PROGRAMA DEL CURSO "PLANEACION DE SISTEMAS AMBIENTALES URBANOS"

(del 10 al 15 de febrero de 1975)

Hora	LUNES	MARTES	MIERCOLES	JUEVES	VIERNES	SABADO
9 a 10:50	Definición del Problema. Enfoque de Sistemas. (O)	Determinantes categóricos urbanos (R)	Planeación de Ciudades (H)	Simulación de crecimiento de las ciudades (SUPERCLUG) (S)	Política de crecimiento de ciudades. (Ejemplo real) (H)	Estructura General de planificación urbana. (S)
		C A F E				
11 a 13	Experiencias de aplicación (O)	Sistemas legales e institucionales (H)	Metodología de predicciones Panoramas. (R)	CONTINUACION.	Dinámica urbana (R)	Simulación BALDICER (S)
13 al4		C O M I D A				
14 a 15:50	Problemática del desarrollo. Planeación (Sk)	Transferencia de Tecnología (H)	Conservación de Energía. (H)	CONTINUACION.	Modelos Intersticiales (R)	
		C A F E				
16 a 18	Problemática de evaluación y cuantificación de variables (Sk)	Enfoque de sistemas. Modelos, Validación, etc. (R)	Simulación por juegos. (R)	CONTINUACION.	Discusión (grupo)	

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PLANEACION DE SISTEMAS AMBIENTALES URBANOS.

EL MEDIO AMBIENTE URBANO EN MEXICO.

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E L M E D I O A M B I E N T E U R B A N O
E N M E X I C O .

I. La Problemática del Desarrollo y su Relación con Sistemas Urbanos.

II. Planeación del Desarrollo de Sistemas Urbanos.

DR. FRANCISCO SZEKELY.

I. LA PROBLEMATICA DEL DESARROLLO Y SU RELACION CON SISTEMAS URBANOS.

La palabra "desarrollo" ha sido usada con mucha popularidad en la década de los sesentas y en los años setentas, definiendo a un mundo dividido entre ricos y pobres. Lo importante hoy día es definir claramente -desde el punto de vista de los paises del Tercer Mundo- lo que "desarrollo" significa.

De acuerdo con los modelos que pretenden promover el desarrollo, podríamos definir el desarrollo mismo a través de los objetivos que estos modelos quieren alcanzar. Estos objetivos son -entre otros- productividad industrial, alto ingreso per capita, avance tecnológico, educación y otros. Sin embargo nos preguntamos: ¿Es este tipo de desarrollo suficiente y apropiado para aquellos paises que están hoy día planeando su porvenir?. El Sociologo Denis Govlet nos indica que en los paises que han alcanzado este tipo de desarrollo -tales como los Estados Unidos- este proceso:

> " . . . No es genuino. Es anti-desarrollista, una simplificación del verdadero proceso . . . Consideramos que paises prósperos económicamente son avanzados. Sin embargo desarrollo significa mas que carreteras congestionadas con automoviles, televisiones en cada casa. Lo que economistas llaman frecuentemente riqueza Nacional es muchas veces solo desperdicio . . ." (1)

Antiguamente, el concepto del desarrollo podía entenderse y definirse mejor como una serie de cambios que se han logrado a través de los siglos en la parte occidental del mundo. Estos cambios han propiciado a través de un incremento en la productividad y el consumo un mundo más facilmente vivible para la humanidad. Los signos mas obvios de una sociedad desarrollada bajo estos términos son la creciente concentración de la gente en urbes y, un papel mas determinante de la industria en la economía de esa sociedad.

Desde 1950 en adelante, el proceso de desarrollo fué percibido no solo como un proceso de cambios sociales y políticos, sino como "El proceso histórico que influyó en todos los demás factores que crean una sociedad."

El entender el proceso del desarrollo en el contexto anteriormente indicado y extrapolado a todas las sociedades del mundo, delimitó y clasificó diferencias sociales y económicas básicas que existen entre las diferentes culturas. Se pensó que las areas no-desarrolladas eran simplemente más desafortunadas que las que ya lo eran y que la linea a seguir era aquella en la que las sociedades en vías de desarrollo debían de tratar de ser tan productivas, integradas y democráticas como lo eran los paises desarrollados.

Además de esto, esta idea del desarrollo proveía una importante confrontación con los sistemas comunistas, ya que la imagen de un país en desarrollo contenía los elementos mas atractivos de programas comunistas y socialistas, sin requerir el colectivismo. Esta noción del desarrollo enfatizó la propiedad privada proveyendo la rúbrica dentro de la cual una ideología competitiva con el comunismo pudo erigirse.

Como podrá apreciarse, las razones para rechazar una definición del desarrollo en bases comparativas no son dificiles de enunciar. La irreal glorificación de las sociedades "desarrolladas" como naciones poderosas y prosperas, sin problemas sociales (una tendencia típica de los años 1950s) se complementa con nuestra percepción de que esas mismas sociedades son extraordinariamente racistas, economicamente injustas, ecologicamente desastrosas, e interracionalmente inmorales e impotentes.

Después del análisis hasta aquí elaborado y tratando de evitar un estudio mas específico acerca de las fluctuaciones de ideas que existen acerca del desarrollo (lo cual pertenecería a una cátedra centrada únicamente en el tema del desarrollo), podríamos definir en un sentido amplio -y para nuestros propósitos- el desarrollo, ya no en bases comparativas debatibles sino simplemente como "El proceso Histórico de cambios tecnológicos, políticos y sociales que se han originado por una demanda popular por <u>una mejor vida</u>".

CONCENTRACION URBANA.

Cada especie animal requiere un "nicho" para subsistir, esto es, una serie de condiciones naturales precisas que permitan su reproducción y super vivencia. El hombre primitivo podía ajustar su existencia a sólo dos elementos, el ambiente natural que lo rodeaba y su choza. El hombre moderno, en contraste, requiere una gran variedad de medios de subsistencia muy complejos (sus exigencias mínimas se han aumentado).

La actitud del hombre moderno hacia su entorno se halla profundamente enraizada con tradiciones y concepciones filosóficas y religiosas. El ser humano ha pasado de la etapa de la exploración a la explotación del planeta. Percibir el agua y el aire como bienes gratuitos es parte de esta concepción que considera a la naturaleza como objeto de explotación.

La ciudad contemporanea es el producto eminente del siglo XIX Europeo. La metrópoli moderna data solo de 100 años atrás.[2] En la antiguedad tanto el habitante urbano como el rural, se encontraban, en estrecha relación con su ambiente inmediato que en un mismo lugar concentraba su habitación y lugar de trabajo. El desarrollo de orden económico crea una separación del individuo respecto a su hogar, aislándolo y situándolo en una relación impersonal con su empleo.

Debido al efecto de todos estos cambios, los habitantes urbanos desarrollaron y dieron contenido a las nuevas formas de acción que caracterizan a la ciudad moderna. Estas formas son mas de caracter particular durante el siglo XIX que lo fueron anteriormente en la asamblea tradicional de la ciudad tipo medieval.

El fenómeno migratorio del campo a las concentraciones urbanas se inicia, tangiblemente, a mediados del siglo XIX. Como consecuencia de la rapidez con que este desplazamiento tuvo lugar, conjuntamente con la falta de planificación, el crecimiento vino a ser en cierta forma caótico. Las zonas periféricas a las grandes urbes recintieron estos efectos principalmente lo cual impidió que aquellos que habían empleado la movilidad como un medio para mejorar su vida económica y social llevaran a cabo sus objetivos.

La crisis en asentamientos humanos existen hoy día debido a la dificultad con la que el hombre se encuentra para establecer su nicho en un lugar determinado. Esta crisis es tanto de cantidad como de calidad. Según calculos de las Naciones Unidas (3), la población del mundo aumentará aproximadamente al doble -un poco mas de seis y medio miles de millones- en las próximas tres décadas (3). Para el año 2000, por primera vez en la historia, habrá mas gente en areas urbanas que en rurales. Habrá cerca de tres mil y medio millones de personas en urbes de 20,000 habitantes ó mas.

Las políticas del Desarrollo, particularmente en el Tercer Mundo, deben enfrentar algunos hechos inevitables. Los asentamientos humanos requieren una mayor atención debido a que los centros urbanos aumentan al doble, y las grandes metrópolis aumentan al doble también.

Estos aumentos son mas marcados en la presente era de constantes inovaciones tecnológicas, las cuales cambian la forma, dimensión, impacto y duración de actividades económicas en modos dificilmente predecibles.

En la mayoría de los paises en vias de desarrollo, y tambien en la localización histórica de los asentamientos de ciudades planeadas en una forma centralista las poblaciones se encuentran donde están como un sub-producto de políticas y decisiones basadas unicamente en intereses de tipo económico pero no social. La cuenca de un río, una bahía abierta, la explotación de una riqueza mineral, etc., determinan la localización original de un asentamiento humano. Después, las demandas económicas concentradas en esa misma área, aunados con los aumentos en infraestructura y necesidad de movilidad del producto económico -de adentro hacia afuera y viceverza- crean una dinámica la cual, por ejemplo, transformó New York de un puerto de 20,000 habitantes a un área urbana de 20 millones en solamente un siglo y medio. Pero decisiones económicas, impulsadas por otras decisiones económicas no producen por si mismas un orden de tipo humano y social. Ellas pueden dejar minorías en regiones desarrolladas y mayorías en áreas sub-desarrolladas con niveles de vida muy bajos. Este proceso crea una amenaza para la calidad del ambiente urbano desde los puntos de vista económicos, social y político. La evidencia de que lo antes expuesto es válido es claro, la realidad nos lo muestra, si estrategias mayormente económicas hubieran sido suficientes para crear centros urbanos convenientes, equilibrados y justos, los tendríamos ahora. La crisis que enfrentamos es que no los tenemos. Lo que nos queda como tarea entonces, es el buscar alternativas y políticas que mejoren nuestros centros urbanos.

ORIGEN DE LAS CRISIS EN LOS CENTROS URBANOS.

Las grandes concentraciones humanas -los centros urbanos- crean logicamente un efecto en la calidad del Medio Ambiente. Esto se puede observar a través de la acumulación de materias sólidas, líquidas y gaseosas, resultado de muchas de las actividades humanas diarias. Esto produce un impacto dentro del ecosistema en el que el hombre vive el cual pone en peligro la vida de algunos seres, incluso la del hombre mismo. Las fuentes de contaminación aparentemente mas notorias son aquellas representadas por los desperdicios sólidos o basura, la producción de energía eléctrica ó atómica, la explotación minera, la actividad agrícola e industrial y la de los transportes de motores de combustión interna.

En México, por ejemplo, los desperdicios sólidos de orígen doméstico e industrial en el Valle de México alcanzan un total de 8000 toneladas diarias. La contaminación del aire en el mismo Valle de México está generado por la existencia de aproximadamente 50,000 unidades industriales, cerca de 4,000 calderas (de panaderías, hoteles, hospitales, etc.) y mas de 650,000 automóviles circulando en la Ciudad de México (arrojando 4,884 Kgs. de hidrocarbonos orgánicos y 24077 Kg. de partículas diarias), y otras actividades productivas y de transporte cuyo consumo diario en el Valle de México durante 1972 fué de 13,600 toneladas de gas natural, 3,670 toneladas de gas combustoleo, 5,599 de gasolina y 1,688 de gas licuado. (4). Respecto a la actividad industrial en México: ingenios azucareros, destilerías, rastros y empacadoras, industrias químicas farmacéuticas y otras: el 20.5% de estos establecimientos estan concentrados en la Ciudad de México y el 5% en el Estado de México, creando contaminantes de tipo orgánico e inorgánico, y tambien ruidos inarticulados y desagradables que especialmente en zonas urbanas adquieren caracter dramático.

Las consecuencias que los impactos ambientales creados por la contaminación ocasionan pueden enumerarse como sigue:

1. Reducción en la visibilidad (Una reducción en la visibilidad en el Valle de México que vá de los 12 Km. en 1940, a menos de 2 Km. en 1970).

2. Odor en el aire.

3. Contaminación del agua.
4. Alteración del Clima.
5. Erosión del suelo.
6. Efectos en la Salud pública urbana.
7. Efectos psicológicos (ansiedad, depresión).

Como un breve paréntesis cabe indicar aquí que aunque nuestra atención está enfocada en el área urbana, el problema rural es mucho más difícil ya que se carece de todo tipo de recursos empezando por la falta de la propiedad de la tierra y el bajo ingreso económico. Si se considera que en México 55 por ciento de la población rural - aproximadamente 12 millones de personas- percibe un ingreso per capita de $2 pesos diarios. La mitad de estos 12 millones obtienen un ingreso por debajo de un peso cincuenta centavos diarios. En el año de 1969 el 60% de la fuerza de trabajo agrícola eran campesinos sin tierra. Aproximadamente cinco mil poblaciones de 500 a 2,600 habitantes carecen de servicios de agua potable en México.

Otras causas que crean la problemática del desarrollo y los centros urbanos -además de los impactos y efectos contaminantes antes descritos- son:

1) El crecimiento de la población debido a los problemas del desarrollo.
2) El crecimiento mismo de las ciudades.

3) Las diferencias en las necesidades vitales del ser humano.

4) La existencia de las zonas marginadas ó ciudades perdidas.

5) Los valores de la Sociedad Moderna.

1. CRECIMIENTO DE LA POBLACION.

Las poblaciones en los centros urbanos se han aumentado considerablemente debido a que estos son como magnetos humanos, debido a que las actividades económicas se realizan príncipalmente ahí.

En el presente siglo, la Población Urbana de la República Méxicana que vive en localidades de 15,000 ó mas habitantes, creció con mayor rapidéz que la población total del país.[5] Alta urbanización se contempla principalmente en 3 ciudades: México, Guadalajara y Monterrey.

La tasa de crecimiento de la población se ha ido incrementando en México aún mas durante los últimos años de 2.7% anual de 1940-1950 pasó a 3.1% y 3.4% para los períodos 1950-1960 y 1960-1970 respectivamente. La tasa de crecimiento de este último período fué, después de la de Libia y Costa Rica, la mas elevada del mundo.

En 1970 el 45% de la población mexicana vivía en zonas urbanas, mientras el 28% radicaba en comunidades de menos de un mil habitantes. Si extrapolamos estas tendencias hacia el futuro concluiríamos que para 1980, México será un país predominantemente urbano.

El mismo fenómeno se presenta en otros paises Latino-Americanos. Por ejemplo, en Brasil, a partir de 1940 la población sufre una importante transformación: el paso de lo rural a lo urbano. En 1940 la población brasileña era de 41,236 millones de habitantes, de estos el 31.2% (12,800 millones) era población rural. Para 1970 habían 94,506 millones de brasileños, 55.8% habitantes urbanos (ó 52,908 millones) y 44.2% habitantes rurales (41,604 millones). Si estos datos se extrapolan cetis paribus, para 1980 Brasil habrá cambiado diametralmente su estructura poblacional. Una tercera parte de los habitantes urbanos (1940) se convertirá en las 2/3 partes (1980) y, correspondientemente, mas de dos terceras partes de los pobladores en 1940 (rurales) constituirán ahora el otro tercio. (6)

2. EL CRECIMIENTO DE LAS CIUDADES.

Aproximadamente un 40% de los habitantes de la tierra viven en nucleos de población ó urbes. Este proceso es de caracter dinámico a través de la historia. Japón muestra un típico Ejemplo de esta dinámica de cambio cuantitativo. En 1900 la población de Jaón fué de 40 millones, 10% (4 millones) era población Urbana. Con el proceso de desarrollo industrial, para 1945 alcanzó los 80 millones de habitantes, 40% población Urbana. En 1970 la tasa de crecimiento había decrecido, pero aún así habían 100 millones de Japoneses, 65% de éllos habitantes urbanos. Si extrapolamos estas tendencias del crecimiento de la población, para el año 2000, habrá 120×10^6 japoneses. 90% de ellos población urbana. Esto significaría probablemente que estos habitantes urbanos estarían viviendo una "Gran Megalopolis" alrededor de la Bahía de Tokio. (7)

La crisis de la cantidad de personas puede ser expresada en términos de construcción. En general, mas edificios se necesitarán en las 3 próximas décadas que todos los que se han construido hasta la fecha en la historia de la humanidad.

La crisis puede expresarse también en términos de costos. Tomando en cuenta de nuevo el ejemplo de Japón podemos pensar que además de los costos incurridos durante los últimos 25 años, debido a las necesidades normales de crecimiento de la población y los daños de la guerra en concentraciones urbanas, para los próximos 25 años el capital necesario que ha de invertirse es 20 veces más. (1)

Pero la crisis puede tambien expresarse en términos de calidad. Aquí existen 2 paradojas: asentamientos humanos crecen continuamente, y tradicionalmente, las ciudades han representado el éxito del proceso del desarrollo. Mas urbanismo debería - teoricamente - llevar hacia el mejoramiento social. Las mismas palabras "Urbanismo" y "Civilización" se derivan de la creencia de que el orden hecho por el hombre, belleza estética, cultura, dignidad y prestigio florecen mejor en ambientes urbanos.

Sin embargo, la calidad de los asentamientos urbanos contemporaneos parece estar muy lejos de aquellos ideales urbanos. El desarrollo tecnológico comenzó a localizar el trabajo del hombre fuera del campo y a concentrarlo en fábricas y como resultado, los laboradores vinieron del campo a las ciudades para buscar trabajo y vivienda. Las primeras ciudades industriales fueron tan congestionadas, contaminadas, violentas y ruidosas que el movimiento hacia afuera de la gente mas rica a los suburbios empezó a definir la forma de las "regiones urbanas", por ejemplo, para la mitad del siglo XIX, la Ciudad de New York pasó su densidad máxima (en 1860).

Pero aún así, mientras una cantidad de gente se emigraron de las ciudades, otras inmigraron a estas. Esto se puede observar en el proceso histórico de los paises desarrollados, sin embargo las ciudades continuaban concentrando la población. Paises como Inglaterra y Holanda han llegado a ser 90% urbanas. Aún así, muchos de sus problemas urbanos fundamentales no han llegado a ser resueltos aún mientras comunidades urbanas se convierten en estacionarias.

Esta es la gran paradoja, aún de los viejos sueños del urbanismo, el crecimiento urbano en las primeras fases de desarrollo tecnológico no se desenvolvió en una forma aceptable, atractiva y conveniente para la sociedad. Una muestra de que esto es cierto es que hoy día, los turistas buscan generalmente ya sea ciudades viejas, magnificos sectores pre-industriales, ó las bellezas naturales - no-urbanas- de los mares y las montañas. Los visitantes detestan ya los grandes centros urbanos como Chicago, Yokohama, París y otras para sus momentos de recreo. Podríamos concluir que así como el hombre se convierte cada vez mas urbano, el inventa ciudades que él mismo no está gozando. Las nuevas ciudades hacen que la satisfacción sea cada día mas difícil. Problemas como la deposición de desechos sólidos se incrementan en su complejidad. En los Estados Unidos por ejemplo las gentes tiraban al principio de los años 70s 48 billones de latas, 26 billones de botellas, 65 billones de tapas de botes y 7 millones de automoviles en desuso. (9)

La segunda paradoja es que aún del reconocimiento general de la problemática urbana, una gran cantidad de personas ven estos sistemas urbanos como el objetivo de sus ambiciones. Esto sucede aún mas en los paises en desarrollo donde el fenómeno mencionado de mover gentes del campo a las ciudades se acentúa.

Veamos ahora como se ha comportado este crecimiento de las ciudades en nuestro medio mexicano.

El crecimiento poblacional y desarrollo urbano en México puede observarse claramente en las 8 ciudades mas grandes del país: México, Guadalajara, Monterrey, Puebla, Ciudad Juárez, Chihuahua y León. De estas, el área metropolitana se desarrolló con mayor rapidez que las otras ciudades del país hasta 1960, año en que la tasa de crecimiento del área urbana de la ciudad de México se mantuvo más o menos constante. Es importante notar sin embargo que desde 1950 a nuestros días las ciudades de Guadalajara y Monterrey han registrado tasas de crecimiento sensiblemente mayores que la del área urbana de la ciudad de México.

El crecimiento de estas ciudades mexicanas ha sido muchas veces desproporcionado a su densidad. En 1970 Guadalajara contaba con un millón 199 mil habitantes en una superficie de 187.91 Km^2. Esto representa una densidad de 6 mil 362 habitantes /Km^2. Guadalajara tiene 36.38% de la población total del Estado de Jalisco. Otra muestra clara de la gran concentración de la población en zonas urbanas.

El proceso de urbanización en México actualmente puede observarse principalmente en ciudades pequeñas y medianas. Sin embargo, la mayoría de las poblaciones en México tienen muy escaza población. Aquí los niveles de vida son generalmente muy bajos y los servicios públicos elementales son muy escazos ó inexistentes.

VALORES DE LA SOCIEDAD MODERNA.

Otro factor importante que parece haber contribuído a las crisis urbanas es que dentro de muchas sociedades, el hombre desea vivir en las grandes concentraciones humanas. Parece que no importan muchos de los inconvenientes que representan las ciudades, con los congestionamientos de los centros de las ciudades, las dificultades para escapar a la naturaleza, etc., porque para muchas personas, el objetivo de su vida es el de establecerse en la gran ciudad. En paises del Tercer Mundo, donde las ciudades no son aptas para proporcionar muchos mas servicios rápidamente, el fenómeno migratorio de pequeñas ciudades a mas grandes, o del campo a la ciudad se vé mas dramático que en circunstancias como las de los paises economicamente avanzados.

NECESIDADES VITALES DEL SER HUMANO.

Por definición, un asentamiento humano debe de existir primordialmente para satisfacer necesidades humanas. En términos Ecológicos un asentamiento es un nicho y su eficiencia debe estar medida por el grado mediante el cual satisface las necesidades de todos los seres que lo habitan. Sin embargo, esta definición no es muy definitiva. Los seres humanos somos una especie que ya no está acostumbrada a vivir siguiendo simplemente los impulsos de sus instintos. Los humanos podemos definir y planear nuestras propias necesidades. Nosotros podemos necesitar tantas cosas como imaginamos, las cuales no tienen limite.

Hay ciertas necesidades, sin embargo, que son comunes a todas las comunidades. Estas son las necesidades biológicas tales como: alimentación (proteínas), agua, habitación, salud y otros. Normalmente la forma de poder adquirir estas necesidades es a través de la percepción de un salario adecuado.

Un problema muy complejo de definir entonces es el ponerse de acuerdo en cuales son aquellos estandards mínimos para que los humanos puedan desarrollarse satisfactoriamente en sus asentamientos. Estos estandards -por supuesto- deben ser variables y flexibles. Las necesidades de calorías ó habitación varían de acuerdo con clima, localización geográfica, ocupación, edad, y otros. Hasta ahora, estos indicadores sociales y económicos de necesidades humanas básicas no han sido aún determinadas. Sin embargo, es claro que debe existir una preocupación para encontrar esos estandards mínimos sobre todo en las comunidades mas pobres del mundo.

Estos mínimos estandards afectarán entonces la manera en que el uso de las riquezas del mundo se llevan a cabo. Para ejemplificar esta idea, podemos decir que los paises desarrollados gozan de cerca de 75% de las riquezas del planeta para beneficiar a únicamente 25% de la población mundial. Solamente los Estados Unidos consumen 35% de l as riquezas del mundo contando unicamente con 6% de la población mundial.

Si pudiesemos lograr que el ser humano asegure sus necesidades biológicas mínimas, entonces podremos pensar en determinar necesidades de otro tipo, tales como materiales, sociales, y cuturales (no necesariamente en este orden cronológico). Estas necesidades a las que hacemos referencia podrían desglosarse como sigue:

1. Libertad y seguridad individual.
2. Independencia del individuo dentro de la comunidad.
3. Interacción social y participación popular en los asuntos de la comunidad.
4. Libertad de expresión cultural y oportunidad para desarrollo individual.
5. Necesidad de lugares de recreo, privacía, paz y quietud.
6. Igualdad de acceso a servicios públicos y facilidades.
7. Libertad de movimiento y de decisión personal.

Hay muchas mas necesidades que podrían engrozar nuestra lista, lo importante es notar que además de ser estas variadas, son subjetivas y su validez depende de la sociedad particular a la que nos estemos refiriendo en un momento determinado.

El aceptar que existen necesidades básicas del ser humano en cuanto a su habitación y funcionamiento Biológico, Social y Económico nos conduce a cristalizar todas las ideas anteriores en el reconocimiento de la existencia de sociedades -ó partes de una sociedad- que viven en condiciones muy por debajo de los mínimos estándards establecidos dentro de sus propias culturas. Estas sociedades se congregan en territorios conocidos como Zonas Marginadas.

ZONAS MARGINADAS.

Las zonas marginadas, Ciudades perdidas, barriadas ó fabellas son aquellos asentamientos humanos que han formado personas -dentro de las ciudades ó en su periferia- que generalmente tienen un salario muy bajo (casi nulo) y que no tienen esperanzas o posibilidades de mejorar económica, social, ó físicamente. Son las porciones "rurales" de los centros urbanos. Las personas que viven en estas ciudades perdidas viven a niveles mínimos de subsistencia (aproximadamente $400.00 por familia por mes)(9). Este sector de la sociedad no posee la tierra o habitación en la que viven. En el caso de la ciudad de México, el 2.3% de la población Metropolitana viven en las ciudades perdidas. (ejemplos: la colonia Buenos Aires.

Existen otros arreglos urbanos parecidos a las ciudades perdidas en México con condiciones parecidas, aunque un poco mejores. Estos son:

1) Las vecindades
2) Las colonias proletarias
3) Las unidades habitacionales (10)

1) Las vecindades son generalmente construcciones de uno o dos pisos localizadas principalmente en el centro de las ciudades mexicanas (especialmente la Metrópoli). Este tipo de arreglo habitacional comprende aproximadamente 23% de la población total de la Metrópolí. Las facilidades aquí son de tipo comunal. (Por ejemplo Colonias Las Vizcainas, La Casa Blanca).

2) Las colonias proletarias son zonas de pequeños lotes individuales donde se alberga 36% de la población de la metrópoli. Localizados en la periferia, sin servicios ni buenas facilidades de transporte, estas colonias están integradas esencialmente por población jóven; generalmente formadas por mano de obra semi-calificada. (Ejemplos son las colonias Lomas de San Agustín, y Ciudad Netzahualcoyotl).

3) Las unidades habitacionales, son edificios multifamiliares o conjuntos de casas subencionadas por el gobierno. Esta forma de hábitación comprende el 6% de la población metropolitana.

Si identificamos el nível mínimo de subsistencia ($400/familia/mes) como "S", podríamos establecer una relación entre los niveles que caracterizan a los diferentes sistemas urbanos antes descrito.

Esto puede observarse en Tabla I.

TABLA I. NIVELES DE VIDA

EN LA CIUDAD DE MEXICO (11)

ASENTAMIENTO	NIVEL DE VIDA.
Ciudades Perdidas.	S
Vecindades	5S - 8S
Colonias Proletarias	3S - 5S
Unidades Habitacionales	8S

La Tabla I habla por sí misma, los niveles comparativos indican que las ciudades perdidas primero, y las colonias proletarias después, son los asentamientos que sufren niveles de vida mas bajos.

En la provincia mexicana el problema de las ciudades perdidas es muy asentuado también. En Guadalajara -por ejemplo- el 40% de la ciudad está integrada por las colonias llamadas populares. La característica fundamental de estas colonias es la falta de uno ó varios servicios públicos. En toda la ciudad, hay de 160 a 200 mil personas (del 13.33 al 16.66% de la población de Guadalajara) que habitan en construcciones deficientes, desplomables en cualquier momento. Según un estudio de la Subdirección de Regeneración del Ayuntamiento del Estado, se calculó que no menos de 40,000 viviendas se encuentran en esta situación.

Como en México, el problema de las ciudades marginadas se extiende a la mayoría de los paises del Tercer Mundo. Existen cerca de 240,000 personas en esta situación en Turkía. 45% y 21% de las poblaciones de Angola e Instanbul viven en ciudades perdidas (5). Para la Ciudad de Manila el porcentaje en esta situación es de 20 y en Venezuela de 65% (en zonas rurales y urbanas) con 35% en Caracas y 50% en Maracaibo. En Chile, Singapur y Jamaica las cifras son 25%, 15 y 12% respectivamente. Así podríamos continuar una impresionante casi indefinible lista de casos y datos. (12)

El problema urbano de las zonas marginadas no puede ignorarse en los paises del Tercer Mundo.

II. LA PLANEACION DEL DESARROLLO.

Nuestra definición del desarrollo como una serie de cambios de demanda popular para lograr una mejor vida presupone la reducción de la pobreza, desempleo y desigualdades economico-sociales. Esta definición enfatiza el control humano sobre la tecnología y otros factores de cambio. Lo importante ahora es el saber como podemos traducir estas abstracciones en acciones pragmáticas. En pocas palabras, ?Bajo que guías vamos a planear el desarrollo?

Un criterio básico para comenzar es el considerar que los modelos en desarrollo deben de estar dentro del contexto de factores social, culturales y económicos de la sociedad en cuestión. También estos modelos deben ser Ecológicos. Entre las técnicas ó estrategias que deben enfatizarse están la promoción de industrias intensivas de mano de obra, una aplicación de métodos tradicionales en combinación con otros modernos, reciclaje de productos usados y, regreso a los ciclos naturales ecológicos. Sin embargo, hasta aquí estas premisas parecen mas bien de caracter académico, les falta la premisa fundamental: El derecho de soverania de las Naciones para determinar por sí mismas el tipo de desarrollo que desean. Esta última premisa - Por condiciones que se explicarán mas adelante- ha sido muy difícil de alcanzar en países del Tercer Mundo.

Las estrategias para planear el desarrollo se extienden inevitablemente mas allá de la planeación de los centros urbanos _per se_ y los cuales tienen que ser planeados dentro del contexto de las políticas del desarrollo.

La realidad de las sociedades marginadas no se debe a la localización física de la comunidad, ni de la falta de servicios, ni de carencias urbanas. La verdadera raíz de la marginalización se encuentra en la condición social y económica de las personas que habitan las ciudades perdidas, la falta de su accesibilidad a los recursos, la tremenda pobreza en que se encuentran junto con problemas de vivienda, educación y salud. Para acabar con las ciudades marginadas debemos de plantearnos estrategias de desarrollo dentro de este amplio contexto, es decir concebir un plan del desarrollo que reflejen la realidad, donde se relacionen -entre sí- los distintos factores que afectan a la sociedad urbana.

Para ser coherente con la dirección que pienso este curso tomará a través del análisis y las metodologías que les serán expuestas en días sub-secuentes por los profesores americanos, usaré la metodología del "enfoque de sistemas" para aplicarla a la planeación. Es importante sin embargo, advertir de antemano -y como después analizaremos- que el "Desarrollo" es un problema tan complejo, que no es posible sistematizarlo ú optimizarlo. Aún así, la metodología de sistemas nos ayuda -a través del manejo de la información- a observar el comportamiento de algunos panoramas auto-diseñados en el caso de que tomemos unas u otras decisiones.

El enfoque de sistemas (13) podría definirse como la constitución de 5 etapas:

1. Definir los objetivos del sistema, la eficiencia del sistema.

2. Definir el ambiente del sistema, los límites físicos.

3. Indicar cuales son los Recursos del Sistema.

4. Definir los componentes del sistema, sus actividades, y metas.

5. La administración del sistema.

Analizamos el problema del desarrollo urbano desde el punto de vista de sistemas según los puntos indicados anteriormente.

1) OBJETIVOS DEL SISTEMA : Aquí debemos definir primeramente si hablamos de objetivos inmediatos ó a largo plazo. Por ejemplo, controlar inundaciones podría ser un objetivo inmediato, mientras que a largo plazo nuestros objetivos de administración de aguas podrían ser : conservar el agua para utilizarla en generar energía, incrementar la producción, y mejorar los niveles de vida. Una vez determinado el período de tiempo en que planearemos pasarnos a los objetivos. El objetivo principal de la planeación de un sistema urbano es el de promover el bienestar

social de los habitantes de una región determinada. ¿Como? Bien pues -como se indicó anteriormente- analizando a fondo la plausibilidad de hacer real una política de planeación urbana, por ejemplo. participando en la solución de los problemas sociales y económicos del sector social en estudio ...

2) AMBIENTE FISICO DEL SISTEMA. El ambiente en la planeación de sistemas urbanos se determina por una variedad de factores : sociales, culturales, económicos, etc. El mas importante quizás es la influencia social ejercida en el hogar. La habitación es el lugar central, el punto de comienzo de toda la vida en asentamientos humanos. La tragedia que existe en las ciudades perdidas es que privan al individuo de los fundamentos de de seguridad, respeto por si mismo, y esperanza para progreso humano. El hogar es donde se aprende -o no se aprende- se aspira- o se cae en profunda frustración-, del hogar se deriva muchas veces el sentido de la vida.

3) RECURSOS DEL SISTEMA: Recursos físicos locales, Educación, Capital, Recursos Humanos, Disponibilidad de los Recursos.

4) COMPONENTES: Variables que entrarán al sistema . . . .

5) ADMINISTRACION DEL SISTEMA: Para que la planeación de un sistema urbano pueda estar completa, la participación de los habitantes del sitema en planeación es fundamental. Normalmente este tipo de participación resulta ser de caracter paternalista. Los típicos líderes "conocedores" que quieren imponerle a la gente que y como hacer las cosas. Sin embargo,

el simple hecho de que los habitantes del sistema planeado conocen mejor que nadie sus condiciones, limitantes y problemas personales, la participación local de habitantes debe ser asegurada. Así los individuos de una sociedad sentirán que son partícipes de planeación popular y crearán así una relación entre ciudadanos, sus líderes, y los lugares en los que ellos tendrán que vivir.

Así también, puede decirse que los habitantes que participan en la planeación son los mejores guardianes de los asentamientos en los que viven.

B I B L I O G R A F I A .

1. Golvet, D., A., " A case of Anti - Development" Motive , Jan. 1970.

2. Secretaría de la Presidencia, Gobierno de México. Medio Ambiente Humano. Problemas Ecológicos Nacionales. México, 1972.

3. Naciones Unidas. Documento Preparatorio para la Conferencia Mundial de la Población, Bucharest, Rumania 1974. Naciones Unidas Ginebra, Suiza.

4. Secretaría de la Presidencia. Ibid.

5. Censos Generales de Población de México. Gobierno de México, 1970.

6. Arreola, G. Las Ciudades Perdidas. Fondo de Cultura Económica, Junio 1974, México.

7. Ward, B., Human Settlements: Crisis and Opportunity. United Nations, Ottawa, Canada. January 1974.

8. Ward, B. Ibid.

9. Arreola, G. Ibid.

10. Massachussetts Institute of Technology. Urban Dwelling Environments: Mexico City. School of Architecture and planning, M.I.T. Cambridge, Mass., June 1974.

11. M.I.T. Ibid.

12. Abrahms, C., _Man's Struggle for Shelter in an Urbanizing World._ The M.I.T. Press, March 1970.

13. Churchman, C. W., _The Systems Approach._ A Delta Book, New York 1968.

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PLANEACION DE SISTEMAS AMBIENTALES URBANOS.

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Chapter 1

OVERVIEW

1.1 Historic Overview

1.11 Growth of Cities:

For hundreds of thousands of years man lived in small, temporary settlements, in caves or huts. Then, some 8,000 to 10,000 years ago, he created villages with hundreds of inhabitants and somewhat later, his first cities, they functioned as trading posts, etc. They were small, never exceeding 50,000 people, usually remaining below 20,000. They were limited in space, usually surrounded by walls. They were small, static nuclei of man's urbanized life surrounded by vast expanses of open countryside. Until seventeenth century, only the capitals of the great empires such as Rome and Constantinopole grew beyond this description, not to exceed 1 million people and they either shrank back to smaller sizes as Rome or Constantinopole did or died completely as Changan (China) when their empires were dissolved.

1.111 Historical Development of Industrialization

a) agricultural revolution; villages; a central management place; organization

b) development of commerce, government, service

c) industrial revolution and mass production; transportation; standard of living

d) mass consumption

e) information

*Identify phenomena of "specialization of class structure" occurring in world today.

1.112 What is your definition of a city?

a) cultural unit

b) religious unit

c) political unit

d) other

1.12 Growth of Urbanization:

With the advent of scientific, technological, social and industrial revolutions, the cities began to grow continuously; from static they became dynamic and soon reached and exceeded a population of millions. Tokyo and London had 1 million inhabitants and today London, New York and Tokyo have passed the 10 million mark. Many other cities are beginning to be interconnected in broader systems of the tens of millions. From small city, man moved to the dynamic city, to the dynamic metropolis and today moves on to the megalopolis.

There are now 13 megalopolises around the world (Fig. 2) as a recent study (1) has demonstrated, and many more will emerge. As a matter of fact, we are heading toward the merging together of megalopolises into broader systems; toward the emergence of long strips of developed land which will be interconnected into a huge network; and thus toward the creation of a universal system of human settlements which will cover the whole earth. This is the next stage of the historical process: The creation of the Universal City or Ecumenopolis (Fig. 3).

1.2 Urban Systems (and their environment)

1.21 The Human Community:

The human community is the basic unit with which a city is built. The whole idea of the human cell is based on human experience which is the result of long experimentation. On the basis of this, human communities are created that can serve all man's purposes within a limited unit and can guarantee the human function and the human scale of the environment.

1.22 The Urban Systems:

Human communities are only the cells of the urban systems. Urban systems developed to provide man with a satisfying habitat. Urbanization is a complex process that has evolved, with industrial development, into a physical pattern necessary for the functioning of human communities.

1.3 Urbanization

1.31 Functions:

1. Production - distribution - consumption
2. Socialization
3. Social control
4. Social participation
5. Mutual support

1.32 Parameters:

1. People
2. Food
3. Energy

4. Water

5. Economic opportunity

6. Education

7. Transportation and communication

8. Climate

9. Government (how people organize themselves)

10. Security

1.33 Problem areas:

1. Services

2. Population growth

3. Changing needs

4. Rebuilding the older urban centers

5. Inequities of social and economic segregation

6. Equal opportunity for all to share in the benefits of urban life

7. Diseconomy of scale

1.4 Growth and Development

Although economic growth is an ultimate objective in development, the essence of development process is human development.

1.41 Social Development:

1.411 Education

1.412 Health

1.413 Welfare

1.414 Public Utilities

1.415 Security

1.416 Education

1.417 Recreation

1.42 <u>Growth (stages) (4)</u>:

1.421 Tradiational society

1.422 Pre-conditions

1.423 Take-off

1.424 The drive to maturity

1.425 High mass consumption

1.5 <u>Quality of Life</u>

A measure of one's success in the pursuit of happiness-success in the progressive satisfaction of a continuum of needs.

1.51 Life Style
Materialistic measure of a civilization's progress

1.52 Standard of Living
An aggregate of life style

1.53 Hierarchy of Needs (2), (3)

(1) Air

(2) Water

(3) Food — Physiological

(4) Shelter

(5) Health

(6) Safety-security

(7) Belongingness, love — Cultural

(8) Esteem

(9) Self actualization

1.6 Developed and Developing Nations

1.61 Developed nations have as one distinguishing feature their creative technology andsocietal acceptance of transfers.

1.62 The developing nations on the other hand, have not historically undergone much of the transfer as yet, and have attempted to identify essentially in isolation with the latest technology.

1.63 Ranking based on qualitative and quantitative indicators of human resource development.

1.7 Dangers in Future

1.71 The danger for nature and the ecological balance with man.

1.72 The danger for man because of the disappearance of the human scale: Variety, dehumanization, homogenaity.

1.73 The danger for man because of the disappearance of local cultures under the pressure of universal forces.

1.8 Objectives of the Course

1.81 Urban Systems and Problems - Aggregate Systems

1.811 Systems Approach

1.812 Models - An abstract presentation. A symbolic representation of a real life situation.

1.82 Methodologies and Techniques

1.83 Future

1.84 Data Needs - Averages

1.85 Plan of conscious actions and alternatives

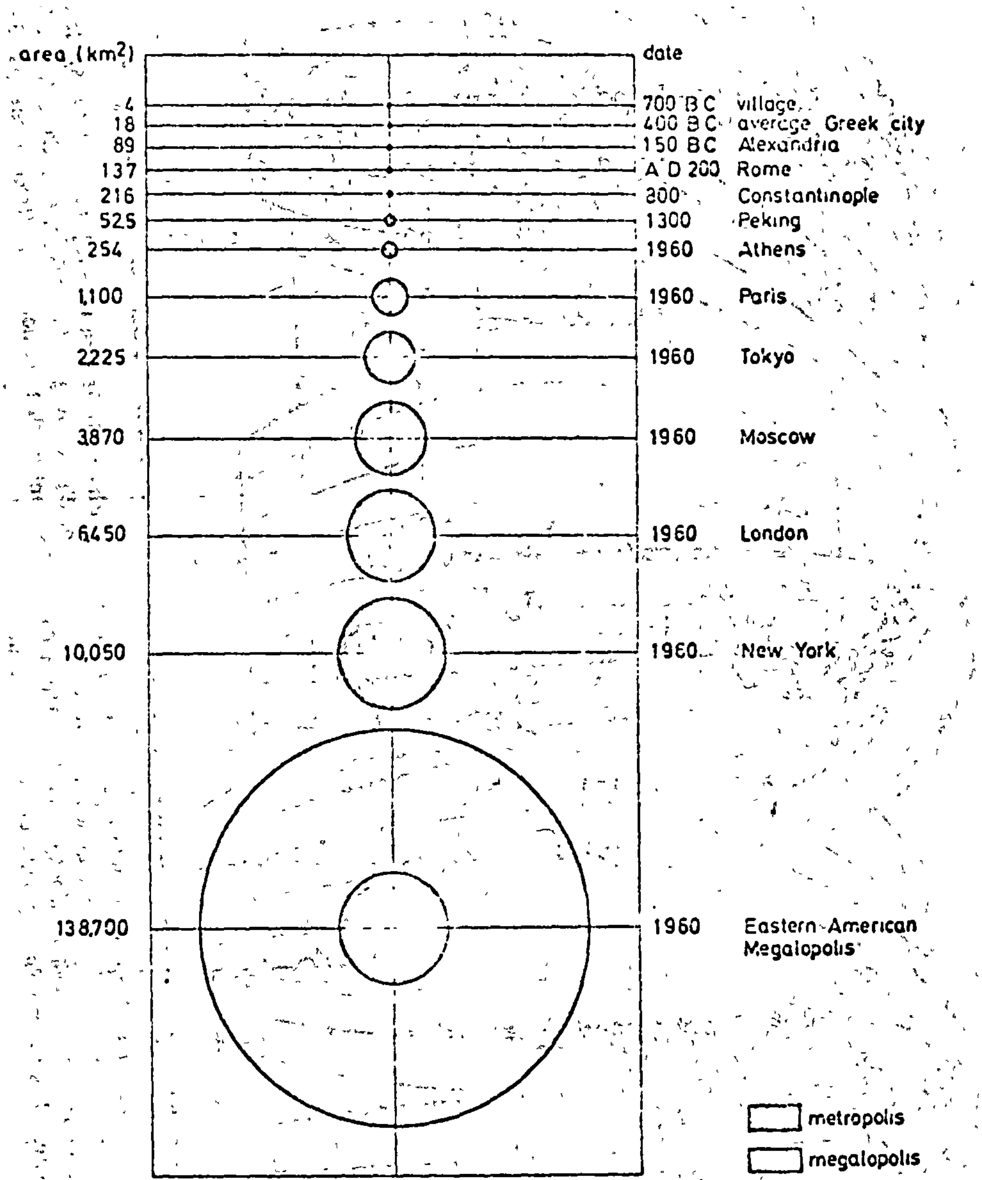


Figure 1 Evolution of the size of human settlements.

Figure 1

Figure 2

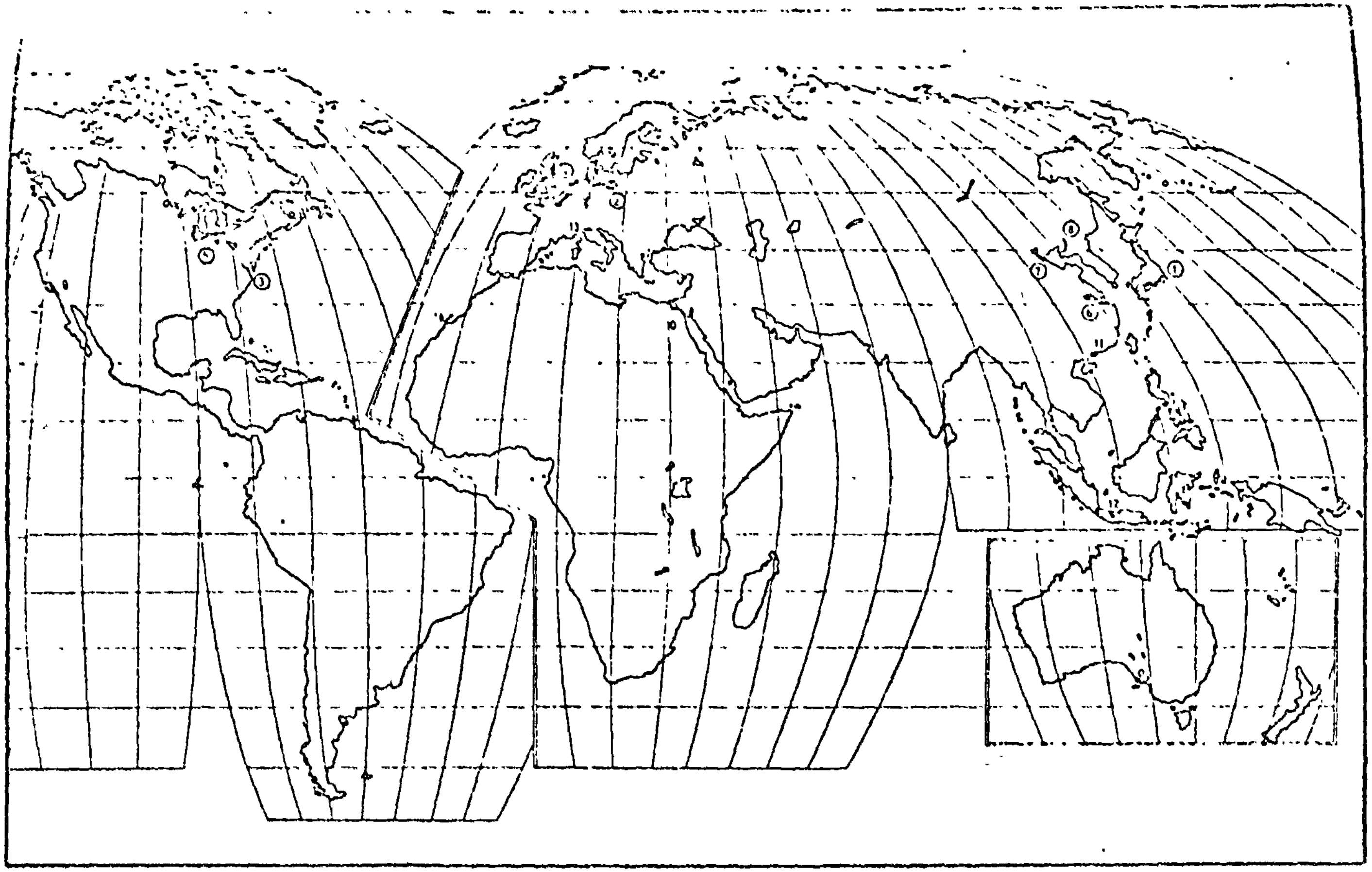
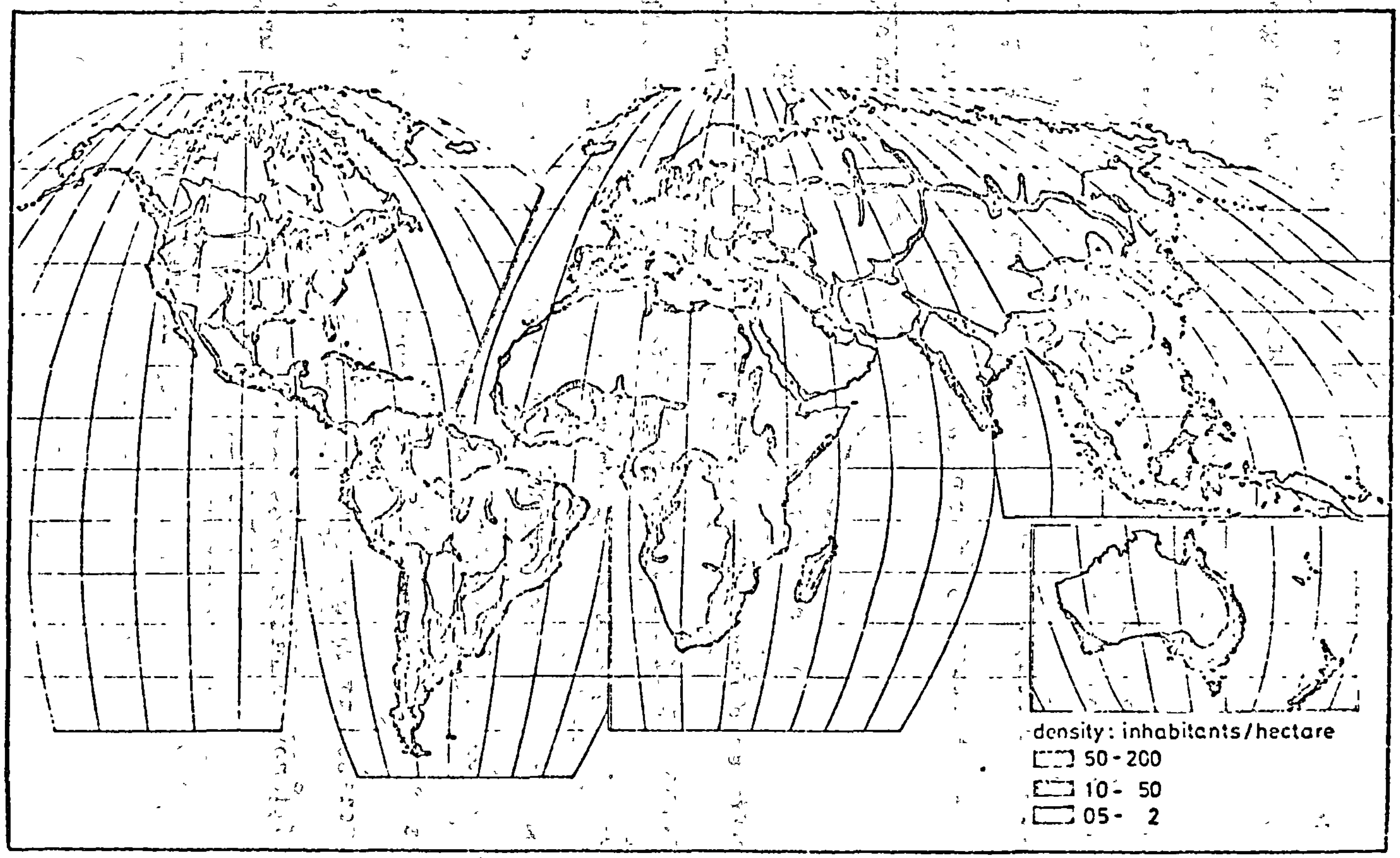


Figure 2 The thirteen megalopolises in the world today. (1) Japanese, (2) Rhine, (3) Eastern (U.S.A.), (4) English, (5) Great Lakes (U.S.A.), (6) Shanghai-Nanking, (7) Peking-Tientsin, (8) Shenyang-Dairen, (9) Los Angeles-San Diego, (10) Cairo-Alexandria, (11) Hong Kong-Canton, (1) Djakarta-Bandoeng, and (13) Milan-Turin. The numbers that are not circled (from 9 through 13) indicate pre-megalopolises, that is, they have populations of 3 to 10 million.

Figure 3



Ecumenopolis at the end of the twenty-first century.

Chapter 2

URBAN SYSTEMS AND THEIR PROBLEMS

The urban area is depicted as a wide-open economy, heavily dependent on external trade. The larger the urban area, the more it resembles the nation as a whole and the more predictable it is in both growth rate and growth stability. It is a living, self-controlling system that regulates its own flows of people to and from the outside environment.

An urban system consists of a non-static or dynamic area and related outside world. It assumes that the technology, the living standards, and the nature of economic activity in the area change to keep pace with the outside along with all the problems inherent in such a system.

2.1 Urban Environmental Problems

Urban regions are subject to unprecedented stresses and problems. All human history is a long record of man's struggle against hunger, disease, war and ignorance. What is new and menacingly urgent are today's expanded dimensions and accelerating frequencies.

Below are listed the areas of problems:

(1) Urban growth and services,

(2) Social and economic disparities,

(3) Metropolitan interdependence,

(4) Governmental obstacles.

2.2 Urban Growth and Services

2.21 Urban growth is a complex process requiring a wide variety of public and private resources.

2.22 Future growth virtually restricted to urban areas.

2.23 Concentration of economic activity and population.

2.24 Need for urban land tends to grow at a faster rate than the population increase. In the United States, urbanized land will grow from 2,400 square mile in 1960 to 5,200 square miles in 1985.

(1) Highways and other transportation channels

(2) Schools, houses, shopping centers, parks

(3) Hospitals, offices

(4) Water supply, utilities, local roads

2.25 Dependence of urban growth upon private supply of facilities and services.

(1) Public supply limited

(2) Private supply profit oriented

(3) Need for control and planning

2.3 Social and Economic Disparities

2.31 Racial and economic segregation; severe consequences for disadvantages groups.

2.32 Migrations from rural areas to urban areas

Migration from old central cities to the suburbs

2.33 Cultural isolation

(1) Low income families

(2) Broken families

(3) Elderly, unemployed

(4) Negroes

2.34 Local tax structure

(1) Local revenues

(2) Local spending

2.35 Failures of urban renewal

(1) Failures of relocations

(2) Failures of highway construction

2.36 Opposition to renewal and rebuilding

(1) Mistrust

(2) Discontent

(3) Shortage of housing, services

2.4 Metropolitan Interdependence

2.41 Failure of government institutions to come to grips with the growing interdependence of people and communities within metropolitan areas.

2.42 Search for housing and employment within a region circumscribed more by the convenience than by local government boundaries.

2.43 According to U. S. Bureau of the Budget and U. S. Bureau of Census, the general concept of a metropolitan area is one of an integrated economic and social unit with a recognized large population nucleus.

2.431 SMSA's - Standard Metropolitan Statistical Areas

At least one city of 50,000 inhabitants or more or twin cities with a combined population of at least 50,000.

2.432 "Spillovers" - the effects of local action (or inaction) that spread into other communities.

2.4321 The prevalence of spillovers constitutes a strong case for cooperation

2.4322 Joint planning by local governments

(1) Water supply

(2) Sewage disposal

(3) Transportation

(4) Highways

(5) Mass transit

2.5 <u>Governmental Obstacles</u>

2.51 Local governments

2.511 Small area of jurisdiction - inadequate for administration

2.512 Small funds and resources

2.513 Fragmentation of local government brings it "closer to the people"

2.514 Compounded difficulties of coordination

2.52 Federal system

2.521 Federal aid programs

2.522 Cities have found a more sympathetic hearing in Washington than in the state capital.

2.6 <u>Growth Processes</u>

2.61 Growth phase

2.62 Equilibrium

2.63 Decay, aging, stagnation

2.7 Excerpts of "Urban Problems"

. . . the cause of America is the cause of mankind. Now, throughout the world, the cause of all mankind is increasingly to find the good life in an urbanized environment.

. . . a long agenda of problems that can be solved only by public action. The agenda includes providing public investments and services to keep pace with population growth and changing needs rebuilding the older urban centers, eliminating the inequities of social and economic segregation, and offering equal opportunities for all to share in the benefits of urban life.

Thus social critics, noting the contrast between splendid new surburban homes, an abundance of high-powered cars, and recurrent crises in such areas of public responsibility as education and water supply, concluded that there is a striking imbalance in national priorities. Galbraith, in The Affluent Society, attributes this curious urban blend of private splendor and public squalor to a national folklore that assigns high value to private production, with a corresponding neglect of important public investments.

The great majority of people and economic activities in the United States are now concentrated in over 200 metropolitan areas, and virtually all future growth is expected to take place within these areas. Inside metropolitan areas, however, growth does not take a concentrated form but tends to spread well beyond the established cities into fringe territory. By now, more than half the metropolitan population lives outside the central cities.

By 1975, we will need over 2 million new homes a year. We will need schools for 10 million additional children, welfare and health facilities for 5 million more people over the age of 60, transportation facilities for the daily movement of 200 million people, and more than 80 million automobiles.

In less than 40 years, urban population will double, city land will double, and we will have to build in our cities as much as all that we have built since the first colonist arrived on these shores. It is as if we have 40 years to rebuild the entire urban United States.

The need for urban land tends to grow at a faster rate than population increase. There is no shortage of land in the United States. Problems arise in making this land suitable for urban living. Highways, schools, water supply, parks, hospitals, utilities, local roads, and shopping centers are all needed. In New York, the necessary public service investments alone will cost an estimated $16,800 for each new household. Thus one of the major shortcomings in water supply and waste disposal is the continued reliance on private wells and individual septic tanks in communities where the growing density of population calls for public water and sewerage systems. Despite crabgrass and faulty septic tanks, most new residents of the suburbs enjoy good living conditions.

As a result of this combination of forces, low-income families, broken families, the elderly, the unemployed, and Negroes are concentrated in the central cities of most large metropolitan areas. People in the central cities need many kinds of government services: welfare, education, health, police, and fire portection. Yet the tax resources of these cities are limited by the very nature of their population.

Educating slum children is far more difficult than educating middle-class children; yet many schools in wealthy suburbs spend $1,000 per pupil annually and provide a staff of 70 professionals per 1,000 students, while slum schools are likely to spend only half as much, and to provide 40 or fewer professionals per 1,000 pupils.

People look for housing and employment within a broad region circumscribed more by the convenience of commuting and by personal preferences than by local government boundaries. . . . concept of a metropolitan area is one of an integrated economic and social unit with a recognized large population nucleus.

Fragmentation of this kind may appear to bring government "closer to the people", but it compounds the difficulties of achieving coordination within metropolitan areas. Activities of all three levels of government now function in close juxtaposition, subject to an extremely complicated web of federal, state, and local laws, and administrative regulations. For a number of reasons, the cities have found a more sympathetic hearing in Washington than in the tate capital

The 1960 Census of Population found nearly two-thirds of the entire population of the United States living in metropolitan reas - 112.9 million persons of the nationwide total of 179.3 million. The 212 areas recognized as metropolitan in 1960 accounted for 84 percent of all the increase in the Nation's population during the 1950-60 decade. For these areas, the growth was 23.6 million persons, or 26 percent, while the population of the remainder of the country rose only from 62 to 66.4 million, an incr ase of 7 percent. Similarly, during the previous decade, 1940-50, these 212 areas had accounted for nearly 80 percent of the total population growth of the United States. In the past two decades accordingly, the 212 areas now recognized as metropolitan have increased 55 percent in population, from 72.8 to 112.9 million persons, while the population of the rest of the United States has grown only 11 percent, from 59.3 to 66.4 million persons. . . .58 million out of 112.9 million lived within the central cities in 1960.

Economic resources are highly concentrated in the metropolitan areas of the United States -- even disproportionately concentrated, relative to the metropolitan share of national population. 63 percent of the people were living in metropolitan areas, these areas accounted for 78.6 percent of all bank deposits in the United States. And in 1958, metropolitan areas accounted for more than 3/4 (76.8 percent) of the value added by manufacture, contained 67.2 percent of the country's manufacturing establishments, accounted for 73.8 percent of the total number of industrial employees, and 78.5 percent of all manufacturing payrolls.

Distribution of Taxable Property, 1961

Class of real property	Percent of taxable assessed valuations: Within SMSA's	Percent of taxable assessed valuations: Outside SMSA's
Residential	63.7	42.9
Acreage and farms	3.5	32.8
Commercial and industrial	29.7	18.6
Other	3.1	5.7
TOTAL	100.0	100.0

Race, age, mobility status, family composition, education, occupation, employment status, family income, housing characteristics, and commuting patterns. . .largely determine how he lives.

The strongest conclusion to be drawn from the analysis is that very few meaningful generalizations about economic, social, and racial disparities can be applied to all metropolitan areas.

The classic dichotomy of the poor, underprivileged, nonwhite central city contrasted with the comfortable white suburb does not hold true throughout the country. While racial disparities are large everywhere, the other elements of the dichotomy -- education, income, employment, and housing -- fit the stereotype consistently only in the large metropolitan areas and those located in the Northeast. In areas of the South and West, poverty, especially among nonwhites, is more typical of the suburbs than the central city.

On the whole, cities and suburbs show little difference in the proportion of their adult populations with less than four years of high school -- an inadequate education by today's standards -- or in their high school dropouts rates. Under-education of youth and adults is an equally serious problem in both urban and suburban segments of most metropolitan areas.

Local Government Revenue, 1962

	Within SMSA's		Outside SMSA's		United States	
	per capita amount	%	per capita amount	%	per capita amount	%
Total General Revenue	$223.78	100.0	$175.06	100.0	$206.36	100.0
Property taxes	111.78	50.0	76.30	43.6	99.09	48.0
Other local taxes	18.41	8.2	5.74	3.3	13.88	6.7
State aids	55.35	24.7	64.29	36.7	58.54	28.4
Other general revenues	38.24	17.1	28.73	16.4	34.85	16.9

Local Government Expenditure, 1962

	Within SMSA's	Outside SMSA's	United States
Total	$267.05	$199.68	$242.96
Education	97.29	95.29	96.57
Highways	18.46	22.85	20.03
Public Welfare	16.13	9.78	13.86
Police Protection	12.59	5.28	9.98
Fire Protection	7.79	2.91	6.05
Sewerage	8.44	3.98	6.85
Housing and Urban Renewal	8.69	1.61	6.16
Parks and Recreation	6.43	1.77	4.77

Most of the people and wealth of the country are now found in **metropolitan areas, and virtually all future growth is expected to take place in metropolitan setting.**

Fifteen different functions account for more than 85 percent of direct general expenditures by local governmencs in the United States: education, police and fi e protection, transportation, water supply and sewage disposal, welfare, hospitals, and medical care facilities, housing, urban renewal, libraries, parks and recreation, planning, health, refuse collection and disposal, and air pollution control.

It is well within the technical and economic capacity of our metropolitan areas to develop dependable sources of pure water and to make reasonable provision for disposing of liquid wastes.

The governmental jurisdiction responsible for providing any service should be large enough for the benefits from that service to be received primarily by its own population. Neither the benefits from the service nor the social costs of failing to provide it sould "spill over" into other jurisdictions.

The unit of government should be large enough to permit realization of the economies of scale. For example, it costs $58 per million gallons to provide primary sewage treatment in a million-gallon capacity facility, but less than half this amount in a 10-million gallon capacity facility.

The unit of government carrying on a function should have a geographic area of jurisdiction adequate for effective performance, as illustrated by the desirability of a sewage disposal system's conforming to a natural drainage basin.

The unit of government should have the legal and administrative ability to perform services assigned to it.

Every unit of government should be responsible for a sufficient number of functions so that its governing processes involve a resolution of conflicting interests and a balancing of governmental needs and resources.

The performance of public functions should remain subject to public control.

Functions should be assigned to a level of government that provides opportunities for active citizen participation and still permits adequate performance.

Local governments have prime responsibility for municipal water supply and waste disposal. The states activities focus on allocation, regulation, and facilitation of local activity. In addition some states recently have been giving attention to overall water resources planning and the development of water projects which are beyond the capabilities of the local units.

The Federal Government has been responsible for most multipurpose river basin developments. Federal agencies also loom large in navigation, flood control, irrigation, sewage treatment assistance, pollution control and, more recently, in water use for recreational purposes.

Government at all levels, regardless of the particular role of an individual agency, is faced with the constant problem of balancing and adjusting the claims of various interests -- urban, industrial, navigation, flood control, conservation, and recreation -- in the allocation, regulation, and development of a scarce resource.

Most of these conflicts are not merely the result of inadequate communications or a failure to plan. In most areas where such conflicts arise, there are not sufficient quantities of water at comparable prices and quality to sufficient quantities of water at comparable prices and quality to supply all users. The stakes for the contestants in terms of protecting investments and insuring future development are tremendous. Competition for the use of existing supplies of water will always exist; it is not likely to be eliminated through indefinite expansion of supply or through the perfection of planning and administrative devices.

Often there is a facile assumption that if planning were intensified, the structure of decisionmaking overhauled, and intergovernmental responsibilities more carefully specified, consensus and solutions would follow with ease. Such hopes are usually unfounded. Only rarely will a plan or policy for water use appeal to all parties. To the contestants in water politics, each level of government is a different arena, with varying advantages and disadvantages for different participants and the resolution of differing issues.

If governments are to provide needed services, however, they must be able to cope with conflict, mediate between different interest groups, and reach acceptable compromises as a basis for action.

The total quantity of water available in the United States is constant. For centuries, 30 inches of annual rainfall have been producing an average of 4,300 billion gallons of water per day. Approximately 14 percent of this water, about 600 billion gallons per day from both surface and ground sources, is usuable.

In 1900 less than 8 percent of the 600 billion gallons per day was needed for all water uses. Today's requirements exceed 300 billion gallons per day. Less than 10 percent of this water is used in urban areas. Municipal water use averages about 147 gallons per capita per day. Of this, 41 percent is attributable to domestic use, 18 percent to commercial use, 24 percent to industrial use, and 17 percent to public use. Before the end of the century, it is estimated that daily consumption for all purposes will exceed the usable supply.

Most of the water used in urban areas serves as a solvent, cleanser, or coolant. Pending such technological developments as economical desalinization which would increase greatly the total quantity of usable water, most of the projected increase in water requirements will be met through reuse.

To be suitable for reuse, water must be of adequate quality. While urban uses have a relatively minor effect on the quantity of water, they seriously reduce water quality. Thus water supply and sewage disposal, which developed as separate functions of local government and still are administered separately in most communities, are in effect two phases of the single function of water resource management.

In cities with a population of over 25,000, 20 percent reported deficiencies in water main capacity, 33 percent insufficient pumping capacity, 40 percent inadequate capacity, 43 percent too little elevated storage, and 29 percent lacked sufficient ground storage.

Sewage treatment works and interceptor serves to overcome the 1955 backlog would cost in excess of $1.9 billion. It is forecasted that during 1955-65 replacement of obsolete sewage treatment acilities would involve another $1.7 billion, and treatment works to meet population increases could be expected to require an additional investment of approximately $1.7 billion. 5,290 communities had inadequate sewage treatment facilities. Over 90 percent of the deficiences reported were in communities of less than 10,000.

Metropolitan water and sewage services are often handled by a series of small, separate governmental units and private companies. Small municipalities and sewer districts often fail to process wastes at all, or treat them only inadequately. The suburbs are the critical aspect of the metropolitan water problem.

The many approaches to governmental reorganization will be taken up in a sequence that moves generally from smaller to larger structural modifications: use of extraterritorial powers, intergovernmental agreements, voluntary metropolitan councils, the urban county, transfer of functions to State governments, metropolitan special districts, city-county separation, city-county consolidation, and federation.

National policies for urban water supply and pollution control must change to meet the impact of population growth, increased per capita consumption, and industrial use. A comprehensive and well-understood national goal for urban water supply and sewage disposal is needed, within whiich gaps in programs can be filled and individual activities coordinated. A national policy should be established by the President and the Congress covering the provision of adequate water supply and pollution control in a broad framework of promoting sound development of the Nation's urban areas, including assistance to State and local governments to accomplish this purpose.

An important responsibility . . . is to develop the comprehensive river basin policies that will give full consideration to urban needs. The Federal Government should insure that water resource planning and development by each of its water agencies, and on each river basin in which the Federal Government has an immediate interest, take into account the needs of urban areas as well as the needs of agriculture, power production, industry, recreation, fish and wildlife.

The Water Resources Planning Act of 1965 establishes a Federal Water Resources Council and provides a procedure for establishing river basin commissions to develop plans on a comprehensive and coordinated basis for the optimum use of water and related land resources. The Council is to review plans with special regard to the effect "on the achievement of other programs for the development of agriculture, urban, energy, industrial, recreational, fish and wildlife, and other resources of the entire nation".

Chapter 3

URBAN PATTERNS OF LIVING

3.1 The Developmental Society:

(i) Once a society begins the long and hard road to better conditions of living, it only gradually discovers that it is also trying to escape the limitations of its own culture and tradition.

(ii) The process of looking beyond one's boundaries for answers to problems that the society has not before encountered becomes quite common as development accelerates. Gradually there evolves in the society a new element that gains its prestige from introducing and reducing to practice the useful ideas and information originating outside.

(iii) The carriers and interpreters of world culture are the doctors and dentists, the engineers, the top administrators, the educators, the enterprisers and many of the technicians. It is readily understood why such men will tend to become attached almost as much to the world at large as to their own people and their own culture.

3.2 Population:

(1) Need for social control over population increase

(2) Annual rate of overall increase is 0.8 to 1.0%

(3) The maximum capacity of the planet earth by one estimate is 50 billion people and 10^7 cal /person/ year.

(4) Factors inhibiting population control

(5) Atomic bomb toxic substances

(i) Religion

(ii) Nationalism

(iii) Tribalism

(5) Methods to control population

(i) Abortion

(ii) Birth control

(iii) Contraception

3.3 Elements of Standard of Living:

(1) Activity: arrangements for working time and leisure

(2) Family: size, age structure, interrelations

(3) Consumption: maintenance of social status and efficiency

(4) Saving: security and deferred consumption

3.4 Migrants:

(1) Abrupt change in environment;

misery, confusion, hostility

(2) Shock;

cultural, trade, living conditions

(3) Ghettos

(4) Urban villages;

The answer to the assortment of human problems associated with mass urbanization is to decant the waves of migrants from the rural hinterland into communities called "urban villages."

3.5 Special Problems of Megalopolis:

(1) Journey to work - congestion, time consumming, etc.

(2) Perishable foodstuff

(3) Movement of goods

(4) Disposal of wastes

(5) Water supplies

(6) Conflicting land use requirements

(7) Decay of slums

(8) Smog

3.6 Industrialization and Its Impact on Urban Environment:

3.61 History of industries:

(1) Household manufactures

(2) Village handicrafts

(3) Artisan's workshops

(4) Primitive factories

(5) Integrated "assembly lines"

(6) Continuous flow processes

(7) Automatic factory

3.62 Concepts in industrialization:

(1) capital

(2) Labor

(3) Productivity

(4) Automation

(5) Consumer

(6) Standard of living

(7) Technological innovations - diffusion

3.63 Scales of industries:

(1) Scattered small scale intrepreneurs using make-shift equipment and methods.

(2) Decentralized, government sponsored factories with local participation and some centralized regulation.

(3) Large, modern industrial units with strong initial government participation.

3.64 New Industries:

(1) Microbiological food

(2) Atomic power

(3) Fresh water from sea water

(4) Steel by hydrogen reduction

(5) Cheaper communication systems

(6) Fully rationalized construction methods

3.65 Urbanization, Industrial Growth

(1) Industry, R & D, filtered down

(2) Integrated

(3) Regional

(4) Natural

(5) Multinaturals

Chapter 4

SYSTEMS APPROACH AND PLANNING

4.1 Systems:

A system is a set of parts coordinated to accomplish a set of goals.

4.11 Basic considerations about systems

4.111 System objectives - measures of performance

4.112 System's environment - the constraints

4.113 System's resources available

4.114 System components - subsystems

4.115 Management of the system itself

4.12 Dimensions of the Systems Approach

Since the model to be developed is being designed for both intermediate and long-range planning, a brief analysis will be presented to show how the systems approach deals with the complex feedback interactions between all sectors and elements of the system under study. This inherrently poses a challenge to the systems approach which generally does not come into sharp focus if short-range reactive type of planning is the correct approach for changes in the systems environment.

In his book on the systems approach, Churchman indicated "that the systems approach really consists of a continuing debate between various attitudes of mind with respect to society." This debate may be conceived to take place along at least two coordinates: the first called the horizontal which emerges from continuous feedback interaction between the general and the particular. Dimensionality refers to the degree of systematic interrelatedness pertaining to different attitudes toward economic, social, dempgraphic, political, and technological aspects, each of which may be further subdivided. The second coordinate is referred to as the vertical. This may be discussed in a framework of the basic three-level structure proposed by Ozbehkan and others for planning. The structures are composed of: normative or policy planning, strategic planning, and operational planning.

When referring to dynamic social systems, the notion of policy is concerned with the formulation of regulating principles. Vicker's view of policy can be applied here. He believes that it is "regulating a system over time in such a way as to optimize the realization of many conflicting relations without wrecking the system in the process." At the strategic level, goals are general aims formulated in terms of outputs (missions) or functional outcomes. The difference between notions such as "making potable water available" and "drilling wells" illustrates the hierarchical relationship between strategic goals and operational targets. This outcome -- orientation of thinking -- enforces the adoption of at least a partial systems view. This is the essence of governmental planning in the framework of the Planning-Programming-Budgeting System (PPBS). Only at the operational level is planning and action directed at fixed, attainable targets or technical products. To get to these targets poses a problem which can be solved in typical cases. The "ends and means" to which economic theory frequently refers are usually defined at the operational level. Operational planning is input-oriented, focusing on alternative ways to organizing inputs to attain fairly well-perceived targets.

The normative process of planning and change unfolds in the feedback interaction between these three planning levels. Churchman has written extensively on the concept that a normative systems approach involves planning for objectives, goals, and targets while inseparably searching for and questioning these objectives, goals, and targets in light of moral valuation. With this in mind the feedback interaction can be depicted as shown in Figure 1.

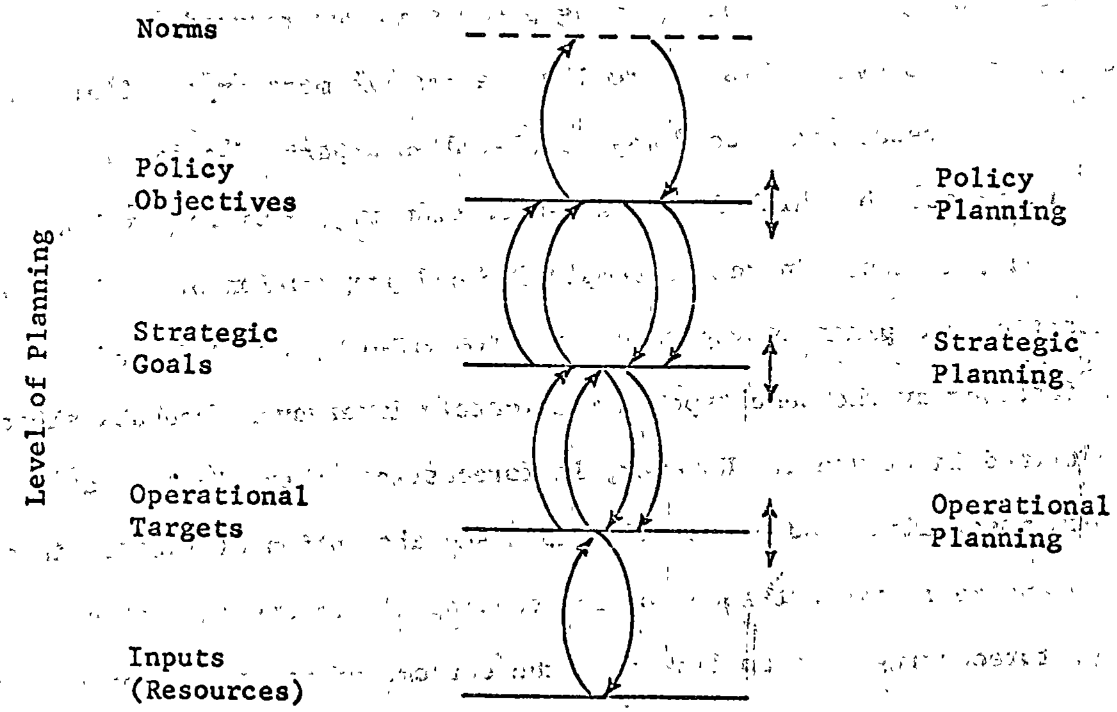


Figure 1. Vertical integration Across Planning Levels

Each level of planning comes through two inter-meshed feedback loops, one reaching "upward" and one "downward", so that planning levels not only "touch each other, but share feedback loops with adjacent levels. The feedback loops may be conceived as being themselves composed of samll feedback loops representing the continuous fluctuation between attitudes pertaining to the creation and appreciation, to the sy thesis and analysis, constituting the infrastructure of the learning process which is sometimes called planning, sometimes self-organization, and which characterizes human systems which include social systems. The important thing is that the learning process is not reduced to one or two levels. However, this is usually the case in most types of planning.

Forecasting itself may be viewed as a part of a feedback learning process by which it is linked to planning, decision making and in the end, action. In the contemplation and preparation of social change, forecasting and planning represent two complementary aspects, again tied together by the same type of intricately intervoven feedback process as outlined in Figure 1. However, in forecasting, there is alteration between possibility and potential, input and absorption of ideads, imagination and realistic attitudes of approaching future system states. Finally, forecasting is also linked to the outcome of action by the evaluation process which modifies continuously the information basis for forecasting, and more importantly, the value basis.

The intent of this section has been to show that the systems approach is a viable one for the examination of the problem under study.

The model to be presented in the remainder of this chapter is both a planning and a forecasting one. The planning phase of the problem will be described by the utilization of heuristics and the forecasting aspect will be carried out using simulation techniques to be presented later.

