMPACTO DEL PLAN 3 EN: CAMBIO EN LA VEGETACION

AREA DE ESTUDIO   VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

OPCIONES USADAS PARA ESTE MAPA

10 EL TITULO DEL MAPA ES

LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO I	USO DEL SUELO II	USO DEL SUELO III
ACTIVIDADES DE ESPARC.	ESTRUCTURAS	ESTACIONAMIENTOS
CALZADA	VIS	CAMINOS
CABALLERIZAS		ESTAC./ TRAILERS

EVALUACION DEL IMPACTO DEL PLAN Nº 1 EN: EROSION

62

AREA DE ESTUDIO VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO I

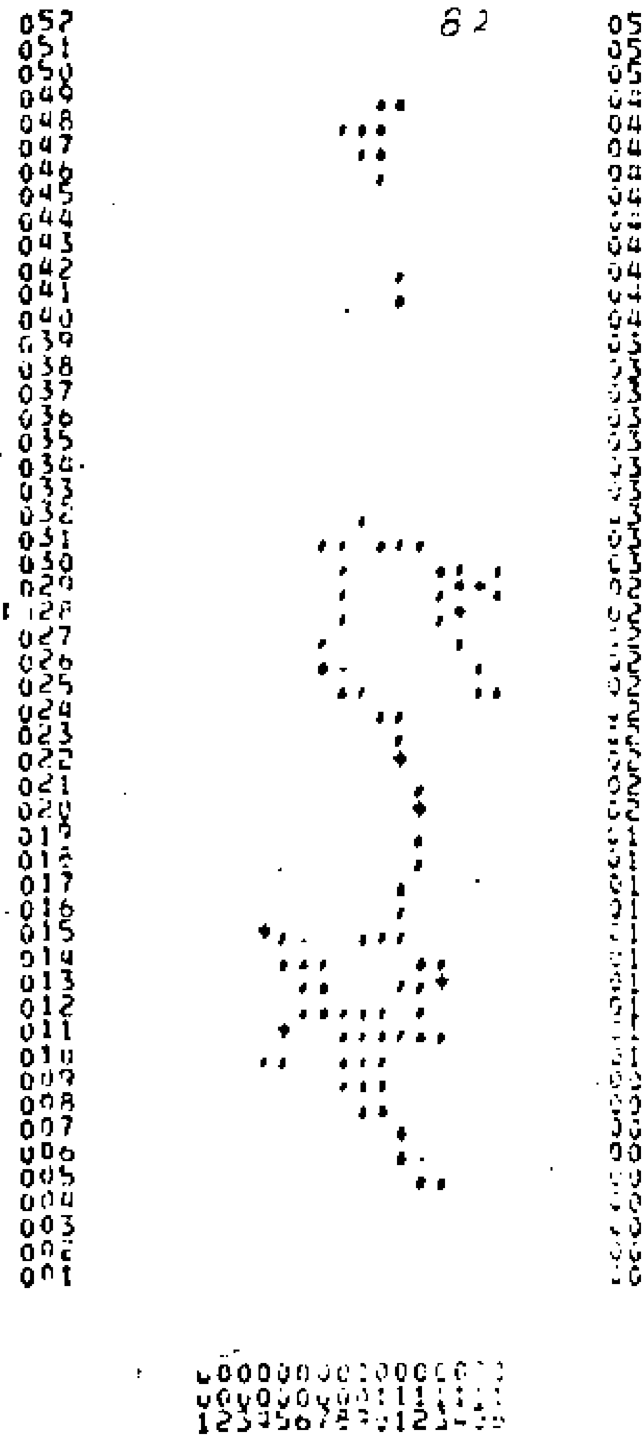
ACTIVIDADES DE ESPRC.
CAMINATA

USO DEL SUELO II

CAMINOS
ESTACIONAMIENTOS
ESTRUCTURAS

USO DEL SUELO III

SERVICIO INF. TURISTICA
CABALLERIZAS
ESTAC./ TRAILERS



NIVELES	0	1	2	3	4	5
SIMBOLOS	.	'	;	+	X	O
FRECUENCIA	0	42	38	6	0	0

EVALUACION DEL IMPACTO DEL PLAN N 1 EN

CAMBIO EN LA VISUALIDAD

AREA DE ESTUDIO VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO 1

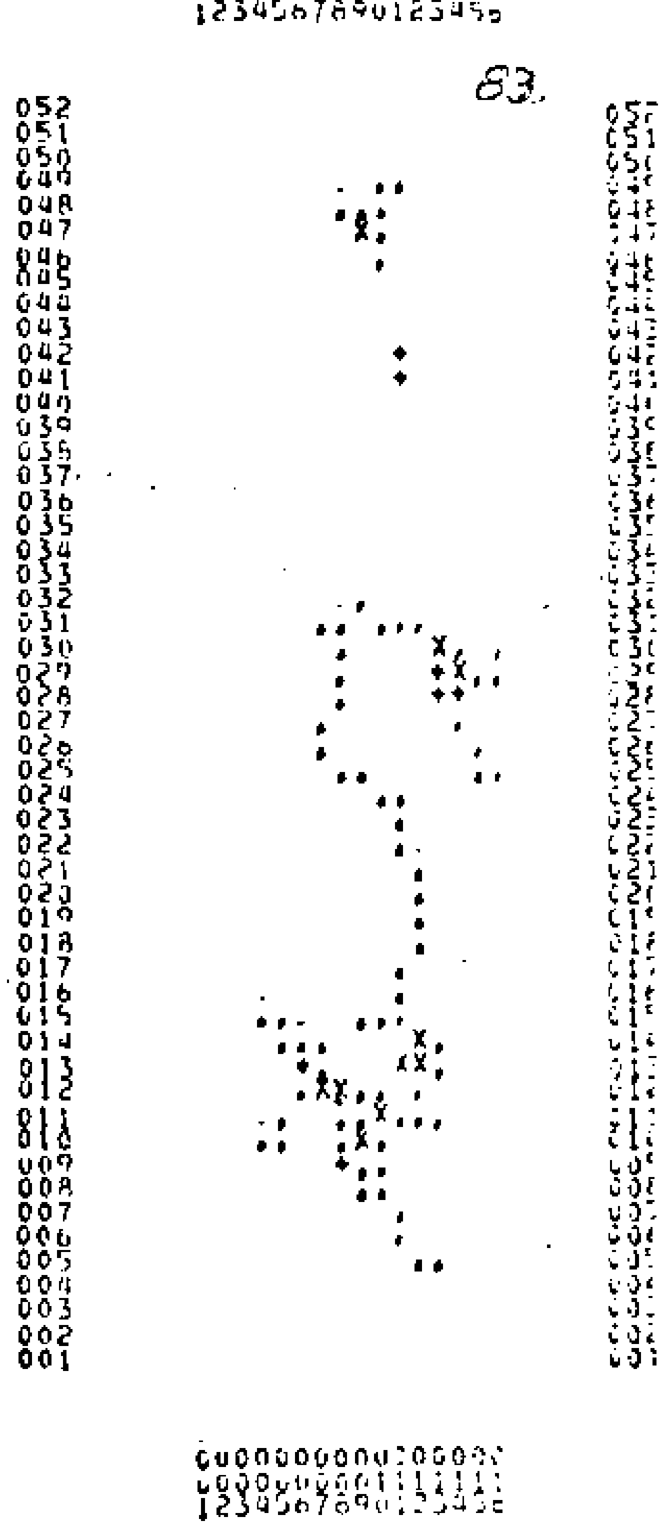
ACTIVIDADES DE ESPARC.
CAMINATA
CABALLERIZAS

USO DEL SUELO 11

ESTRUCTURAS
VIS

USO DEL SUELO 111

ESTACIONAMIENTOS
CAMINOS
ESTAC./ TRAILERS



NIVELES	0	1	2	3	4	5
SIMBOLOS	. . . . .	' ' ' ' '	• • • • •	+ + + + +	X X X X X	O O O O O
FRECUENCIA	0	13	53	7	10	[illegible]

