DIRECTORIO DE PROFESORES

DINAMICA DE SISTEMAS (FORRESTER)

DEL 11 AL 15 DE FEBRERO

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DINAMICA DE SISTEMAS (FORRESTER) 1985

DIA	HORA	TEMARIO	PROFESOR
11 de febrero	9 a 13	Enfoque de Dinámica de Sistemas Identificación del Problema	Dr. José de Jesús Acosta Flores
	15 a 19	Simulación Manual	Dr. José de Jesús Acosta Flores
12 de febrero	9 a 13	Conceptualización del Sistema Introducción a Dynamo	Dr. José de Jesús Acosta Flores
	15 a 19	Formulación del modelo	Dr. José de Jesús Acosta Flores
13 de febrero	9 a 13	Taller. Crecimiento de una urbe Crecimiento de la urbe en área finita	Dr. José de Jesús Acosta Flores
	15 a 19	Taller. Envejecimiento de los edificios para oficinas Crecimiento de la Población	Dr. José de Jesús Acosta Flores
14 de febrero	9 a 13	Taller. Población y estructuras empresariales	Mat. Mario Rodríguez Green
	15 a 19	Taller. Población y vivienda. Vivienda y empleos	Mat. Mario Rodríguez Green
15 de febrero	9 a 12	Análisis del modelo y macros	Dr. José de Jesús Acosta Flores
	12 a 13	Dynamo III	M. en I. Jorge Silva Midences
	15 a 17	Planeación del Desarrollo Regional Istmo de Tehuantepec	
	17 a 19	Modelo para la Planeación de la Política Petrolera en México	M. en C. Luis Mario León Estrada

'pmc.

EVALUACION DE LA ENSEÑANZA

SU EVALUACION SINCERA NOS AYUDARA A MEJORAR LOS PROGRAMAS POSTERIORES QUE DISEÑAREMOS PARA USTED.

TEMA	ORGANIZACION Y DESARROLLO DEL TEMA	GRADO DE PROFUNDIDAD LOGRADO EN EL TEMA	GRADO DE ACTUALIZACION LOGRADO EN EL TEMA	UTILIDAD PRACTICA DEL TEMA	
ENFOQUE DE DINAMICA DE SISTEMAS. IDENTIFICACION DEL PROBLEMA					
SIMULACION MANUAL					
CONCEPTUALIZACION DEL SISTEMA. INTRODUCCION A DYNAMO					
FORMULACION DEL MODELO					
TALLER :Crecimiento de una urbe					
TALLER: Envejecimiento de los edifi.					
TALLER:Población y estructuras ...					
TALLER: Población y vivienda.Viviend..					
ANALISIS DEL MODELO Y MACROS.					
DYNAMO III					

ESCALA DE EVALUACION: 1 a 10

EVALUACION DEL CURSO

CONCEPTO		EVALUACION
1.	APLICACION INMEDIATA DE LOS CONCEPTOS EXPUESTOS	
2.	CLARIDAD CON QUE SE EXPUSIERON LOS TEMAS	
3.	GRADO DE ACTUALIZACION LOGRADO CON EL CURSO	
4.	CUMPLIMIENTO DE LOS OBJETIVOS DEL CURSO	
5.	CONTINUIDAD EN LOS TEMAS DEL CURSO	
6.	CALIDAD DE LAS NOTAS DEL CURSO	
7.	GRADO DE MOTIVACION LOGRADO CON EL CURSO	

ESCALA DE EVALUACION DE 1 A 10

1. ¿Qué le pareció el ambiente en la División de Educación Continua?

MUY AGRADABLE	AGRADABLE	DESAGRADABLE

2. Medio de comunicación por el que se enteró del curso:

PERIODICO EXCELSIOR ANUNCIO TITULADO DIVISION DE EDUCACION CONTINUA	PERIODICO NOVEDADES ANUNCIO TITULADO DIVISION DE EDUCACION CONTINUA	FOLLETO DEL CURSO

CARTEL MENSUAL	RADIO UNIVERSIDAD	COMUNICACION CARTA, TELEFONO, VERBAL, ETC.

REVISTAS TECNICAS	FOLLETO ANUAL	CARTELERA UNAM "LOS UNIVERSITARIOS HOY"	GACETA UNAM

3. Medio de transporte utilizado para venir al Palacio de Minería:

AUTOMOVIL PARTICULAR	METRO	OTRO MEDIO

4. ¿Qué cambios haría usted en el programa para tratar de perfeccionar el curso? __________

____

____

5. ¿Recomendaría el curso a otras personas?

SI	NO

6. ¿Qué cursos le gustaría que ofreciera la División de Educación Continua?

____

____

7. La coordinación académica fue:

EXCELENTE	BUENA	REGULAR	MALA

8. Si está interesado en tomar algún curso <u>intensivo</u> ¿Cuál es el horario más conveniente para usted?

LUNES A VIERNES DE 9 A 13 H. Y DE 14 A 18 H. (CON COMIDAS)	LUNES A VIERNES DE 17 A 21 H.	LUNES, MIERCOLES Y VIERNES DE 18 A 21 H.	MARTES Y JUEVES DE 18 A 21 H.

VIERNES DE 17 A 21 H. SABADOS DE 9 A 14 H.	VIERNES DE 17 A 21 H. SABADOS DE 9 A 13 Y DE 14 a 18 H.	O T R O

9. ¿Qué servicios adicionales desearía que tuviese la División de Educación Continua, para los asistentes? _______________________

____

10. Otras sugerencias:

____

____

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DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

DINAMICA DE SISTEMAS (FORRESTER)

ENFOQUE DEL PROBLEMA

IDENTIFICACION DEL PROBLEMA Y CONCEPTUALIZACION DEL SISTEMA

DR. JOSE DE JESUS ACOSTA FLORES

FEBRERO, 1985

Palacio de Minería Calle de Tacuba 5 primer piso Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

ENFOQUE DE SISTEMAS.-

1.1 Problemas y sistemas de retroalimentación.

La parte central de un estudio de Dinámica de Sistemas no es un sistema, sino un problema. Los problemas tratados desde la perspectiva de Dinámica de Sistemas tienen al menos dos rasgos en común: son dinámicos y surgen en sistemas de retroalimentación.

Un problema es dinámico si involucra cantidades que cambian en el tiempo. A continuación se analizan con todo detalle los sistemas de retroalimentación.

La retroalimentación es la transmisión y regreso de la información. Por ejemplo, un sistema de calefacción produce calor en una habitación. Un termostato conectado al sistema, regresa información sobre la temperatura del cuarto al sistema, encendiéndolo o apagándolo y por tanto, controlando esta temperatura. Juntos el termostato y el sistema de calefacción forman un sistema de retroalimentación.

Un circuito de retroalimentación es una sucesión cerrada de causas y efectos, una ruta cerrada de acciones e información. Por ejemplo, un sistema de control de inventarios. Los envíos bajan el inventario, cayendo a algún nivel deseado, alguien en el almacén coloca pedidos que producen la subida del inventario. La información (el inventario actual) se transmite (al departamento de pedidos y después a los productores) y eventualmente regresa (en la forma de artículos que se reciben en el almacén).Ver la figura No. 1.1.

Un sistema de retroalimentación es un conjunto interconectado de circuitos de retroalimentación.

Tradicionalmente, cuando se descubre un problema, se reflexiona sobre él, se desarrolla un plan y se actúa acorde con el plan. Usualmente se olvida el hecho que nuestra acción altera el estado del sistema, como se sugiere por la linea punteada en la figura 1.2, dando como resultado una nueva comprensión del problema o quizá un conjunto nuevo de problemas que deben atacarse. Considere por ejemplo el problema de administrar un área pública para recreación como un parque natural, un lago, o una montaña para escalar. Mientras más y más personas descubren las delicias de acampar y caminar en tales áreas, la administración tiene un dilema: cómo proteger y preservar el carácter y belleza natural de un área y al mismo tiempo hacerla disponible al público para que la goce. Alguien puede ver la situación como en la figura No. 1.3. Esta visión carece de la perspectiva de retroalimentación, sugiere que una política razonable para minimizar el daño ambiental y preservar la calidad de las experiencias de los visitantes es tratar de aumentar el área de contacto y los servicios porporcionados por el parque. Animar la utilización de veredas poco usadas, hacer más veredas, construir más áreas para acampar con baño e instalaciones para recolectar basura, proveer instalaciones educativas como centros apoyados por guardabosques experimentados.

Aunque algunas de tales políticas pueden ser necesarias y deseables, la perspectiva que las generó es inadecuada. Se han ignorado los efectos de retroalimentación. Por ejemplo, el valor de la experiencia vivida tendrá un efecto obvio sobre el número de visitantes, como se muestra en la figura No. 1.4. La conclusión de aumentar servicios ya no es tan clara. Un aumento en los servicios eleva el valor de la experiencia, lo que incrementa los visitantes por año, acrecentando el amontonamiento que amplía el daño ambiental y disminuye el valor de la experiencia vivida. Las implicaciones a largo plazo de la política de ampliar servicios ya no son tan evidentes como lo fueron en la figura 1.3

1.2 El comportamiento de sistemas de retroalimentación.

Los circuitos de retroalimentación se dividen en dos categorías: los positivos y los negativos. Los negativos están buscando una meta y tratan de negar cualquier desviación de ella. Se muestran tres ejemplos en la figura 1.5. Los positivos amplifican las desviaciones produciendo el crecimiento. Se presentan tres ejemplos en la figura 1.6.

La distinción entre los circuitos de retroalimentación positivos y negativos se captura en la historia del cobertor eléctrico mal conectado de la figura 1.7.

Los problemas reales están formados por circuitos positivos y negativos acoplados; sin embargo, se ha observado que se responde a estos problemas como si fueran sistemas negativos de retroalimentación muy simplificados. Algunos ejemplos son:

Problema	Respuesta
Cosechas dañadas por plaga de insectos	regar con insecticida
Congestionamiento en el tráfico	construir más carreteras
Crimen	Contratar policías
Aumento en los costos	Fijar los précios

Los problemas reales a menudo son tan complicados que comprender su comportamiento y predecir las respuestas a diversas políticas es imposible sin un modelo formal. Dinámica de Sistemas procura proveer la comprensión de sistemas complicados de retroalimentación a fin de diseñar políticas que funcionen para mejorar el comportamiento del sistema.

1.3 Enfoque de Dinámica de Sistemas

Se parte de que el "comportamiento dinámico es una consecuencia de las estructuras de retroalimentación del sistema" y por tanto se buscan dentro de él las causas de su comportamiento porblema y no se piensa que sean agentes externos los responsables.