4.2 Basic Philosophies about Systems Approach:

4.21 Efficiency - identify trouble spots and wastes

4.22 Use of science - build a model of the system (like scientific method -- fallible: belief that there is a solution to everything)

4.23 Humanists approach - human values

4.231 Values

Economic

Humanities

4.24 Anti-planners approach

4.241 Opposed to analytical approach

4.242 The sceptic philosophy

4.243 The determinist philosophy

4.25 The essence of the system approach is enlightenment, continuing perception, continuing reviewing of the world, the whole system and of its components.

4.3 The Systems Approach:

Model

Metrics - measuring $

Alternatives - different routes

Goals

Validation - reality

4.4 Model and Modeling:

A model is a way in which the human thought-processes can be amplified.

There is a fundamental limitation of any modeling of a system, that the system is always embedded in a larger system (real system, time, space).

4.5 Operations Research:

A tool to analyze quantitative and qualitative aspects of human activities based on scientific methods (based on scientific approach).

4.51 Programming

Linear

Non linear

Convex

Geometric

Dynamic

4.52 Econometrics - Management Science

Micro, Macro

Inventory, Allocation

Benefit - Cost

Cost Effectiveness - Replacement

Discounting

4.53 Statistics

Regression analysis

Correlation matrix

Probability

Multivaliate analysis

4.54 Simulation

4.55 Networks, flowcharts, CPM, sequencing

4.56 PPBS - Program Planning and Budgeting

4.57 Decision theory (Refer to Chapter 21.0)

Game theory

Decision tree

Operational gaming

4.58 Time series - stochastic

Factor analysis

Spectral analysis

4.6 Time:

4.61 The "larger system may be the future world. The larger system, in this sense, is infinite, stretching endlessly into future generations.

4.62 The future is always less certain than the present, thus each successive stage of planning is vaguer, less predictable and so less feasible to plan beyond a certain point.

4.63 Errors, if predictable, of measurement increase with time

4.64 Benefits and costs both diminish at each successive stage.

4.65 Multistage thinking

Multi-structure

Multi-variant

4.651 Multistage planning

4.652 Replacement models

4.653 Waiting line models

4.654 Inventory models

4.655 Net-works, flowcharts

4.656 CPM, PERT, Bantt harts

4.66 Opportunity cost:

Cost of lost opportunity

4.67 Discounting to future

Quantitative

Non-quantitative

4.68 Cybernetics

Mathematical method of evaluating and controlling a process on the basis of its experience (Black box experience - look at whole).

4.681 Management Information Systems.

4.682 Purposive machine

4.7 <u>Planning</u>

Planning is one of the activities of a system and we must look at it in terms of its measures of performance and of its advantages and disadvantages to the organization.

Surprise is an unsatisfactory state of affairs to a planner.

471 Elements of planning

4.711 Decision maker

4.712 Alternatives

4.713 Goals

4.714 Objectives for later stages

4.8 Program of Planning

4.81 Social Interaction

4.881 Justification

4.812 Organizing Subsystems

4.813 Communication

@ Persuasion

@ Mutual education

@ Politics

4.82 Measurement

4.821 Identification of a "decision maker"

Problem: who should be it? Consumer should make decision rather than professionals?

4.822 Alternatives

4.823 Goals

4.824 Ultimate objectives

4.825 Effectiveness

4.826 Optimizing

4.83 Verification

4.831 Simulation

4.832 Counter planning

4.833 Controlling the plans and implementation

4.9 Symbiosis:

Healthy relationship between managers and planners. It means that they live together in a mutual education mode.

4.10 Urban Economics - Excerpt from the book, Urban Economics by Harry W. Richard (Refer to next page).

URBAN ECONOMICS[1]

Of all the challenges and problems that face mankind in the rest of the century there are few that look so intractable yet affect so closely the daily lives of so many people as the problem of the city. . .. Presence of externalities makes it difficult, if not impossible, to allocate resources optimally; many urban investments are 'lumpy', absence of a market for many urban goods and services.. . a degree of monopoly power in the urban land market; the planning authority, property companies, mortgage institutions,sellers of land, builders and the design professions. Misallocation shows itself as central city congestion and urban sprawl. If the city is growing, the allocation of a given activity to a given site is likely to remain optimal only for a short time, yet resources are not easily transferred once they have been committed.

Three factors: market mechanisms and the constraints under which they operate; external and other agglomeration economies; and transport costs. Spatial organization of the city is largely the result of a process that allocates activities to sites. The price (rent) of land is an inverse function (typically a negative exponential function) of distance from the city center.

Rent/distance function: external and other agglomeration economies and transport costs. Agglomeration economies would probably induce activities to cluster together spatially even in the absence of transport costs or high land prices.

$$E = aP^2,$$

where E equals the external economies, and P is the population.

Moreover, household may spend up to 25 per cent of their disposable income on housing. Micro-economic approach is to concentrate on the individual household and to explain its location decision in terms of its choices and preferences.

Behavioral models: The first type makes journey to work costs (whether measured in money and/or time) the main explanatory variable, minimizing travel costs; in more moderate and more acceptable forms, the models emphasize the importance of trade-offs between travel costs and housing costs (location rent). The second major alternative approach consists of theories which stress choice of house and area and environmental preferences as the principal determinants of residential location; the role of journey to work costs/time is relegated to that of an outer constraint.

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1 Richard, Harry W., Urban Economics, Penguin Books, Ltd., 1971.

Households should live as close to the workplace as possible. This is completely inconsistent with imperical observation. Changes of residences are usually associated with a longer, or at least equal, journey to work, and surveys of consumer preferences indicate a strong desire of most households to live further out, if and when they moved. Journey-to-work applies only to the very poor and the very rich.

It is usually assumed that: households substitute travel costs for housing costs and the rate of substitution is governed by each households preference for high or low density living.

$$\text{Income} = Y_n + t$$

$$Y_h + t = P_m Q_m = t_{om} \qquad (1)$$

where P and Q represent the price and quantity of land (and housing) and t equals transport costs

Rearranging

$$P_m Q_m = Y_h + t - t_{om} \qquad (2)$$

Thus expenditure on housing is a function of transport cost savings.

The tendency for average incomes to increase with distance is largely due to the intercorrelation of both variables with the age of the dwelling in question. People prefer new houses and these are found on the outskirts. Land of the inner core is dominated by non-residential uses. Decentralization of work and shopping activities and the construction of fast roads is making urban services and activities more accessible to suburban than to central city households. As yet, this development is more prevalent in the United States than in Britain.

To select a house as expensive as they can afford, can be interpreted in terms of households' maximizing housing costs. The implications for planning of how households decide where to live cannot be overemphasized, especially in an age characterized by increasing job mobility and growing overspill problems. In a situation where jobs cannot be decentralized fast enough, then the appropriate prescription for transportation planning from travel-cost minimisation models is to improve speeds and reduce costs, and for the planning of housing to build at very high densities as centrally as possible. On the other hand, if households locate primarily to satisfy housing preferences, then more emphasis should be given to supplying the type of houses people want in the kind of environment and area they desire; this might be more important than marginal reductions in travel time.

For certain activities, especially retail trade, population is an approximate measure of market potential. Distribution of daytime population is more important. . . Index of population potential.

For business service establishments, the spatial distribution, number and size of client establishments are the main determinants of revenue (and turnover).

Factor costs will be lower away from the city core for almost all establishments. Those establishments that still prefer a central location must find that higher costs are offset either by agglomeration economies such as access to complementary firms and specialist services, or by higher turnover.

1. Activities serving the city market as a whole are more likely to locate centrally. Activities serving non-local markets will tend to occupy peripheral sites.

2. The more specialized a function, the greater its tendency to occupy a central location.

3. The larger the site area required by an establishment, the more likely it is to acquire a suburban location. This follows from the fact that the price of land tends to be inversely related to distance from the city center.

4. Influenced by the existence of land use controls and other urban planning restrictions of the use of central land. Land use controls and zoning have a marked stabilizing effect on the city's location patterns.

5. The presence of pecuniary external diseconomies (e.g. rising site costs) or technological external diseconomies (smoke, noise, traffic congestion) induces a degree of decentralization, though the response varies depending on how much an establishment is tied to the central core.

6. In some cases, a site at one of the secondary centers may offer an acceptable compromise.

7. Urban location decisions are interdependent in agglomeration. Complementary activities tend to agglomerate. On the other hand, some activities repel each other, for example, nuisance-creating manufactures and high class residences.

8. Historical forces. . . railway

9. In advanced industrial countries, there is increasing locational concentration in a few large cities but a marked decentralization trend within these areas.

In nineteenth century cities, manufacturing plants are usually located at central sites. New plants tend to be established at peripheral sites.

For the typical manufacturing firm, then, a suburban location is usually advantageous. Many firms remain for non-economic reasons. External economies obtainable at the central core and these outweight higher costs. One of the major economies is labour market accessibility. Larger plants can very often internalize these external economies, not tied to a core location.

The overriding locational requirement for retail shops is a site that will attract custom.. . greatest intracity accessibility.

First, recursive models involving step-wise projections are widely used, in which the changes taking place in a given period depend on the state of the system at the beginning of the period. Secondly, to make up for the scarcity of time-series data, time is injected into these models by introducing specified amounts of exogenous variables such as population change, in-migration, economic growth and income expansion. Urban simulation models are usually molded on these lines.

The testable models are too crude, while the models approaching reality are too cumbersome in their data requirements to test. . . Urban growth will normally be associated with both upward and outward expansion. Central densities will rise, and central land will be used more intensively. . . . the settled urban area will expand outwards.

Sub-centers develop because with extensive urbanization and increases in scale it is no longer efficient to service a large city from one core. Voorhees (1968) has argued that a population increment of 100,000 can justify an additional center to serve it. Candidates for the title of sub-center include intraurban transport junctions, secondary business zones, large establishments such as hospitals or universities, and suburban shopping centers. . . by application of the hierarchical principles of a central place model, is inevitable in a large city since it becomes difficult to reach the main shopping center from a distance of, say, more than six miles away.

The metropolis of today and increasingly in the future is not only one city, but a federation o general and special centers.

Spatial allocation models. These attempt to distribute units of growth (people, firms, activities) among different parts of a metropolitan area with the aid of allocation criteria, behavioral assumptions or optimal decision rules or in line with the previous pattern of development. Others use a recursive approach in which development in one period is influenced by the path of previous development.

The emphasis in urban growth literature on increases in population rather than on rising per capita income means that there is a greater danger of a divergence between growth and welfare criteria. Thus, a city's growth defined in population-change terms, need not imply an increase in the welfare of its citizens.

'Urban growth' . . . has little to do with the determinants and sources of urban growth . . .tends to assume that the urban economy is growing, and then proceeds to explore the repercussions of growth on the spatial structure of the city. . . conversion of land from one use to another as a consequence of urban growth. It explicitly considers the variable space which is very desirable when our concern is with bounded areas, and it highlights the physical planning implications of growth and development.

Central place analysis and urban base theory. . . The central place theory, the city grows as a result of supplying goods and services to the surrounding region. In other words, a city's growth is a function of its hinterland population (and income level). The process of city growth generates internal needs. Central place analysis exaggerates the role of business and service activities. Cities grow to a considerable extent by attracting resources.

Thus, in base models, the urban economy is treated as an endogenous system with exports as the sole exogenous determinant; investment is always induced. This theory contains grains, but only grains, of truth.

A location theory model of urban growth.
It links urban growth and industrial location theory by making the attraction of job-creating investments the chief determinant of the city's expansion and by arguing that the capacity to attract depends upon relative locational advantages and disadvantages. . . External economies, socio-cultural amenities and other economies of urbanization. . . Population is used as an index of city size and employment as a proxy for economic activity.

The urban growth function will turn downwards if diseconomies begin to overwhelm agglomeration economies in large cities. A city's capacity for growth is determined less by export sales than by the in-migration of labor and inflows of capital.

There is strong evidence of a very high income elasticity of demand for private car transportation services and a low elasticity for public transport services. Only if the city is strongly decentralized with widely diffused origins and destinations will the motor car be the most efficient means of transport.

. . .defines UR as 'a deliberate effort to change the urban environment through planned, large-scale adjustment of existing city areas to present and future requirements for urban living and working. A crucial feature of UR is the involvement of government.

. ... Town and Country Planning Acts stemming from the Act of 1944; local governments were called upon to prepare not only overall development plans but also comprehensive redevelopment schemes.

In Britain, for instance, there has been a considerable shift of emphasis towards rehabilitation with the new improvement grants under the Housing Act of 1969. . . by improvement grants or local authority acquisition. The 1969 Housing Act made provision for grants for environmental improvement, and by the end of 1970, 102 general improvement areas (covering 35,700 dwellings) had been declared in England and Wales.

The Tiebout Hypothesis - Given that individual preferences differ and that social goods are paid for by a community's citizens, it is in the interest of individuals to associate with those with similar public goods preferences. An individual dissatisfied . . . can register his preferences by moving.. . Locational moves of this kind should lead to a more homogeneous set of preferences <u>within</u> each community.

The three most common sources of finance are property taxes (rates), central government grants and user charges.

In the first place, pollution generation rates are often a function of population size and density and hence are particularly high under conditions of spatial concentration. Secondly, there are marked similarities between environmental pollution and the more familiar forms of urban congestion such as traffic jams or strain on public service facilities.

Both phenomena are subject to large externalities. . . The presence of other users can adversely affect the quality of services rendered to the individual. Disturbance becomes noticeable only when capacity has been used up, but then it increases disproportionately. . . Action can be taken to increase capacity or to reduce the quality impairment: widening roads, installation of sewage treatment plants, recycling of waste residuals formerly effused directly into the atmosphere, rationing devices at swimming pools and museums, and so on.

Social congestion. With congestion, all consumers use the medium in much the same way and each is damaging the quality of service for other and himself to more or less the same extent. With pollution, on the other hand, some users abuse the medium (the polluters) while others are adversely affected by the pollution (the public); redistributional aspects of welfare become relevant. . . One class of externalities - the disposal of waste residuals - is a normal and inevitable part of the production and consumption process. The use of common property resources (air, streams, the ocean, etc.) as inputs, the use of environmental media in which to 'dispose of' wastes, and unwanted inputs (pollutants) in production - are transferred at a zero price, despite the fact that they may be scarce or may provide services or disservices. There is no market in which they might be exchanged. The solution in the general equilibrium model is to construct a surrogate market for them by using shadow prices. Thus, the common property resources are treated as a subset of raw materials, and are assigned shadow prices which represent, in effect, an income from the environment. The pollutants are introduced as a set of environmental disservices and are given negative shadow prices. The supply of these residuals can be adjusted by price changes, and this fact creates scope for imposing congestion charges on polluters.

A general prescription to deal with pollution is to internalize the external costs. . . Intervention by a regional or national government may be necessary to internalize the external costs, because the costs of pollution impoased on others may be external to the polluting city but internal to the region or nation. Responses might include technological changes in favor of lower waste-generating techniques, disposal of wastes on the site, that is by recycling, or locational shifts out of urban areas in cases where urban authorities levy exceptionally high charges on heavy polluting plants. In the economy as a whole, however, the total amount of waste residuals and pollutants generated is a function of the level of economic development (as measured by <u>per capita</u> income) and the rate of population growth.

The answer if found in the familiar phenomenon of neighborhood effects. The individuals own incremental contribution to pollution control would be negligible compared with the aggregate contribution of the rest of the community. The benefits of anti-pollution devices on cars accrue from other people's devices, not from one's own, but the individual has to pay only for his own device while the costs of the devices from which he gains benefits fall on others. It will be in his self-interest not to install one. It can be shown, by using a variant of the n-person non-zero sum game sometimes called 'the prisoner's dilemma', that if all individuals act like this, equilibrium is uniquely determined when all individuals fail to install the device.

Plans are justified in terms of the whole community so that all costs and benefits, including many nonmeasurable items, have to be included. Most planning decisions benefit some interests but hurt others, so that the ratio of benefits to costs will vary from one group to another. Accordingly, it is difficult to avoid paying attention to equity as well as efficiency considerations.

Systems analysis is a much broader version, because the determination of goals and objectives is considered as part of the problem rather than given, of cost-effectiveness studies but differs from these by relying on human judgement as much as on quantitative techniques and models. . . . refers to any analytical study designed to assist a decision-maker in identifuing a preferred choice among possible alternatives.

Success can frequently only be measured by performance measures and standards (persons per room and amenity standards in housing, for example) which are often expressed in input terms, and these make insufficient allowance for quality differences. Equity considerations have to be taken into account in urban planning decisions, and these are difficult to handle (as all welfare economists know). . . . Urban growth is the net outcome of a complex interaction between public and private decision makers, and the long-run behavior of the latter (that is households and firms) is very difficult to predict.

Chapter 5

GOALS, ALTERNATIVES, STRATEGIES AND DATA

5.1 General - Goals:

Goals are one of the basic elements of models. The type of goals obtained from a model is a function of the type of model utilized (i.e. explanation, prediction or decision) or the type of data (i.e. qualitative or quantitative) or the type of inputs (i.e. deterministic, probalistic, or stochastic model). Goals are the outcomes desired or the objectives: Goals are also termed the objective function.

5.11 Short-term vs. long-term goals

The setting of short-range objectives is sometimes termed "goals" and the setting of long-range objectives is sometimes termed "objectives". Thus goals should be developed early in the planning phase and at various stages of development of the model. (See Figures 1 and 2).

5.12 The objective function

The goals are also referred to the objective function. The objective function is often expressed in terms of optimizing (i.e. the benefits of development of a reservoir) or minimizing (i.e. the cost of building a reservoir).

5.13 Constraints - limiting factors or conditions

Objectives may also be treated as constraints, to establish acceptable levels.

Figure 1

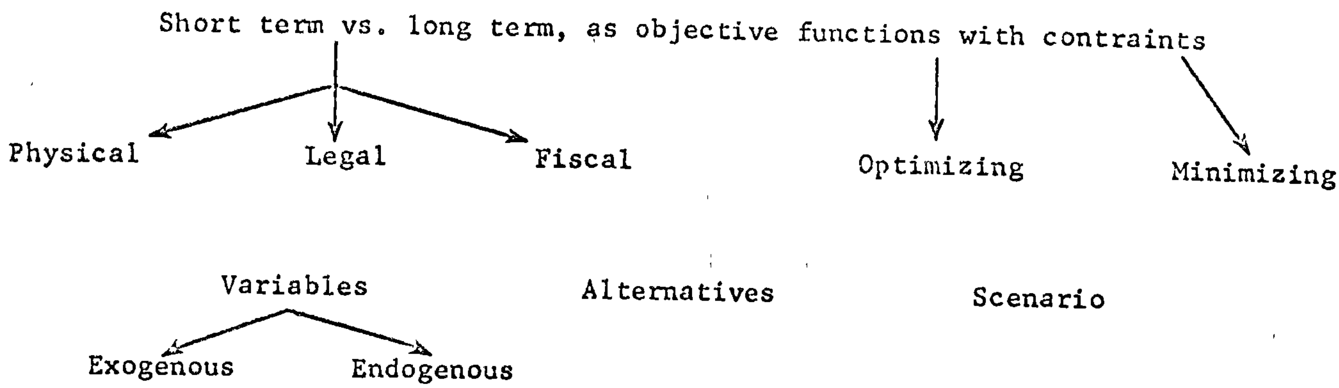
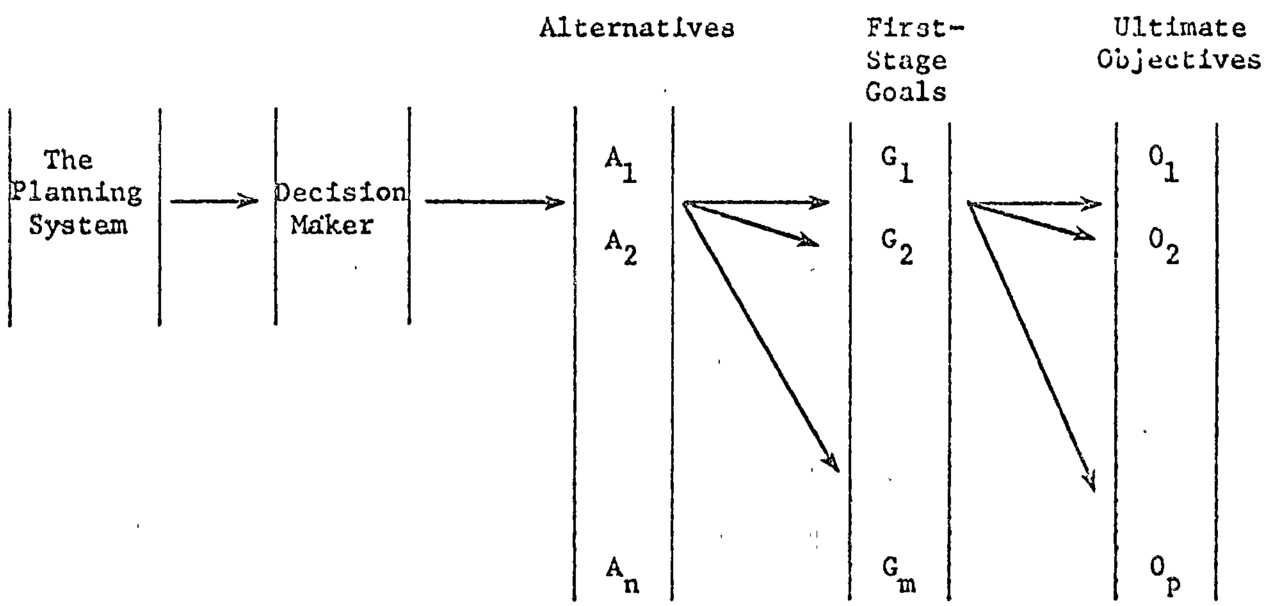


Figure 2



5.131 The objective may be linear, non-linear, or mixed.

5.132 Constraints may be described by equalities, inequalities, or absent.

5.133 Constraints may be classified by substantive area

(1) Physical constraint (i.e. total water available)

(2) Legal constraint (i.e. permissible pollutional level)

(3) Fiscal constraint (i.e. money available)

5.14 Variables

The selection of appropriate variables is an important step in the process of model building. The variables may be classified as endogenous or exogenous.

5.141 Endogenous variables are those which the model builder can control. They are internal; i.e. a decision.

5.142 Exogenous variables are those which the model builder has no control; they are said to be external or a non-decision variable; for example - climatic conditions.

5.15 Alternatives (Figure 3)

A method of identifying all the possible ways in which the goals and objectives can be achieved. During the planning process there is a need to consider range of alternatives and determine which ones are reasonable to pursue.

5.151 The creation of alternative plans leads sometimes to the difficulty of a possible change in the larger system. A redesign of the larger system may make all of the alternatives of the subsystem completely irrelevant.

FIGURE III

Professes	Sanitary or Environment Goals % Eff. SS	BOD	Mechanical Requirements	Chemical & Biological Control	Electronic Requirement	Relation Costs
Sand Filter	100	90	Valves, pipes	None	None	10
Innhoff Tank	70	30	Valves, pipes	W	N	6
Primary Settling	100	35	Pumps, Pipes, Plows, Gas Control	None	None	126
Trickling Filter		80	Pumps, Pipes, Siphon	None	None	214
Act. Sludge		95	Compressor and Diffusors	X	Transducers Remote Control	211
Denitrification	--- Nitrogen	---	Above plus Chemical Feeding	X	Remote Sensing Automatic Dosing	350
Complete Advanced Waste	100	100	Above, plus, chemicals, flocculation, filtration	X	Electronic Gear	1000

Figure I illustrates the total requirements of a process. Not to provide a "wedding", one must look at the societal and environmental mixes, in Figure II.

FIGURE III

Location	Pop/Employee	GNP / Yr.	Personal Income	Household Size	Occupational Mix: Professional	% White Collar	% Blue Collar	% Unemployed
Developed	3.1	4	8.000	3.5	20	25	30	6.0
Underdeveloped	7	1	600	6.0	1	5	10	12.0

5.152 Technology may be regarded as a specific way of creating new alternatives, but should not be considered the only way.

5.153 Various techniques have been developed to select the "best" alternative. For example, the development of a water resource system consisting of benefits to be gained from power irrigation, flood control, and low-flow augmentation, and costs for impoundment and treatment presents a typical problem. The selection is sometimes handled by combining on a one-to-one basis the responses to the stimuli under essentially conditions of isolation. The technique involves the ordering or ranking of several alternative combinations of reservoirs and uses to arrive at the best alternative.

5.16 Scenario - a verbal description.

I. E., Future Shock, Year 2000, 1984

5.2 Classification of Data

Data may be classified by level, type of measurement, substantive area, and source. (See Figure 4) The Problem Realm -- first by level as follows.

5.21 Primary vs. Secondary

5.22 Hard vs. Soft

5.23 Direct vs. Indirect

5.24 Raw vs. Derived

5.25 Raw vs. Digested

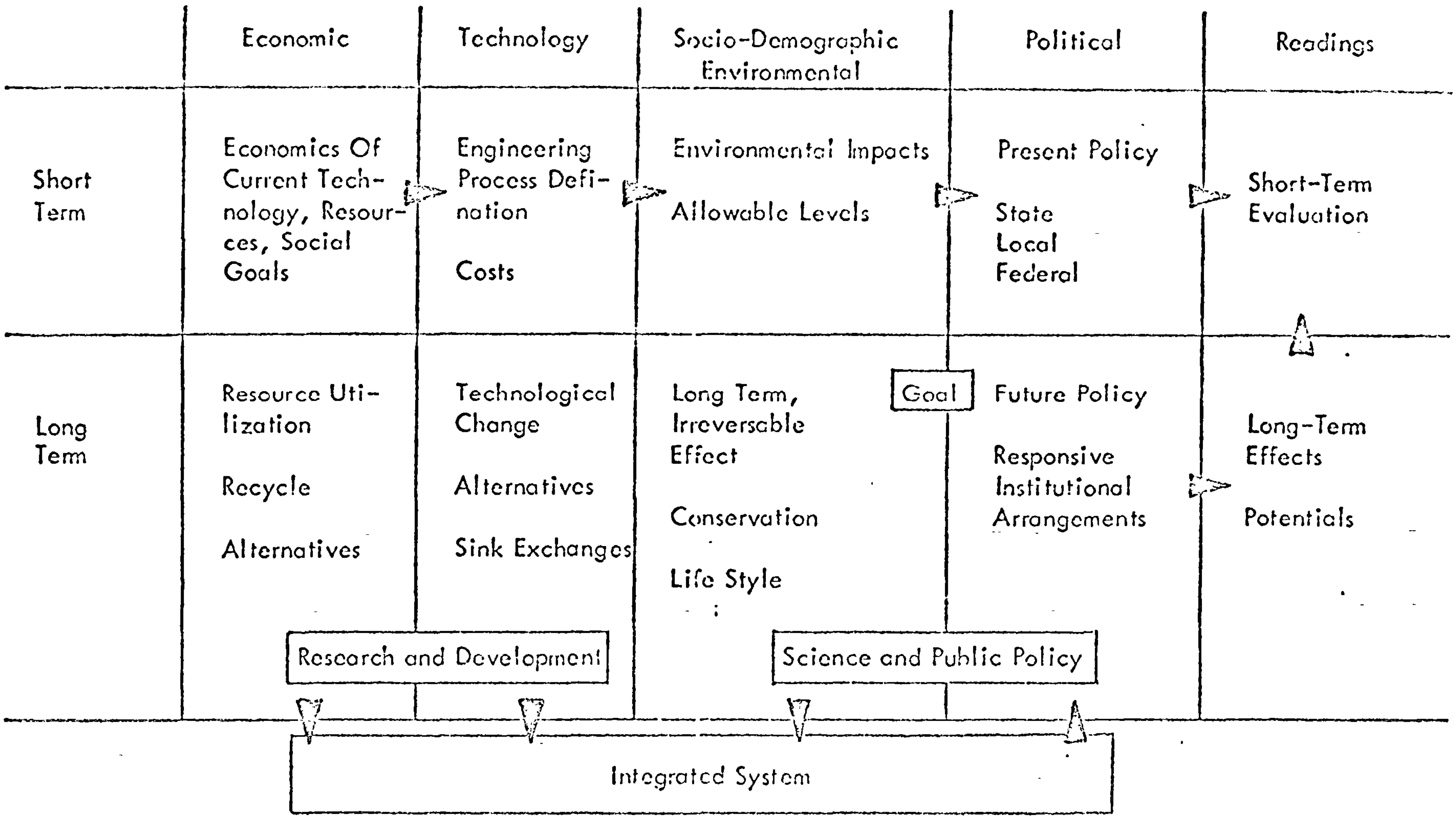


Figure 4. The Problem Realm

5.3 Type of Measurement

Quantitative vs. Qualitative (See Water Quality Standards - EPA, "Evaluation Criteria" and "Mandatory Limits" and "Recommended Limits", Figure 5)

5.4 Substantive Area - Environmental

Batelle Laboratories have established Parameter Importance Units for Environmental Impacts, totaling 1000 points.

Ecology	240
Environmental Pollution	402
Esthetics	153
Human Interest	205
	1000

(See "Environmental Impacts" from EPA Proposal, Figure 6 - Environmental Consequences)

5.5 Substantive Area - Physical Data

Example: 1965 Water Quality Standards

5.6 Substantive Area - Economic Data

(See "Economic Model Format", Figure 7 and see "PPBS Format--Water Resources Case", Figure 8.)

5.7 Substantive Area - Demographic Data

Example: Census Data

5.8 Others

Each substantive area may be broken down into a number of sub-headings. There is often an interrelationship and overlapping types of daya included in a substantive area. Other substantive areas are as follows.

Figure 5

Sanitary Survey of Drinking Water Systems on Federal Water Resource Developments

A Pilot Study
EPA Office of Water Programs, August 1971

EVALUATION CRITERIA

Each water supply system was investigated on three bases: 1) drinking water quality was determined by sampling the finished and distributed water and returning these samples to the laboratories of the Division of Water Hygiene for bacteriological, chemical, and trace metal analyses (radiochemical samples were not collected in the study); 2) the status of the water supply system facilities were determined by a field survey of the system and the recording of data on three standard forms with respect to a) source (s), b) treatment, if any, c) distribution system pressures, and d) operation; 3) the status for the surveillance program over the water supply system was determined by obtaining bacteriological water quality data for the previous 12 months of record from State and County health department files.

To prevent health hazards from developing in a water supply system, someone not associated with the supply should review operation procedures and the adequacy of physical facilities on a regular basis. These sanitary surveys should be at least as detailed as the reviews made during the pilot study, and may be more time-consuming depending on the complexity of treatment and the capabilities of the operators. Section 2.2 of the Public Health Drinking Water Standards 1962, provides that "Frequent sanitary surveys shall be made of the water supply system to locate and identify health hazards which might exist in the system."

The "number of systems exceeding the DWS" and "the percent of systems exceeding the DWS" will be referred to several times in this report. It should be understood, however, that the frequency and adequacy of the sanitary survey was not one of the criteria used in making these determinations. For some of the water systems it was difficult to obtain information reliable enough to include in an accurate statistical summary for this report. Although not included in the statistical summaries, the adequacy of the sanitary survey for water supply systems in this study is discussed in the body of this report.

Water Quality Criteria

Water quality was judged as follows:

(1) Not to exceed the constituent limits of the PHS Drinking Water Standards.

(2) To exceed at least one "recommended" constituent limit (some are aesthetic parameters), but does not exceed any "mandatory" constituent limit.

(3) To exceed at least one "mandatory" constituent limit.

In this report when a water supply system is referred to as exceeding the constituent limits of the DWS, the determination is based on the maximum concentration of a constituent measured in one or more samples collected from the system.

Figure 5 (Continued)

MANDATORY LIMITS

(The presence of the following substances in excess of the concentrations listed shall constitute grounds for rejection of the supply therefore, their continued presence should be carefully measured and evaluated by health authorities and a decision made regarding corrective measures or discontinuing use of the supply.)

Constituent	Limit
Arsenic	0.05 mg/l
Barium	1.0 mg/l
Cadmium	0.01 mg/l
Chromium (hexavalent)	0.05 mg/l
Coliform organisms (Measured by membrane filter technique)	Fails std. if: a) Arithmetic average of samples collected greater than 1 per 100 ml b) Two or more samples (5% or more if more than 20 examined) contain densities more than 4/100 ml
Cyanide	0.2 mg/l
Fluoride	
Temp. (Ann. Avg. Max Day - 5 yrs. or more)	
50 0-53.7	2.4 mg/l
53 8-58.3	2.2 mg/l
58 4-63 8	2 0 mg/l
63 9-70 6	1.8 mg/l
70.7-79.2	1.6 mg/l
79.3-90.5	1.4 mg/l
Lead	0.05 mg/l
Mercury *	5 μg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l

* Proposed for inclusion in the Drinking Water Standards

The Drinking Water Standards constituent limits measured in this study are summarized as follows:

Partial List of Bacteriological, Chemical, and Physical Constituent Concentration Limits Taken from the 1962 U.S. Public Health Service Drinking Water Standards.

RECOMMENDED LIMITS

(If the concentration of any of these constituents are exceeded, a more suitable supply or treatment should be sought).

Constituent	Limit
Alkyl Benzene Sulfonate (Measured as methylene-blue-active substances)	0.5 mg/l
Arsenic	0.01 mg/l
Chloride	250 mg/l
Color	15 Units
Copper	1 0 mg/l
Carbon-Chloroform Extract (CCE)	0 200 mg/l
Cyanide	0.01 mg/l
Fluoride	
Temp (Ann. Avg. Max. Day, 5 yrs or more)	
50 0-53 7	1.7 mg/l
53 8-58 3	1 5 mg/l
58.4-63 8	1.3 mg/l
63.9-70 6	1.2 mg/l
70.7-79.2	1.0 mg/l
79.3-90 5	0 8 mg/l
Iron	0.3 mg/l
Manganese	0 05 mg/l
Nitrate	45 mg/l
Sulfate	250 mg/l
Total Dissolved Solids (TDS)	500 mg/l
Turbidity	
Untreated	5 Units
Treated by more than disinfection	1 Unit
Zinc	5 mg/l

Figure 5 (C

Facilities Criteria

Source, treatment, operation, and distribution facilities were judged* either:

1) To be essentially free from major deficiencies, or

2) To be deficient in one or more of the following (where applicable):
   a) Source protection (in absence of disinfection or buying chlorinated water)

   b) Control of disinfection (if practiced or if purchasing chlorinated water)

   c) Control of clarification (if clarification practiced)

   d) Pressure (20 psi) in some or all areas of the distribution system

Bacteriological Surveillance Program Criteria

The bacteriological surveillance program over the water supply system was judged on the following criteria:

1) Collection of the required number** of bacteriological samples during the period of the year the water system is in operation.

* See "Manual for Evaluating Public Drinking Water Supplies, PHS Publication No. 1820, 1969" for basis of judgement.

**See pages 3-6 of the Drinking Water Standards.

Figure 6. Environmental Consequences

Enviromental Impacts

	Ecological	Environmental	Asthetic	Social
Reversible	Fauna Wild Life Fish, Fowl Animals Domestic Life Animal Food Floral Crops Natural Vegetation	Aquatic - Resource Pollution Level Air - Resource Level Solid Waste Level Noise	Visual Odors Structures Noise	Historical Cultural Life Patterns Health Land Use Settlement Patterns
Non-Reversible	Extinct Species	Land Use		Historical Monuments

Figure 7. Economic Model Format

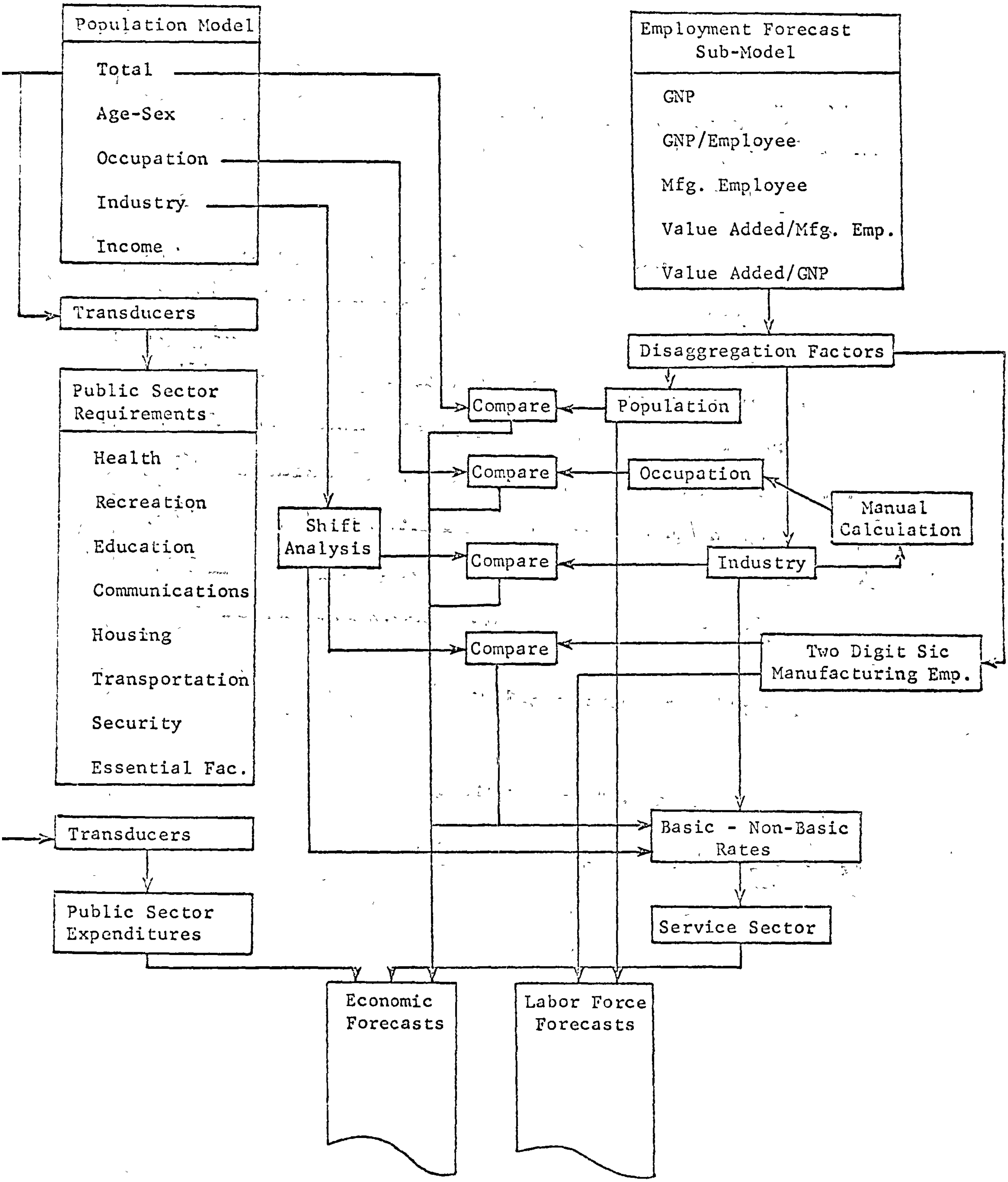
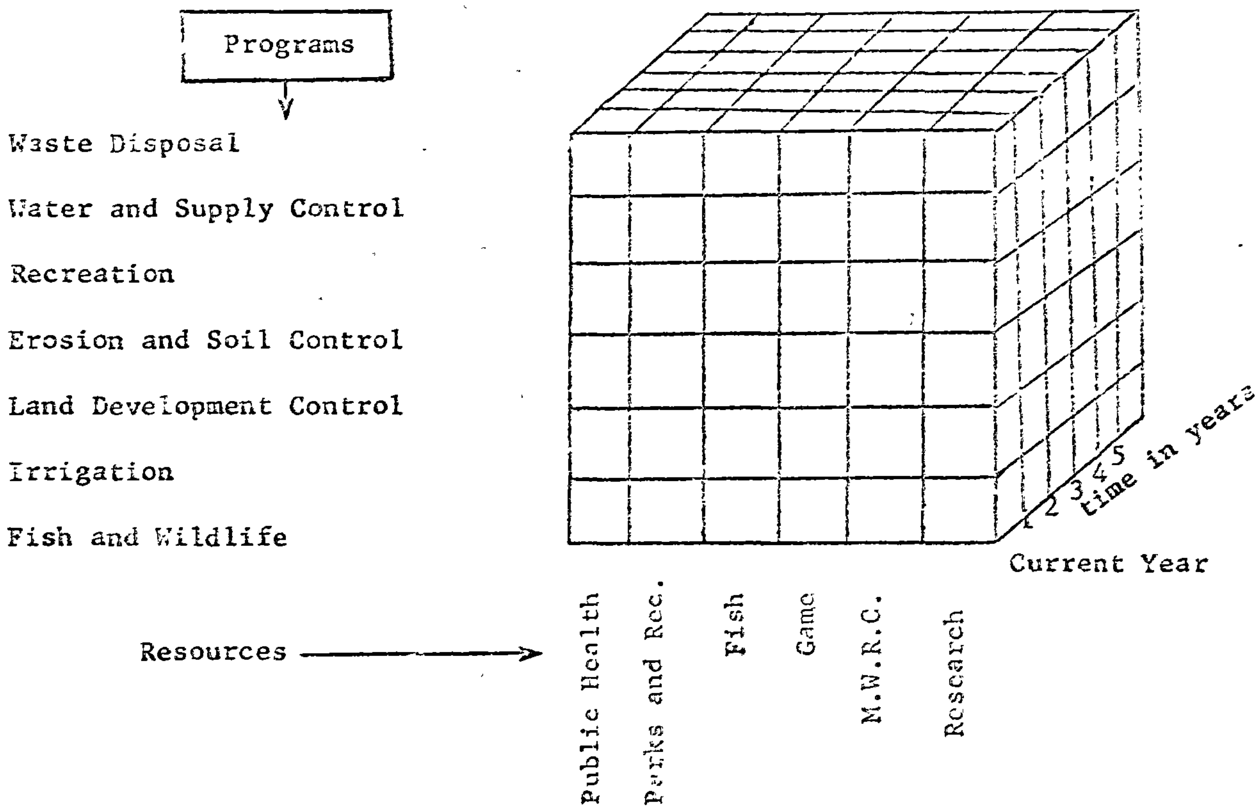


Figure 8

Up to this point the prime analysis has been on Benefit/Cost Analysis and comprehensive planning. More recent interest has been in PBS, and Cost Effectiveness.

PPAS Format - Water Resource Cast



The process, illustrated above, is basically a matter of articulation towards goals. Government agencies are rarely organized by function (activity or program) and as such results are difficult to evaluate.

5.81 Technological

5.82 Political

5.83 Biological

5.84 Ecological

5.9 Concepts of Inadequate Data - In the context of data needed for a model for the design of water quality management.

5.91 Some questions that arise

(1) What significant paramenters of water quality should be measured for the system?

(2) What should be the periodicity of time interval in collecting specific data?

(3) What are the cross correlations of these parameters?

(4) Are there any synergistic relationships between the parameters?

(5) What is being accomplished to develop instrumentation that can gage quantitatively those essential parameters, such as BOD, that are not being measured automatically at the present time?

5.92 Data has a cost, collection, and deferral of decisions.

5.93 Concept of quality measurements

(1) Criteria

(2) Standard

5.94 Concept of prediction and forecasting of data, i.e., population growth and demand.

5.95 Accuracy of data: reliability, validity, objectivity.

5.96 Difficulty in systems approach are identified as follows.

(1) To identify all elements or number of variables of the system.

(2) To identify and quantify the inter-relationships and components of the system.

(3) To achieve an inter-disciplinary approach.

5.10 Modelling Management and Scheme

(See Figures 9 and 10.)

Figure 9. Data Needs Management Model

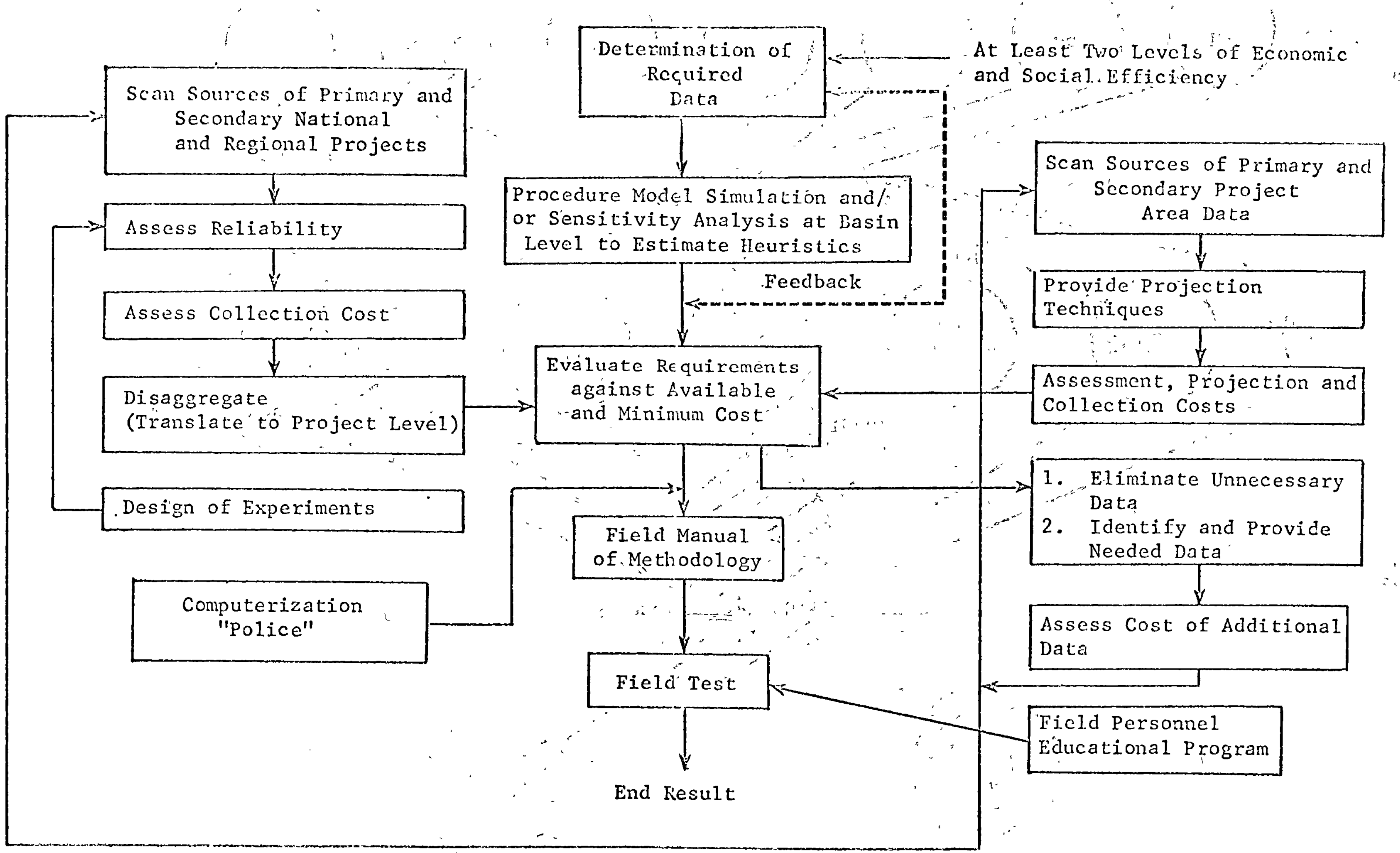
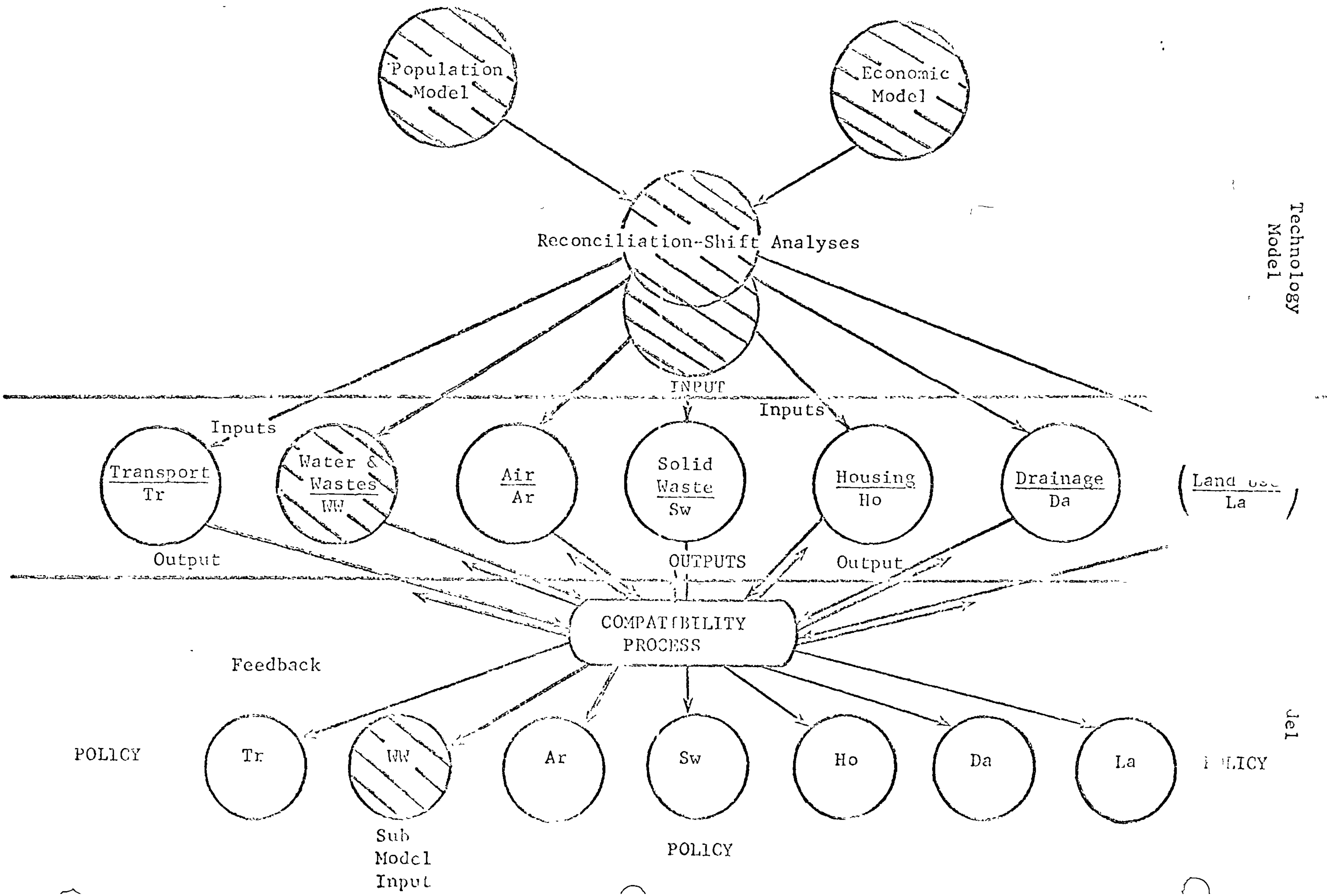


Figure 10

Generalized Scheme Model



Chapter 6

MODEL AND MODELING

The main objective of models and modeling is to obtain an economy of thought and serves the purpose of explanation and elucidation of complex ideas in a single schematic form.

Models, in general, function to predict and to analyze activities and their effects.

6.1 Type of Models

6.11 Physical

The system is constructed, generally, to a small scale (a prototype to a scale) to study the behavior of the components and the system as a whole. Example: Iconic Model.

6.111 True model - A true model is one where there is complete similarity or similitude between the model and the prototype.

6.112 Distorted model - A distorted model is one where complete similarity is not possible because of physical considerations of cost.

6.12 Mathematical or Isomorphic

Simplified and idealized abstraction of a system in a mathematical form. Opposite of a scenario.

6.2 Model Format or Characterization

6.21 Analytic (algebraic equation) or Numeric (numerical construction)

The analytic mode is an expression of a real life situation in symbolic form via an algebraic equation.

If the same problem is cast directly in computer logic, it is in the numeric mode. It could be classes as a verbal or language model constructed to be handled by a computer. (There is a lot of latitude on this point.)

6.22 Descriptive or Optimizing

With the descriptive model, the focus is on describing a real-life situation while the optimizing model stresses the process of selection from a ranking of alternative solutions.

6.23 Quantitative or Qualitative

The symbols in a quantitative model stand for numbers (constants or variables), while in qualitative models, they represent properties of components.

6.24 Deterministic, Stochastic, or Probabilistic

In a deterministic model, a given input will always result in a given output. In a stochastic or probabilistic model, the outcome is probabilistic.

6.25 Micro or Macro Models

Degree of fineness. A micro model represents a system on a micro (small detail) scale while a macro model represents the system on an aggregate (group or cluster) scale. As models go into the future they become less fine.

6.26 Static or Dynamic

Either model can be in equilabrium or non-equilibrium. The difference is one of management over time, or one of a series of steps or of a sequence of events. Static example: Fixed Cross-Section.

6.27 Ready-made or Custom-built

The "ready-made" models describe general, standard systems while "custom-built" models are constructed to simulate a specific system.

6.3 Model Elements

6.31 Goals

Also known as the objective function which is a formal statement of goal. In an optimization model, one tries to maximize or minimize the objective function. When the number of variables increase then model breaks down.

6.32 Variables

Input and output quantities.

Dependent and independent. (Endogenous and Exogenous)

Real and complex.

6.33 Constraints

Conditions - acceptable levels

Equalities, inequalities

Limiting perimeter of the solution space

6.34 Transducers (transformers)

Transfer matrix

Open loop input/output relationships essential to internal definition.

6.35 Externalities

Decision variables have secondary effects or social costs or benefits.

6.4 The Uses of Models

6.41 Descriptions

6.411 Measures of performance

(1) Ratio of input data to output data

(2) Accuracy and cost of generating data

(3) Applicability of the model to other times and places

6.42 Predictions

(1) Cause-effect relationships and causal sequence

(2) Endogenous variables (end of the sequence)

(3) Exogenous variables (beginning of the sequence)

(4) End result is explanation

6.43 Planning

(1) Specification of alternatives (programs or actions)

(2) Prediction of the consequences for each action

(3) Scoring of these consequences according to a metric of goal achievement

(4) Choosing the alternative with highest score optimizing

6.44 Forecasting

(1) Future state of affairs

(2) Extension or projection of present growth

(3) End result is to clarify options for decision makers

6.5 Applications of Modelling (Figures 6.1 and 6.2)

6.51 Demographic

(1) Recursive model

(2) Growth of "P"

6.52 Economic

Supply Model

6.53 System Application

(1) Model ⟶ deterministic, stochastic, probability
(sequences) (risks involved)

(2) Data ⟶ goals - alternatives ⟶ forecasts

(3) Validation procedure ⟶ Convergence

(4) Implementation

6.6 Model Sensitivity

6.61 Sensitivity Analysis

To determine how sensitive anyone of the inputs is to the output. All except one of the variables in a system are held constant. This single exception is allowed to vary through its full possible range while the effects on certain measures of systems performance are noted. This tests the sensitivity of the system to the one variable with the output function as a curve.

$$\Delta \$ = e_1 N_1 + e_1 NX_1, \text{ etc.}$$

higher coefficient = more sensitive

In a mathematical sense, the slope of the output as a function of input is a sensitivity measure. Two variables of a system may be permitted to vary simultaneously, each having an effect on the

Figure 6.1

USE OF ESTIMATING TECHNIQUES

Type	Year	Application
Eye Births over deaths Logistic	1930's	Engineers and Demographers
Arithemetic Geometric Incremental Population theory Curvilinear	1940's	Engineers
Population synthesis Regional analysis Market demand model	1950's	Economists
Supply model Factor and component-analysis Cohort analysis Input/output analysis	1960's	Econometricians
Goal Orientation Econometric techniques	1970's	Reid Study

Type	Past Projection		Goals	Coals		Constraints	
	one	more	Demographic	Economic	Demographic	Economic	Physical
Eye	x						
Birth/death		x					
Arithmetic	x						
Geometric	x						
Incremental	x						
Population theory	x		x				
Curvilinear		x	x				
Population Synthesis				x		x	
Regional analysis		x					x
Market demand model		x				x	
Supply model		x		x	x		
Factor analysis		x					
Cohort analysis		x					
Input/output		x					
Goals (Reid)		x	x	x	x	x	x

Figure 6.2

output measure. Mathematically, this becomes a three-dimensional model; the output function becomes a surface called response surface (or a two-dimensional plane).

6.62 Sensitivity Tests

Play a particularly essential role in the model building and validation. They identify essential parameters and troublespots, check the logic and internal consistency, and identify the most profitable areas for data-collection activities. The relative sensitivity of a parameter is an indication of the priority that should be given to obtain better estimates of its value.

6.7 Biases of Large Scale Models

(1) Hyper comprehensiveness

(2) Grossness

(3) Excessive amount of input data

(4) Deviations from the claimed model behavior

(5) Complicatedness

(6) Mechanicalness - no human interfall

(7) Expensiveness

6.8 Model Solutions

6.81 Optimizations - Taken from the word, optimum, meaning the best or most favorable degree, quantity, or number. Optimization is a method of solving problems in a common structure ("model") for the attainment of an optimum in a system which can be characterized mathematically. The practical attainment of an optimum design is generally a consequence of a combination of mathematical analysis, empirical information, and the subjective experience of the scientist and engineer.

6.811 Variational Method - Assumes that a preliminary specification has been made and then inquires about the effect of small changes.

(1) Leads to "necessary conditions:, or equations which define optimum.

(2) Analysis of the effects of small perturbations about a nonoptimal specification leads to computional procedures which produce a better specification.

(3) Provides a logical framework for studying optimization in new classes of systems.

6.812 Perturbation Method - A method of suboptimizing with mathematical characterization of a system whether the problem is mathematical or experimental or a judicious combination of both. Expressed by a regular elliptic curve with continuous motion.

6.82 Simulation

The word "simulation" has a wide variety of meanings. In popular usage, it is often a fancy term for an imitation. However, "simulation" also may mean simply that one thing is much like another, that it reproduces the characteristics of something else in certain important respects, but is otherwise somewhat different. Simulation has certain characteristics and lacks others;

it is possible to lead the inquirer slowly toward the more complete comprehension.

A simulation is a special kind of model, distinguished by the fact that a simulation is a dynamic or operating model; therefore changes over time in the model correspond to changes over time in the system being modeled. The term simulation refers to the construction and manipulation of an operating model.

A simulation can also be thought of as a dynamic model. Simulators, therefore, must try not only to build a model of system structure, but also to incorporate system processes. In doing so they abstract, simplify, and aggregate, in order to introduce into the model more clarity than exists in the referent system.

6.821 Simulation Processes

(1) Abstraction

(2) Simplification

(3) Substitution

6.822 Simulation Benefits

(1) Economy

(2) Visibility

(3) Reporducibility

(4) Safety

6.823 Simulation Gaming

(1) Decision Making

(2) Systems Analysis

(3) Teaching

(4) Theory Exploration Research

6.9 Uncertainty Problems in Modelling Development

Two principle types of uncertainty can be identified in planning for the future which are also inherent in models.

6.91 State uncertainty is the problem of inaccurary of needs and undefined objectives. It is related to the quantity and quality of available data which is caused by a scarcity of reliable knowledge. State uncertainty is basically a data problem due in part to continuing broad institutional and social changes.

6.92 Process uncertainty is the problem of understanding how the socio-economic system operates as a process. It makes it extremely difficult to forecast even the relative short- and long-run effects of alternative strategies. Theoretical models of causal and structural relationships perform this type of system simulation.

6.10 Cross-Correlation Analysis

New analysis techniques are beginning to be applied (via matrices and models) in technology assessment. These have a dual relationship to measurement. They can assist in attaching problems such as structuring and interdependence, but their applicability and interpretation are limited by the level of measurement scale developed. They attempt to combine the use of "judgment" (soft) data with hard.

6.10.1 Cross-support

Used to determine the support effect of each item of a field on all other items

(1) Matrix

(2) Square array with the item-to-item effect described by the matrix elements.

(3) Scale is ordinal.

(4) Cannot be summed numerically.

(5) Sum of "like" numbers diagonally would indicate relative total cross-support of each item.

(6) Sum of rows can be rated numerically to indicate items total cross-support.

6.102 Cross Impact

Used to establish the change in the probability of individual events with the occurrence or non-occurrence of related events.

(1) Matrix.

(2) First column indicates the best estimate that an event will occur, independent of the other events.

(3) Elements of matrix rated by panel of experts as positive or negative, depending on enhancement, inhibition, etc.

(4) Example: Given Event 1 will occur in Time 1, how would the probabilities of each of the other innovations be affected?

6.103 Relevance (Figure 6.3)

Used to establish the relationship between two fields by considering each item within the fields.

(1) Oldest of three.

(2) Matrix.

(3) Assigned "value" to technology involves subjective judgment.

(4) Examples: PATTERN, PROFILE, QUEST, and the TRIMATRIX Techniques.

Goal cross-support matrix (illustrative)

Goals	g_1	g_2	g_3	g_4	—	—	—	g_n	Total cross support
Housing for 90% population by 1979 (g_1)		1	1	2					27
90% literacy rate for 10-25 yr age group by 1979 (g_2)	1		1	4					21
Adequate nutrition for 100% population by 1980 (g_3)	1	4		1					24
8% increase in GNP per yr (g_4)	8	2	4						16

Cross-impact matrix (illustrative)

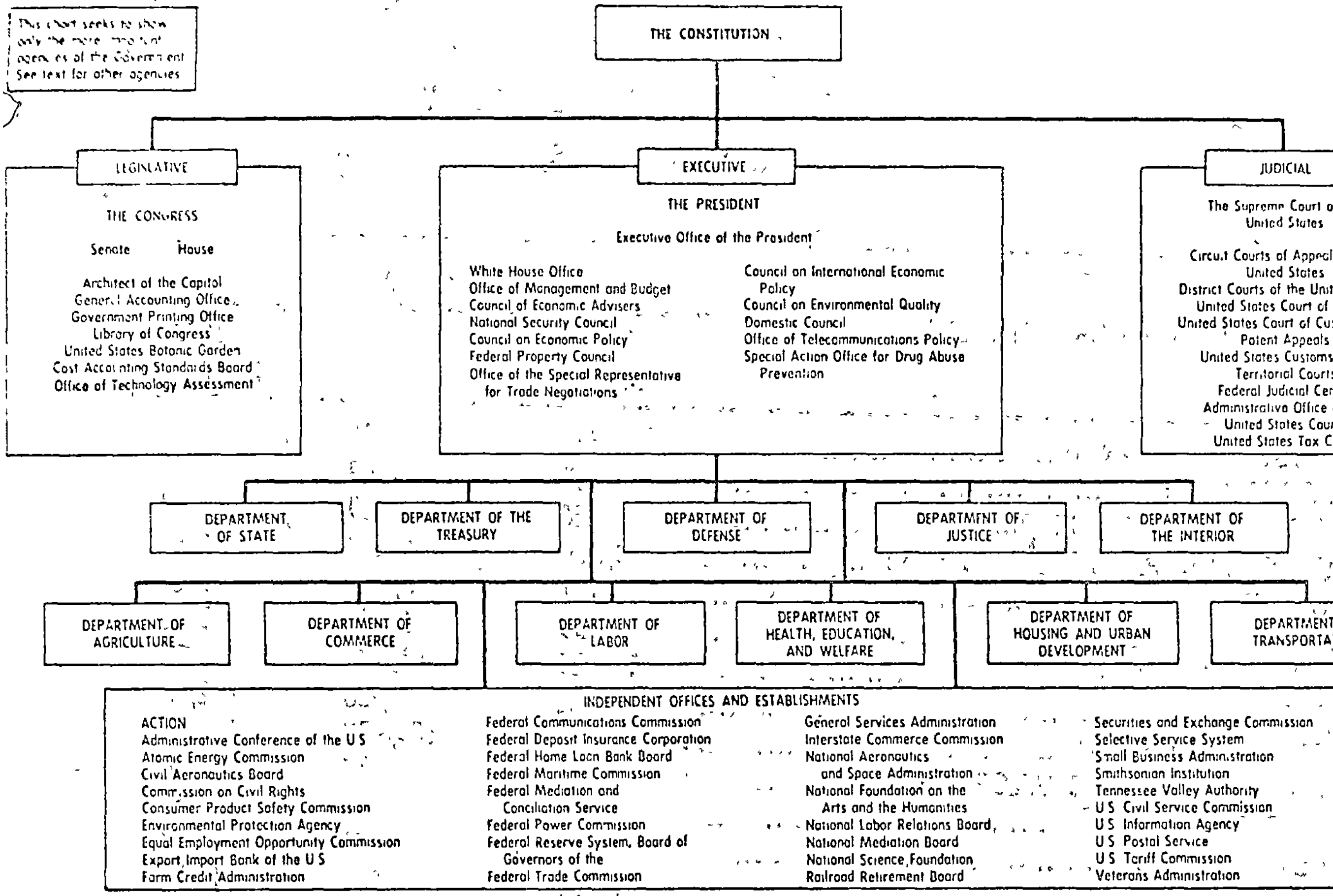
By 1985 original probabilities	If this innovation occurred	The probabilities of these innovations would be affected as follows:					
		T_1	T_2	T_3	T_4		T_n
.75	CATV in 80% homes (T_1)	—	.9	0	0		
.4	80% communications by satellite (T_2)	.8	—	.4	0		
.3	News by remote facsimile transmission (T_3)	.5	0	—	0		
.2	Manufacture of drugs in space (T_4)	0	0	0	—		

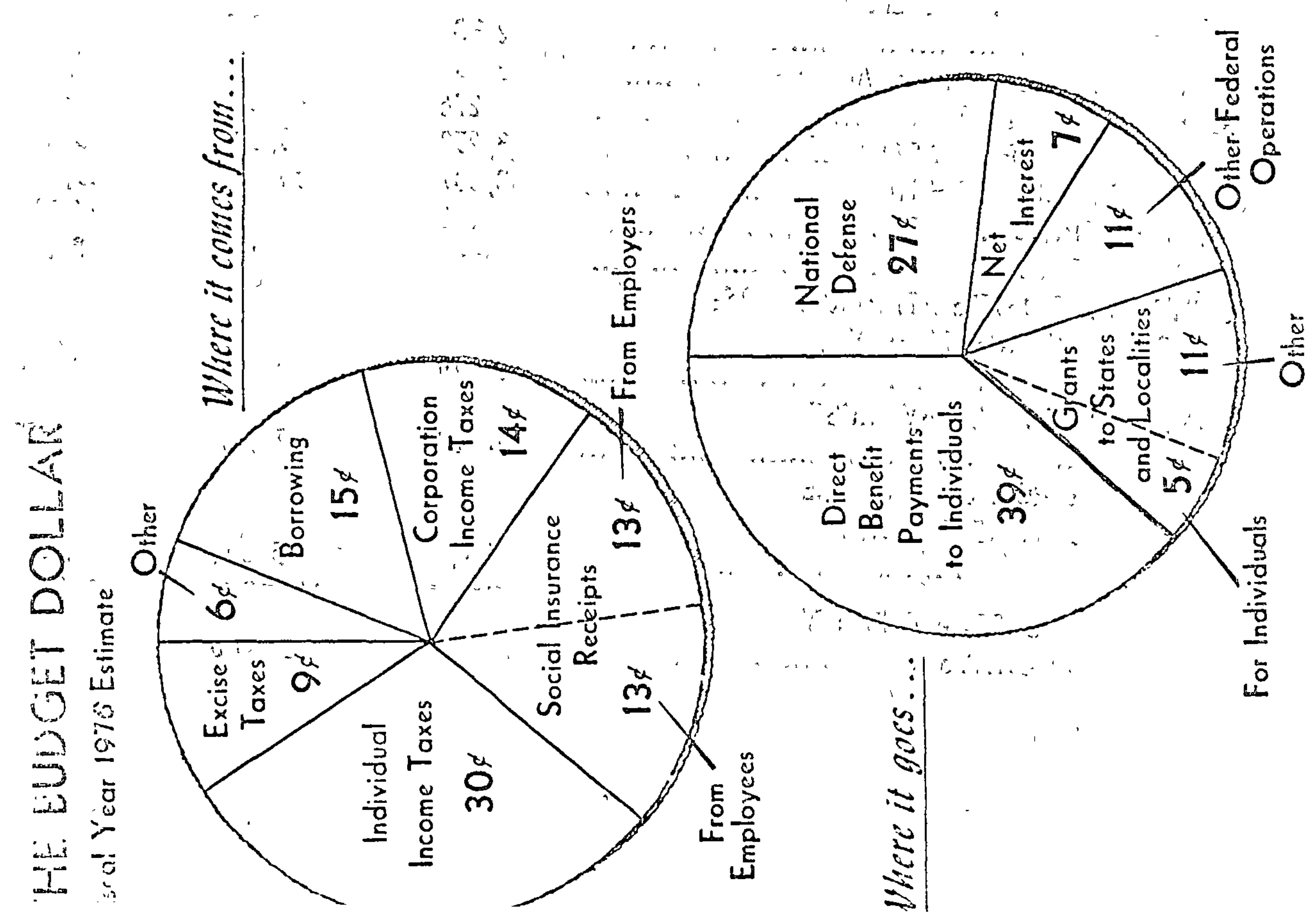
Indicators/goal impact/relevance matrix

Weights	W_1	W_2	W_3	W_4		W_n	Total relevance index
Indic. \ Goals	g_1	g_2	g_3	g_4		g_n	
e_1	β_{11}	β_{12}	β_{13}	β_{14}		$\beta_1 n$	$\sum_{j=1}^{n} \beta_1 j W_j = u_1$
e_2	β_{21}	β_{22}	β_{23}	β_{24}		$\beta_2 n$	$\sum_{j=1}^{n} \beta_2 j W_j = u_2$
e_3	β_{31}	β_{32}					
e_4	β_{41}	β_{42}					
e_m	βm_1	βm_2				βmn	$\sum_{j=1}^{n} \beta mj W_j = u_m$

Figure 6.3

THE GOVERNMENT OF THE UNITED STATES

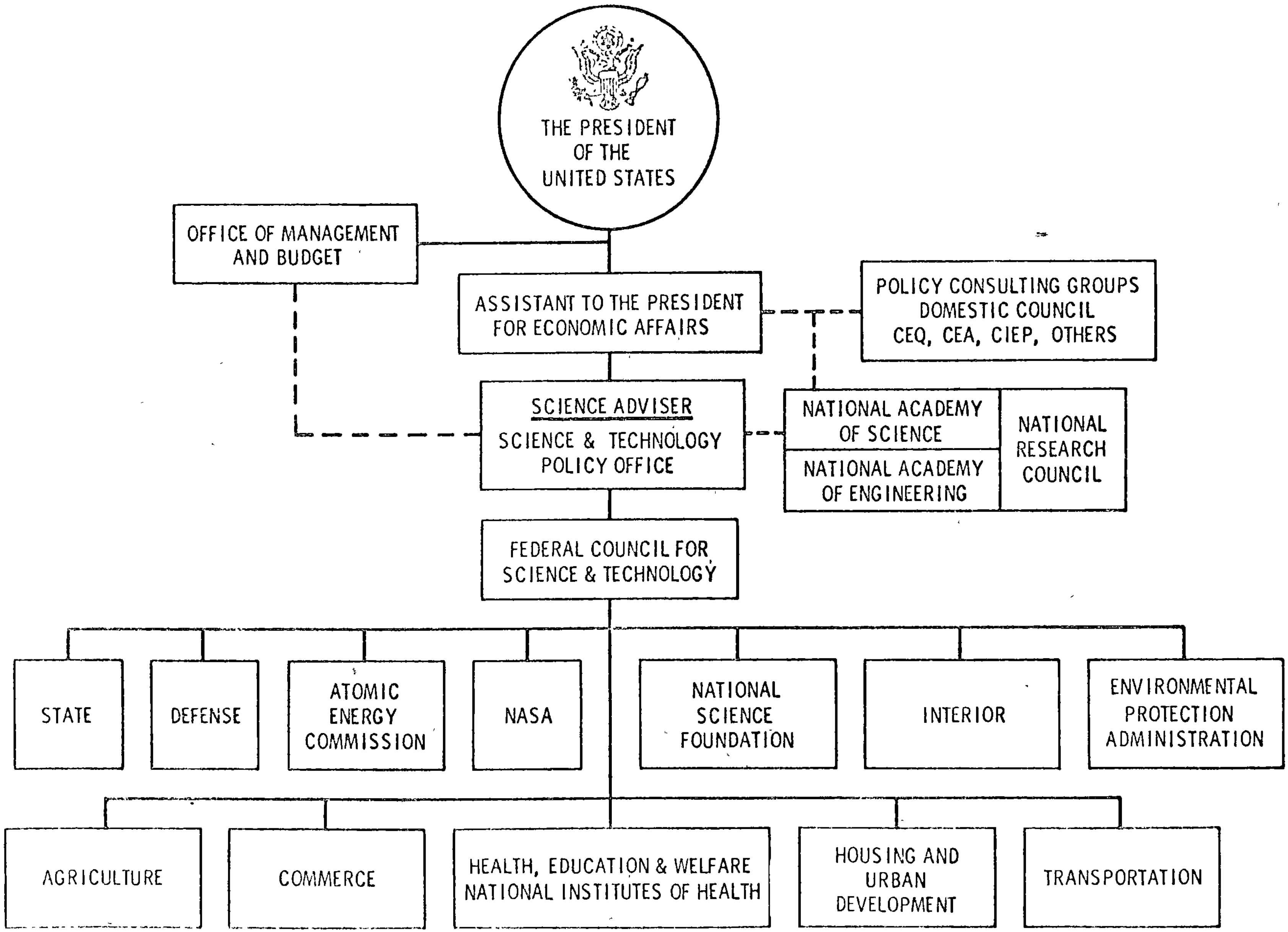




BUDGET AUTHORITY AND OUTLAYS BY AGENCY
(IN MILLIONS OF DOLLARS)

DEPARTMENT OR OTHER UNIT	OUTLAYS		
	1974 ACTUAL	1975 ESTIMATE	1976 ESTIMATE
LEGISLATIVE BRANCH	625	744	882
THE JUDICIARY	205	308	342
EXECUTIVE OFF. OF THE PRESIDENT	66	109	70
FUNDS APPROP. TO THE PRESIDENT	3,329	4,607	6,610
AGRICULTURE	9,767	8,756	9,662
COMMERCE	1,455	1,644	1,789
DEFENSE-MILITARY	77,625	83,493	90,775
DEFENSE-CIVIL	1,682	1,928	2,005
HEALTH, EDUCATION, & WELFARE	93,735	109,932	118,377
HOUSING & URBAN DEVELOPMENT	4,786	5,517	7,055
INTERIOR	1,779	2,236	2,503
JUSTICE	1,797	2,061	2,221
LABOR	8,966	18,966	22,617
STATE	735	871	950
TRANSPORTATION	8,104	9,142	9,991
TREASURY	35,993	39,665	43,453
ENERGY RESEARCH & DEVELOPMENT ADMIN.	2,308	3,090	3,815
ENVIRONMENTAL PROTECT. AGENCY	2,030	2,937	3,080
GENERAL SERVICES ADMIN.	-276	-1,008	-476
NAT'L AERO. & SPACE ADMIN.	3,252	3,207	3,498
VETERANS ADMINISTRATION	13,337	15,445	15,576
OTHER INDEPENDENT AGENCIES	13,742	15,935	16,712
ALLOWANCES	—	700	8,050
UNDISTRIBUTED OFFSETTING RECEIPTS:			
EMPLOYER SHARE, EMPLOYEE RETIREMENT	-3,319	-4,070	-3,888
INTEREST RECEIVED BY TRUST FUNDS	-6,583	-7,769	-8,305
RENTS AND ROYALTIES ON THE OUTER CONTINENTAL SHELF LANDS	-6,748	-5,000	-8,000
TOTAL BUDGET AUTHORITY AND OUTLAYS	268,392	313,446	349,372

COORDINATION OF SCIENCE & TECHNOLOGY IN THE FEDERAL GOVERNMENT



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Chapter 7

QUALITY OF THE ENVIRONMENT

GNP does not and can not possible measure everything that is relevant to our feeling of well-being; it is only a measure of our production of goods. Many activities of production, movement and consumption though do, unfortunately, inflict unwanted penalties on others. The fear is that such unwanted effects may grow in importance as population and incomes increase, leading to a deterioration in the quality of the environment. It is this quality, present and future, which is being measured by various indices other than GNP.

7.1 Environmental Problem Areas

7.11 Water Pollution

7.12 Air Pollution

7.13 Chemical substances such as pesticides

7.14 Urban development — Land Pollution

7.15 Rural development — Land Pollution

7.2 Problems in Achieving Solutions

7.21 A search for systematic evaluation of external effects of many activities is still going on.

7.22 The processes affecting the quality of the physical environment have become increasingly subtle.

7.23 The demand for a "good physical environment can be expected to grow much faster than population and even per capita income.

7.24 The doubts about the adequacy of present institutional arrangements to deal with the environmental problems.

7.3 External Effects of Change on Environmental Problems

7.31 Reasons for externalities

(1) Technological change and changes in consumer tastes

(2) Consumer or producer ignorance

(3) Consumption or production not entirely within the control of consumer or producer respectively

7.32 Results of external effects

(1) Misallocation of resources

(2) Misallocation of production

7.33 Ways to handle allocation problem arising from external effects

(1) Units that generate the effect to come to agreement with the recipients of the effect on the proper level of the effect -- perhaps with a payment from one to the other.

(2) "Internalize" the problem so that a single economic unit will take into account all of the losts and benefits associated with the effect.