CONTAMINACION DE LA SUP. DE AGUA

AREA DE ESTUDIO VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO I

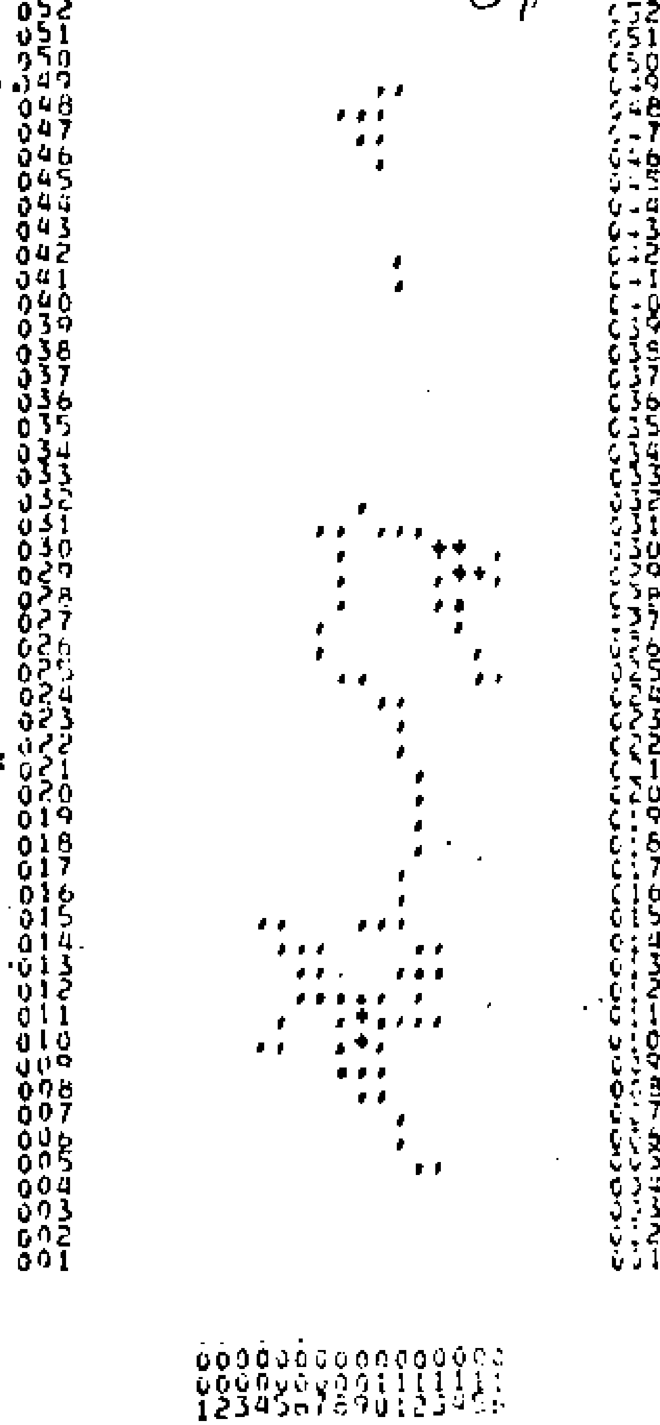
ACTIVIDADES DE ESPARC.
CAMINATA

USO DEL SUELO II

ESTACIONAMIENTOS
ESTRUCTURAS
CAMINOS
VIS

USO DEL SUELO III

CABALLERIZAS
ESTAC./ TRAILERS



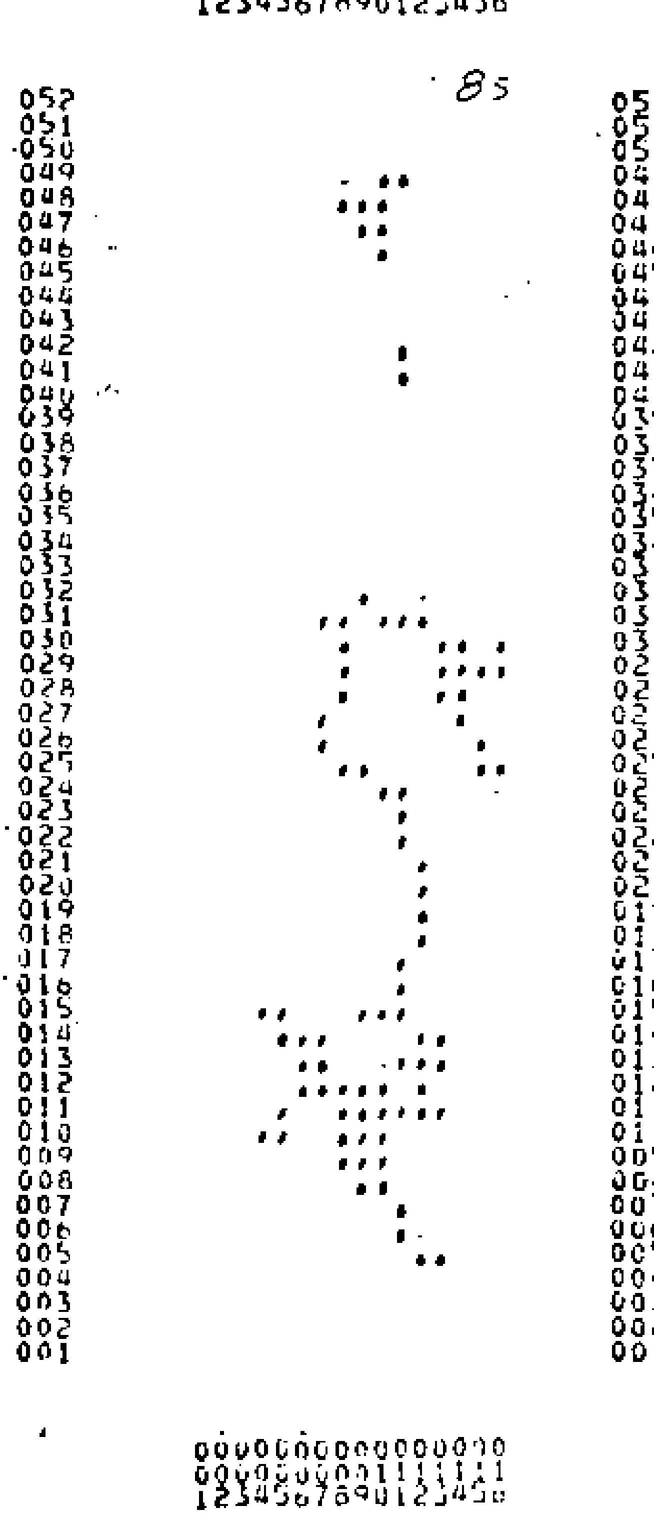
NIVELES	0	1	2	3	4	5
SIMBOLOS	....0....	....1....	....2....	++++3++++	XXXX4XXXX	0000500000
FRECUENCIA	0	73	9	0	0	0

EVALUACION DEL IMPACTO DEL PLAN N 1 EN:

VULNERABILIDAD A FUEGOS

AREA DE ESTUDIO VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA



LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO I
ESTACIONAMIENTOS
CABALLERIZAS
CAMINOS

USO DEL SUELO II
ACTIVIDADES DE ESPARC.
ESTRUCTURAS
VIS

USO DEL SUELO III
ESTAC./ TRAILERS
CAMINATA

NIVELES	0	1	2	3	4	5
SIMBOLOS	....0....	....1....	....2....	++++3++++	XXXX4XXXX	00005000
FRECUENCIA	0	45	43	0	0	0

EVALUACION DEL IMPACTO DEL PLAN Ñ 1 EN:

DESLIZAMIENTOS DE TIERRA

AREA DE ESTUDIO   VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

S USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

SO DEL SUELO 1

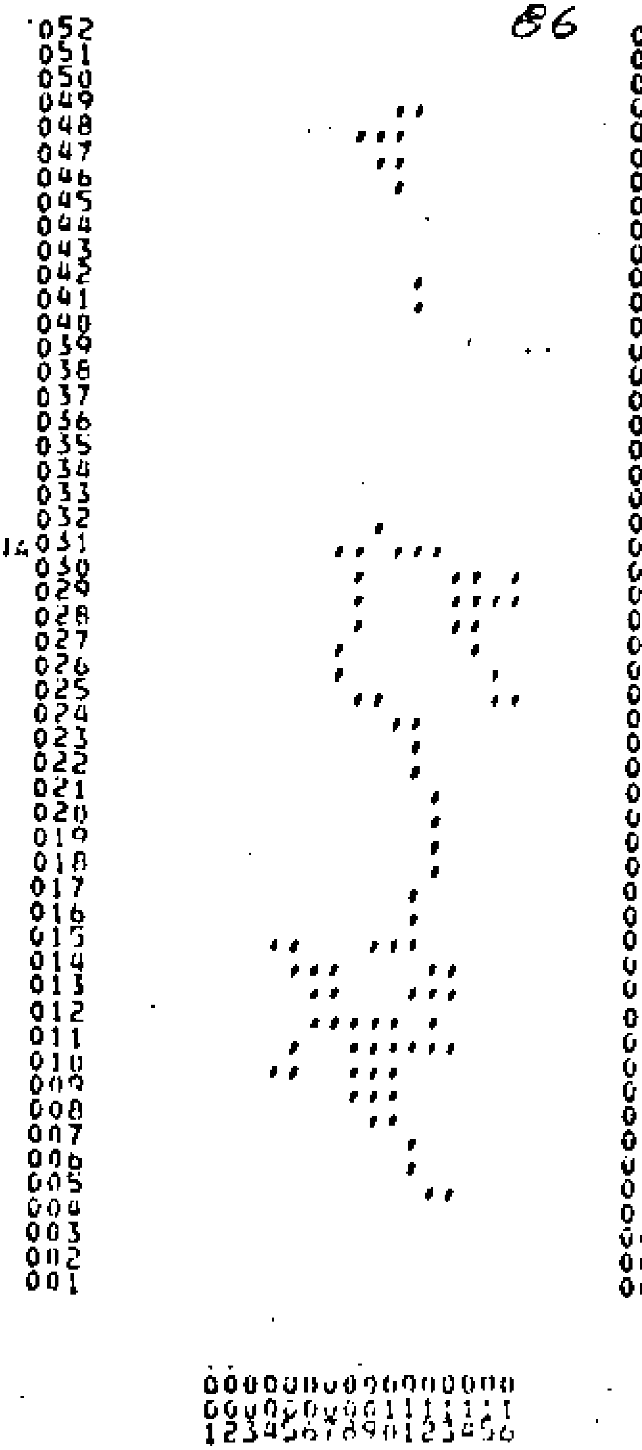
CTIVIDADES DE ESPARC.
MINATA

USO DEL SUELO 11

CABALLERIZAS

USO DEL SUELO 111

ESTACIONAMIENTOS
ESTRUCTURAS
VIS
CAMINOS
ESTAC./ TRAILERS



NIVELES	0	1	2	3	4	5
SIMBOLOS	.....0.....	.....1.....	.....2.....	++++3++++	XXXX4XXXX	00005000
FRECUENCIA	0	88	0	0	0	0

EVALUACION DEL IMPACTO DEL PLAN Ñ1 EN:

BASURA EN EL MAR

AREA DE ESTUDIO VALLE DEL PACIFICO

LABORATORIO DE PLANEACION URBANA

LOS USOS DEL SUELO SE AGRUPARON EN LOS GRUPOS:

USO DEL SUELO I

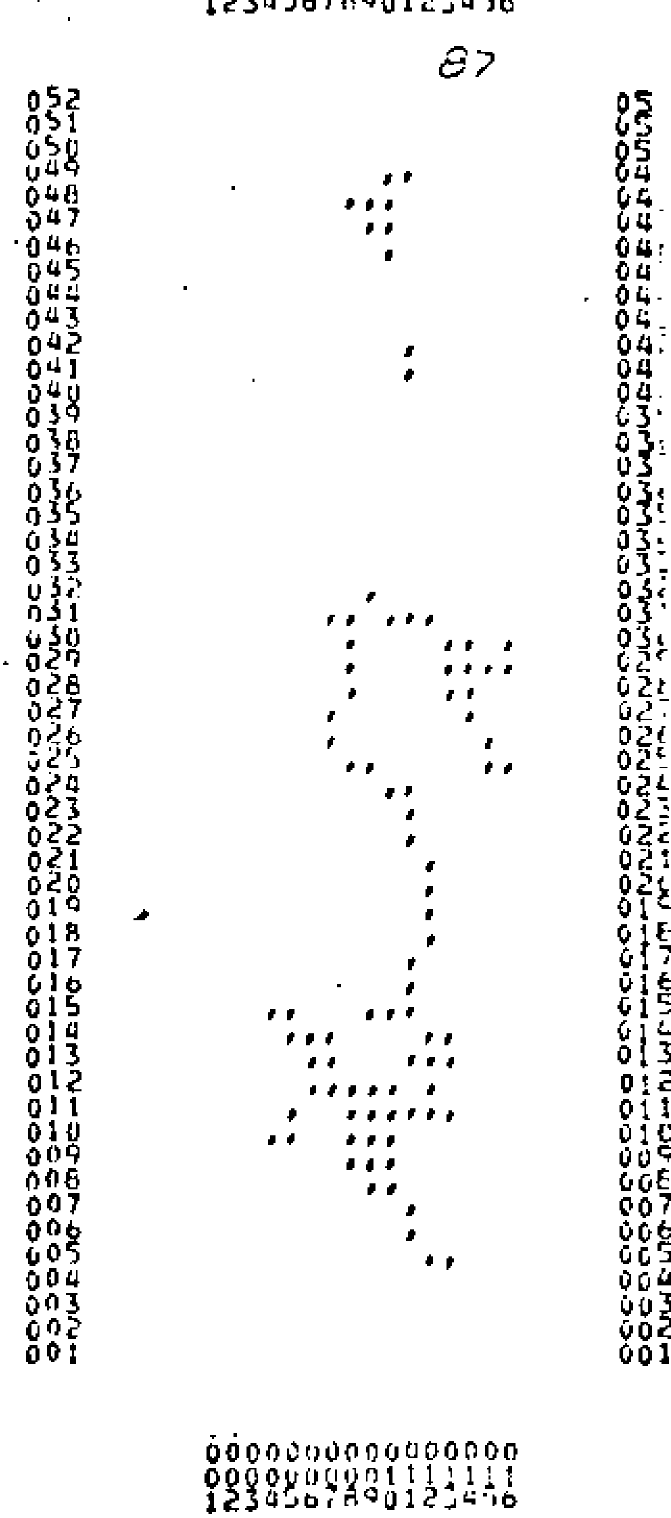
ACTIVIDADES DE ESPARC.
CAMINATA
CABALLERIZAS

USO DEL SUELO II

ESTRUCTURAS

USO DEL SUELO III

ESTACIONAMIENTOS
VIS
CAMINOS
ESTAC./ TRAILERS



NIVELES	0	1	2	3	4	5
SIMBOLOS	.	,	*	+	X	O
FRECUENCIA	0	88	0	0	0	0

VI.2 EL PAQUETE MAP

El paquete MAP maneja una variedad de opciones que controlan el tamaño, el simbolismo y los textos del mapa. Toda opción una vez, especificada seguirá siendo válida en los mapas subsecuentes a menos que sea cambiada. Las opciones 1-7 deben ser siempre especificadas ya que el programa no tiene condiciones estándar en caso de no activarlas. Debe especificarse un paquete MAP para cada mapa que se desee correr.

El paquete se prepara de la manera siguiente:

Tarjeta 1:

Col. 1-3 — MAP para identificar el paquete.

Tarjetas 2-4:

Col. 1-72 — Información que se desea al pie del mapa. Pueden dejarse en blanco, pero deben incluirse las tres tarjetas necesariamente.

Tarjetas siguientes: Opciones deseadas.

Penúltima tarjeta: 99999 para indicar que termina el paquete.

Ultima tarjeta:

Col. 12 — Número de la variable ó archivo que se va a mapear. Perforado como entero justificado a la derecha.

Tarjeta de terminación:

Col. 1-3 — END Debe colocarse después del último paquete MAP de la corrida.

VI.3 OPCIONES DEL PAQUETE MAP

1. Tamaño de la retícula.
2. (No se usa en esta versión de IMGRID).
3. Número de niveles ó intervalos de clase.
4. (No se usa en esta versión de IMGRID).
5. (No se usa en esta versión de IMGRID).
6. (No se usa en esta versión de IMGRID).
7. Simbolismo.
8. Punto señal.
9. Histograma.
10. Texto explicativo.
11. (No se usa en esta versión de IMGRID).
12. Mapa puntual.
13. Numeración de la retícula.
14. Datos escalados.

Opción 1.- TAMAÑO DE LA RETICULA
(1 tarjeta)

Col. 5 1 para identificar la opción.
Col. 11-20 Número de celdillas que contiene la retícula en sentido vertical.
Col. 21-30 Número de celdillas que contiene la retícula en sentido horizontal.
Col. 31-40 Número de caracteres con que se desea imprimir cada celdilla en el sentido vertical.
Col. 41-50 Número de caracteres con que se desea imprimir cada celdilla en el sentido horizontal.

Los números en los campos 2, 3, 4, 5, se perforar como números decimales ó como enteros justificados a la derecha.

Opción 3.- NUMERO DE NIVELES O INTERVALOS DE CLASE
(1 tarjeta)

Col. 5 3 para identificar la opción.
Col. 11-20 Número de niveles ó intervalos de clase en que se subdivide la variable. Perforado como número decimal ó entero justificado a la derecha.

Opción 7.- SIMBOLISMO
(5 tarjetas)

1a. tarjeta:

Col. 5 7 para identificar la opción.

2a. tarjeta:

Col. 1-10 Caracteres que se desea imprimir ó sobre-imprimir para representar a cada nivel o categoría de la variable, dados en orden y perforados en la columna correspondiente. Sólo debe usarse el número de columnas necesario.
Col. 11-20 Caracteres para especificar el simbolismo de los puntos señal que aparecen al centro de cada celdilla y en la clase del histograma correspondiente a cada uno de los niveles o categorías.
Col. 25 Caracter para especificar el simbolismo que aparece fuera del área de estudio.

Opción 8.- PUNTO SEÑAL
(1 tarjeta)

Col. 5 8 para identificar la opción.

Col. 20 1 si se desea suprimir la impresión del punto se

ñal.
0 sí se desea restablecer la impresión.

Cuando se hace un mapa en el que un caracter representa una celdilla, se suprime automáticamente el punto señal y debe restablecerse para mapas subsecuentes. Para otros casos, si no se especifica nada, el punto señal aparecerá impreso en el centro de cada celdilla.

Opción 9.- HISTOGRAMA
(1 tarjeta)

Col. 5	9 para identificar la opción
Col. 20	1 para generar un histograma al pie del mapa, el cual muestra las frecuencias de celdillas de la retícula en cada nivel ó categoría.
Col. 30	1 para suprimir la información numérica que se imprime junto al simbolismo de los niveles ó intervalos de clase.

Sí no se especifica esta opción, no se imprime el histograma y se incluye la información numérica correspindiente. Para regresar el estándar debe perforarse un 0 en los campos 2 y 3.

Opción 10. TESTO EXPLICATIVO
(3 a 32 tarjetas)

1a. tarjeta:

Col. 4-5 10 para identificar la opción.

Tarjetas restantes:
(no mas de treinta)

Col. 1-12 Cualquier información adicional que se desea aparezca al pie del mapa.

Ultima tarjeta:

Col. 1-7 ENDTEXT para indicar que termina el texto.

Si no se especifica esta opción no aparece ningún texto. Si se desea eliminar el texto en mapas subsecuentes, deben alimentarse solo la primera y la última de las tarjetas.

Opción 12. MAPA PUNTUAL
(1 tarjeta)

Col. 4-5	12 para identificar la opción.
Col. 20	1 para especificar simbolismo puntual.
	0 para restablecer simbolismo gris.

Como una alternativa al simbolismo normal mediante esta opción se puede producir un mapa puntual representando cada celdilla mediante 4 caracteres en sentido vertical, 5 en el horizontal y utilizando el simbolo Ø. Se pueden tener hasta 20 niveles ó intervalos de clase. El número de caracteres impresos en la celdilla es -- igual al número del nivel ó intervalo.

Opción 13. NUMERACION DE LA RETICULA
(1 tarjeta)

Col. 4-5	13 para identificar la opción.
Col. 20	1 para numerar la malla
	0 para regresar al estándar.
Col. 21-30	Número de columna de la celdilla de referencia. Perforado como número decimal ó entero justificado a la derecha.
Col. 31-40	Número de hilera de la celdilla de referencia. Perforado como número decimal ó entero justificado a la derecha.

Esta opción imprime numeración para las hileras y las columnas en los cuatro lados de la retícula para ayudar al usuario a localizar celdillas individuales sobre el mapa. La celdilla superior izquierda es denominada celdilla de referencia de la retícula y sus coordenadas sirven de orígen para numerar hileras y columnas. Si estas coordenadas no son especificadas el programa supone que son: columna = 1, hilera = n, donde n es el número de hileras especificado en la opción 1. Si no se especifica no se numera la retícula.

Opción 14. DATOS ESCALADOS
(1 tarjeta)

Col. 4-5	14 para identificar la opción.
Col. 20	1 para indicar que los datos estan escalados.