En la figura 1:8 se presentan las etapas para atacar un problema desde esta perspectiva, comenzando y terminando con la comprensión de un sistema y sus problemas. Cada una de estas etapas se verá con mayor detalle en las sesiones siguientes.

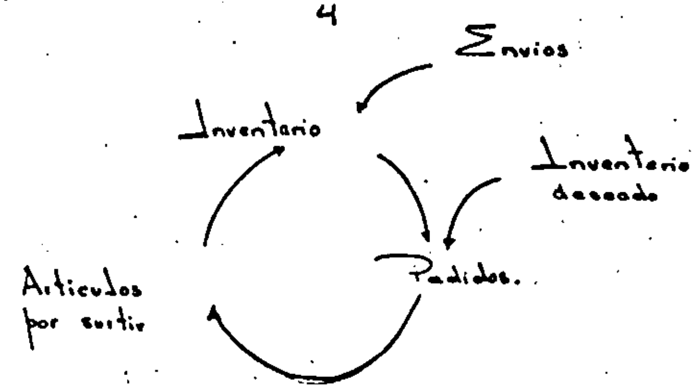


figura Nº 1.1.

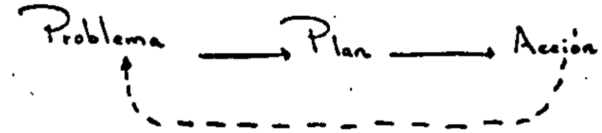


figura Nº 1.2

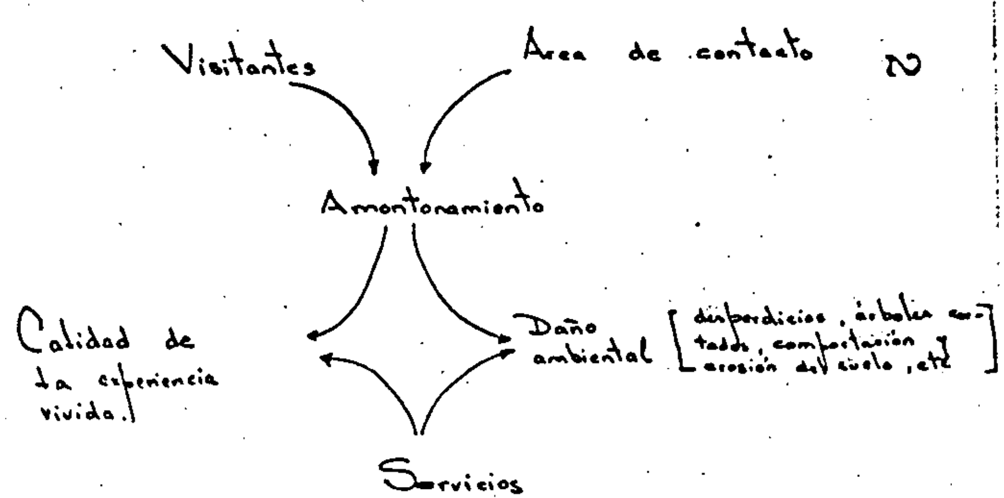


Figura Nº 1.3

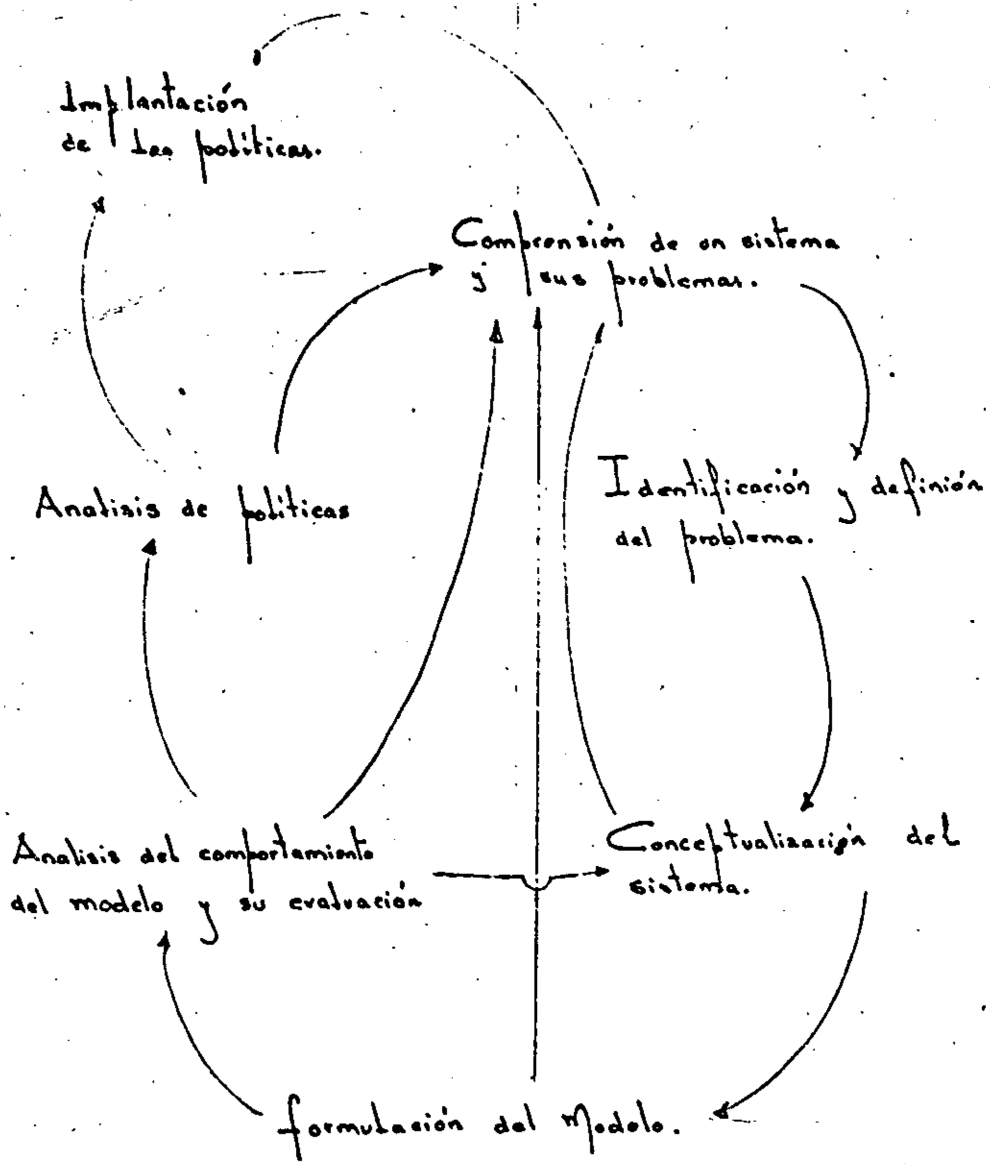


figura Nº 1.8

Identificación del problema y conceptualización del sistema.

La identificación del problema y la conceptualización del modelo son las etapas aparentemente menos técnicas de un estudio de Dinámica de Sistemas. Dentro de estas etapas el modelador desarrolla una explicación del contexto y síntomas de un problema, grafica los modos de comportamiento de referencia, articula los propósitos del modelo, establece una frontera del sistema y desarrolla una visión de la estructura del sistema en términos de circuitos de retroalimentación de acción e información. La figura 2.1 resume cómo se ajustan estas etapas, así como las etapas cuantitativas posteriores del proceso de modelado.

A continuación se explica en qué consisten la identificación del problema y la conceptualización del modelo presentándose al final un ejemplo.

2.1. Definición del problema.

La identificación del problema incluye su conocimiento así como su definición sin ambiguedad. Establece verbalmente el contexto y los síntomas del problema. Define dinámicamente al problema en función de sus modos de comportamiento de referencia. Puede haber tres conjuntos de modos de referencia: gráficas que muestran el comportamiento del problema, comportamiento deseable y comportamiento observado.

El contenido del modelo se ve influenciado por el problema que se va a analizar, la audiencia para los resultados del estudio, las políticas con las que uno desea experimentar y la implementación deseada.

2.2. Conceptualización del modelo.

Una explicación clara del propósito del modelo contribuye tanto a la definición del problema como a la conceptualización del modelo.

Para un propósito dado, se deberá definir la frontera. La frontera es la línea imaginaria que separa lo que se considera dentro del sistema y lo que se considera fuera. Abarca el número más pequeño de componentes que es necesario para generar el comportamiento de interés del sistema.

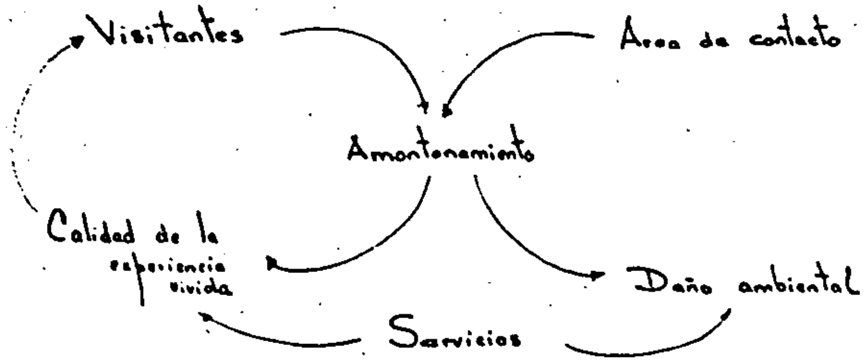
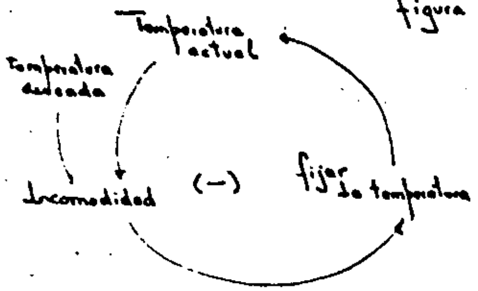
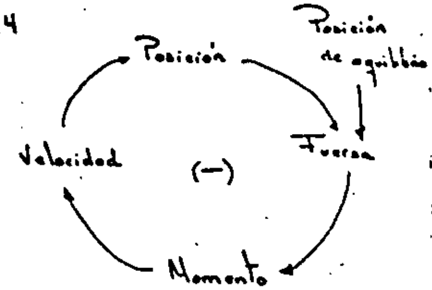