(3) Control production directly, perhaps by governmental operation of the activity that produces the external effect.

7.4 Indicators of Water Pollution

7.41 Degradable Pollutant

(1) Aerobic degradation - stream self purification; reoxygenation, oxygen sag.

(2) Anaerobic - use of organically or inorganically bound oxygen,

breakdown of nitrates, sulphates-methane, hydrogen sulfide, foul odors, aesthetically offensive.

7.411 Temperature

7.412 Reaction rates k_1, k_2

7.413 BOD, COD, TOD, TOC, etc.

7.414 Nutrients: algal growth - nitrogen - phosphates

7.415 Bacteria

7.42 Non - Degradable Pollutants

7.421 Inorganic substances-inorganic colloidal matter, ordinary salt and the salts of numerous heavy metals.

7.422 Toxicity

7.423 Chlorides, etc.

7.424 Corrosion, Scaling, pitting

7.425 Water softening

7.43 Persistent Chemicals

(1) ABS, Pesticides, Phenols

(2) Long lived radio nuclides - radio active wastes

7.44 Areas of Research in Water Pollution

(1) Costs of Water Quality deterioration

(2) Problems in devising a system of quality control

(3) Institutional arrangements for quality management

7.5 Indicators of Air Pollution

7.51 Primary Pollutants - stable pollutants that are not changed in the air and consequently are comparatively easily tracked to their source.

7.511 Sources - industrial, commercial, domestic, transport, agricultural.

7.512 Form - dust, smoke, funes, droplets (aerosols)

7.513 Effects - decrease visibility, dirty buildings, damage properties, corrode metals and affect life processes.

7.52 Secondary Pollutants - are more intractable, have less predictable effect and possibly are more dangerous to health than primary pollutants.

7.521 Source - they do not arise directly from any industrial, municipal or household source but are produced by photochemical or physicochemical interactions between primary pollutants within the atmosphere.

7.522 Los Angeles smog - 3 million cars emit 8,050 tons of CO and 1,650 tons of hydrocarbons each day. 850 tons of oxides of nitrogen combine with other ingredients.

7.523 Effects - eye irritating, breath-taking.

7.53 Problems of Air Pollution

(1) Morbidity and mortality statistics suggest that communities with the highest air pollution loads tend to rank high in death rates from a number of diseases (cancer of esophagus, and stomach, lung cancer, arteriosclerotic disease).

(2) There are fewer means of dealing with air pollution.

(3) Air pollution from fixed sources is usually much more localized.

(4) Wind patterns - horizontal movement of pollutants, lapse rate - vertical movement of pollutants, inversions, etc.

(5) Air quality standards.

7.6 Indicators in the Use of Chemicals as Pesticides

7.61 Effects of Pesticides

(1) Increased crop yields

(2) Improved quality of crop

(3) Reduction of the frequency of years with very low yields.

(4) Reduction in the cost of production of food.

(5) Reduction in the incidence of malaria

(6) Acute poisoning - about half of these in children

(7) Long erm effects on human upon prolonged exposure to pesticides (pathological & genetic)

(8) Acute effects on wildlife

7.62 Regulation

(1) U. S. Department of Agriculture and H. E. W.

(2) Food and Drug Administration

(3) Tolerance evel generally 1/100 of the threshold level

7.7 Indicators of Cost in Urban Development

Certain costs resulting from noise, congestion, dirt and foul air are associated with the benefits of the compact habitation afforded by urban areas.

7.71 Imposition of external diseconomies

7.72 Environmental perception

7.73 Social psychology

7.74 Aesthetic preferences

7.75 Areas of Problems:

(1) Transportation

(2) Housing - slums

(3) Local governments

(4) Utilities

7.8 <u>Indicators of Rural Development</u>

7.81 Highways

(1) Increasing volume of traffic

(2) Increasing number of cars

(3) Increasing demand for services

(4) Increasing number of structures required

7.82 Mining

(1) Ubiguitous

(a) Sand and gravel pits; clay pits

(b) Limestone quarries

(2) Strip mining - coal, minerals

(3) Hard-rock mining

7.83 Wildlife, Hunting,Fishing

7.84 Streams and Reservoirs

(1) Aestheitc value

(2) Recreational value

7.85 "Natural" Areas

(1) Wilderness - parks

(2) Seashores - beaches

Land Treated with Insecticides in the 48 Contiguous States, 1962

Type of land	Total acres (millions)	Per cent treated
Urban or built-up	53	28
Cropland and cropland pasture	457	15
Fruits, nuts	3	80
Cotton	16	75
Vegetables	4	50
Grains	217	15
All other	217	9
Desert, swamp, dunes, and wildland	77	3.2
Forest	640	.28
Grassland	630	.25
Other	78	-
Total - 48 states	1,935	4.6

7.9 Trade offs

There is an exchange of production vs. pollution affecting environmental problems and their measurement.

Urban	Rural
Smoke Smog Noise Odor Flooding Congestion	Agricultural Chemical Erosion
Job opportunities High income Better education	Limited

7.10 Environmental Impact Statements

7.10.1 Indicators of Quality for physical area

7.10.2 Predictors of change

7.10.3 Required for major developments

7.10.4 Integrated systems

Preparation of Environmental Impact Statements: Guidelines*

On May 2, 1973, the Council on Environmental Quality published in the FEDERAL REGISTER, for public comment, a proposed revision of its guidelines for the preparation of environmental impact statements. Pursuant to the National Environmental Policy Act (P.L. 91-190, 42 U.S.C. 4321 et seq.) and Executive Order 11514 (35 FR 4247) all Federal departments, agencies, and establishments are required to prepare such statements in connection with their proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The authority for the Council's guidelines is set forth below in § 1500.1. The specific policies to be implemented by the guidelines is set forth below in § 1500.2.

The Council received numerous comments on its proposed guidelines from environmental groups, Federal, State, and local agencies, industry, and private individuals. Two general themes were presented in the majority of the comments. First, the Council should increase the opportunity for public involvement in the impact statement process. Second, the Council should provide more detailed guidance on the responsibilities of Federal agencies in light of recent court decisions interpreting the Act. The proposed guidelines have been revised in light of the specific comments relating to these general themes, as well as other comments received, and are now being issued in final form.

The guidelines will appear in the Code of Federal Regulations in Title 40, Chapter V, at Part 1500. They are being codified, in part, because they affect State and local governmental agencies, environmental groups, industry, and private individuals, in addition to Federal agencies, to which they are specifically directed, and the resultant need to make them widely and readily available.

Sec.
1500.1 Purpose and authority.
1500.2 Policy.
1500.3 Agency and OMB procedures.
1500.4 Federal agencies included; effect of the act on existing agency mandates.
1500.5 Types of actions covered by the act.
1500.6 Identifying major actions significantly affecting the environment.
1500.7 Preparing draft environmental statements; public hearings.
1500.8 Content of environmental statements.
1500.9 Review of draft environmental statements by Federal, Federal-State, State and local agencies and by the public.
1500.10 Preparation and circulation of final environmental statements.
1500.11 Transmittal of statements to the Council; minimum periods for review; requests by the Council.

*38 Fed. Reg. 20550–20562, August 1, 1973.

AUTHORITY: National Environmental Policy Act (P.L. 91-190, 42 U.S.C. 4321 et seq.) and Executive Order 11514.

§ 1500.1 Purpose and authority.

(a) This directive provides guidelines to Federal departments, agencies, and establishments for preparing detailed environmental statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment as required by section 102(2)(C) of the National Environmental Policy Act (P.L. 91-190, 42 U.S.C. 4321 et. seq.) (hereafter "the Act"). Underlying the preparation of such environmental statements is the mandate of both the Act and Executive Order 11514 (35 FR 4247) of March 5, 1970, that all Federal agencies, to the fullest extent possible, direct their policies, plans and programs to protect and enhance environmental quality. Agencies are required to view their actions in a manner calculated to encourage productive and enjoyable harmony between man and his environment, to promote efforts preventing or eliminating damage to the environment and biosphere and stimulating the health and welfare of man, and to enrich the understanding of the ecological systems and natural resources important to the Nation. The objective of section 102(2)(C) of the Act and of these guidelines is to assist agencies in implementing these policies. This requires agencies to build into their decisionmaking process, beginning at the earliest possible point, an appropriate and careful consideration of the environmental aspects of proposed action in order that adverse environmental effects may be avoided or minimized and environmental quality previously lost may be restored. This directive also provides guidance to Federal, State, and local agencies and the public in commenting on statements prepared under these guidelines.

(b) Pursuant to section 204(3) of the Act the Council on Environmental Quality (hereafter "the Council") is assigned the duty and function of reviewing and appraising the programs and activities of the Federal Government, in the light of the Act's policy, for the purpose of determining the extent to which such programs and activities are contributing to the achievement of such policy, and to make recommendations to the President with respect thereto. Section 102(2)(B) of the Act directs all Federal agencies to identify and develop methods and procedures, in consultation with the Council, to insure that unquantified environmental values be given appropriate consideration in decisionmaking along with economic and technical considerations; section 102(2)(C) of the Act directs that copies of all environmental impact statements be filed with the Council; and section 102(2)(H) directs all Federal agencies to assist the Council in the performance of its functions. These provisions have been supplemented in sections 3(h) and (i) of Executive Order 11514 by directions that the Council issue guidelines to Federal agencies for preparation of environmental impact statements and such other instructions to agencies and requests for reports and information as may be required to carry out the Council's responsibilities under the Act.

§ 1500.8 Content of environmental statements.

(a) The following points are to be covered:

(1) A description of the proposed action, a statement of its purposes, and a description of the environment affected, including information, summary technical data, and maps and diagrams where relevant, adequate to permit an assessment of potential environmental impact by commenting agencies and the public. Highly technical and specialized analyses and data should be avoided in the body of the draft impact statement. Such materials should be attached as appendices or footnoted with adequate bibliographic references. The statement should also succinctly describe the environment of the area affected as it exists prior to a proposed action, including other Federal activities in the area affected by the proposed action which are related to the proposed action. The interrelationships and cumulative environmental impacts of the proposed action and other related Federal projects shall be presented in the statement. The amount of detail provided in such descriptions should be commensurate with the extent and expected impact of the

or details of the proposed action which would present different environmental impacts (e.g., cooling ponds vs. cooling towers for a power plant or alternatives that will significantly conserve energy); alternative measures to provide for compensation of fish and wildlife losses, including the acquisition of land, waters, and interests therein. In each case, the analysis should be sufficiently detailed to reveal the agency's comparative evaluation of the environmental benefits, costs and risks of the proposed action and each reasonable alternative. Where an existing impact statement already contains such an analysis, its treatment of alternatives may be incorporated provided that such treatment is current and relevant to the precise purpose of the proposed action.

(5) Any probable adverse environmental effects which cannot be avoided (such as water or air pollution, undesirable land use patterns, damage to life systems, urban congestion, threats to health or other consequences adverse to the environmental goals set out in section 101(b) of the Act). This should be a brief section summarizing in one place those effects discussed in paragraph (a)(3) of this section that are adverse and unavoidable under the proposed action. Included for purposes of contrast should be a clear statement of how other avoidable adverse effects discussed in paragraph (a)(2) of this section will be mitigated.

(6) The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity. This section should contain a brief discussion of the extent to which the proposed action involves tradeoffs between short-term environmental gains at the expense of long-term losses, or vice versa, and a discussion of the extent to which the proposed action forecloses future options. In this context short-term and long-term do not refer to any fixed time periods, but should be viewed in terms of the environmentally significant consequences of the proposed action.

(7) Any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented. This requires the agency to identify from its survey of unavoidable impacts in paragraph (a)(5) of this section the extent to which the action irreversibly curtails the range of potential uses of the environment. Agencies should avoid construing the term "resources" to mean only the labor and materials devoted to an action. "Resources" also means the natural and cultural resources committed to loss or destruction by the action.

(8) An indication of what other interests and considerations of Federal policy are thought to offset the adverse environmental effects of the proposed action identified pursuant to paragraphs (a)(3) and (5) of this section. The statement should also indicate the extent to which these stated countervailing benefits could be realized by following reasonable alternatives to the proposed action (as identified in paragraph (a)(4) of this section) that would avoid some or all of the adverse environmental effects. In this connection, agencies that prepare cost-benefit analyses of proposed actions should attach such analyses, or summaries thereof, to the environmental impact statement, and should clearly indicate the extent to which environmental costs have not been reflected in such analyses.

(b) In developing the above points agencies should make every effort to convey the required information succinctly in a form easily understood, both by members of the public and by public decisionmakers, giving attention to the substance of the information conveyed rather than to the particular form, or length, or detail of the statement. Each of the above points, for example, need not always occupy a distinct section of the statement if it is otherwise adequately covered in discussing the impact of the proposed action and its alternatives—which items should normally be the focus of the statement. Draft statements should indicate at appropriate points in the text any underlying studies, reports, and other information obtained and considered by the agency in preparing the statement including any cost-benefit analyses prepared by the agency, and reports of consulting agencies under the Fish and Wildlife Coordination Act, 16 U.S.C. 661 et seq., and the National Historic Preservation Act of 1966, 16 U.S.C. 470 et seq., where such consultation has taken place. In the case of documents not likely to be easily accessible (such as internal studies or reports), the agency should indicate how such information may be obtained. If such information is attached to the statement, care should be taken to ensure that the statement remains an essentially self-contained instrument, capable of being understood by the reader without the need for undue cross reference.

action, and with the amount of information required at the particular level of decisionmaking (planning, feasibility, design, etc.). In order to ensure accurate descriptions and environmental assessments, site visits should be made where feasible. Agencies should also take care to identify, as appropriate, population and growth characteristics of the affected area and any population and growth assumptions used to justify the project or program or to determine secondary population and growth impacts resulting from the proposed action and its alternatives (see paragraph (a)(1)(3)(ii), of this section). In discussing these population aspects, agencies should give consideration to using the rates of growth in the region of the project contained in the projection compiled for the Water Resources Council by the Bureau of Economic Analysis of the Department of Commerce and the Economic Research Service of the Department of Agriculture (the "OBERS" projection). In any event it is essential that the sources of data used to identify, quantify or evaluate any and all environmental consequences be expressly noted.

(2) The relationship of the proposed action to land use plans, policies, and controls for the affected area. This requires a discussion of how the proposed action may conform or conflict with the objectives and specific terms of approved or proposed Federal, State, and local land use plans, policies, and controls, if any, for the area affected including those developed in response to the Clean Air Act or the Federal Water Pollution Control Act Amendments of 1972. Where a conflict or inconsistency exists, the statement should describe the extent to which the agency has reconciled its proposed action with the plan, policy or control, and the reasons why the agency has decided to proceed notwithstanding the absence of full reconciliation.

(3) The probable impact of the proposed action on the environment.

(i) This requires agencies to assess the positive and negative effects of the proposed action as it affects both the national and international environment. The attention given to different environmental factors will vary according to the nature, scale, and location of proposed actions. Among factors to consider should be the potential effect of the action on such aspects of the environment as those listed in Appendix II of these guidelines. Primary attention should be given in the statement to discussing those factors most evidently impacted by the proposed action.

(ii) Secondary or indirect, as well as primary or direct, consequences for the environment should be included in the analysis. Many major Federal actions, in particular those that involve the construction or licensing of infrastructure investments (e.g., highways, airports, sewer systems, water resource projects, etc.), stimulate or induce secondary effects in the form of associated investments and changed patterns of social and economic activities. Such secondary effects, through their impacts on existing community facilities and activities, through inducing new facilities and activities, or through changes in natural conditions, may often be even more substantial than the primary effects of the original action itself. For example, the effects of the proposed action on population and growth may be among the more significant secondary effects. Such population and growth impacts should be estimated if expected to be significant (using data identified as indicated in § 1500.8(a)(1)) and an assessment made of the effect of any possible change in population patterns or growth upon the resource base, including land use, water, and public services, of the area in question.

(4) Alternatives to the proposed action, including, where relevant, those not within the existing authority of the responsible agency. (Section 102(2)(D) of the Act requires the responsible agency to "study, develop and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources"). A rigorous exploration and objective evaluation of the environmental impacts of all reasonable alternative actions, particularly those that might enhance environmental quality or avoid some or all of the adverse environmental effects, is essential. Sufficient analysis of such alternatives and their environmental benefits, costs and risks should accompany the proposed action through the agency review process in order not to foreclose prematurely options which might enhance environmental quality or have less detrimental effects. Examples of such alternatives include: the alternative of taking no action or of postponing action pending further study; alternatives requiring actions of a significantly different nature which would provide similar benefits with different environmental impacts (e.g., nonstructural alternatives to flood control programs, or mass transit alternatives to highway construction); alternatives related to different designs

(c) Each environmental statement should be prepared in accordance with the precept in section 102(2)(A) of the Act that all agencies of the Federal Government "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and decisionmaking which may have an impact on man's environment." Agencies should attempt to have relevant disciplines represented on their own staffs; where this is not feasible they should make appropriate use of relevant Federal, State, and local agencies or the professional services of universities and outside consultants. The interdisciplinary approach should not be limited to the preparation of the environmental impact statement, but should also be used in the early planning stages of the proposed action. Early application of such an approach should help assure a systematic evaluation of reasonable alternative courses of action and their potential social, economic, and environmental consequences.

(d) Appendix I prescribes the form of the summary sheet which should accompany each draft and final environmental statement.

§ 1500.9 Review of draft environmental statements by Federal, Federal-State, State, and local agencies and by the public.

(a) *Federal agency review.* (1) *In general.* A Federal agency considering an action requiring an environmental statement should consult with, and (on the basis of a draft environmental statement for which the agency takes responsibility) obtain the comment on the environmental impact of the action of Federal and Federal-State agencies with jurisdiction by law or special expertise with respect to any environmental impact involved. These Federal and Federal-State agencies and their relevant areas of expertise include those identified in Appendices II and III to these guidelines. It is recommended that the listed departments and agencies establish contact points, which may be regional offices, for providing comments on the environmental statements. The requirement in section 102(2)(C) to obtain comment from Federal agencies having jurisdiction or special expertise is in addition to any specific statutory obligation of any Federal agency to coordinate or consult with any other Federal or State agency. Agencies should, for example, be alert to consultation requirements of the Fish and Wildlife Coordination Act, 16 U.S.C. 661 et seq., and the National Historic Preservation Act of 1966, 16 U.S.C. 470 et seq. To the extent possible, statements or findings concerning environmental impact required by other statutes, such as section 4(f) of the Department of Transportation Act of 1966, 49 U.S.C. 1653(f), or section 106 of the National Historic Preservation Act of 1966, should be combined with compliance with the environmental impact statement requirements of section 102(2)(C) of the Act to yield a single document which meets all applicable requirements. The Advisory Council on Historic Preservation, the Department of Transportation, and the Department of the Interior, in consultation with the Council, will issue any necessary supplementing instructions for furnishing information or findings not forthcoming under the environmental impact statement process.

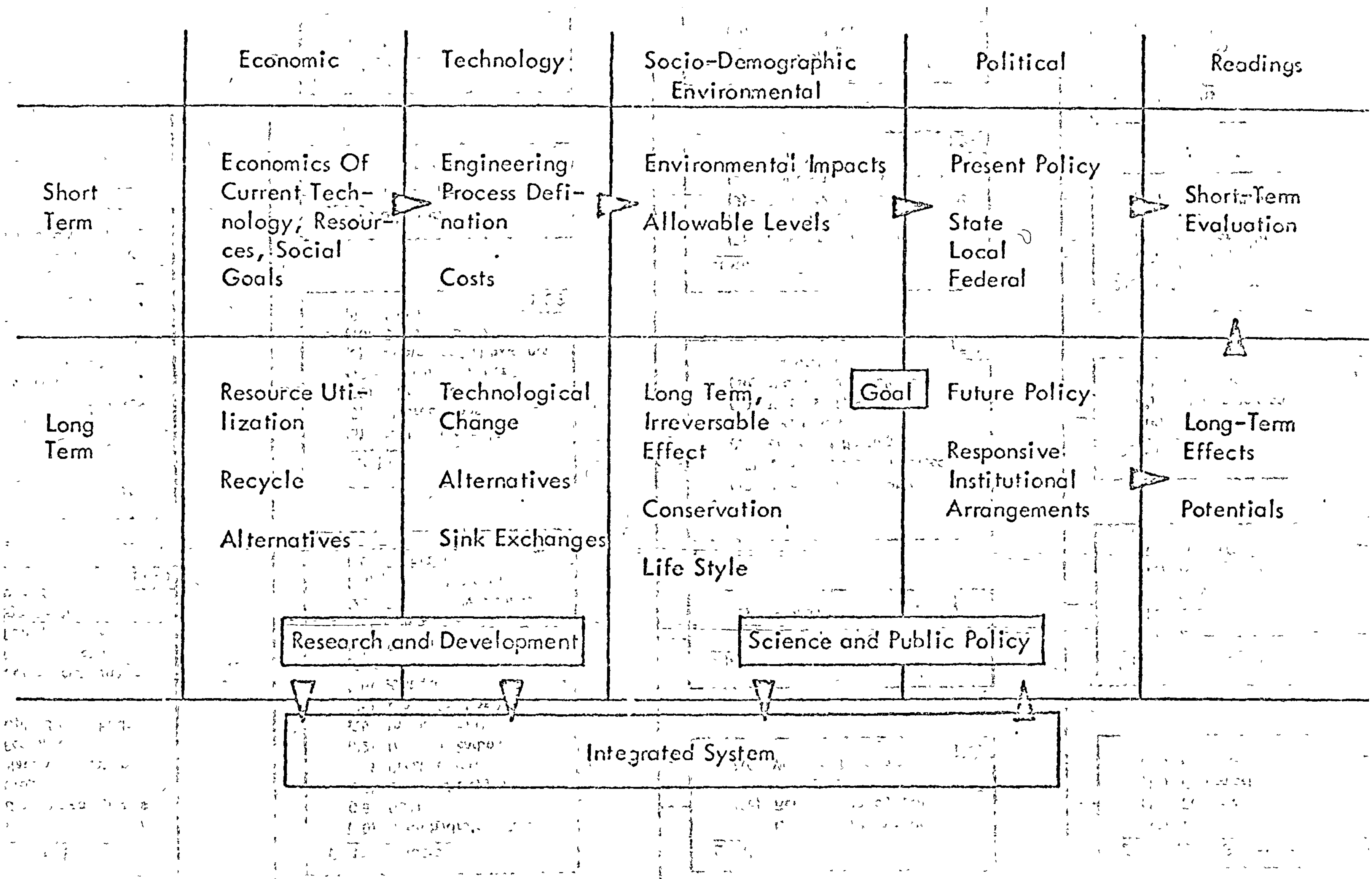
(b) *EPA review.* Section 309 of the Clean Air Act, as amended (42 U.S.C. § 1857h-7), provides that the Administrator of the Environmental Protection Agency shall comment in writing on the environmental impact of any matter relating to his duties and responsibilities, and shall refer to the Council any matter that the Administrator determines is unsatisfactory from the standpoint of public health or welfare or environmental quality. Accordingly, wherever an agency action related to air or water quality, noise abatement and control, pesticide regulation, solid waste disposal, generally applicable environmental radiation criteria and standards, or other provision of the authority of the Administrator is involved, Federal agencies are required to submit such proposed actions and their environmental impact statements, if such have been prepared, to the Administrator for review and comment in writing. In all cases where EPA determines that proposed agency action is environmentally unsatisfactory, or where EPA determines that an environmental statement is so inadequate that such a determination cannot be made, EPA shall publish its determination and notify the Council as soon as practicable. The Administrator's comments shall constitute his comments for the purposes of both section 309 of the Clean Air Act and section 102(2)(C) of the National Environmental Policy Act.

(c) State and local review. Office of Management and Budget Circular No. A-95 (Revised) through its system of State and areawide clearinghouses provides a means for securing the views of

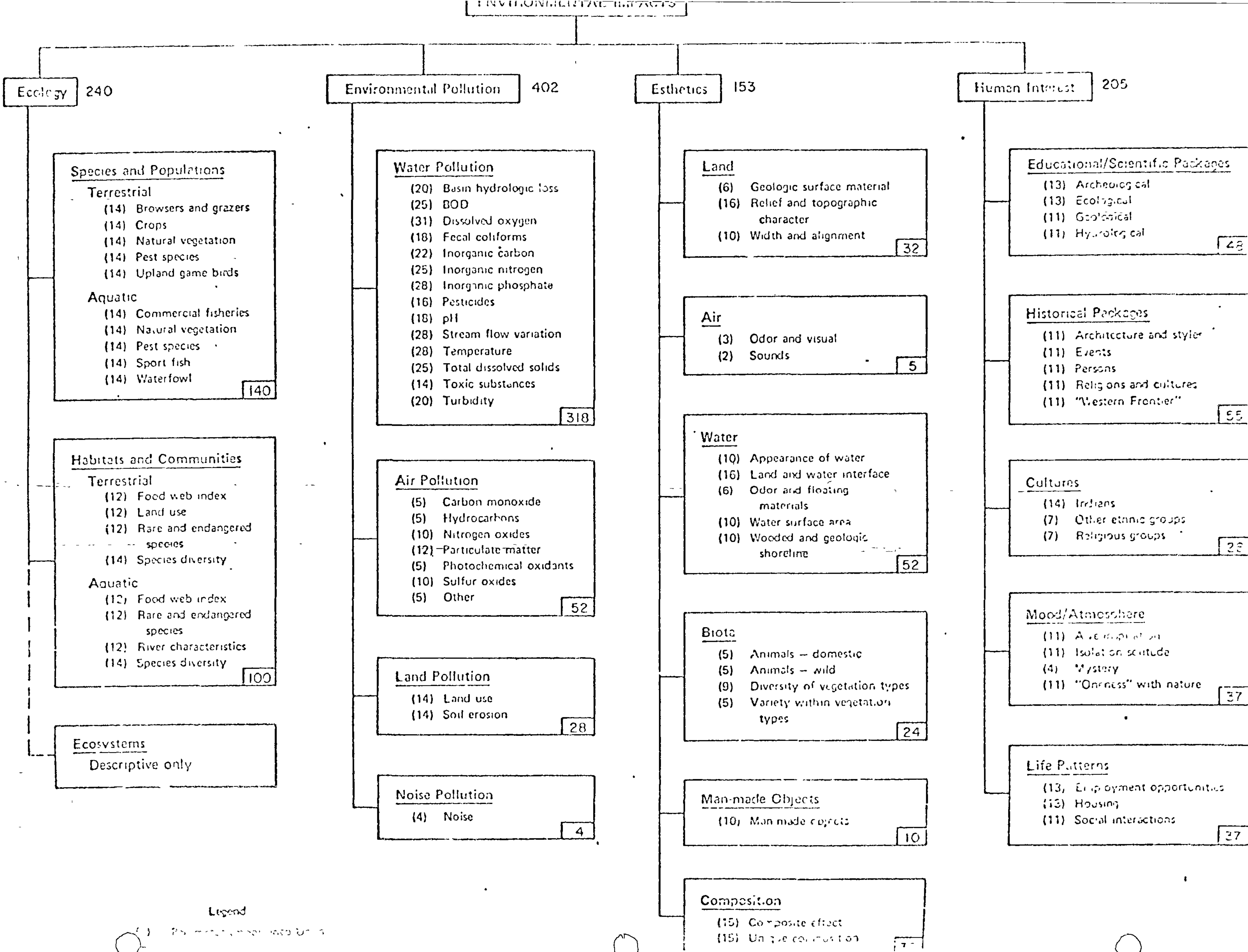
Enviromental Impacts

	Ecological	Environmental	Asthetic	Social
Reversible	Fauna Wild Life Fish, Fowl Animals Domestic Life Animal Food Floral Crops Natural Vegetation	Aquatic - Resource Pollution Level Air - Resource Level Solid Waste Level Noise	Visual Odors Structures Noise	Historical Cultural Life Patterns Health Land Use Settlement Patterns
Non-Reversible	Extinct Species	Land Use		Historical Monuments

Enviromental Consequences



The Problem Realm



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(14) Natural vegetation
(14) Pest species
(14) Sport fish
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(13) Archeological
(13) Ecological
(11) Geological
(11) Hydrological
48
Historical Packages
(11) Architecture and styles
(11) Events
(11) Persons
(11) Religions and cultures
(11) "Western Frontier"
55
Cultures
(14) Indians
(7) Other ethnic groups
(7) Religious groups
28
Mood/Atmosphere
(11) Awe-inspiration
(11) Isolation/solitude
(4) Mystery
(11) "Oneness" with nature
37
Life Patterns
(13) Employment opportunities
(13) Housing
(11) Social interactions
37
Legend

	ECONOMIC INDICES									SOCIAL INDICES							DEMOGRAPHIC INDICES			
	Income	Interest Rate	Occupation	Employment	Patent Trends	New Construction	Inventory R & D	Price Index	Incorp. Dist.	Occupation	Employment	Education	Env. Index	Pol.&Com. Part	Life Style	Incorp.Dist.	Population	Pop. Change	% Urbanization	Family Size
Housing	1	2	3 II			3 V						4		III	VII		I		IV	VI
Drainage				3	6								4 II	I			1 II	5	2 III	
Security	5		4	II				V				2				I	1 III		3 IV	
Water	5 VI		3 IV	2 III										I	III		1 II	4 V	V	
Sewerage				3 IV									4 V	I			1 II		2 IV	
Transp.	1			2 I		III	II					4		V			5		3 III	
Air	4		I	1			5							IV			3 III		2 II	
Solid Waste	2 II		4	4	3	6				4	4		7	8 I	II		1 III			

Priorities listed from first to eighth in arabic numbers to indicate present priorities, and in Roman numbers to indicate future priorities.

Chapter 8

POPULATION MODEL

The basic ingredient of any plan is people. Population forecasting is primarily a matter of judgement. Population and its composition determine the economic status and future demands and needs.

8.1 Methods of Population Projections

8.11 Disaggregation - based on the national projections of the Bureau of Census. National population is disaggregated to the region or urban area.

8.12 Cohort-survival - analyzes the population by age, sex, race, occupation, income, etc., measures the capacity of the existing p population resource to grow through natural increase and net migration

8.13 Migration and natural increase - simpler, involves an analysis of only two components. Provides estimates only for the total population.

8.14 Future employment

8.15 Mathematical and graphical extrapolation - arithmetic and geometric projections, trend extrapolation by least squares method; logistic curves.

8.2 Basic Assumptions

(1) The form of government and the political, economic and social organization and institutions of the nation will remain substantially unchanged.

(2) No all-out war, internal revolution, nation-wide devastation, epidemic or other disaster will occur.

(3) No large scale epidemic, destruction by military action, fire, earthquake or other disaster will occur in the area or within the geographical or economic region to which the area is closely related.

8.3 Migration

8.31 Reasons for migration

(1) Desire for better economic opportunity;

(2) Attraction of milder or more suitable climates;

(3) Desire for better living or housing conditions;

(4) Movements due to health, education or retirement.

8.32 Methods of estimation (Bureau of the Census)

(1) Method I uses the total change in the elementary school enrollment from the last census date to the current date, taken as a percentage of the census date enrollment, as a rough indication of net migration occurring during this period.

(2) Method II develops an estimate of the enrollment based on natural increase along with the difference between the hypothetical and actual enrollment of grades 2-8 being used as an estimation of net migration.

8.4 Employment and Income Forecasts

8.41 Employment

Used in population studies, estimating space needs for residential areas and community facilities. It also provides a direct measure for scaling land requirements for industrial and commercial areas.

8.411 Methods

(1) Use of input-output technique which uses a matrix of inter-industry relationships, to show the changes in all industrial categories as a result of the change in any one category.

(2) Step down procedure.

8.42 Income

Income forecasts are necessary for two purposes as follows.

(1) Housing market analyses - this has application in land use planning in providing a guide for establishing the amounts of underdeveloped and redeveloped land allocated to different residential densities.

(2) Land requirements of commercial uses - income is translated into expendible income, to sales and then to floor space.

8.421 Methods

(1) At the national level, total personal income is compared to GNP and the growth rate is projected based on the trend of the GNP. This can then be disaggregated to per capita income and household income.

(2) Income can be built up from the forecast of the labor force, occupation.

8.5 The Model (Reid's Population Model)

Two methods of population forecasting were used to produce the population model. (See Figure 8.1)

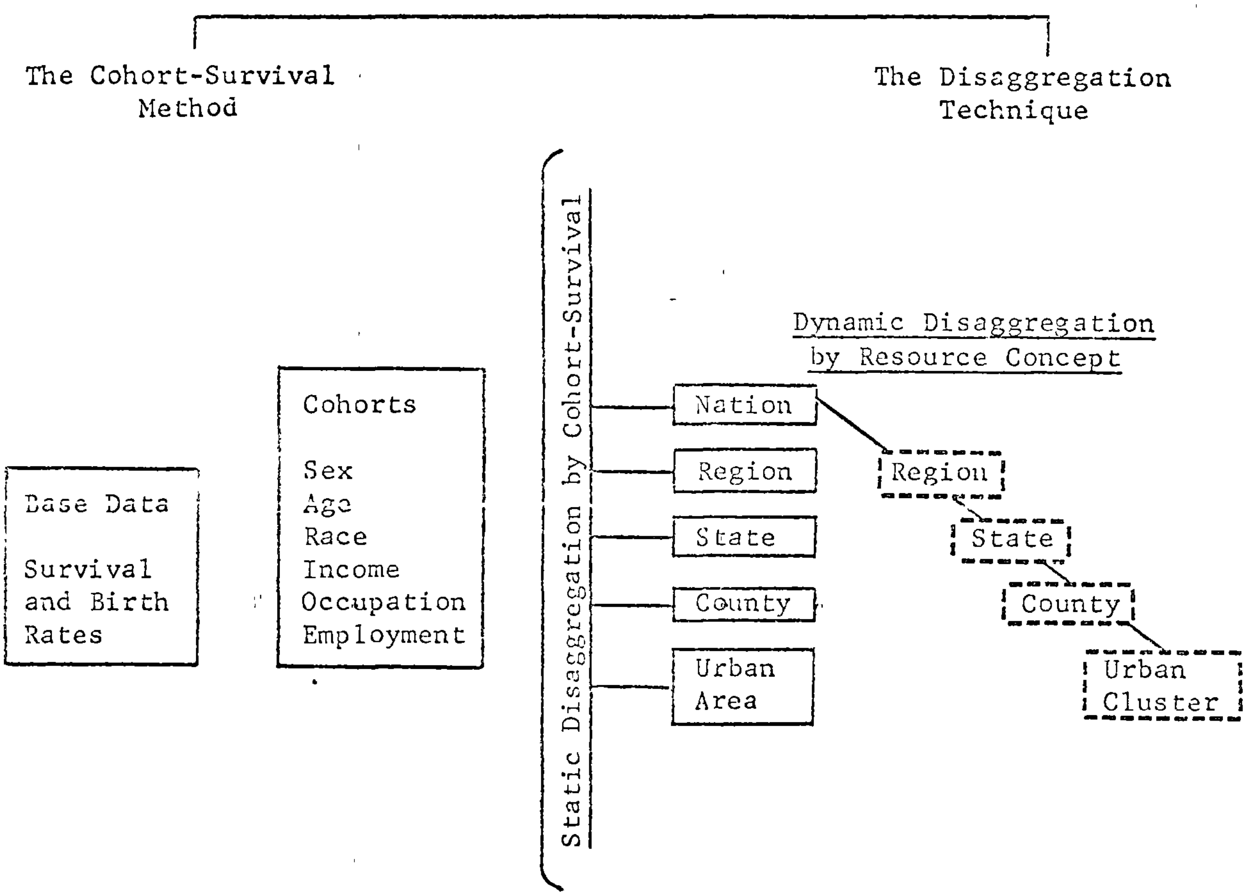
8.51 The Disaggregation Model

The disaggregation model is based on the national projections of the Bureau of Census which has several assumptions concerning the various population characteristics as a base. The national population is then disaggregated to the region, state, county, urban cluster, etc, which is under study. The disproportionate change (of the region, etc.), either growth or loss, is determined by using weighing factors that are based on policy decisions. These factors have the references to growth standards, indices and potentials incorporated within themselves. The technique used is essentially based on the decomposition of the resources capability, past, present and future. The actions and behavior of people constitute the resources in this context.

The statistical region population is then allocated to the Standard Metropolitan Statistical Areas in the region. A step-down technique based on past performance of the current SMSA's in the region is used as the basic approach. The population of the nation is disaggregated to a region and then distributed by this step-down procedure to a particular urban cluster while the balance with other urban clusters is being examined.

The step-down procedure is also a decision level process during which sets of alternative goals are presented to the decision

Figure 8.1. The Population Model



maker. These goals are expressed in terms of the quantity and types of people who could reside in an urban cluster at some future time.

8.52 Cohort - Survival Model

The purpose of the cohort - survival portion of the model is to analyze the population of the urban cluster by age, sex and race groups, occupation groups, industrial groups and income groups, and to measure the capacity of the existing population resource to grow through natural increase and net migration. This would estimate growth if all past trends continued and no one "tinkered with the works". The model of the probable world provides a comparison base.

The cohort - survival method of forecasting population is widely accepted for large areas. This method requires considerable data, although this data is readily available from the U. S. Census of Population and other sources.

8.53 Comparison of the two methods

Comparing the cohort - survival method and the disaggregation technique, the former projects forward the characteristics of the existing population and provides a more refined projection of age structure characteristics in that the method ages the population. The latter, the disaggregation technique, results in an examination of the development of the total population potential at each five-year interval. However, by combining the two methods a more balanced projection of characteristics and distribution is obtained.

8.54 Printouts of Model

Printouts of the population projections by five-year increments are listed according to sex, age, race; household and labor force by income, population by occupation, and labor force by industry.

GEOGRAPHIC AREA

Model Geographic Area	TMAPC Area Used
1. Nation	50 states, District of Columbia, and Puerto Rico
2. Region	Bureau of Census West South Central region (Arkansas, Louisiana, Oklahoma, and Texas)
3. Cluster	Indian Nations Council of Governments (Creek, Osage, Rogers, Tulsa, and Wagoner Counties)
(4) Special	a. Each individual county, SMSA, and the Metropolitan Area (Tulsa County and the five-mile perimeter) b. Cities and towns in the Metropolitan Area (Bixby, Broken Arrow, Collinsville, Glenpool, Jenks, Owasso, Sand Springs, Skiatook, Sperry, and Tulsa)

POPULATION CHARACTERISTICS

Code	Race and Sex
1	White Male
2	White Female
3	Non-White Male
4	Non-White Female

AGE GROUPS

Code	Age
1	0 - 4
2	5 - 9
3	10 - 14
4	15 - 19
5	20 - 24
6	25 - 29
7	30 - 34
8	35 - 39
9	40 - 44
10	45 - 49
11	50 - 54
12	55 - 59
13	60 - 64
14	65 - 69
15	70 - 74
16	75 - 79
17	80 - 84
18	85 over

OCCUPATION
(1960 U. S. Census definitions for first five groups)

Code	Occupations
1	Professional, technical, and kindred workers
2	Managers, officials, and proprietors, except farm
3	Clerical and kindred workers
4	Sales workers
5	Farmers and farm managers
6	Farm laborers and farm foremen
7	Skilled laborers, craftsmen, foremen, and kindred workers
8	Operators and kindred workers
9	Private household workers
10	Service workers except private household
11	Laborers, except farm and mine
12	Unemployed, but employable
13	Unemployed, not employable--children, students, housewives, elderly, and disabled
14	Armed Forces

INDUSTRY

(Standard Industrial Classification Manual definitions)

Code	Industries
1	Agriculture, forestry, and fisheries
2	Mining
3	Contract construction
4	Manufacturing
5	Transportation, communication, electric, gas and sanitary services
6	Wholesale and retail trade
7	Finance, insurance, and real estate
8	Services
9	Government
10	Non-Classifiable

LABOR FORCE INCOME

Code	Income Group
1	Under $ 1,000
2	$ 1,000 - 1,999
3	2,000 - 2,999
4	3,000 - 3,999
5	4,000 - 4,999
6	5,000 - 5,999
7	6,000 - 6,999
8	7,000 - 7,999
9	8,000 - 8,999
10	9,000 - 9,999
11	10,000 - 10,999
12	11,000 - 11,999
13	12,000 - 12,999
14	13,000 - 13,999
15	14,000 - 14,999
16	15,000 - 19,999
17	20,000 - 24,999
18	25,000 - 49,999
19	50,000 - over

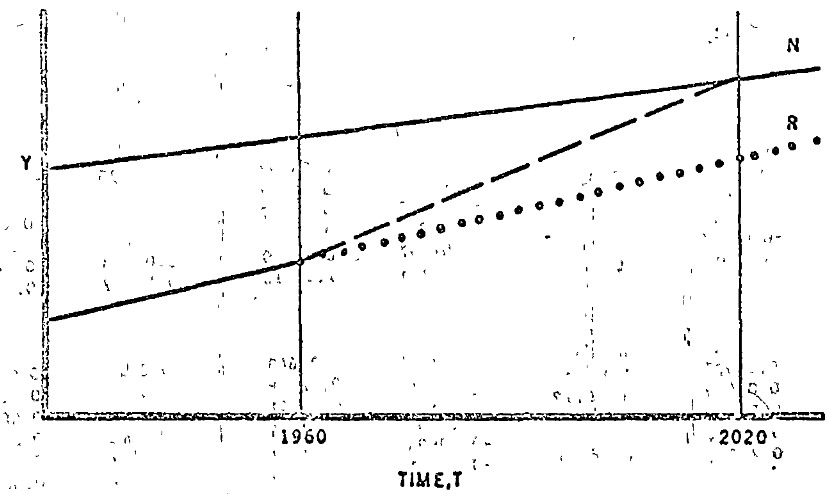
DISAGGREGATION FUNCTION REGRESSION EQUATIONS (for F-value)

	% of N values are accounted for
Density People/sq. mi.	
$y = 0.466t - 864.89$	$R^2 = .98$ [a]
$y = 0.386t - 718.3$	$R^2 = .99$ [b]
Land acre/pop	
$y = -.128t + 260$	$R^2 = .99$
$y = .023t + 61.95$	$R^2 = .99$
Water gal/cap/day	
$y = -.67t + 272$	$R^2 = .99$
$y = .043t - 27.48$	$R^2 = .99$
Energy BTU/10^2 pop	
$y = 2.5t - 4600$	$R^2 = .98$
$y = 9.2t - 17600$	$R^2 = .99$
Urbanization percentage x 10^{-2}	
$y = 0045t - 8$	$R^2 = .98$
$y = .00874t - 16.5$	$R^2 = .99$
Income \$/capita/yr.	
$y = 66.85t - 128797$	$R^2 = .99$
$y = 56.05t - 108066$	$R^2 = .98$

a. National
b. Regional

METHOD TO DETERMINE F_1

Shows schematically how the new regional values were derived.



N - The nation curve "N" is considered to be based on static trends. It is projected by five-year increments from the period 1960 to 2020. The equation used is the linear equation ($y_n = at+B$) developed in the first phase.

R - The regional equation "R" is dotted to show its relative value if projected through time. These values would exist if things continued as they have in the past. The dashed line represents the dynamic (new) regional values. The equation of this line is determined, and it also is evaluated by five-year increments from 1960 to 2020.

The dynamic regional value and the static national value are then combined to form the dynamic Xi input values.

Solving the equation $F_i = B_0 + \sum_{1}^{6} Bi\ Xi$ using the dynamic Xi produces the dynamic Fi's. These Fi's applied to the static national population cohort produce the dynamic regional population cohorts. See the table below for the B values established for the region.

AGE, SEX, OCCUPATION, INDUSTRY, AND INCOME DISAGGREGATION EQUATIONS

B VALUES

ID	Intercept B_0	Density B_1	Urbanization B_2	Energy B_3	Water B_4	Land B_5	Income B_6	R^2
<u>Male</u>								
Age								
0- 4	-0.06246	-0 02164	0.01191	-0.00542	0.26193	-0 00335	-0.00000	.93
5-19	0.04791	0 18038	0 00054	-0 00118	0.26668	-0.00126	-0.00000	.93
20-24	0.11493	0.00549	0 00126	-0 00009	-0.02387	0 00009	0.00000	.99
25-44	0 09795	-0.00663	-0 00324	-0 00059	-0.00430	0.00019	0.00000	.98
45-64	-0.00552	-0.00634	-0.04353	0.01257	0.15000	0 00063	0.00000	.97
65 +	-6.13428	0.38398	0.00930	-0.12765	7.99316	-0.13807	-0.00021	.96
<u>Female</u>								
Age								
0- 4	-0.00234	-0.06008	-0.00479	-0 00502	0.21665	0.00263	-0 00000	.95
5-19	0 10884	-0 11925	-0 00357	-0 00134	0.12678	0.00001	0.00000	.95
20-24	0 11493	-0 00469	0 00272	0 00007	-0.01041	0.00012	-0.00000	99
25-44	(09632	0.01702	-0 00101	-0 00187	-0 02244	0 00031	0.00000	.90
45-64	-2.17629	0 26541	-0.22582	-0 00903	2.94604	-0.03027	-0.00002	.98
65 +	-4.32106	0.21731	0.00742	-0.10631	5.72146	-0.11657	0.00015	.88
<u>Occupation</u>								
Prof.	0 30594	0.05188	0 06016	-0 01172	-0.39914	0.00221	0.02822	.99
Clerical	0.42858	0 03924	-0.06085	-0.00142	-0.60082	0.00013	0.06721	.92
Farm	-3.38754	0.20320	0.08426	-0 06179	4.48678	-0.14995	0.01652	.99
Skilled	0.98351	0 14967	-0.07655	-0 00210	-1.18476	0.01373	-0 01950	.84
Semi-Skill	1.16539	0.27175	-0.04138	0 02278	-1.61874	0 01331	0.01295	.99
Unemp.	-2.01135	0.02733	-0 00459	-0 01283	2.30447	0 11929	0 08552	.99
Not Emp.	1 53344	0.33626	0 03968	-0 02486	-2.14600	0 01891	-0.04074	.99
Armed Frces.	-0.49325	0 07295	0.07710	-0 01308	0.79835	-0.00497	-0.16560	.99
<u>Industrial</u>								
Agri.	-0 51878	0 15875	0.25488	-0.09706	0.81074	-0.15835	0 02765	.99
Mining	-2.37202	-0 01396	0 31764	-0 03223	2 32295	0.29844	-0 04503	.98
Const.	0.21504	0.06461	0 02080	-0 00567	-0.28322	0 00748	0 04808	.98
Manf.	-0.21402	0 06074	0.03903	-0.01329	0.24283	-0.00662	0.05040	.93
Trans.	-4 95983	0.18048	-0 26436	-0 06221	6.59500	-0.07332	0.14696	.99
Trade	0.38718	0.05674	-0.02861	0.00807	0.42031	0 00124	0 01500	.84
Finance	0.41395	0.06082	0 04611	-0.00500	-0.59114	0 00444	0.06764	.97
Service	-3 57547	-0.00577	-0.01781	-0.07117	4.73897	-0.04319	0.11269	.99
Gov't.	5.61252	-0.22428	-0.07457	0.12381	-6.88616	0 06968	-0.13425	.99
Non-Class	-0.39022	0.07921	0.02030	-0 00681	0.83120	-0.01409	-0.28128	.95
<u>Income</u>								
(Total)	0.13261	-0.02593	-0.01122	-0.00074	-0.02345	0.00004	0.00000	1.00

The disaggregation functions to the cluster were designated F_2. These are ratios of the following form: $\frac{\text{urban cluster}}{\text{region}}$. The procedure for developing dynamic F_1's would not be acceptable at this level because the urban cluster already has a higher density and urbanization than that of the region. Therefore, it was decided to use the static F_2's. This essentially states that the urban cluster receives the same share of the dynamic regional growth as it has in the past.

A more sophisticated valuation of F_2's is under development. Essentially, this is a step-down procedure using the SMSA's in a regional prorating on the industrial trends.

The models have available an internal check, namely E_i's; these are expansion factors. A method of expansion is also feasible and is under development to provide an independent imperative value.

Using a deterministic rational besides a set of "goals", or even more definitively "people goals", the E_i's can be postulated. For example, C^n_{t+k} (occupation) postulates that in terms of averages there will be an upgrading generation by category.

Category	1960	1980	2000	2020
Professional		----greatly increased-----		
Farmer		-----decrease-----		
Clerical		-----static-----		
Skilled		increase	decrease	decrease
Semi-skilled		½	0	0
Not employed	4%------------	------------	------------	-----8%
Unemployed	4%------------	------------	------------	-----0%
Military				

Obviously, it could assume most any format, and similarly, the other cohorts can be so exputed.

Chapter 9

FORECASTING AND TECHNOLOGICAL FORECASTING

9.1 Forecasting

A forecast is an opinion or assertion about a future state of affairs. Forecasting is a natural activity of the mind.

9.11 Prediction

A forecast differs from a prediction in that a forecast serves to convince us to act in the present either to move toward or away from the future state of affairs described by the forecasts. A prediction seeks to confirm as hypothesis or theory (not necessarily dealing with the future) and serves this function whether or not anyone is persuaded to change his behavior in the present. The end result of prediction is explanation, i.e. a confirmation of the particular theory or hypothesis. The end result of forecasting is to clarify options and to influence choice behavior in the present.

9.12 Purpose of forecasting

Having and understanding choice options are deeply rooted in the concept of human freedom. To improve the process of decision making in the present, we have to learn to improve the process of forecasting.

9.2 Characteristics of Forecasts

9.21 Plausibility - describes a state of affairs which could grow out of the present and be continuous with the present.

9.22 Specified time frame

9.23 Internal consistency

9.24 Clearly articulated assumptions

9.25 Realism

9.26 Imagination - a forecast which simply projects a naive extrapolation of the present; lacks imagination because it assumes no new interventions or causes which could deform or influence the future.

9.27 Justification

9.3 Components of Forecasts

9.31 Theory

9.32 Data

9.4 Types of Forecasts

9.41 Unconditional - no exogenous events will occur to change the prediction value.

9.42 Conditional - conditional upon the realization of some other event or events.

9.43 Plan or target - a study of some economic or plysical system and the formulation of a model to predict it. Remains valid in future.

9.44 Point and interval

(1) Point predictions are points of change enroute to goals. Point is confined to one event with one value.

(2) Interval predictions yield a set of situations that may be

realized in the future. Interval is given by a pair of values.

9.45 Single and multiple - single predictions are confined to one event and multiple refers to several events or several aspects of a single event.

9.5 Approaches to Forecasting

9.51 Statistical approach - This approach assumes that the data generating system will remain constant and that there is available a good approximation to the effect of the true generating mechanism.

9.52 Econometric approach - This approach requires more insight into the causal mechanism and more effort in estimiating the various quantities involved. Example: specifications of supply and demand relationship in order to forecast future prices.

9.6 Techniques of Forecasting

9.61 Moving averages - Involves summing the averages of some number of recent observations, then dividing by that number, and using the final value as the forecast. Moving averages can be used to forecast with any polynominal model by taking moving averages of moving averages to estimate the various coefficients in the models.

9.62 Exponential smoothing - Used for predicting polynomial models. Each observation is included in the forecast but more recent observations are given more relative weight. A limitation is that only the data from the process itself are used to predict future values.

9.63 Regression and correlation analysis - Used to establish and measure the strength of the relationships among variables. The equation resulting from the regression process is used to forecast values of the dependent variable in future time period.

The principal difference between this technique and exponential smoothing is in the specification of the model. In exponential smoothing, the principal difference between this technique and exponential smoothing is in the specification of the model. In exponential smoothing, the model is specified to provide the initial conditions. Regression analysis is used to ascertain what model best fits the data.

9.7 Abuses of Forecasts

Lack of skills to critically examine forecasts leads to the following abuses.

9.71 Forecasts used as a powerful tool to manipulate and control people.

9.72 Encourage sloppy and fuzzy thinking on the part of futurists which leads to "prophet syndrome".

9.73 Great deal of harm done by encouraging unreasonable or unjustified expectations.

9.8 Methodologies for Forecasting

9.81 Projections

9.811 Extrapolations

These are simply the projections of individual time series (demographic, occupational, national product) under verying assumptions. Two basic assumptions are continuation of force and extension of previous pattern.

9.812 Growth analogies

Initial advance is exponential, followed by a continued diminuition of the rate of advance as "maturity" is approached. One of the simplest situations for prediction on the basis of trend characteristics is one in which the extension of a well-established exponential rate of progress intercepts a known physical limit.

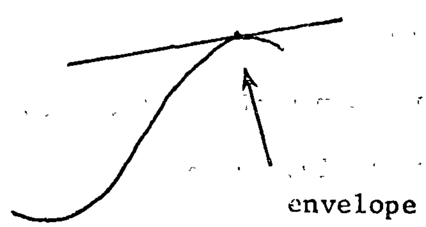
9.813 Trend correlation

The trend of a technical parameter which is complex and difficult to predict by itself may sometimes be more easily expressed as a result of a relationship between two or more other trends. Combinations of primary variables from trends are compared and projected. The prediction is then completed by projection of the unknown variable on the basis of the relationship between the primary variables.

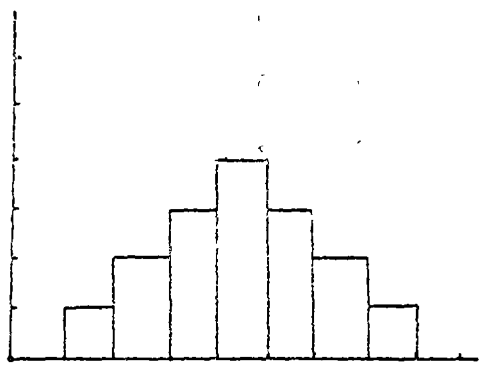
9.8131 Single Parameter - Time series data of a technical attribute that reflects a significant aspect of the technology or its application can be plotted and then extrapolated in some manner to predict its future state.

9.8132 Compound Parameter - Time series data of combinations of parameters so that the data will reflect the basic, interrelated changes in the device or service (e.g. power per unit of weight or space; computer operations per dollar).

9.8133 Envelope curves - A fundamental capability that society desires continues to advance by support of a succession of increasingly effective technologies. As the S-curves of earlier technologies begin to fall off, a new technology emerges to maintain progress of the fundamental capability. A curve approximately tangent to the tops of the S-curves describes an "envelope" of anticipated change.



9.8134 Step Functions - Different industries show patterns of behavior in the scale and timing of technological changes that they introduced into products and facilities, expecially as these factors relate to total demand. It is a discrete distribution rather than continuous, responding to such forces as markets, prices, costs, technological considerations, new technology, etc.



Nomogram

9.8135 Technological Progess Function - The technological process function assumes that a technical parameter improves with cumulative numbers of units produced in the manner exhibited by unit cost and manufacturing time in learning curve theory. The function provides a basis for technology predictions against growth of technology production or usage instead of time.

9.814 The Delphi technique

As exemplified by the Rand study, this is essentially a "panel technique" in which a group of experts makes predictions in specific areas. These results are then "fed back" repeatedly to the individuals in order to clarify the agreements and disagreements among panel members.

9.82 General methods

9.821 Senarios

9.822 Delphi

9.823 Trends or normative

9.824 Dynamic modelling

9.825 Cross impact

9.826 Correlation plot

9.827 Exp. position papers

9.828 Relevance trees

9.829 Analogy or metapho

9.8210 Economic projections

9.8211 Morphological approach

9.8212 Operations research

9.8213 Emperical

9.8214 Analytical

9.8215 Quasic

9.8216 Heuristic forecasting

9.8136 Substitution Theory (Fisher-Pry) - If a new technology beings to replace an existing technology without a major change in function, it will tend to go to completion, and the time and amount of substitution can be predicted according to a hyperbolic tangent function based on the average annual rate of displacement.

9.8137 Correlation analysis - A technological device changes through a blend of many factors of performance, construction, cost, and social usage. Therefore, historical data on the important interrelated parameters should be developed and plotted. Trial extrapolations are then made to test relationships threrby to determine the most likely future state or direction. The basic notion is to search for consistency and logical relationships.

9.9 Forecasting Models

These are combinations of series, mathematically expressed that make assumptions about future expectations. Examples of these are the "Brookings Econometric Model of Quarterly Economic Projections: and the "Tobin-Solow Long Range Forecasting Model:" being developed.

9.91 Cybernetic models

These are forecasting models that try to build in, either on a stochastic or a more determinate basis, some anticipated or actual feedbacks so as to allow for continual readjustments. There are few such large scale social models in existence, though Soviet economists and mathematicians are busily drafting such cybernetic models for the Soviet economy.

9.92 Polynomial models

9.921 Exponential smoothing

9.922 Regression - correlation analysis

9.93 Transcendental models

9.931 Fourier series

9.932 Time series analysis

The components are as follows.

(1) Trend

(2) Seasonal

(3) Cyclical

(4) Random

9.933 Spectral analysis - Inspects the size of the amplitude of each frequency to be found in a time series.

9.94 Selective models

9.941 Consider technology autonomous and chart the adjustment to a major technological advance - example, relationship of natural resources to population or demand, etc.

9.942 Concentrate on those technological changes that induce social change and those social decisions that will have technological consequences - example, spending for space, sciences, military, etc.

9.943 Ecologies of change - select those combinations of technology and social structure that fit together.

9.95 The therapeutic model

Do not accept the situation as given or as defined by the client but keep open a range of generalized goals. Emphasize self scrutiny, feedback and reevaluation of means and goals.

9.10 <u>Forecasting of Technological Change</u>

9.10.1 Technology that changes is the set of tools and techniques.

Hard - new machine tools, etc.

Soft - computer programs, methods of work, etc.

9.10.2 Stages of process of technological change

9.10.21 Invention - creation of new product or process

9.10.22 Innovation - introduction of the invented product or process into use.

9.10.23 Diffusion - spread of the product or process beyond the first use.

9.10.3 The identification of innovations

9.10.31 Major innovative items - restructuring of organization or methods of intellectual work or reorganization of markets.

9.10.32 New products

9.10.4 New social forms - not-for-profit corporation, etc.

9.10.5 New doctrines - revolutions in military technology

9.11 Forecasting the Rate and Direction of Diffusion of Technology

9.11.1 The diffusion of technology takes place in a complex economy and more broadly still in a total complex culture.

9.11.2 Characteristically, predictions of rate of diffusion tend to be optimistic for the short term and pessimistic for the long term.

9.11.3 Techniques of analysis

(1) Analysis of historical diffusion curves - plots of dollar, volume, number of units in use or the like against time.

(2) Industry by industry or product by product analysis of diffusion - manpower, industrial growth or corporate profits.

9.12 The Specification of Diffusions

9.12.1 Most social change proceeds less from giant new innovations than from diffusions of existing techniques, or more importantly, of privileges.

9.12.2 Changes in the character of higher education proceed not only from the new role of research, but equally from the fact that what was once restricted to a few is now open to the many.

9.12.3 "Change of scale" is the element that creates the problem

9.13 Attitudes toward Forecasting

9.13.1 Forecasts may function as self-fulfilling or self-defeating prophecies. In light of this, many maintain that forecasting is either impossible or undesirable.

9.13.2 There is a second view that, although it admits the weakness of current forecasting methodology, it emphasizes the ways in which the conduct of public and private programs requires planning and forecasting as necessary ingredients.

9.13.3 Some see forecasts as tools or aids for decision rather than as assertions about the future.

9.13.4 There is a tendency among those interested in forecasting to concentrate on the methodology rather than its use.

9.14 Definitions

9.14.1 A technological forecast is the forecast of the invention, innovation or diffusion of some technology.

9.14.2 A technological projection is a conditional assertion that one or more of the propositions will be true if certain other conditions are met.

9.14.3 Technological change is closely linked to social and economic factors

9.15 Testing of Models and Forecasts

9.15.1 Verification - Testing of a model after a certain period of time has elapsed, so that it is possible to ascertain if the forecast is true or not, thereby verifying use of the model.

9.15.2 Predictive tests

9.15.21 Janus quotient - used as a criteria of stable model structure, i.e., guards against the possibility of "overfitting", as a measure of prediction accuracy.

9.15.22 " heil coefficient" - is a quotient involving predicted and observed values. It seeks to measure the efficacy of the forecast and procedure.

9.15.3 Validation

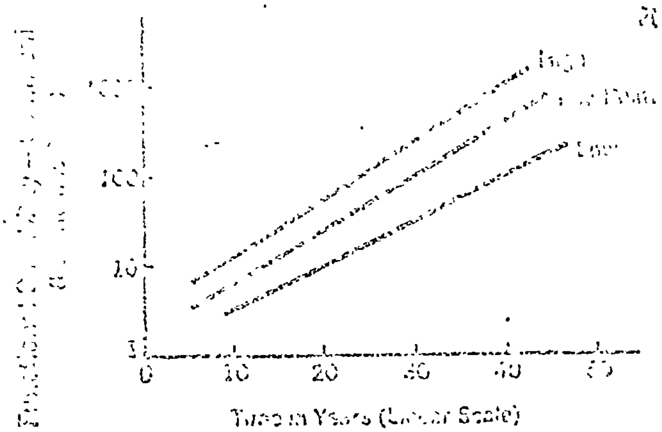
(1) Another system

(2) Economic vs. demographic

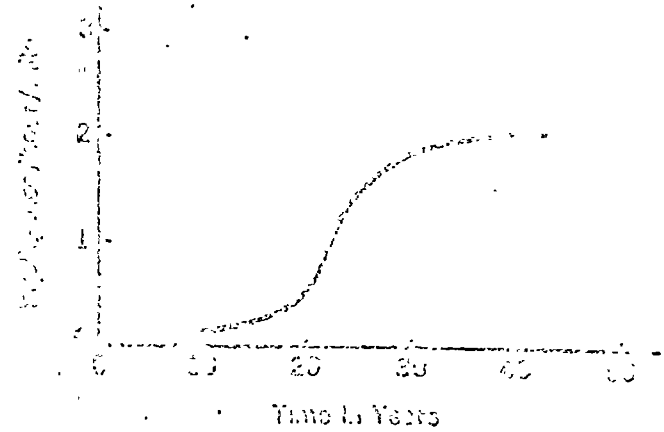
(3) Deterministic vs. probabilistic

(4) Goals - forward vs. backward

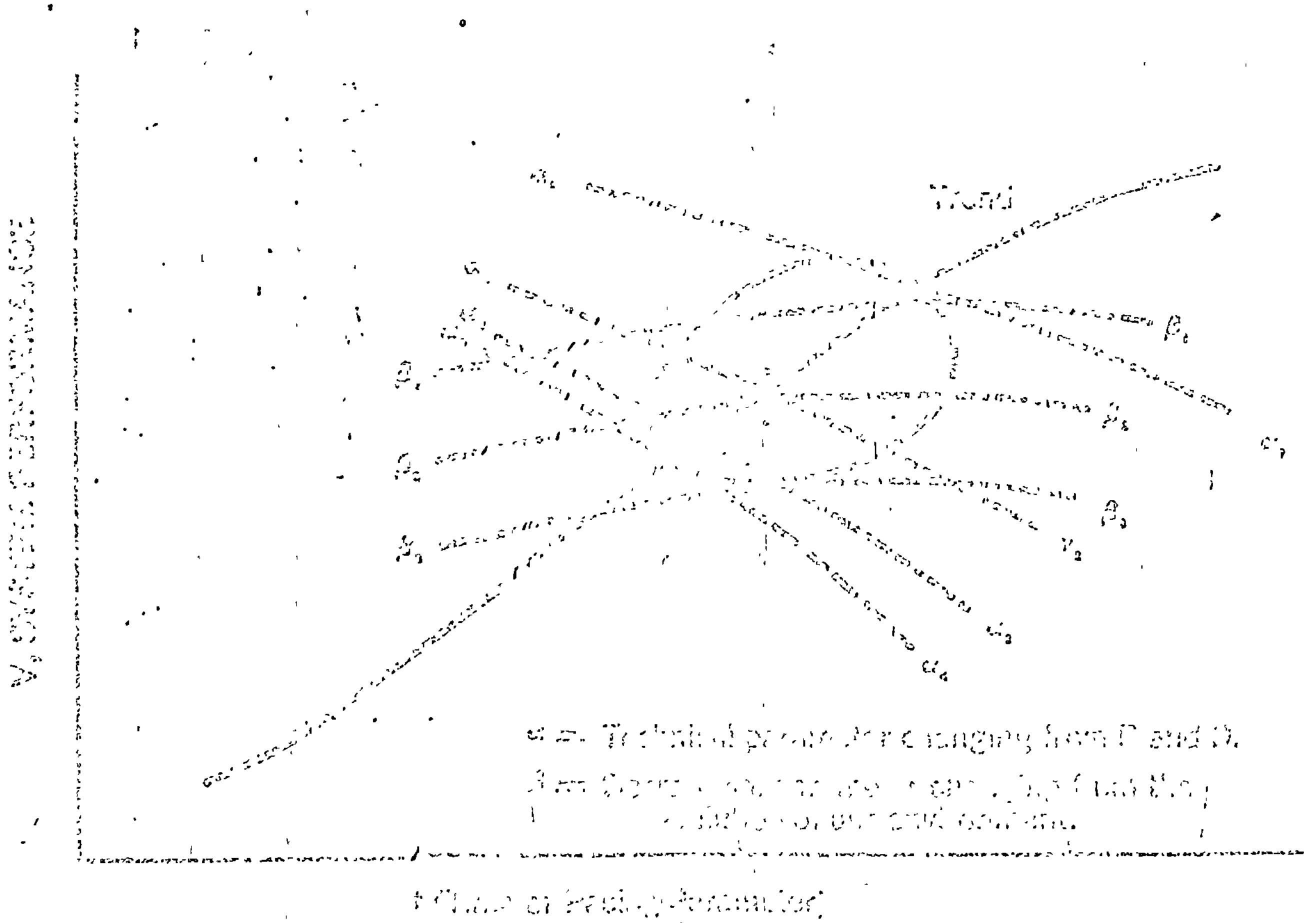
9.16 Forecasts (Figure II-1 through II-11)



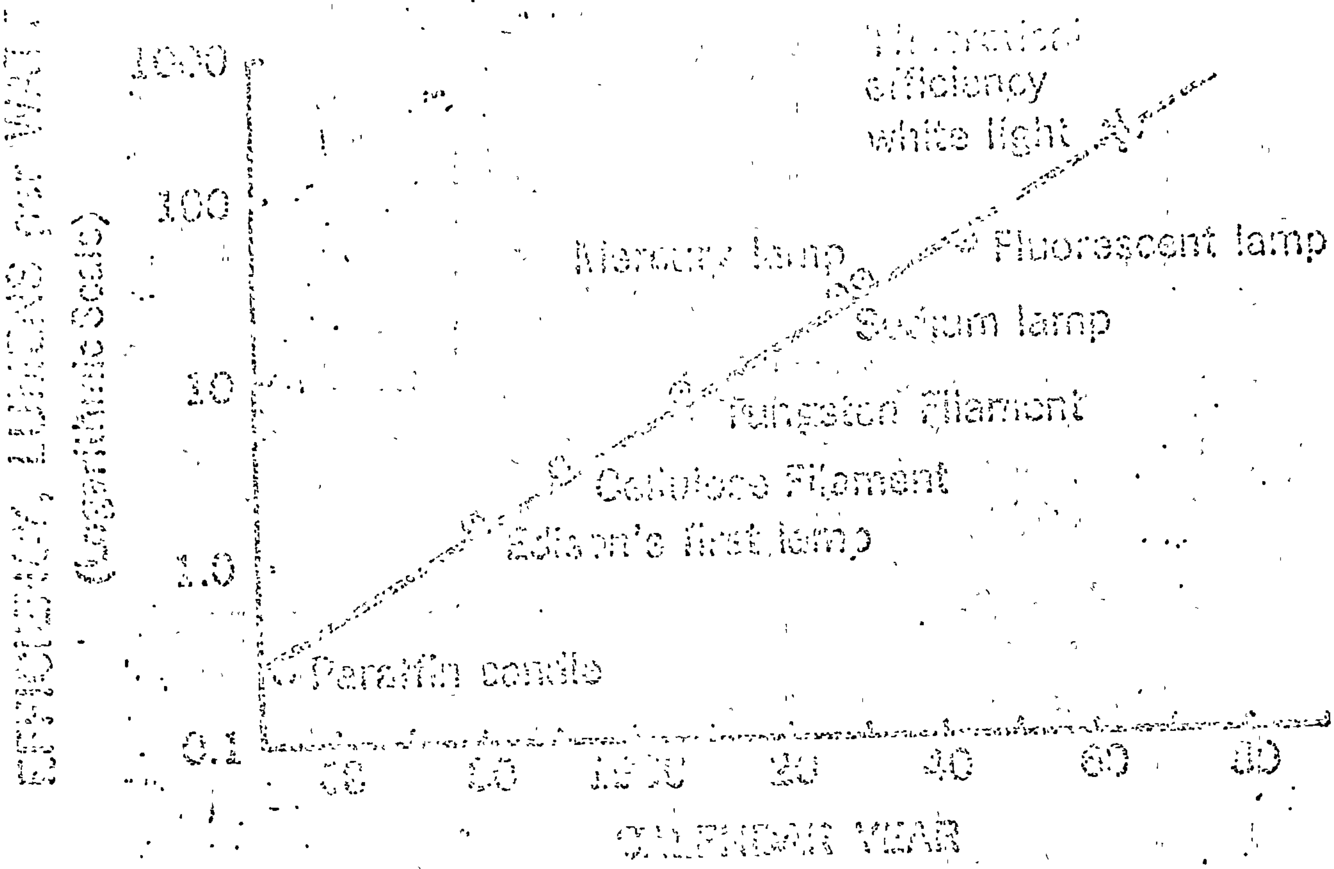
[illegible] II-1.—Typical Functional Capability—Time History.



[illegible] II-2.—Changes in Technology Leading to [illegible] Functional Capability.