Esta opción siempre debe activarse en esta versión del programa.

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graphic features will also have the many shading, line type, text and scaling options that are available in the mapping system. Figure 2 povides an example of the some of graphics the system is capable of producing. The user will also be able to integrate these graphics with maps produced by the system.

Geographical Searching

Release 4 provides a spatial searching capability which allows the ser to conduct a point/polygon/line relational search of his locational data. This is enhanced by a SUBSETTING routine which subsets both the locational and non-locational data based on the criteria of the spatial search or another user definition. Spatial searching is carried out as either within a specifed distance and angle or as an overlap or intersect. The system also provides an AGGREGATE facility to total components of the non-locational data.

Figure 3 shows an example of th automatic location of census tracts within a specified distance of a given line.

Utilities

Release 4 will allow conversion of polygon, line or point data (both locational and non-locational) to a grid matrix. This is meant to facilitate interfacing to other software such as SYMVU and ASPEX.

Printing of information held in GIMMS system files is made easier in the new release.

The *FILEDUMP command has the capabilities to print, or transfer to a user file, the contents of GIMMS files. The output is character formatted and is useful for transfer of information to other systems.

Value Symbolism

Figure 4 shows some of the range of GIMMS symbolism. Symbols 1 to 3 show the basic three types of GIMMS shading, cross-hatching, dot screen, and bar shading. They may be mixed in a multiple of ways of which symbol 7 shows one option but there are many. Symbol 4 shows a dot map and symbols 5 to 7 show label mapping. Symbols 8 to 24 show various combinations of point symbol mapping with shading and label mapping to provide some variety. Symbols 26 to 34 show multi-component point maps and symbol 35 shows a two component bar shaded map.

This is not the total of GIMMS symbolism. All of the symbols may have different colours and line types. For example, interesting shading patterns can be produced using dashed lines instead of solid ones and the uses of colour are obvious. In addition the combinations of symbolism are tremendous. For example, each shading level can have up to 4 layers of crosshatch and each crosshatch can have up to 7 parameters specified for it. Since the first four parameters are separation between lines, angle of lines, pen colour and line type (solid, dotted etc.) it can be seen that there is a virtually infinite range of just this one symbol type.

Release 4 will provide the user with the facility to shade areas, graphs and pie charts with symbols from the many accompanying alphabets which he may construct himself. In other words if the user is mapping the distribution of dairy cows the map can display a pattern of dairy cow symbols. This enhancement to the symbolism option will also provide halftone and continuous shading as user options. The enhancements are completed by the inclusion of a routine to generate flow arrows.

Cosmetics

GIMMS has a wide range of capabilities to add basic and supplementary information to a map. The most important of these is the *TEXT command which has a very wide range of facilities. The basic alphabets provided are the basic GIMMS alphabets and the Hershey font alphabets. Unlike several other implementations of these alphabets, structured access is provided to the alphabets. For example:

*TEXT ---- ALPHABET=14, TEXT='Test text'

would produce the text required in the requested alphabet. As an example of the flexibility of the system, there are three levels at which the alphabet may be chosen. It may be chosen by the *TEXTPARM command to apply to all text produced except where requested otherwise. It may be selected by the *TEXT command to apply to a particular string, thus over-riding any *TEXTPARM specification; and it may be specified within the string to apply to subsequent characters until changed.

In the *TEXT command, there are extensive facilities such as centering, full justification or right justification of multi-line text strings, variable ratio of characters (to make characters tall and thin or short and fat), proper underlining and repetition of characters to make them bolder.

The addition of a block letter alphabets with the capability of being shaded is an additional feature of Release 4. As is the capability to shield text from shading and line drawing. Examples of these features are provided in Figure 5.

The system also has facilities to draw north arrows, linear information of any kind, legends of various kinds, with even greater flexibility now provided in Release 4.

Interactive Design

One of the most useful facilities of the system is the interactive compilation (*COMPILE) system which allows the user to create map frameworks using an interactive graphic terminal (e.g. a Tektronix 4000 series). This removes the delay in waiting on output returning from the plotter to find that a piece of text is too far to the right by 1 cm. Since the user can point (using *COMPILE) at the appropriate position, not only are better maps produced but they are produced more quickly and efficiently.

Other facilities

The GIMMS system has a variety of facilities to control both plotting and the structure of maps and graphs. In the former category fall facilities such as the selection of solid, dotted, dashed or chained lines which may be done for any object to be drawn (e.g. text), and the scaling up or down of any picture so that a picture may be developed at one size and final reproduction may be at another. The facilities which affect the structure of the output include the ability to draw several separate maps or graphs in one run, to draw several maps or graphs within one sheet, to overlay different maps or graphs, to produce insets and other such facilities.

Integration of facilities

It is the combination of all the above facilities, in an inter-related manner, which makes GIMMS such a flexible system. Since the quality of the output depends on the quality of the plotter/drawing device GIMMS can produce medium to high quality maps. As an example of high quality colour maps produced by GIMMS, the reader is advised to consult the 1976 census bulletins of Statistics Canada.

OUTPUT INTERFACE

While all of the above facilities are provided within GIMMS, the system does not drive a plotter directly since to do so would cause GIMMS to be dependent on that device. Instead GIMMS calls installation supplied graphic routines to interface to a physical device. Even graphic routines provided by installations are very variable, however, and therefore GIMMS' dependence on this is minimised. In fact, the only drawing routines called are those to move the pen either with the pen raised or lowered.

The system is interfaced to graphic devices usually plotters via a set of user provided subroutines which generally call manufacturer provided software. Sets of these subroutines are provided for common graphics libraries such as the CALCOMP basic software and the GINO-F graphics system.

In addition to a plotter interface, GIMMS Release 4 has an interactive graphics interface and software is included to drive the Tektronix 4000 series of terminals including full support for the Tektronix 4027 colour graphics display.

The flexibility of the output interface was utilised by Statistics Canada who used GIMMS to produce pages for the TELIDON viewdata system. Now that AT&T have announced a standard for US public viewdata systems that encompasses the TELIDON standard the use of GIMMS to produce pages of text and graphics for such systems gives a company or government department the capability to reach the public with text and colour graphic information at minimal extra cost. Given an existing graphics device, using GIMMS could save thousands of dollars since an input and editing terminal need not be bought.

DATA REQUIREMENTS

The general structure of GIMMS is shown in figure 6 (which was also produced by GIMMS) as well as the inputs and outputs of the system. The three primary inputs to the system are on the left of the diagram and consist of the locational data input, which are the geographic descriptions, the non-locational data, usually statistical data relating to them, and the commands to control the system.

Locational Data

This consists of either point, line or area descriptions. In the case of area descriptions they may be input as either segments, which is preferable, or complete area descriptions. If areas are input as segments then they are first checked using a topological edit program and then linked to form areas (polygons). In all cases, the co-ordinates may be transformed on input from the co-ordinate system to another (e.g. from digitiser table co-ordinates to UTM co-ordinates). Points are input as a simple list of x, y co-ordinates. Lines are input as a label followed by a string of x, y co-ordinates.

If it is wished to ensure that the lines form a linked network then either the user must ensure that the end points of the input lines match exactly or he must use the GIMMS matching procedure (AUTONODE).

As each line is input the end points are matched to the current set of node points within the tolerance specified. If a match is not made then a new node is created. The end points of the line are then replaced by the nearest matching node point. This ensures that lines do match exactly at node points. To avoid problems where nodes are very close they may be explicitly entered.

The input of areas by segment is carried out the same way as for lines except that instead of a single label, each segment must have two labels, one for the area on the left of the segment and one for the area on the right. There are many auxiliary facilities to help the input procedure such as hierarchical labelling. Runlength encoding is also provided to provide better economy in data input. Finally, the option of assigning generalization codes at the time of polygon creation allows for further economies during the map production stage.

Area descriptions may also be input as complete polygon descriptions but in this case the user is responsible for ensuring that common boundaries match.

In addition to these standard input facilities, GIMMS allows the user to input point, area, or segment data directly through a user provided subroutine interface. A special part of the *FILEIN module will read SYMAP B-DATA or A-CONFORMOLINES packages. It is also possible to create special purpose interfaces.

Non-Locational Data

Non-locational data describe the nature of geographical distributions, such as the percentage of voters in each constituency who voted Social Democrat at the Last General Election, or the number of patients attending each dental surgery in Edinburgh during a given week. An example of entering non-locational data would be:

```
*FILEIN
DATAFILE NAME=ELECTED
TITLE='POLITICAL COMPLEXION OF CONSTITUENCY M.P.s'
ZONES=630
VARS=2 NAMES=PARTY MAJORITY
BEGIN
.
.
DATA
.
.
```

The effects of these options would be as follows:

By issuing the keyword DATAFILE the *FILEIN module is told to expect non-locational data. Once read this will be stored on the data file and given the GIMMS name of ELECTED. The GIMMS name is internal the system and allows the user to check that he is using the correct file.

A title has also been supplied. The purpose of this being to remind the user of the nature of the stored data when he comes to re-use it at a later date. This is particularly useful when the user has a large number of GIMMS files. The system is then told that there are 638 zones for which data are to be entered, and that there are two variables for each zone, the first is known as PARTY and the second as MAJORITY.

The geographic descriptions and the data relating to them must be input in the same order. This applies to all data except where areas have been input as segments (which tends to be the most common case). When the area file is being created (*POLYGON command) then the user may re-order the zones to correspond to a differently ordered data set.