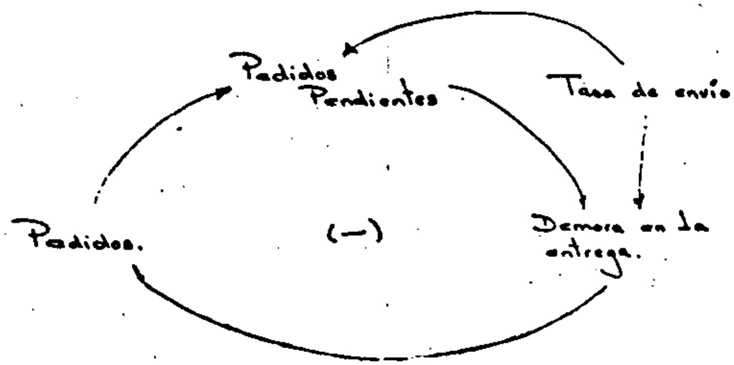
figura Nº 1.4



A.- Cobertor eléctrico

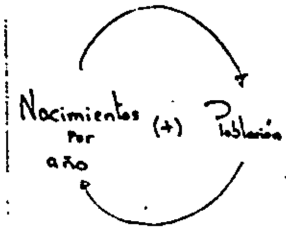


B.- Péndulo

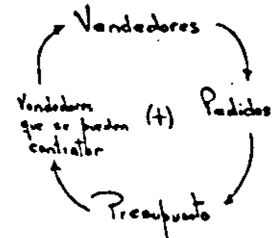


C.- Demora en la entrega de un producto.-

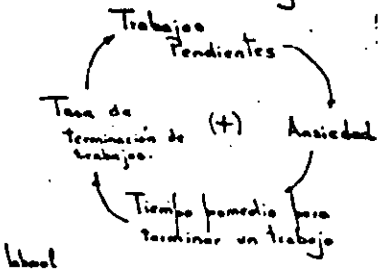
figura No 1.5



A.- Crecimiento de la población

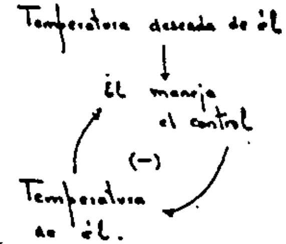


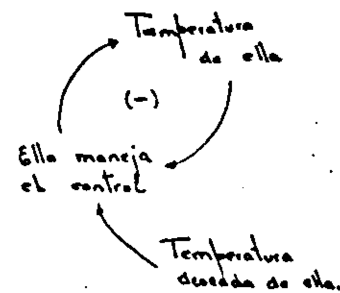
B.- Crecimiento en la fuerza laboral



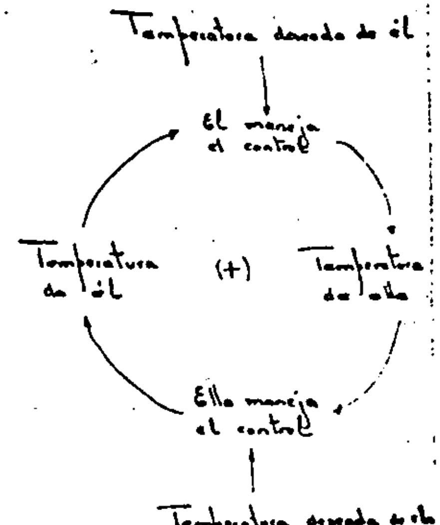
C.- Sobrecarga de trabajo.-

figura Nº 1.6.





A.- Conexión adecuada



B.- Conexión errónea.-

figura Nº 1.7.

La conceptualización del modelo comienza construyendo éste en áreas funcionales, sectores y piezas simples. Primero se desarrolla la estructura física del sistema, después los flujos de información, seguidos por percepciones y finalmente se enfoca sobre las presiones que surgen de las percepciones que influencian los cambios del sistema.

Buscando la estructura de retroalimentación, el modelador trata de obtener las cadenas de causas y efectos hasta que forman circuitos. La expresión más simple de un circuito es en la forma de un diagrama. En Dinámica de Sistemas son comunes dos clases de diagramas: los causales y los de tasa/nivel.

En los causales se define:

$$A \xrightarrow{+} B$$

Una liga causal de A a B es positiva 1) si un cambio en A produce un cambio en B en la misma dirección ó 2) si A le suma algo a B.

Por ejemplo en la figura 2.2. existe una relación directa entre la diferencia y la decisión de servir, luego se trata de una liga causal positiva.- Al servir se le suma al nivel del vino. Esta no es una relación porporcional ya que al disminuir la tasa, el nivel del vino no disminuye (a menos que alguien se lo beba) sino que simplemente aumenta con menor rapidez. También es una liga causal positiva.

$$A \xrightarrow{-} B$$

Una liga causal de A a B es negativa si 1) un cambio en A produce un cambio en B en la dirección opuesta ó 2) A le resta algo a B.

Un circuito de retroalimentación es positivo si contiene un número par de ligas causales negativas (figura 2.3).

Un circuito de retroalimentación es negativo si contiene un número non de ligas causales negativas.

Los diagramas de tasas y niveles muestran las variables donde se presentan acumulaciones, por ejemplo, el vino se acumula en una copa cuando se vierte en ella. Las figuras 2.4, 2.5 y 2.6 exhiben tres ejemplos.

2.3. Un ejemplo de definición y conceptualización del problema.

Un problema común en los proyectos son los desbordamientos: exceso de costo, la necesidad de contratar y entrenar personal adicional en medio del proyecto, e ir más alla del tiempo programado.

Para la definición del problema se presentan los modos de referencia de comportamiento en las gráficas de las figuras 2.7, 2.8 y 2.9.

En la figura 2.7 se presenta el comportamiento deseado, en la 2.8 los desbordamientos en personal y tiempo programado y en la 2.9 el progreso actual y el percibido.

Propósito del modelo. Vamos a suponer que nuestros clientes son los responsables de la administración de proyectos grandes y que desean alguna guía para prevenir o minimizar los desbordes. El modelo deberá ser una herramienta que permita a nuestros clientes experimentar con políticas para mejorar la administración de los proyectos.

Frontera del sistema. El propósito del modelo indica que éste deberá enfocar sobre los aspectos que potencialmente están dentro del control de las personas en el proyecto, por ejemplo:

- definición del proyecto (actividades que se van a ejecutar)
- personal.
- productividad.
- tiempo extra
- avances
- correcciones
- percepción de horas-hombres requeridas
- programa
- alteraciones en el programa
- costos
- estructura de retroalimentación.

En las figuras 2.10 a 2.17 se muestra el desarrollo de esta estructura.

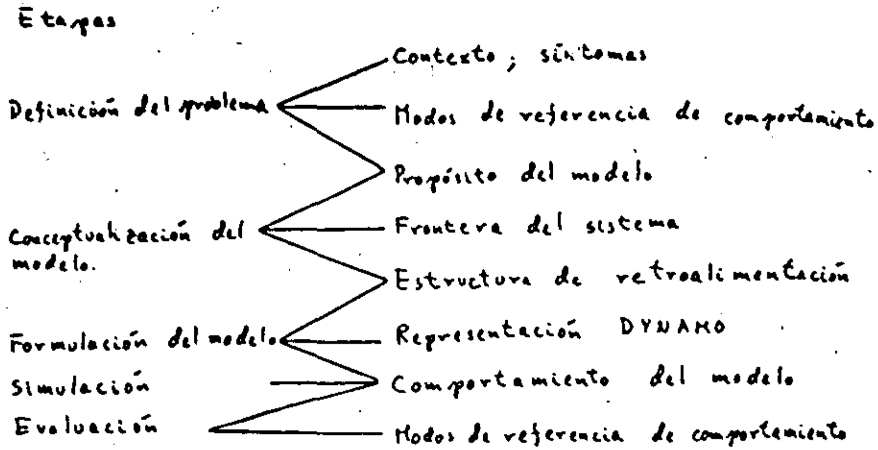


Figura 2.1: Etapas en el proceso de modelado en Dinámica de sistemas.