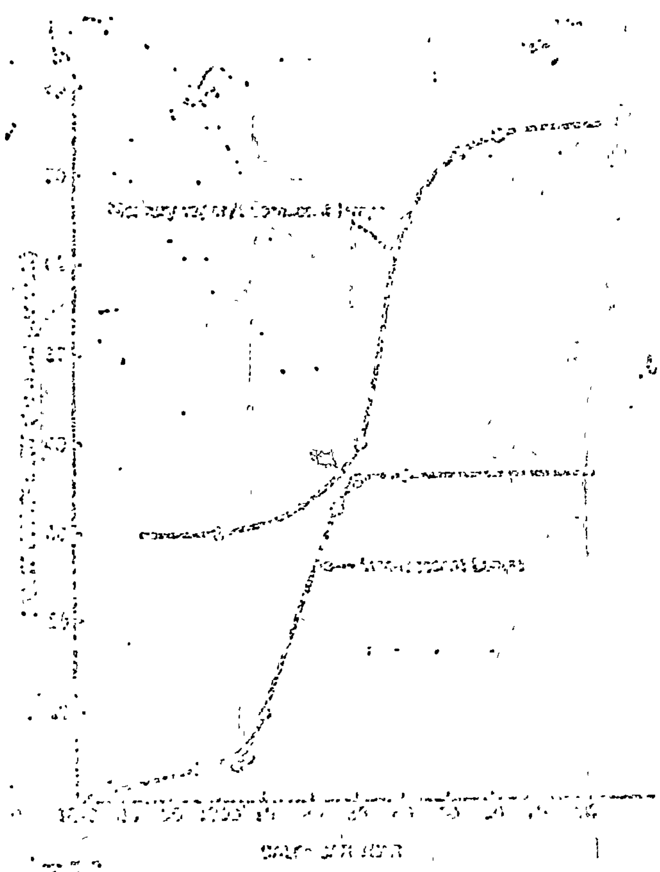


[illegible]



efficiency
white light
Fluorescent lamp
Tungsten Filament
Cellulose Filament
Edison's first lamp
Paraffin candle
(Logarithmic Scale)
1000
100
10
1.0
0.1
40
60

[illegible]



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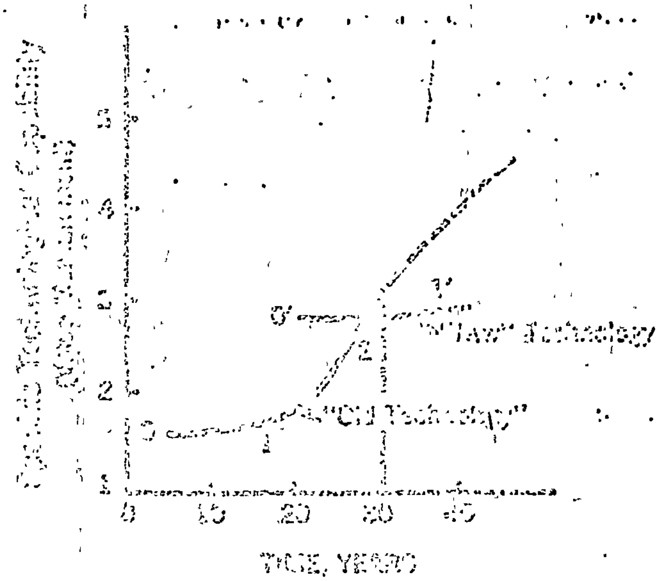


"Old Technology"

[illegible]

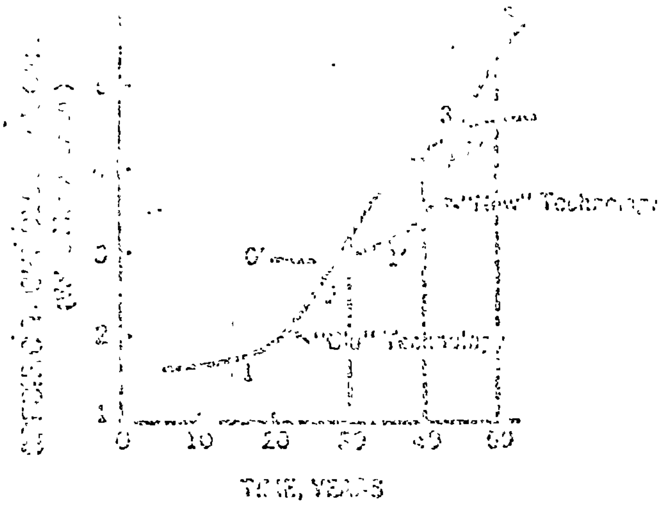


Figure XI-7—[illegible]

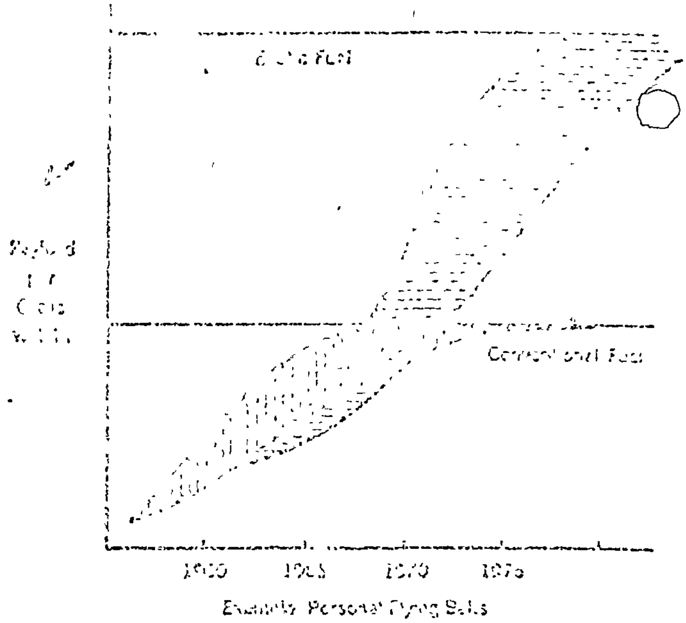


Figure XI-[illegible]—[illegible]

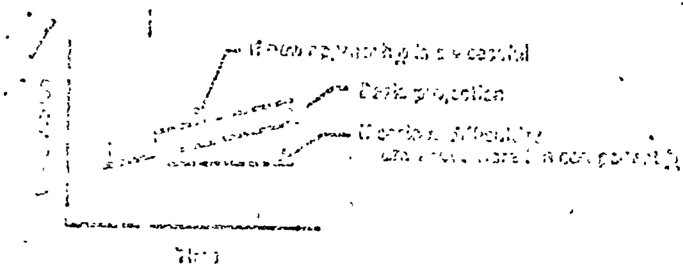


Figure [illegible]—[illegible]

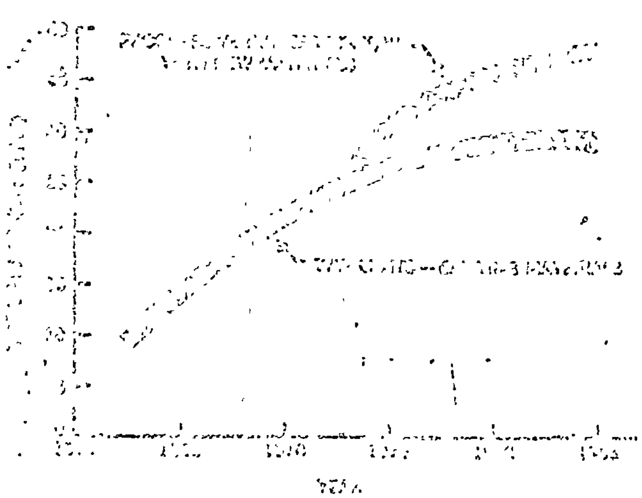


Figure [illegible]

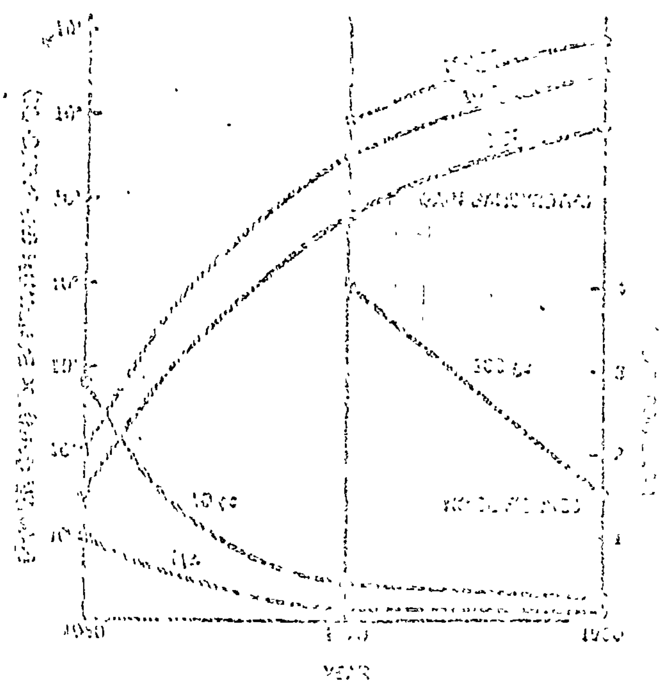
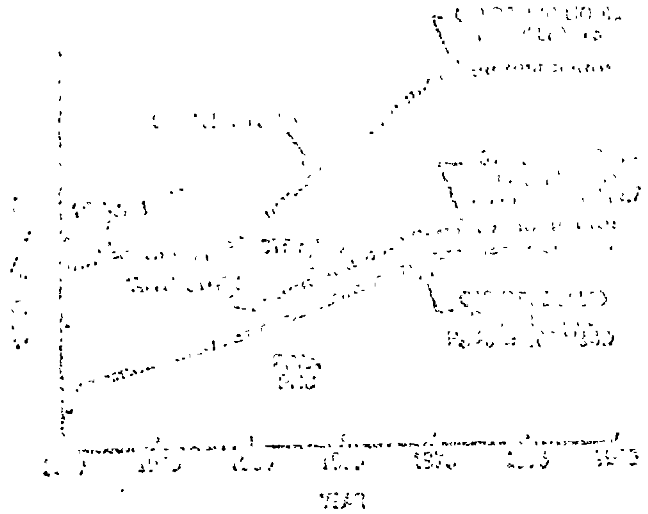
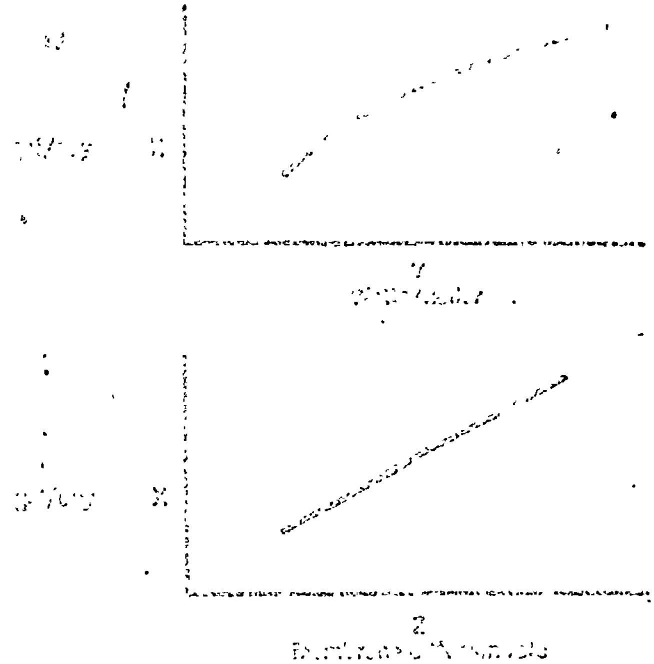
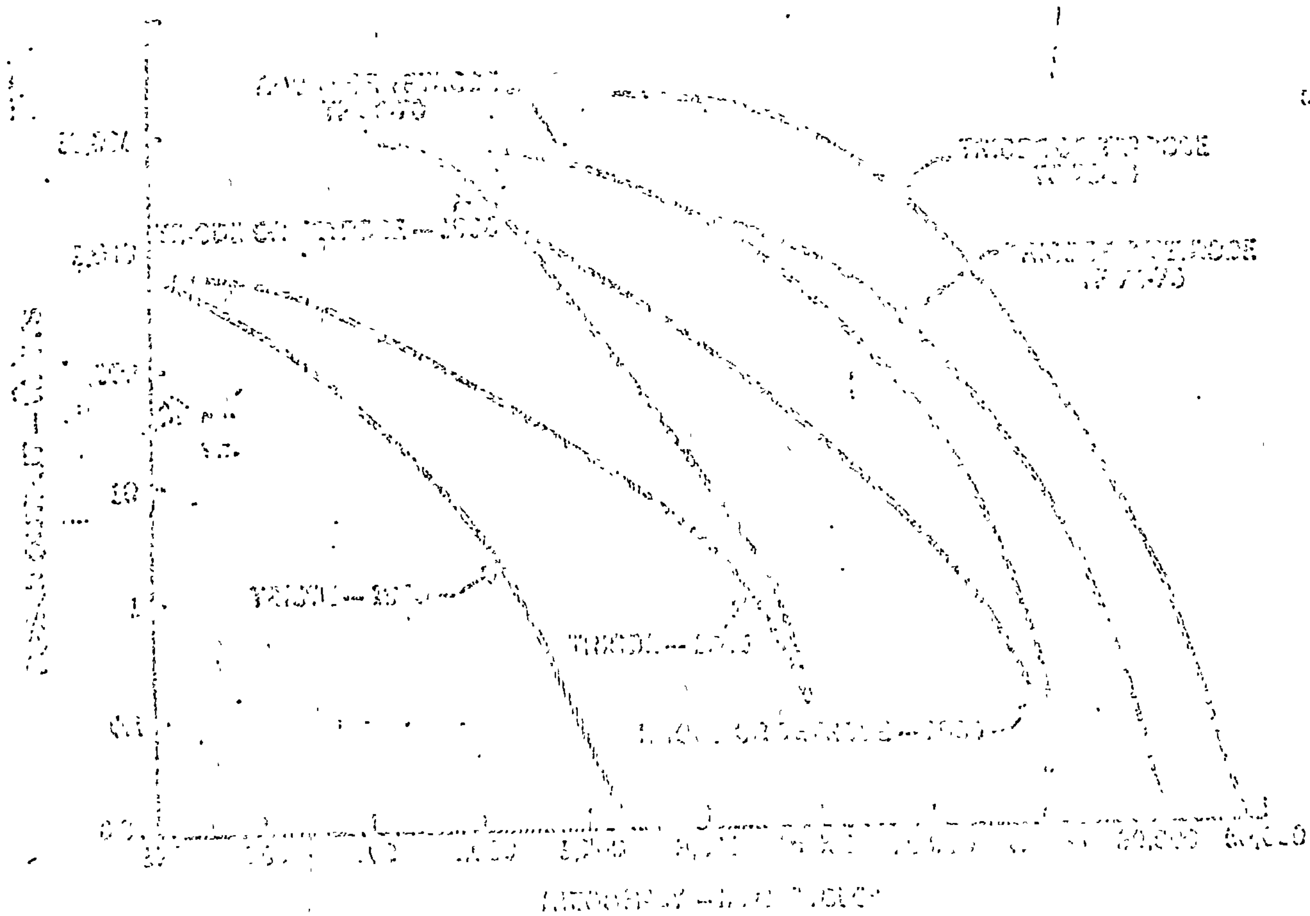
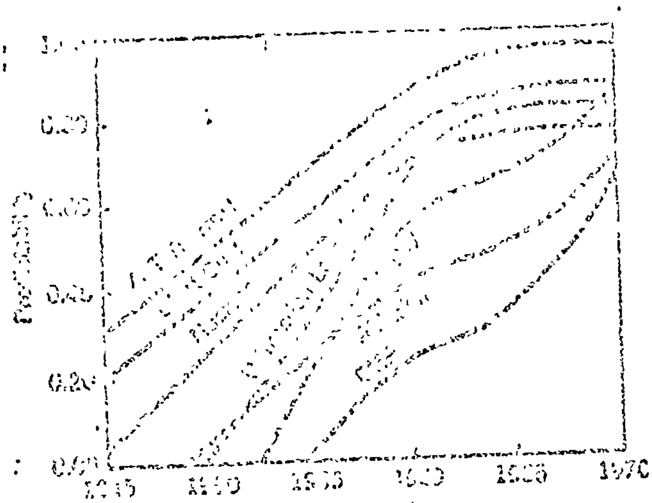


Figure [illegible]

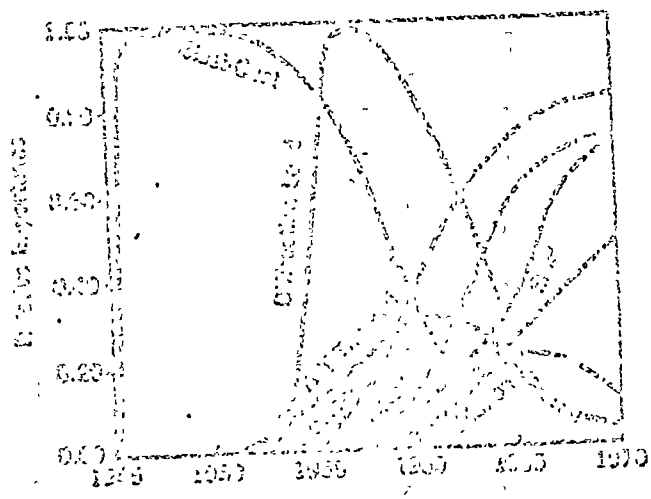




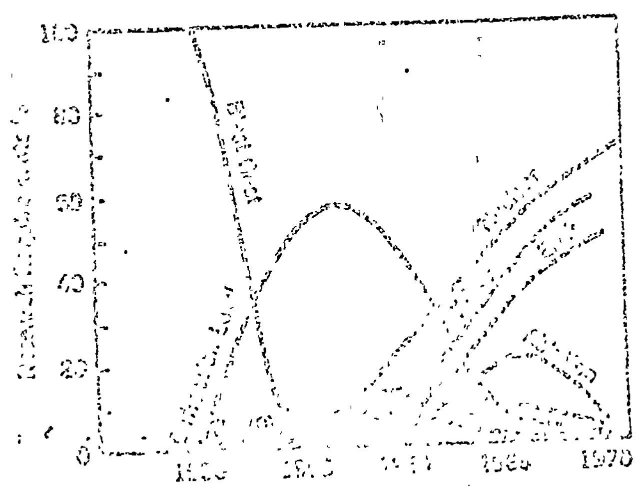




a. [illegible] Trends



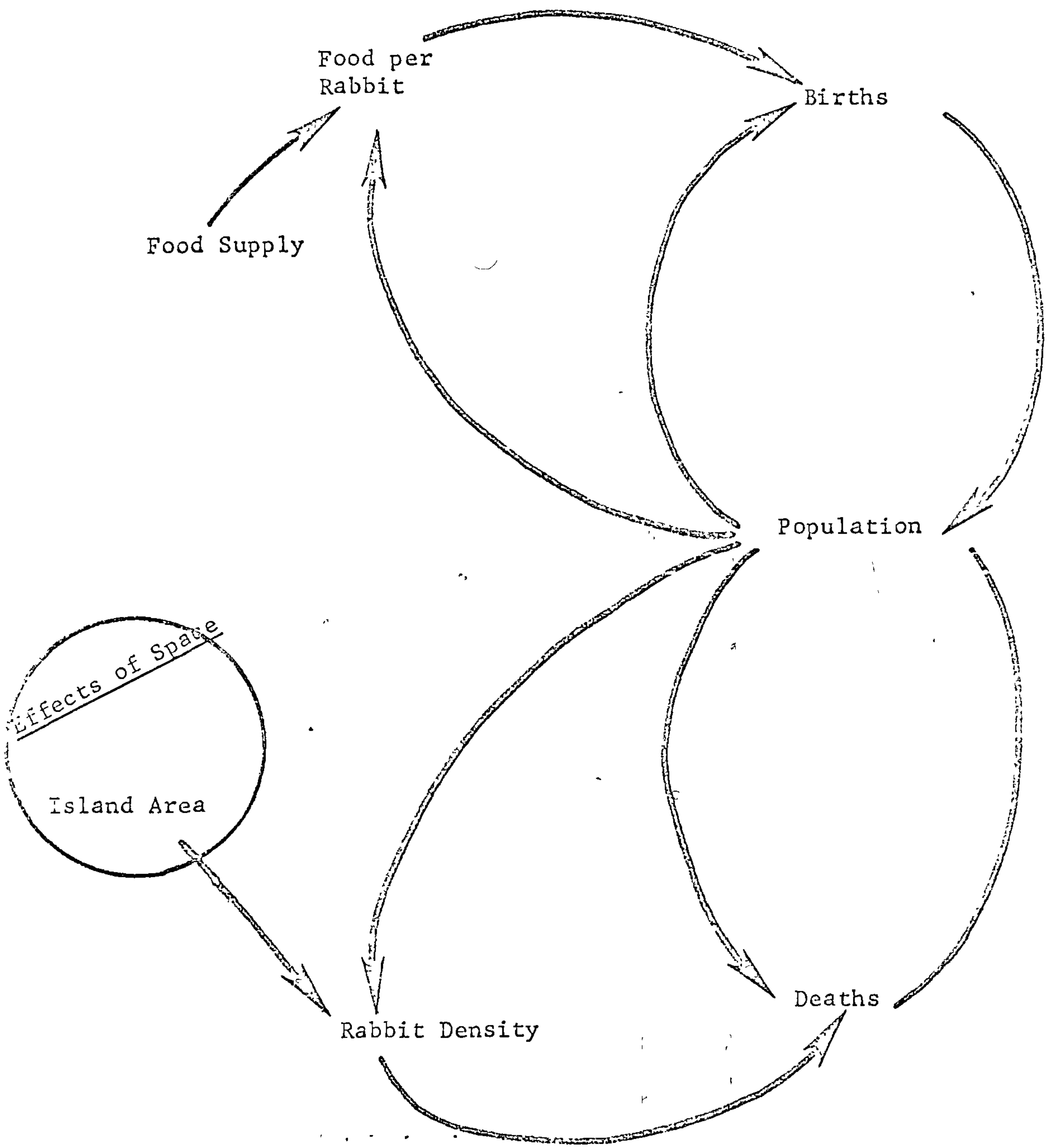
b. Relative Importance Trends



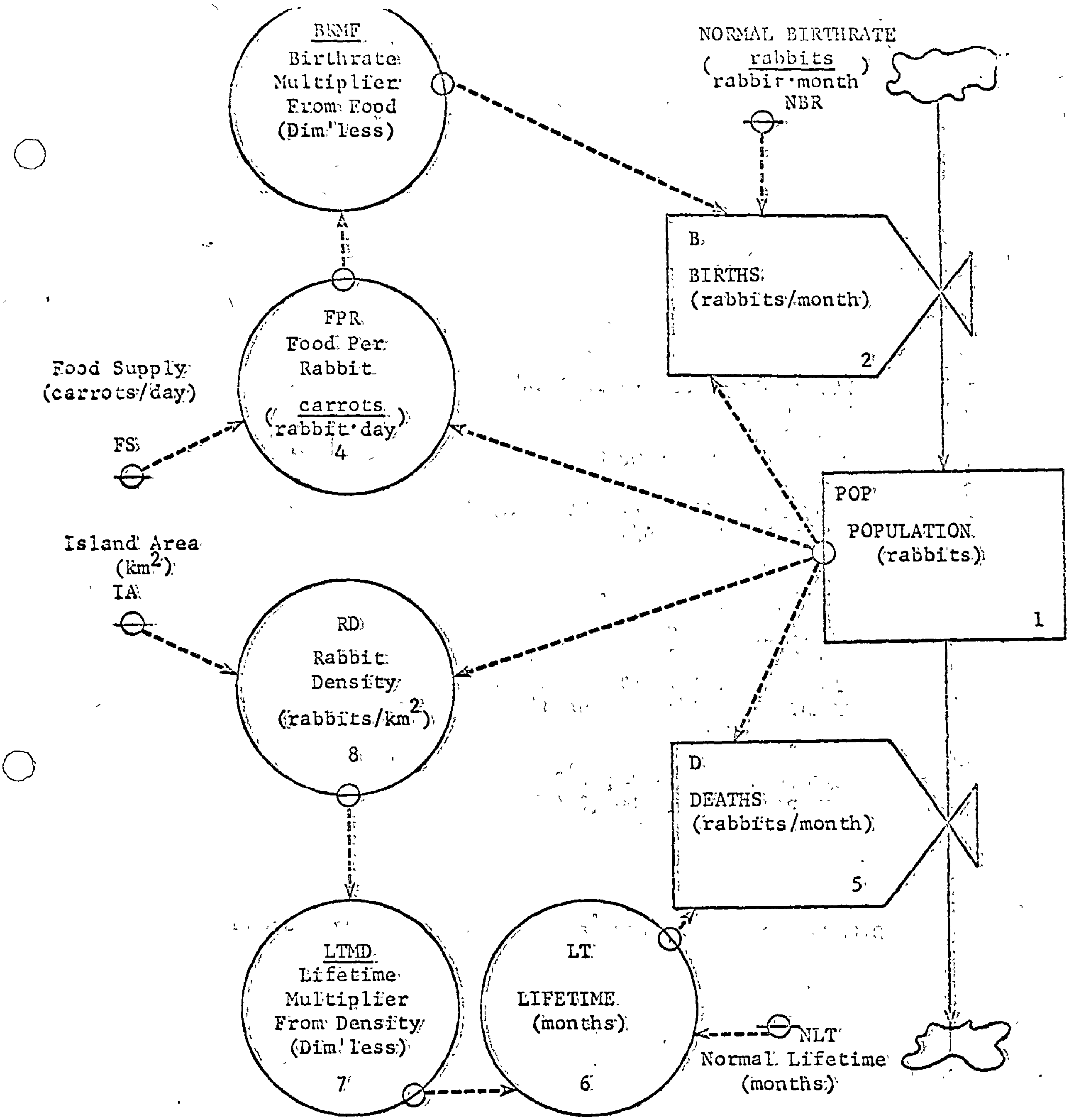
c. [illegible]

[illegible] Nuclear Weapons Effects
[illegible] Program.

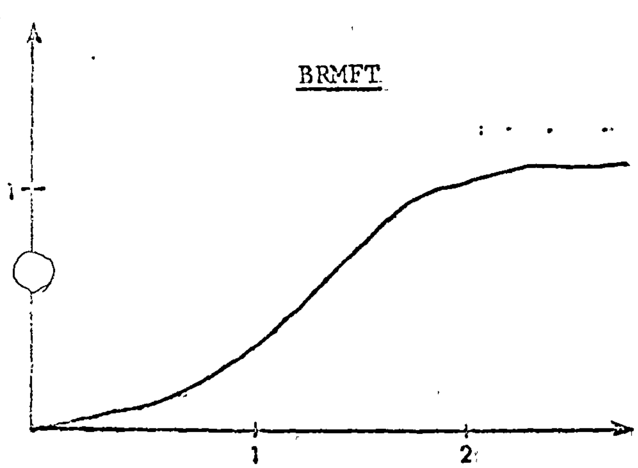
9.17 Dynamic Modeling - Is a model of situational interactions which enables the analyst to vary components of the system to study interactions and thus to provide useful understanding of future states. Jay Forrester's systems dynamics approach to the study of world problems is internationally known.

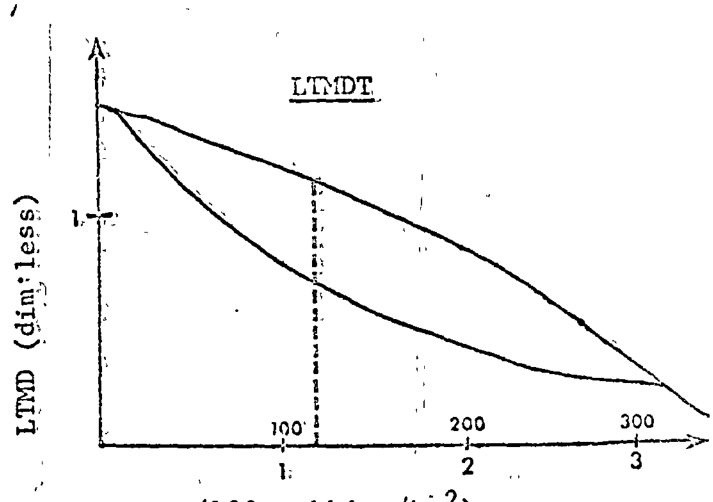


Casual Diagram for the Rabbit System when Including Disease.



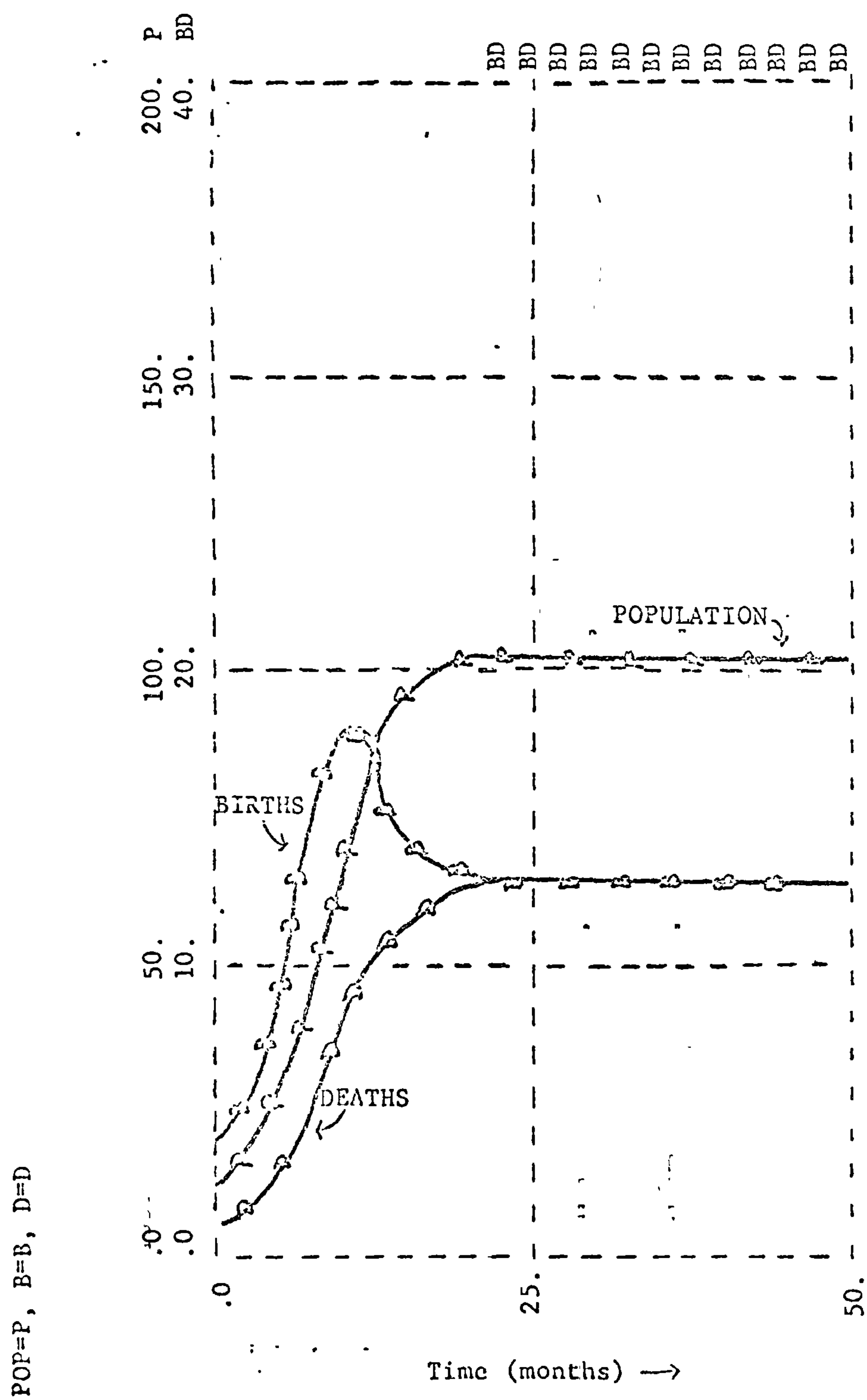
DYNAMO Flowdiagram for the Rabbit Model Including Disease



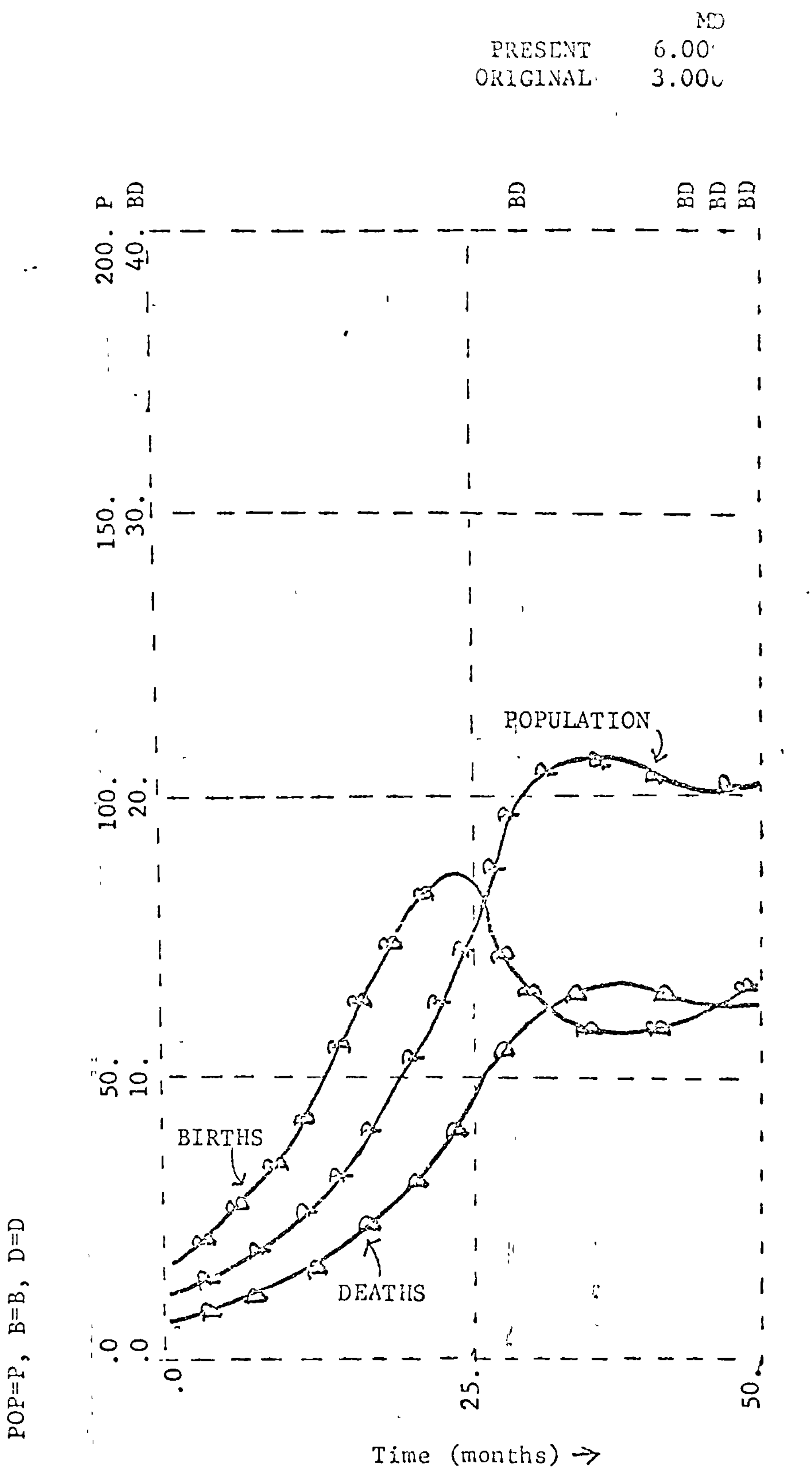


```
L       POP,K=POP.J+(DT) (B,JK-D,JK)                     1
N       POP=POPI
C       POPI=10
R       B.KL=WBR=BRMF.K=POP,K                            2
C       NBR=.3
A       BRMF.K=T .BHL(BRMFT.FPR.K,0,W,.5)                3
T       BRMFT=0/.I/.42/.9/1
A       FPR.K=FS/POP.K                                   4
C       FS=100
R       D.KL=POP.K/LT.K                                  5
A       LT.K=NLT*LTMD.K                                  6
C       NLT=8
A       LTMD,K=TA8IIL(LTMDT, RD.K.0,300,50)              7
T       LTMDT=1.I/1.1/1/.82/.6/.3/0
A       RD.K=POP,K/IA                                    8
C       IA=1
SPEC    LENGTH=56/DT=.1/pltper=2.5
PLOT    POP=P(0,200)/B=B,D=D(0,40)
```

DYNAMO program for the rabbit model including disease.

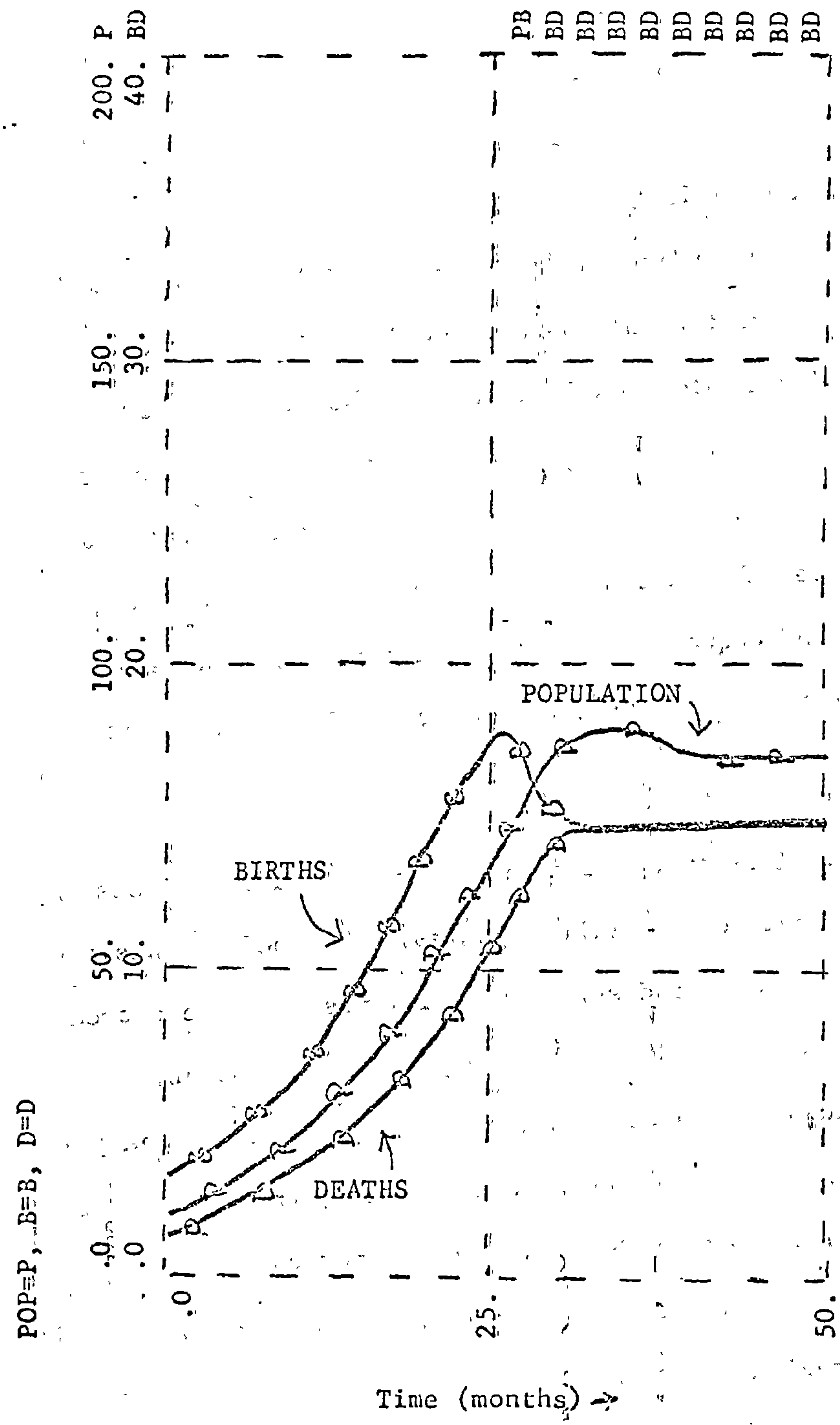


Simulation run showing the effect of including disease in the rabbit model.



The effect of doubling the maturation delay MD in the rabbit model including such a delay (but not including disease). The behaviourmode is not different from the one shown in figure 1-9.

	NLT
PRESENT	6.000
ORIGINAL	8.000



The effect of decreasing the normal lifetime NLT by 25% (in the rabbit model with maturation delay and without disease).

Chapter 10

THE DEMAND MODEL (Reid Model)

This chapter deals with Reid's Interstitial Demand Model which is actually a sub-model routine now used in conjunction with the Water and Sewerage Models. The Demand Model calculates the actual water demands and sewage output for a study region by selected areas and topics. It gives not only the future requirements of the study area, but also the incremental increases that the area will have. By applying this model the user can gain an adequate perspective of the water and sewer network prior to application of the individual Water and Sewerage Models.

10.1 Model Concept

The Demand Model is an application of technical coefficients which were developed or acquired from other studies. The coefficients are modeled to derive the water and sewage requirements with the accounting of these requirements to the different study areas for output.

The data is supplied to the model for each statistical analysis unit (SAU). The SAU's are selected in approximately one square mile areas, but with not more than two or three square miles per unit. Any system can be used that will require six numerical digits and account for all the areas in the study region. The SAU's can be as small as needed for the type of detail wanted. The rural areas can be larger.

10.2 Coding

The time spent by a planning agency coding the SAU's in their study area will be worthwhile if it is compatible with all other boundary areas used in this program (i.e., political jurisdiction, watershed, etc.). It is suggested that a map be used that has the other boundaries on it (including census tracts) and SAU's be made using these boundaries as much as possible. This will allow better analysis of the output results.

10.21 The coding for other areas are as follows:

(1) Political jurisdiction

(2) Watershed

(3) Water treatment plant

(4) Storage system

(5) Waste treatment plant

(6) Receiving stream

(7) Water sources

10.22 Also, it is suggested that all areas except watershed and receiving streams be coded numerically, in sequence.

(1) Start with one and numerically allocate each succeeding number of each area till they are all accounted for.

(2) Each new plant or jurisdiction will be assigned the next number in its area.

(3) Numbers of the area members are needed to set the "Do Loops" within the model. These numbers also prevent the program from handling large matrices that have many zeros in their structure.

10.23 The demand model also has the capability of looking at several special areas made up of selected SAU's independently or with the general study. This allows the user to game several alternatives at one time to see which special area is more suited for certain goals or objectives. The model also has the capability of handling special users of water. These areas can be handled individually and relieves the model of complicated functions for water usage or sewage return flow.

10.3 Advantages

10.31 Capable of handling special users of water. These areas can be handled individually and this relieves the model of complicated functions for water usage or sewage return flow.

10.32 Greatly reduces the process of computing water and sewage demands for large metropolitan areas.

10.33 Allows the user a large degree of freedom for exploring the future worlds.

10.34 Incremental change output (as model is run) greatly increases the users' gaming options to determine how changes increase the actual demands on system above their present operation.

10.35 Output is also extremely valuable in examining the delta change in the specific study area.

10.4 Disadvantages

10.41 Data requirements are quite extensive.

10.42 Requires good data management to keep it in proper order.

10.43 Use of equipment with good editing capabilities is mandatory if good use of alternative runs is to be made.

10.5 Data Files

A data file of all information is needed for each run of the Demand Model. The model is then run for each time increment wanted. These data files will be duplicated as far as the area codings are concerned with this base year containing the initial data input (10.6, Input).

The data files for the future years are developed from the projected data (10.7, Output). These files have to be built using the same areas that existed in the previous files, but can have new SAU's in addition to the old ones.

10.6 Input

10.61 For each SAU

(1) SAU code

(2) Political jurisdiction code

(3) Watershed code

(4) Water treatment plant code

(5) Storage system code

(6) Waste treatment plant code

(7) Receiving stream code

(8) Source of raw water code

(9) Special user code

(10) Population forecast

(11) Land use forecast

(12) Commercial land use forecast

(13) Employment forecasts by SIC code (21)

(14) Agricultural land use forecast

(15) Irrigated land forecast

(16) Special user forecasts

(a) Colleges

(b) Military bases

(c) Hospitals

(d) Industrial

10.62 Unit use factors

(1) Domestic by political jurisdiction (gal/capita)

(2) Institutional (gal/acre)

(3) Commercial (gal/acre)

(4) Industrial by SIC codes (gal/employee)

(5) Rural (gal/rural dweller)

(6) Irrigation (gal/acre)

(7) Special users (gal/person)

10.63 Sewage flow factors

(1) Domestic

(2) Institutional

(3) Commercial

(4) Industrial by SIC code

(5) Rural

(6) Irrigation

10.7 Output

10.71 Provided for the following categories

(1) Domestic

(2) Institutional (including hospitals, schools and military bases)

(3) Commercial

(4) Industrial by SIC code and special user

(5) Rural

(6) Irrigation

10.72 Water requirements

(1) By political jurisdiction

(2) By source of supply

(3) By water treatment plant

(4) By treated water storage system

(5) By special area

10.73 Sewage loads

(1) By political jurisdiction

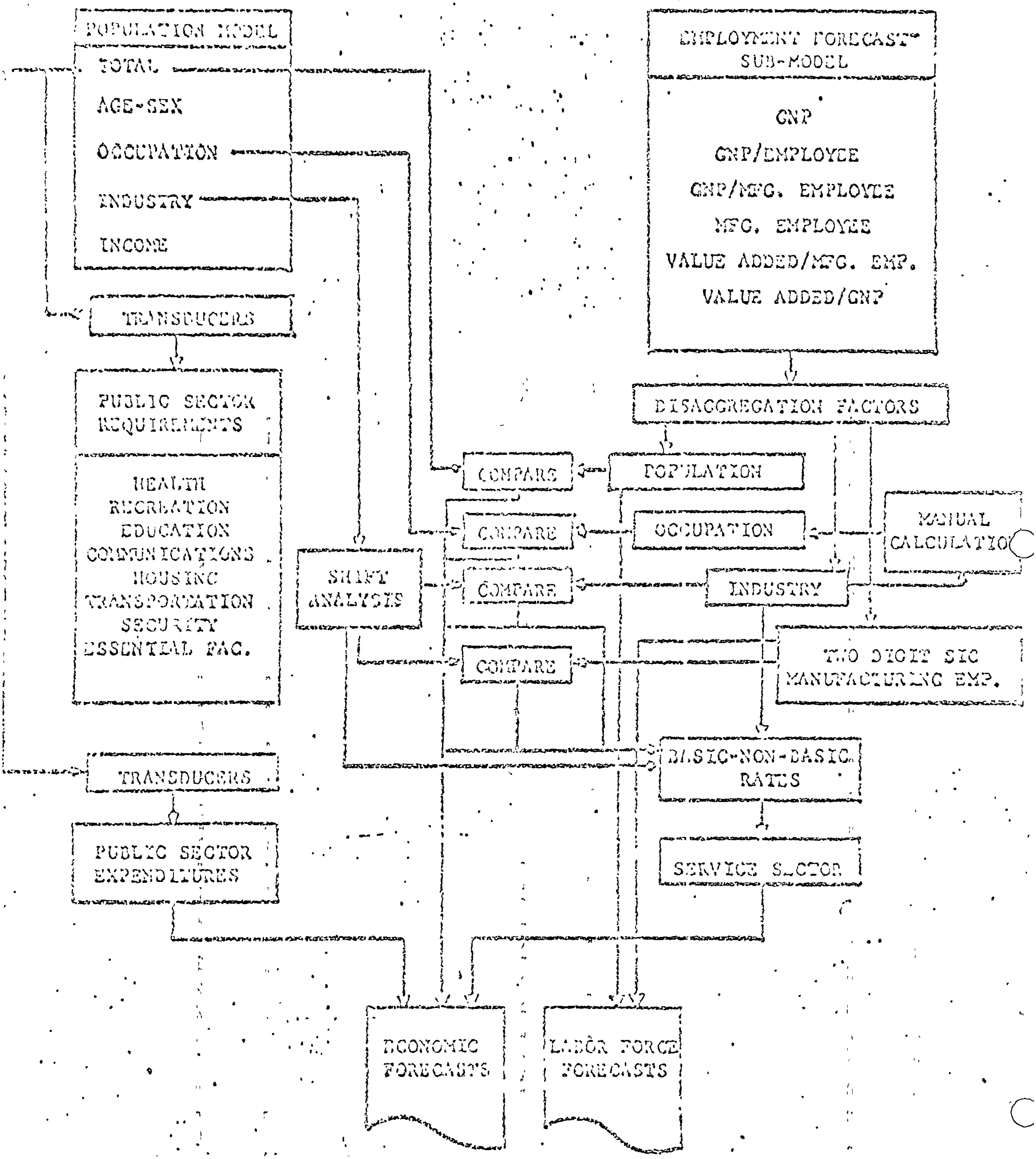
(2) By watershed

(3) By sewage treatment plant

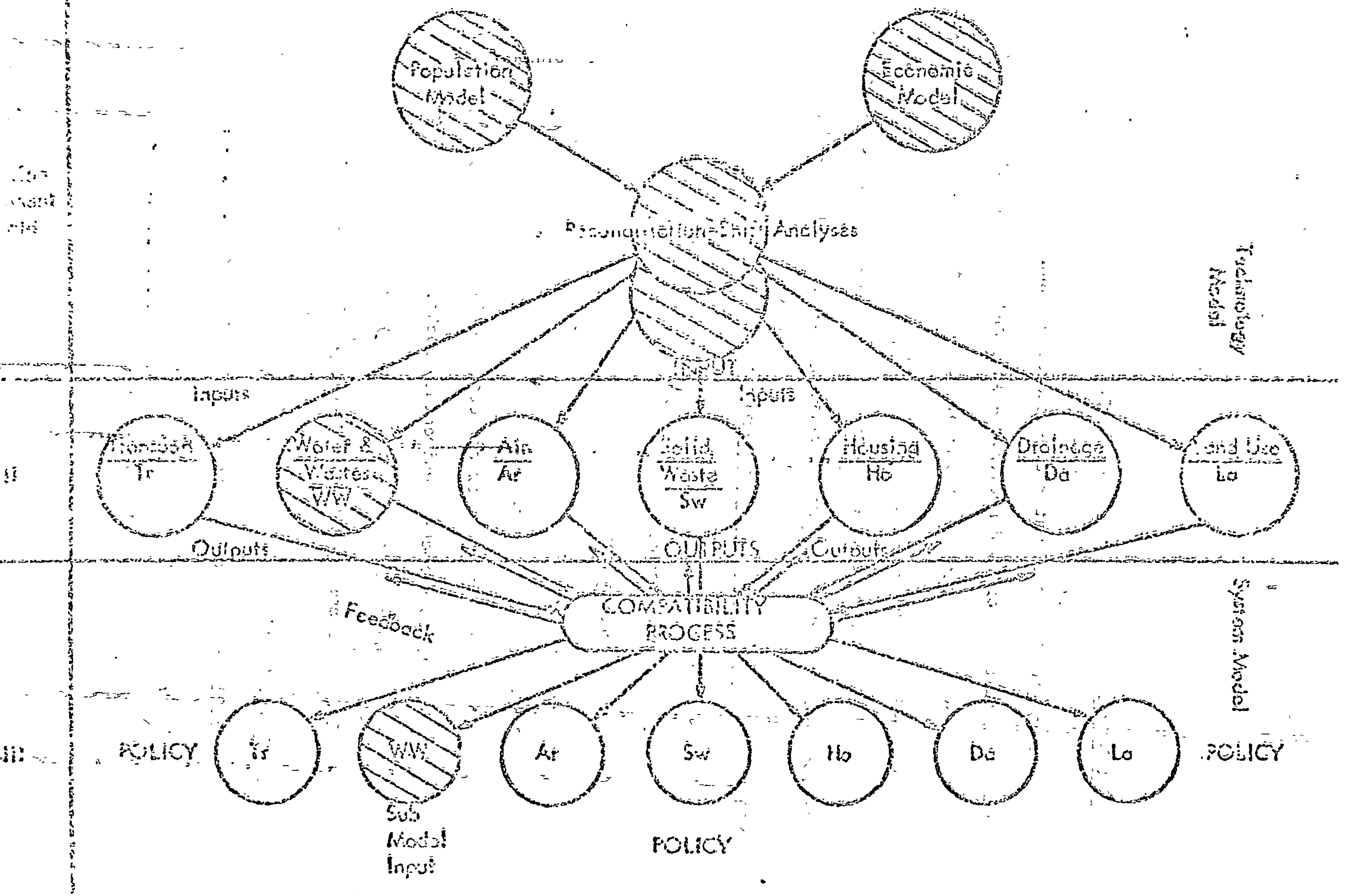
(4) By receiving stream

(5) By special area

ECONOMIC MODEL FORMAT



GENERALIZED SCHEME MODEL



Chapter 11

WATER SUPPLY

Adequate supply of water of satisfactory sanitary quality is a primary requisite for good health. A safe and adequate water supply for 2 billion people, about two-thirds of the world's population, is still a dream. Recent studies using modeling tools for water supply systems have produced results such as: excesses and deficiencies for a city and information about world water supply activities (see Figures 1 and 2).

11.1 Water Cycle and Its Characteristic

(see Figure 2)

11.11 Surface water

11.12 Ground water

11.13 Rain water

11.14 Geology - rocks

Underground water sources - wells, etc.

Igneous rocks, sedimentary rocks, metamorphic rocks

Shale and slate, sand and clay, etc.

11.15 Streams, lakes, impoundments, swamps, etc.

11.2 Water Quality

11.21 Public water supply criteria sources

(1) U. S. Public Health Service

1962 drinking water standards

WATER – EXCESSES AND DEFICIENCIES FOR NORMAN					
	Time Intervals				
	1970	1975	1980	1985	1990
POPULATION	52,117	59,500	68,000	76,500	87,000
Water Usage-GPCD***	118	120	124	129	137
Water Usage-MGD	6.15	7.14	8.43	9.87	11.92
Industrial Water Usage-MGD	1.65	7.42	3.81	5.47	7.12
Total USAGE MGD	7.80	9.56	12.24	25.34	19.04
SOURCE					
Thunderbird Lake AVG-MGD	8.55	8.55	8.55	8.55	8.55
Ground supply* AVG-MGD	30 wells** 9.00	30 wells 9.00	30 wells 9.00	30 wells 9.00	30 wells 9.00
Total MGD	17.55	17.55	17.55	17.55	17.55
Excess/Deficiency MGD	9.75	7.99	5.31	2.21	-1.49
Treatment plant-MGD	6.0	6.0	6.0	6.0	6.0
Excess/Deficiency-MGD	up to 6.0	up to 5.44	up to 2.76	-6.34	-2.55

* Ground supply requires no treatment other than chlorination.

** Aug. vied = 0.24 MGD/well

*** Maximum Daily Demand

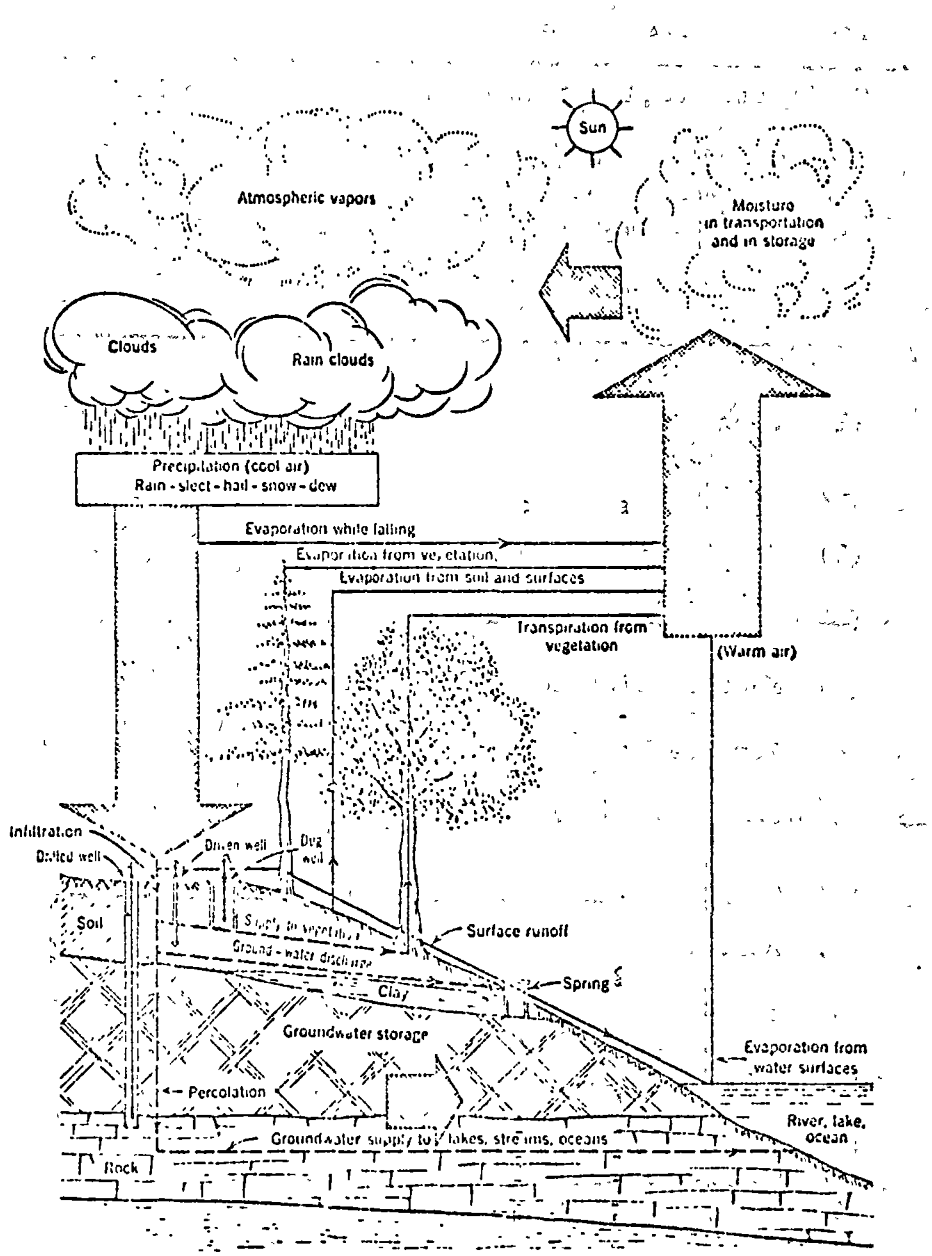
Figure 1. Water – Excesses and Deficiencies for Norman

Figure 2. WHO Water Supply

COLLABORATION PROVIDED BY PAHO IN COMMUNITY WATER SUPPLY AND OTHER ENVIRONMENTAL ACTIVITIES
(STAFF AND SHORT-TERM CONSULTANTS), 1972

Type of services	Zone I							Zone II				Zone III							Zone IV				Zone V	Zone VI			
	Barbados	Guyana	Jamaica	Surinam	Trinidad and Tobago	West Indies	Venezuela	Cuba	Dominican Republic	Haiti	Mexico	British Honduras	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Bolivia	Colombia	Ecuador	Peru	Brazil	Argentina	Chile	Paraguay	Uruguay
COMMUNITY WATER SUPPLY																											
Water authorities—Organization or improvement	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	
Other agencies—Organization or improvement		X	X	X		X			X	X	X					X				X	X	X	X	X	X	X	
Water supply system—Design				X					X	X	X	X			X	X		X	X	X				X		X	
Organization and management	X	X		X	X	X			X	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X
Problems		X		X	X	X			X	X	X	X				X		X		X	X		X	X			X
Planning—National or regional					X	X			X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X
Water rates—Establishment or improvement				X	X	X			X		X		X					X	X	X		X	X	X			
Public relations				X		X			X		X								X				X			X	
Rural community water supply		X		X		X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Groundwater exploration, drilling				X					X	X	X		X				X	X	X	X						X	X
Community development self-help									X	X	X	X		X		X	X	X	X	X			X	X		X	
Water quality control	X	X	X	X	X	X			X	X	X	X		X			X	X	X	X	X	X	X	X	X		
Water resources study			X	X		X			X	X	X	X	X			X		X		X	X			X	X		
Revolving fund mechanism									X		X					X			X		X		X	X		X	
Fluoridation	X		X	X	X	X				X	X		X				X		X	X	X	X	X				
Laboratories—Installation operation		X		X		X			X	X	X						X		X	X	X	X	X	X	X		
Design standards criteria—Development			X	X		X			X		X	X	X	X		X				X	X	X		X	X	X	
UNICEF projects				X		X	X							X		X	X		X	X	X	X	X			X	X
Financing—Method or loan request preparation				X	X				X	X		X		X	X	X		X	X	X						X	
OTHER ENVIRONMENTAL SANITATION																											
Ministry of health—Assistance	X	X	X	X		X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sanitary engineering department—Assistance	X	X	X	X		X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Environmental sanitation (miscellaneous)	X	X	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pollution control sewage treatment, industrial waste	X		X	X		X			X		X			X				X		X	X	X	X	X	X		X
Privy program				X		X			X	X			X	X	X	X	X	X	X		X	X		X		X	
Oxidation ponds—Design and use									X		X					X			X	X	X		X	X	X		X
Solid waste sanitary landfill	X	X		X		X			X		X		X			X			X	X	X	X	X	X	X		
Air pollution control			X				X				X		X	X	X			X	X	X	X	X	X	X	X		X
Industrial hygiene and radiation	X	X	X			X	X		X				X			X			X	X	X	X	X	X			X
Studies or surveys	X	X	X			X			X	X	X	X		X					X		X		X	X	X	X	
UNDP projects—Supervision or development		X		X			X		X		X					X	X		X	X	X	X	X	X	X		X
Sanitary engineering programs—Universities		X		X			X		X	X	X		X	X	X	X	X	X		X	X	X		X	X	X	X
Short courses—Organization or presentation	X		X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Courses—Sanitary inspectors		X	X						X			X	X	X	X	X				X	X	X		X	X		
Seminars symposia		X	X		X						X				X				X	X	X		X	X	X	X	
Centers or institutes											X								X	X			X	X	X		
Manuals—Preparation			X	X	X		X		X		X			X		X		X	X	X	X		X	X	X	X	X

Figure 3. Hydrologic or Water Cycle



(2) Water Quality Criteria, April 1968 (see Figure 4)

Report of the National Technical Advisory Committee,

Secretary of the Interior

11.22 Sanitary survey - water sampling

11.23 Bacterial examination

Coliform, fecal cotiform, E-coli, total count

Membrane filter technique

Streptococci, enterococci

Most probable number (MPN)

11.24 Physical examination

(1) Odor

(2) Taste

(3) Turbidity

(4) Color

(5) Macroscopic and nuisance organisms

(6) Temperature

11.25 Chemical examination

(1) Hardness

(2) Alkalinity

(3) pH

(4) CO_2

(5) D. O.

(6) Lead

(7) Copper

(8) Lime

(9) Chlorides - of intestinal origin; residual

Figure 4. Surface-water Criteria for Public Water Supplies

Constituent or Characteristic	Permissible Criteria	Desirable Criteria
Physical:		
Color (color units)	75	<10
Odor	†	Virtually absent
Temperature*	do	†
Turbidity	do	Virtually absent
Microbiological:		
Coliform organisms	10,000/100 ml[1]	<100/100 ml[1]
Fecal coliforms	2,000/100 ml[1]	<20/100 ml[1]
Inorganic chemicals:	(mg/l)	(mg/l)
Alkalinity	†	†
Ammonia	0.5 (as N)	<0.01
Arsenic*	0.05	Absent
Barium*	1.0	do
Boron*	1.0	do
Cadmium*	0.01	do
Chloride*	250	<25
Chromium,* hexavalent	0.05	Absent
Copper*	1.0	Virtually absent
Dissolved oxygen	≥4 (monthly mean) ≥3 (individual sample)	Near saturation
Fluoride*	†	†
Hardness*	do	do
Iron (filterable)	0.3	Virtually absent
Lead*	0.05	Absent
Manganese* (filterable)	0.05	do
Nitrates plus nitrites*	10 (as N)	Virtually absent
pH (range)	6.0–8.5	†
Phosphorus*	†	do
Selenium*	0.01	Absent
Silver*	0.05	do
Sulfate*	250	<50
Total dissolved solids* (filterable residue)	500	<200
Uranyl ion*	5	Absent
Zinc*	5	Virtually absent
Organic chemicals:		
Carbon chloroform extract* (CCE)	0.15	<0.04
Cyanide*	0.20	Absent
Methylene blue active substances*	0.5	Virtually absent
Oil and grease*	Virtually absent	Absent
Pesticides:		
Aldrin*	0.017	do
Chlordane*	0.003	do
DDT*	0.042	do

Figure 4. Surface-water Criteria for Public Water Supplies (continued)

Constituent or Characteristic	Permissible Criteria	Desirable Criteria
Pesticides (cont'd)		
Dieldrin*	0.017	do
Endrin*	0.001	do
Heptachlor*	0.018	do
Heptachlor epoxide*	0.018	do
Lindane*	0.056	do
Methoxychlor*	0.035	do
Organic phosphates plus carbamates.*	0.1[2]	do
Toxaphene*	0.005	do
Herbicides:		
2,4-D plus 2,4,5-T, plus 2,4,5-TP*	0.1	do
Phenols*	0.001	do
Radioactivity:	(pc/l)	(pc/l)
Gross beta*	1,000	<100
Radium-226*	3	<1
Strontium-90*	10	<2

Source. *Water Quality Criteria,* Report of the National Technical Advisory Committee to the Secretary of the Interior, Washington, D.C., April 1968, p. 20.

*The defined treatment process has little effect on this constituent. (Coagulation, sedimentation, rapid sand filtration and chlorination.)

‡No consensus on a single numerical value that is applicable throughout the country. See Report and text.

[1]Microbiological limits are monthly arithmetic averages based on an adequate number of samples. Total coliform limit may be relaxed if fecal coliform concentration does not exceed the specified limit.

[2]As parathion in cholinesterase inhibition. It may be necessary to resort to even lower concentrations for some compounds or mixtures. (Permissible levels are based on the recommendations of the Public Health Service Advisory Committee on Use of the PHS Drinking Water Standards.)

(10) Iron

(11) Managanese

(12) Sodium

(13) Sulfates

(14) Total dissolved solids

(15) Fluorides

(16) ABS - Alky Bengene Sulfonate

(17) Free Amonnia

(18) Albuminoid Ammonia

(19) Nitrites

(20) Nitrates

(21) Hydrogen Sulfide

(22) Uranyl Ion

(23) Phenols

(24) Radioactivity (gross beta)

(25) Carbon -- chloroform extract (CCE)

(26) Pesticides

(27) Phosphorous

(28) Mercury

11.26 Microscopic examination

Plankton - algae, fungi, protozoa, rotifera, crustacea

11.3 Demands for Water Supply

(see Figure 5)

Figure 5. Guides for Water Use

Type of Establishment	gpd*
Residential:	
Dwellings and apartments (per bedroom)	150
Temporary quarters:	
Boarding houses	65
Additional for nonresident boarders	10
Campsites (per site)	100
Cottages, seasonal	50
Day camps	15 to 20
Hotels	65 to 75
Mobile home parks (per unit)	125 to 150
Motels	50 to 75
Restaurants (toilets and kitchens)	7 to 10
Without public toilet facilities	2½ to 3
With bar or cocktail lounge, additional	2
Summer camps	40 to 50
Public establishments:	
Boarding schools	75 to 100
Day schools	15 to 20
Hospitals (per bed)	250 to 500
Institutions other than hospitals (per bed)	75 to 125
Places of public assembly	3 to 10
Turnpike rest areas	5
Turnpike service areas (10 percent of cars passing)	15 to 20
Amusement and commercial:	
Airports (per passenger)	3 to 5
Country clubs	25
Day workers (per shift)	15 to 35
Drive-in theaters (per car space)	5
Gas station (per vehicle serviced)	10
Milk plant, pasteurization (per 100 lb of milk)	11 to 25
Movie theaters (per seat)	3
Picnic parks with flush toilets	5 to 10
Self-service laundries (per machine)	400
Shopping center (per 1,000 ft² floor area)	250
Stores (per toilet room)	400
Swimming pools and beaches with bathhouses	10
Farming: (per animal)	
Cattle or Steer	12
Milking cow	35
Goat or Sheep	2
Hog	4
Horse or Mule	12
Cleaning milk equipment and tank	2
Cow washer	5 to 10
Liquid manure handling, cow	1 to 3
Poultry (per 100):	
Chickens	5 to 10
Turkeys	10 to 18
Cleaning and sanitizing equipment	4

*Per person unless otherwise stated.

Figure 5. Guides for Water Use (continued)

Miscellaneous Water Use Estimates	Water Use			
Home:	Gallons			
Water closet, tank	4 to 6 per use			
Water closet, flush valve 25 psi(pounds per square inch)	30 to 40/min			
Washbasin	1½/use			
Bathtub	30/use			
Shower	25 to 30/use			
Dishwashing machine	9½ to 15½/load			
Garbage grinder	1 to 2/day			
Automatic laundry machine	34 to 57/load			
Garden hose:				
5/8 inch, 25-ft head	200/hr			
3/4 inch, 1/4 inch nozzle, 25-ft head	300/hr			
Lawn sprinkler	120/hr			
3,000 square ft lawn, 1 in. per week	1,850/wk			
Air conditioner, water-cooled, 3-ton, 8 hr per day	2,880/day			
Water demand per dwelling unit:				
Average day	400 gpd			
Maximum day	800 gpd			
Maximum hourly rate	2,000 gpd			
Maximum hourly rate with appreciable lawn watering	2,800 gpd			
Home water system: (Minimums)	Bedrooms			
	2	3	4	5
Pump capacity, gal/hr	250	300	360	450
Pressure tank, gal	42	82	82	120
Service line from pump, diameter in in.†	¾	¾	1	1¼
Other:	Gallons			
Fire hose, 1½ in., ½ in. nozzle, 70-ft head	2,400/hr			
Drinking fountain, continuous flowing	75/hr			
Dishwashing machine, commercial				
Stationary rack type, 15 psi	6 to 9/min			
Conveyor type, 15 psi	4 to 6/min			
Fire hose, home, 10 gpm at 60 psi for 2 hours, ¾ inch	600/hr			
Restaurant, average	35/seat			
Restaurant, 24-hr	50/seat			
Restaurant, tavern	20/seat			
Gas station	500/set of pumps			

Developing areas of the world:
- One well or tap/200 persons; controlled tap or hydrant — Fordilla type
- Average consumption, 5 gal/capita/day at well or tap
- Water system design, 30 gal/capita/day (10 gal/capita is common)
- Pipe size, 2 in. and preferably larger (1 and 1½ in. common)
- Drilled well, cased, 6 to 8 in. diameter
- Water system pressure, 20 lb/sq in.
- (Keep mechanical equipment to a minimum)

†Service line less than 50 ft long, brass or copper. Use next larger size if non-pipe is used. Use minimum 1¼ in. service with flush valves. Minimum well yield, 5 gal/min.

11.4 Treatment of Water (see Figure 6)

12.41 Chlorination

12.42 Plain sedimentation

12.43 Micro straining

12.44 Coagulation and settling

12.45 Filtration

12.45.1 Slow sand filter

12.45.2 Rapid sand filter

12.45.3 Pressure sand filter

12.45.4 Diatomaceous earth filter

11.5 Control of Microorganisms

(see Figures 7 and 8)

11.6 Causes of Tastes and Odors

(1) Oils

(2) Minerals

(3) Gases

(4) Organic matter

(5) Microorganisms

(6) Wastes from plants; sewage

(7) Weeds, decaying vegetation

(8) High concentration of Fe, Mn, SO_4, H_2S, CL

11.7 Methods to Remove or Reduce Objectional Tastes and Odors

(see Figure 9)

(1) Free residual chlorination or superchlorination

Figure 6.

Treatment of Water—Design and Operation Control

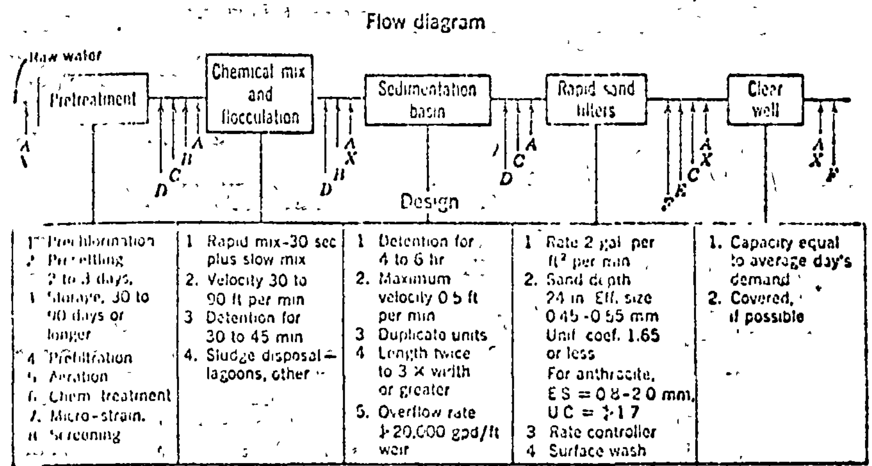


Figure 3-16 Rapid sand filter plant flow diagram.

Possible Chemical Combinations

A Chlorine. Also bar racks and coarse screens if needed.

B Coagulant; aluminum sulfate (pH 5.5 to 8.0), ferric sulfate (pH 5.0 to 11.0), ferrous sulfate (pH 8.5 to 11.0), ferric chloride (pH 5.0 to 11.0), sodium aluminate, activated silica, organic chemicals (polyelectrolytes).

C Alkalinity adjustment, lime, soda ash, or polyphosphate.

D—Activated carbon, potassium permanganate.

E Dechlorination; sulfur dioxide, sodium sulfite, sodium bisulfite, activated carbon.

F Fluoridation treatment.

X Chlorine dioxide.

NOTE. The chlorinator should be selected to prechlorinate surface water at 20 mg/l and postchlorinate at 3 mg/l. Provide for a dose of 3 mg/l plus chlorine demand for groundwater.

Figure 7. Dosage of Copper Sulfate to Destroy Microorganisms, Pounds per Million Gallons

Organism	Taste, Odor, Other	Dosage
Diatomaceae	(Usually brown)	
Asterionella	Aromatic, geranium, fishy	1.0 to 1.7
Cyclotella	Faintly aromatic	Use chlorine
Diatoma	Faintly aromatic	-
Fragilaria	Geranium, musty	2.1
Meridon	Aromatic	-
Melosira	Geranium, musty	1.7 to 2.8
Navicula		0.6
Nitzchia		4.2
Stephanodiscus	Geranium, fishy	2.8
Synedra	Earthy, vegetable	3.0 to 4.2
Tabellaria	Aromatic, geranium, fishy	1.0 to 4.2
Chlorophyceae	(Green algae)	
Cladophora	Septic	4.2
Closterium	Grassy	1.4
Coelastrum		0.4 to 2.8
Conferva		2.1
Desmidium		16.6
Dictyosphaerium	Grassy, nasturtium, fishy	Use chlorine
Draparnaldia		2.8
Enteromorpha		4.2
Eudorina	Faintly fishy	16.6 to 83.0
Gloeocystis	Offensive	-
Hydrodictyon	Very offensive	0.8
Microspora		3.3
Palmella		16.6
Pandorina	Faintly fishy	16.6 to 83.0
Protococcus		Use chlorine
Raphidium		5.3
Scenedesmus	Vegetable, aromatic	8.3
Spirogyra	Grassy	1.0
Staurastrum	Grassy	12.5
Tetrastrum		Use chlorine
Ulothrix	Grassy	1.7
Volvox	Fishy	2.1
Zygnema		4.2
Cyanophyceae	(Blue-green algae)	
Anabaena	Moldy, grassy, vile	1.0
Aphanizomenon	Moldy, grassy, vile	1.0 to 4.2
Clathrocystis	Sweet, grassy, vile	1.0 to 2.1
Coelosphaerium	Sweet, grassy	1.7 to 2.3
Cylindrospermum	Grassy	1.0
Gloeocapsa	(Red)	2.0
Microcystis	Grassy, septic	1.7
Oscillaria	Grassy, musty	1.7 - 4.2
Rivularia	Moldy, grassy	[illegible]
Protozoa		
Bursaria	Irish moss, salt marsh, fishy	-
Ceratium	Fishy, vile (red-brown)	2.8
Chlamydomonas		4.2 - 8.3
Cryptomonas	Candied violets	4.2
Dinobryon	Aromatic, violents, fishy	1.5
E. histolytica (cyst)		Use chlorine 5 to 25 mg/l
Euglena		4.2
Glenodinium	Fishy	4.2
Mallomonas	Aromatic, violets, fishy	4.2
Peridinium	Fishy, like clam-shells, bitter taste	4.2 to 16.6
Synura	Cucumber, musk-melon, fishy	0.25
Uroglena	Fishy, oily, codliver oil	0.4 to 1.6
Crustacea		
Cyclops		16.6
Daphnia		16.5
Schizomycetes		
Beggiatoa	Very offensive, decayed	41.5
Cladothrix		1.7
Crenothrix	Very offensive, decayed	2.5 to 4.2
Leptothrix	Medicinal with chlorine	-
Sphaerotilis natans	Very offensive, decayed	3.3
Thiothrix		Use chlorine
Fungi		
Achlya		-
Leptomitus		3.3
Saprolegnia		1.5
Miscellaneous		
Blood worm		Use chlorine
Chara		0.8 to 4.2
Nitella flexilis	Objectionable	0.8 to 1.5
Phaeophyceae	(Brown algae)	-
Potamogeton		2.5 to 6.7
Rhodophyceae	(Red algae)	-
Xantophyceae	(Green algae)	-

Figure 8. Dosage of Copper Sulfate and Residual Chlorine, which if Exceeded May Cause Fish Kill

Fish	Copper Sulfate (lb/mil gal)	Copper Sulfate (mg/l)	Free Chlorine, (in mg/l)	Chloramine, (in mg/l)
Trout	1.2	0.14	0.10 to 0.15	0.4
Carp	2.8	0.33	0.15 to 0.2	0.76 to 1.2
Suckers	2.8	0.33		
Catfish	3.5	0.40		
Pickerel	3.5	0.40		
Goldfish	4.2	0.50	0.25	
Perch	5.5	0.67		
Sunfish	11.1	1.36		0.4
Black bass	16.6	2.0		
Minnows			0.4	0.76 to 1.2
Bullheads				0.4
Trout fry				0.05 to 0.06
Gambusia				0.5 to 1.0

Figure 1. Processes of Iron and Manganese Removal

Treatment Processes	Oxidation Required	Character of Water	Equipment Required	pH Range Required	Chemicals Required	Remarks
Aeration Sedimentation Sand filtration	Yes	Iron alone in absence of appreciable concentrations of organic matter	Aeration, settling basin, sand filter	Over 6.5	None	Easily operated. No chemical control required.
Aeration, contact oxidation, sedimentation, sand filtration	Yes	Iron and manganese loosely bound to organic matter, but no excessive carbon dioxide or organic acids content	Contact aerator of coke, gravel, or crushed pyrolusite, settling basin and sand filter	Over 6.5	None	Double pumping required. Easily controlled.
Aeration, contact filtration	Yes	Iron and manganese bound to organic matter, but no excessive organic acid content	Aerator and filter bed of manganese coated sand, "Birm," crushed pyrolusite ore, or manganese zeolite	Over 6.5 ±	None	Double pumping required unless air compressor, or "sniffler valve" is used to force air into water. Limited air supply adequate. Easily controlled.
Contact filtration	Yes, but not by aeration	Iron and manganese bound to organic matter, but no excessive carbon dioxide or organic acid content	Filter bed of manganese coated sand, "Birm," crushed pyrolusite ore, or manganese zeolite	Over 6.5	Filter bed reactivated or oxidized at intervals with chlorine or sodium permanganate	Single pumping. Aeration not required.
Aeration, chlorination, sedimentation, sand filtration	Yes	Iron and manganese loosely bound to organic matter	Aerator and chlorinator or chlorinator alone, settling basin and sand filter	7.0 to 8.0	Chlorine	Required chlorine dose reduced by previous aeration but chlorination alone permits single pumping.
Aeration, lime treatment, sedimentation, sand filtration	Yes	Iron and manganese in combination with organic matter, and organic acids	Effective aerator, lime feeder mixing basin, settling basin, sand filter	8.5 to 9.6	Lime	pH control required.
Aeration, coagulation and lime treatment, sedimentation, sand filtration	Yes	Colored, turbid, surface water containing iron and manganese combined with organic matter	Conventional rapid sand filtration plant	8.5 to 9.6	Lime and ferric chloride or ferric sulfate, or chlorinated copperas, or lime and copperas	Complete laboratory control required
Zeolite softening	No	Well water *devoid* of oxygen, and containing less than about 1.5 to 2 ppm iron and manganese	Conventional sodium zeolite unit, with manganese zeolite unit or equivalent for treatment of by-passed water	Over 6.5 ±	None, added continuously, but bed is regenerated at intervals with salt solution	Only soluble ferrous and manganous compounds can be removed by base exchange, so aeration or double pumping is not required
Lime treatment, sedimentation, sand filtration	No	Soft well water *devoid* of oxygen containing iron as ferrous bicarbonate	Lime feeder, enclosed mixing and settling tanks and pressure filter	8.0 to 8.5	Lime	Precipitation of iron in absence of oxygen occurs at lower pH than otherwise. Absence of oxygen minimizes or prevents corrosion. Double pumping not required

Source: Charles R. Cox, *Water Supply Control*, Bull. No. 22, New York State Department of Health, Albany, 1952, pp. 159-160.

(2) Chlorine-ammonia treatment

(3) Aeration or forced-draft degasifier

(4) Application of activated carbon

(5) Filtration through granular carbon or charcoal filters

(6) Coagulation and filteration of water

(7) Control of reservoir intake level

(8) Elimination or control of source of trouble

(9) Chlirine dioxide treatment

(10) Ozone treatment

(11) Control of sources of H_2S, Fe, Mn

11.8 Water Softening

12.81 Soda-lime process

12.82 Excess lime process

12.83 Zeolite (ion exchange process)

12.84 Fluoridation (does not soften water)

11.9 Emergency Disinfection of Small Volumes of Water

(see Figure 10)

11.10 Water Network Model

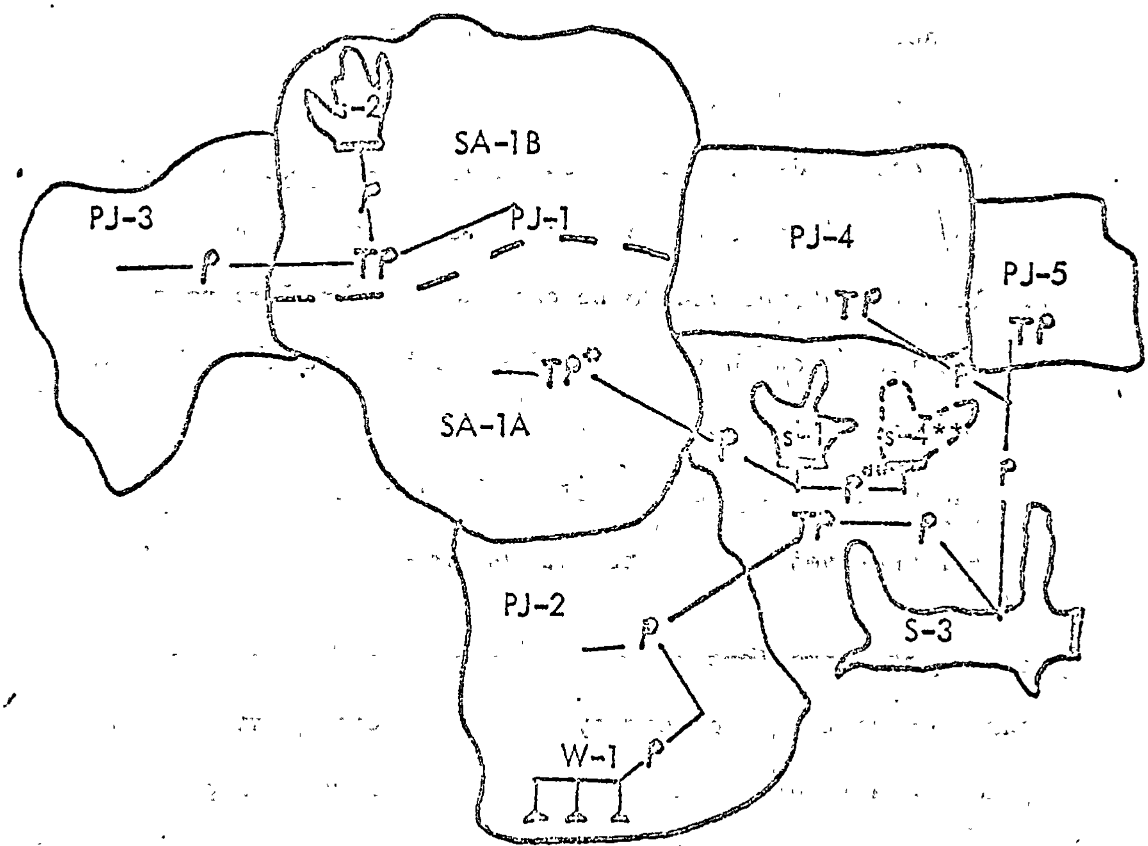
The water supply model is basically a regional water network (see Figure 11). Figure 12 shows the structure of the water supply network model. The model begins with the formulation of networks and continues with a coarse sort of the alternative networks. By using a specific program, an out-of-kilter algorithm, feasible alternatives are analyzed next, together with their associated costs, to reach the optimal solution.