<u>Commands</u>

The GIMMS system is operated by a series of user commands. This language is more fully described in:

WAUGH, Thomas C. 'A parameter driven language for use in application systems'
Proceedings of Advanced Symposium on Topological Data Structures
Laboratory for Computer Graphics and Spatial Analysis
Harvard University, October 1977

The language is free format, keyword oriented, and is very flexible in the method of input. For example, the numbers labelling the different 'mini-maps' in figure 4 were produced by one *TEXT command of the form:

*TEXT SIZE=0.25,ALPHABET=16 X=0.4,Y=0.4 '1' / Y=4.4 '2' / Y=8.4 '3'

and so on

The parameters could have been given in another order (e.g. *TEXT ALPHABET=16, SIZE=....). The oblique tells the system to draw the text but keep all the parameters as they were and so only the Y value need be changed for the next piece of text. In the above example, the values for X, Y and SIZE could have been set using a graphic cursor in an interactive session.

Each of the 'mini-maps' in figure 2 were created by a set of *SYMBOLISM commands (to change the symbol type), a *MAP command (to do the drawing), preceded by an *ORIGIN command (to move the outlines to the proper position).

For example, to create 'mini-map' 4 required the commands:

*ORIGIN 0 12   *MAP 1 DOT

and to create 'mini-map' 5 required:

*ORIGIN 0 16   *SYMBOLISM LABEL, SIZE=0.15   *MAP 1 LABEL

and for 'mini-map' 8:

*ORIGIN 4 0

*MAP ; POINT

and for 'mini-map' 9;

*ORIGIN 4 4

*SYMBOLISM POINT,DEPICT=1 (selects circle symbolism)

*MAP ; POINT

Thus it can be seen that different map types can be selected very easily using this language.

Program Limits

Every program has data limits and programs vary in how easy it is to change the more restrictive ones. The main limits in GIMMS which may be increased by changing two subroutines (installation dependant) are;

Maximum number of co-ordinates per polygon 10000

Maximum number of co-ordinates per line or segment 10000

Maximum number of segments (i.e. common boundaries) per polygon 500

Maximum number of hierarchual labels per polygon 100

In addition there are some display and data limits which would be difficult to change;

Maximum number of class levels 20

Maximum number of components in a multi-component symbol 20

There is no theoretical limit to the number of data zones (points, lines or areas) that may be dealt with, it depends on the file storage space. There are also other limits which are not particularly restrictive (e.g. the maximum number of alphabets able to be entered into the system is 99).

Implementation

GIMMS is written in FORTRAN IV (G-level) and was developed on a Xerox Sigma 7/9, an IBM 360/370, an AMDAHL 470, ICL System 4, and several ICL 2900 machines all of which are 32 bit word machines. It has also been implemented on ICL 2900 and 1900 (24 bit word) ranges, CDC Cyber, Honeywell 6/CP6 (GCOS pending) and DEC10 machines. Release 4 will also be available on PRIME and VAX machines. There is one subroutine in assembler (logical left and right shift).

It has been mounted on at least six different operating systems and interfaced to at least five graphic software systems driving at least five different makes of plotter.

Availability

Release 4 of GIMMS will be available for 'IBM Type' machines with Virtual Memory on 1 October 1981. The appropriate versions for the various machine ranges mentioned earlier will follow promptly thereafter.

The price of the system will be $1000 per annum with an initial cost of $500 for new users (i.e. sites not possessing GIMMS Release 3). As with most systems, it is licensed for only one machine per organisation.

CONCLUSION

GIMMS is a flexible and general purpose geographic information system with a large range of facilities. In particular, Release 4 of the system provides many new facilities such as the decision graphics subsystem providing a line, bar, pie, and scatter graph capability. The geographical search capability will prove especially useful for resource management problems. A wide range of new symbolism, text facilities, and associated facilities make the capabilities of GIMMS unrivalled in geographic systems.

Figure 1

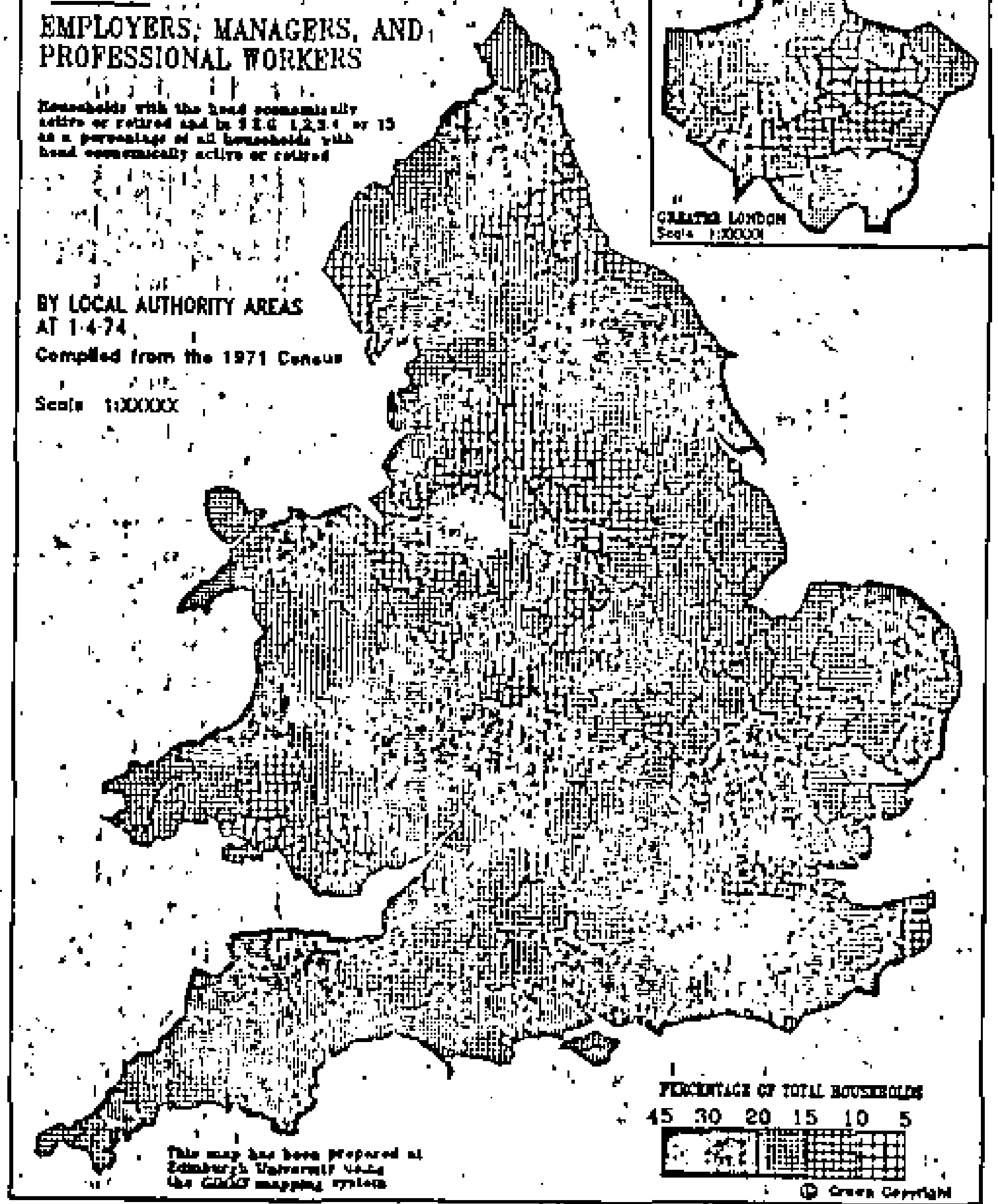
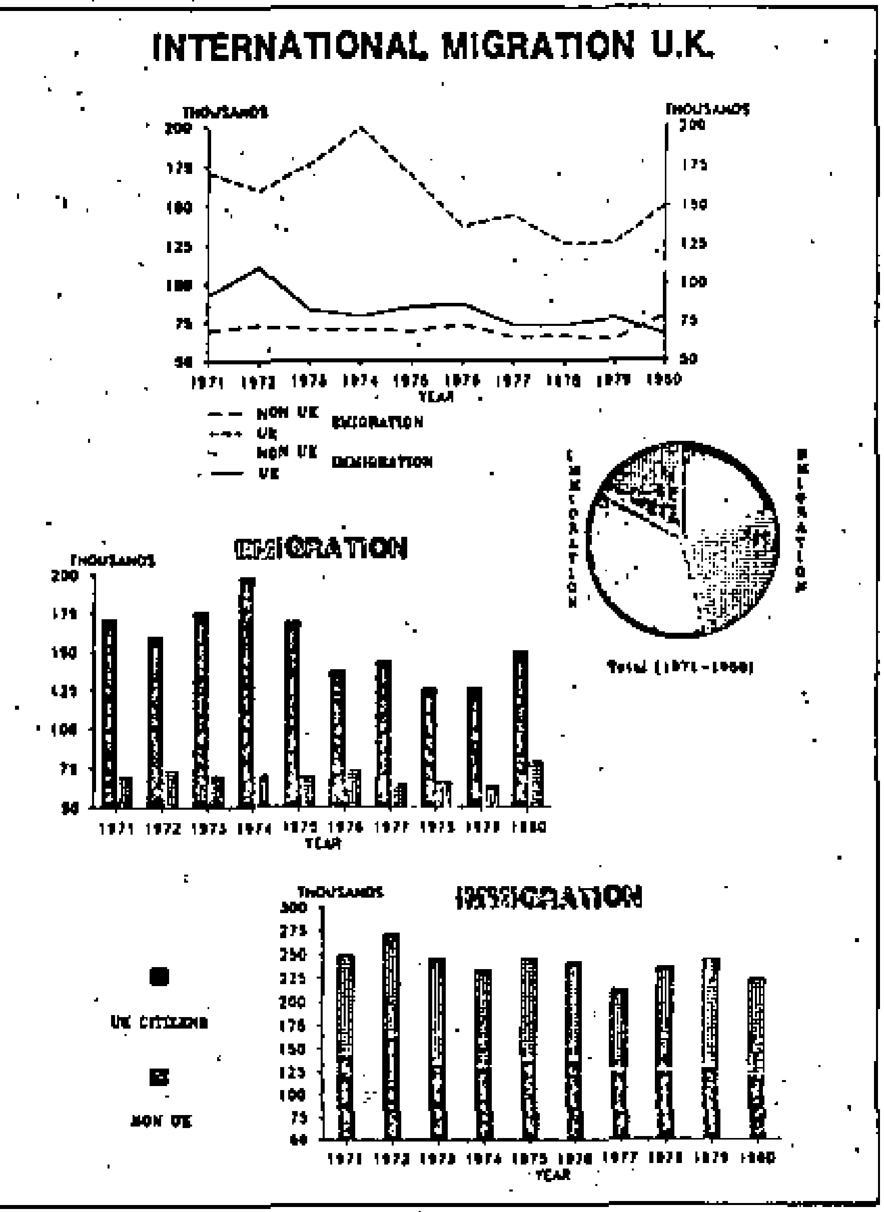
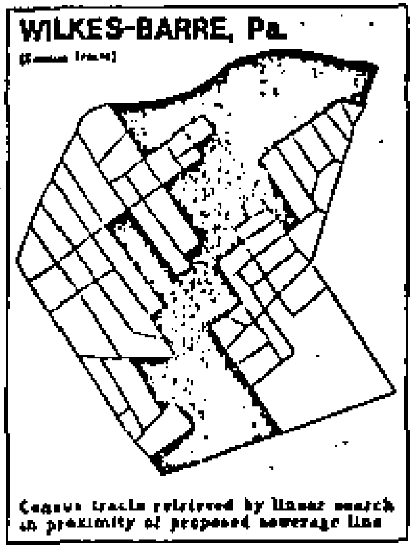