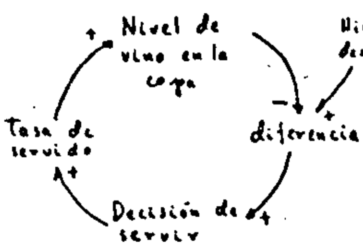


Figura 2.2

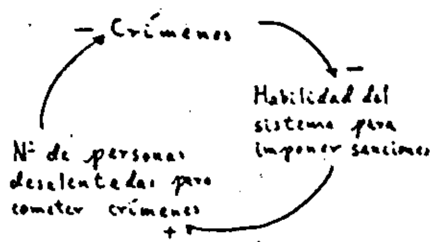


Figura 2.3

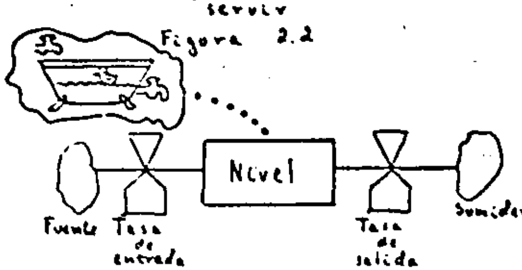


Figura 2.4

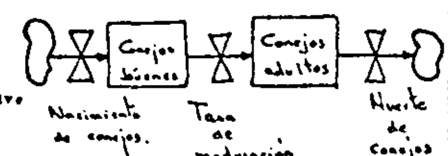


figura 2.5

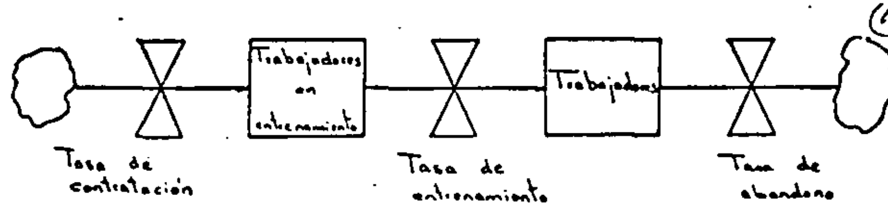


figura 2.6

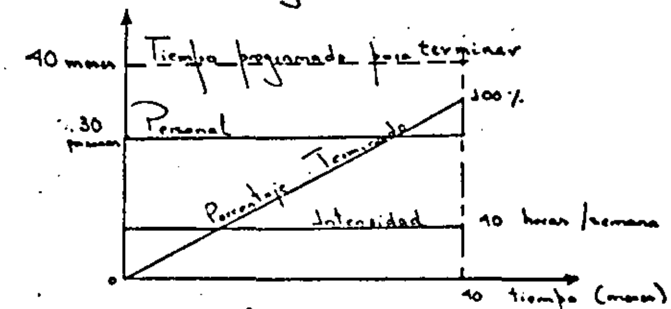


figura 2.7

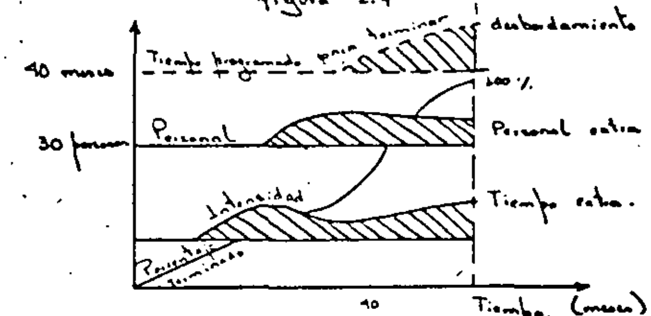


figura 2.8

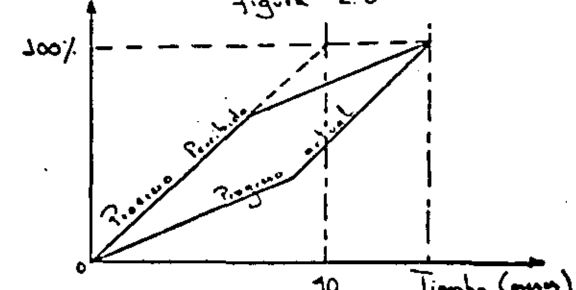


figura 2.9

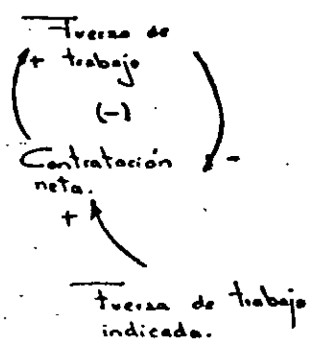


Figura 2.10

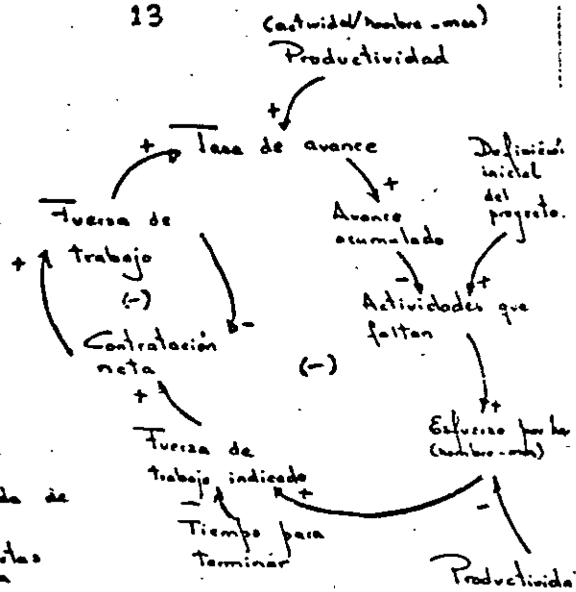


figura 2.11.

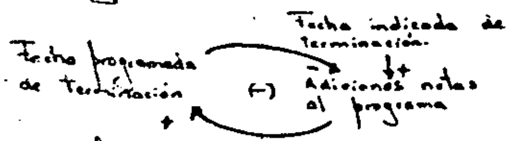


figura 2.12

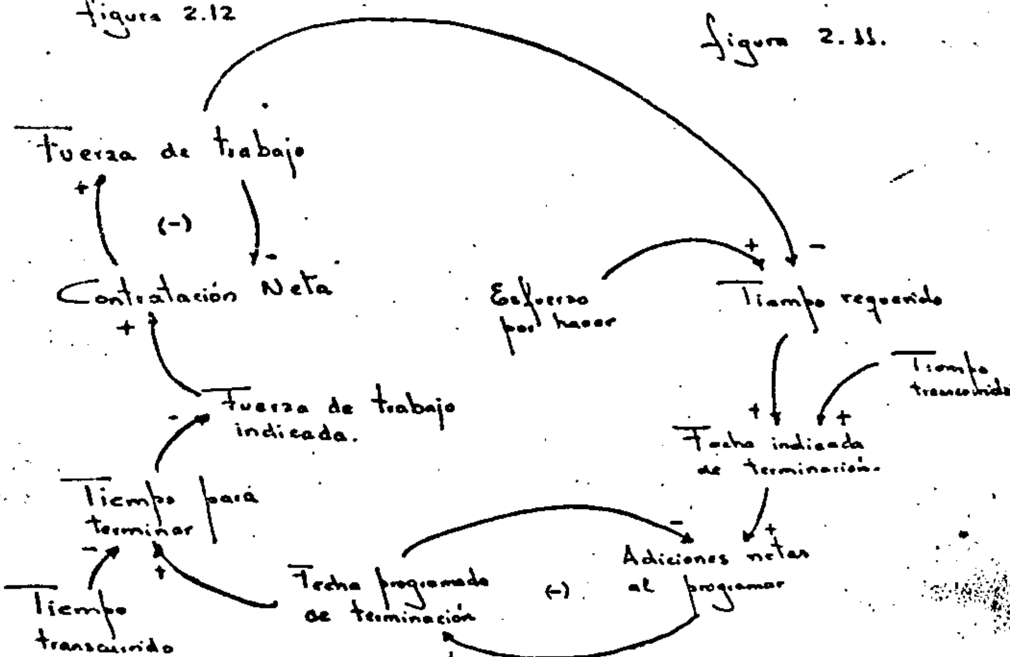


Figura 2.13.

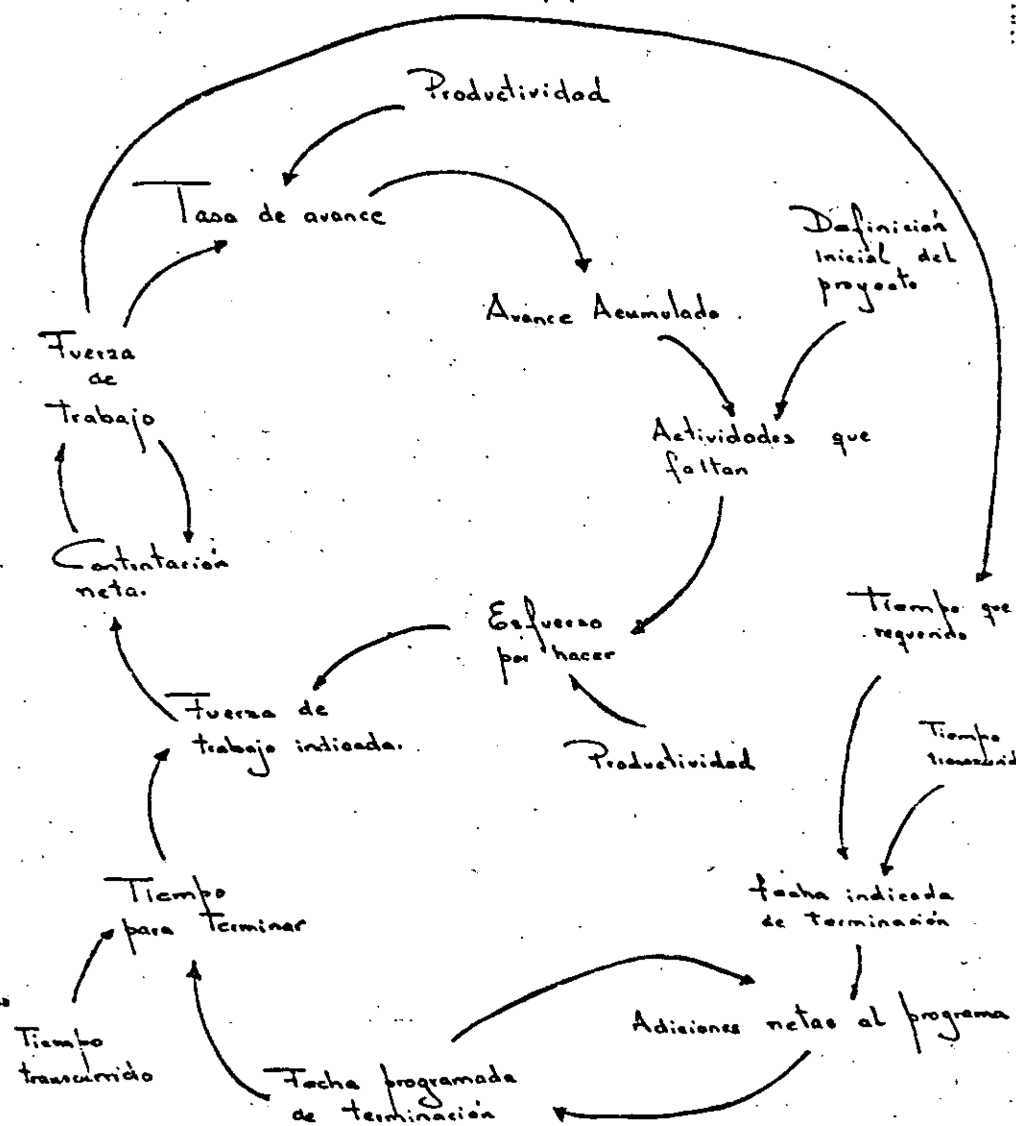


figura 2.14.