Figure 10. Emergency Disinfection of Small Volumes of Water

Product	Available Chlorine, %	Stock Solution*	Quantity of Stock Solution to Treat 1 gal of Water†	Quantity of Stock Solution to Treat 1,000 gal of Water†
[illegible]	1	Use full strength	30 drops	2 quarts
[illegible] 101 Solution	2½	Use full strength	12 drops	1 quart
[illegible], White Sail, [illegible], Rainbow, [illegible]	5¼	Use full strength	6 drops	1 pint
[illegible] Hypochlorite	10	Use full strength	3 drops	½ pint
[illegible] Hypochlorite	15	Use full strength	2 drops	¼ pint
[illegible] Hypochlorite, "Bleaching Powder," or Chlorinated Lime	25	6 heaping table-spoonfuls (3 oz) to 1 qt of water	one teaspoonful or 75 drops	1 quart
[illegible] Hypochlorite	33	4 heaping table-spoonfuls to 1 qt of water	one teaspoonful	1 quart
HTH, Perchloron, [illegible]chlor	70	2 heaping table-spoonfuls (1 oz) to 1 qt of water	one teaspoonful	1 quart

*One quart contains 135 ordinary teaspoonfuls of water.

†Let stand 30 min before using. To dechlorinate, use sodium thiosulfate in same proportion as chlorine. One jigger = 1½ liquid oz. Chlorine dosage is approximately 5–6 mg/l. ([illegible] Chlorination.) (1 liquid oz = 615 drops.) Make sure chlorine solution or powder is [illegible]; check by making orthotolidine test.



PJ - Political Jurisdictions
S - Water Source Surface
W - Water Source Sub-surface
SA - Special Area of Political Jurisdiction
TP - Treatment Plant
* - Programmed for Expansion
** - Programmed New Facility

Figure 11. Existing Metropolitan Study Area.

11.11 Basic Considerations

The basic objective of the model is to determine how the desired level of network service can be most efficiently provided to the metropolitan area at the least cost. In the accomplishment of this objective, there are certain primary considerations that have to be made.

11.11.1 The selection of source and treatment plants can be modified depending on quality and treatment required. The selection of sources and the required treatment can be modified in part to fit the network.

11.11.2 The cost indebtedness of existing facilities is fully considered as is the obsolescence of these same facilities.

11.11.3 If alternatives are to be considered, then the feasible locations for these facilities, within the network must be known prior to a model run.

11.11.4 The maximum flow or capacity can also be used to explore alternatives and constraint resources.

11.12 Water Model Cost Functions

The "model" consists of the employment of the different types of cost functions that are incurred in the development of water supplies. Basically they can be categorized into four components.

11.12.1 Water source costs for either surface or groundwater which include costs for reservoirs, streams diversions and well fields.

11.12.2 Transmission costs which include costs for pumping stations and pipelines used to convey the water from its source to the area of use.

11.12.3 Treatment costs which include costs for raw water storage, treatment plants and pumping plants.

11.12.4 Distribution costs, which include costs for pumping stations, storage tanks and water mains.

In general the costs are broken down into capital expenditures and operation and maintenance costs. Capital expenditures include costs for engineering design, land and right-of-way, water rights, constructions, administration and financing. Operation and maintenance costs include labor, materials, administration and overheads, chemicals and power. Capital costs are presented as equivalent annual costs using an interest rate of 6% and a period of 25 years. Operation and maintenance costs are presented as annual costs.

C_n = Equivalent annual unit costs of pumping stations in thousands of dollars/station/mgd

11.13 Cost Equations*

11.13.1 Water source costs

$$C_R = 74.2\, X_R^{-.38} \qquad (1)$$

where, C_R = Annual unit costs of impounding reservoirs in thousands of dollars per billion gallons.

X_R = Design capacity of reservoir in billion gallons

$$C_S = 3.95\, X_S^{-.178} \qquad (2)$$

where, C_S = Equivalent annual unit cost in thousands of dollars/mgd

X_S = Design capacity in mgd

* Equations are not standard equations but examples for demonstration purposes only.

11.13.2 Transmission costs

$$C_p = 41.3\ X_p^{-.49} \qquad (3)$$

where, C_p = Equivalent annual cost for pipelines in thousands of dollars/mile/mgd

X_p = Pipeline design capacity in mgd

$$A_p = 1.32\ X_{p'}^{-.49} \qquad (4)$$

where, A_p = Annual operation and maintenance cost in thousands of dollars/mile/mgd of flow

$X_{p'}$ = Pipeline utilization level in mgd

$$C_n = 6.65\ X_p^{-.314} \qquad (5)$$

where, C_n = Equivalent annual unit cost of pumping stations in thousands of dollars/station/mgd

X_p = Design capacity of pipeline

$$A_n = 2.12\ X_{p'}^{-.314} \qquad (6)$$

where, A_n = Annual operation and maintenance cost in thousands of dollars/station mgd of flow

$X_{p'}$ = Pipeline flow level in mgd

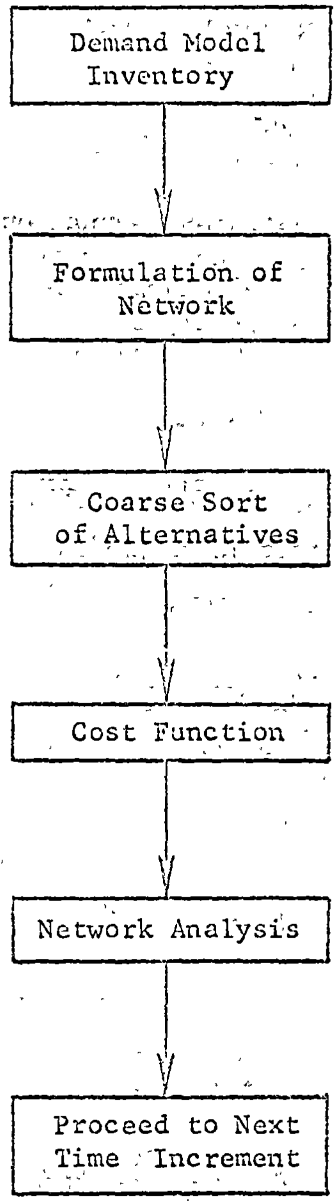
11.13.3 Treatment Costs

$$C_{rs} = 1.55\ X_{rs}^{-.201} \qquad (7)$$

where, C_{rs} = Equivalent annual unit costs for raw water storage in thousands of dollars/million gallons

X_{rs} = Raw water storage design capacity in million gallons

Figure 12. The Water Supply Network Model



$$A_{rs} = 0.10\ X_{rs}^{-.201} \qquad (8)$$

where, A_{rs} = Annual operation and maintenance cost in thousands of dollars per million gallons

X_{rs} = Raw water storage design capacity in million gallons

$$C_t = 25.6\ X_t^{-.247} \qquad (9)$$

where, C_t = Equivalent annual unit cost of treatment plant in thousands in dollars per mgd

X_t = Design capacity of treatment plant in mgd

$$A_t = 7.25\ X_{t'}^{-.257} \qquad (10)$$

where, A_t = Annual operation and maintenance of treatment plant in thousands of dollars per mgd

$X_{t'}$ = Operating level of plant in mgd

11.13.4 Distribution Costs

$$C_{ts} = 14.3\ X_{ts}^{-.274} \qquad (11)$$

where, C_{ts} = Equivalent annual unit cost for treated water storage in thousands of dollars per million gallons

X_{ts} = Design capacity of treated water storage facilities in million gallons

$$A_{ts} = 1.80\ X_{ts}^{-.274} \qquad (12)$$

where, A_{ts} = Annual operations and maintenance costs in thousands of dollars per million gallons.

X_{ts} = Design capacity of treated water storage facilities in million gallons

11.14 Flow Network of Total Costs

(See Figure 13)

The model starts with a "super source" which is basically the environment, and feeds the water sources that supply the network. These sources are the first series of nodes. Since each node can be interconnected with one or more arcs, the cost functions can be disaggregated by the user. This is accomplished by determining the fixed cost, the cost incurred by the using agency no matter whether the facility is used or not, and assigning a flow of 1 mgd to this arc. In other words, the fixed costs of a link in the network are assigned to an arc that connects the two nodes which denote the entrance and exit of that facility. Then a flow of 1 mgd is assigned as the upper and lower limits. These "1 mgd fake flows" have to be added to the "super source" link for each arc of fixed costs that are assigned to the network. They must also be balanced in the network starting with the "super sink" and working backwards to the "super source".

The costs for different variables, which are linear in this model, are then assigned to another arc that describes the facility,and the proper upper and lower bounds are also designated. By using this technique, the cost functions can be closely approximated for each link (see Figure 14).

The network is made up of a system of nodes and arcs that are interconnected by arcs (see Figure 15). Each node represents an intake or exhaust of some facilities. Depending on the degree of accuracy needed, computer capabilities and available cost data, this network can be as detailed as needed. An arc-node grouping can represent a complete treatment

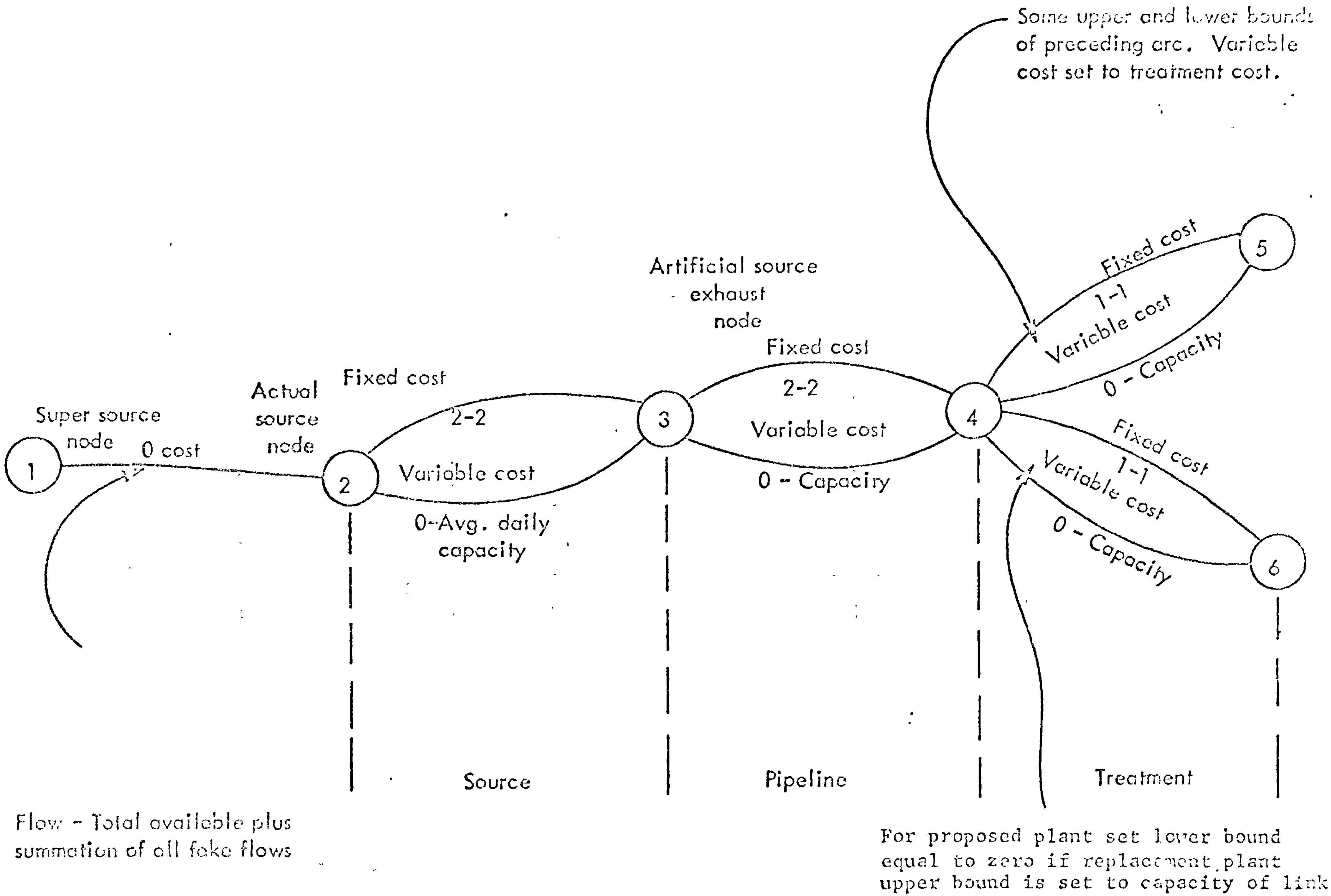


Figure 13. Flow Network Diagram

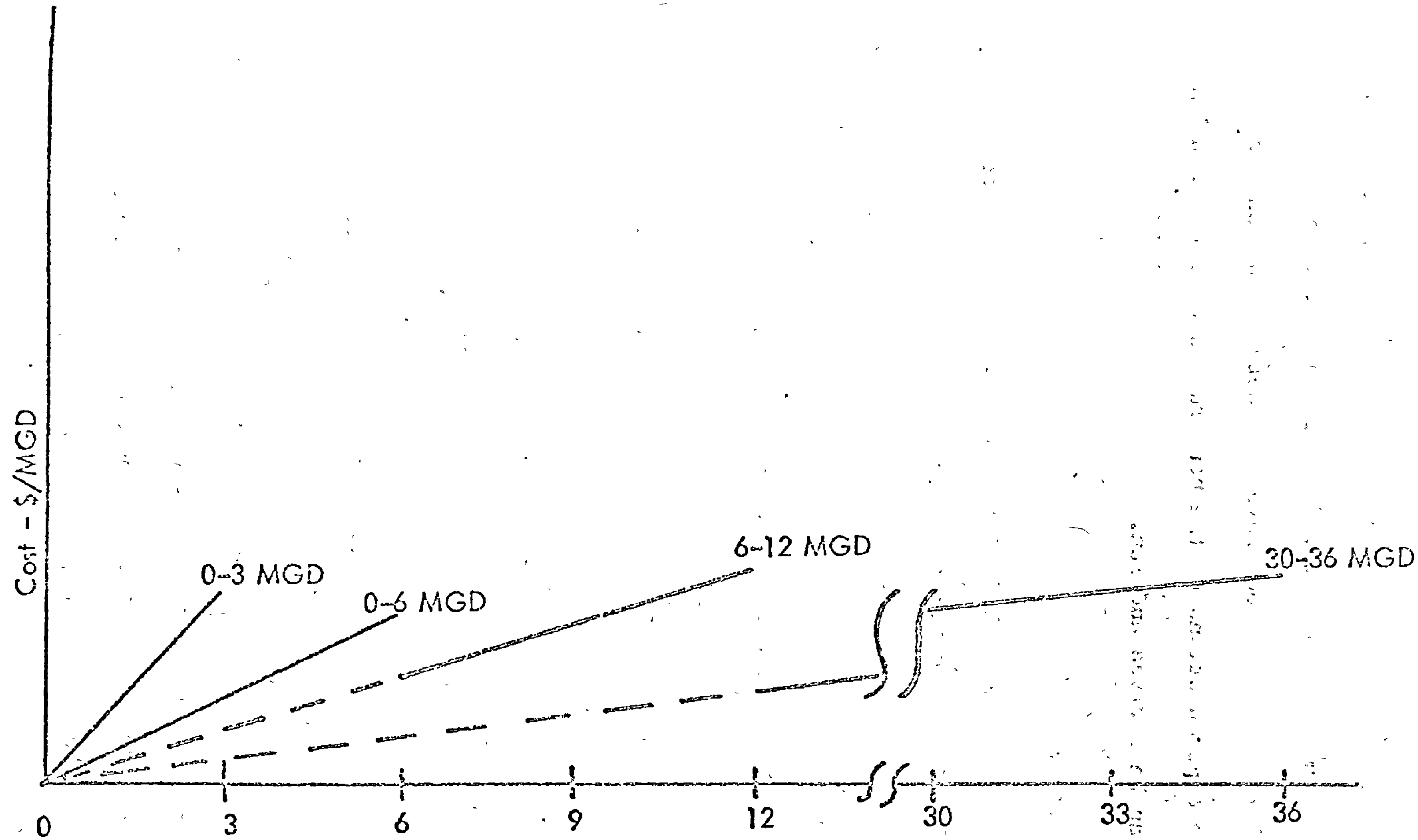
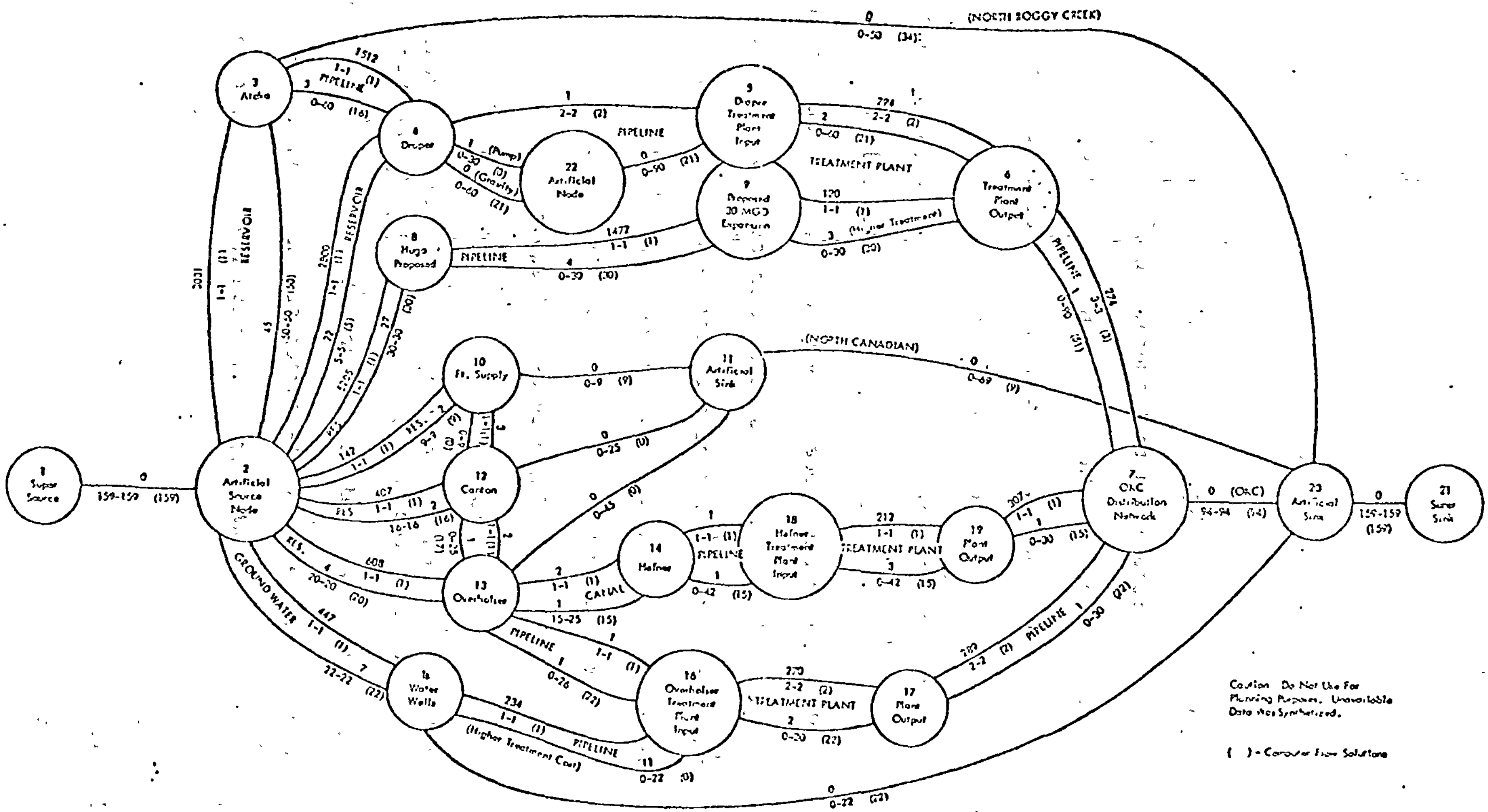


Figure 14. Linear Cost Functions.

plant or each of the steps through the plant. The usual procedure is to simplify the network as much as possible, depending primarily on cost data, for the initial runs. When flows have been determined, then unfeasible or undesirable permulations of the network can be removed and new networks in detail can be derived and run.

Figure 15.



(NORTH BOGGY CREEK)
1 Super Source
2 Artificial Source Node
3 Atoka
4 Draper
5 Draper Treatment Plant Input
6 Treatment Plant Output
7 OKC Distribution Network
8 Hugo Proposed
9 Proposed 30 MGD Expansion
10 Ft. Supply
11 Artificial Sink
12 Canton
13 Overholser
14 Hefner
16 Water Wells
17 Plant Output
19 Plant Output
21 Super Sink
22 Artificial Node
23 Artificial Sink
PIPELINE
RESERVOIR
TREATMENT PLANT
(NORTH CANADIAN)
CANAL
GROUND WATER
(Higher Treatment Cost)
Caution: Do Not Use For Planning Purposes. Unavailable Data Was Synthesized.
( ) = Computer From Solution

Chapter 12

WASTEWATER TREATMENT AND DISPOSAL

It is generally recognized that improved water quality will enhance the immediate environment, augment the useful supply of water, and reduce costs stemming from the use of polluted water. Water quality is impaired primarily by the use of the water as a receptor of wastes.

Natural water is not pure. Its quality is affected by a variety of geologic, hydrologic, and biologic factors (see Figure 12.1). Natural impurities such as sediments, decaying vegetation, and wastes from wild animal populations impose measurable levels of contamination on many watercourses. Dissolved minerals rendered some of our surface and ground waters unfit for certain uses long before man appeared on the scene. But most of what we call pollution today results from disposal of the waste products of civilization.

Pollution sources are of two types as follows:

(1) Waste discharges from identifiable points (point sources);

(2) Diffused wastes reaching water through land runoff, washout from the atmosphere, or other means (nonpoint-sources).

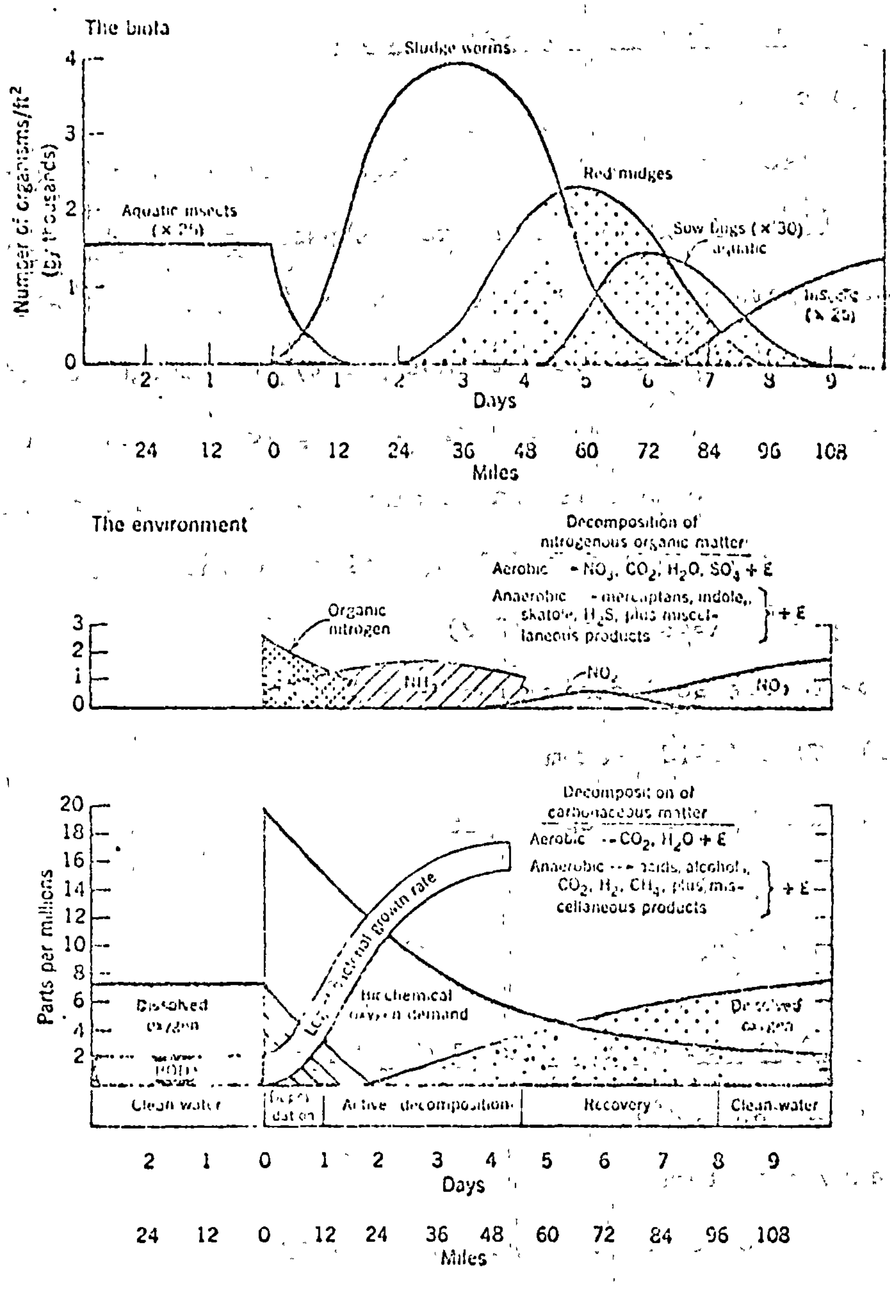
The two differ in their amenability to control. Discrete point sources may be controlled directly while nonpoint-sources are extermely difficult to control. Modelling is being done in both areas for planning and management purposes.

12.1 Types of Wastewater

(1) Sewage

(2) Industrial wastes

(3) Stormwater



The biota
Sludge worms
Red midges
Aquatic insects (× 25)
Sow bugs (× 30) aquatic
Number of organisms/ft² (by thousands)
Days
Miles
The environment
Decomposition of nitrogenous organic matter
Organic nitrogen
Decomposition of carbonaceous matter
Parts per millions
Dissolved oxygen
Biochemical oxygen demand
Clean water
Active decomposition
Recovery
Clean water

Figure 12.1

12.2 Types of Collection Systems

(1) Organized

(2) Dispersed

12.3 Small Water-borne Sewage Disposal Systems

12.31 Septic tank

A septic tank is a watertight tank designed to slow down the movement of raw sewage and wastes passing through so that solids can separate or settle out and be broken down by liquefaction and bacterial action. It does not purify the sewage, eliminate odors or destroy all solid matter. The septic tank simply conditions the sewage so that is can be disposed of to a sub-surface leaching system or to an artificial sand filter without prematurely clogging the system (see Figure 12.2).

12.32 Sub-surface soil absorption systems

(1) Tile field system

(2) Leaching or seepage pit

(3) Cesspool

(4) Dry well

12.4 Small Sewage Disposal Systems for Tight Soils

12.41 Evapotranspiration

12.42 Transvap systems

12.43 Modification of conventional tile field system

12.44 Waste stabilization pond

12.45 Aerobic sewage treatment unit

12.46 Sand filter

TABLE 4-12 TYPICAL SEPTIC TANK AND SUBSURFACE SAND FILTER EFFLUENT

	Sewage Effluent*	
Determination	Septic Tank	Subsurface Sand Filter
Bacteria per ml, Agar, 36°C, 24 hr	76,000,000	127,000
Coliform group MPN	110,000,000	150,000
Color†	3.5	2
Turbidity (mg/l)	50	5
Odor†	4.5	1
Suspended matter†	3	1
pH	7.4	7.4
Temperature °C	17	14
BOD, 5 day (mg/l)	140	4
DO (mg/l)	0	5.2
DO saturation (%)	0	52
Nitrogen, total (mg/l)	36	21
Free ammonia	12	0.7
Organic	12	3.4
Nitrites	0.001	0.02
Nitrates	0.12	17
Oxygen consumed (mg/l)	80	20
Chlorides (mg/l)	80	65
Alkalinity (mg/l)	400	300
Total solids (mg/l)	820	810
Susp. solids (mg/l)	101	12

Source J. A. Salvato, Jr., "Experience with Subsurface Sand Filters," *Sewage and Industrial Wastes*, 27, No. 8, 909–916 (August 1955)

*Median results, using 51 samples from septic tanks and 56 from filters.

†1 = very slight, 2 = slight, 3 = distinct, 4 = decided, 5 = extreme. Normal municipal domestic sewage has an MPN of 50–100 million coliform bacteria per 100 ml.

TABLE 4-13 TYPICAL EFFICIENCIES OF SUBSURFACE FILTERS*

Determination	Percent Reduction
Bacteria per ml, Agar, 36°C, 24 hr	99.5
Coliform group: MPN per 100 ml	99.6
BOD, 5 day (mg/l)	97
Susp. solids (mg/l)	88
Oxygen consumed (mg/l)	75
Total nitrogen (mg/l)	42
Free ammonia	94
Organic	72

Source. J. A. Salvato, Jr., "Experience with Subsurface Sand Filters," *Sewage and Industrial Wastes*, 27, No. 8, 909–916 (August 1955).

*Effluent will contain 5.2 mg/l dissolved oxygen and 17 mg/l nitrates.

Figure 12.2

12.5 Small Treatment Plant

12.51 Planning

(1) Tailor-made to fit the local conditions

(2) Take into consideration probable future additions

12.52 Chlorination

Chlorine is added to sewage for a variety of purposes. One of its major uses is for the partial or complete destruction of pathogenic organisms including some viruses in sewage. Other uses are control of odors, undesirable growths, sewage flies, septicity and chemical or bacterial reactions unfavorable to the treatment process.

12.53 Treatment of sewage

12.53.1 Primary settling tank

12.53.2 Secondary treatment (see Figure 12.3)

12.54 Trickling filter

A trickling filter may be used following a primary settling tank, a septic tank or Imhoff tank to provide secondary treatment.

Small standard rate trickling filter - 200,000 to 300,000 gpd per acre-ft. 200 to 600 lb. of BOD/acre-ft./day.

12.55 Extended aeration

Extended aeration plants also referred to as aerobic digestion plants (see Figure 12.4).

12.56 Waste stabilization pond

In areas where ample space is available, preferably 1,000 ft. or more from habitation, with consideration to the prevailing

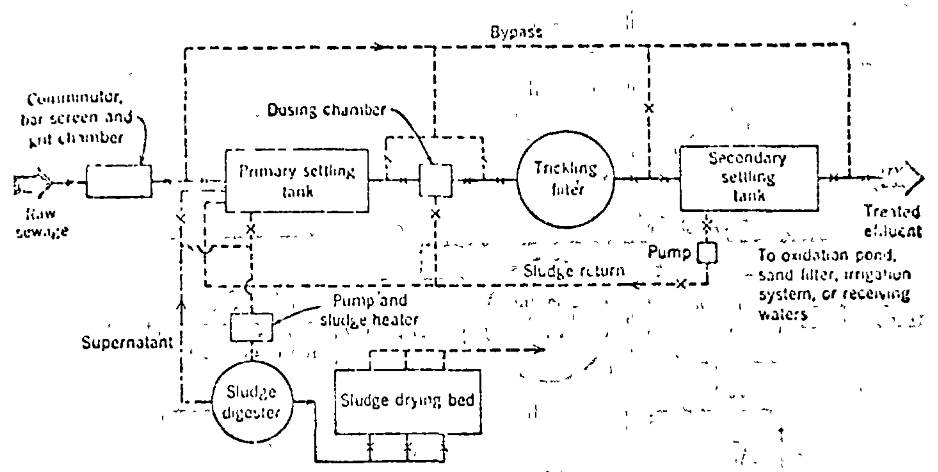


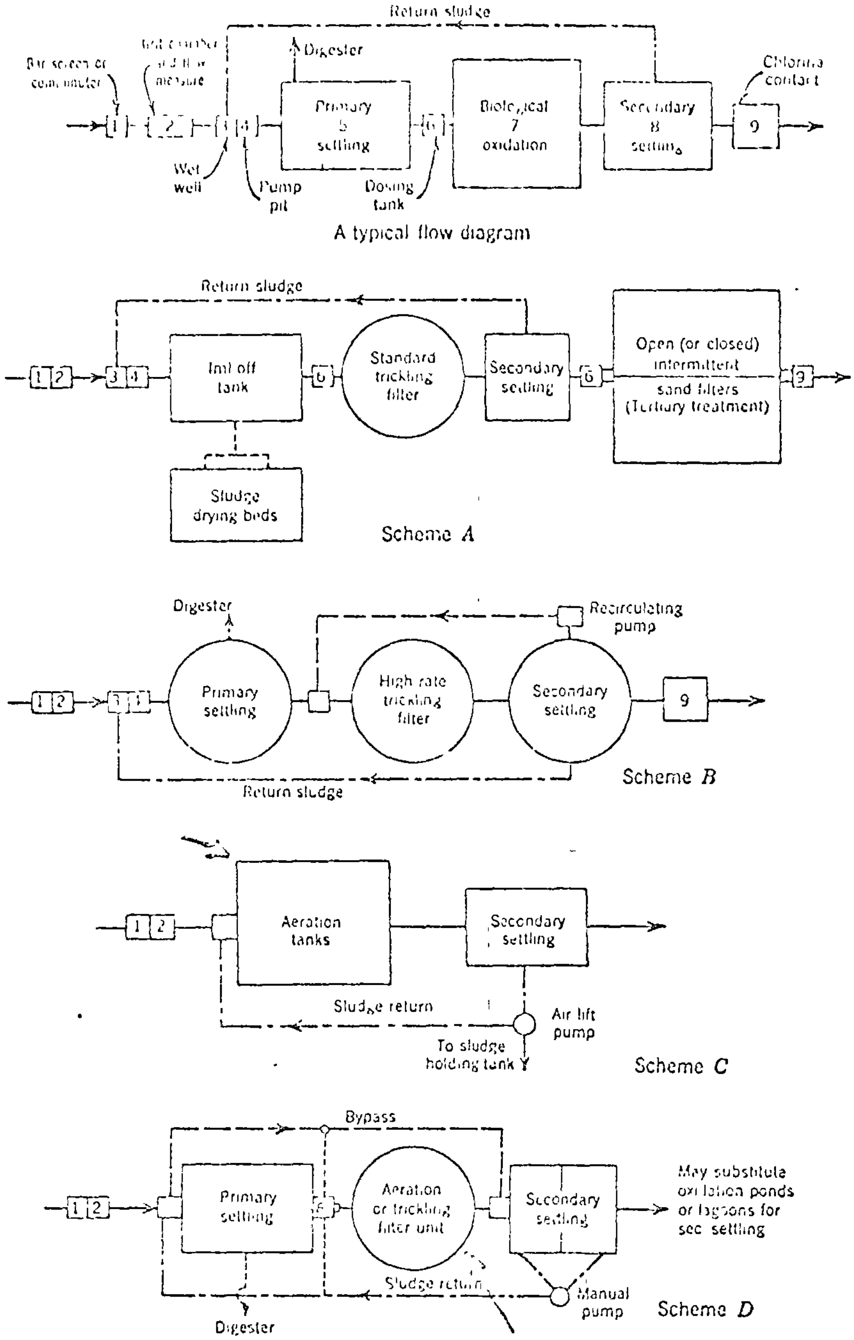
Figure 4-37 A secondary sewage treatment plant. (Units are usually in duplicate.)

Sewage Treatment Plant Unit Combinations and Efficiencies

Treatment Plant	Total percent Reduction—Approximation: Suspended Solids	Biochemical Oxygen Demand
Sedimentaton plus sand filter	90 to 98	85 to 95
Sedimentation plus standard trickling filter, 600 lb BOD per acre-foot maximum loading	75 to 90	80 to 95
Sedimentation plus single stage high rate trickling filter	50 to 80	35 to 65*
Sedimentation plus two stage high rate trickling filter	70 to 90	80 to 95*
Activated sludge	85 to 95	85 to 95
Chemical treatment	65 to 90	45 to 80
Pre aeration (1 hr) plus sedimentation	60 to 80	40 to 60
Plain sedimentation	40 to 70	25 to 40
Fine screening	2 to 20	5 to 10
Stabilization (aerobic) pond	—	70 to 90
Anaerobic lagoon	70	40 to 70

* No recirculation. Efficiencies can be increased within limits by controlling organic loading, efficiencies of settling tanks, volume of recirculation, and the number of stages; however, effluent will be less nitrified than from standard rate filter, but will usually contain dissolved oxygen. Filter flies and odors are reduced. Study first cost plus operation and maintenance.

Figure 12.3



Typical flow diagrams.

Figure 12.4

winds, a waste stabilization pond may be a relatively inexpensive and practical solution to a difficult problem. 20 pounds of BOD/acre/day; detention time 90 to 180 days.

12.6 General Treatment

12.61 Treatment processes

(1) Lagoon

(2) Primary

(3) Activated sludge

(4) Extended aeration

(5) Minimum solids

(6) Standard trickling filter

(7) High rate trickling filter

(8) Activated sludge

12.62 Treatment process substitution (see Figure 12.5)

12.63 Treatment costs

(1) Municipal (see Figure 12.6)

(2) Industrial (see Figure 12.7)

(3) Relationship between Quality and cost (see Figure 12.8)

12.7 Large Sewage Treatment Plants

12.71 Planning

(1) Regional and area wide sewage planning

(2) Water quality and effluent standards

(3) Alternative solutions

12.72 Conventional treatment processes (see Figure 12.9)

12.72.1 Preliminary or screening

(1) Racks

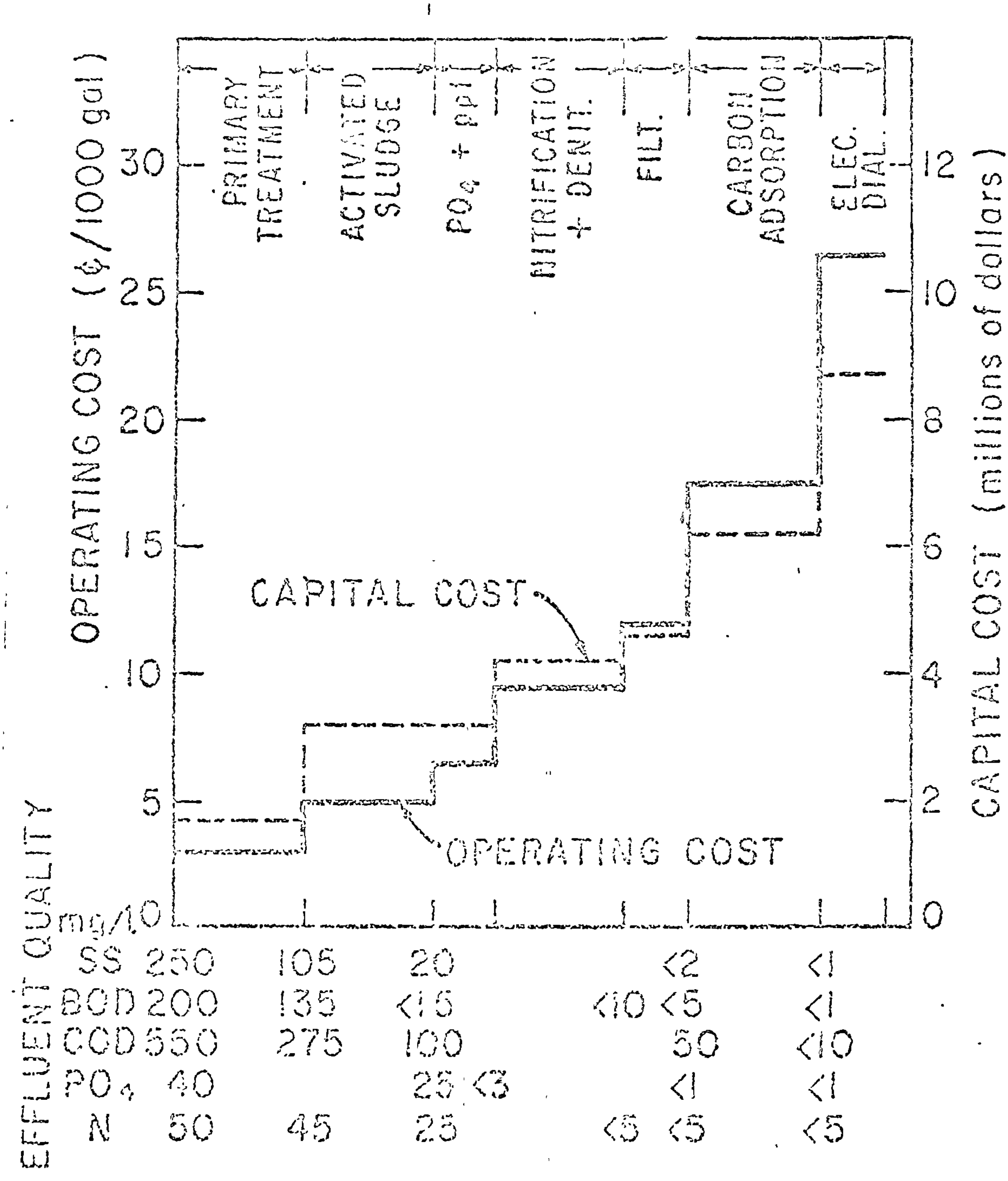
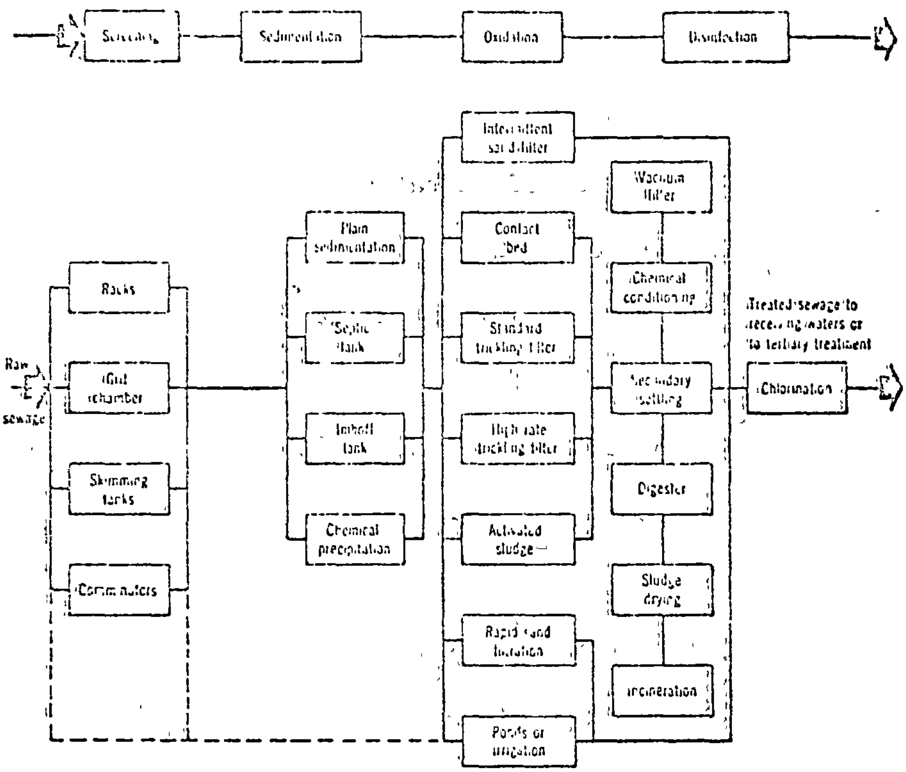


FIG. 3. RELATIONSHIP BETWEEN EFFLUENT QUALITY AND CAPITAL AND OPERATING COST



Conventional sewage treatment processes.

Figure 12.9

(2) Screens

(3) Grit chambers

(4) Skimming tank

(5) Comminutors

12.72.2 Settling

(1) Plain sedimentation

(2) Imhoff tank

(3) Chemical precipitation

12.72.3 Biological treatment

(1) Intermittent sand filter

(2) Contact bed

(3) Trickling filter

(4) Activated sludge

(5) Rapid sand filter

(6) Stabilization pond

12.72.4 Sludge disposal

(1) Digester

(2) Vacuum filter

(3) Wet combustion

(4) Incineration

(5) Drying bed

12.72.5 Disinfection

Chlorination

12.8 Sewer Network Model

The sewerage network varies from the water network in that it is primarily a gravity flow system. The use of pumps, pressurized lines and lift stations are normally avoided and are only implemented when absolutely necessary.

The sewerage network begins within each small basin with a collector system. These grid or block by block collector networks are sized by using the technique described in "Systems Approach to Metropolitan and Regional Area Water and Sewer Planning" by G. W. Reid. The sewage then flows from the collector systems into the sewer mains. These mains are also designed using the technique described in the above mentioned report.

The procedure for formulating the sewer network is identical to that of water network. The first step is to establish the current network from the inventory data. The procedures and firms used are same as in water network model. The only difference between this phase, which is for the sewer networks and those for water is that the flow is reversed. The identification of the real network and its shortages and capabilities is handled in the same manner as water. It is also advanced into the "desirable" worlds and evaluated as to their incremental capabilities, deficiencies and availabilities using those techniques described in the previously mentioned report.

The data requirements for this model are the same as those required for the water network. The only difference is in the cost curves and functions used to provide the actual costs.

The sewerage model has a format similar to the water supply model (see Figure 11.). The model begins with the formulation of networks and continues with a coarse sort of the alternative networks, analysis of feasible alternatives (see example, Figure 12.10).

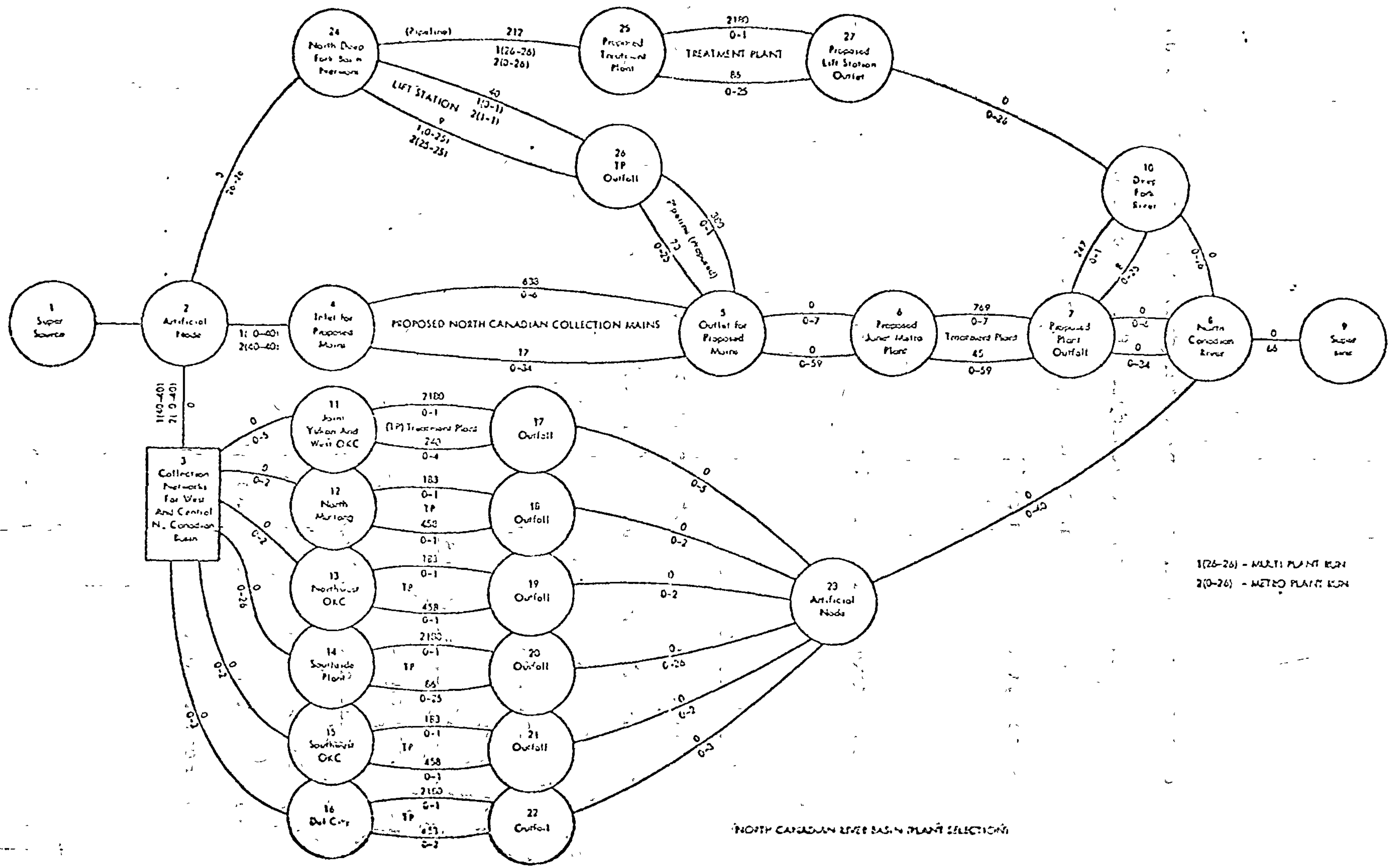

PROPOSED NORTH CANADIAN COLLECTION MAINS
TREATMENT PLANT
LIFT STATION
1(26-26) - MULTI PLANT RUN
2(0-26) - METRO PLANT RUN
NORTH CANADIAN RIVER BASIN PLANT SELECTION

Figure 12.10

Chapter 13

SOLID WASTE

Waste is a material that its producer does not want and does not ask reimbursement for it. Wastes are residues of resource use which result from the application of current technology under present concepts of economics and social objectives (see Figure 1).

Annually, 250 x 10^6 tons of solid waste are produced and this amount is increasing at about 4% per year. The problem of solid wastes will not be resolved by some great scientific breakthrough similar to the splitting of the atom.

13.1 Solid Waste Sub-model

A sub-model for solid waste is not completely developed, but it is being constructed along the same lines as the water and sewerage networks. The structure would be similar to that of the water supply network model (see Chapter 11, Figure 12).

13.2 Sources of Solid Wastes

(1) Residential

(2) Restaurants and hotels

(3) Institutions

(4) Public offices and facilities

(5) Health services

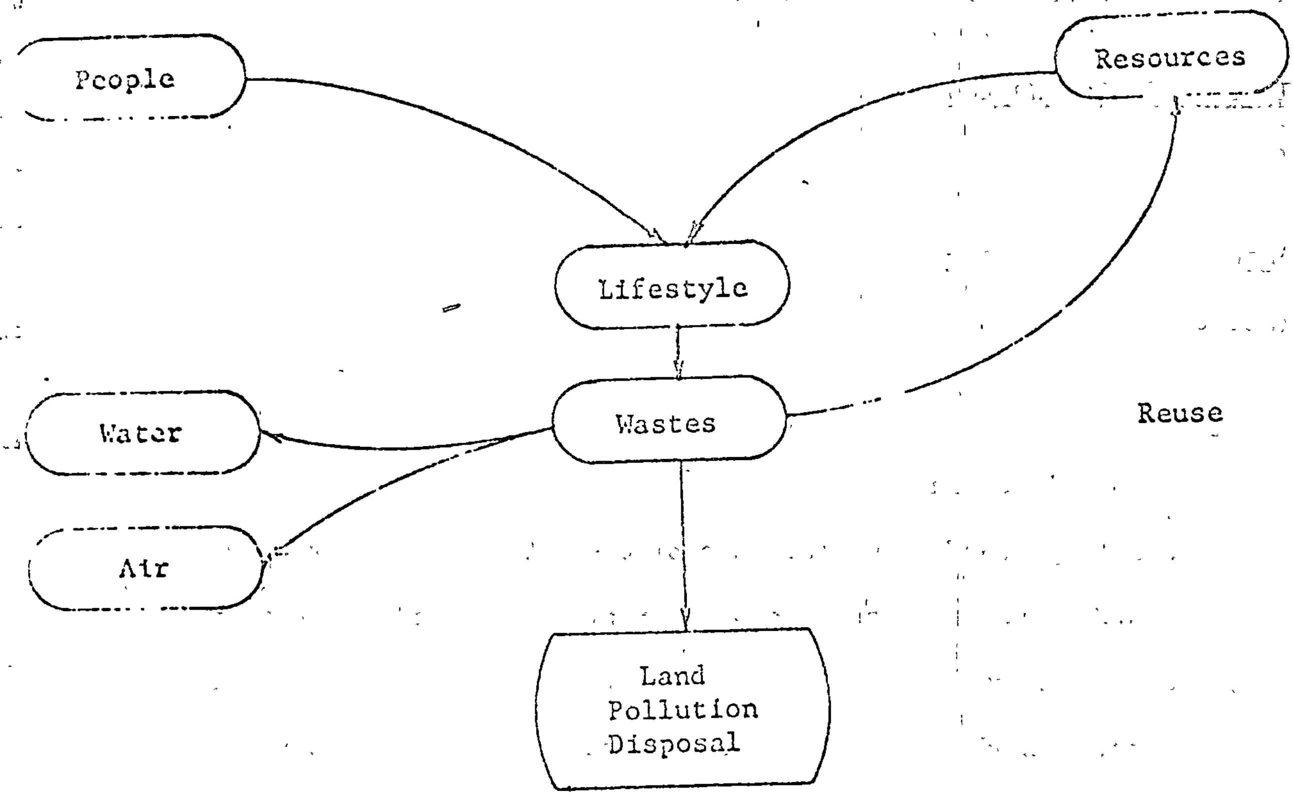


Figure I. Generalized Problem

(6) Commercial

(7) Construction and demolition

(8) Agriculture

(9) Industries

(10) Mining

(11) Miscellaneous manufacturing

(12) Non-classifiable establishments

13.3 Types of Solid Wastes

(See Figure 2)

13.4 Amounts of Solid Wastes

(See Figures 3, 4, 5, 6 and 7)

13.5 Solid Waste Disposal

13.51 Disposal to sink

Sanitary landfill is the main process by which this type of waste disposal is carried out. Sanitary landfill, according to some authors, is a thing of the future, i.e., it is the only major method of waste disposal to take care of our future solid wastes. From all indications, this is quite true. Sanitary landfilling is increasingly being adopted by the agencies engaged in waste disposal.

13.52 Change of state

Incineration where refuse is incinerated. Atmosphere becomes the ultimate sink for the gases produced. This is practiced on a large scale too.

Figure 2

REFUSE MATERIALS BY KIND, COMPOSITION, AND SOURCES

	Kind	*Composition*	*Sources*
Refuse	Garbage	Wastes from preparation, cooking, and serving of food; market wastes, wastes from handling, storage, and sale of produce	Households, restaurants, institutions, stores, markets
	Rubbish	Combustible: paper, cartons, boxes, barrels, wood, excelsior, tree branches, yard trimmings, wood furniture, bedding, dunnage	
		Noncombustible: metals, tin cans, metal furniture, dirt, glass, crockery, minerals	
	Ashes	Residue from fires used for cooking and heating and from on-site incineration	
	Street Refuse	Sweepings, dirt, leaves, catch basin dirt, contents of litter receptacles	Streets, sidewalks, alleys, vacant lots
	Dead Animals	Cats, dogs, horses, cows	
	Abandoned Vehicles	Unwanted cars and trucks left on public property	
	Industrial Wastes	Food processing wastes, boiler house cinders, lumber scraps, metal scraps, shavings	Factories, power plants
	Demolition Wastes	Lumber, pipes, brick, masonry, and other construction materials from razed buildings and other structures	Demolition sites to be used for new buildings, renewal projects, expressways
	Construction Wastes	Scrap lumber, pipe, other construction materials	New construction, remodeling
	Special Wastes	Hazardous solids and liquids: explosives, pathological wastes, radioactive materials	Households, hotels, hospitals, institutions, stores, industry
	Sewage Treatment Residue	Solids from coarse screening and from grit chambers, septic tank sludge	Sewage treatment plants; septic tanks

Figure 3

Amounts of Solid Waste

Item	National Averages (lb/cap/day) Urban	Rural	Total
Domestic	1.26	0.72	1.14
Commercial	0.46	0.11	0.38
Combined	2.63	2.60	2.63
Industrial	0.65	0.37	0.59
Deomolition-construction	0.23	0.02	0.18
Street sweepings	0.11	0.03	0.09
Miscellaneous	0.38	0.08	0.31
TOTALS	5.72	3.93	5.32

Figure 4

PER CAPITA COLLECTIONS OF SOLID WASTES AS REPORTED IN APWA SURVEYS[1]

City	1955		1957-58		1965		1968	
	lbs/cap/yr	lbs/cap/day	lbs/cap/yr	lbs/cap/day	lbs/cap/yr	lbs/cap/day	lbs/cap/yr	lbs/cap/day
Cincinnati, Ohio	—	—	1,103	3.03	1,235	3.4	1,365	3.74
Garden City, N.Y.	1,187[2]	3.3[2]	1,438[2]	3.9[2]	1,308[2]	3.6[2]	1,454[2]	3.98[2]
Los Angeles, Calif.	—	—	1,677	4.6	2,373	6.5	2,536	6.95
New York, N.Y.	826	2.3	1,325	3.6	1,483	4.1	—	—
Seattle, Wash.	842	2.3	1,370	3.8	1,508	4.1	1,431	3.89
Washington, D.C.	—	—	1,638	4.5	1,545	4.2	1,739	4.76

[1]Includes refuse actually collected under city auspices, regardless of method of collection. Does not include automobiles or cinders. In the 1959 survey, apartment house incinerator ash was calculated in terms of equivalent amounts of household refuse.
[2]No industrial refuse.

Figure 5

ANALYSIS OF SELECTED CLASSES OF SOLID WASTES COLLECTED IN SELECTED REGIONS[1]

Class	Pounds per Day per Capita					
	National Average	New England	South-east Region	South-west Region	Great Lakes Region	Pacific Coast Region
Combined household & commercial refuse	4.05	4.60	3.48	3.20	3.73	9.28
Demolition refuse	0.66	0.84	0.16	0.69	1.16	0.12
Tree & landscape refuse	0.18	0.21	0.81	0.40	0.13	0.34

[1]Derived from *Preliminary Data Analysis: 1968 National Survey of Community Solid Waste Practices.*

Figure 6.

SOLID WASTES COLLECTED IN THE UNITED STATES[1]

Class	*Total* Pop. (1,000) Reporting	*Total* lbs/cap/day	*Urban* Pop. (1,000) Reporting	*Urban* lbs/cap/day
Combined household & commercial refuse[2]	46,970	4.05	34,213	4.29
Industrial refuse	29,330	1.86	25,213	1.90
Institutional refuse	20,533	0.24	17,337	0.16
Demolition & construction refuse	23,697	0.66	21,716	0.72
Street & alley cleanings	35,340	0.25	32,705	0.25
Tree & landscaping refuse	25,890	0.18	23,405	0.18
Park and beach refuse	17,230	0.16	17,006	0.15
Catch basin refuse	22,010	0.04	20,042	0.04
Sewage treatment plant solids	20,504	0.47	19,100	0.50
Total solid wastes collected		7.92		8.19

[1] 1968 National Survey of Community Solid Waste Practices.

[2] It is of interest to note that the survey indicates that where household wastes and commercial wastes are collected separately, the combined total figure is only 3.76 lbs/cap/day (2.51 household plus 1.25 commercial). For the urban sector only the corresponding figures are 3.71 lbs/cap/day (2.48 household plus 1.23 commercial).

Figure 7

REFUSE OUTPUT--DOMESTIC AND COMMERCIAL
(Avg. values in lb/capita-yr 1959-61)

Country	Population Served (range for communities reported)	Range	Median
U. S. A.	50,000 - 8,500,000	1,100 - 1,700	1,400
England	70,000 - 8,600,000	450 - 1,080	650
France	50,000 - 4,500,000	400 - 900	575
Germany	700,000 - 2,200,000	470 - 535	480
Scotland	500,000 - 1,125,000	450 - 600	635
Sweden	400,000 - 800,000	400 - 750	635

13.53 Conversion

Composting, digestion. An abundance of literature exists about these types of waste disposal processes.

13.54 Direct recycling

Salvage has created much interest among research workers and industries.

13.55 Indirect recycling

Pyrolization, wet oxidation, bio-oxidation, rendering, reprocessing, animal feeding, etc.

13.56 Reduction at source

Reduction is achieved at the source of generation of wastes.

13.57 Diversion at source

The waste stream is partially diverted at the waste generation source to a different sink land or water source. Much of the garbage ends up in the sewage.

13.6 Solid Waste Systems

13.61 Type

(1) Municipal and industrial

(2) Agricultural

13.62 Functions

13.62.1 Storage

(1) Conventional closed storage

(2) Storage in specialized container

(3) No storage

13.62.2 Collection and transportation

(1) Vehicular transportation

(2) Pipeline transport

Separate pneumatic pipeline systems for the transportation of solid wastes have been proposed and in a few cases constructed. The costs of such systems appear to be approximately thirty times the cost of standard vehicular systems.

13.62.3 Processing (See Figure 8)

(1) Incineration

Incineration reduces the wet weight of municipal wastes by approximately 80% and the volume by approximate 90%; it is, however, an expensive operation (presently about 4 to 8 times more expensive than sanitary landfill) Costs can be expected to increase still more as increasin standards of air quality are established and enforced.

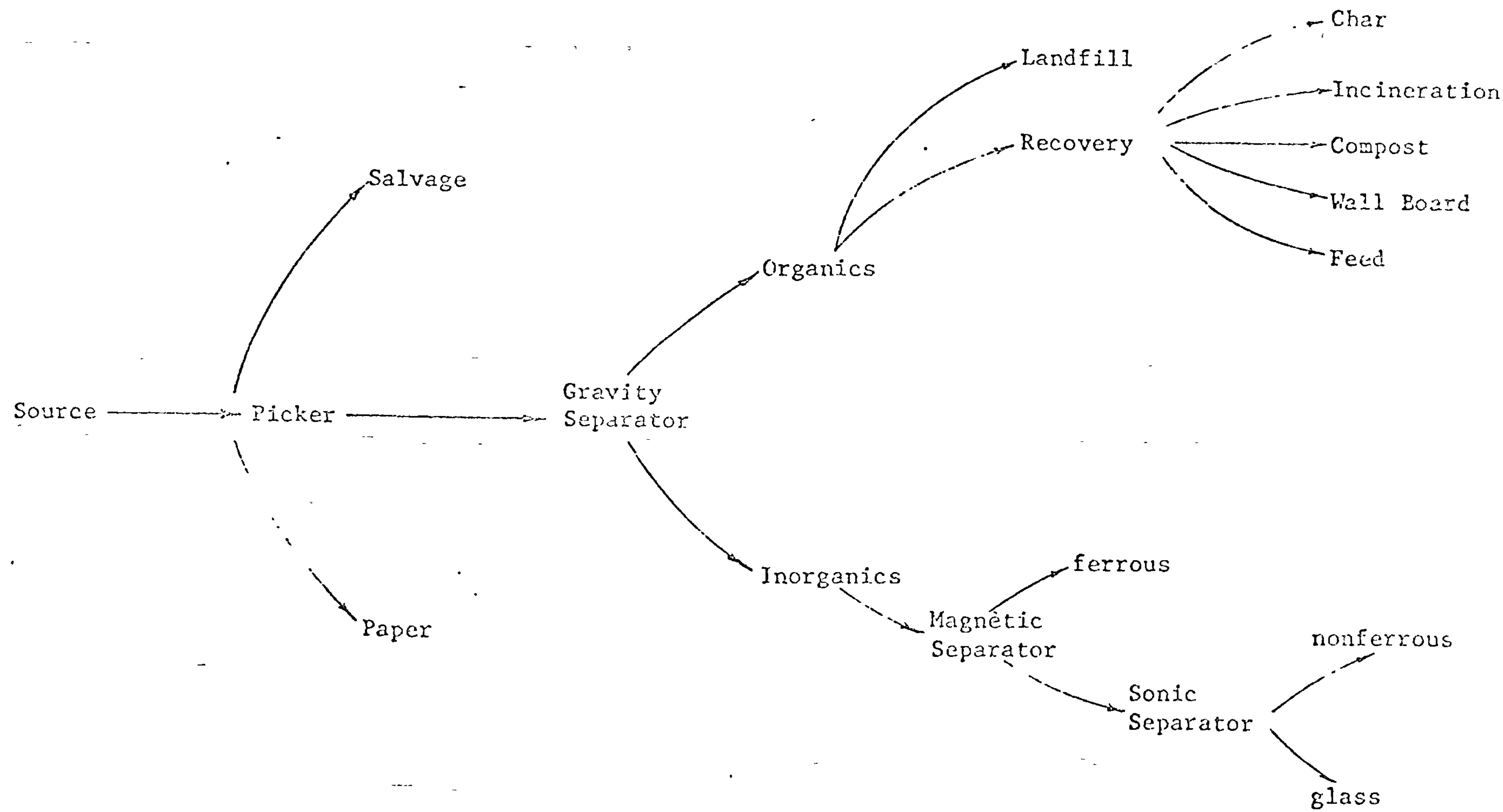
(2) Composting

Although many composting operations have not been successful, the potential benefits of composting can not be overlooked. Most failures are caused by high initial operations cost and lack of market for the product.

(3) No processing

No processing assumes only incidental processing that is not basic to the concept.

Figure 8. Solid Waste Disposal Methodology



13.62.4 Disposal

(1) Land - sanitary landfilling

(2) Atmosphere

(3) Ocean

13.62.5 Recovery

13.7 Effectiveness Measures for Solid Waste Management Systems

(1) Pest and vector propagation

(2) Other physically disagreeable or harmful effects

(3) Safety hazards

(4 Incidence of disease

(5) Convenience to the waste producer

(6) Adaptability to statutory or other changes in requirements

(7) System reliability

(8) Production of saleable by-products

(9) Salvage of resources for return to the economy

(10) Conservation of land resources. One can optimize benefits such as this or costs.

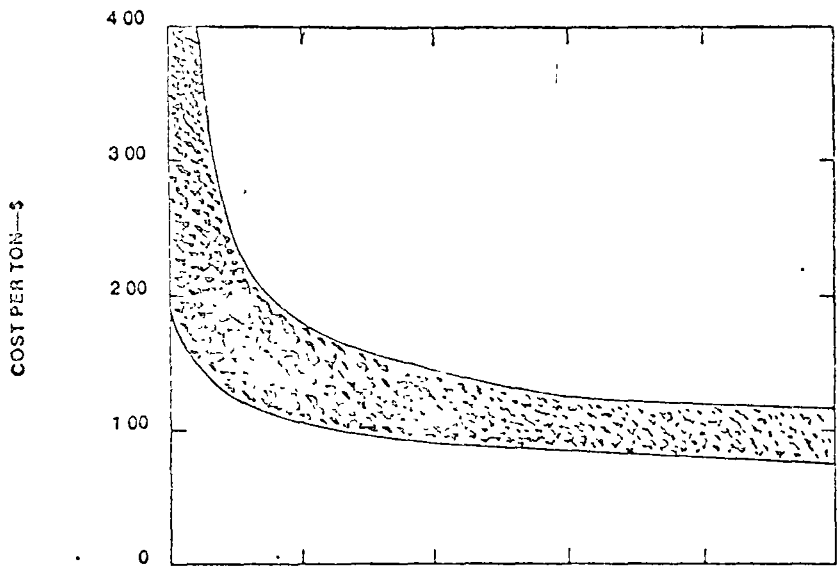
13.8 Costs of Solid Waste Management Systems

(See Figures 9, 10 and 11)

13.9 Equipment Requirements

(See Figure 12)

Figure 9

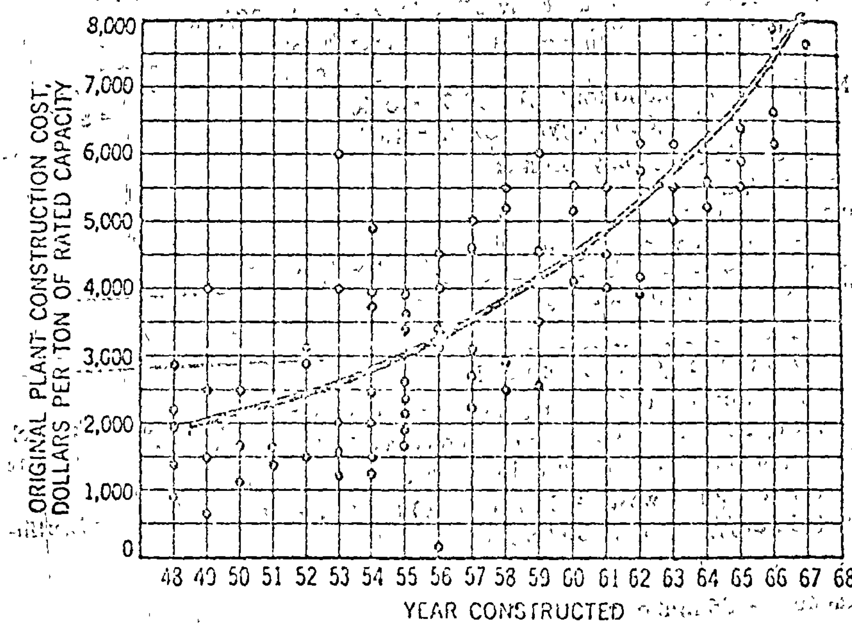


[1] Based on 6-day work week.
[2] Based on national average of 4 5 lbs per person per calendar day.

Estimated Capital Costs, Energy and Manpower Needs, Three Mechanical Compost Plants (1970 Figures)

	Fairfield			MetroWaste			IDC		
Capacity T/day	$ \times 10^6$	hp	Labor	$ \times 10^6$	hp	Labor	$ \times 10^6$	hp	Labor
100	1.4	900	8	0.9	1250	12	1 4	600	20
200	2.1	1400	11	1.2	1700	17	2.1	800	28
300	2.5	1700	14	1.5	1900	25	2.7	950	36
400	3.2	2500	20	1 6	2000	30	3 2	1100	45

Figure 10



Original construction costs for 74 central incinerators, built for municipalities between 1948 and 1968. Costs were computed on the basis of the number of tons the incinerator can burn in a day. The highest cost plant was built in 1966, the lowest in 1956. (Prepared from data of the Solid Wastes Engineering Section, Committee on Sanitary Engineering Research, American Society of Civil Engineers).

Figure 11

Material Recovery System (without shredding costs)

BASIS Cost of shredding *not* included, i.e., the MRS system is added onto a system that includes shredding

COSTS

Capital cost = $600,000

Annual capital cost @6%, 20 yr life = $52,000

Operating costs

Labor–4 men (1 per shift) @$10,000/yr =	$40,000	
Payroll extras @25% =	10,000	
Maintenance =	20,000	
Total cost =	$122,200	
Total unit cost @121,000 ton/yr		= $1.01/ton
Total unit cost @186,000 ton/yr		= $0.66/ton

INCOME

Ferrous @5% of "as received" solid waste @ $15/ton	= $0.75	
Aluminum @0.5% "as received" solid waste @ $200/ton	= 1.00	
Glass, sand, etc., @15% "as received" solid waste @ $3 00/ton	= 0.45	
Other metals @0 25% "as received" solid waste @ $300/ton	= 0.75	
Total income	= $2.95/ton	
Net *income* (186,000 ton/yr.) = $2.95 - 0.66		= $2.29/ton
(121,000 ton/yr) = $2.95 - 1.01		= $1.94/ton

For ferrous recovery only assume:

costs = $0 25/ton

income = $0.75/ton

net income = $0 50/ton of "as received" solid waste

Source Combustion Power Company

CPU-400--Electricity Production Only

BASIS. 3 power modules burning 110 ton/day each 24 hr/day, 7 day/wk, each generating 2250 kW of electricity; "as received" solid waste includes solid waste burned plus 15% air classifier fallout plus 5% water loss on shredding

"As received" solids waste = (110 ton/day) (3)/0.80 = 390 ton/day @85% utilization (310 day/yr) = 121,000 ton/yr

COSTS

Capital costs = $6 million

Annual capital cost @6%, 20 yr = $522,000

Unit capital cost @121,000 ton/yr = $4.30/ton

Operating cost

Labor–16 men (4 shifts) @$13,250/yr =	$212,000	
Payroll extras @25% =	53,000	
Maintenance =	252,000	
Utilities (900 kW @$0 010/kWh) =	76,700	
Total annual operating cost =	$593,700	
Unit operating cost @121,000 ton/yr		= $4 90/ton
	Total cost	= $9.20/ton

INCOME

Electrical 5.02 X 10^7 kWh @$0.007/kWh = $352,000/yr

Unit income @121,000 ton/yr = $2.91/ton

Net disposal cost = $6 29/ton

Source. Combustion Power Company

Figure 12.

AVERAGE EQUIPMENT REQUIREMENTS

Population	Daily tonnage	No.	Type	Equipment Size in lb	Accessory*
0 to 15,000	0 to 46	1	tractor crawler or rubber-tired	10,000 to 30,000	dozer blade landfill blade front-end loader (1- to 2-yd)
15,000 to 50,000	46 to 155	1	tractor crawler or rubber-tired	30,000 to 60,000	dozer blade landfill blade front-end loader (2- to 4-yd) multipurpose bucket
		*	scraper dragline water truck		
50,000 to 100,000	155 to 310	1 to 2	tractor crawler or rubber-tired	30,000 or more	dozer blade landfill blade front-end loader (2- to 5-yd) multipurpose bucket
		*	scraper dragline water truck		
100,000 or more	310 or more	2 or more	tractor crawler or rubber-tired	45,000 or more	dozer blade landfill blade front-end loader multipurpose bucket
		*	scraper dragline steel-wheel compactor road grader water truck		

Source: *Sanitary Landfill Facts*, U.S. Public Health Service Pub. No. 1792, Dept. of HEW, Washington, D.C., 19[illegible], p. [illegible].

Chapter 14

AIR POLLUTION PREDICTION MODEL

14.1 Objective:

Construct a mathematical model to predict future air pollution:

emissions

concentrations

costs-to-abate

for a typical United States city.

14.2 Constraints:

14.21 Model must be driven by city growth parameters predicted by a population model

14.22 Model should have the capability of being manipulated with either pencil and paper, calculator, or computer.

14.3 Background information:

14.31 Late 1940's: Pittsburgh, Pa. started cleaning up its smoke problem. The invention of the electrostatic precipitation made this possible

14.32 1950's: Many cities developed air pollution problems, due in part to the vast increase in automotive activity. i.e.

- Los Angeles
- New York
- Chicago
- Houston

14.33 1960's: Many new techniques for air sampling, analysis, and clean up were developed. More rigid control laws were enacted.

14.34 1970's: Federal guidelines and tough new state laws are forcing the abatement of air pollution problems

14.35 1975-76: Automotive engine pollution control laws will become effective.

14.4 Legislative Development

14.41 1953: The public health service established a national air sampling network.

14.42 1955: Federal air pollution research and technical assistance act. Directed the Public Health Service to conduct research, provide technical assistance to states, train personnel, and disseminate information.

14.43 1958: 1st National Air Pollution Conference sponsored by the Public Health Service

14.44 1960: U.S. Surgeon General established the Division of Air Pollution as part of the Public Health Service

14.45 Late 1960: The 2nd National Air Pollution Conference

14.46 1963: Clean Air Act of 1963 intensified federal air pollution control efforts.

14.47 1964: Senate Special Report, "Steps Toward Cleaner Air" recommended legislation to regulate automotive emissions

14.48 1967: The president proposed strong national authority to control air pollution, however, The Air Quality Act of 1967 retained state control.

14.49 1970: Clean Air Act of 1970, requires vehicles manufactured during and after 1975 to reduce CO and hydrocarbon emissions by 90% of the 1970 legal emission rates, and vehicles manufactured during and after 1976 to reduce NO_x emissions by 90% of the 1971 vehicle measured emission rate.

14.5 Technical Background

14.51 Air Pollution: any substance suspended in the air in sufficient concentrations to be injurious to health, well-being, or harmful to possessions.

14.52 Major Pollutants:

Particulates - from any dust generating source

Sulfur oxides - from heating of sulfur-containing compounds

Carbon monoxide - natural result of oxidation with an oxygen deficiency

Nitrogen oxides - from high-temperature combustion using atmospheric oxygen

Hydrocarbons - from unburned fossil fuels

14.53 National Ambient Air Quality Standards

Primary Standards: protect public health

Secondary Standards: protect public welfare

14.54 U.S. Primary Standards:

Particulates . . . . 75 ug/M^3

SO_2. . . . . 80 ug/M^3

CO . . . . 10 ug/M^3

NO_x. . . . . 100 ug/M^3

Hydrocarbons . . . . 160 ug/M^3

14.6 Data Gathering

14.61 Need city data that will correlate as a function of the demographic parameters, i.e. emissions as a function of:

population

income

land area, etc.