Figure 2



19

Figure 3



20

Figure 4

21

NEW TEXT FACILITIES

NORMAL

This small paragraph of text is designed to show the use of various layout modes.

CENTERING

This small paragraph of text is designed to show the use of various layout modes.

RIGHT JUSTIFICATION

This small paragraph of text is designed to show the use of various layout modes.

FULL JUSTIFICATION

This small paragraph of text is designed to show the use of various layout modes.

MANY NEW Alphabets

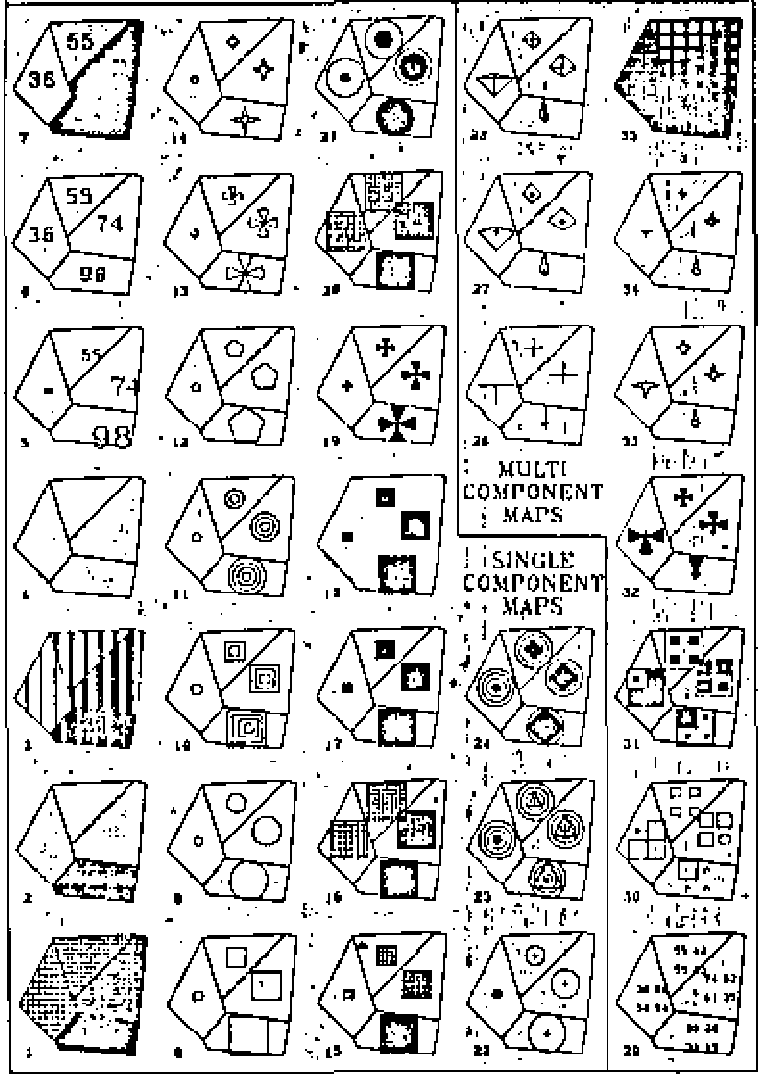
SHADED ALPHABETS

TEXT ACROSS

SAY DOWN

SHIELDED TEXT

GIMMS symbolism chart



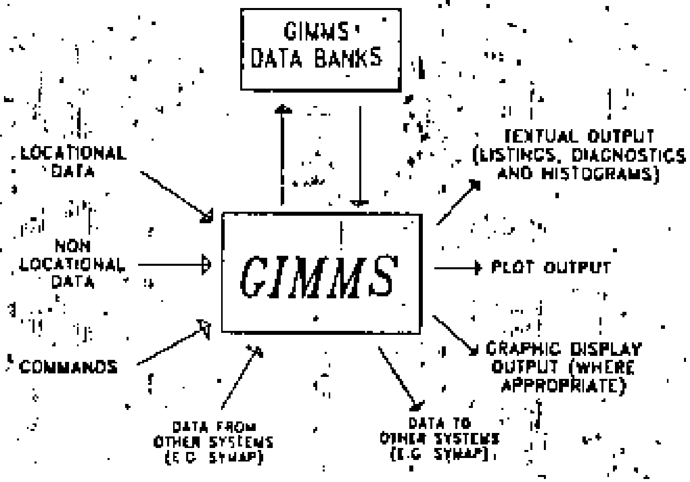


Figure 2.1

THE COMPUTER GRAPHICS INDUSTRY

by Patrick Kenealy, GML Corporation

The following paper is excerpted from GML Corporation's DISPLAY TERMINALS PRICING STRATEGY SERVICE, a multi-client market research report done for major display terminal manufacturers. Statistics were taken from GML's Keyboard Display Database, a constantly updated database storing 100 marketing and technical facts on each of 1200 currently manufactured and obsolete display terminals. Source data is available from the author at 594 Marrett Road, Lexington, MA 02173.

INTRODUCTION

The growth of the graphics industry in the past five years has been accelerating. The number of vendors marketing graphics displays is still small compared to other terminal subindustries, such as the editing terminal industry, but with user demand increasing, and profits per unit high, more vendors will be considering their own graphics introductions in the near future.

There are two basic types of graphics terminals:

- limited graphics terminals, which approximate curves and diagonal lines through the arrangement of graphics characters on a low resolution screen;
- full graphics terminals, which display diagonal lines and/or curves by specifying parameters such as the endpoints of a line, or the center and radius of a circle. Generation can be through hardware or software control, and screen resolutions generally exceed 512x512 displayable points.

Limited graphics is popular in personal and business computing for displaying relatively simple diagrams and forms. Some limited graphics terminals display more complex graphics, but their applications are still limited by small memories and low resolution CRT's.

Full graphics terminals allow the virtually unlimited display and manipulation of visual data. It is this type of

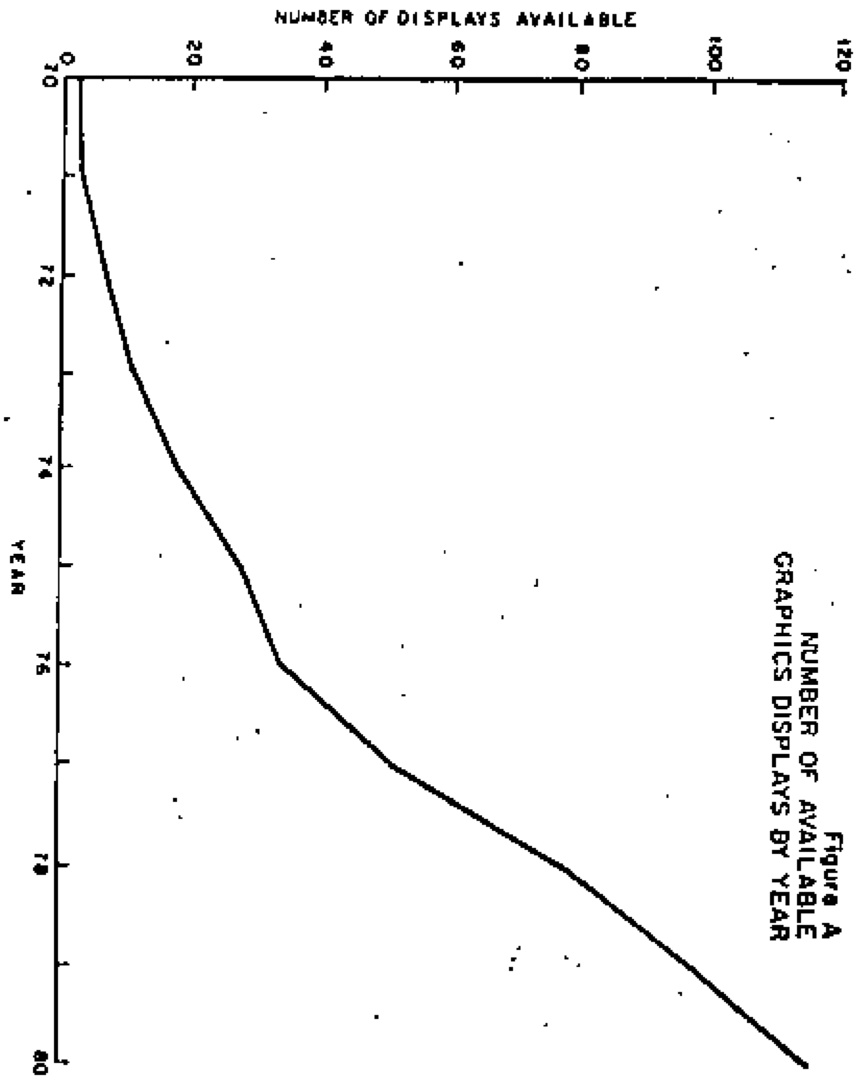


Figure A
NUMBER OF AVAILABLE
GRAPHICS DISPLAYS BY YEAR

terminal that has become indispensable to designers, manufacturers, researchers, draftsmen and others, and new applications are being developed continually.