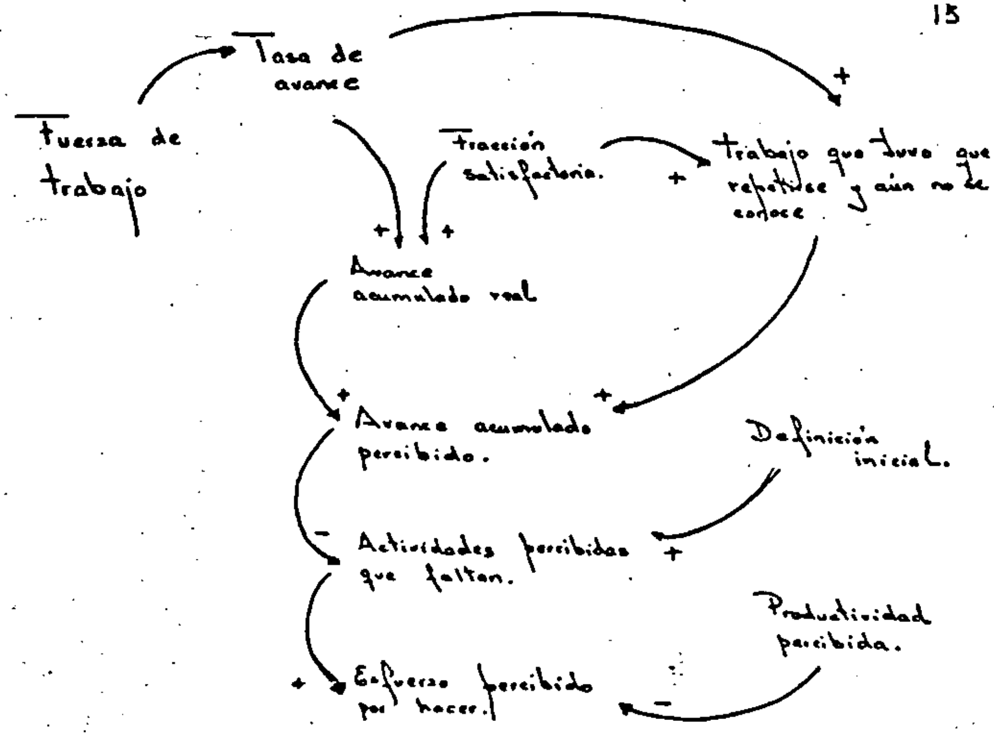


figura 2.15

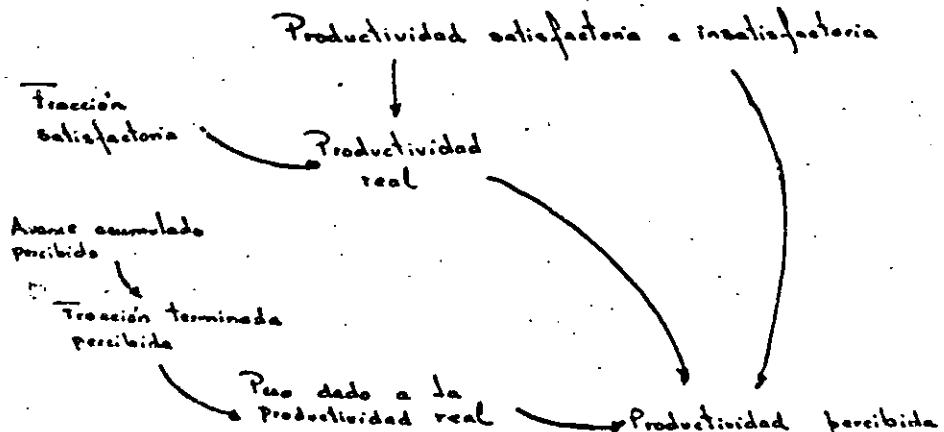


Figura 2.16

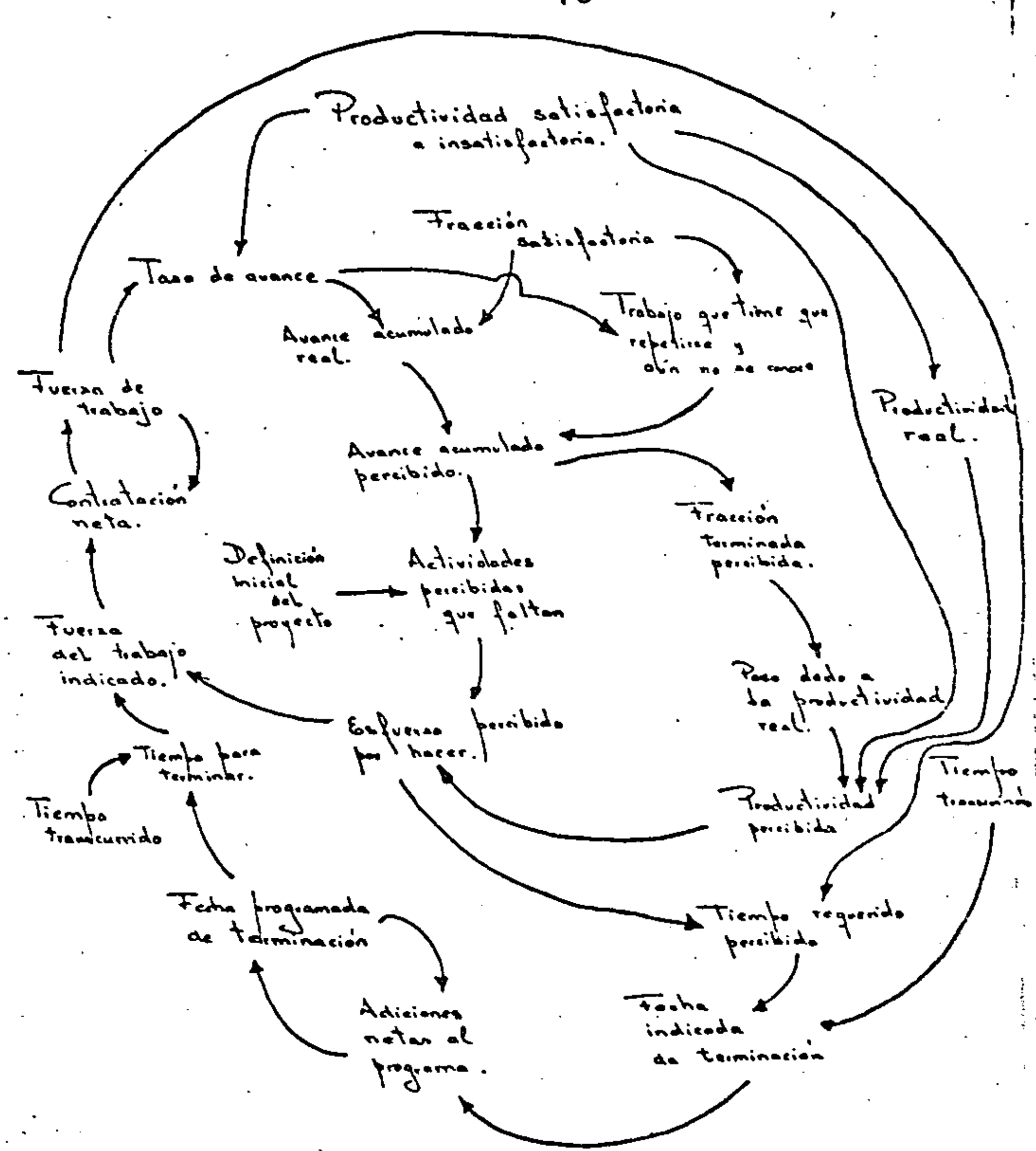


figura Nº 2.17.

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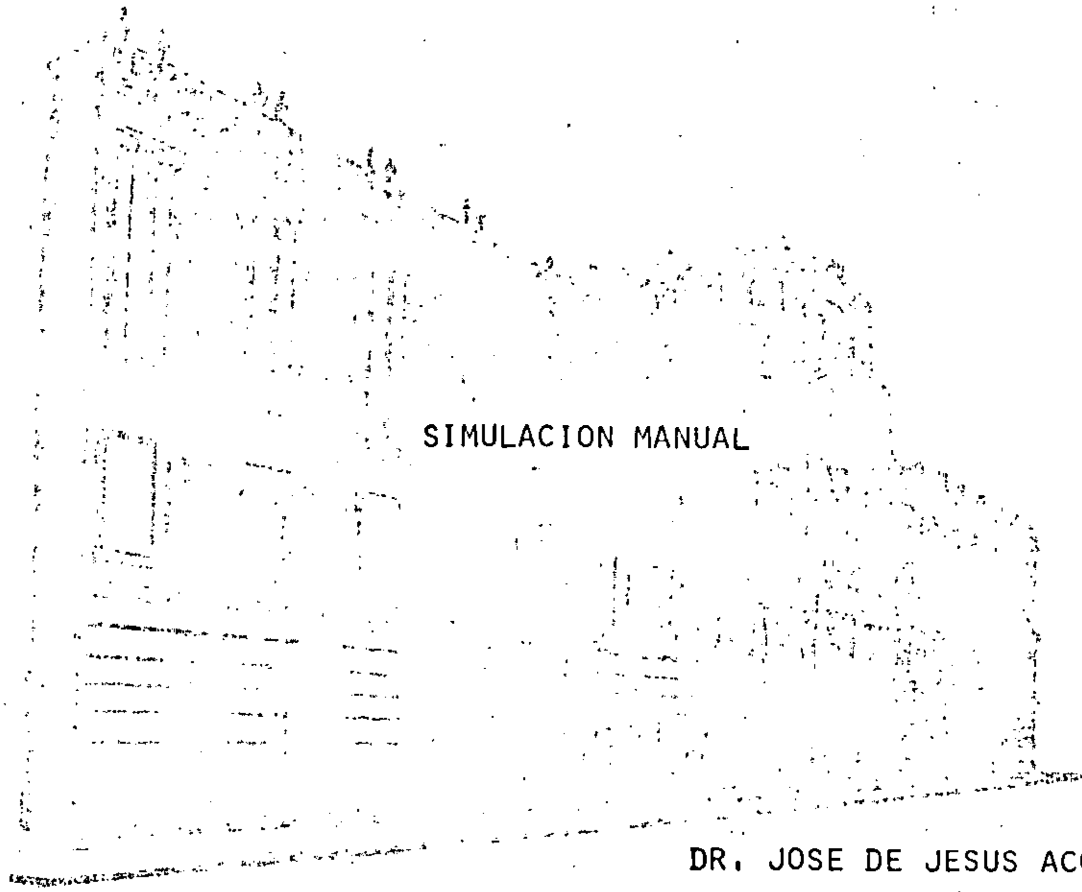
DINAMICA DE SISTEMAS (FORRESTER)



SIMULACION MANUAL

DR. JOSE DE JESUS ACOSTA FLORES

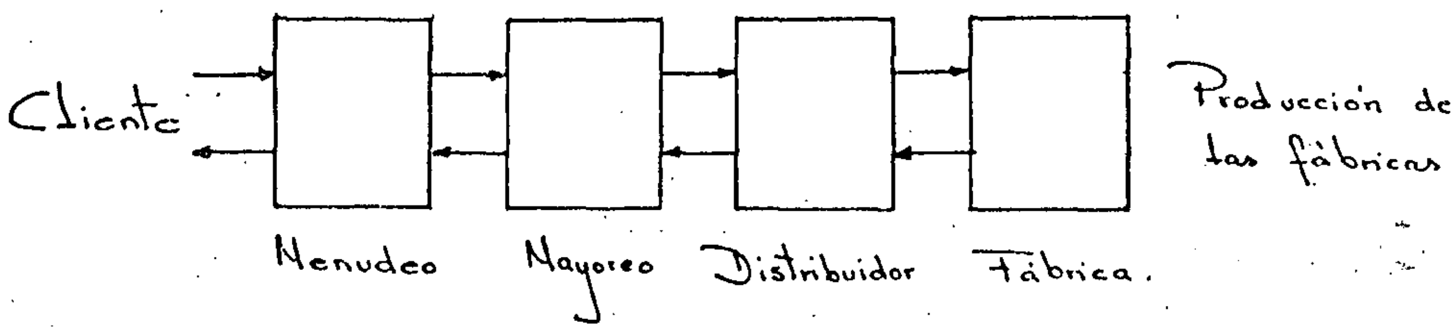
FEBRERO, 1985

Palacio de Minería . Calle de Tacuba 5 primer piso . Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

SIMULACION MANUAL DE JAY W. FORRESTER.