14.62 Requested reports for consultation on the metropolitan cities air quality control regions:

50 cities were contacted

31 cities responded

These reports did not contain sufficient data.

14.63 Requested the following data from 120 cities:

Emissions data (Tons/unit time)

Particulates

SO_2

CO

NO_x

Hydrocarbons

14.64 Demographic Data:

Land Area (Total)

Zoned: Industrial

Commercial

Residential

Population

Per Capita Income

%/Capita Income from MFG

%/Capita Population Employed in MFG

Only 23 of the 120 cities provided complete data.

14.7 Modelling

14.71 Model Structure (see Figure 14.1)
14.72 Data Processing

Input

Demographic Data

Output I

Emissions

Output II

Concentrations

Output III

Costs-To-Abate

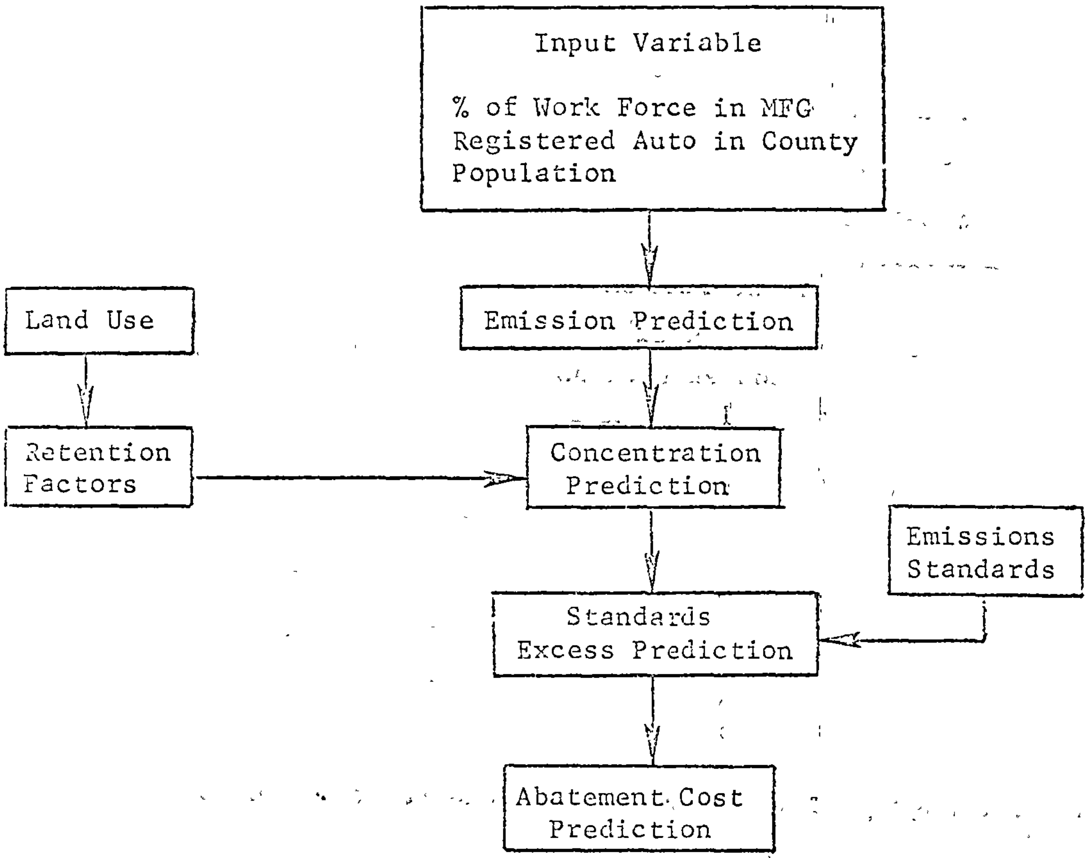
14.72 Only 3 demographic parameters were found to have a usable correlation with emissions data:

- Population
- Number of automobiles registered in the country
- % of the work force employed in MFG

14.73 Since the air pollution is from three major sources, these three parameters should provide a measure of:

- Domestic pollution
- Vehicular pollution
- Industrial pollution

Figure 14.1. The Air Pollution Model



14.74 A multiple regression analysis is suggested here:

y	x_1	x_2	x_3

However, this technique is three dimensional so the three parameters were summed and a linear regression was used.

This summary requires a common mean so:

Population	÷ 0.000
% of work force in MFG	÷ 0.437
Registered Autos	+ 0.261

Input parameters used later are:

Land Area

Concentration Standards

So now a linear regression is used:

y	ΣX_i

14.75 The correlations can be seen in the plot of particulates against the sum of the demographic parameters (see Figure 14.2).

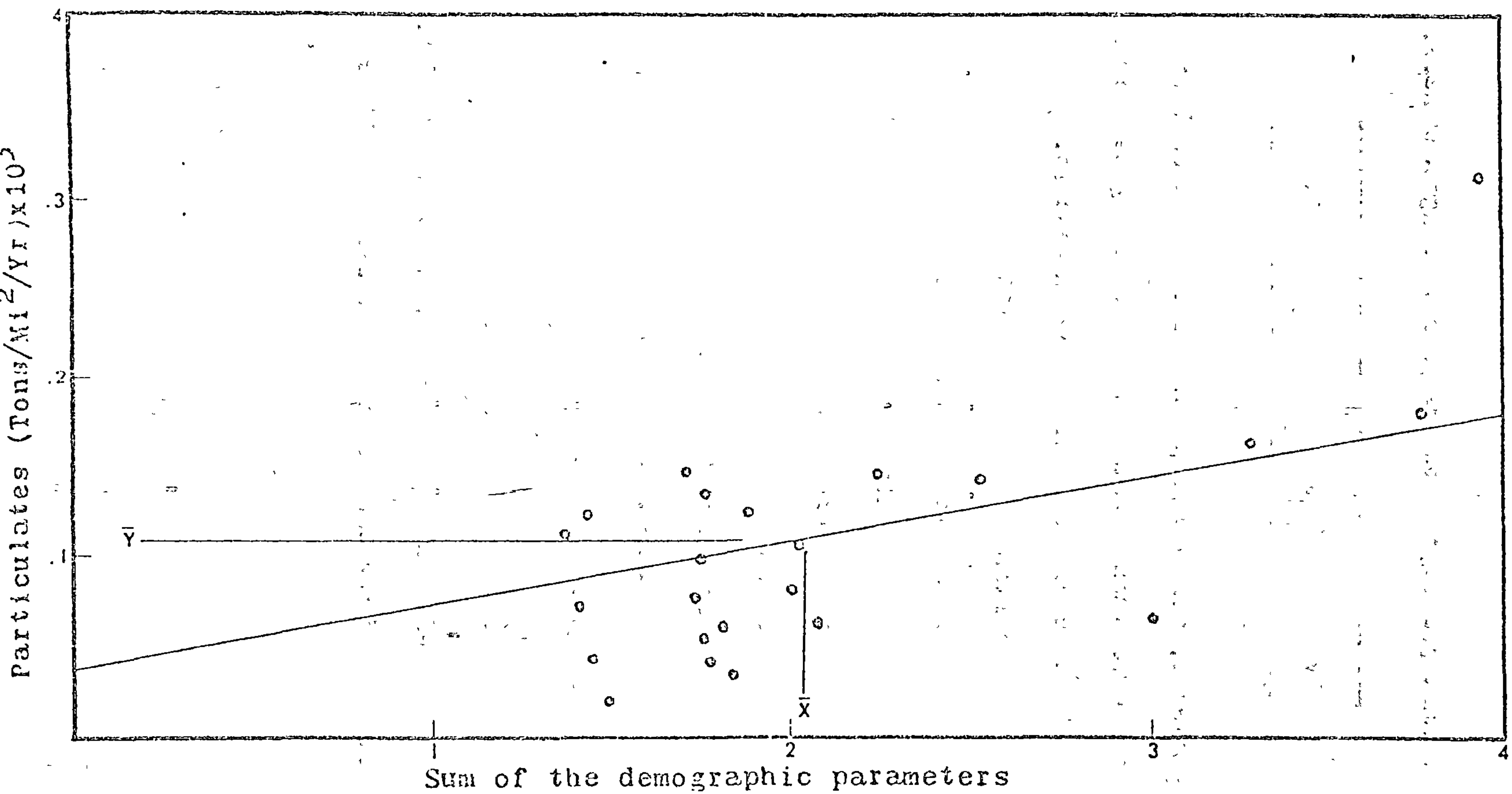


Fig. 14.2 Regression of Particulate emissions on the sum of the demographic parameters.

14.8 Model Development:

14.81 Emission Prediction

A. To locate a point (y') on a regression line, use the basic line formula:

$$y' = d + \beta(x)$$

But: x is now ΣX_i

so, $y' = d + \beta(\Sigma X_i)$

After shifting, X_i becomes X_i', so

$$y' = d + \beta(\Sigma X_i')$$

However: $\Sigma X_i = \Sigma X_i + K(y - \bar{y})$

Therefore: $y' = d + \beta[\Sigma X_i + K(y - \bar{y})]$

However: $y = d + \beta(\Sigma X_i)$

So: The final prediction formula becomes:

$$y' = d + \beta[\Sigma X_i + K(d + \Sigma X_i - \bar{y})]$$

B. Measured Emissions Correlation Option

$$y' = d + \beta[\Sigma_i + K(y_m - \bar{y})]$$

where: y_m = measured emissions in tons/mi^2/yr

C. Vehicular Emissions Reduction (Clean Air Act of 1970)

% of Reduction = $P_1 \times P_2 \times P_3 \times P_4$

where P_1 = % of total emissions by motor vehicles

P_2 = % of light duty vehicles

P_3 = % of new vehicles each year

P_4 = % emissions reduction required by law

Amount of reduction = $y' -$ % of reduction $\sum_{1}^{10}$

where: $m = i - I$

$I = 1974$

$i = 1975, \ldots, 1984$

D. Concentrations Predictions:

1. Needed: Predicted emissions

Meteorological retention

2. George C. Holzworth developed these retention factors for the United States (see Figure 14.3).

To find the correct retention for a city

- determine city diameter in kilometers from the following table:

Land Area (Mi^2)	Diameter (km)
0 - 60	10
70 - 184	20
185 - 254	30
255 - 579	40
580 - 859	50
860 - 1199	60
1200 - 1599	70
1600 - 2049	80
2050 - 2559	90
2560 - 3100	100

- find retention zone on the map (Figure 14.4)

- determine retention factor from Table 14.1

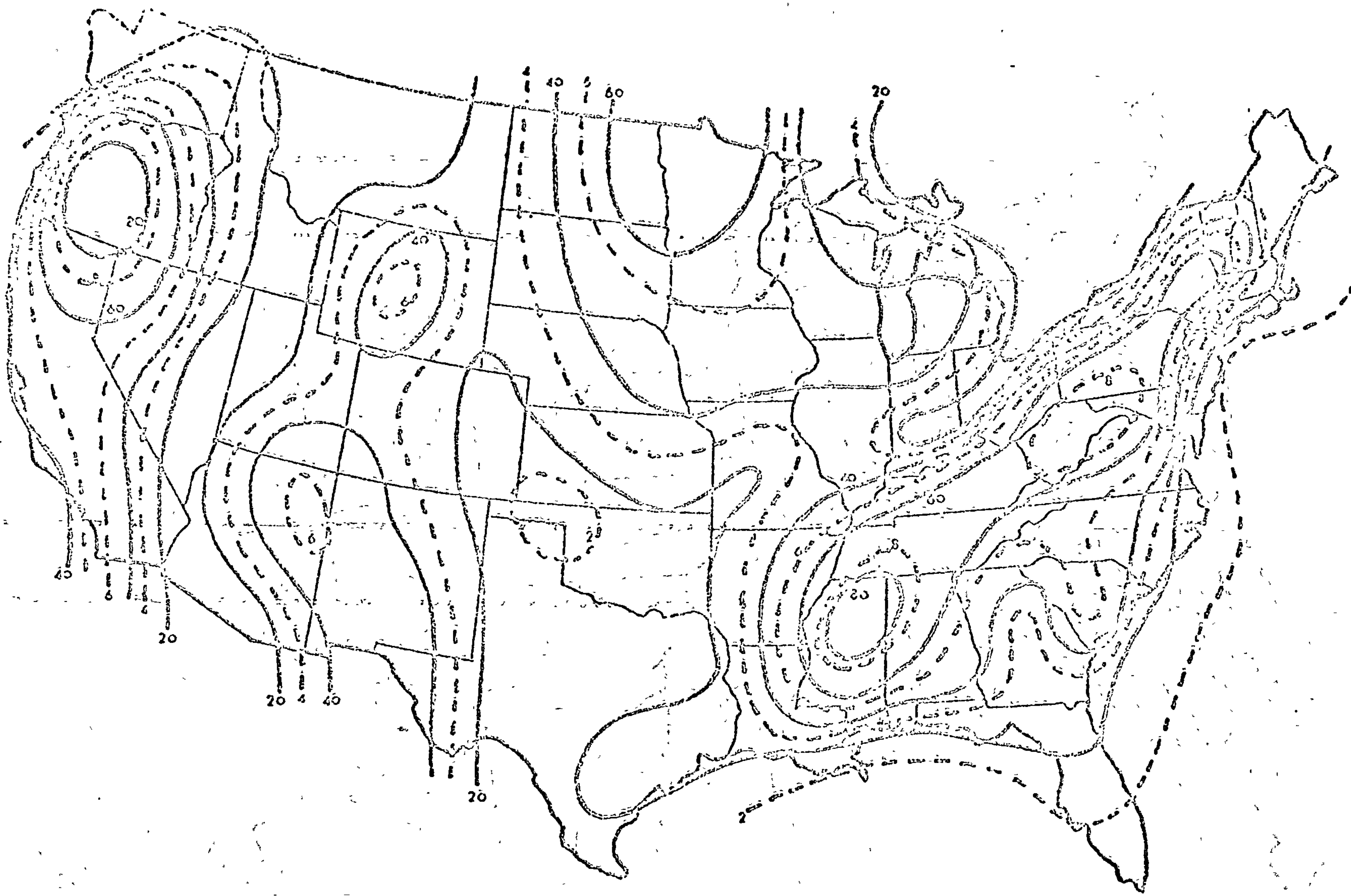
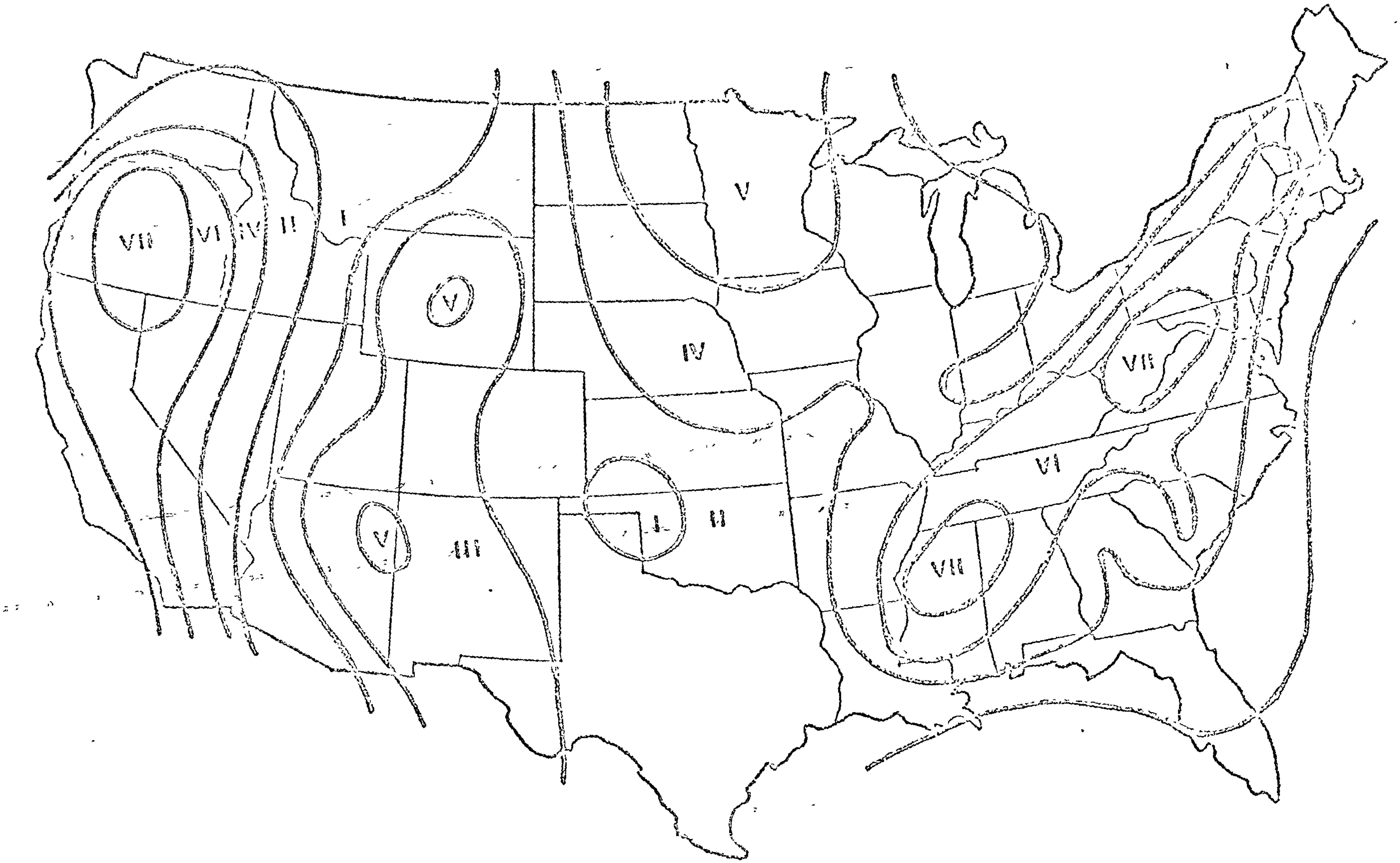


Fig. 14.3--Holzworth's retention factors. Solid isopleths for 100 Km cities(sec $M^{-1}X10^{-1}$), dashed isopleths for 10 Km cities(sec $M^{-1}X10^{-1}$).



Retention Zones
Figure 14.4

Retention Factors by Zone and City Size

City Diam (Km)	Retention Factors						
	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII
10	20	30	40	50	60	70	80
20	40	60	80	100	120	140	160
30	60	90	120	150	180	210	240
40	80	120	160	200	240	280	320
50	100	150	200	250	300	350	400
60	120	180	240	300	360	420	480
70	140	210	280	350	420	490	560
80	160	240	320	400	480	560	640
90	180	270	360	450	540	630	720
100	200	300	400	500	600	700	800

Table 14-1.

The concentration prediction formula is:

$$c = y' (.0111) RF$$

where: c = concentration in ug/m^3

y' = predicted emissions

(.0111) = changes $Tons/Mi^2$/ year to $ug/M^2/sec$

RF = retention factor

3. Standards excess prediction

$$E = y' - Standard/.0111/RF$$

4. Abatement costs prediction

$$A = E(\$54.59/Ton)$$

14.9 <u>Validation</u>:

The model was run for 9 cities which had measured emissions available. Predicted emissions were compared with measured emissions (see Table 14-3).

Predicted concentrations were compared with measured concentrations (see Table 14-4 Figures 14.5, 14.6, 14.7 and 14.8.)

Excess emissions and costs-to-abate were calculated (see Table 14-5).

14.10 <u>Model Limitations</u>:

1. No more accurate than population model
2. Probability model - possible world was not considered; goals of a city were not considered
3. 1976 cost predictions <u>only</u> - inflationary trends were not considered
4. Model accurate for 40,000 - 2 million population <u>only</u>
5. Poor for cities with little MFG or with nuclear electric power
6. Poor for resort areas (autos are not registered in county).

TABLE 14-3

PREDICTED AND MEASURED EMISSIONS
FOR VALIDATION CITIES

CITY	EMISSIONS (TONS/MI^2/YR)									
	PART		SO_2		CO		NO_x		HC	
	PRED	MEAS	PRED	MEAS	PRED	MEAS	PRED	MEAS	PRED	MEAS
DENVER	89	57	199	57	1138	173				
TULSA	78	110	162	66			110	110		
CHATTANOOGA	71	110	139	77			186	226	206	200
ATLANTA	90	38	202	17						
INDIANAPOLIS	102	139	241	280	1364	1641				
ST. LOUIS	111	64	273	72	1540	759				
MEMPHIS	98	35	228	123						
MILWAUKEE	120	311	304	865						
DETROIT	205	168	591	780						
AVERAGE PREDICTION ACCURACY %	58.77		45.59		49.19		69.02		97.08	

AVERAGE EMISSIONS PREDICTION ACCURACY FOR ALL POLLUTANTS = 63.93%

TABLE 144

PREDICTED AND MEASURED CONCENTRATIONS
FOR VALIDATION CITIES

CITY	CONCENTRATION ($\mu g/M^3$)									
	PART		SO_2		CO		NO_x		HC	
	PRED	MEAS	PRED	MEAS	PRED	MEAS	PRED	MEAS	PRED	MEAS
DETROIT	171	140	328	300						
MEMPHIS	82	90	127	130						
DENVER	30	40	44	60	253	320				
CHATTANOOGA	55	72	72	52			45	58	320	404
ST. LOUIS	74	95	121	130	683	650				
ATLANTA	60	70	90	100						
INDIANAPOLIS	68	80	107	130	606	540				
MILWAUKEE	100	117	169	156						
TULSA	39	53	54	78			37	40		
AVERAGE PREDICTION ACCURACY %	81.33		84.62		87.77		85.04		79.20	

AVERAGE CONCENTRATION PREDICTION ACCURACY FOR ALL POLLUTANTS = 83.59%

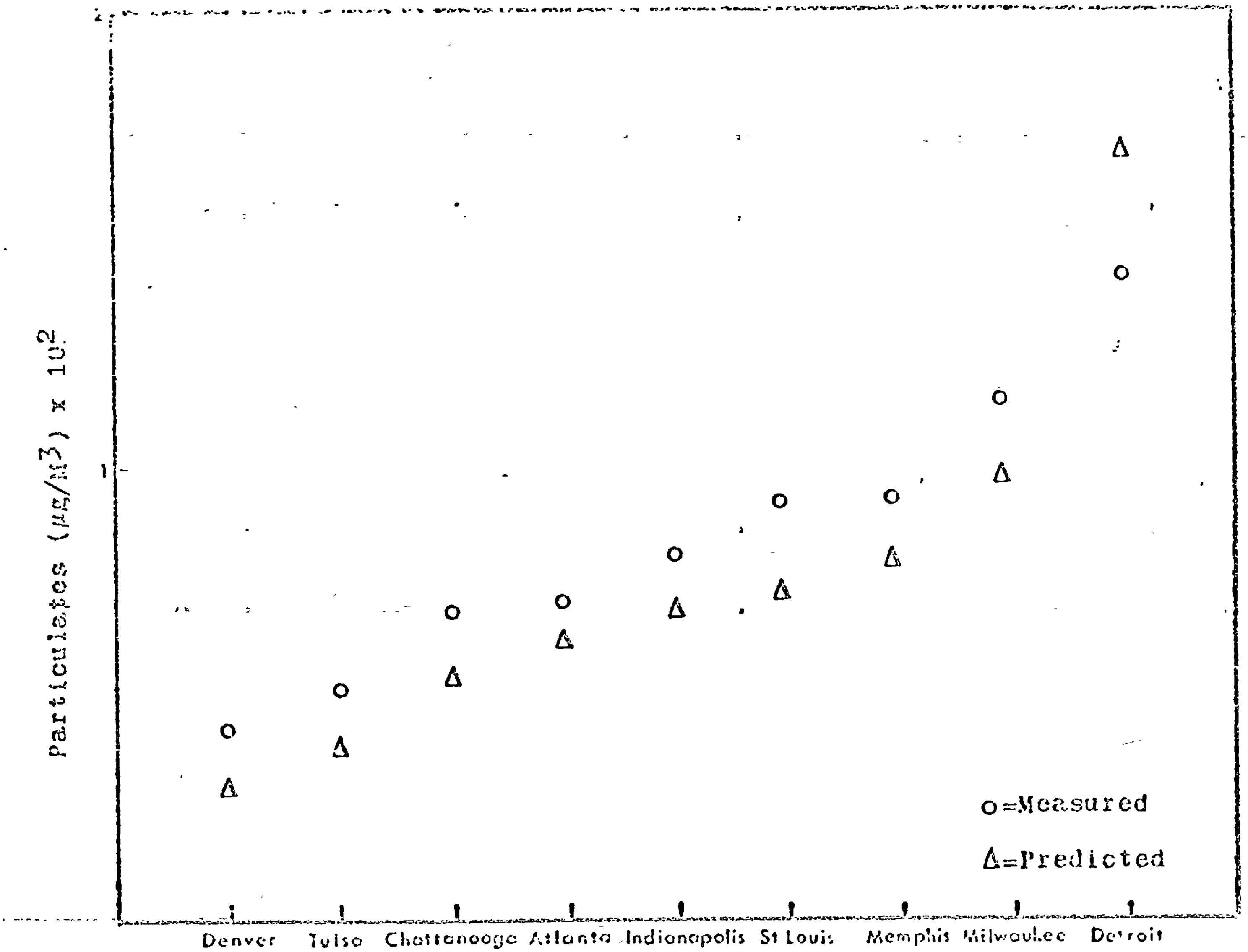


Fig. 14.5 Predicted vs measured Concentrations of Particulates

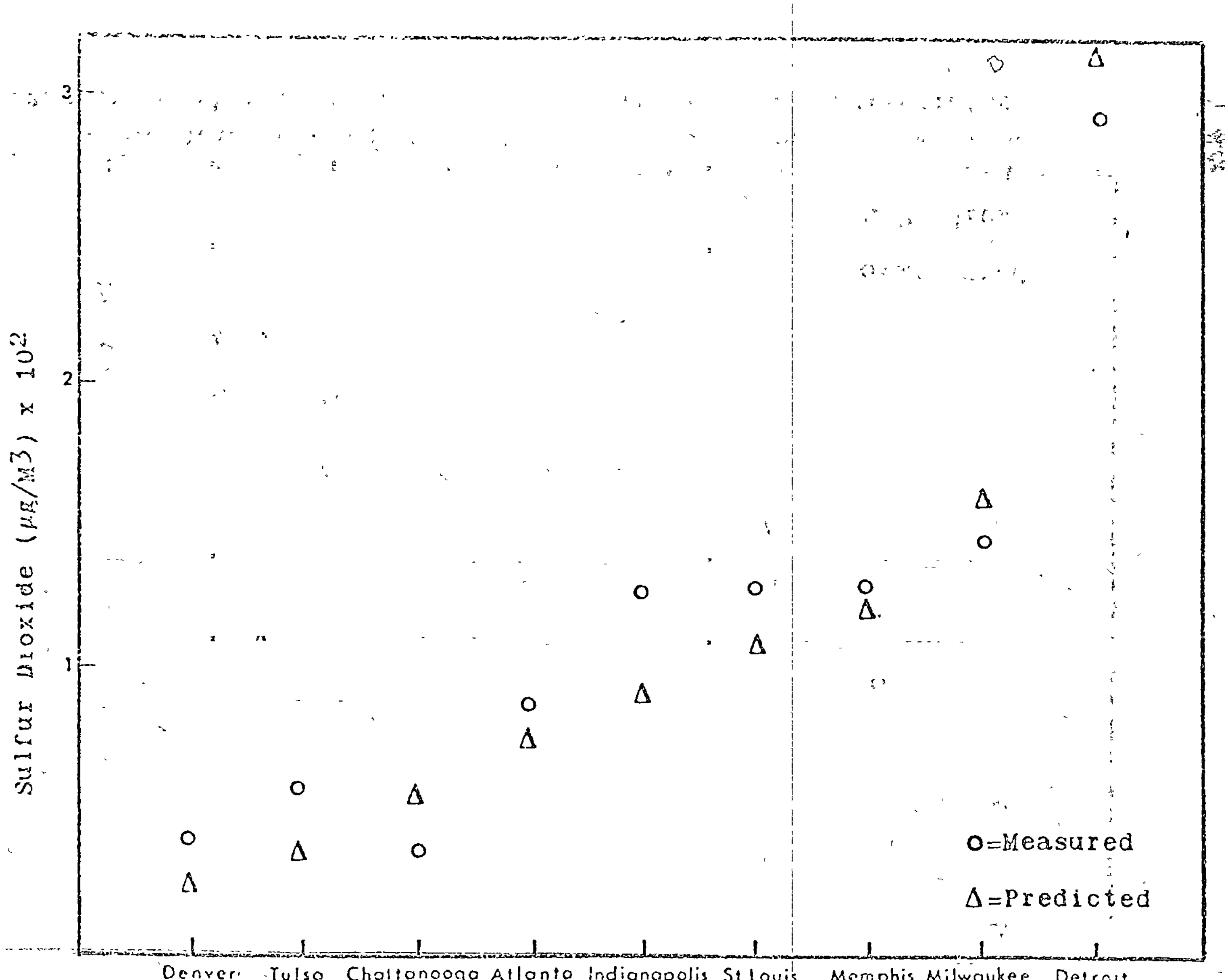


Fig. 14.6 Predicted vs measured concentrations of Sulfur Dioxide

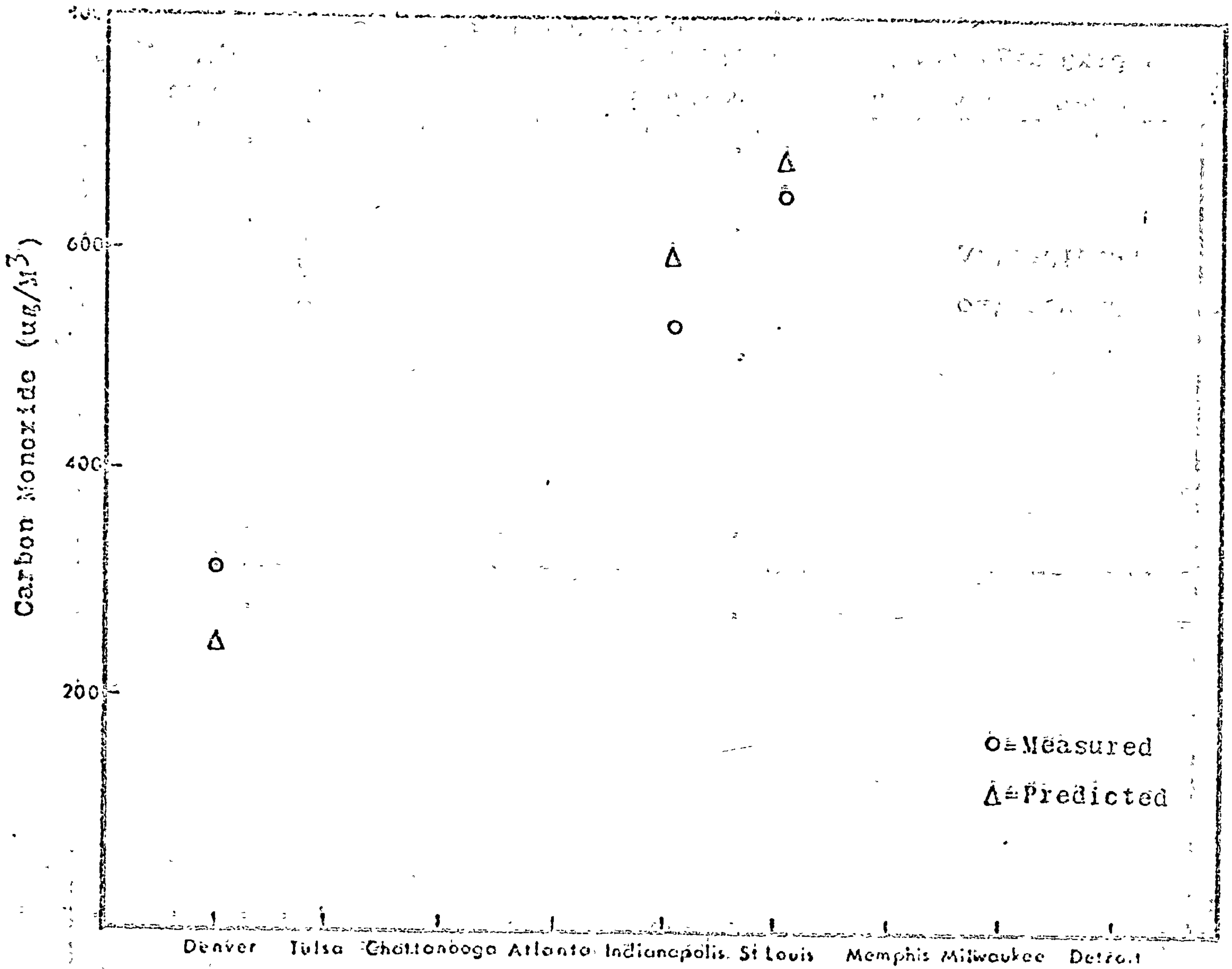


Fig. 14.7 Predicted vs measured concentrations of Carbon Monoxide

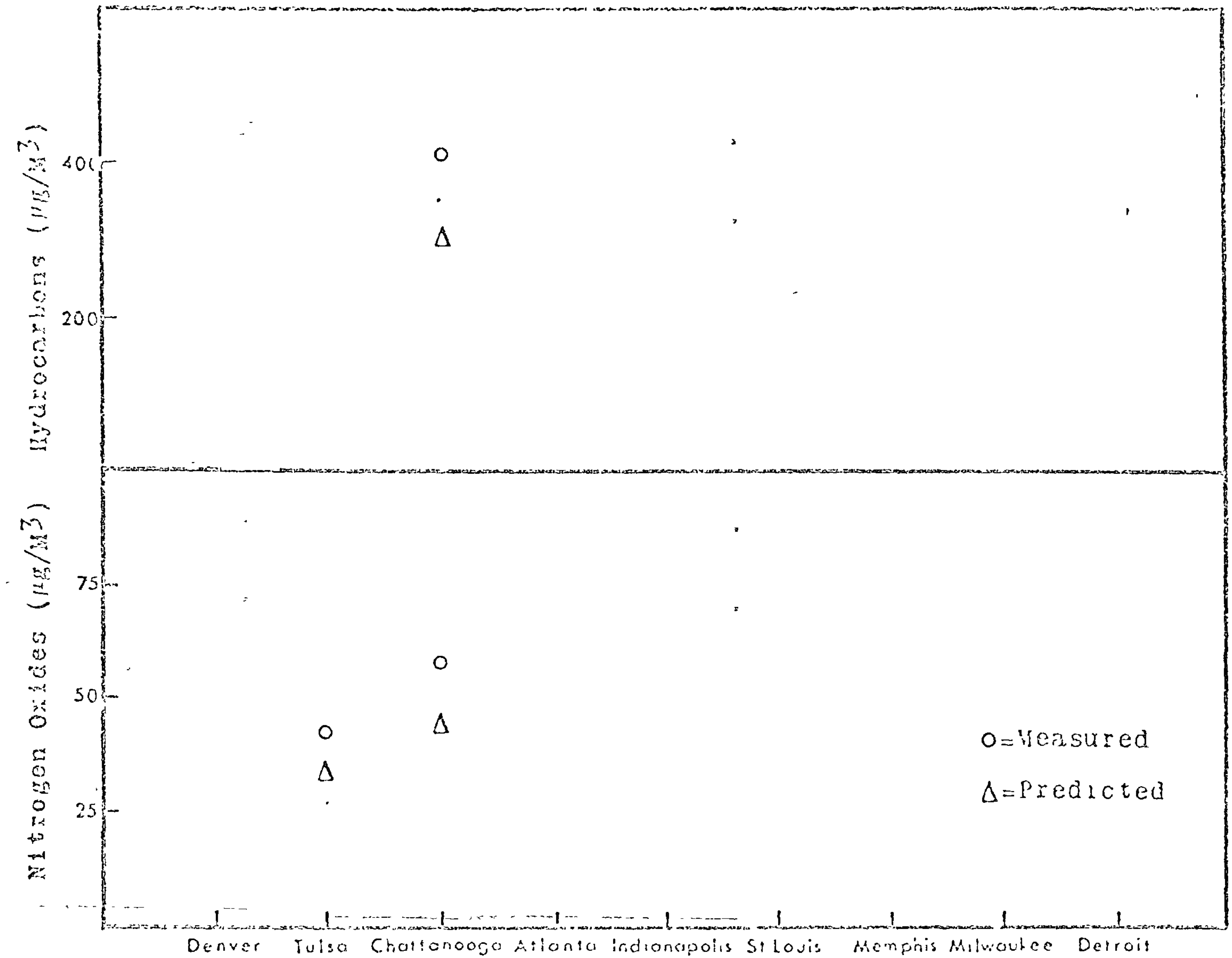


Fig. 14.8 Predicted vs measured concentrations of Nitrogen Oxides and Hydrocarbons

TABLE 14-5

EXCESS EMISSIONS AND COST-TO-ABATE
FOR VALIDATION CITIES

	EXCESS EMISSIONS ($TONS/MI^2/YR$)					COST-TO-ABATE ($DOLLARS/MI^2/YR$)				
	PA	SO_2	CO	NO_x	HC	PA	SO_2	CO	NO_x	HC
DENVER			-	-				-	-	
TULSA										
CHATTANOOGA					103.1					5628.23
ATLANTA		21.8					1190.06			
INDIANAPOLIS		60.8	-	-			3319.07	-	-	
ST. LOUIS		92.8					5065.95			
MEMPHIS	7.9	83.9				431.26	4580.10			
MILWAUKEE	29.9	159.8				1632.24	8723.48			
DETROIT	114.9	445.8	-	-		6272.35	24336.22	-	-	

U.S. PRIMARY STANDARDS

PA = 75 $\mu g/M^3$

SO_2 = 80 $\mu g/M^3$

CO = 10 mg/M^3

NO_x = 100 $\mu g/M^3$

HC = 160 $\mu g/M^3$

COST-TO-ABATE/TON

$54.59

CHAPTER 15

TRANSPORTATION MODEL

15.1 Introduction

The objective of the transportation sub-model is to develop a methodology which can be used to assist in the planning of an urban area. A network systems transportation model was developed initially but due to some difficulty with the mathematical programming used in the model, it requires further testing before it can be used. The development and the format of the network transportation model will be discussed in the next section of this chapter.

Traditionally, the transportation plan of an urban area is formulated based on a total transportation planning process. Several years ago, the Tulsa-INCOG área conducted a transportation study based on this process. The results of that study were several alternative transportation plans for the area. To illustrate how the transportation sector fits into the complete urban system model, the total transportation planning process is also included in this chapter.

15.2 The Network Systems Transportation Sub-Model

The objective of this sub-model is to develop a transportation systems design model which is based on goal-directed/backward-seeking model systems. In this system one starts with the goals for the selection of transportation alternatives and then tries to proceed through the consequences of alternative plans to the selection of the alternative plan which will best, or at least satisfactorily, achieve the desired goals. The significance of this system is the likely increase in efficiency with which goal or optimal alternatives can be found and then selected. This planning model is an extension and application of a goal-directed model system developed by Morlok for the Northeast Corridor (1), for an urban area.

One of the major distinctions between the different kinds of planning models is whether it is an action-directed or a goal-directed model system. In the action-directed model system each alternative is considered in turn, its consequences are predicted and evaluated, and, finally, a choice is made. Thus, the search is structured around the generation of alternatives which, it is hoped, will conform to the objectives. The existing action-directed planning models cannot be reversed because these models are not analytical models and consequently do not possess enough theoretical structure either to permit operation in both directions, or to evaluate the consequences of a given action. Then the alternative plans considered in a standard transportation study are far fewer than the actual number of alternative plans, which are also subject to the financial, time and dimensional constraints of the problem.

In the case of goal-directed models, the search may be intuitive in the sense of design, or it may be a formalized linear programming model. In the first case, the input for selection is several sets of alternative actions whereas the output of selection is a set of consequences for each set of the actions. In the second case, the input is a set of desired consequences, and the output is the required action set. Therein lies the reason and need for a flexible and efficient formalized computer-based design model. The second version of the goal-directed models is also called "the backward-seeking model" because it starts from the consequences and proceeds backwards to the action.

15.2.1 General Model Description

The components of the transportation system which are being considered in this model are:

(i) activity system,

(ii) vehicle or person flow network, and

(iii) fixed plant network.

For a transportation study, a city is divided into traffic zones. These traffic zones are connected with each other by means of a network which is called the fixed plant and consists of a series of links and nodes. The links of the fixed plant correspond to routes such as roads and streets, while the nodes correspond either to origins and destinations of travelers or to intersections or interchanges. The network is characterized in terms of such information as street width, capacity, speed limits, distances, location-coordinates, etc.

The sequence of links which is used by a vehicle to travel from one zone to another is called a path. There may be one or more paths between zones. Each path is characterized by variables of functions which are relevant to travelers' trip-making decisions, such as travel time, walking and waiting time, parking cost, fare, frequency of service, etc. These path characteristics are called level-of-service variables. Some of these variables are a function of the demand volume. In order to deal separately with the changes in the fixed plant and with the changes in possible paths and path characteristics (in any given fixed plant), the path network is called the vehicle flow network.

Options about networks include the general configuration pattern of the network as well as the approximate geographical location of the links of the network. Changing the network configuration can be done by introducing several other supplemental links or changing the relationship of a link with other links by adding or eliminating intersections between links, or changing the characteristics of the link itself by changing its physical location or widening it. Other options are those regarding the number and type of vehicles that run over the link as well as speeds, schedules, stopping times and fares. So there exists a wide range of options which might be considered in transportation planning.

Besides making changes in the fixed plant network and the vehicle flow network, new technologies can be introduced. One possibility is binary -- for example, the choice of adding a new link or not in the network of a particular mode, the choice of using a particular technology, or the choice of constructing a new terminal. Other choices, namely those within each model technology, can be represented as continuous choices with a range of values.

15.2.2 Input Models to the System

These models are used as imput models and they are:

(i) Boston direct travel demand model,

(ii) the network performance or supply model, and

(iii) the cost models.

The travel demand model is a "direct travel demand model" (2). In a direct travel demand model, the travel flows between origins and destinations are expressed as a function of the characteristics of the people at origins, the activity characteristics at destinations, the characteristics of the vehicle flow network, and the level-of-service variables pertaining to a fixed plant. The first two sets of variables, characteristics of the origins and destinations, are given inputs to the planning model system; while the last two the vehicle flow network and the fixed plant, are the subject of the present model. Thus, the travel demand model acts as a liaison between the activity system and the transportation requirements of that system.

The second input models are supply models. A supply model characterizes the performance of the vehicle flow network. Some of the supply models are functions, such as travel time being a function of demand volume, street width, and access control; others are just simple numbers such as fare, frequency or parking cost. All these functions or variables characterizing the vehicle flow network fall under the heading "supply" models.

The third and last set of imput models are the cost models. The costs are, of course, dependent on the characteristics of the fixed plant, on the choices made with regard to the vehicle flow network, and on the flows in the network. For example, the road costs are a function of the desired road type (access-control vs. no access-control), of the desired level of service, and of the length and location of the roadway. The bus costs are a function of route lengths and frequencies on each route; a bus capacity cost may also be a pertinent cost.

15.2.3 Plan Evaluation

For this study the method of evaluation is the minimization of costs subject to the achievements of desired levels of benefits. Minimum cost evaluation, given that certain objectives ("benefits") are attained, has a relation to cost-effectiveness analysis, which was recently suggested as a strategy for the evaluation of alternative transportation plans (3). In cost-effectiveness analysis, there are two classes of information, costs and indicators of effectiveness. The evaluation of the alternatives and subjective choice is based on these two classes of information. The effectiveness measures are the measures of "benefit", that is, measures of the extent to which the alternatives achieve the stated objectives. These stated objectives may again be assumed by the planner or proposed by the decision-maker for analysis purposes. In the present model the objectives are related to the performance of the transportation system. In spite of substantial heuristic evidence of the relationships between the transportation system performance and the activity system performance are measured by employment, poverty, economic development, etc., the present model does not include these relationships since the model's solution algorithm requires analytical relationships. Hence, demand is the only relationship linking the activity and the transportation systems. Of course, the transportation system must be designed so that the capacity is able to accommodate the demand.

15.2.4 Mathematical Operation of the Model System

The mathematical problem presented in the previous section is a constrained external problem. The objective is to find a minimum cost transportation improvement program for a given level of effectiveness. Thus, the levels of effectiveness (the objectives) are specified first, and then the model system seeks the minimum cost improvement program.

It was noted earlier in the description of the transportation system that transportation improvements relating to fixed plants are of a binary nature whereas improvements relating to vehicle flow network are continuous in nature. It was also noted that these two kinds of improvements need different kinds of mathematical treatment. This need for separate mathematical treatment derives from the fact that it is better to use dynamic programming when binary variables are involved (fixed plants) while linear (or separable) programming is more efficient in dealing with continuous variables (vehicle flow network). This combined dynamic-linear program is proposed by Norlok (1) and works as follows:

Each stage of the dynamic programming corresponds to one time period, and the states in a given stage correspohd to different types of the fixed plant. For each fixed plant there exists an infinite number of choices regarding the vehicle flow network; these choices are made by using linear programming. Thus, the linear programming is run for each fixed plant (state) and for each time period (stage), to arrive at the optimal vehicle flow network. The results of the linear programming runs are then entered into the dynamic programming problems. For each state and stage the discounted operating costs of the vehicle flow network and discounted capital costs of the fixed plant are entered. The dynamic programming then selects the optimal transportation improvement program over time.

It is important to note that different plans are not represented in terms of different fixed plants but in terms of different levels of effectiveness, that is, objectives. Different types of government policies regarding transportation and their effects in network improvements and on costs may be examined by changing the effectiveness constraints.

Another important consideration relates to the uncertainty of the forecasts. The effect of uncertainty on network improvements may be examined by undertaking a sensitivity analysis of the various parameters in the model system. It is well known that this type of sensitivity analysis is often an integral part of any linear programming application.

It appears that the model system presented above lends itself to analysis which helps the decision-makers to select reasonable choices.

15.2.5 Model Structure

There are four major components in the network systems model:

(i) the network generation model,

(ii) the optimal multimodal network model (auto and bus only),

(iii) the capital cost model, and

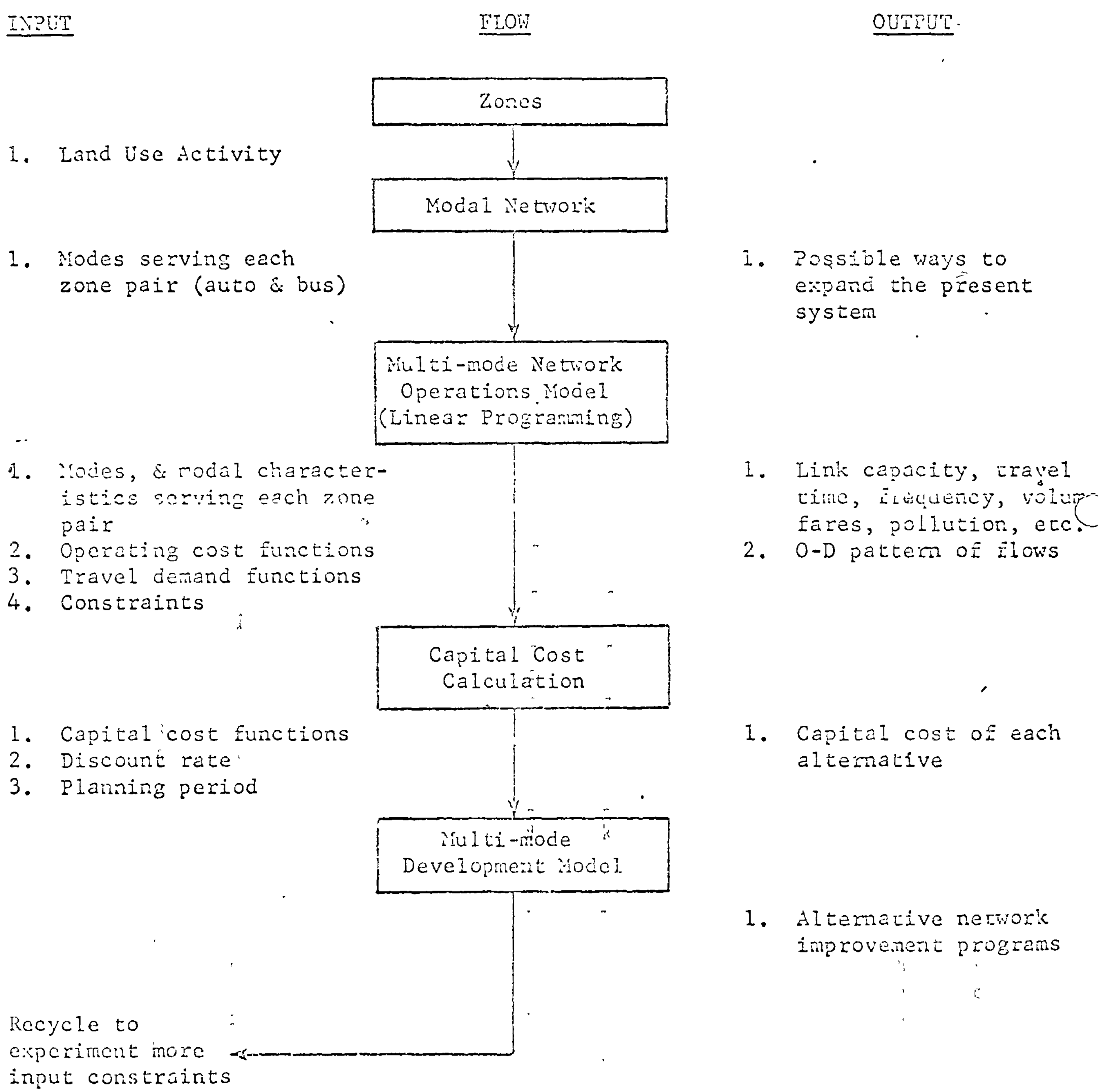
(iv) the optimal network development model.

These four models, along with certain human interaction, are shown in their logical relationship to one another in Figure 15.2.5-1.

The model system begins by generating all possible graphs which mights be used to connect the nodes representing various zones in the study area. These graphs represent both possible fixed plant networks and possible networks of vehicular flows. The graph-generating program may also be used to identify possible paths of development or expansion

Figure 15.2.5-1

Logic Diagram for the Network Transportation Model



of either the existing network or modifications of it.

Once the admissible multimodal (auto and bus) networks for both the fixed plant and vehicular flows have been identified for each time period under analysis by employment of both the network generation model and human interaction, the analysis proceeds to the optimal multimodal network operations model. This model essentially accepts as given, for each run, the fixed network of the transportation system and certain choices regarding the operating rules for that system and the desired levels of effectiveness of the transportation system. On the basis of this information and certain consequences of various operational choices, this model proceeds to select the optimal method of system operation in terms of such variables as frequency, travel time, price, and capacity. The predictive relationships included in this model refer to the cost of operating the various modes, technological relationships such as capacity relationships, and travel demand functions. The constraints which reflect levels of effectiveness can refer to a wide range of possible types of effectiveness measures, ranging from pure level of service or accessibility constraints to impact relationships dealing with the social state and human opportunity levels.

This model is run for each fixed network and set of possible links in the vehicular flow network for each time period under consideration. It deletes from further consideration those networks which cannot be operated in such a manner as to achieve the desired levels of effectiveness.

Once the set of transportation systems which are feasible in terms of levels of effectiveness for each time period are identified, then the choice of the actual path of development of the transportation system, in terms of both capital investments and operating sch s, is addressed. This is done by associating both the operating costs an capital costs, appropriately discounted, with each possible alternative path of system development. Discounted capital costs are calculated by the capital cost model. The optimal network model considers each possible path of network development and selects the one which achieves the desired levels of effectiveness, corresponding to each time period in the analysis, at the least total discounted cost.

15.2.6 Analytical Form of the Model

Objective Function (Costs)

Functions of the fixed plant of the transport system are to be optimized. The choices are made as to system operations and flows on the network at each point in time. The cost at each time period is represented by a function of capital costs and operating costs. The capital cost function at any time period includes both the improvements made from the preceding time period and the plant in existence at the time considered. Road capital costs are related to actual performance measures such as vehicle flow capacity and vehicle travel time. Road operating costs are associated with the operation of motor vehicles between each pair of zones, or the quantity of travel demanded over all paths between each pair of zones. The operating costs for buses are associated with the number of vehicle trips operated on each vehicle flow network link. A general form of the objective function between zones i and j for an area is given as follows:

$$a \cdot c_{ij\ auto} + b \cdot t_{ijk} + c \cdot d_{ijk} + d \cdot f_{ij\ bus}$$

where, $c_{ij\ auto}$ = Vehicle flow capacity of road link ij, vehicles/day,

t_{ijk} = Travel time on road link ij by mode k (line haul time and access time), minutes,

d_{ijk} = Daily person flow from zone i to j by mode k, trips/day,

$f_{ij\ bus}$ = Daily vehicle trip frequency of a bus on link ij, trips/day,

a,b,c and d = Parameters obtained from Morlok's (4) study of transport technology.

Constraints

(1) Demand Functions

The demand functions used in this model are based upon the concepts of abstract transportation mode demand models, in which the demand for travel on each mode between each pair of zones is related to the characteristics of those zones and characteristics of the competing mode. The quantity demanded on a particular mode is related to the travel time, frequency and price of that mode and the travel time, frequency and price of the competing mode. The general form of the constraint is the following:

$$d_{ij\ auto} \geq a_1 \cdot t_{ij\ auto} + b_1 \cdot p_{ij\ auto} - c_1 \cdot t_{ij\ bus}$$

where, p_{ijk} = Price of the trip associated with mode k like access cost and linehaul cost, \$,

a_1, b_1 and c_1 = Parameters obtained from the Boston direct demand model (5).

(2) Technological Constraints

This constraint ensures that the capacity chosen for a link is sufficient to accommodate all of the traffic flowing on that link. Therefore, each link capacity is constrained to be at least as great as the sum of the demands for road travel for all paths of the person flow network which use that fixed link.

$$d_{ij\ auto} + d_{ji\ auto} \leq \frac{1}{L} \cdot c_{ij\ auto}$$

where, L = Average auto occupancy = 1.5

For a bus, it is required to provide sufficient vehicle capacity on each vehicle flow link to accommodate all the passengers assigned to it, which is given by

$$d_{ij\ bus} + d_{ji\ bus} \leq Cap_{ij\ bus}$$

and

$$2\ Cap_{ij\ bus} \leq f_{ij\ bus}$$

where, $Cap_{ij\ bus}$ = Bus capacity assumed to be 35 passengers.

In the absence of a strong supply model for the bus for such functions as waiting and walking times and its effect on the access time of the bus, an approximate model was constructed. This model is based on the variables of bus route densities in the zones and the bus frequencies. Waiting time is assumed to be 1/2 of the headway between successive units, and walking time is a function of the average travel speed for a person walking including delay time at intersections and existing bus route density in a particular zone. Bus route density again is dependent on the linear miles of road in a zone on which buses are routed and the area of the zone. The following form has been used:

$$t'_{ij\ bus} + 8RD_i + 8RD_j - f_{ij\ bus} = 46$$

where $t'_{ij\ bus}$ = Access time for bus mode on link ij, minutes

RD_i = Road densities in zone i.

(3) Level of Service or Accessibility Constraints

Accessibility constraints reflect one type of effectiveness measure which can be used to evaluate alternative networks in the general network generation and evaluation schemes. Accessibility is defined as the ease with which travel can occur from a particular zone to other zones. Such an accessibility objective for a particular place is reflected in a constraint on the level of service choices of the modes serving that zone. These are, of course, directly related to the choice variables of modes (frequencies, capacities, road design, travel times and travel costs). Some of these act as upper or lower bounds or both for choice variables.[1]

15.2.7 Model Validation

The validity of this transportation planning model is dependent upon the validity of its component models, which are a direct demand model, cost model and supply model. The main purpose of the present study was to construct a transportation planning model and not to create new, strong and effective demand, supply and cost models to be utilized for planning purposes. There was no reason as well as time to create new models. Hence help of existing models was sought such as the Boston Demand Model, Tulsa cost model and supply model. It was known that some of these models, especially supply models, are not efficient, as in the case of access time for transit to help in constructing a flexible transportation planning model. The aggregate validity of these models can be given as follows:

Boston Demand Model

Error of 65% of mean level of transportation volume, which is better than the conventional UTP, of error 140%.

Supply Model

For a highway this model is good as the parametric values of different choice variables are predicted quite precisely. In the case of transit, it may be poor as no research has been carried out so far in the variables. The most influencial factor is the access time of transit which requires more predictive studies.

Tulsa Cost Model

This model is fairly good for a transit mode, but in the case of the highway, there are some factors which require further study. The effect of location on costs is yet to be established and relevant functions developed.

The transportation planning model is still at the stage of mathematical operation, and no definite results have been achieved so far, hence it is difficult to establish its validity as a part of the larger model.

15.2.8 Conclusions and Recommendations

The model to be produced is meant to serve as a public policy model. For this reason it must be of interactive variety and permit great flexibility with regard to changes in consequences, objectives and trade-off's and various monetary constraints. The output of the model will be a program for implementation, cast in terms of transportation systems options. This program will have some desirable, satisfying (if not optional) properties. This modeling method will allow a sensitivity analysis with regard to options, as the values of various parameters are likely to be questionable. This sub-model of a transportation planning system for Tulsa will become a part of the larger model or its environment according to Figure 15.2.8-1.

Recommendations

1. To make this sub-model more effective and efficient, requires further development and research into the supply and cost models which form its base components along with the demand model.
2. The socioeconomic data of the study area (Tulsa-INCOG) is found to be very inconsistent which makes the process of dividing the area into zones quite difficult when combining and relating different socio-economic factors effectively together for one particular zone.
3. The following simplifications in defining the system components are made solely for convenience in order to limit the size of the problem:

Figure 15.2.8-1

Transportation System and Its Environment

Input (Population Model)

--$
--Persons
--Goods
--Jobs
--Nature
--Info

→

SYSTEMS

-Physical elements (vehicles, links, terminals, etc.)
-Management/Control (operation policies)
-Persons/Goods
-Information

→

Outputs

-Movements
-By-Products

→

Impacts

-User
-Non User
-Owner/Operator
-Gvt.

↑

Non-transportation Options

-zoning
-wage-price control
-staggering work-hours
-location of schools, shopping centers, utilities, etc.

(i) freight traffic is totally ignored,

(ii) auto ownership figures are taken as given· however, fleet size is explicity considered, and

(iii) the terminals and their operations are ignored.

These simplifications are not due to the model structure and may be included at a later stage.

15.3 The Total Transportation Planning Process

As stated earlier, the network transportation model originally developed for this study ran into some difficulties with the mathematical programming used. It was then decided to include a different transportation model in the complete urban system model.

Several years ago, the Tulsa-INCOG area conducted a transportation study. As a result of this study, several future alternative transportation plans for the area were formulated. The study was based on techniques usually used in transportation planning processes and on certain urban growth projections made for the area. Since the outcome of this transportation study is already available, the methodology used will be included in this report as a transportation sub-model for the present study.

15.3.1 General Model Description

The total transportation planning process as shown in Figure 15.3.1-1 (6) is comprised of four main parts:

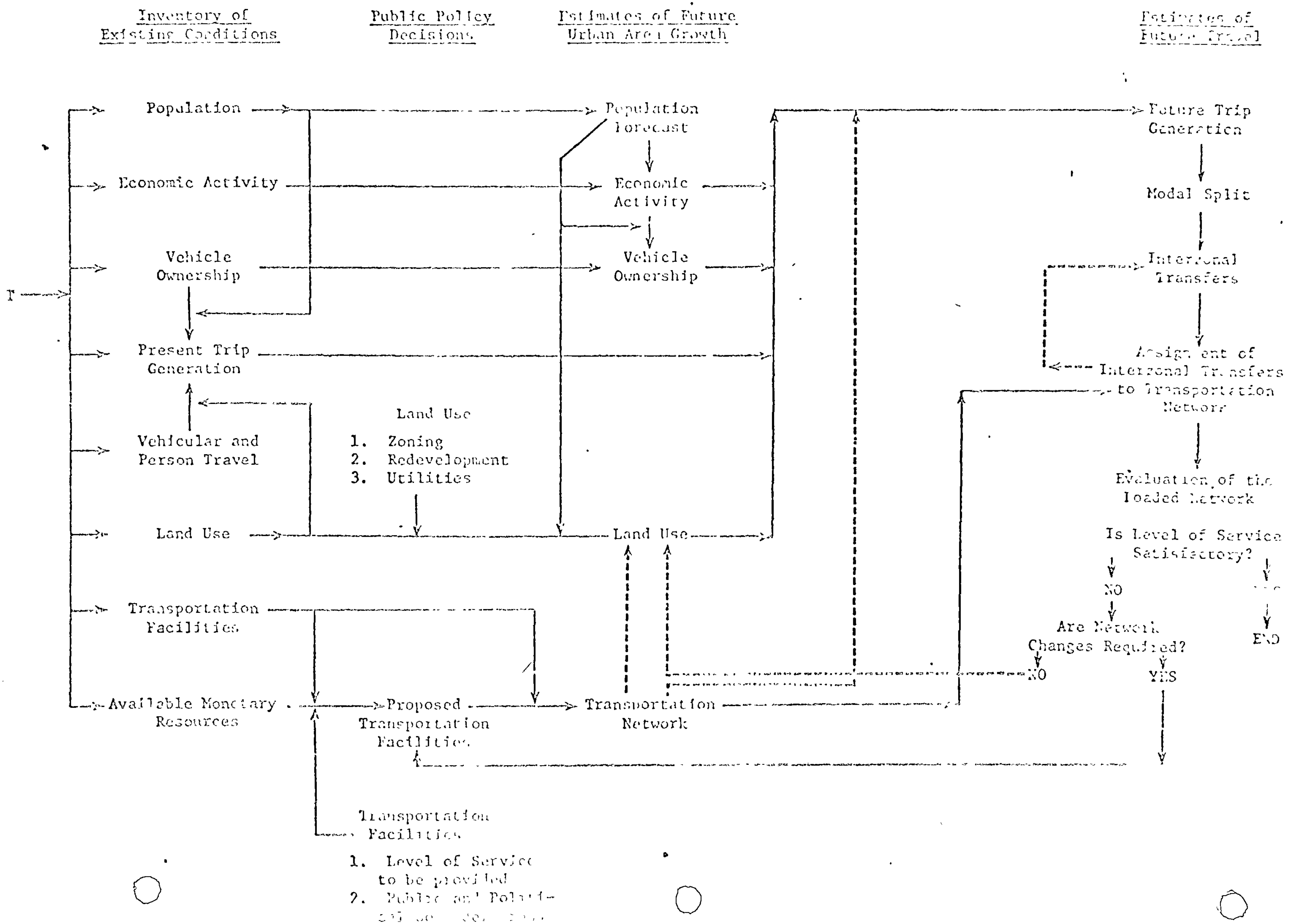
(i) inventory of existing conditions,

(ii) public policy decisions,

(iii) estimates of future urban area growth, and

Figure 15.3.1-1

The Total Transportation Planning Process



(iv) estimates of future travel.

It represents the integration of many interacting characteristics of the urban environment. Although the elements of the process are listed in a logical order as shown in Figure 15.3.1-1, it is not a sequential one. Many of the components of the process must be considered as parallel elements. The first three parts of the process are more or less related to or stated in the other sectors of the total urban system model; they will only be mentioned briefly here. The last part, estimates of future travel, will be discussed more lengthily hereafter.

15.3.2 Inventory

Inventories of the existing conditions for a transportation study include land use, population, vehicle ownership, vehicular and person travel, transportation facilities, economic activities, available monetary resources, and trip generation.

A land use inventory provides the basis for measuring the relationship between land use and trip generation. In general, a land use inventory includes site activities and intensity of site usage, plus information on the location of site with respect to other sites (accessibility) and land use patterns.

The population inventory counts the number of residents per unit area. Most of the data can be obtained from census data. The population model described earlier supplies detailed information on the population inventory.

The vehicle ownership inventory is essential to the transportation model. Knowledge of the number of vehicles owned by the residents of any zone is kmportant in determining present and future vehicular travel.

The inventory covers different vehicle types and ownership characteristics as shown in Table 15.3.2-1. Vehicle ownership data is normally collected in conjunction with the home interview, truck, taxi, and mass transportation origin and destination surveys, or from state motor vehicle registration bureaus.

Inventory of vehicular and person travel provides the basic data necessary for the present trip generation analysis. It is a sample representing all travel occuring in a study area on an average weekday and it can be expanded to indicate total characteristics of person and vehicular trips in the present urban area.

The purpose of taking inventories of the existing transportation facilities was to account for the current available facilities so that the maximum use could be made of them in future transportation plans. These inventories mainly include information on arterial streets and expressways. Arterial streets provide access to land and also serve through traffic. Expressways are designed to eliminate the conflict between land service and traffic service by concentrating exclusively on the traffic services function with no direct access to adjacent land permitted.

Inventories of existing facilities also include determining the existing capacity which measures the ability of the existing arterials and expressways to carry vehicles. There are three definitions of capacity. Basic capacity is a theoretical number, indicating the maximum possible number of vehicles that can pass a point under ideal conditions. Possible capacity is less than basic and represents the maximum number of vehicles that can pass a point under the prevailing roadway and traffic conditions. Practical capacity is the maximum number of vehicles that can pass a

TABLE 15.3.2-1 VEHICLE TYPES AND OWNER CHARACTERISTICS

Vehicle Type	Owner Characteristics
1. Automobile	1a. Residents for private use 1b. Business firms, government for commercial or official use
2. Trucks a. light b. medium c. heavy	2. Business firms, government for commercial or official use
3. Taxis	3. Commercial usage
4. Mass transportation	4. Government for mass transportation, school transportation usage

given point in a roadway or in a designated lane during one hour, without the traffic density being so great as to cause unreasonable delay, hazard or restriction to the drivers' freedom of movement to maneuver under the prevailing roadway or traffic conditions. For a detailed method for determining capacity, see reference (6).

Travel time, which is indicative of a level of service and has obvious connections with speed, is also measured during the inventory stage. Many of the important stages of a transportation plan are based on this quantity. These stages include the estimation of interzonal transfers and the assignment of vehicles to particular routes. Travel time data is used to determine the relative accessibility of different zones. As a matter of fact, travel time is the variable which connects all the building blocks of a transportation model together.

The inventory of mass transportation facilities has the same objectives as the highway inventory. It includes equipment used, schedules and routes for all forms of public transportation in a study. The variables affecting the quality of service provided by mass transit should be determined. The data collected included travel time, frequency of service, location of routes and delays at terminals and interchange points between modes.

Available monetary resources is another important component of the inventory. This inventory will enable the planner to know what the possible financing for the future network's construction and operation cost is.

15.3.3 Trip Generation

Trip generation is the term commonly used to denote the study of the interacting relationship between travel characteristics and the surrounding urban environment. Trip generation equations determined at the present time can also be used, with some modification, to predict future trip generation.

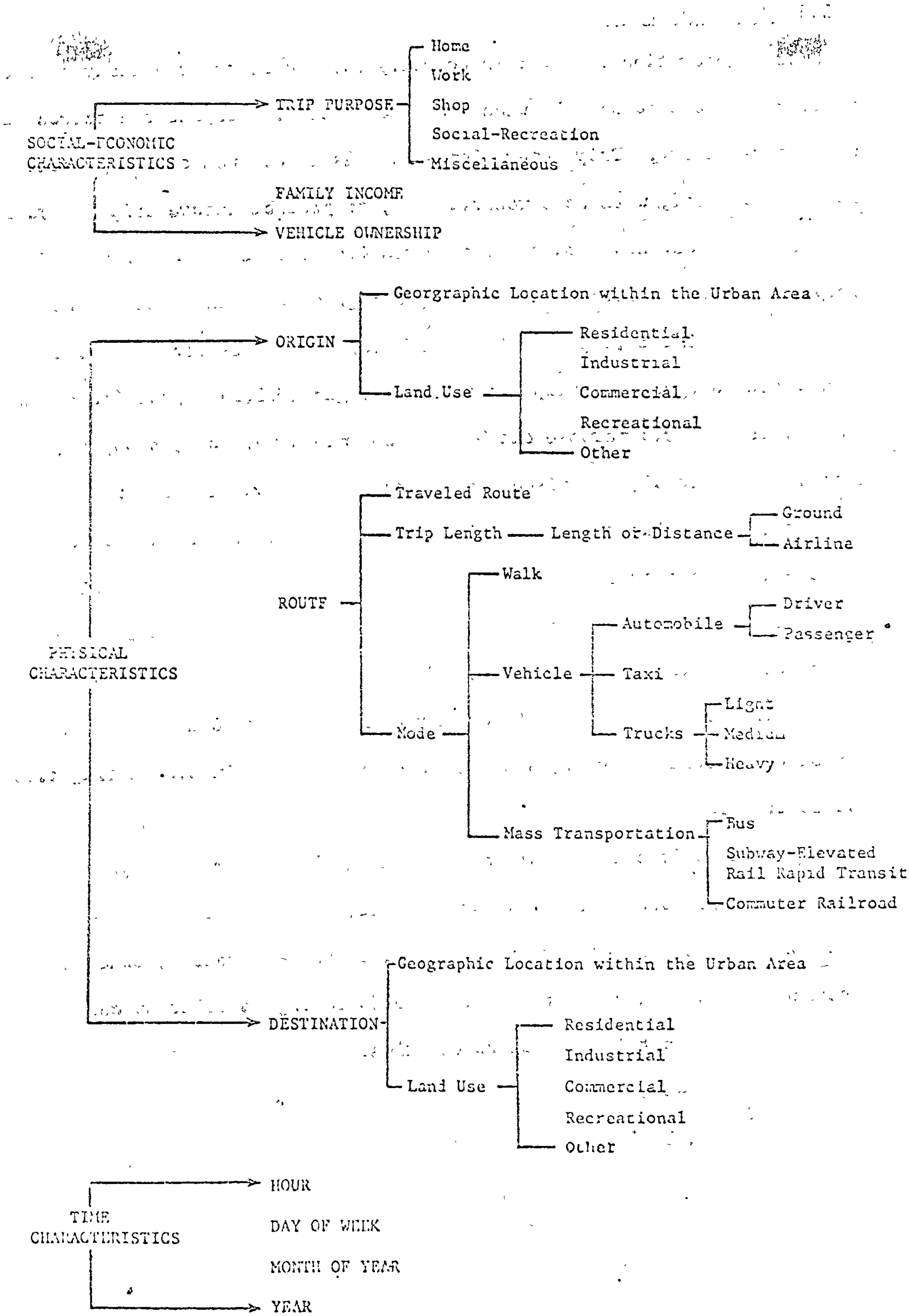
The simplest approach to trip generation is a geographic study of trip origins and destinations. Multiple regression techniques are usually used to determine trip generation. Different variables from the urban environment are used in trip generation. Figure 15.3.3-1 shows the variables usually used. Trip purpose can be divided into home, work, shopping, social-recreational, and miscellaneous trips. In addition to trip purposes, family income and vehicle ownership are also considered as social-economic characteristics. The origin and destination of trips are dependent on geographical location within the urban area and land use, which includes residential, industrial, commercial, recreational and other. The route of trips includes trip length and trip mode. Hour, day of week, month of year, and year are usually used in considering time characteristics.

By using multiple regression techniques, the number of trips by purpose designated as the dependent variable, can be expressed as a function of some independent variables, e.g., income, vehicle ownership, distance from CBD, etc. For example, the following formulation can be used to indicate a trip generation equation:

$$T_p = \sum_{i=1}^{i=n} a_i x_i$$

Figure 15.3.3-1

Variables Used in Determining Trip Generatio.



where, T_p = Trips per person

a_i = Multiple regression coefficient

x_i = Independent variables, e.g., family income, vehicle ownership, residential density, distance from CBD, etc.

For details of trip generation techniques, see references (6) and (8).

Trip generation encompasses the detailed analysis and study of a number of different variables and their interrelationships. It ties person and vehicular travel to the urban environment in which it takes place. If the hypothesis that trip generation characteristics remain stable with respect to time is made, then future person and vehicular travel can be estimated, utilizing present trip generation characteristics as one of the necessary inputs.

15.3.4 Public Policy and Decision and Estimates of Future Urban Area Growth

The public policy decision and estimates of future urban area growth are also part of a total transportation planning process. Essentially, estimates of future urban area growth include the following: a population forecast, a future economic activities forecast which includes basically employment and per capita income projections, a future vehicle ownership forecast, and a future land use forecast. Since most of these have been considered in the heuristic land use model, the population model or earlier in the inventories they will not be discussed here. However, before determining future travel demand, it is necessary to outline the initial future transportation network which will be discussed next.

15.3.5 Future Transportation Network

The basic method used to determine the future transportation network is described briefly in this section. The detailed methodology is stated in references (6) and (10).

Before estimating interzonal transfers and assigning traffic to facilities, an initial future transportation network is required. This will contain the existing network and additional arterials and expressways. It is desirable that the additional facilities in the network used for the first assignment be located as accurately as possible, so that numerous repetitions will not be necessary. Usually, additional transportation facilities are planned in such a way that they relate the existing network capacity to existing travel and also to the estimated future travel.

In order to facilitate the comparison of supply and demand for transportation, capacity, and travel must be expressed on an area basis. This comparison may take two forms, and most transportation studies use both forms to some extent. The comparison may be either (i) an area analysis or (ii) a detailed analysis by corridors. In the area analysis, the difference between the supply of facilities and the demand for travel is computed for each unit of area, e.g., zone, or half square mile. A detailed analysis by corridor is developed directly from the area method. In this method, a detailed analysis is made of each major corridor of travel and the deficiencies of capacity located. Both of the methods can be used with existing travel patterns and also any future travel pattern. The study of the deficiencies in capacity provides a basis for the preliminary planning of new facilities.

For many areas the excess demand for travel cannot be accommondated on a single facility, and thus, a network of additional facilities may have to be designed. This is particularly likely to happen in areas which are outside of the existing urban complex, but will be within the future urban area. In most instances in the past, the future network has been arranged on an intuitive basis by the planner. However, the Chicago Area Transportation (CAT) Study (10) used a more rationalized method. The method is principally concerned with an abstract pattern of facilities which may be modified to fit the real situation. The study determined an optimum spacing for arterials and expressways in an abstract network, based on the following considerations:

(i) construction cost of local streets, arterials and expressways,

(ii) travel costs (annual cost capitalized value over 30 years and an interest rate of 5%), and

(iii) the distance traveled on local streets, arterials, and expressways.

The methods used to define these costs and distances were stated in the CAT study (10).

15.3.6 <u>Determine Future Travel Demand</u>

To determine future travel demand, the following are considered:

(i) future trip generation,

(ii) future modal split,

(iii) interzonal transfer, and

(iv) assignment of traffic to facilities.

<u>Future Trip Generation</u>

Future trip generation forms the important link between the estimates of future urban growth and the person and vehicular travel expected on all forms of transportation facilities for specified years. Basic present trip generation equations can be used to predict future trip generation by using projected economic activities, vehicle ownership, land use and other changes of the urban characteristics generation. Figure 15.3.5-1 shows the inputs and outputs of future trip generation.

Future Modal Split

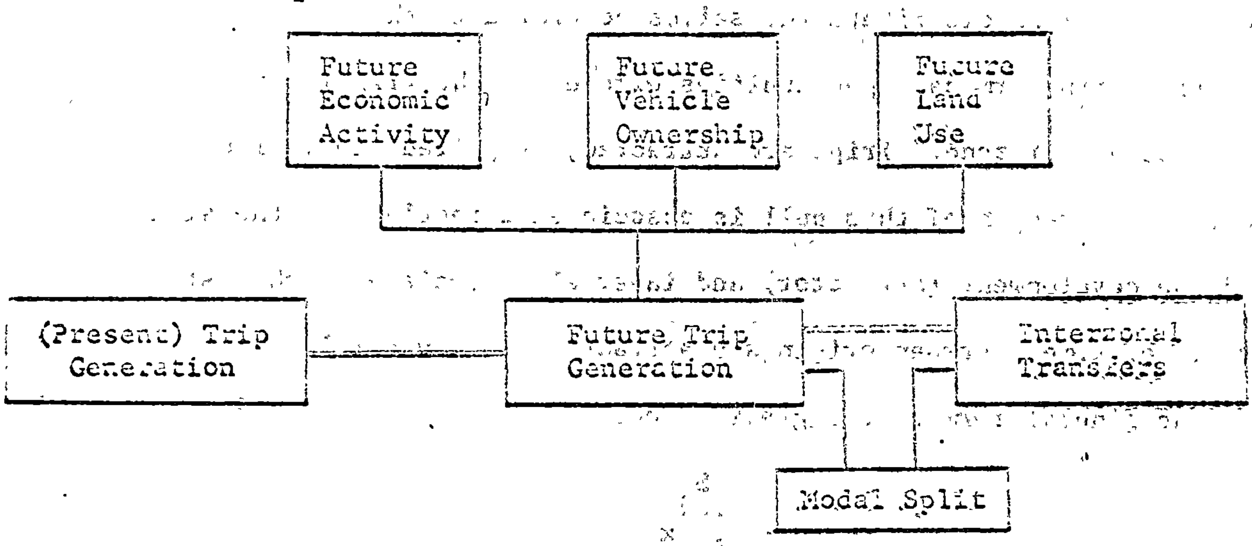
In a complete urban area transportation study, before the use of facilities can be estimated, a division has to be made between the users of public and private transportation. Very often travel by mass transit are those trips going to the central business district, school trips, etc. Methods concerning the determination of modal split are stated in reference (6).