This report deals exclusively with full graphics displays. Limited graphics capability no longer defines a terminal type in the same way that full graphics does and limited graphics is a standard or optional feature on the majority of alphanumeric (dumb, editing, and intelligent) terminals. Displays with vector graphics capabilities are generally designed specifically for use in graphics applications and, in general, are significantly different from alphanumeric terminals. Still, even a $200,000 minicomputer-based, stand-alone graphics system is properly considered a terminal in the sense that it is designed to provide visual output of computer-generated information. Both stand-alone graphics systems and graphics terminals which rely on the host for all, or some memory and processing are included in this report.

THE INDUSTRY

Figure A shows the growth of the number of available graphics displays from 1970 through 1980. The growth rate fell off significantly in 1980, probably due more to economic factors than to any trends within the industry. Neither the media nor vendors reported a drop in units installed that year but the GML database showed a slow-down in product development that reflects some conservatism on the part of graphics terminal vendors.

Graphics displays are currently manufactured by over fifty vendors. A half-dozen companies specializing in graphics have emerged as industry leaders, but recently the data processing giants have again shown signs of making a push into the field. In the graphics field, as in the mini-computer industry, there are many more system house type vendors than there are manufacturers. General-purpose graphics software is scarce and too complex for many users to understand and roughly 200 companies sell turnkey graphics packages for mapping, circuit design, medical and dozens of other specific applications. Standardized software as endorsed by ACM SIGGRAPH and other organizations will speed the development of true general purpose systems in the low, medium, and high price ranges, allowing manufacturers to build more units but fewer different models. Systems houses will offer customized software for the general purpose terminals, and technologically advanced manufacturers will offer more and more capable hardware.

Introduction rates will be limited by the immense software and hardware development costs (relative to other terminals) incurred by full graphics units and by economic factors affecting the borrowing cost of development money. Manufacturer mortality rates are lower for graphics terminal builders than for builders of other display types since builders must necessarily be well-funded to even build a viable unit. In all, introductions of new graphics display hardware should continue to grow with more models coming from established builders than from small innovators. Introductions of turnkey packages from system houses should be explosive, at least until graphics software becomes easy for current computer users to use. Everyday business graphics will spur introductions of partial graphics terminals while presentation-quality business graphics and the rush to improve design and manufacturing productivity will encourage full graphic introductions.

PRICES

Graphics displays range from modified editing terminals to room-sized systems complete with minicomputers, disk drives, digitizing tablets, plotters, and multiple workstations. Given this variation in hardware and the relatively small number of systems on the market, mean and average prices for these terminals are less meaningful than for the mainstream terminal types studied in earlier focus reports.

The current price distribution (Fig. 8) reflects the spread in features and capabilities of the different systems. A large number of displays are sold in the five to ten thousand dollar range; these are generally terminals with features similar to those found on many intelligent terminals, with the addition of low resolution raster graphics. A terminal in this price range might offer a 15-inch, 512x256 point screen, 64KB of user memory and a diskette drive. Function keys and a light pen are also often included, with additional storage and some video or serial matrix hard copy optional.

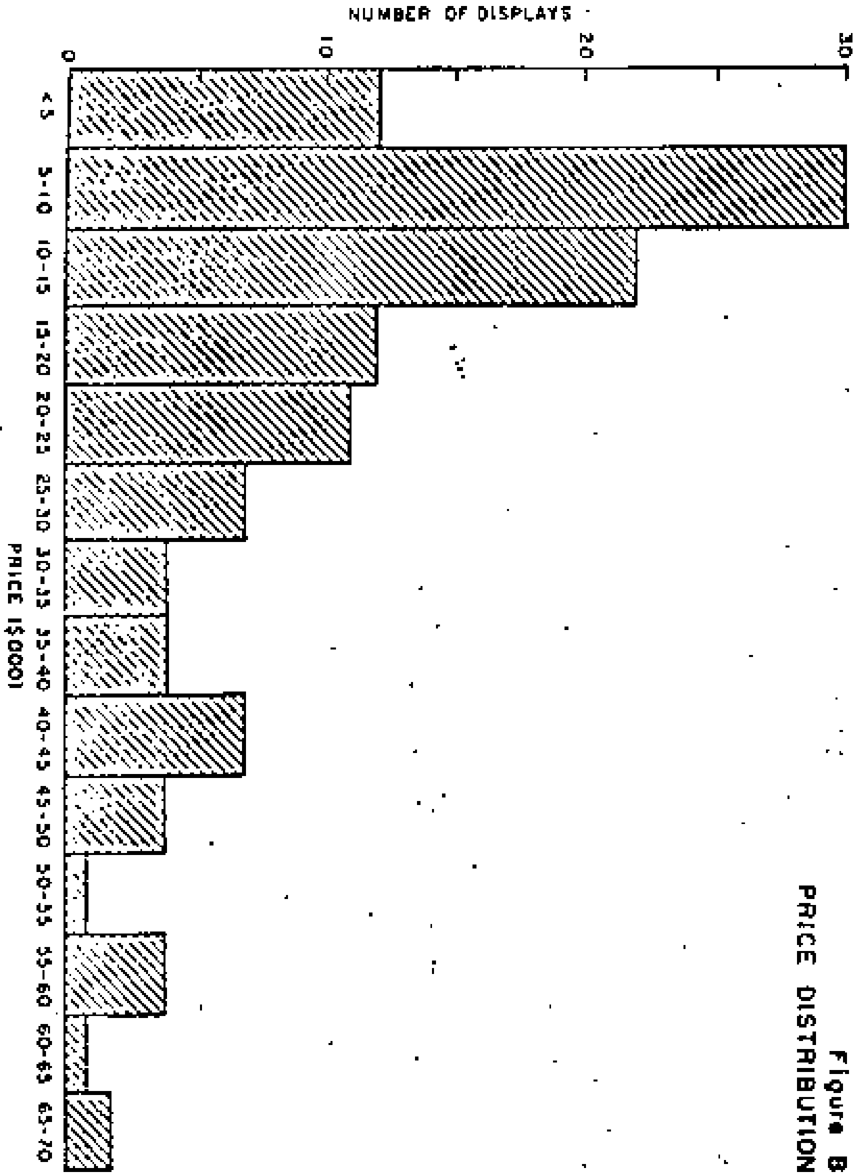


Figure B
PRICE DISTRIBUTION

Graphic terminals selling for less than $5,000 are typically more limited in their display capabilities, often providing smaller, lower resolution screens and less memory than the more expensive terminals.

Although the number of terminals priced above $10,000 drops rapidly, it levels off at about $25,000 and stays fairly constant from this price on up to $50,000. Displays in the $25-50,000 range offer more extensive features, including disk storage, digitizers, large, high resolution, multicolor screens, plotters, and powerful applications software. Many of these systems are used in CAD/CAM applications and provide the memory and processing power necessary for dynamic, complex figures.

A number of systems are available for more than $50,000, some costing as much as $250,000 in typical configurations. Image processing and more powerful CAD/CAM systems are often in this price range. These systems are generally minicomputer-based with memories of 500 KB and more, and provide a number of sophisticated graphics peripherals arranged in configurations that cost as much as those in medium-sized data processing environments.

FEATURES

Despite the diversity of graphics display terminals, it is possible to identify a number of principle distinguishing features. One of the most fundamental differences between

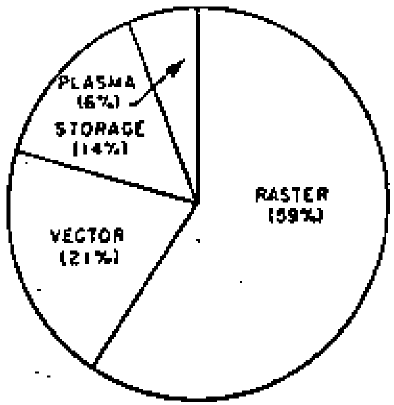


Figure C
SCREEN TECHNOLOGY

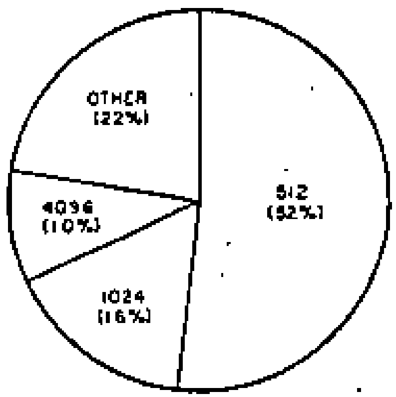


Figure D
RESOLUTION (NUMBER OF HORIZONTAL ELEMENTS)

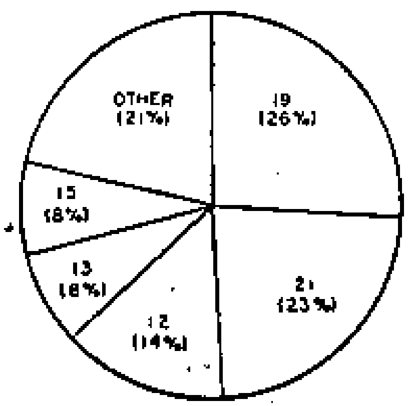


Figure E
SCREEN SIZE (DIAGONAL INCHES)

graphics terminals is display screen technology. Almost all alphanumeric and partial graphics terminals use low resolution raster scan technology, but in graphics, a number of technologies have proved popular.