DISTRIBUCION DEL SISTEMA

-Un problema normal que encaran los empresarios es el de control de inventarios. El mantenimiento de un inventario estable se complica a menudo por inventarios múltiples involucrando fábricas, distribuidores, mayoreo y menudeo y por demora en la transmisión de bienes y pedidos. Los pedidos proceden del cliente al través de todos los sectores serialmente a la fábrica y los bienes fluyen de la fábrica serialmente al través de todos los inventarios al cliente.



Para examinar los problemas inherentes en este sistema de producción-distribución se simulará manualmente y posteriormente puede hacerse en una computadora. Primero se desarrolló un modelo de simulación humano para reproducir la estructura del sistema. Cada persona en esta simulación representará el papel de un decisor de sector. Su trabajo será satisfacer pedidos del sector a su izquierda y colocar órdenes solicitando bienes del sector a su derecha.

Las decisiones para ordenar artículos se hacen una vez a la semana. Todos los sectores en el sistema son idénticos excepto por el tiempo que se requiere para recibir artículos del siguiente sector después que se ha hecho un pedido. Menudeo, mayoreo, y el distribuidor reciben sus bienes dos semanas después de colocar sus pedidos, a menos, por supuesto, que el siguiente sector no tenga suficiente inventario para satisfacer la cantidad de artículos que está demandando. El almacén de la fábrica debe esperar tres semanas para que se elaboren los artículos cuya producción ordena (la fábrica tiene un abastecimiento infinito de materias primas). Las órdenes del cliente están predeterminadas. Las órdenes que se reciben en los otros sectores son las que se colocaron un período antes por el sector a la izquierda.

Cada persona en la simulación puede usar cualquier esquema para ordenar que considere necesario para evitar las situaciones sin artículos almacenados. Sin embargo, no tiene otra alternativa, más que satisfacer todos los pedidos siempre que exista un inventario adecuado. Para duplicar las condiciones del mundo real se supone que todos los pedidos se demoran una semana en el correo y todos los bienes tienen también una demora de una semana en el transporte.

Para ilustrar la operación del sistema y las reglas de competencia considere las acciones del distribuidor. El distribuidor recibe pedidos del mayorista después de una demora de una semana en el correo y envía las unidades que se le requirieron inmediatamente, siempre y cuando tenga la cantidad suficiente de bienes. El material se recibe un período después por el mayorista. Cuando no existen suficientes unidades disponibles, la parte del pedido que no satisface va a englosar el concepto de pedidos no satisfechos y se enviarán cuando se tengan unidades adicionales del almacén de la fábrica. El distribuidor hace sus pedidos al almacén de la fábrica una vez a la semana para mantener su propio inventario. Existen dos costos asociados con cada inventario, los de tener artículos y los de no tenerlos. Siempre que se tiene una unidad en inventario uno deja de ganar intereses sobre el dinero invertido; estos costos se tomarán como un peso por unidad por período. Siempre que la demanda no pueda satisfacerse inmediatamente existen costos asociados con la insatisfacción de quien hizo el pedido (cliente, menudeo, mayoreo o distribuidor.) Para propósito de competencia se tomaron estos costos como dos pesos por unidad por período. Para minimizar los costos totales cada sector en el sistema de distribución intenta mantener su inventario en el nivel más bajo que sea suficiente para satisfacer cambios inesperados en la demanda. Si el inventario comienza a estar bajo de este nivel deseado se ordenarán unidades extra. Cuando el inventario empieza a acumular debido a una escasez momentánea en la demanda, los pedidos disminuirán. La acumulación de costos es una forma conveniente de medir el éxito o fracaso de los esquemas del control de inventarios por lo que se calcularán para ver cuál equipo de los cuatro decisores fué capaz de satisfacer la demanda del cliente con el costo total más bajo.

1.- Durante la simulación se transmitirán los pedidos en hojas de papel. No comunique sus pedidos a ningún otro sector en ninguna otra forma.

2.- Lo pedidos del cliente se revelarán al sector de menudeo una vez por semana.

3.- Cada sector comienza con un inventario de doce artículos.

4.- Durante cada período de la simulación se seguirán los pasos siguientes. Una persona, el supervisor de simulación describirá cada paso totalmente en las primeras iteraciones. Después será suficiente con mencionar únicamente la letra correspondiente a cada operación.

A) Satisfaga del inventario cualquier orden que tenga, colocando el número requerido de unidades para transportarse al sector que está a su izquierda. Si no se van a transportar en unidades, coloque un papel con una notación de cero. Si la orden pudo cumplirse totalmente destrúyala, si no, réstele las unidades enviadas de las unidades requeridas, y déjela.

B) Registre su inventario y unidades no surtidas.

C) Llegan las unidades por el transportista.

D) Decida cuántas unidades desea ordenar y coloque su pedido en el correo.

E) Registre el número de unidades que pidió.

F) Llega el correo, la simulación de las actividades de la semana ha terminado y la secuencia comienza de nuevo.

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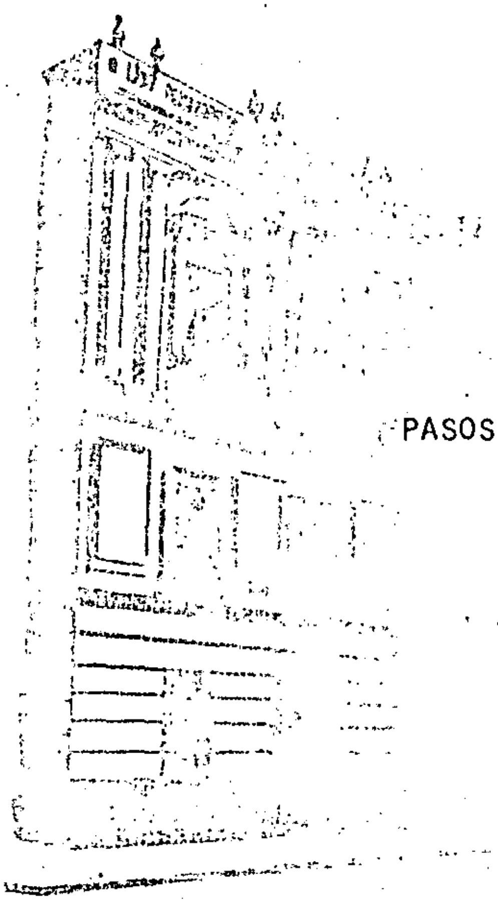
DINAMICA DE SISTEMAS (FORRESTER)



PASOS DE LA SIMULACION MANUAL

DR. JOSE DE JESUS ACOSTA FLORES

FEBRERO, 1985

Palacio de Minería Calle de Tacuba 5 primer piso Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

PASOS DE LA SIMULACION MANUAL

1. Satisfaga del inventario cualquier orden no satisfecha de los pedidos por surtir colocando el total de unidades requeridas en el lado derecho del cuadro de retraso en la entrega en el sector a su izquierda. Si se envian cero unidades coloque un pedazo de papel en lugar de las unidades. Si la orden fué cumpletamente satisfecha, remueva de los pedidos por surtir y descártela. Si no fue completamente descartada, reste el número de unidades enviadas de el número de unidades requeridas y deje la orden en el registro de pedidos.

2. Registre su inventario efectivo en la hoja correspondiente. El inventario efectivo es igual al inventario actual menos los pedidos por surtir, y puede ser positivo o negativo (El inventario efectivo negativo indica "sin existencias").

3. Avance las unidades de la parte izquierda del retraso en la entrega a sus inventarios.

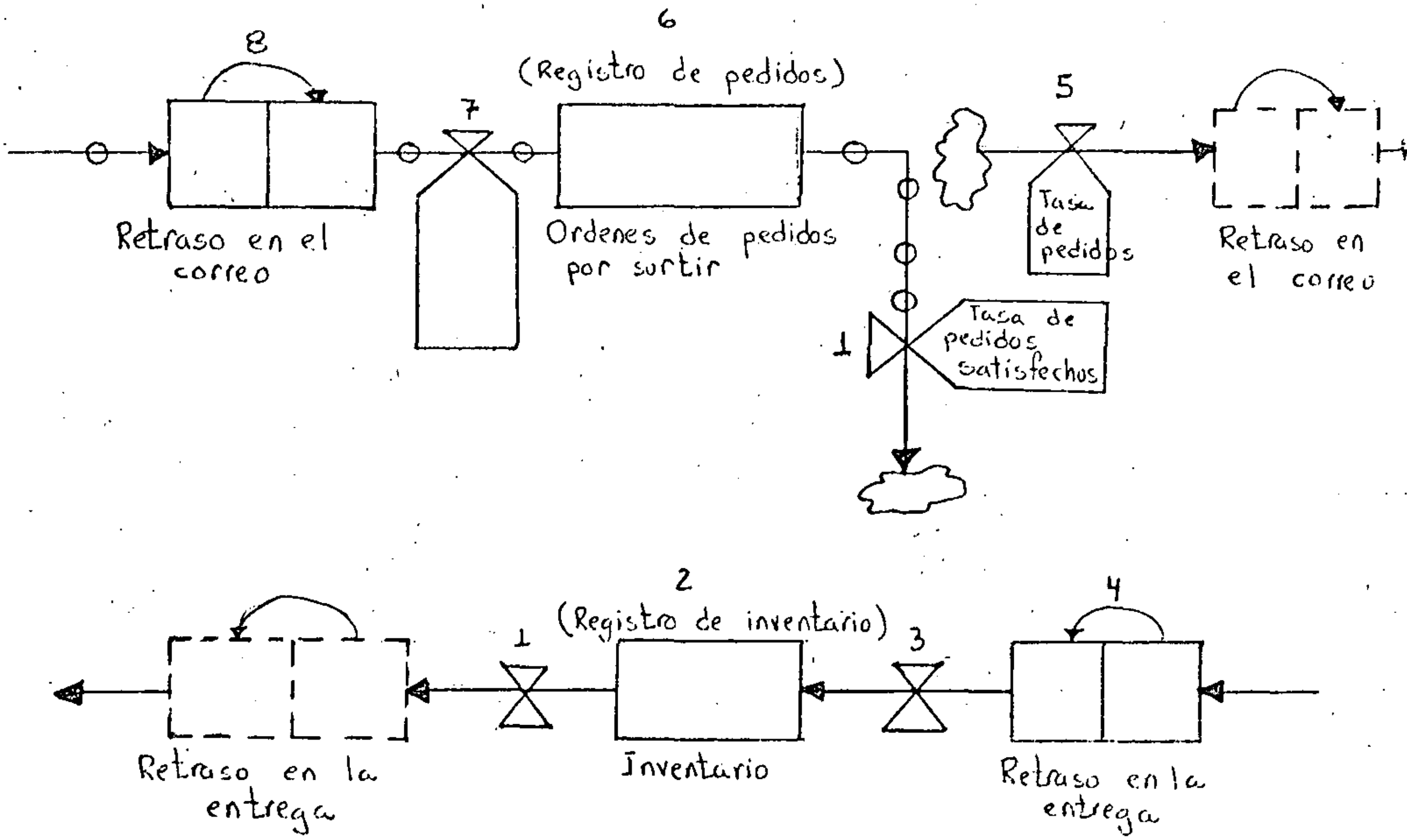
4. Avance las unidades de la parte derecha del retraso en la entrega a la izquierda. (las fábricas también avanzan los bienes en la zona de Bienes en Proceso).