Interzonal Transfers

After obtaining the number of future trips by trip generation equations, interzonal distributions of these trips are made. Various mathematical procedures have been developed and used for this purpose. Usually, they are divided into two groups - growth factor methods and inter-area travel formulas. Among the growth factor methods, there are the uniform factor method, the average factor method, Detroit method, and Fratar method. Among the inter-area travel formulas, the gravity model is more often used than the interactance model or the opportunity model. Since the gravity model was used in the Tulsa-INCOG study, it will be included here; the other methods were stated in reference (6). The gravity model description which follows can be found in Calibrating and Testing A Gravity Model for Any Size Urban Area (9).

Figure I5.3.5-1

Future Trip Generation Inputs and Outputs



Principal Interactions

Supporting Interactions

Gravity Model

The principle underlying this model states that all trips emanating from a given zone distribute themselves according to the number of effective trip terminal opportunities offered to the trip makers by each destination zone. Trips are attracted, or pulled, to various land uses. The strength of this pull is associated directly with the size of land use development (attractor) and inversely associated with distance (or travel time) between origin and attracting land use (9).

The general form of the gravity model equation is the following:

$$t_{ij} = t_i \frac{\frac{S_j}{D_{ij}^x}}{\frac{S_1}{D_{i1}^x} + \frac{S_2}{D_{i2}^x} + \dots + \frac{S_n}{D_{in}^x}} \qquad \text{(E1)}$$

where, t_{ij} = Present vehicle trips between zone i and zone j (i, j=1, 2, ···,n) due to an attractive force located in zone j

t_i = Present vehicle trips originating in zone i, where

$$\sum_{j=1}^{n} t_{ij} = t_i$$

s_j = The attractive force of zone j (size dependent upon land use characteristics of zone j and trip purpose under consideration)

D_{ij} = The travel time or distance between zone i and zone j

x = Distance exponent (value dependent upon trip purpose).

S_j, the attractive force of zone j, is a function of the size and type of land use development. D_{ij}^x is the travel resistance between zones i and j, and is a function of ground distance, travel time, congestion, etc. The gravity model distributes trips from any zone to all other zones in accordance with the number of trips originating in that zone, the attractive forces of the other zones, and the travel resistances between the corresponding zones.

Various assumptions are implied in the use of the gravity model. These are:

(i) that an average travel pattern can be applied to all zones within the urban area, regardless of the social and economic characteristics of the zonal population,

(ii) that the average length of a trip is entirely influenced by the closeness, or remoteness, of the attractive forces which cause trips to occur,

(iii) that trip length distributions (by purpose) remain constant throughout the urban area (i.e., the exponent is independent of geographic location),

(iv) that distance (travel time) between zones remains constant and can be accurately determined for the particular time (day, year, etc.) period chosen, and

(v) that the average travel pattern is independent of zonal locations (i.e., whether the two zones involved are radial or circumferential to each other).

To use the gravity model, attraction units for each different trip purpose, interzonal distances, and distance exponent values must be determined. Usually, three or four different trip purposes are selected, depending upon the differences in trip length distributions and the appropriate attraction forces. Interzonal distance is usually measured by means of travel time, determined through field runs between zonal centroids. In some locations airline distance between zonal centroids may be an adequate measure of travel resistance, if the quality of service offered by different forms of highway facilities is approximately constant. Exponent values must be determined experimentally, since they vary according to the purpose of the trip and with the particular urban area involved. A small sample home interview origin and destination survey is often conducted to provide the necessary correlation data. The exponential values selected should minimize the variation between the model results and the actual data obtained.

The gravity model formulation does not guarantee the correct number of arrivals in each destination zone (i.e., $\sum_{j=1}^{n} t_{ij}$ is not necessarily equal to $(t_j)_{tg}$). Therefore, iteration procedures such as

$$S'_j = \frac{S_j^2}{\sum_{i=1}^{n} (t_{ij})_{tg}} \qquad \text{(E2)}$$

where, S'_j = Adjusted attractive force of zone j, and is used in the next iteration of the model

may have to be used, especially when work trips are considered. This is obvious, since there cannot be more work trips to a particular zone than there are jobs. For other trip purposes, iteration to a predetermined trip generation estimate is not necessary, since the model distributes trips proportionally and non-work trip generation estimates are not sufficiently precise to warrant further iteration.

The notation used in the last two equations is for estimating present travel patterns. This work has been based on the premise that if it is possible to synthesize today's traffic patterns by use of mathematical models, then future traffic patterns can likewise be predicted by utilizing the same techniques. Therefore, for predicting future vehicle trips, the following equation is used:

$$T_{ij} = T_i \frac{\frac{S_j}{D_{ij}^{x}}}{\frac{S_1}{D_{i1}^{x}} + \frac{S_2}{D_{i2}^{x}} + \ldots + \frac{S_n}{D_{in}^{x}}} \qquad \text{(E3)}$$

where, T_{ij} = Future vehicle trips between zone i and zone j. (i, j=1, ..., n) due to an attractive force located in zone j.

T_i = Future vehicle trips originating in zone i, where, $\sum_{j=1}^{n} T_{ij} = T_i$

S_j = The future attractive force of zone j

D_{ij} = The distance between zones i and j (a function of time and the units of measurement utilized)

x = The exponent of distance (it is assumed that this value remains constant in the future)

To a great extent, the validity of the above equation depends upon accurate estimates of the future interzonal distance (travel times). To obtain this data, knowledge of the expected traffic volumes and the planned transportation facilities must be known. However, the former is the quantity desired in this equation while the latter represents the ultimate goal of the urban area transportation study. In order to overcome this interdependence problem, a trial transportation network, with appropriate travel times, must be assumed for purposes of approximating future interzonal travel. Successive iterations of the above equation must be made until the predicted interzonal volumes balance the travel times resulting from these volumes. This feedback is obviously important, although it has usually been ignored in the past. While some research has been done on incorporating this feature into gravity model interzonal transfer computer programs, much additional work remains to be done in perfecting this technique.

Assignment of Traffic to Facilities

After distributing trips between zones, trips will be assigned to different routes of the network. Any given network will only carry a particular number of vehicles or persons under certain operating conditions. The success of a network depends primarily upon its location and its ability to carry vehicles and persons. Hence, it is necessary to determine whether the location and capacity of a network are correct. This is done by assigning the interzonal transfers to the network and reviewing the finished assignment. The review will involve inspection of the relative loading of different sections of the network, the determination of the travel time on sections of the network, and an economic feasibility study. Usually several assignments and reviews are done for each network until desired results have been obtained.

The assignment procedure provides the data for the review of a proposed plan. While individual assignment programs vary in some details, the principal information supplied by an assignment program, is as follows:

(i) the volumes of vehicles or persons expected to use each link of the network under test,

(ii) the volume of vehicles making turning movements at intersections, or the volume of persons using interchanges ,

(iii) data for the evaluation of the quality of service provided by the network. This may be in terms of speed, travel time, or some other desired measure,

(iv) data for the evaluation of the location of present and proposed transportation facilities, and

(v) data towards an evaluation of the economic feasibility of constructing proposed sections of the transportation network. This data may either be in the form of total vehicle miles or total vehicle hours of operation on the network.

Once an assignment program has been compiled, assignments may be made for the present or any future year for any desired time period during a day.

The assignment program is usually tested by making assignments to the existing network using survey data. These results are compared with screen line counts made during the survey period.

With the development of more refined assignment programs, several methods or obtaining the final results have evolved. These methods fall into four general categories:

(i) "all or nothing" assignment with no capacity restraints,

(ii) diversion curve assignment with no capacity restraints,

(iii)"all or nothing" assignment with capacity restraints, and

(iv) proportional assignment with capacity restraints.

In "all or nothing" assignment, all vehicles are assigned to the path with the least travel resistance between origin and destination zones. Diversion curve assignments divide the total number of trips, between origin and destination, between two route, depending upon the relative values of travel resistance on the two routes. Proportional assignment divides the total trips between several routes, depending upon the relative values of travel resistance for the several routes.

15.3.7 Evaluation of Loaded Network

As shown in Figure 15.3-1, the last step in the total transportation planning process is the evaluation of the loaded network. If the level of service is satisfied, it will end the planning process. If the level of service is not satisfied, then network changes may be required. If the latter is the case, the tentative future network will be modified and re-assignment of interzonal transfers will be done and then evaluated. The assignment and evaluation are repeated until satisfactory results are reached. However, the final evaluation of the loaded network is generally the last step in the total transportation planning process.

REFERENCES

1. Morlok, A Goal Directed Transportation Planning Model.

2. Talvitie, A. An Econometric Model for Downtown Work Trips, Chicago Area Transportation Study, December 1971.

3. Thomas, E. and Schofer, J. Strategies for the Evaluation of Alternative Transportation Plans, NCHRP Report 96, Washington, D. C., 1970.

4. Morlok, E. K. and Thomas, E. N. The Development of a Geographic Transportation Network Generation and Evaluation Model.

5. Domencich, T. A., Kraft, G., and Valette, J. P. Estimation of Urban Passenger Travel Behavior: An Economic Demand Model, Cambridge, Mass.: Charles River Associates. Presented at the Annual Meeting of the Highway Board, January 1968.

6. Martin, Brian V., Memmott, Frederick W. III, and Bune, Alexander J. Principles and Techniques of Predicting Future Demand for Urban Area Transportation, M. I. T. Report No. 3, The Massachusetts Institute of Technology Press, Cambridge, Massachusetts and London, England, 1961.

7. Homburger, Wolfgang. Urban Mass Transit Planning, The Institute of Transportation and Traffic Engineering, University of California, 1967.

8. U. S. Department of Transportation, Bureau of Public Roads. Guideline for Trip Generation Analysis, 1967.

9. Alan M. Voorhees, "A General Theory of Traffic Movement", Proceeding of the Institute of Traffic Engineers, 1955.

10. U. S. Department of Commerce, Bureau of Public Roads. Chicago Area Transportation Study, Volume I (1959), Volume II (1960), Volume IV (1962).

11. U. S. Department of Commerce, Bureau of Public Roads. Calibrating and Testing a Gravity Model for Any Size Urban Area, 1965.

12. Tulsa Metropolitan Area Planning Commission, Transportation Study, Volume I (Inventory Findings and Analysis), Volume II (Transportation Plan) and their Technique Supplements, 1967.

Chapter 16

AIRPORT MODEL

16.1 Objective: To construct a mathematical airport development model that would predict the future volume of aviation activity over the time period to 1980.

16.11 The approach used was unique among airport plans in that it took into account socio-economic factors as well as those more directly related to airport activity.

16.12 The study used econometric and system techniques to develop a fully computerized model.

16.13 Airports of similar socio-economic characteristics were grouped for each model. The models and the output forecasts are capable of impact studies and modification over time.

16.14 The statewide airport plan provides a priority rating system responsive to more immediate needs.

16.2 Verification and Classification of Airports:

16.21 This phase was accomplished by a mailed inventory with a limited field check to obtain all available data from the Federal Aviation Agency and the Oklahoma Aeronautics Commission. All publicly and privately owned airports important to the state system were inventoried.

(1) The data collection revealed information regarding classification of aircraft movements, airport users, identification, airport ownership, runway size and load specification, and airport services. (See Appendix E and F).

(2) The second step was to verify and up data existing data.

(3) A series of figures have been developed to illustrate the magnitude of aviation development in Oklahoma. (See Appendix E).

(4) Tabulated data: (Refer to Table 5-F-19 and F-31 list). Also shown is the total operations. Other tabulated data included in Table 5:

1. User identification codes
2. Type of airport ownership
3. Runway specifications, type, and strength of its surface
4. Lighting presently on the field
5. Other significant factors such as fuel, storage, services, and conveniences

16.3 <u>Determinants of Airport Facilities:</u> This phase was studied by subjecting social and economic characteristics of an airport service area and the volume of aviation activity to statistical correlation tests. The conditions considered as determinants (deciding factors) of the airport facilities are:

16.31 Population and Economic Characteristics

The characteristics that correlated highly with demands for airport facilities are:

# of families in a service area with incomes greater than $10,000
# of industries with greater than 20 employees
the volume of retail sales expressed in terms of sales units
the total labor force
# of students enrolled in college
the total personal income

16.32 Geographic Isolation of an Area - No significant relationship could be found.

16.33 Aeronautical Activity

The total number of aircraft based at an airport is a good indicator of the volume of activity at the airport. A better indicator can be obtained if the aircraft are divided into two categories, general aviation aircraft and air-carrier aircraft.

16.34 The Effect of Advancing Aviation Technology

Congestion is not a ciritical problem in Oklahoma yet. The data gathered indicates that forseeable growth and congestion problems at Oklahoma airports can be alleviated by advanced technology.

16.35 Existing Airport Facilities

Refer to Appendix E, Figure 7 for the classification of the major airports in each county and the total number of annual operations.

16.36 Recreational Development

The Oklahoma airport system is already linked with all existing recreational facilities in the state. Thus, all points of interest to the tourists are accessible to general aviation.

16.37 Potential Industrial Development

The determinants of airport demands are highly related to industry. In particular, the number of industries in a service area with more than 20 employees, the total labor force in the service area, and the number of industries in a service area with state, regional, or national sales are dependent on adequate airport facilities.

16.38 Regional Aeronautical Activity

The development of a regional airport in Oklahoma is not considered feasible at present or within the time period covered by this study. In addition to the tremendous investment required, the proximity of the Dallas-Fort Worth regional airport should obviate the need for a similar Oklahoma facility until 1980 or beyond.

16.39 Other Requirements

In addition to the determinants discussed, the following factors influence airport development and must be considered in planning specific sites.

(1) Airport costs

(2) Optimal distance between airport and population center

(3) Sources of airport financing

(4) Sources of federal government financing

(5) Sources of state and local financing

(6) Sampling aviation activity for updating the plan. It is recommended that a 24-hour count on a typical week day and week-end day during fall, winter, spring, and summer should be obtained. These counts can be expanded to an annual operation figure by the following formula:

Total Annual Operations =

$$\frac{5(\text{Av. Week Day Count} + 2(\text{Av. Week-End Day Count})365}{7}$$

The impact of each determinant varies throughout the state to the extent that no single relationship between airport requirements and airport determinants can be specified for the state as a whole. Consequently, a technique to group cities (airport) into groups of similar socioeconomic characteristics was created. There were five such groups, and a predictive equation or model was developed for each. The total number of variables used to predict airport activity was seven; however, all were not used on each model.

16.4 Aviation Development Model

The aviation development model is composed of two submodels--a forecasting model which can be used to determine the volume of aviation activity that can be expected to occur in an airport service area at any future year up to 1980, and a second submodel which is uded to compare the volume of aviation activity and financial resources of the service area. The total annual operations in each service area were forcast for 1975 and 1980 using trip generation equations developed by statistical means.

16.41 Submodel for Aviation Activity Forecast

A number of transportation studies have justified the technique of relating the volume of trips generated in an area to social and economic factors associated with the area. But these are not simple relationships. Two towns of similar population size rarely exhibit similar volumes of travel. The proportion of trips by purpose also varies between towns. Travel information cannot be related strictly to population and vary with regions of the state because of the vastly different regional topography and diverse population social/economic characteristics. The objective of this phase of the study was to develop a method of predicting the travel volume in any area of the state in a format suitable for use by a transportation planner. For the purpose of this submodel, the state was divided into areas of similar travel demand. Separate and distinct travel forecasting equations had to be developed for each area.

The first step was to develop a method of dividing a region into areas of similar travel demand. The demands for surface travel and air travel are directly related; increases in requirements for new highways are accompanied by new airport requirements. In addition, areas that exhibit high volumes of aircraft activity also exhibit high volumes of ground transportation activity. Based on this analysis, data was collected from selected towns throughout the state. Towns were studied on the basis of general aviation demand, ground transportation demand, population, per capita income, number of housing units, and other pertinent socio-economic variables. A factor analysis was used to group counties with similar transport demand characteristics into clusters.

When this procedure was completed, Oklahoma counties had been grouped into nine clusters, six for the semirural areas of the state and three for the metropolitan portions (See Figure 9, Appendix E). Development of the forecast equations and the cluster techniques is shown in Appendix F. The demand for transportation varies greatly from cluster to cluster, but counties within each cluster exhibit similar trends in travel demand.

Equations termed trip generation equations were developed by multiple regression analysis. The final equations, a separate one for each cluster, are shown in Table 6, Appendix F. The equations can be used to forecast general aviation activity out of any airport service area within a cluster in terms of the annual number of operations.

16.42 Submodel for Development Criteria

Any one of three primary types of criteria--number of operations, type of airport facility requirements for proposed industrial development, and/or geographic isolation--can justify airport development alone if the need is sufficiently great. However, the three criteria are ranked in order of importance; expansion and importance of aviation facilities because of operational requirements is the highest criteria, industrial development is next and geographic isolation is lowest.

16.421 Criteria for Number of Operations

As the number of operations at an airport increases, the size of aircraft utilizing the airport also increases. And as the size of aircraft increases, the runway length, width, and thickness requirements also increase. After considering the particular types of aircraft now operating at Oklahoma airports and the probable types of aircraft that will be operating at those airports in the future, the following is recommended:

Annual Number of Operations	Minimum FAA CClass Facility
Less than 5,000	LS
More than 5,000 but less than 20,000	BU I
More than 20,000 but less than 45,000	BU II
More than 45,000 plus business jet demand of of more than 1,000	GU

An LS, BU I, or BU II facility should be located within 15 minutes driving time of the majority of users. A GU or higher class facility should be located within 30 minutes driving time of the majority of users. The expansion of a BU II class airport to a GU facility will be justified when there are more than 45,000 annual operations and the industries/businesses of the area project a utilization of more than 1,000 annual operations by aircraft requiring runway lengths longer than presently available.

16.422 Criteria for Industrial Development

16.423 Criteria for Geographic Isolation

Because of the high degree of correlation between social/economic activities and determinates of aviation demand, the counties that are economically depressed, socially deprived, and geographically isolated show no projected growth in aviation activity between now and 1980. Airports should be developed in geographically isolated areas for two reasons. First, it is considerably easier to encourage investments in business and recreation facilities if an airport is already in existence, and second, there is a safety problem associated with flying over certain portions of the state where there are no airports. Therefore, safety and socio-economic improvements are suitable criteria for aviation development.

The ultimate goal would be to have an airport located within 15 minutes travel time of every city which is less than 25,000 but greater than 1,000. Cities larger than 25,000 meet criteria for airport development other than geographic isolation and are not a concern of geographic isolation criteria.

It is recommended to have an airport located within 35 minutes travel time of every city which is less than 25,000 but greater than 1,000 by 1975 and within 15 minutes of these class cities by 1980.

16.5 Testing the Model:

16.51 Comparison of ctual versus Predicted Operations Comparing the actual number of operations occurring within a service area (y) with the number predicted by the appropriate trip generation equation ($\hat{y}$) establishes the validity of the model. This test was applied to selected airports in each cluster except the large urban areas in cluster two.

For example: for cluster one (see Fugure 9, Appendix E), the Alva service area was tested using the trip generation equation:

$$\hat{y} = 1054(X_1) + 4.4(X_2) + 771(X_3) + 3949(X_4) - 5544$$

Broken down, this equation simply states that the predicted operations at Alva ($\hat{y}$) are equal to 1054 times the number of industries with more than 20 employees (X_1), plus 4.4 times college enrollment (X_2), plus 771 times eligible single-engine aircraft (X_3), plus 3949 times eligible multi-engine aircraft (X_4), minus 5544. The equation was solved by substituting values of X_1 through X_4 from the appropriate columns of Appendix A in the following fashion:

$$\hat{y} = 1054 \times 4 + 4.4 \times 276 + 771 \times 23 + 3949 \times 1 - 5544$$

$$\hat{y} = 21{,}706$$

Thus, the predicted number of operations at Alva was 21,706. The reported (actual) number of operations at Alva for the same period was 22,000. The error $(\hat{y} - y)$ was 22,000 - 21,706 = 294, or within 1.4 percent.

16.52 Test Statistics

16.53 Test of Reasonableness

Seven independent variables were used in the final analysis. Each of these variables is directly related to aviation activity, and the growth forecasts of each variable are relatively easy to obtain. The variables are:

X_1 = # of industries in a service area with more than 20 employees

X_2 = college enrollment in services areas

X_3 = # of single-engine aircraft

X_4 = # of eligible multi-engine aircraft

X_5 = total labor force

X_6 = total personal income

X_7 = # of airmen

The output from the models was tested against airport plans from Lawton, Oklahoma City, Tulsa and the FAA National Airport Plan. The validity of the output was proven by the compatibility of results. In most cases however, the output of the model indicated more conservative levels of design than those recommended by the FAA.

16.6 Schedule of Projected Airport Investments for Oklahoma:

16.61 Projected Criteria

The first step is forecasting the growth of the determinants (X_1 through X_7) of airports from the present to 1980.

The basic criteria used in these projections are:

1. If during the study period, projected operations ($\hat{y}$) at an airport exceed 5000 operations per year, it was justified to construct a paved BU I airport with low intensity runway lights and all necessary taxiways and aprons.

2. If the projected operations exceeded 20,000 operations per year, there was justification to develop the next stage (BU II) of the airport with the necessary expansion of runways, taxiways, aprons, and lights. Medium intensity runway lights could justify the expenditure.

3. If the projected operations exceeded 45,000 operations, the airport should be expanded to a General Utility with medium intensity runway lights. A site study should be made to determine if additional runways are required for better wind coverage. Construction of paralled taxiways and larger aprons are also justified.

4. Basic Transport type runways are justified when the economics or industrialization requirements of the area dictate a specific type of field.

5. Geographic isolation was also used as a criteria in airport development. If an area with a population of more than 1,000

be used to determine which airports to fund. The following priority point system, based on four determinants given immediately below, is recommended.

1. Aviation Activity.
2. Industrial Development.
3. Geographic Isolation.
4. Air Freight.

The point system has 100 total possible points with a maximum of 40 points for aviation activity, a maximum of 30 points for industrial development, a maximum of 20 points for geographic isolation and a maximum of 10 points for 10 points for air freight. The scoring of points should be done as follows:

1. Aviation Activity (40-point maximum). One point for each 2,000 existing annual operations at an airport with all airports having 80,000 or more annual operations receiving the maximum 40 points.

2. Industrial Development (30-point maximum). Five points for each industry with more than 20 employees that the Industrial Development and Park Department estimates will be attracted to the area within two years after airport development, and one point for each 10 new job openings that will be created within two years by the airport development. A combination of new industrial development and new job openings can add a maximum of 30 points to the score. For example, one new industry with an employment of 250 will score 30, or three industries and 150 employees would also score 30.

3. Geographic Isolation (20-point maximum). Two points for each five-minute travel time increment from the center of the proposed airport service area to the nearest existing airport, and one point for each 500 inhabitants in the service area. For example, an airport 40 minutes travel time from the nearest airport with a service area population of 1500 would have a score of 19 points.

4. Air Freight (10-point maximum). One point for each five tons of annual air freight volume generated or projected within two years. Airports having 50 tons per year or more would receive 10 points.

This priority system can be used to evaluate both existing airports and potential airports. The point system is responsive to immediate future situations instead of long-term projections. The rating system can be used for either a service area where airport improvement is required or for an area where new airport development is required. Once the rating points have been established for each airport submitted, the airports can be ranked in order of their point rating.

APPENDIX E

LIST OF FIGURES

FIGURE 1
LOCATION OF EXISTING AIRPORTS BY FAA CLASSIFICATION

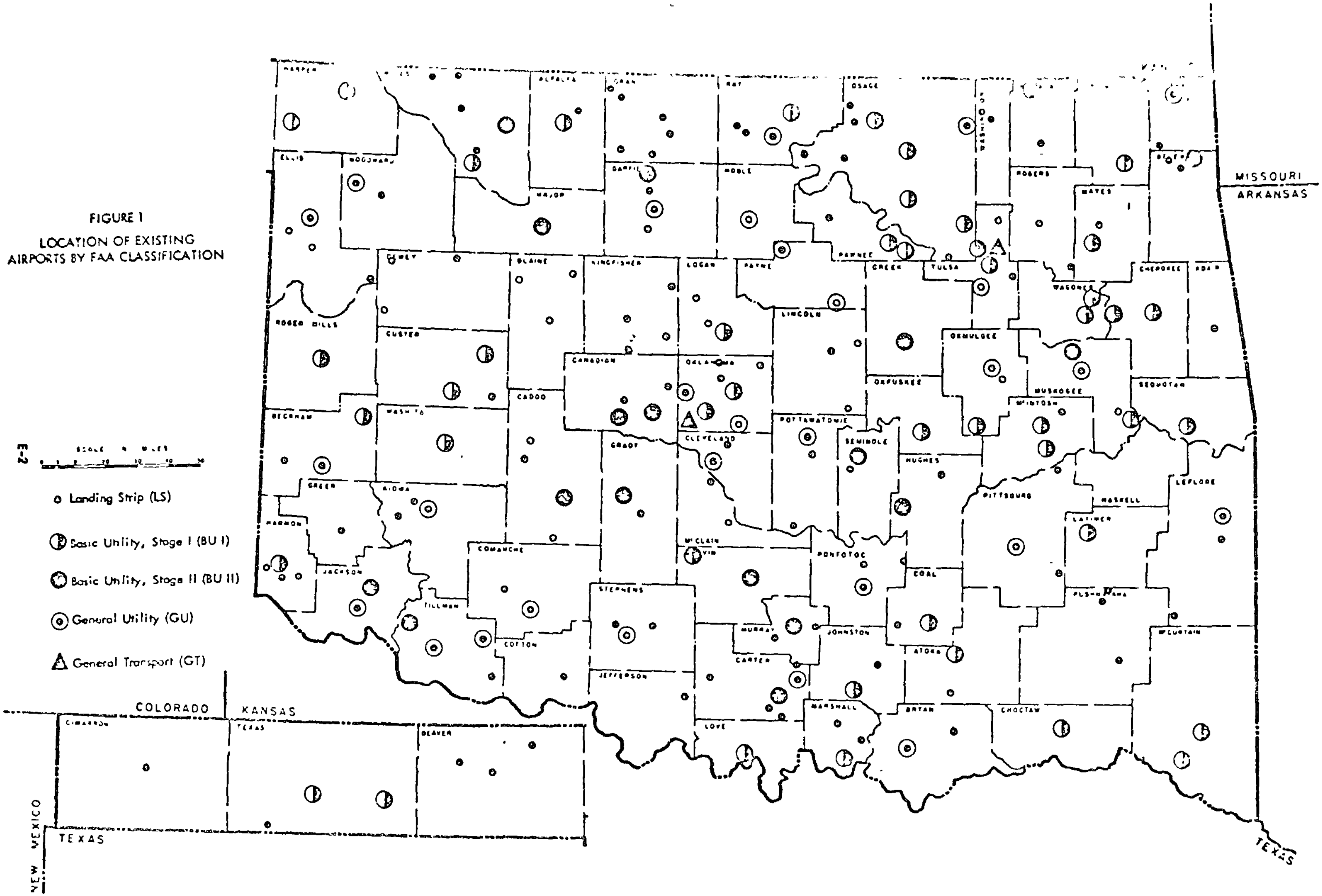


FIGURE 2
COMMERCIAL AIRLINE ROUTES

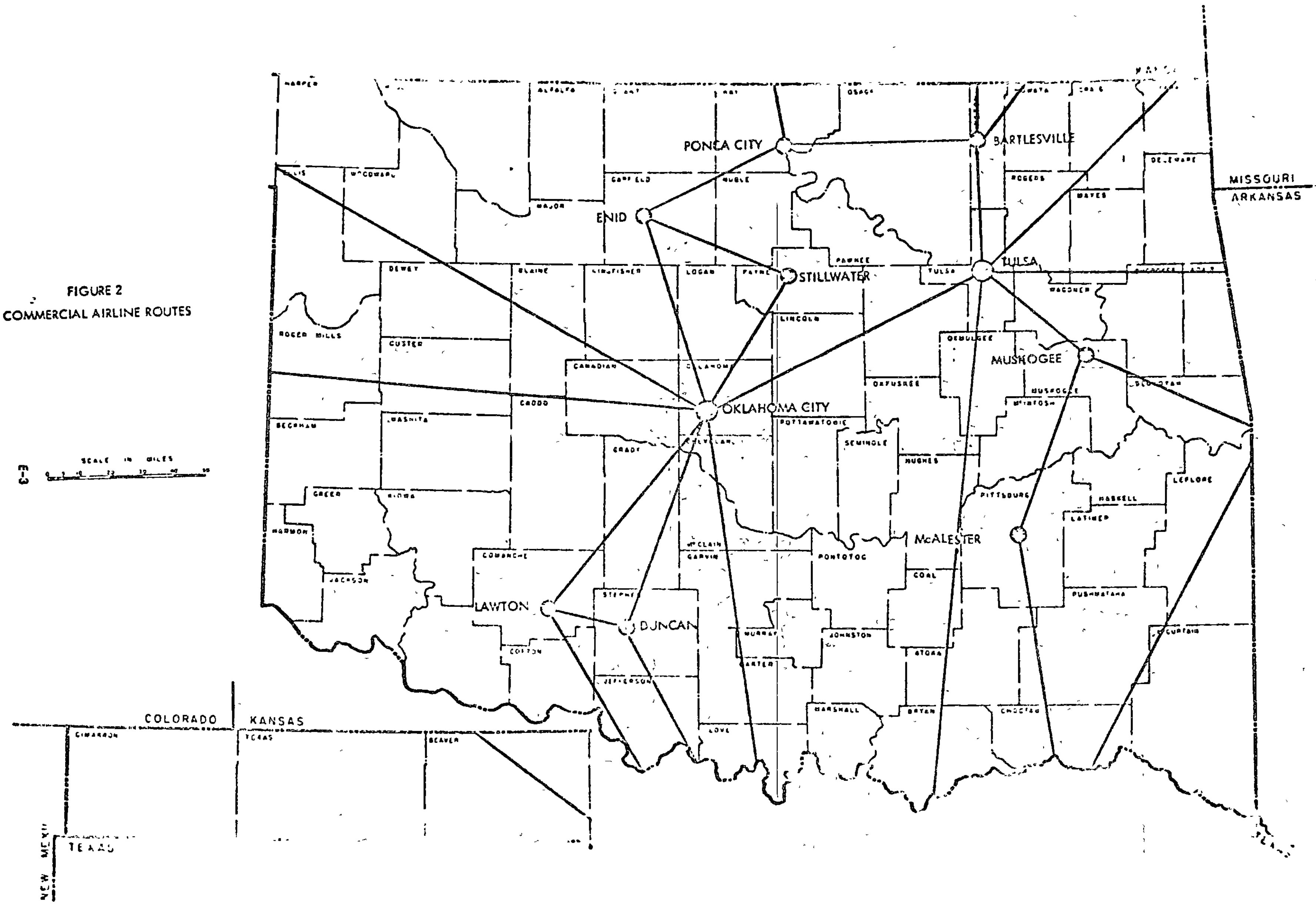


FIGURE 3

AIR STAR ROUTES

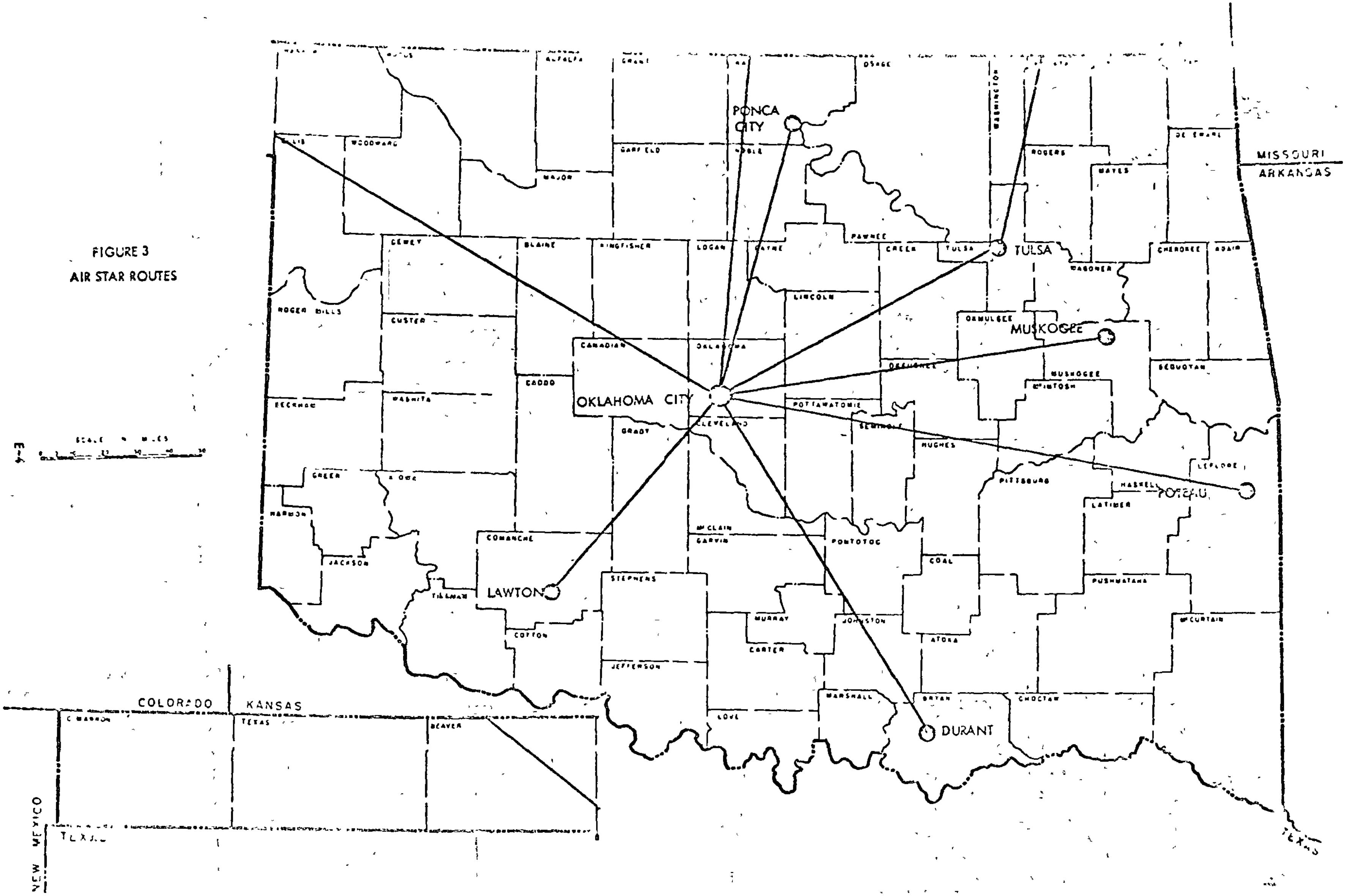


FIGURE 4
NAVIGATIONAL AIDS

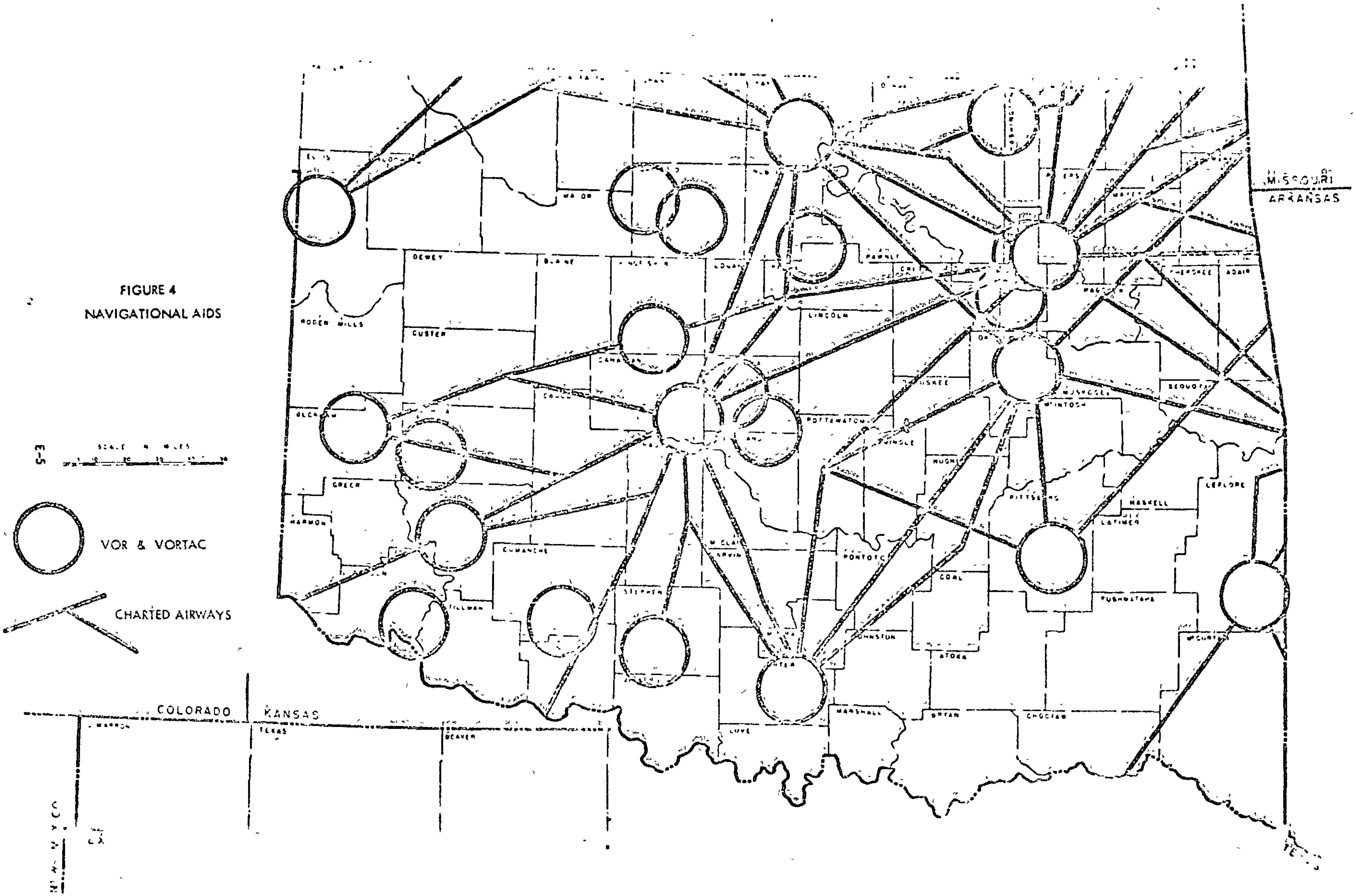
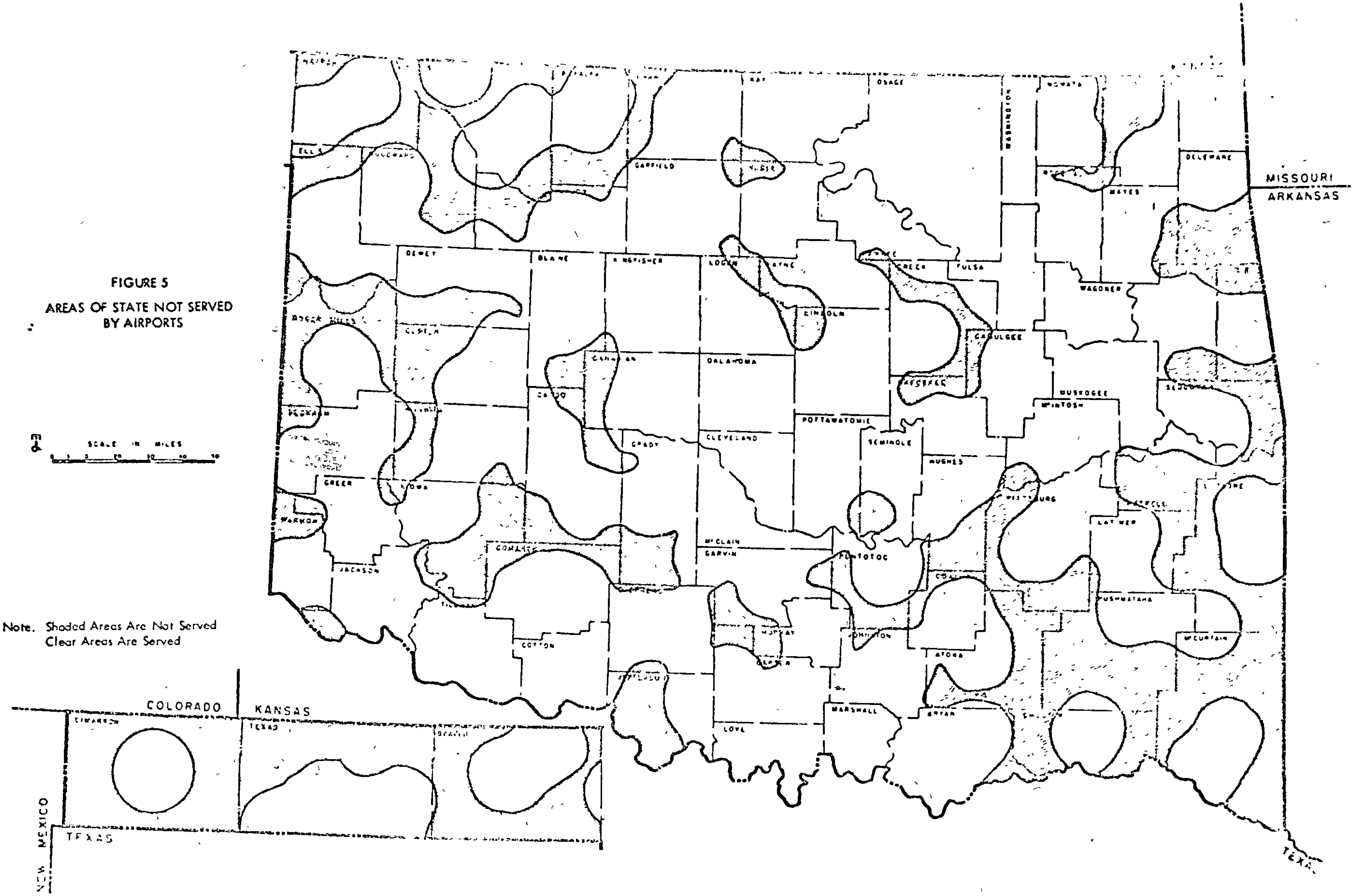


FIGURE 5

AREAS OF STATE NOT SERVED BY AIRPORTS



Note. Shaded Areas Are Not Served
Clear Areas Are Served

FIGURE 6

COUNTY AIRCRAFT DISTRIBUTION

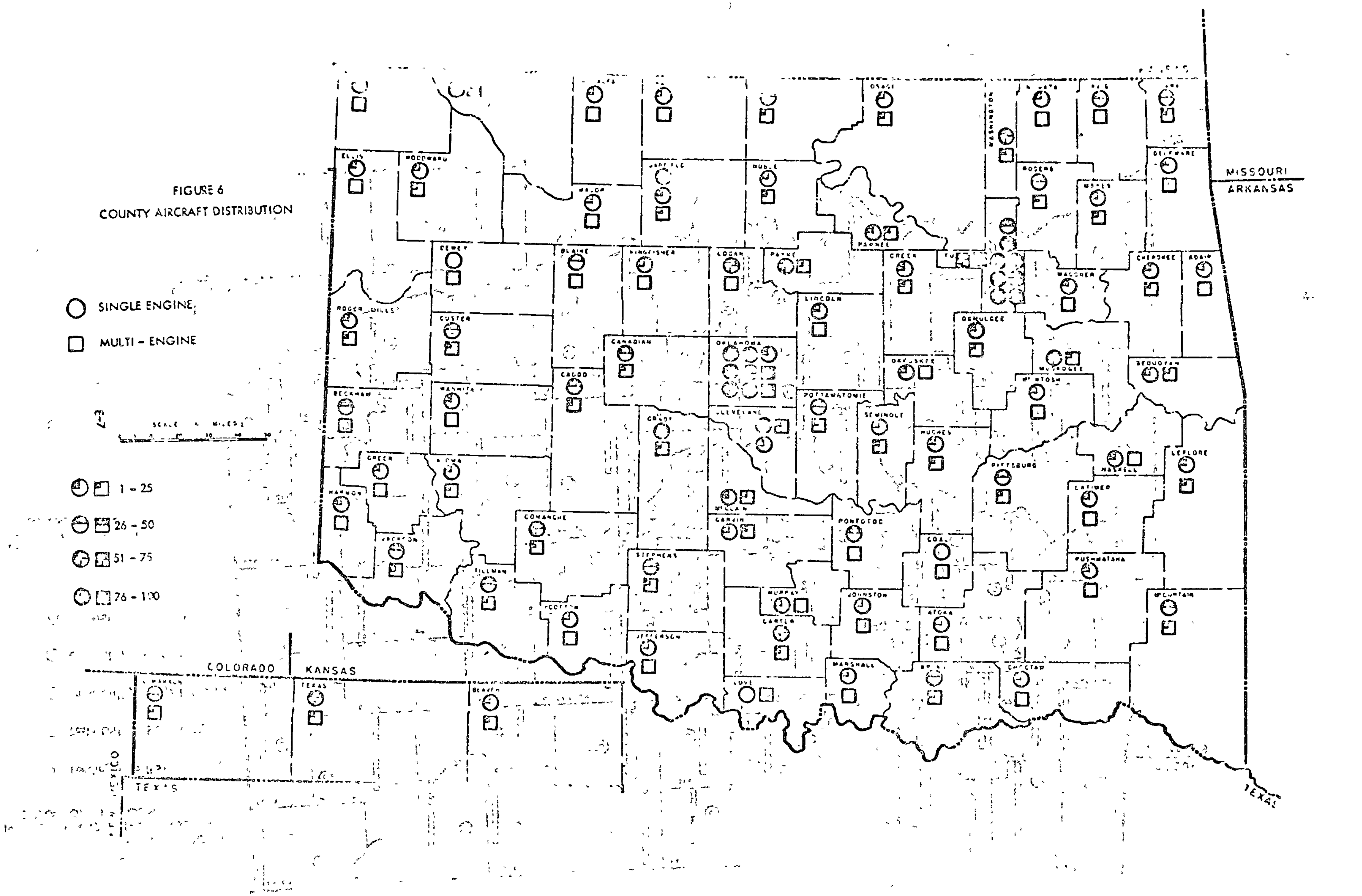
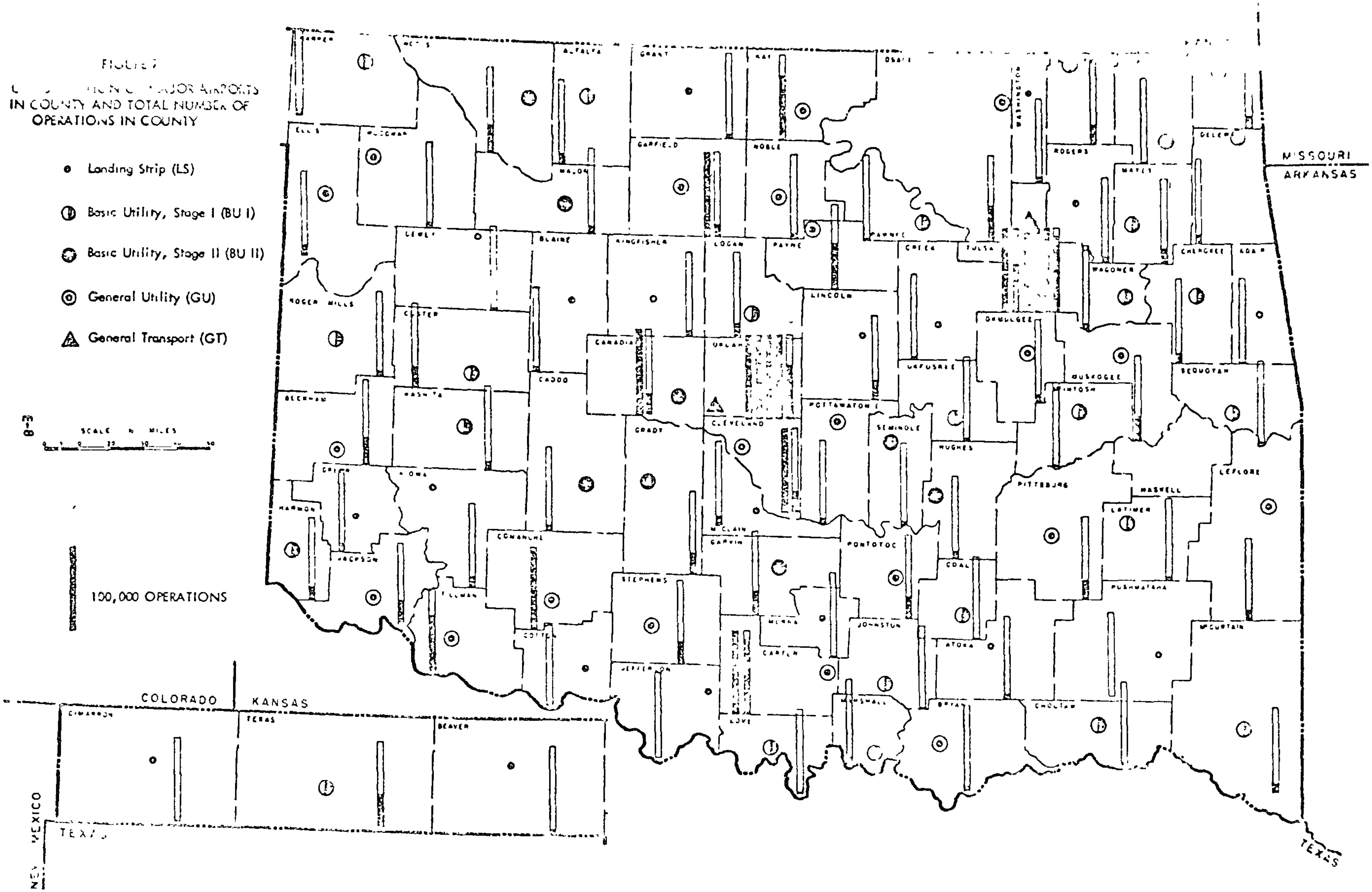


FIGURE 7
IN COUNTY AND TOTAL NUMBER OF OPERATIONS IN COUNTY



8-3

FIGURE 8
RECREATIONAL AREAS

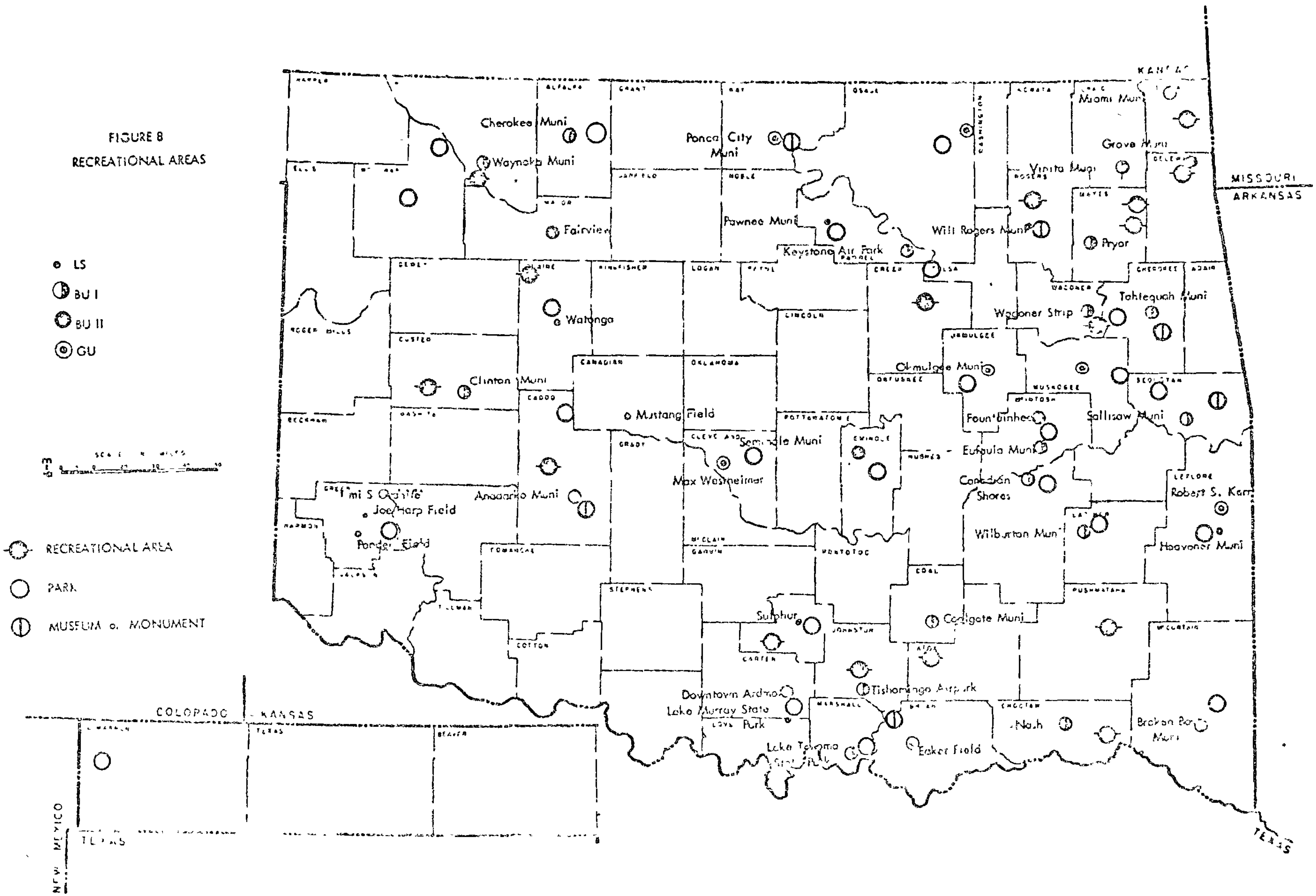
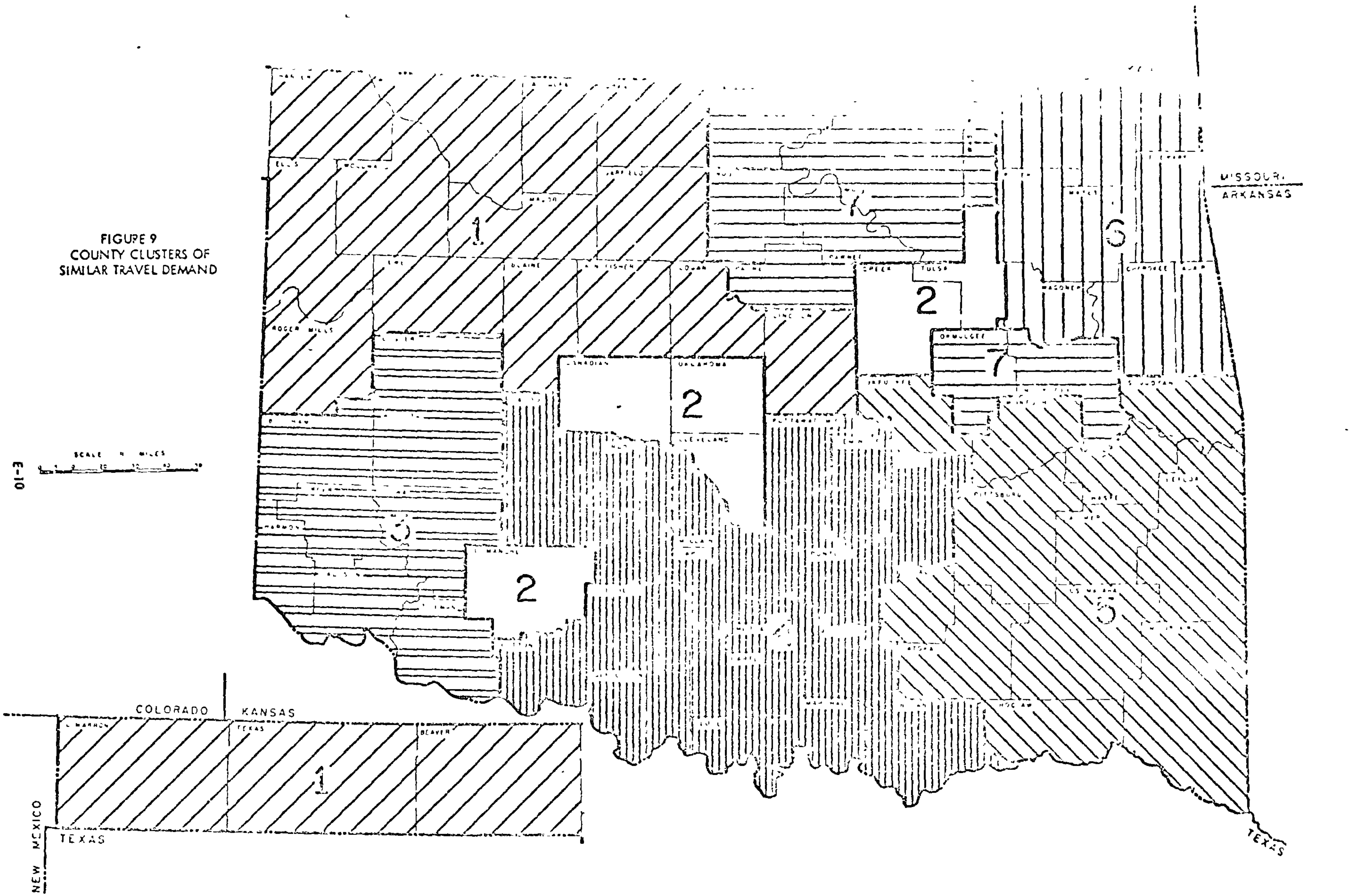


FIGURE 9
COUNTY CLUSTERS OF
SIMILAR TRAVEL DEMAND



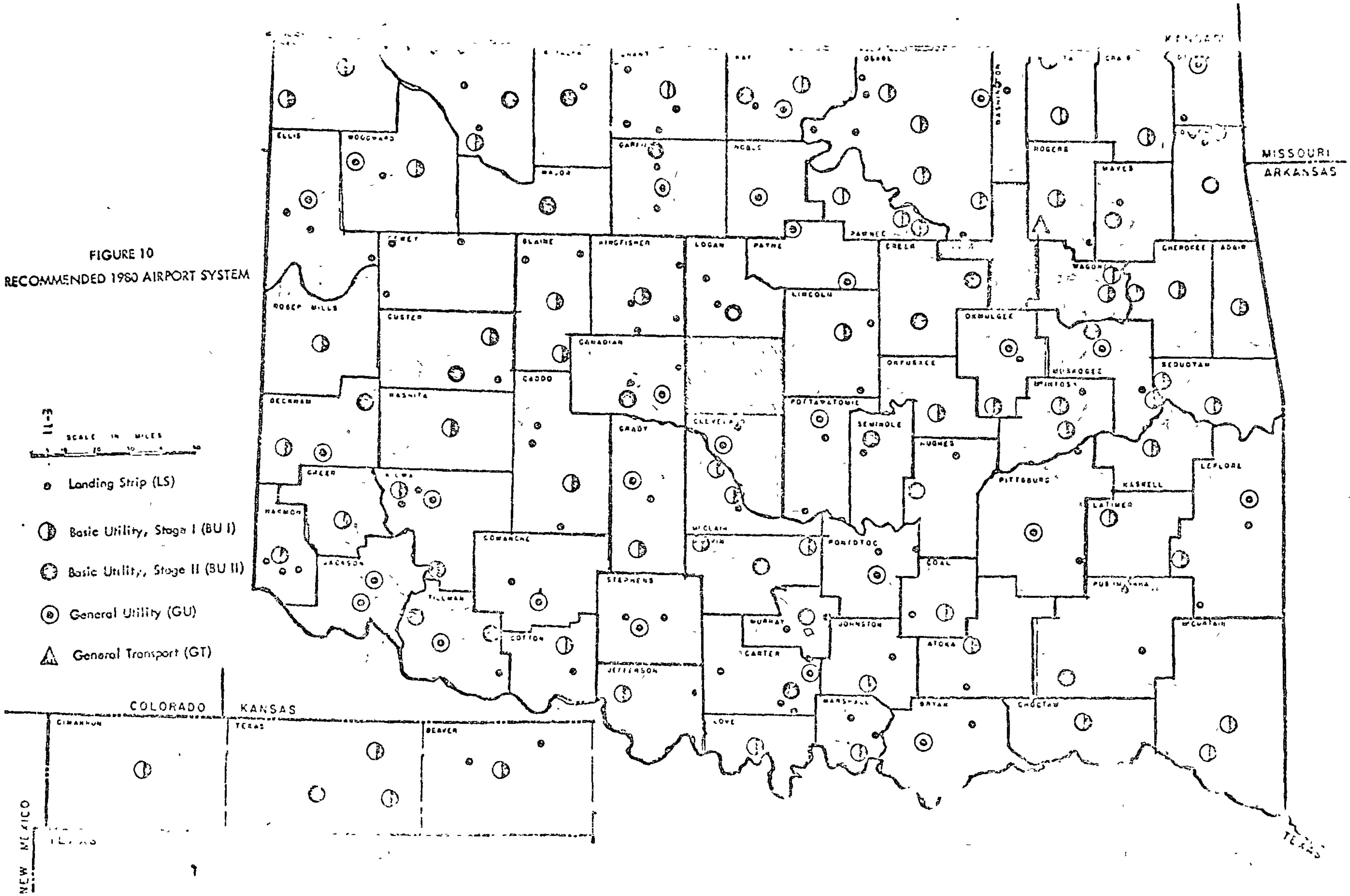
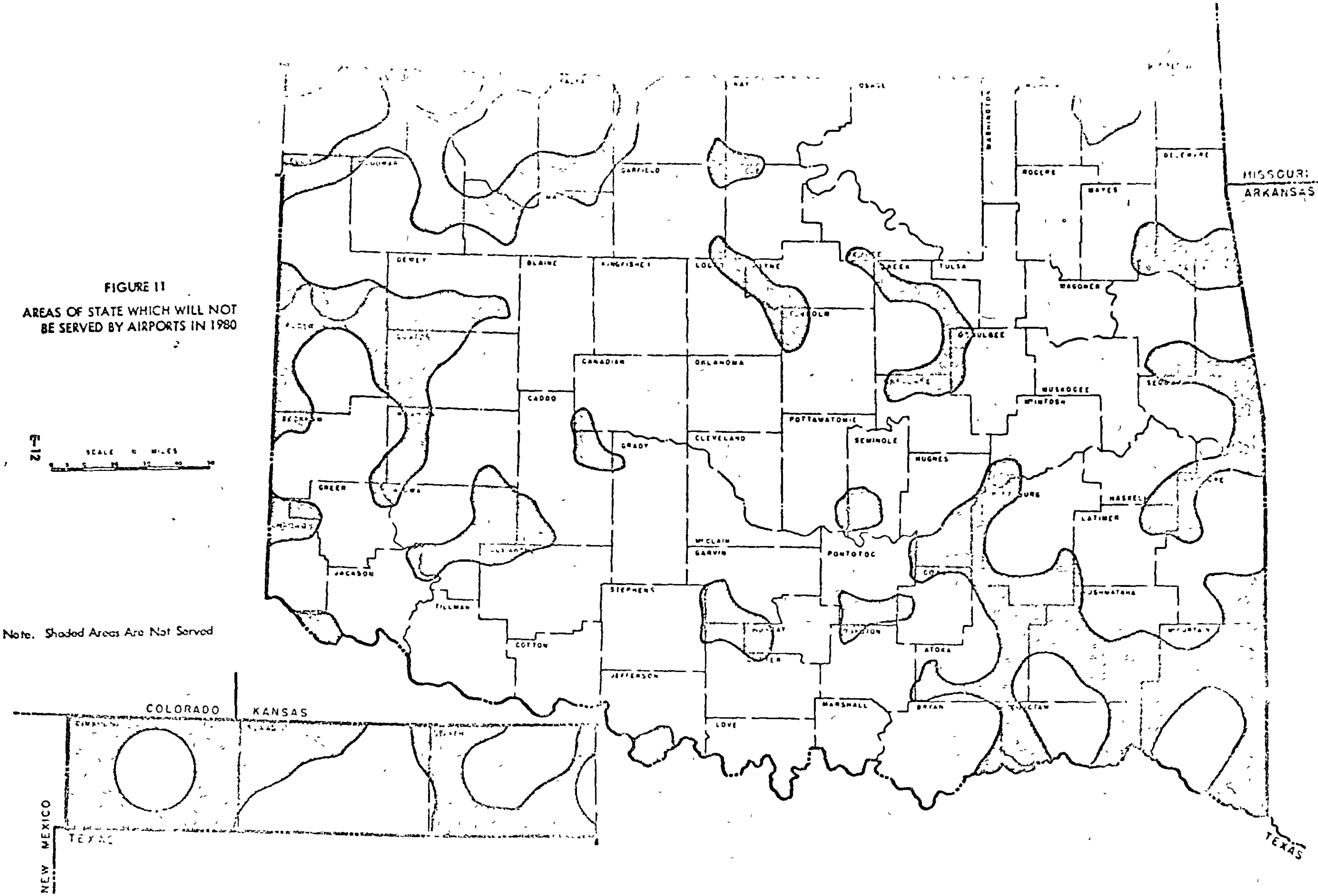


FIGURE 10
RECOMMENDED 1980 AIRPORT SYSTEM

FIGURE 11

AREAS OF STATE WHICH WILL NOT BE SERVED BY AIRPORTS IN 1980



Note. Shaded Areas Are Not Served

E-12

TABLE 5

INVENTORY DATA

FOR

OKLAHOMA AIRPORTS

INTRODUCTION TO USE

This table is used to depict the state airport system as it existed at the time of the inventory. Columns (1) and (2) are self explanatory, while column (3) contains the new FAA airport classification system. This data was determined by FAA publication, AC 150/5300-4A - Utility Airports and AC 150/5300 - Airport Design Standards - General Aviation Airports - Basic and General Transport.[1,2]

The definitions of the FAA classification terms used are as follows:

Landing Strip (LS). Landing Facilities smaller than Basic Utility airport, Stage I.

Basic Utility, Stage I (BU I). A stage I airport can accommodate about 75 percent of the propeller aircraft under 12,500 pounds and the runway must meet minimum length criteria which are dependent upon maximum normal temperature and airport elevation.

Basic Utility, Stage II (BU II). A stage II airport can accommodate about 95 percent of the propeller driven air craft under 12,500 pounds and also must meet minimum runway length criteria.

General Utility (GU). This type of airport must meet minimum runway length criteria and accommodate substantially all propeller driven aircraft of less than 12,500 pounds. The airport should have a substantial usage or potential usage of aircraft having a gross weight of over 3000 pounds.

Basic Transport (BT). The Basic Transport type of airport is planned to accommodate turbo jet powered aircraft which are 60,000 pounds gross weight. This classification so applied to the General Utility airports on a percentage basis. Example: BT 60-90 ... that the airport can accommodate 60 percent of the Basic Transport fleet @ 90% ... load. This type of airport is planned for use by the "business jets".

General Transport (GT). The General Transport airport accommodates transport category airplanes up to 175,000 pounds gross weight.

Scheduled Air Transport (AT). Airports used or to be used by CAB and state certificated air carriers which use transport category aircraft.

Column (4) contains the present operations count at the airports by category. An operation is defined as either a landing or a takeoff.

The operations are shown as local, itinerant, and total. A local operation is a takeoff and landing at the same airport with no intermediate stops. An itinerant operation is an operation with departure or destination at a different airport. An itinerant operation can be either interstate or intra-state. A breakdown of itinerant operations into the lower categories was deemed unfeasible. Airport personnel contacted had no accurate way of estimating the percentage of interstate or intra-state traffic and could offer only a guess on their already estimated itinerant count. A research of available statistics also revealed that the data was unavailable. The total operations are also shown. The number in parenthesis under the total number of operations is the percentage that present operations are to the airports capacity. The airports capacity was determined using AC 150/5060-1A, Airport Capacity Criteria Used in Preparing The National Airport Plan.[3]

Column (5) shows the users identification based on the type of services and use available at the airport. The definition of the symbols is as follows:

1. B - Business
2. C - Commercial
3. P - Pleasure
4. I - Instructional

5. M - Military
6. T - Taxi
7. E - Balanced

Column (6) is the type of airport ownership. PUB is for public ownership, while PVT, is for private ownership.

Column (7) is the principal runway specifications and type and strength of its surface. Example: 3400 x 75, Asph 9.5S-12.8D-19.0DT. This means the length is 3400 feet while the width is 75 feet, the surface is asphalt, and the estimated load carrying capability is 9,500 pounds for a single wheel, 12,800 pounds for a dual wheel, and 19,000 pounds for a dual tandum wheel.

Column (8) is the type of lighting presently on the field. An explanation of the symbols is as follows:

1. RB - Rotating Beacon
2. LIRL - Low intensity runway lights
3. LITL - Low intensity taxiway lights
4. MIRL - Medim intensity runway lights
5. MITL - Medium intensity taxiway lights
6. HIRL - High intensity runway lights

Column (8) is used to list other significant factors that influence the number operations of airports. An explanation of the symbols used in this column is as follows:

A. Fuel
   1. F1 80/87
   2. F2 100/130
   3. F3 115/145
   4. F4 Jet

B. Storage
   1. H-3 Conventional hanger followed by number of structures.
   2. T-4 T-Hangers followed by number of stalls

C. Services

1. S1 Minor Repair
2. S2 Major Repair

D. Conveniences

1. C1 Rest Rooms
2. C2 Restaurant
3. C3 Transportation
4. C4 Unicom
5. C5 Wind "Tees" or Cones

COUNTY (1)	AIRPORT (2)	(3) FAA CLASS	(4) OPERATIONS LOCAL	ITINERANT	TOTAL (% capacity)	(5) USER IDENT	OWNERSHIP (6)	RUNWAY SPECS (7)	LIGHTING (8)	(9)
Cimarron	Boise City	LS	1000	2200	3200 (3.37%)	B,P,C	PUB	3450x40 Asphalt 12.5(gross)	LIRL	F-1,F-2,T-11, S-1,C-3,C-4, C-5
Cleveland	Max Westheimer	GU BT 60-60	80,000	30,000	110,000 (65-85%)	E	PUB	4765x200 Asphalt 15S-2-D-30DT	RB MIRL MITL	F-1,F-2,F-3,F-4 T-30,H-3,S-2, C-1,C-2,C-3, C-4,C-5
	12th Street Airpark	LS	2700	1030	3730 (4.15%)	B,P,C,I	PVT	2740x100 Asphalt & Turf 4S (gross)	None	F-1,H-5,S-2 C-1,C-3,C-5
Coal	Municipal (Coalgate)	BU [illegible]	Not Established new Airport			B,P	PUB	2640x60 Asphalt Unavailable	None	C-5
	Rice [illegible]	LS	0	300	300 (0.53%)	B,P	PVT	1750x66 Turf	None	C-5
Comanche	Huscher Field	LS	3000	1200	4200 (3.82%)	B,P,C,I	PVT	2000x140 Turf	None	F-1,H-2,S-4 C-1,C-5
	Municipal (Lawton)	GU BT100-60	56,565	34,743	91,308 (83%)	E	PUB	5450x100 Concrete 50S-75D-135DT	RB MIRL	F-1,F-2,F-4, T-20,H-3,S-2, C-1,C-2,C-3, C-4,C-5
Cotton	Temple	LS	1000	1500	2500 (2.73%)	B,P,C,I	PVT	2400x65 oil mat	None	F-1,T-2,H-1, C-5

COUNTY (1)	AIRPORT (2)	(3)FAA CLASS	(4) OPERATIONS LOCAL	ITINERANT	TOTAL (%capacity)	(5)USER IDENT	OWNERSHIP(6)	RUNWAY SPECS(7)	LIGHTING (8)	REMARKS (9)
Craig	Municpal Vinita	BUI	200	2100 (2.34%)	2300 (2.56%)	B,P,C	PUB	3000x60 Asphalt 9.5S-12.8D-19DT	LIRL LITL	F-1,F-2,T-4,H-1 S-2,C-1,C-2, C-3,C-4,C-5
Creek	Jones Memorial	BU II	1000	1500	2500 (2.78%)	B,P,C,I	PUB	3400x60 Asphalt 5S-gross	RB LIRL	F-1,H-1,S-2 C-1,C-3,C-4, C-5
Custer	Municipal (Clinton)	BUI	5500	8500	14,000 (8.5%)	E	PUB	3200x75 Asphalt 12.5S-20D 36DT	RB LIRL LITL	F-1,F-2,T-2, H-1,S-1, C-1, C-3,C-4, C-5
	Municipal (Thomas)	BU I	2000	1250	3250 (3.61%)	B,P	PUB	3000x50 Asphalt 6S-9D-11.3DT	None	F-1,F-2,T-3,C-3 C-5
	Weather-ford	LS BU I	Not available, new Public airport being built (Thomas P. Stafford) 4400' runway			B,P	PVT	2628x50 Oil mat	None	T-2,H-1,C-3, C-5
Delaware	Island Farms	LS	300	400	700 (0.78%)	B,P	PVT	3100x100 Grass	None	H-1,C-1,C-2 C-3,C-4,C-5
	Monkey Island	LS	100	4000	4100 (4.56%)	B,P	PVT	2600x100 Turf	None	F-1,F-2,C-1, C-2,C-3,C-5

COUNTY (1)	AIRPORT (2)	(3)FAA CLASS	(4) OPERATIONS LOCAL	ITENERANT	TOTAL (%capacity)	(5)USER IDENT	OWNERSHIP(6)	RUNWAY SPECS(7)	LIGHTING (8)	REMARKS (9)
Nowata Cont'd	Municipal (Nowata)	LS	3200	4320	7520 (8.35%)	B,P,C,I	PUB	2500x50 Asphalt 7.5S-12.8D-19DT	RB	F-1,H-1,C-5
Okfuskee	Okemah	BU I	900	1800	2700 (3.0%)	BCCI	PUB	3000x100 Turf	None	F-1,H-3,C-5
Oklahoma	Downtown Airpark	BU I	7250	21,750	29,000 (30.6%)	E	PVT	3240x100 Asphalt 12.5 Gross	LIRL	F-1,F-2,F-4,T-28, H-3,S-2,C-1,C-2, C-3,C-4,C-5
	Expressway Junction	BU I	8100	24,000	32,100 (35.6%)	B,P,C,I	PVT	3000x70 Asphalt 15S-20D-30DT	RB LIRL	F-1,F-2,T-20,H-3,S-2 C-2,C-3,C-4,C-5
	Jane's Pasture	GU	700	100	800 (0.84%)	B,P	PVT	5000x150 Turf	None	F-2,T-1,H-1 C-2,C-3,C-5
	Service	LS	400	300	700 (0.78%)	B,P	PVT	2400x200 Turf	None	F-1,F-3,C-5
	Stamper Ranch	LS	Not	Available		B,P	PVT	1500x75 Turf	None	C-5
	Wiley Post	GU BT100-60	94,429	96,443	190,000 (6[illegible]-[illegible]0%)	E	PUB	7200x150 Conc & Asphalt 15S-20D-30DT	RB MIRL	F-1,F-2,F-4,T-103 H-[illegible],S-2,C-1,C-2 C-3,C-4,C-5

COUNTY (1)	AIRPORT (2)	(3) FAA CLASS	(4) OPERATIONS LOCAL	ITINERANT	TOTAL (% capacity)	(5) USER IDENT	OWNERSHIP (6)	RUNWAY SPECS (7)	LIGHTING (8)	[illegible] (9)
Oklahoma cont'd	Will Rogers	AT	66,262	136,299	202,561 (84%)	E	PUB	9800x150 Asp & Conc 100S-200D-300DT	RB HIRL MITL	F-1,F-2,F-4,[illegible], S-2,C-1,C-2,C-3 C-4,C-5
	Wynn	LS	600	1200	1800 (2.0%)	B,P	PVT	2250x200 Turf	None	C-3,C-5
Okmulgee	Ashley	LS	150	10	160 (0.18%)	B,P,C,I	PVT	1600x50 Turf	None	T-1,H-1,C-5
	Municipal (Henryetta)	BU I	500	1500	2000 (2.22%)	B,P	PUB	3000x50 Asphalt 9.5S-12.8D-19DT	LIRL	F-1,T-5,H-1 C-5
	Municipal (Okmulgee)	GU	4500	3600	8100 (8.1%)	E	PUB	4300x150 Concrete 30S-50D-80DT	RB MIRL	F-1,F-2,H-1,C-1 C-3,C-4,C-5
Osage	Codding Cattle	BU I	0	100	100 (0.11%)	B,P	PVT	3200x75 Asphalt 15S-20D-30DT	None	C-5
	Cooper Ranch	LS	260	40	300 (0.33%)	B,P	PVT	1600x75 Turf	None	H-1,C-5
	Frank Phillips	GU BT100-60	12,480	12,300	24,780 (26.2%	E	PUB	6200x100 Concrete 74S-[illegible]-193DT	RB MIRL	F-1,F-2,F-4,T-14, H-11,S-2,C-1,C-[illegible] C-[illegible],C-5

TABLE 6

TRIP GENERATION EQUATIONS

Cluster	Equation
1	$Y = 1054\ X_1 + 4.4\ X_2 + 777.0\ X_3 + 3949 X_4 - 5544$
2	The SMSA'S were subjected to an independent analysis
3	$Y = 7456\ X_1 - 41.0 X_2 + 6912$
4	$Y = 461.6\ X_3 + 8858\ X_4 - 18.2 X_5 + 1057 X_7 + 5806$
5	$Y = 367.0\ X_3 + 367.0\ X_4 + 2.0 X_5 - 266.3$
6	$Y = 1425.6\ X_1 + 4.9 X_5 - 1.0 X_6 + 6137$
7	$Y = 31.8\ X_2 - 0.4\ X_6 + 204.4 X_7 + 2579$

Where

Y = The total annual operations in a service area;

X_1 = The number of industries in a service area with more than 20 employees

X_2 = The total college enrollment in the service area;

X_3 = The number of eligible single-engine aircraft in the service area;

X_4 = The number of multi-engine aircraft in the service area;

X_5 = The total labor force in the service area;

X_6 = The total personal income in the service area;

X_7 = The total number of airmen in the service area;

TABLE 7

STATISTICAL ANALYSIS OF MULTIPLE REGRESSION VARIABLES

Cluster	Coefficients of Independent Variables							Test Statistics				
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Standard Error	Actual Error	R	R^2	F
1	1054	+4.4	771	3949				10716	294	0.983	0.966	21.8
2	THE SMSA'S WERE SUBJECTED TO AN INDEPENDENT ANALYSIS											
3	7456	-41.0						9644	640	0.83	0.67	9.99
4			461	8858	-18.2		1066	14572	2680	0.97	0.94	33.60
5			367	367	2			1639	400	0.97	0.94	55.90
6	1425.6				4.9	1.0		2712	2100	0.92	0.84	7.43
7		31.8		0.4			204.4	11343	3380	0.83	0.67	5.37

CHAPTER 17

HOUSING MODEL

17.1 Introduction

The housing sub-model is designed to determine the housing needs in an urban area. The model basically deals with the identification of households and the identification of housing units in which households are distributed. Households were categorized and forecasted earlier in the population model are also used as inputs for the housing model. Housing unit is the physical structure which a household occupies and it will be discussed in the description of the model.