Direct-view storage tubes, developed by Tektronix, are the oldest and were the most popular graphics displays. These displays need little memory since images are stored on the CRT's phosphor and have high resolution and low flicker. But storage tubes have low brightness, limited color capability, and erasure or screen editing is not selective.

Stroke refresh or vector scan displays use the same random drawing method as direct-view storage tubes but vector scan displays refresh their images by periodically redrawing them. They offer high resolution, high brightness, and can be selectively erased. Vector scan displays begin to flicker as the number of simultaneous vectors they display increases, and provide only limited color capability at high additional cost over black and white..

Raster scan graphics displays use the same raster refresh system used in alphanumeric CRT's, forming images on a continually scanned matrix of individually addressable points. Resolution is dependent on local refresh memory more than on CRT technology. 1024x1024 displayable points is the usual maximum resolution for raster displays but resolution is rising with each new year's introductions. Raster displays are getting less expensive as memory prices fall,and their color capability is excellent. Raster displays

Figure F
NUMBER OF COLORS

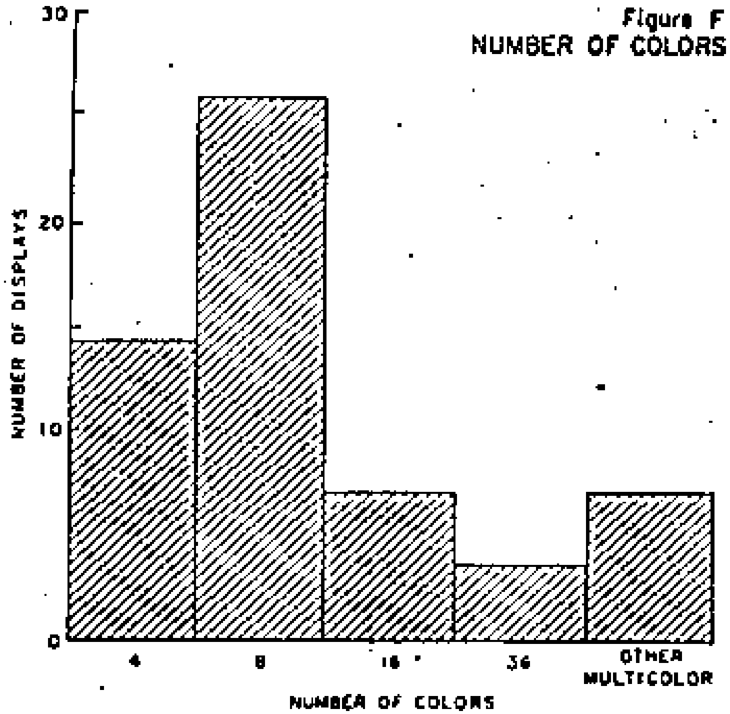
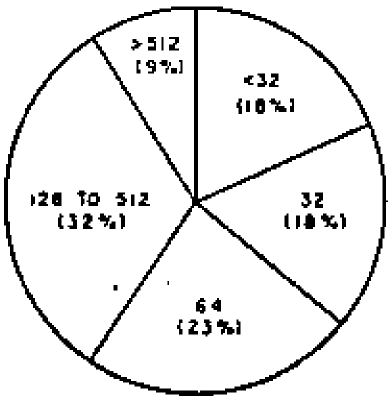


Figure G
USER MEMORY
(KB)



permit selective erasure and dynamic display for good real time animation of displayed objects.

Raster scan displays are currently found on 58% of graphics terminals, vector scan on 21%, and storage tubes on 14%. Flat gas plasma displays are found on 6% of all graphics terminals and are used in limited space and ruggedized applications, but Magnavox, the principal vendor of plasma graphics displays, has announced that it will stop producing graphics displays by the end of 1981.

In addition to display technology, screen resolution and size are major distinguishing features. Figures D and E show the distribution of the different screen resolutions and sizes among graphics displays. The most commonly found resolution is 512 horizontal by 512 vertical pixels (picture elements), found on almost half of all graphics displays. A few displays have 512x256 pixel resolutions. These coarser resolutions allow a fairly sharp image and are available for well under $20,000. Users requiring fine detail or exceptional clarity can choose from resolutions of up to 8192x 8192 pixels if their budgets exceed $100,000; 1024x1024 and 4096x4096 pixel displays are readily available in the $25-50,000 ranges.

Rectangular screen sizes range from five to 26-inch (measured diagonally), with almost 50% of all devices providing 19- or 21-inch screens. Circular CRT screens are popular in air traffic control and some design applications but only the largest circular screens offer a larger display workspace than current rectangular displays.

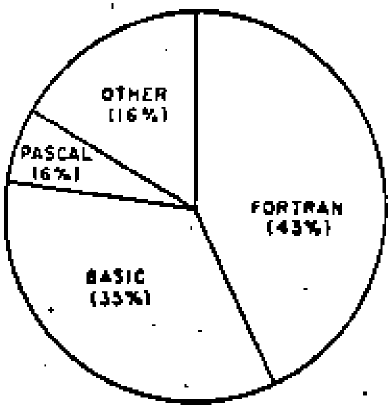


Figure H
LANGUAGES

Figure I
OFF-LINE STORAGE

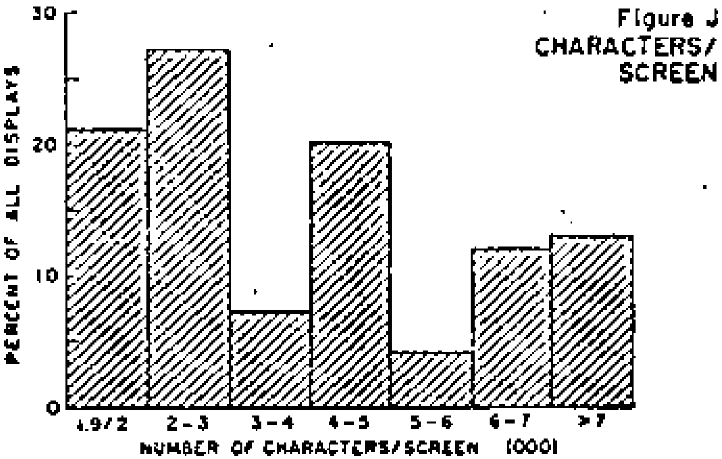


Figure J
CHARACTERS/
SCREEN

Multicolor displays are becoming more popular, and 45% of all graphics displays offer four or more colors (Fig. F). Of these, 45% provide eight color displays, and 25% offer four colors. Other color displays offer 16, 32, 125 and 256 pure colors. Low cost color units are based around commercial color TV displays while high performance, wide-color-range displays are based on expensive specialized technology which can make color capability an option costing as much as $30,000.

Virtually all graphics displays provide user memory (Fig. G). About 60% of all displays have maximum user memories of sixty-four or fewer kilobytes. Only 8% of all displays provide more than 512KB of memory.

Three-quarters of all graphics displays are programmable in a high-level language (Fig. H). Of these, 43% use FORTRAN, and 35% offer BASIC. Several displays utilize PASCAL. COBOL is found on a few, and most of the rest use proprietary graphics languages.

Off-line storage is available with 70% of all graphics displays (Fig. I), and 45% of these offer diskette drives. Disk storage is available with about one-quarter of all displays and a number of systems offer magnetic tape and cartridge tape drives. Hardcopy, too, is a popular feature, and about three-quarters of all displays offer a plotter, usually as an option.

Over 90% of all displays provide function keys and graphic input devices of some sort, such as light pens, trackballs, joysticks, tablets, touch sensitive screens, and others. RS232C interfaces are equally popular.

Many applications require alphanumeric as well as graphics display, and almost all displays have alphanumeric capabilities equal to that of multifont mainstream editing terminals. A number of displays go quite a bit beyond the standard capabilities, offering as many as 15,000 characters per screen (Fig. J). The great majority of terminals allow for user-programmable fonts as well, with one or more fonts already in firmware.

THE FUTURE

Both graphics technology and the market for this technology have been growing at a rapid pace. There is every indication that this trend will continue throughout the 1980's.

Competition among systems costing under $25,000 will intensify as graphics software is standardized by ACM SIGGRAPH, NCGA, and other organizations. Volume-related economies of scale will become important as performance specs for low cost units converge and price becomes the more important number in price/performance ratios.

Competition among high end vendors will still revolve around resolution, refresh rates, color capability and all-out performance but will become more like data processing

system competition: factors like hardware and software upgradability, field service, and peripheral availability will affect buyers' decisions. The GML database shows that virtually all graphics terminal vendors offer their own graphics software and specialized graphics peripherals.

Introduction rates and profit margins for the graphics display terminal market are the highest of any terminal type, but hardware, software, and peripheral development costs are higher than for even sophisticated intelligent terminals.

Most of the past twelve months' hardware introductions have come from recognized graphics industry leaders or from data processing giants like Digital Equipment and Data General. Small firms are faced with high development costs for high-end systems, and with lower profit margins and fierce competition among large low-end vendors, but well-financed, innovative companies continue to enter the graphics market where demand still exceeds most vendors' production capacity.

The graphics terminal industry is similar to the intelligent terminals industry in that profits and development costs are much higher than for dumb or editing terminals. Unlike the intelligent terminal though, the graphics terminal is almost universally seen as a way to decrease costs and increase efficiency in all aspects of industry. Production of a graphics terminal by a non-graphics terminal company represents a foray into software, peripherals, and systems sales just as the production of a first intelligent terminal would, but the current and expected future demand for graphics terminals makes development of a system a risk many terminal vendors should strongly consider.