5. Decida cuantas unidades desea ordenar, y coloque su pedido en la parte izquierda del cuadro retraso en el correo de su abastecedor en el sector a su derecha.

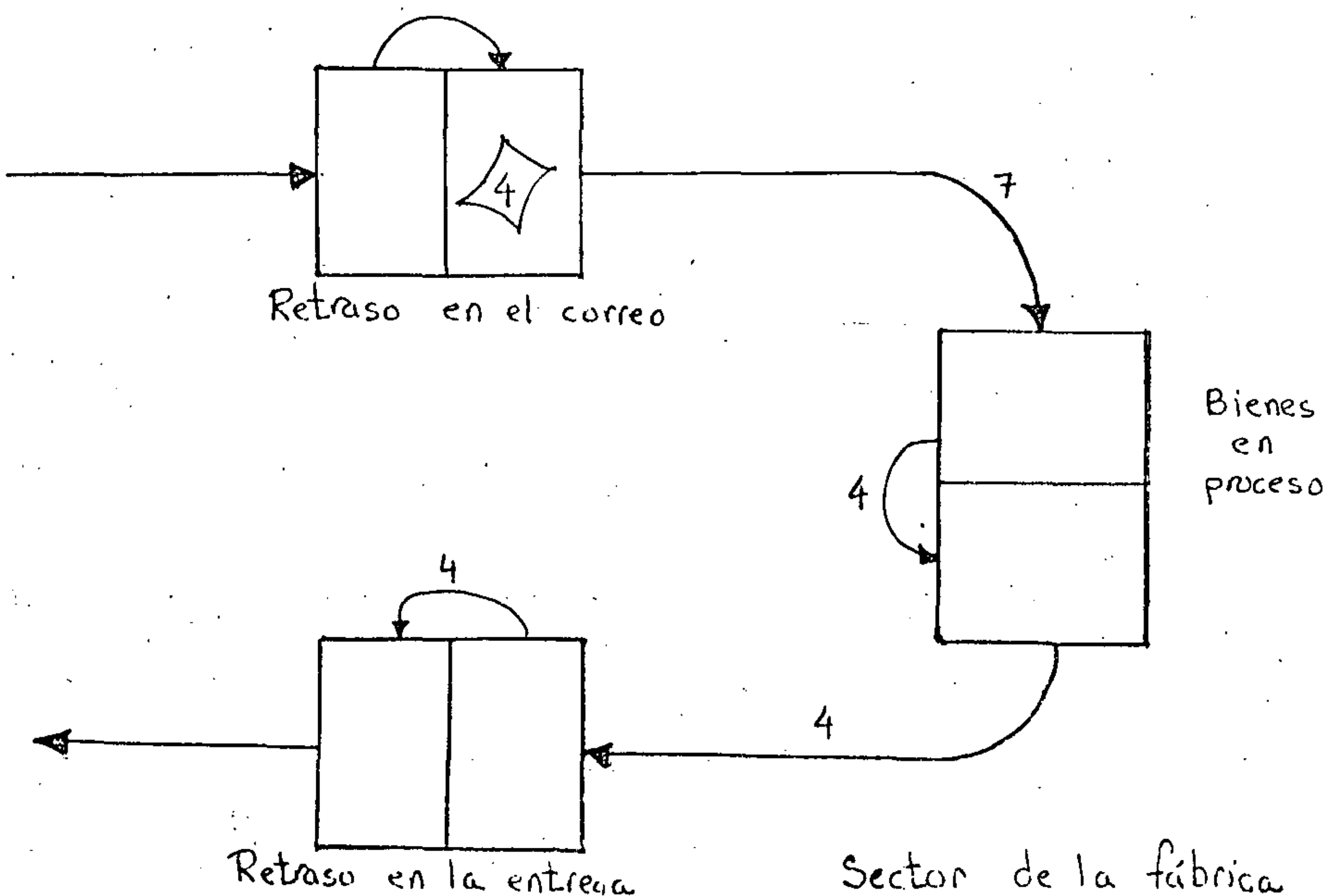
6. Registre en la hoja correspondiente el número de unidades que solicitó.

7. Tome la orden de la parte derecha del cuadro retraso en el correo y coloquela en el cuadro de pedidos por surtir. (los minoristas toman del orden del "cúmulo de órdenes"; Las fábricas remueven las ordenes de la parte derecha de su cuadro retraso en el correo, e introducen un número equivalente de bienes en la parte alta del cuadro de Bienes en Proceso.

8. Avance la orden de la parte izquierda del cuadro retraso en el correo a la derecha. La simulación de las actividades de una semana han concluído y la secuencia comienza de nuevo en el paso 1.



Secuencia de pasos en una componente de la simulación manual



Sector de la fábrica

HOJA DE REGISTRO

TIEMPO	INVENTARIO EFECTIVO	ARTICULOS SOLICITADOS
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
SUMA PARCIAL		

TIEMPO	INVENTARIO EFECTIVO	ARTICULOS SOLICITADOS
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
SUMA PARCIAL		
SUMA TOTAL		

DIVISION DE EDUCACION CONTINUA
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DINAMICA DE SISTEMAS (FORRESTER)

INTRODUCCION A DYNAMO

DR. JOSE DE JESUS ACOSTA FLORES

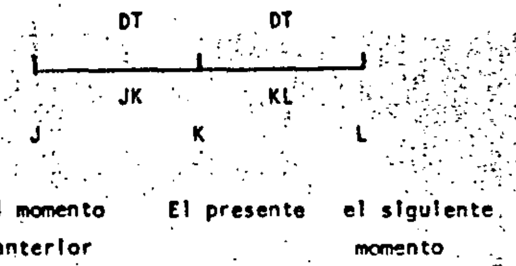
FEBRERO, 1985

Palacio de Minería Calle de Tacuba 5 primer piso Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

INTRODUCCION A DYNAMO

Dynamo es un lenguaje de cómputo para simulación. Su nombre, una fusión de las palabras "dynamics models", indica su uso: modelar sistemas del mundo real de manera que su comportamiento en el tiempo pueda ser generado, (imitado, simulado) por una computadora.

La notación Dynamo ayuda a comunicar precisamente cómo se lleva a cabo el cómputo. Las variables en Dynamo tienen índices indicando su lugar en el tiempo. K representa el presente; J el punto en el tiempo inmediato anterior, y L el punto en el futuro inmediato. El símbolo DT se usa para representar el tiempo que pasa entre J y K o K y L.



UN EJEMPLO:

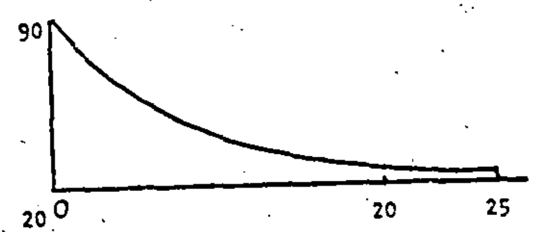
Para demostrar el esquema de cómputo usado por Dynamo para simular un sistema, se considera el ejemplo simple del enfriamiento del café en una tasa. La ley de Newton del enfriamiento es suficiente para nuestro propósito. Newton postuló que el café se debería enfriar con una tasa directamente proporcional a la diferencia entre la temperatura de la habitación que rodea la tasa y la temperatura del café. Esto es, Cambio en la temperatura del café = constante * (temp. de la habitación -temp. del café), donde la constante representa cosas tales como la circulación del aire en el cuarto, conductividad de la tasa, etc.
Se presentan a continuación los cálculos y las ecuaciones de este ejemplo.

Tiempo	CAFE °C	HAB. °C	HAB.- -CAFE °C	CAMBIO °C/min.	CAMBIO en 0.5 min.
0	90	20	- 70	- 14	- 7
.5	83	20	- 63	- 12.6	- 6.3
1	76.7	20	- 56.7	- 11.3	- 5.7
1.5	71	20	- 51	- 10	- 5.1
2	65.9	20	- 45.9	- 9.2	- 4.6
2.5	61.3	20	- 41.3	- 8.2	- 4.1
3	57.2	20	- 37.2	- 7.4	- 3.7
3.5	53.5	20	- 33.5	- 6.7	- 3.4
4	50.1	20	- 30.1	- 6.	- 3.0

DT = 0.5 minutos CONST = 0.2 1/min., HAB =20

ECUACIONES DYNAMO.

CAFE.K = CAFE.J + (DT) (CAMBIO. JK)
CAFE = 90
CAMBIO.KL = CONST * (HAB - CAFE.K)



TIPOS DE ECUACIONES

variables: suscritos K, J, KL, o JK.
constantes:
los valores no cambian en todo el curso de la simulación

C HAB = 20
C CONST = 0.2

Ecuaciones de Nivel

L NIVEL.K = NIVEL.J + DT * (ENT. JK - SAL. JK).
hasta 6 caracteres, el lo. debe ser una letra.

DYNAMO no acepta espacios en sus ecuaciones, ninguna ecuación se puede extender más allá de la columna 72.

Ecuaciones de tasa.

R CAMBIO KL = CONST * (HAB - CAFE.K)
NACIM. KL = TN * POB.K
MUER.KL = POB.K / VPROM

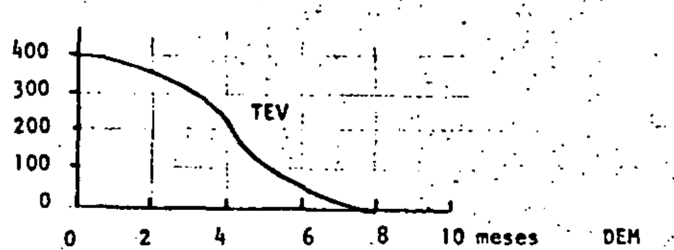
Ecuaciones auxiliares
difícil escribir ecuaciones de tasa..