Previously, a housing model, the Oklahoma Housing (1), was developed by the Bureau of Water and Environmental Resources Research at the University of Oklahoma. However, that model was designed to assist in the overall state housing planning rather than to be used in an urban area study. Hence, an effort was made to develop a different model. Although much of the present housing model developed in this research was based on the New York State housing model (7), the choice of the type of model was made after an extensive study of the existing housing models. The choice of the model type will be discussed first in the following, and then the general description of the model.

17.1.1 Background on the Choice of Model Type

The development of the housing sub-model was preceded by an extended study of the existing housing and housing market models. As a result of that study, a categorization of different types of housing models was done. The categorization was based on the time characteristics considered, the size of the geographical area encompassed, and the kind and the amount of data used in the models.

The time characteristics in a model include the length of time used to age the variables in the model. It was found that, in their forecasting process, most models age in five year increments. This was done because "five-years" is half of the time span between two consecutive censuses conducted nationally. The San Francisco model (3), however, makes six runs with time intervals of two years each. This was thought to be a somewhat unrealistic time interval as major housing selection or migration of the average household probably does not take place in such a short period (two years). In the development of the housing sub-model, it was decided to leave the time of aging as flexible as possible so that it will be able to fit the periods used in the over-all urban system model.

Next, the characteristic of the size of the geographical area encompassed by a model was studied. Models are generally of two basic categories - regional (or state) and sub-regional. Regional models, such as the New York State housing model (7), encompass a large area and, therefore, predict housing trends on a broader base. The data required for this type of model are usually quite easily accessible in the form of census data. Sub-regional models, such as the Delaware (5), or the San Francisco model(3), tend to require data with a higher complexity for a smaller area. Hence, it was decided to use a regional type model in this study simply because of the large urban area considered in the development of the model and the availability of data.

The kind and the amount of data used in a model were then studied. The variation of the amount and the kind of data used in a model ranges from household and housing data, essentially census data, used by the New York State model (7), to the monumental amount of data used in the San Francisco model (3).

The New York State model categorizes households according to income and age, and divides housing into eighteen types based on value, tenure, and structure. Although data on housing could be broken down further to encompass more types (the San Francisco model uses 288) based on additional variables such as labor force, employment, city conditions, transportation availability, etc. The model would become extremely complex and data would be too costly and too difficult to be obtained.

Finally, with its flexible structure, the basic format of the New York State Housing model was adapted in this study. The New York model encompasses a workable number of parameters which are sufficiently flexible to be changed as necessary, yet it is not at such an infinitestimally detailed level as to make the model too cumbersome for use.

17.1.2 General Description of the Housing Sub-model

The two main components in the housing sub-model are the housing unit and the household. The model is basically a cohort-survival model in which housing units go through an aging process while households are also aged but outside the sub-model. Actually, household data are derived from the outputs of the population model in which all population components are aged as well as the related variables, such as households.

The model begins by taking inventories of the currently aged housing units and households, and then, the number and the types of new housing needed to be added to the study area are determined. This is done by paring the vacant housing with the number and the type of the households which are dissatisfied with their current housing and those which are newly inmigrated to the area. (See Figure 17.1-1)

Next, new housing is "built" in the sub-model based partially on historical trends and partially on current demands. Three options are available for this new housing "building" process: (i) let the model automatically "build" the required housing according to a pre-programmed ratio indicating the distribution of new housing "built" based on the historical trends and current demand, (ii) participate in the decision making by changing the pre-programmed ratio, and (iii) execute the entire "building" process outside the model by adding a certain amount of new housing units to the market.

Newly "built" housing plus aged housing are considered as the housing characteristic for the area during a particular time span. This characteristic will then be used as the initial inventory in the next cycle in which housing units will go through another aging process and new housing needed will be determined and "built".

17.2 Description of the Model

Each individual component of the housing sub-model is described in this section. To show how these components operate in the overall sub-model, a flow chart of the model is shown in Figure 17.2-1.

17.2.1 Housing Inventory--Types of Housing

The sub-model begins by reading in an inventory which includes housing, and household population. The housing inventory is categorized

Figure 17.1-1. The Housing Model

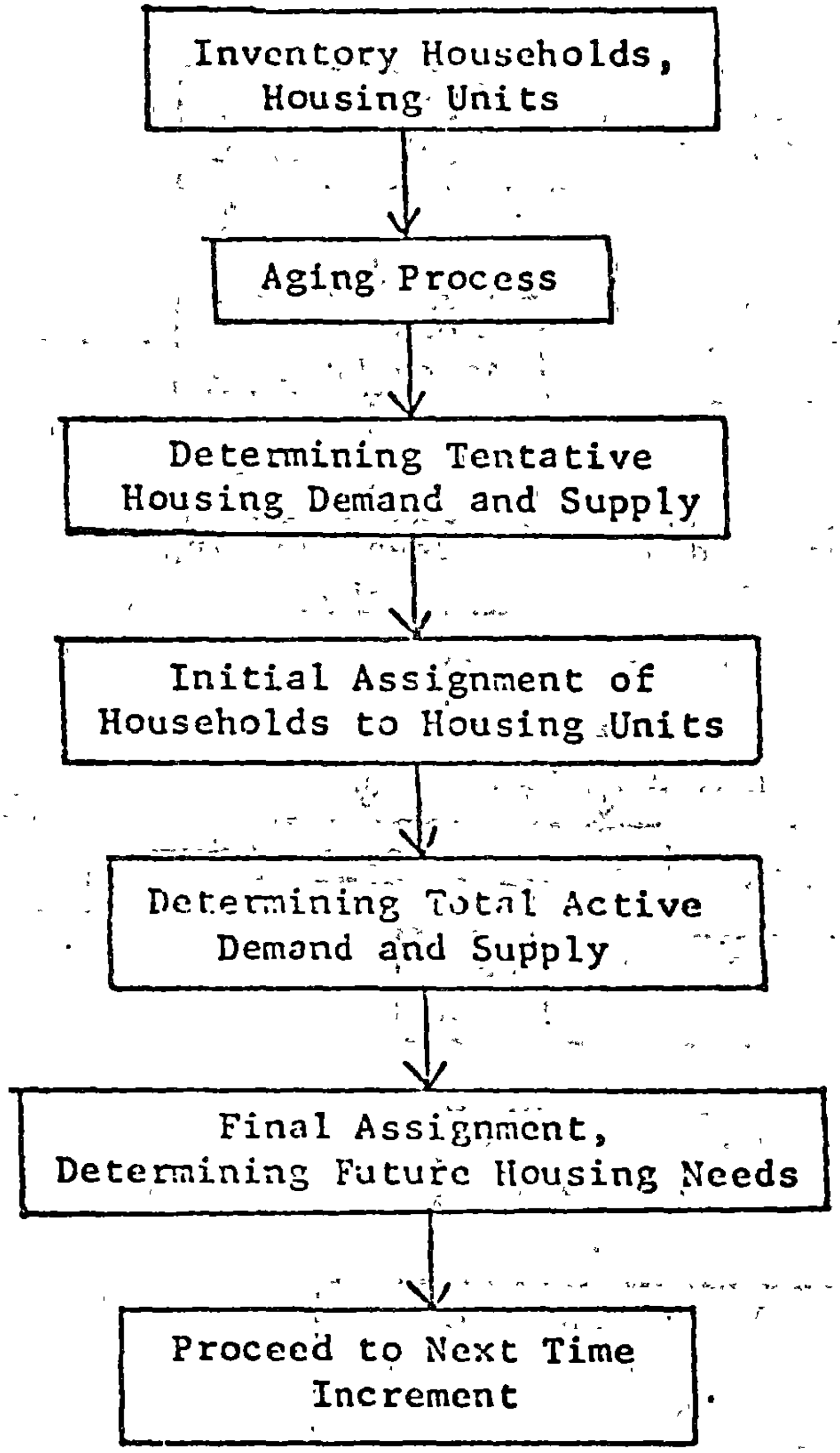
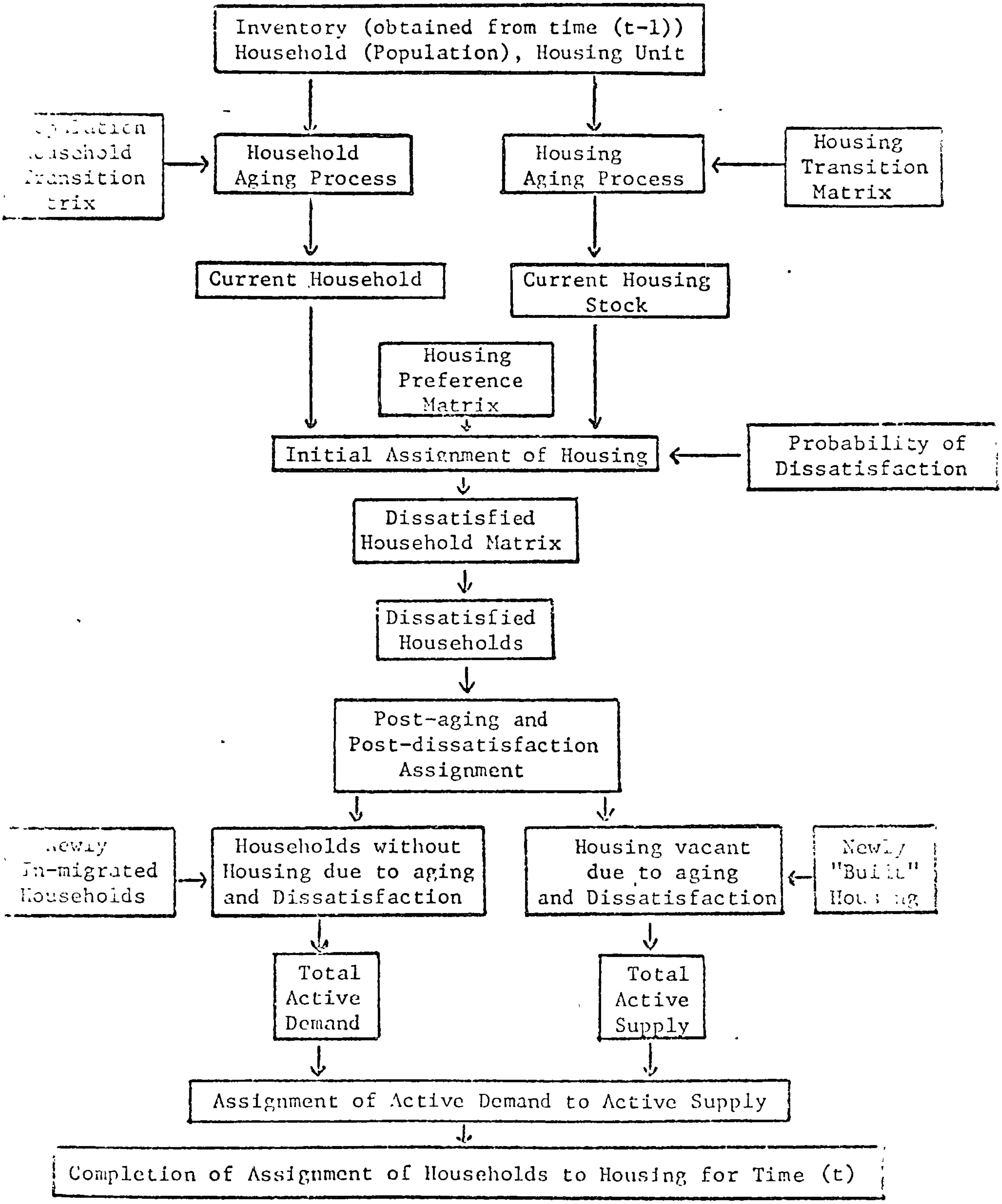


Figure 17.2-1 Operation of the Housing Model



by the value, the tenure, and the structure of the housing unit. Housing values are divided into high, medium, and low groups. The structure of housing is based on whether it is a single family unit, multiple family unit, or mobile home. Owner-occupied and renter-occupied are the two sub-categories used to define the tenure of housing.

Using these sub-divisions, a total of eighteen types of housing are derived as shown in Table 17.2.1-1. The development of these sub-divisions was based on the availability of census data. Hence, there should not be any difficulty in obtaining the housing inventory, although some computations are needed to convert raw census data into usable data. The population and the household inventory needed for this sub-model are obtained indirectly from the population model described earlier.

17.2.2 Housing Aging Process--Housing Transition Matrix

After obtaining the initial housing inventory, the housing aging process takes place. This is accomplished by multiplying the initial housing units by a housing transition matrix. The housing transition matrix gives the probability of moving a housing unit from one of the eighteen types of housing to another type within a certain time span, e.g., between time (t-1) and time (t).

A sample housing transition matrix is shown in Figure 17.2.2-1. The first column of the matrix designates the original eighteen types of housing which will move to one of the housing types indicated by the first row of the matrix. As noted in the first row of the matrix, besides the originally defined eighteen types of housing, there is an additional category: demolished housing. Thus, the housing transition matrix pro-

Table 17.1-1

HOUSING TYPES

Housing type	Value*	Tenure	Structure
1	low	owner-occupied	single-family
2	low	owner-occupied	multi-family
3	low	renter-occupied	single-family
4	low	renter-occupied	multi-family
5	medium	owner-occupied	single-family
6	medium	owner-occupied	multi-family
7	medium	renter-occupied	single-family
8	medium	renter-occupied	multi-family
9	high	owner-occupied	single-family
10	high	owner-occupied	multi-family
11	high	renter-occupied	single-family
12	high	renter-occupied	multi-family
13	low	owner-occupied	mobile
14	low	renter-occupied	mobile
15	medium	owner-occupied	mobile
16	medium	renter-occupied	mobile
17	high	owner-occupied	mobile
18	high	renter-occupied	mobile

*For owner-occupied units, value categories are defined according to the value of the housing.

- low - less than $15,000.00
- medium - $15,000.00 - $24,900.00
- high - $25,000.00 or more

For renter-occupied unite, value categories are based on rent and defined as follows:

- low - less than $100.00/month
- medium - $100.00 - $150.00/month
- high - $150.00/month or more

Figure 17.2.2-1

HOUSING TRANSITION MATRIX

To housing type:

From housing type:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Demolished
1	.85	.00	.05	.00	.06	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.04
2	.00	.88	.00	.05	.00	.05	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
3	.02	.00	.87	.00	.00	.00	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07
4	.00	.02	.00	.90	.00	.00	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.05
5	.01	.00	.00	.00	.88	.00	.05	.00	.04	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02
6	.00	.01	.00	.00	.00	.90	.00	.05	.00	.03	.00	.00	.00	.00	.00	.00	.00	.00	.01
7	.00	.00	.01	.00	.02	.00	.91	.00	.00	.00	.02	.00	.00	.00	.00	.00	.00	.00	.04
8	.00	.00	.00	.01	.00	.02	.00	.93	.00	.00	.00	.01	.00	.00	.00	.00	.00	.00	.03
9	.00	.00	.00	.00	.02	.00	.00	.00	.92	.00	.05	.00	.00	.00	.00	.00	.00	.00	.01
10	.00	.00	.00	.00	.00	.02	.00	.00	.00	.92	.00	.05	.00	.00	.00	.00	.00	.00	.01
11	.00	.00	.00	.00	.00	.00	.02	.00	.02	.00	.94	.00	.00	.00	.00	.00	.00	.00	.02
12	.00	.00	.00	.00	.00	.00	.00	.02	.00	.02	.00	.95	.00	.00	.00	.00	.00	.00	.01
13	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.73	.05	.02	.00	.00	.00	.20
14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.02	.76	.00	.02	.00	.00	.20
15	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.00	.69	.05	.01	.00	.15
16	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.10	.02	.72	.00	.01	.15
17	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12	.00	.73	.05	.10
18	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.12	.02	.76	.10

vides for the elimination of some of the units. The output of the housing aging process is the housing stock which existed in the previous period and after some of them have changed from one type to another are also considered as part of the current housing units.

17.2.3 Household -- Population-Household Transition Matrix

Household inventory is obtained indirectly from outputs of the population model described earlier. It is categorized by the age of household head and household income. As shown in Table 17.2.3-1, three types of household income are considered: low (annual income less than $5,000), medium (annual income between $5,000 and $12,000), and high (annual income greater than $12,000). There are ten categories of the age of household head: those younger than 25 years old (1 group), those between 25 and 65 in five-year increments (8 groups), and those older than 65 (1 group). As a result of this categorization, thirty types of households are derived.

In the population model, each population component goes through an aging process in a particularly defined time span. The aged population components are then used to determine the number of each type of household by using a population - household transition matrix. This matrix indicates the percentage of each population component being used to define the number of households in each period. In other words, the household figures in each period are derived from the population components after the population components have gone through an aging process.

17.2.4 Assignment of Housing--Housing Preference Matrix

After the aging processes of housing and household have been done, an assignment of the previously existing households to previously exist-

Table 17.2.3-1

HOUSEHOLD TYPES

Household type	Age of household head	Household income*
1	less than 25	low
2	25-29	low
3	30-34	low
4	35-39	low
5	40-44	low
6	45-49	low
7	50-54	low
8	55-59	low
9	60-64	low
10	65 or over	low
11	less than 25	medium
12	25-29	medium
13	30-34	medium
14	35-39	medium
15	40-44	medium
16	45-49	medium
17	50-54	medium
18	55-59	medium
19	60-64	medium
20	65 or over	medium
21	less than 25	high
22	25-29	high
23	30-34	high
24	35-39	high
25	40-44	high
26	45-49	high
27	50-54	high
28	55-59	high
29	60-64	high
30	65 or over	high

*Household income categories are defined as follows:

low - annual income of less than $5,000.00
medium - annual income of $5,000.00 - $12,000.00
high - annual income of $12,000.00 or more

ing housing is made. Households are assigned to housing according to the housing preference matrix. As shown in Figure 17.2.4-1 the housing preference matrix indicates the preferences of the thirty different types of the households for each one of the eighteen types of housing.

In general, the higher income households are assigned to their preferred housing before assignments of the lower income households are made. As a result of the dissolution in the aging process of both households and housing units, some previously existing households are without housing and some housing units are vacant.

17.2.5 The Dissatisfied Household Process -- Dissatisfied Household Matrix

After the initial housing assignment, the dissatisfied household process is considered. As indicated in the housing preference matrix, each type of household has relative preferences among the eighteen available types of housing. The probability of a household's dissatisfaction with present housing depends on its relative preferences for that housing. Thus, a very small percentage of households will be dissatisfied if their present housing is their first choice, while for those whose currently assigned housing is their last choice, the percentage of dissatisfied households will be large. An example of the dissatisfaction probabilities of dissatisfaction to the inital housing assignment, the dissatisfied household matrix can be obtained (see Figure 17.2.5-1). An example of the dissatisfied household matrix is shown in Figure 17.2.5-2.

Each entry in the dissatisfied household matrix indicates the number of households of a particular type which are assigned to housing units of a particular type and are dissatisfied with that assignment. By summing

Figure 17.2.4-1

HOUSING PREFERENCE MATRIX

Household type	Preferences of each household type for housing																	
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th
1	4	3	2	1	13	14	8	7	6	5	15	16	12	11	10	9	17	18
2	3	4	1	2	13	14	7	8	5	6	15	16	11	12	9	10	17	18
3	1	2	3	4	13	14	5	6	7	8	15	16	9	10	11	12	17	18
4	1	2	3	4	13	14	5	6	7	8	15	16	9	10	11	12	17	18
5	2	1	4	3	13	14	6	5	8	7	15	16	10	9	12	11	17	18
6	1	3	2	4	13	14	5	7	6	8	15	16	9	11	10	12	17	18
7	1	3	2	4	13	14	5	7	6	8	15	16	9	11	10	12	17	18
8	1	3	2	4	13	14	5	7	6	8	15	16	9	11	10	12	17	18
9	4	2	3	1	13	14	8	6	7	5	15	16	12	10	11	9	17	18
10	4	2	3	1	13	14	8	6	7	5	15	16	12	10	11	9	17	18
11	8	7	6	5	15	16	4	3	2	1	13	14	12	11	10	9	17	18
12	7	8	5	6	15	16	3	4	1	2	13	14	11	12	9	10	17	18
13	5	6	7	8	15	16	1	2	3	4	13	14	9	10	11	12	17	18
14	5	6	7	8	15	16	1	2	3	4	13	14	9	10	11	12	17	18
15	6	5	8	7	15	16	2	1	4	3	13	14	10	9	12	11	17	18
16	5	7	6	8	15	16	9	11	10	12	17	18	1	3	2	4	13	14
17	5	7	6	8	15	16	9	11	10	12	17	18	1	3	2	4	13	14
18	5	7	6	8	15	16	9	11	10	12	17	18	1	3	2	4	13	14
19	8	6	7	5	15	16	4	2	3	1	13	14	12	10	11	9	17	18
20	8	6	7	5	15	16	4	2	3	1	13	14	12	10	11	9	17	18
21	12	11	10	9	17	18	8	7	6	5	15	16	4	3	2	1	13	14
22	11	12	9	10	17	18	7	8	5	6	15	16	3	4	1	2	13	14
23	9	10	11	12	17	18	5	6	7	8	15	16	1	2	3	4	13	14
24	9	10	11	12	17	18	5	6	7	8	15	16	1	2	3	4	13	14
25	10	9	12	11	17	18	6	5	8	7	15	16	2	1	4	3	13	14
26	9	11	10	12	17	18	5	7	6	8	15	16	1	3	2	4	13	14
27	9	11	10	12	17	18	5	7	6	8	15	16	1	3	2	4	13	14
28	9	11	10	12	17	18	5	7	6	8	15	16	1	3	2	4	13	14
29	12	10	11	9	17	18	8	6	7	5	15	16	4	2	3	1	13	14
30	12	10	11	9	17	18	8	6	7	5	15	16	4	2	3	1	13	14

Figure 17.2.5-1. Probability of Dissatisfaction

Housing Type	Probability of Dissatisfaction
1	0.05
2	0.10
3	0.15
4	0.20
5	0.25
6	0.40
7	0.50
8	0.60
9	0.70
10	0.80
11	0.90
12	0.95
13	0.95
14	0.95
15	0.95
16	0.95
17	0.95
18	0.95

Figure 17.2-5-2

[illegible] Household Matrix

*** [illegible] MATRIX ***

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.	0.	0.	63.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	153.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	45.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	55.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	62.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	107.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	91.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	87.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	74.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	762.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	333.	133.	0.	30.	52.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	571.	0.	245.	0.	175.	0.	0.	0.	0.	0.	0.	0.	119.	37.	0.	0.
13	0.	0.	0.	0.	176.	0.	0.	0.	0.	0.	0.	0.	0.	0.	13.	0.	0.	0.
14	0.	0.	0.	0.	225.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	376.	46.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	227.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	190.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	181.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	155.	0.	116.	77.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	403.	0.	302.	202.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.	14.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	26.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	50.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	58.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	71.	23.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.	82.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.	71.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.	99.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	62.	66.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	144.	0.	0.	0.	0.	0.	0.

the rows of this matrix, the number of each type of household being without housing due to dissatisfaction is determined. In a similar manner, by summing columns rather than rows, the number of housing units of each type vacated due to dissatisfaction is determined.

After obtaining the dissatisfied households, the post-aging process and post-dissatisfaction assignment of previously existing households to previously existing housing is then computed. To get this assignment, each entry of the dissatisfied household matrix is subtracted from the comparable entry of the post-aging process assignment. A post-aging and post-dissatisfaction assignment matrix is shown in Figure 17.2.5-3.

17.2.6 Determining New Housing

The new housing needed to be "built" is based partially on historical trends and partially on current demands. Three options are available when making decisions on the amount of the new housing needed to be "built": (i) let the model automatically "built" the required housing according to a pre-determined ratio indicating the distribution of new housing "built" based on the historical trends and those based on the current demand, (ii) participate in the new housing "building" decisions in this particular cycle by changing the pre-determined ratio mentioned in (i), or (iii) execute the entire new housing "building" process outside the model by adding a certain amount of housing to the current market.

17.2.7 The Complete Assignment of Households to Housing

To complete the assignment of households to housing, the total active demand and the total active supply in each cycle are needed. The total active demand includes: (i) households without housing due to aging (of

Figure 17.2.5-3

***** POST AGING - POST DISSATISFACTION ASSIGNMENT *****

***** HOUSEHOLDS TO HOUSING

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.	0.	0.	1138.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	2516.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	674.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	1166.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	1146.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	2074.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	1738.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	1053.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	1415.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	14471.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	333.	534.	0.	265.	983.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	571.	0.	1389.	0.	3319.	0.	0.	0.	0.	0.	0.	0.	356.	56.	0.	0.
13	0.	0.	0.	0.	3338.	0.	0.	0.	0.	0.	0.	0.	0.	0.	40.	0.	0.	0.
14	0.	0.	0.	0.	4284.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	3385.	868.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	4307.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	3679.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	3434.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	619.	0.	657.	1470.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	1613.	0.	1714.	3831.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	87.	275.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	488.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	954.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	1097.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	635.	443.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.	1563.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.	1343.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.	1881.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	352.	1262.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2737.	0.	0.	0.	0.	0.	0.

households or housing), (ii) households without housing due to dissatisfaction, and (iii) newly in-migrated households which are obtained from the population model. Those included in the total active supply are the following: (i) housing vacant due to aging (of households or housing), (ii) housing vacant due to dissatisfaction, and (iii) newly "built" housing.

After the total active demand and supply have been determined, the total active demand is assigned to the total active supply by utilizing housing preferences as a guideline. Results from this assignment is then summed with the results from the earlier post-aging process and post-dissatisfaction assignment of the previously existing households. This produces the complete assignment of households to housing for the study area for the particular time being considered.

Figure 17.2.7-1, shows the final assignment matrix which indicates the number of households being assigned to various types of housing. Two additional figures are also included in the outputs of the housing sub-model. The first, Figure 17.2.7-2 indicates the number and the types of additional new housing needs to be "built" if all households which have not been assigned <u>first choice housing</u> are assigned to their first, except that it includes both first and second choices, i.e., if a household is not assigned to a first choice housing, it will be assigned to a second choice housing, and then the demand over the supply is designated as the new housing needed to be "built". (See Figure 17.2-7-3)

Figure 17.2.5-3

***** POST AGING - POST DISSATISFACTION ASSIGNMENT *****

***** HOUSEHOLDS TO HOUSING

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.	0.	0.	1138.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	2519.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	674.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	1160.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	1146.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	2074.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	1738.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	1053.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	1415.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	14471.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	333.	534.	0.	269.	983.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	571.	0.	1389.	0.	3319.	0.	0.	0.	0.	0.	0.	0.	356.	50.	0.	0.
13	0.	0.	0.	0.	3338.	0.	0.	0.	0.	0.	0.	0.	0.	0.	40.	0.	0.	0.
14	0.	0.	0.	0.	4284.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	3385.	868.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	4307.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	3679.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	3434.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	619.	0.	657.	1470.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	1613.	0.	1714.	3831.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	87.	275.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	488.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	954.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	1097.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	635.	443.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.	1563.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.	1343.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.	1881.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	352.	1262.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2737.	0.	0.	0.	0.	0.	0.

households or housing), (ii) households without housing due to dissatisfaction, and (iii) newly in-migrated households which are obtained from the population model. Those included in the total active supply are the following: (i) housing vacant due to aging (of households or housing), (ii) housing vacant due to dissatisfaction, and (iii) newly "built" housing.

After the total active demand and supply have been determined, the total active demand is assigned to the total active supply by utilizing housing preferences as a guideline. Results from this assignment is then summed with the results from the earlier post-aging process and post-dissatisfaction assignment of the previously existing households. This produces the complete assignment of households to housing for the study area for the particular time being considered.

Figure 17.2.7-1, shows the final assignment matrix which indicates the number of households being assigned to various types of housing. Two additional figures are also included in the outputs of the housing sub-model. The first, Figure 17.2.7-2 indicates the number and the types of additional new housing needs to be "built" if all households which have not been assigned <u>first choice housing</u> are assigned to their first, except that it includes both first and second choices, i.e., if a household is not assigned to a first choice housing, it will be assigned to a second choice housing, and then the demand over the supply is designated as the new housing needed to be "built". (See Figure 17.2-7-3)

Figure 17.2.7-1

********* FINAL [illegible] MATRIX *********
********* HOUSEHOLDS TO HOUSING *********

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0.	0.	0.	1055.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	3757.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	[illegible]	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	[illegible]	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	1248.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	2109.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	1555.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	1747.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	1496.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	15411.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	587.	597.	0.	194.	981.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	0.	0.	2092.	0.	2092.	0.	4184.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
13	1122.	0.	0.	0.	3545.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	791.	0.	0.	0.	3564.	0.	0.	0.	0.	0.	0.	0.	0.	0.	284.	93.	0.	0.
15	0.	0.	0.	0.	3078.	514.	0.	0.	0.	0.	0.	0.	0.	0.	244.	0.	0.	0.
16	0.	0.	0.	0.	4546.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	3012.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	3623.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	1399.	0.	164.	1554.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	2040.	0.	2040.	4079.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	95.	286.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	595.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	1109.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	1158.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	739.	467.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.	1630.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.	1399.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	0.	0.	0.	1983.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	437.	1310.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	72.	2903.	0.	0.	0.	0.	0.	0.

Figure 17.2.7-2

... Number of Units and Type to give all Households ... First Choice ...

HOUSEHOLD 1 NEEDS 0. HOUSES OF TYPE 4
HOUSEHOLD 2 NEEDS 0. HOUSES OF TYPE 3
HOUSEHOLD 3 NEEDS 0. HOUSES OF TYPE 1
HOUSEHOLD 4 NEEDS 0. HOUSES OF TYPE 1
HOUSEHOLD 5 NEEDS 0. HOUSES OF TYPE 2
HOUSEHOLD 6 NEEDS 0. HOUSES OF TYPE 1
HOUSEHOLD 7 NEEDS 0. HOUSES OF TYPE 1
HOUSEHOLD 8 NEEDS 0. HOUSES OF TYPE 1
HOUSEHOLD 9 NEEDS 0. HOUSES OF TYPE 4
HOUSEHOLD 10 NEEDS 0. HOUSES OF TYPE 4
HOUSEHOLD 11 NEEDS 1309. HOUSES OF TYPE 8
HOUSEHOLD 12 NEEDS 4154. HOUSES OF TYPE 7
HOUSEHOLD 13 NEEDS 1182. HOUSES OF TYPE 5
HOUSEHOLD 14 NEEDS 1169. HOUSES OF TYPE 5
HOUSEHOLD 15 NEEDS 3323. HOUSES OF TYPE 6
HOUSEHOLD 16 NEEDS 0. HOUSES OF TYPE 5
HOUSEHOLD 17 NEEDS 0. HOUSES OF TYPE 5
HOUSEHOLD 18 NEEDS 0. HOUSES OF TYPE 5
HOUSEHOLD 19 NEEDS 1584. HOUSES OF TYPE 8
HOUSEHOLD 20 NEEDS 4079. HOUSES OF TYPE 8
HOUSEHOLD 21 NEEDS 99. HOUSES OF TYPE 12
HOUSEHOLD 22 NEEDS 0. HOUSES OF TYPE 11
HOUSEHOLD 23 NEEDS 0. HOUSES OF TYPE 9
HOUSEHOLD 24 NEEDS 0. HOUSES OF TYPE 9
HOUSEHOLD 25 NEEDS 700. HOUSES OF TYPE 10
HOUSEHOLD 26 NEEDS 0. HOUSES OF TYPE 9
HOUSEHOLD 27 NEEDS [illegible] HOUSES OF TYPE 9
HOUSEHOLD 28 NEEDS 0. HOUSES OF TYPE 9
HOUSEHOLD 29 NEEDS 4378. HOUSES OF TYPE 12
HOUSEHOLD 30 NEEDS 72. HOUSES OF TYPE 12

```
[illegible] TYPE TO GIVE ALL HOUSEHOLDS ****
[illegible] FIRST AND SECOND CHOICE *****
HOUSEHOLD  1 NEEDS       0. HOUSES OF TYPE  4
HOUSEHOLD  2 NEEDS       0. HOUSES OF TYPE  3
HOUSEHOLD  3 NEEDS       0. HOUSES OF TYPE  1
HOUSEHOLD  4 NEEDS       0. HOUSES OF TYPE  1
HOUSEHOLD  5 NEEDS       0. HOUSES OF TYPE  2
HOUSEHOLD  6 NEEDS       0. HOUSES OF TYPE  1
HOUSEHOLD  7 NEEDS       0. HOUSES OF TYPE  1
HOUSEHOLD  8 NEEDS       0. HOUSES OF TYPE  1
HOUSEHOLD  9 NEEDS       0. HOUSES OF TYPE  4
HOUSEHOLD 10 NEEDS       0. HOUSES OF TYPE  4
HOUSEHOLD 11 NEEDS    1175. HOUSES OF TYPE  8
HOUSEHOLD 12 NEEDS    4184. HOUSES OF TYPE  7
HOUSEHOLD 13 NEEDS    1182. HOUSES OF TYPE  5
HOUSEHOLD 14 NEEDS    1168. HOUSES OF TYPE  5
HOUSEHOLD 15 NEEDS     244. HOUSES OF TYPE  6
HOUSEHOLD 16 NEEDS       0. HOUSES OF TYPE  5
HOUSEHOLD 17 NEEDS       0. HOUSES OF TYPE  5
HOUSEHOLD 18 NEEDS       0. HOUSES OF TYPE  5
HOUSEHOLD 19 NEEDS    1554. HOUSES OF TYPE  8
HOUSEHOLD 20 NEEDS    4079. HOUSES OF TYPE  8
HOUSEHOLD 21 NEEDS       0. HOUSES OF TYPE 12
HOUSEHOLD 22 NEEDS       0. HOUSES OF TYPE 11
HOUSEHOLD 23 NEEDS       0. HOUSES OF TYPE  9
HOUSEHOLD 24 NEEDS       0. HOUSES OF TYPE  9
HOUSEHOLD 25 NEEDS       0. HOUSES OF TYPE 10
HOUSEHOLD 26 NEEDS       0. HOUSES OF TYPE  9
HOUSEHOLD 27 NEEDS       0. HOUSES OF TYPE  9
HOUSEHOLD 28 NEEDS       0. HOUSES OF TYPE  9
HOUSEHOLD 29 NEEDS     437. HOUSES OF TYPE 12
HOUSEHOLD 30 NEEDS      72. HOUSES OF TYPE 12
```

17.3 Sub-model Assumption

The model described is based on many assumptions. It is impossible to explicitly delineate every assumption built into a model; however, it is possible to point out some of these assumptions. These asseumptions are sub-divided into two types: (a) those assumptions which can be changed only by making changes in the basic structure of the model, and (b) those assumptions which can be changed without making changes in the basic structure of the model.

17.3.1 Type one Assumptions

With respect to the first type of assumptions, the model assumes that the income and age of the household head are the only household characteristics of significance. There are, of course, a number of other household characteristics which could have been included in the model. These include race, number of persons, age of children (if any), and occupation and education of the household head. These additional characteristics were excluded in order to make the model less complex than it would be if they were included. Generally, it was assumed that the sacrifice in validity resulting from this omission would be more than adequately compensated for by the gain in simplicity. Specifically, the following are the reasons for the omission of each characteristic:

(1) The race variable in spite of recent federal, state and local legislation, racially segregated residential areas persist. Thus, race is an important factor in the assignment of demand to supply in the local housing market. However, the sub-model does not consider the allocation of either households or housing units to geographic sub-divisions within

the market. Since racial segregation occurs only at the sub-market area level, it seems possible that the model can fairly safely omit race as a household characteristic. This assumes that, holding income and age of household head constant, housing preferences and available housing (in terms of value, tenure and structure) do not vary with race. This assumption is not completely valid, but since the location of housing is omitted from the model, perhaps it has a fairly high degree of validity.

(2) The number of persons in a household depends mostly on the number of children in the household, and there exists it seems intuitively, at least some correlation between the age of the household head and the number of children. Likewise, the age of the children (if any) seems to be somewhat correlated with the age of the household head. Thus, both variables relating to the number of persons and the ages of the children have been omitted since they are at least partially represented by the age of the household head.

(3) Occupation and education of the household head may affect the household's selection of housing. Nevertheless, these additional household characteristics have been excluded from the sub-model as probably less relevant than the included characteristics. The ommited characteristics are thus not irrelevant, but only less relevant than age of the household head and income.

It is assumed that the effect of the omission of these presumable less relevant household characteristics on the model's validity is rather small. That is, it is assumed that, had the model included these additional household characteristics, it would not have been much more valid than it now is.

Ignoring the quality, the size and the age of the housing unit is also a first type assumption. The age of the housing unit seems to be, by itself, except in special cases, an unimportant factor in considering housing demand. Quality and size, in combination, are reflected to some extent in the value of the housing. These requirements are a matter of degree, and within limits, they can be satisfied by a range of housing accommodations if suitable price adjustments are made.

Age, quality and size of housing have been omitted not because they are irrelevant, but because they are assumed to be less relevant than the included characteristics. It was assumed that the loss in validity resulting from these omissions would be offset by a gain in simplicity.

The model omits market fluctuations around the equilibrium point. Thus, the model is essentially an equilibrium model, which assumes that supply varies directly with demand. The assumption is obviously not completely true, as market imperfections may cause supply to be either greater than or less than demand at any particular point in time.

Interest rates have been ignored in the model. While the credit is certainly an important factor in looking at the housing market over a period of several months, it is reasonable to assume that credit becomes relatively less important when the market is examined only once every 5 years.

17.3.2 Type Two Assumption

The assumptions described below are those that have been built into the model's data cards, thus, they can be fairly easily changed.

The housing preference matrix holds an important set of these assumptions. The preferences included in this matrix are not the desires and aspirations of households, such as those that might be expressed in response to an interviewer's questions: "In what type of housing would you most like to live?" Rather, the matrix attempts to answer a slightly different question: "given the characteristics (income and age of head) of your household, if you could choose among the 18 housing types, in which would you be most likely to live?" In short, the housing preference matrix is concerned with effective demand.

Following are the major assumptions implicit in the housing preference matrix (and they are also summarized in Table 17.3.2-1.

(1) The most obvious constraint is household income. Regardless of age, the first six housing choices for low-income households are low-value housing units, and the last six choices are high-value units. (Definitions of housing types and household types are presented in Tables 17.2.1-1 & 17.2.3-1). Similarly, the first six housing choices for high-income households, regardless of age, are high-value units, and the last six choices are low-value units. The first six housing choices for medium-income households, regardless of age, are medium-value housing units.

(2) Within this basic income constraint, there is a general preference for renter-occupied units among those households with the head aged less than 30 or over 60. Those households with the head aged less than 30 have a stronger preference for renter-occupied units than do those households with the head aged 60 or over. For households with the head aged between 30 and 60, there is a general preference for owner-occupied units. Those households with the head aged between 30 and 45

TABLE 17.3.2-1

HOUSING PREFERENCE MATRIX ASSUMPTIONS

THREE MAJOR ASSUMPTIONS

1. Preference based on Household Income:
   a. 1st six choices for low income are low value
   b. last six choices for low income are high value
   c. 1st six choices for high income are high value
   d. last six choices for high income are low value
   e. 1st six shoices for medium income are medium value
2. General Preference by Age Groups:
   a. renter-occupied -- less than 30 and over 60
   b. owner-occupied -- between 30 and 60
3. General Preference:
   a. multi-family -- less than 25 and over 60
   b. single family -- between 25 and 60

have a stronger preference for owner-occupied units than do households with the head aged between 45 and 60.

(3) There is a general preference of multi-family units, among those households with the head aged less than 25 or over 60. For households with the head aged between 25 and 60 there is a general preference for single-family units.

The housing transition matrix for aging also includes important assumptions. An initial important question in the creation of this matrix is: what is the probability that a housing unit which exists at a given point in time will no longer exist five years later? The U.S. Census of Housing (1960) provides a good starting point: for the U.S., 8.1% of the 1950 housing stock did not exist 10 years later in 1960. The period of time in one iteration of the model is only 5 years, so the basic loss rate would be about half the 8.1% or approximately 4%. (Upon the advice of those working in the INCOG area this was lowered to 2%.) It is possible to assume that this rate does not depend on the housing type. This is an unlikely assumption, however, so it was assumed that the rate varies with the housing type.

In varying the basic housing demolition rate, the following assumptions were made and they are summarized in Table 17.3.2-2.

(1) Holding tenure and structure constant, the lower the value of the housing unit, the higher will be its loss rate. It seems reasonable to assume that both the accidental demolition rate (e.g. -- due to fire) and the nonaccidental demolition rate (due to deliberate demolition for urban renewal, highway construction, new residential and non-residential construction) would be higher, the lower the value of the housing unit.

TABLE 17.3.2-2

HOUSING UNIT GENERAL ASSUMPTIONS -

HOUSING TRANSITION MATRIX:

1. Tenure & Structure Constant:

   Lower value implies higher loss

2. Value & Tenure Constant:

   Single-family implies higher loss

3. Value & Tenure Constant:

   Mobile homes implies highest loss

4. Value & Structure Constant:

   Renter-occupied implies higher loss

ADDITIONAL ASSUMPTIONS

1. Structure does not change

2. Characteristic change - only one per 5-year period

   example - value but not tenure

3. Value & Structure Constant (multi & single-family)

   Owner-occupied implies greater probability of increase in value

4. Value & Tenure Constant-Probability of increasing value:

   single-family .GT. (greater than) multi-family .GT. mobile homes

5. Greater probability of value increase

   low value .GT. medium value

6. Value is basis for probability of decrease in value

   high value .GT. medium value (non-mobile home)

7. Assumption 6 holds for mobile but with much higher probability

(Table 17.3.2-2 Continued)

8. Tenure & Value Constant

Change from owner to renter-occupied is constant

Change from renter to owner-occupied is constant

9. Probability of change

Owner to renter .GT. renter to owner

DEMOLISHED OR LOSS RATE

set at 2% (from INCOG) in the validation of the model in the INCOG Area.

(2) Holding value and tenure constant, single-family units will have a higher loss rate than multi-family units. It is assumed that the accidental demolition rate would probably be similar for single-family and multi-family units. But the nonaccidental demoliton rate would be higher for single-family units, as the cost of acquisition and demolition would be less than for multi-family units.

(3) Holding value and tenure constant, mobile homes will have a higher demolition rate than either single-family or multi-family units. It is assumed that in general, mobile homes are intentionally built to have a shorter life expectancy than non-mobile homes.

(4) Holding value and structure constant, renter-occupied units will have a higher loss rate than owner-occupied units. The accidental demolition rate would be similar for renter-occupied and owner-occupied units, it is assumed. But, owner-occupants are more likely than renter-occupants to oppose effectively the nonaccidental demolition of their housing units.

In addition to moving from existing to non-existent, there are other changes which a housing unit can make. Theoretically, in fact, a unit may move from its housing type to any one of the other 17 types. In order to eliminate some of the less likely possibilities from consideration, the following assumptions were made:

(1) No housing unit changes structure. That is: once a single-family unit, always a single-family unit. And, similarly: once a multi-family unit, always a multi-family unit. This is obviously an incorrect assumption. However, it is reported that in recent years changes in dwelling units due to net conversions to dwellings and mergers of existing

have about offset each other. Thus, the assumption, although invalid, will distort the number of single-family and multi-family units very little.

(2) A housing unit will change only one characteristic in a single 5-year period. For instance, if its value changes, its tenure will not. Although not entirely realistic, this is made as a simplified assumption. It leaves open the possibility that a unit may change two characteristics over a 10-year period.

(3) Holding value and structure constant, for single-family and multi-family housing, owner-occupied units will have a greater probability of increasing in value than renter-occupied units. The assumption here is that improvements which will increase the value of a housing unit are more likely to be made for owner-occuped units than for renter-occupied units.

(4) Holding value and tenure constant, single-family units have a greater probability of increasing in value than multi-family units, which have a greater probability of increasing in value than mobile homes.

(5) The probability that a low-value unit will increase its value is greater than the probability that a medium-value unit will. A high-value unit cannot increase in value, or at least such an increase cannot be recognized within the model.

(6) For non-mobile housing, the probability of a housing unit decreasing in value, depends on neither structure nor tenure, but only on value. The probability that a high-value unit will decrease in value is greater than the probability that a medium value unit will decrease in value. A low-value unit cannot decrease in value, or at least such

a decrease cannot be recognized within the model.

(7) The same assumption (6) holds for mobile housing as well. Mobile housing has a much higher probability of decreasing in value than does non-mobile housing.

(8) The probability that an owner-occupied unit will become a renter-occupied unit is constant, regardless of tenure or value. Likewise, the probability that a renter-occupied unit will become an owner-occupied unit is constant and is not affected by tenure or value.

(9) The probability of changing from owner-occupied to renter-occupied is greater than the probability of changing from renter-occupied to owner-occupied. It is assumed that as housing ages neighborhoods, and therefore housing units, will shift from owner-occupied to renter-occupied; it is less common to observe a shift from renter-occupied to owner-occupied.

Finally the probability of dissatisfaction is based on the following assumptions:

(1) The preference of the household for its present housing as shown in the housing preference matrix is used to determine the probability of dissatisfaction with present housing. This probability does not vary with the household type. There is no information available to determine whether or not this is a reasonable assumption. But it is probably as reasonable as many other possibilities, besides being a convenient assumption.

(2) The less preferable its present housing, the greater will be the probability that the household will be dissatisfied. This is a rather simple and straight-forward assumption, as long as the housing

preference matrix is accepted as reasonable.

(3) Even if its present housing is its first choice, there is still a small probability that the household will be dissatisfied.

(4) Even if its present housing is its last choice, there is still a small probability that the household will not be dissatisfied. In the model, dissatisfaction is a prerequisite for the search for housing. It seems reasonable to expect that some households, even if presently residing in housing of their first choice, will conduct this search. Similarly, some households, even if presently residing in housing of their last choice, will not condust this search.

SUB-MODEL VALIDATION

The major purpose of the model is to predict the housing that will exist in a housing market at one or more points in time in the future. Therefore, a reasonable question for a public policy maker to ask, prior to using the model, is: how valid is the model? The validity of the model can never be established without doubt. Even if we could determine that the model was perfectly valid for a particular housing market, or for all markets, over one ten year period, this does not necessarily mean that the model will be valid over the following ten year period or the following periods. And in fact, over a past period, the model predictions cannot be compared with real world occurences, but only with an independent estimate of reality.

In spite of these severe constraints, some validity tests have taken place. These have been basically geared to establishing the mathematical functioning of the model. The housing stock input was loaded by first giving 100 units of all types of housing and then 10,000 units. Household types were then loaded giving rations of 1:1, 5:1, 10:1, 20:1, 25:1 and 100:1. The process was reversed holding households constant and varying the ratio of housing. In addition to checking the assignment matrices a section was added to check the percent of housing taken off the market as a result of aging. In every case the model bore out the anticipated and hand calculated results.

A second type of check took the form of running the model with actual data and checking closeness of new housing built with that of a similar area's housing built over that period of time. This check proved to be within reasonable bounds.

It is observed that as the user becomes familier with the workings of the sub-model, his planning bias will certainly be able to be tested within the model.

At the same time continuing validation should certainly be carried out. If at that time discrepancies are found, the model has been so designed as to be easily adjusted by the user. As was indicated earlier it was partially with this in mind that a more flexible model was chosen.

References

(1) Oklahoma Housing, Volume I, II, III and Supplements, The Oklahoma Economic Development Foundation, Inc., Norman, Oklahoma, 1971.

(2) Indian Nations Council of Government, Tulsa, Oklahoma, "Land Use Development Models," Working Paper AHS-13, Dept. of Housing and Urban Development, March, 1970.

(3) Institute of Urban and Regional Development, "Jobs, People and Land - Bay Area Simulation Study (BASS), "University of California, Berkley, 1968.

(4) Little, A.D., "San Francisco Community Renewal Program - Simulation Model for Renewal Programming," U.S. Housing and Home Finance Agency, October, 1964.

(5) Lowry, I.S., "Seven Models of Urban Development: A Structural Comparison," Special Report #97, Highway Research Board, Washington D.C., 1968, pp. 121-163.

(6) Meier, R. L. and Duke, R. D., "Gaming Simulation for Urban Planning," Journal, American Institute of Planners, Jan., 1966, pp. 3-16.

(7) Sears, D.W., "The New York State Regional Housing Model: Simulation for Public Policy Making," Working Paper DWS-701, Office of Planning Coordination of the State of New York, March, 1971.

(8) Sears, D.W., "Major Assumptions of the New York State Regional Housing Model," Working Paper DWS-711, Office of Planning Coordination of the State of New York, Jan., 1971.

(9) Seidman, D. R., "The Construction of an Urban Growth Model," D.V.R.P.C. Plan Report, No. 1, Vol. A.

(10) Steger, W. A., "The Pittsburgh Urban Renewal Simulation Model," Journal American Institute of Planners, May, 1965.

CHAPTER 18

THE DRAINAGE MODEL

18.1 Introduction

The general purpose of the drainage sub-model is develope a method which can be used to provide indicators concerning storm runoff drainage in an urban environment. More specifically it is aimed at obtaining pollutional load indicators.

The present study is based on several previous studies. A recent study by the AVCO Economics System Corporation (1) relating to pollution activities and urban land use was aimed at developing techniques for estimating types and concentrations of contaminants found in run-off from storm water. These techniques require a basic knowledge of land use, street area, sanitary conditions, impervious cover and the average amount of rainfall for each season for the area under study. Although land use allocation is neither sufficient nor sensitive enough to explain the variability of storm water contaminant concentrations, the techniques developed do provide an estimate.

The mathematical models which resulted from this project are of linear form. Each equation contains from one to five independent variables which require careful projection and estimation. The results are reliable and reasonable. However, data were not avaivable to permit development of regression equations based on the detailed variation of land use and population cohorts required for the current research. The measurements of storm water quality and quantity based on the approach used to develop the mathematical models along with land use tabulation would permit a timely and feasible development of output equations for all urban areas.

Another study (2), subsequent to the one just described, carried on by the University of Oklahoma, developed methods for predicting dispersed pollutional storm water loads to receiving streams from land use activity cohorts. Three alternate methods were used. The original methodology was developed with unrestricted cohorts.

The study yielded the average expected pollutional load per season. This is done by estimating the amount of seasonal storm water run-off by rational methods and multiplying these volumes by the average seasonal pollutant concentrations (using the appropriate conversion factors). The product gives each pollutional parameter in pounds per season.

The area of the appropriate drainage basin is multiplied by the average parameter value taken from an appropriate table which summarizes the results. The results yeild pounds of contaminant per season. A summary of important results related to the present research is presented in Table 18.1-1. If the average seasonal precipitation amount over the area differs significantly from the average values in Table 18.1-1, the procedure has been to adjust the computed loadings by an estimated percentage increase or decrease. The desired average loadings are obtained by dividing the events/season, or adding the pounds per season to obtain the average pounds per year.

The study employed linear regression equations, with correct input independent variables, to obtain average seasonal concentrations or loads. This procedure requires extensive information of land use and the sanitary conditions of the area, and it is uniquely applicable to urban areas similar to Tulsa, Oklahoma.

The latest study in the pollution sequence (3) has been an effort to relate urban storm water pollution to the activity of the land, environmental factors, and precipitation on six candidate cities in the United States similar in terrain and activity to Tulsa, Oklahoma. One of the major concerns was to envision measures to control pollution rather than construction of facilities to treat or dispose of it. Also, it dealt with appraisal of the sources of pollution from the various land activities to provide means of control of storm water pollution by regulation of land use and urban planning.

Regression analysis was also used to determine urban pollutional concentrations in that study. The average annual loads for storm water pollution were obtained by multiplying the average pollutant concentrations by the approximate annual rainfall in pounds per acre per year.

The study pointed out that:

(i) the greatest amount of pollutant from the test areas resulted from (a) wash out of materials which were deposited on the areas and (b) the erosion of drainage channels caused by great amounts of run-off,

(ii) the season with the most run-off has the most pollutants,

(iii) functional relationships can be established between storm water pollution parameters and variables grouped in either the precipitation or land use classification to obtain a first order estimate of the average pollutant concentrations at other geographical locations. These techniques provide a procedure for looking at the impact of urban storm water pollutional loads on the receiving streams and also planning for control,

(iv) land surface characteristics with the strongest relationships with storm water pollutant concentrations are (a) environmental conditions (b) geomorphic characteristics which affect drainage and (c) degree of development or urbanization,

(v) the environmental index (see Table 10.2.2-1) which reflects the general sanitary conditions of the sites, is a good prediction variable for bacterial pollution parameters,

(vi) BOD concentrations decrease with increasing flow during the rising limb of the run-off hydrograph. The amounts of BOD contained in the flow increased with run-off rates because the time rate of flow increased at a greater rate than the BOD concentration decreased,

(vii) there is an increase in pollution produced per unit area of commercial and industrial use if the daily number of people who visit the area is high, and

(viii) in the residential section, the amount of pollution produced per unit area increases with the population density.

The research efforts culminating in the reports cited above had the common goal of investigating the urban area drainage problem. The practical purpose has been to enable the engineer and city planner to assess the need for urban drainage systems in the near future, and to do so by looking at the appropriate environmental factors and the correlation between these factors. In these studies, land use classifications, along with land condition and precipitation, have been used as input functions to generate pollutional loads.

.?.2 Model Description

The drainage sub-model developed for this study was based on the above mentioned studies. Regression analysis is used as the main technique for predicting urban storm run-off drainage pollutional loads. However, in order to relate this sub-model to other sub-models developed in this study, only the cohorts of population, land use, and the precipitation were used as inputs for prediction of pollutional loads. Although, in general, due to the decrease in the number of independent variables used, the restricted cohort inputs tend to decrease the accuracy of the estimates by the repgression equations, yet in many cases, reasonable estimates and qualified magnitudes of pollutional loads were obtained.

Generally, urban storm water pollution loads are determined by two factors, storm water run-off volumes and parameter concentrations. These two factors are influenced by the precipitation regimen of the locality, the natural physical characteristics of the land, and the land use pattern and intensity. The dispersed pollution flow chart shown in Figure 8.2-1, illustrates the groups of the variables which influence the pollution loads. It must be noted that no variables can influence the particular pollutant loads to the same degree for each precipitation event. Since both run-off quantity and quality are necessary for estimating the storm water pollution load, methods used in this model to predict storm run-off volumes and quality will be described.

8.2.1 Prediction of the Quantity of Storm Water Run-off

The most widely used method for estimating the storm water run-off volume is the well-known "Rational Method". In this method, the rainfall-run-off relationship can be stated by an equation in the following form:

$$Q = CIA$$

where, Q = The rate of run-off in cubic feet per second

I = Average intensity of precipitation for a duration equal to the time of flow from the most remote portion of the drainage area to the point of design

A = The area in acres tributary to the point of design

C = A complex variable having concealed within it numerous interdependent variables, such as the character of land use, the slope of the ground surface etc.

Two modified methods derived from the Rational Method are developed to estimate the volume of individual precipitation events and the average monthly or annual run-off volumes respectively. The detailed description of these methods are stated in reference (3).

Method 1

The first method which is to determine the volume of run-off of individual events can be illustrated by the following equation:

Volume = (0.5) x (Maximum Rate of Flow) x (Duration of Run-off)

The maximum rate of flow can be determined by using the Rational Method:

$$Q = CIA$$

where, Q = Flow in acre-inches per hour

C = The ratio of peak run-off to average rainfall

I = Average flow intensity in inches per hour for a duration equal to the time of concentration of the basin

A = Area in acres

The equation states that the rate of run-off equals the rate of supply (rainfall excess) if the rain lasts long enough to permit the entire area to contribute. This method presumes that the maximum flow rate occurs when the entire basin is contributing to the flow at the outlet. In order to determine the average flow intensity (I), the time of concentration (t_c) must first be obtained. Even though the rainfall rarely occurs at a uniform rate, the average intensity during t_c is assumed to be constant. It is assumed that, if uniform rainfall continues after this time of concentration, then runoff remains at some fixed percentage, C, of the rainfall rate.

If the rainfall stopped at time t_c, the run-off rate would soon begin to decrease, but the peak discharge would still be the same. The time flow relation is described by the following run-off hydrograph:

The time of concentration is calculated by a method (4) which utilizes the length (L) and slope (S) of the longest path traveled by a drop of water falling in the watershed. The formula is:

$$t_c = 0.0078\ K^{0.770}$$

where, $K = \frac{\text{L (length in feet)}}{\text{S (slope in feel foot)}}$

t_c = Time of concentration in minutes

The intensity, I, can then be determined from mass curves of rainfall obtained from an automatic recording rain gauge or from intensity-duration rainfall curves compiled for the locality. For some extended events, the average intensity for the period of maximum rainfall can be used for the storm, instead of determining different values of I for each of the intense showers within the storm.

The ratio of run-off to rainfall (the run-off coefficient) varies widely between storms in a given drainage area (5). This ratio is affected by many factors. For watersheds with definite sub-units of dissimilar land use, an average value of the run-off coefficient (C) can be computed as a composite value for the watershed:

$$A_t C = \sum_{i=1}^{i=n} C_i A_i$$

The related C_i and A_i are aggregated and divided by A_t to obtain the representative value of C for the watershed.

The rational formula has also been expressed as $Q = 0.9\ IA_s$, where A_s is the street area in the urban watershed. It is interesting to note that the two formulas give almost identical results for drainage sheds with a high percentage of impervious cover, but give values varying by a factor of three to four in outlying regions with a low percentage of imperviousness.

Method 2

This method is used to estimate the average monthly, seasonal or annual run-off volume. Impervious areas within the subject watershed are first delineated by reference to local maps and other available records.

The total area of impervious surface is then multiplied by an appropriate run-off coefficient and by local precipitation data (from the U. S. Weather Bureau's records) to determine the run-off from the impervious portion of the watershed. Run-off data for a primarily undeveloped watershed in the vicinity (from USGS records) are then used to estimate run-off volumes from the pervious areas of the drainage shed in question. The total amount of run-off is given by the sum of run-off volumes from the impervious and pervious areas.

A somewhat simplified calculation can be made if the composite run-off coefficient (C) of the watershed is already known. In this case, the run-off coefficient is multiplied by the area of the watershed (in acres) and the amount of precipitation (in inches) to determine the volume of flow (in acre-inches):

$$\text{Volume of Flow} = (C) \times (\text{Area of Watershed}) \times (\text{Amount of Precipitation})$$

18.2.2 Prediction of the Quality of Storm Water Run-off

Regression equations for predicting the quality of storm water run-off were established by correlating the measurements of surface characteristics of urban watersheds with associated measures of storm water pollutants for various test areas in Tulsa, Oklahoma. The four pollutant items being studied are total coliform, COD, total solids, and soluble orthophosphates. The variables utilized and their symbols and units are listed in Table 18.2.2-1. The regression equations developed for predicting the average concentrations of the four different pollutants are stated as follows.

TABLE 18.2.2-1

SYMBOLS AND UNITS FOR PARAMETERS UTILIZED IN REGRESSION MODELS

Symbol	Item	Units
Dependent Variables		
M_1	Total coliform[a]	thousands/100ml
M_5	COD[b]	mg/1
M_8	Soluble orthophosphate[b]	mg/1
M_9	Total solids[b]	mg/1
Y_1	Total coliform	thousands/100 ml
Y_5	COD	mg/1
Y_9	Total solids	mg/1
Independent Variables		
D_1	Area of watershed	acres
D_2	Length of main stream	ft
D_3	Length to center of area	ft
D_4	Fall of drainage area	ft
D_9	Form Factor*	dimensionless
X_1	Population	number
X_{11}	Environmental Index (EI)**	dimensionless
X_{13}	Arterial streets	acres/acre
X_{14}	Arterial streets	miles/acre
X_{15}	Other streets	acres/acre
X_{16}	Other streets	miles/acre
X_{17}	Residential density	people/ res. acre
X_{18}	Residential density	people/acre
X_{19}	Length of main covered storm sewer	miles
X_{20}	Covered sewer/total length	ratio

TABLE 18.2.2-1 Continued

Symbol	Item	Units
X_{21}	Arterial streets	%
X_{22}	Other streets	%
X_{24}	Commercial land	%
X_{25}	Industrial land	%
X_{29}	Unused space	%

a Geometric mean by events.

b Arithmetic mean by events.

* Form Factor (D_9) - An indicator of the drainage characteristics of a watershed defined by the following equation:

$$\text{Form factor} = \frac{43{,}560\ A}{(L_c)^2}$$

where, A = Area of watershed in acres

L_c = Length to center of area in feet (see definition of this term below)

The form factor itself is dimensionless.

** Environmental Index (X_{11}; EI) - An indicator of the general environmental condition of an urban watershed. The Environmental Index of a watershed is calculated by the following procedure:

It is, first of all, assumed that the environmental quality of an urban watershed is a function of three factors: the housing condition, the vacant lot condition, and the total number of environmental deficiencies (refuse, old autos, privies, and so on).

It is furthermore assumed that, in defining an equation to represent the environmental condition of a watershed, the number of deficiencies should be weighted more heavily than the housing conditions, and the housing conditions should be weighted more heavily than the vacant lot conditions. Stated in equation form:

$$EI = \frac{2A + B + 3C}{6}$$

TABLE 18.2.2-1 Continued

where, $A = \frac{\text{Total Housing Structures}}{G + 2F + 3P}$ (A = Housing Index)

Note: G = number of good houses
F = number oi fair houses
P = number of poor houses

$B = \frac{\text{Total Vacant Lots}}{G + 2F + 3P}$

Note: G = number of good vacant lots
F = number of fair vacant lots
P = number of poor vacant lots

$C = \frac{\text{Total Structures - Total Deficiencies}}{\text{Total Structures}}$

Note: Total deficiencies can be defined as the sum of refuse, burners, rubble, lumber, old autos, poor sheds, livestock, poultry, and privies.

The necessary items, including the different types of environmental deficiencies and the number of houses and vacant lots in each classification, are defined as set forth in the manual "Community Block Survey and Socioeconomic Stratification" published by the Public Health Service.

Factors A and B in the above equation may vary from a minimum of 0.33 to a maximum of 1.00; factor C may vary from a negative number to 1.00. The Environmental Index itself, when the necessary substitutions are made, may vary from a negative number of a maximum of 1.00. En EI of 1.00 denotes an area with all good houses, all good vacant lots, and no parcel deficiencies.

It should be noted that the EI calculated in this manner does not take into consideration a number of other factors which, if used, would result in a more refined indicator of the general environmental conditions of an area. Such items include: air pollution sources, population density, point sources of water pollution, parks, noise level, and traffic volume.

Coliforms

The independent variables used to develop regression equations for the concentration of total coliforms are those shown in the following functions:

$$\text{Concentration of total coliforms} = f(X_1, X_{16}, X_{17}, X_{19}, X_{20}, X_{22}, X_{24}, X_{29}, D_9)$$

The best regression equations for total coliforms together with their coefficients of correlation (R) and F values (99% significance level) are as follows:

for combined land use area:

$M_1 = 430 - 363\ (X_1) \qquad R = -0.856 \qquad F = 35.76$

for residential area:

$M_1 = 521 - 427\ (X_1) \qquad R = -0.883 \qquad F = 17.75$

for commercial and industrial area:

$M_1 = 372 - 329\ (X_1) \qquad R = -0.930 \qquad F = 25.66$

Concentration of COD

$$\text{Concentration of COD} = f(X_1, X_{14}, X_{17}, X_{19}, X_{20}, X_{21}, X_{22}, X_{24}, X_{25}, X_{29}, D_2, D_3, D_9)$$

The best regression equations for COD together with their coefficients of correlation (R) and F values are as follows:

for combined land use area:

$M_5 = 71 - 45.4\ (X_1) + 2.61\ (X_{21}) + 0.00619\ (D_2)$

$R = 0.839$

$F = 6.32$

was located further than 15 minutes travel time from an airport of less than a BU II rating, or 30 minutes travel time from an airport of at least a GU rating, a BU I airport was justified. The proper time period for airport development was determined by the population projections and degree of isolation.

The results of this analysis are shown in Figure 10, Appendix E, which depicts the recommended 1980 Oklahoma Airport System, and Figure 11 Appendix E, which shows the area coverage that this airport system will provide. The output of the model indicates that by 1980, one BT 100-60, three BU II, and twenty BU I class airportw will have to be established in the state. Also during this time, twelve BU I and one BT 100-60 class airports will require new paved runways on existing airport sites. These requirements are in addition to those of the two large metropolitan areas, Oklahoma City and Tulsa, which have their own planning agencies and projections. The airports requiring development or expansion are shown in the schedule of airport development that follows, along with the detailed requirements for each site. Airports that are adequate now and will not require improvement between 1970 and 1980 are not shown in the listing.

16.62 Recommended Priority Point System

During fiscal periods when funds are limited and the number of airports requiring development exceeds the funds available for airport development, some type of priority point system should for residential area:

$$M_5 = 69 - 74.71\ (X_1) + 3.68\ (X_{21}) + 0.0105\ (D_2)$$

$$R = 0.971$$

$$F = 16.55$$

for commercial and industrial area:

$$M_5 = 152 - 52.2\ (X_1) + 1.72\ (X_{21}) + 21.7\ (D_9)$$

$$R = 0.862$$

$$F = 2.89$$

Concentration of Total Solids

Concentration of total solids = $f\ (X_1, X_{13}, X_{14}, X_{17}, X_{19}, X_{20}, X_{21}, X_{22}, X_{24}, X_{25}, X_{29}, D_1, D_4)$

The best regression equations for total solids and their coefficients of correlation (R) and F values are as follows:

for combined land use area:

$$M_9 = 2.12 + 50.2\ (X_{29}) \qquad R = 0.733 \qquad F = 15.13$$

for residential area:

$$M_9 = -139 - 15.4\ (X_{20}) + 16.0\ (X_{22}) + 2.57\ (D_4)$$

$$R = 0.765$$

$$F = 1.41$$

for commercial and industrial area:

$$M_9 = 162 + 67\ (X_{29}) \qquad R = 0.839 \qquad F = 9.51$$

Concentration of Soluble Orthophosphates

Concentration of Soluble Orthophosphates = f $(X_1, X_{13}, X_{14}, X_{15}, X_{17}, X_{20}, X_{21}, X_{22}, X_{24}, X_{25}, X_{29}, D_4, D_9)$

The best equations for soluble orthophosphates and their coefficients of correlation (R) and F values are as follows:

for combined land use area:

$$M_8 = 0.62 + 0.08\ (X_{29}) \qquad R = 0.788 \qquad F = 21.66$$

for residential area:

$$M_8 = 0.66 - 0.0011\ (X_{21}) + 0.0645\ (X_{29})$$

$$R = 0.817$$

$$F = 4.01$$

for commercial and industrial area:

$$M_8 = 1.35 + 0.0252\ (X_{25}) + 0.0622\ (X_{29})$$

$$R = 0.882$$

$$F = 5.26$$

18.3 Validation

By the very nature of the methodology used in developing the model, the accuracy of the predicted pollutant concentrations is limited by a number of factors related to the characteristics of the individual urban areas themselves. The models, for example, are based on the estimation of dispersed, rather than localized, pollution sources. The existence of localized sources of pollutants within the watershed being studied would, of course, result in higher concentrations than would be predicted by the models.

The models, derived from the University of Oklahoma study, are based on the assumption that land use classifications are among the most important factors influencing pollutant concentrations. When the effects of a number of additional watershed characteristics were assessed in the AVCO study, it was found that drainage characteristics were often far more important than land use classifications alone. Finally, the research into the effects of climatological characteristics undertaken during the recent AVCO study has demonstrated that the effects of climate may, in turn, be more significant that either land use or drainage. In any event, storm water pollution is related to a vast number of factors, including climate, land use, environment, and drainage characteristics, as well as many other factors which have not yet been considered in full. It can be expected that future studies to identify the influence of regional differences in precipitation, temperature, geology, and other important factors on the amounts of storm water pollution will modify the models to make their application more valid in regions distant from the Tulsa area.

REFERENCES

1. AVCO Economic Systems Corporation, Storm Water Pollution from Urban Land Acitivity, U. S. Department of Interior, Federal Water Quality Administration, FWQA Publication No. 11034FKL, July 1970.

2. Cleveland, Jerry G. Evaluation of Dispersed Pollutional Loads from Urban Areas, Bureau of Water Resources Research, University of Oklahoma, Norman, Oklahoma, April 1970.

3. AVCO Economic Systems Corporation, A Multi-phasic Component Study to Predict Storm Water Pollution from Urban Areas. U. S. Department of Interior, Office of Water Resources Research, December 1970.

4. Kirpick, Z. P. "Time of Concentration of Small Agricultural Watersheds", Civil Engineering, Vol. 10, No. 6, June 1940, p. 362.

5. Horner, W. W., and Flynt, F. L. "Relation between Rainfall and Run-off from Samll Urban Areas", Transactions of the American Society of Civil Engineers, Vol. 101, 1936, p. 140.

6. Chow, Ven Te, Ed. Handbook of Applied Hydrology, New York, McGraw-Hill Book Company, 1964.

7. Viessman, Warren, Jr. "Run-off Estimation for Very Small Drainage Areas", Water Resources Research, Vol. 4, No. 1, February 1968, p. 87.

8. Betson, R. P. and Marius, J. B. "Source Areas of Storm Run-off", Water Resources Research, Vol. 5, No. 3, June 1965, p. 374.

9. Brater, E. F. "Steps Toward a Better Understanding of Urban Run-off Processes", Water Resources Research, Vol. 4, No. 2, April 1968, p. 335.

10. Forstall, Richard L. "Economic Classification of Places over 10,000, 1960-1963", in The Municipal Year Book 1967, International City Managers' Association, Chicago, 1967.

11. Forstall, Richard L. "A New Social and Economic Grouping of Cities", in The Municipal Year Book 1970, International City Management Association, Washington, D. C., 1970.

12. James River - Wilson Creek Study. U. S. Department of the Interior, Federal Water Pollution Control Administration, Robert S. Kerr Water Research Center, Ada, Oklahoma, June 1969.

13. Schneider, William J. Water Data for Metropolitan Areas, U. S. Department of the Interior, Geological Survey Water-Supply Paper 1371, Washington, D. C., 1968.

14. Dharmadhikari, Vishnu V. "Quality of Run-off from Diversified Urban Watersheds", Department of Civil Engineering and Engineering Mechanics, University of Arizona, 1970.

15. Springfield Zoning and Planning Commission. Neighborhood Analysis, Springfield, Mo., July 1968.

16. Austin, T. A., Brownlee, R. C., and Wells, D. M. "Potential Pollution from Urban Run-off", Paper presented at the 1970 Spring Meeting of the Texas Section of the American Society of Civil Engineers at Galveston, Texas, May 2, 1970.

17. Brownlee, Robert C., Austin, T. A. and Wells, D. M. "Variation of Urban Run-off with Duration and Intensity of Storms" Interim Report, Water Resources Center, Texas Tech University, Lubbock, Texas, September 1970.

18. Peavy, Howard S. Effects of Urban Land Use on Storm Water Quality in Durham, North Carolina, Department of Civil Engineering, Duke University, Durham, N. C., 1970.

19. Langbein, W. B. and Schumm, S. A. "Yield of Sediment in Relation to Mean Annual Precipitation", American Geophysical Union Transactions, Vol. 39, 1958, p. 1076.

20. Weidner, R. B., Christianson, A. G., Weibel, S. R., and Robeck, G. G. "Rural Run-off as a Factor in Stream Pollution", Journal Water Pollution Control Federation, Vol. 41, No. 3, March 1969, p.377.

21. Fuchsa, H. G., Broberb, D. E. and Liggett, F. E. "Flat Channel Terraces", Transactions of the ASAE, Vol. 9, No. 4, 1966, p. 571.

22. Mickelson, Rome H. "Level Pan Construction for Diverting and Spreading Run-off", Transactions of the ASAE, Vol. 9, No. 4, 1966, p. 568.

23. Kramer, Paul J. "Effects of Deficient Aeration on the Roots of Plants", Conference Proceedings, Drainage for Efficient Crop Production Conference, American Society of Agricultural Engineers, St. Joseph, Michigan, December 1965, p. 13.

24. Hittmann Associates. A System Study, Design, and Evaluation of the Local Storage, Treatment, and Reuse of Storm Water, Columbia, Maryland, August 1968.

25. Wolman, M. Gordon, and Schick, Asher P. "Effects of Construction on Fluvial Sediment, Urban and Suburban Areas of Maryland", Water Resources Research, Vol. 3, No. 2, April 1967, p. 451

26. Noland, Richard F. and Decarlo, Dale A. "Stream Pollution and Abatement from Combined Sewer and Overflow" in Combined Sewer Overflow Abatement Technology, U. S. Department of the Interior, Federal Water Quality Administration, FWQA Publication No. 11024, June 1970, p. 291.

27. Marske, Donald M. "Rotary Vibratory Fine Screening of Combined Sewer Overflows", in Combined Sewer Overflow Abatement Technology, U. S. Department of the Interior, Federal Water Quality Administration, FWQA Publication No. 11024, June 1970, p. 57.

28. Mason, Donald G. "The Use of Screening/Dissolved-Air Flotation for Treating Combined Sewer Overflows", in Combined Sewer Overflow Abatement Technology, U. S. Department of the Interior, Federal Water Quality Administration, FWQA Publication No. 11024, June 1970, p. 123.

29. City of Chicago. "Underflow Plan for Pollution and Flood Control", in Combined Sewer Overflow Abatement Technology, U. S. Department of the Interior, Federal Water Quality Administration, FWQA Publication No. 11024, June 1970, p. 139.

30. Keilbaugh, W. A., Glover, G. E., and Yatsuk, P. M. "Microstraining--with Ozonation or Chlorination--of Combined Sewer Overflows", Seminar on Storm and Combined Sewer Overflows, Edison Water Quality Laboratory, Edison, N. J., November 4-5, 1969.

31. American Public Works Association. Water Pollution Aspects of Urban Run-off, U. S. Department of the Interior, Federal Water Pollution Control Administration, FWPCA Publication No. WP-20-15, January 1969.

32. Haar, Charles M. "The Social Control of Urban Space", in Cities and Space: The Future Use of Urban Land, Edited by Lowden Wingo, Jr., Baltimore, The Johns Hopkins Press, 1963, p. 175.

33. Solberg, Erling D. "Old and New Principles of Zoning", in A Place to Live--The Yearbook of Agriculture 1963, Edited by Alfred Stefferud, Washington, D. C., U. S. Department of Agriculture, 1963, p. 383.

34. Talbot, Douglas W. "Capital Improvement Programs and Financing", in Urban Planning Guide, Edited by William H. Claire, New York, American Society of Civil Engineers, 1969, p. 253.

35. Whyte, W. H. The Last Landscape, New York, McGraw-Hill Book Company, 1968.

36. Saldrop, Reuel H. "Community Block Survey and Socioeconomic Stratification", U. S. Department of Health, Education, and Welfare, Public Health Service, Bureau of Disease Prevention and Environmental Control, Atlanta, Georgia.

. Burm, R. J., Krawczyk, D. R. and Harlow, G. L. "Chemical and Physical Comparison of Combined and Separate Sewer Discharges", Journal Water Pollution Control Federation, Vol. 40, No. 1, January 1968, p. 112.

. Environmental Science Services Administration. Climatological Data -- National Summary 1968, U. S. Department of Commerce, Asheville, N. C., Vol. 19. No. 13.

Geldreich, E. E., Best, L. C., Kenner, B. A. and VanDonsel, D. J. "The Bacteriological Aspects of Storm Water Pollution", Prepublication Copy, U. S. Department of Health, Education, and Welfare, National Center for Urban and Industrial Health, Cincinnati, Ohio, 1968.

40. International Business Machines Corporation. "System/360 Scientific Subroutine Package (360A-CM-03X) Version III Programmer's Manual H20-0205-3", White Plains, New York, 1968.