A DIF.K = HAB - CAFE,K
R CAMBIO.KL = CONST * DIF. K

Funciones tabla

Ejemplo:
R PED. KL = VEN.K * EV.K

se piensa que la EV depende de la demora que la organización tiene para entregar los pedidos.



(podrían ser comas en lugar de /) A EV = TABLE (TEV. DEM.K, 0,10,2)
T TEV = 400/360/220/60/0,
TABLE - valores fuera del rango se reportan
TABHL - no se reportan

Ecuaciones N

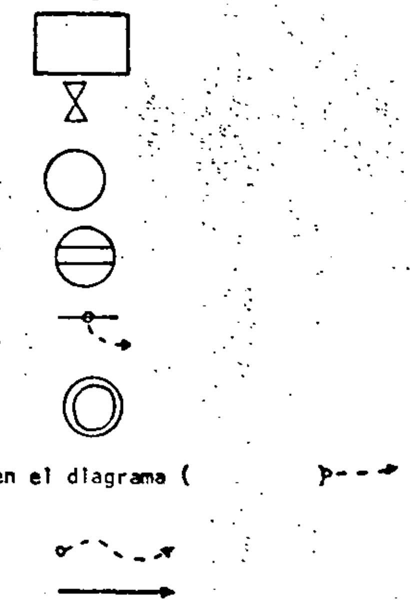
L CAFE.K = CAFE.J + (DT) (CAMBIO.JK)
N CAFE (sin suscritos) = 90

Todas las variables de nivel deben inicializarse

N INV = DIC * AVSHIP

DIC es constante
AVSHIP es tasa

Símbolos para diagrama de flujo.



Nivel L
tasa R
auxiliar A
función tabla
Constante
variable exógena
variable no definida en el diagrama (
liga de información
Flujo de materiales

Obteniendo la salida
SPEC DT=0.5/LENGTH = 100/PRTPER = 10/PLTPER =2
(pueden usarse también comas) (período de impresión) (período de graficación)

TIME.K está dentro del compilador y si TIME.K ≥ LENGTH se para la simulación.

Dynamo considera como valor inicial de TIME el valor cero a menos que se especifique de otra manera. Por ejemplo

N TIME = 1960
LENGTH = 2000 efectúa una simulación de

2000 − 1960 = 40 periodos.

Para imprimir las variables INV, ORD, SHP y AVS se usa la tarjeta

PRINT INV, ORD, SHP, AVS

donde no se usan los índices.

Si se desea que INV se imprima en la 1ª columna, ORD y SHP en la segunda y AVS en la tercera se usa:

PRINT 1)INV/2)ORD, SHP/3)AVS

Para graficar se utiliza la tarjeta con PLOT y después del nombre de la variable se especifica el caracter con que se desea aparezcan dibujados los valores que tome ésta al transcurrir el tiempo. Por ejemplo:

PLOT CON=C/LINC=L/MPL=+

La diagonal hace que cada variable se grafique en escalas separadas. Dynamo selecciona las escalas.

Si uno desea forzar que dos o más variables se grafiquen en la misma escala se separan con comas, así:

PLOT CON=C/TNC=1, TMC=2/LINC=L/MPL=+

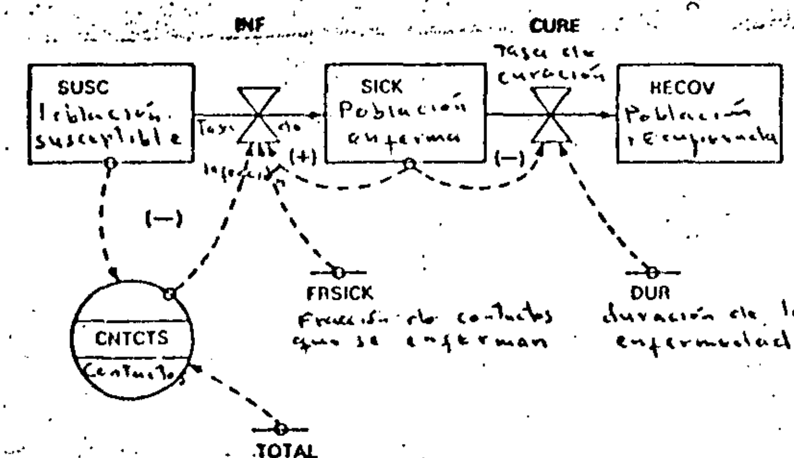
hace que TNC y TMC aparezcan en la misma escala.

También es posible especificar la escala, por ejemplo si uno quiere que CON esté en la escala de 0 a 400 se escribiría:

PLOT CON=C(0,400)/LINC=L/MPL=1

La tarjeta NOTE se usa para letreros.
La Tarjeta RUN hace que comience la simulación.
No se requiere que las tarjetas estén ordenadas.

EJEMPLO.

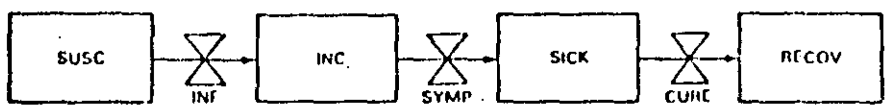



```
NOTE    MODELO EPIDEMICO SIMPLE
L       SUSC.K=SUSC.J+DT*(-INF.JK)
N       SUSC=988
NOTE         POBLACION SUSCEPTIBLE
R       INF.KL=SICK.K*CNTCTS.K*FRSICK
NOTE         TASA DE INFECCION(PERSONAS POR DIA)
C       FRSICK=0.05
NOTE         FRACCION DE CONTACTOS QUE SE ENFER-
NOTE         MAN
L       SICK.K=SICK.J+DT*(INF.JK-CURE.JK)
N       SICK=2
NOTE         POBLACION ENFERMA
A       CNTCTS.K=TABLE(TABCON,SUSC.K/TOTAL,0,1,0.2)
NOTE         SUSCEPTIBLES CONTACTADOS POR PERSONA IN-
NOTE         FECTADA POR DIA
T       TABCON=0/2.8/5.5/8/9.5/10
NOTE
N       TOTAL=SUSC+SICK+RECOV
NOTE
R       CURE.KL=SICK.K/DUR
NOTE         TASA DE CURACION
C       DUR=10
NOTE         DURACION DE LA ENFERMEDAD
L       RECOV.K=RECOV.J+DT*CURE.JK
N       RECOV=10
NOTE         POBLACION RECUPERADA
NOTE
SPEC    DT=0.25,LENGTH=50,PRTPER=5,PLTPER=1
PRINT   SUSC,SICK,RECOV,INF,CURE
PLOT    SUSC=N,SICK=S,RECOV=R/INF=I,CURE=C(0,200)
```

Preguntas.

5 ⑦

1. ¿Qué clase de variable es SICK?
2. ¿Por qué INF aparece en la ecuación de SUSC con un signo negativo?
3. ¿Por qué DUR no tiene un suscrito?
4. ¿Cuántas personas ya habían tenido esta enfermedad y se habían recobrado al inicio de la simulación?
5. ¿Cuánto vale el intervalo de cómputo?
6. ¿Por qué existen solo dos escalas para las cinco variables?
7. ¿Por qué INF tiene el suscrito KL en la ecuación de tasa y JK en las de nivel?
8. Grafique la tabla de CNTCTS
9. ¿Cuántas líneas se imprimen y cuántas se grafican?



En la figura anterior se supone que existe un periodo de incubación antes que se presenten los síntomas de la enfermedad. Las nuevas ecuaciones son

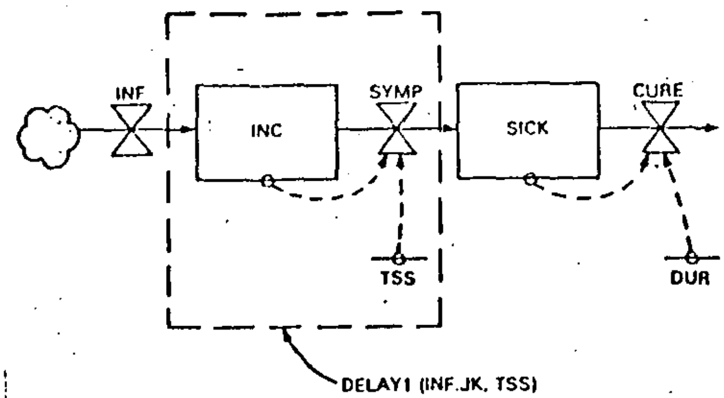
```
L   INC.K=INC.J+DT*(INF.JK-SYMP.JK)
N   INC=TSS*INF
R   SYMP.KL=INC.K/TSS
```

donde TSS es el tiempo para mostrar los síntomas. Para la gripe es alrededor de 3 días.

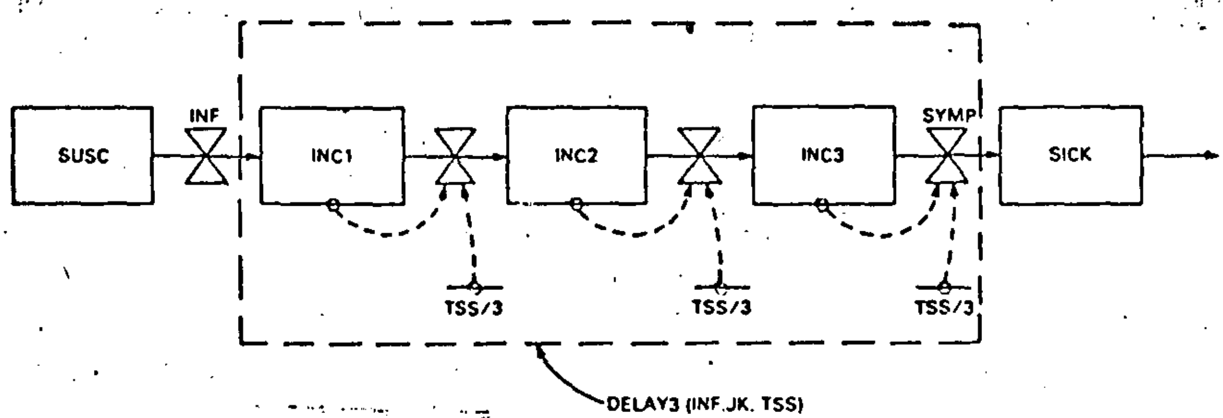
La ecuación siguiente hace lo mismo que las tres ecuaciones anteriores:

```
R   SYMP.KL=DELAY1(INF.JK,TSS)
```

DELAY1 es una demora exponencial de primer orden de materiales.



Se podría sugerir que ya que el tiempo para mostrar los síntomas TSS es tres días, se podría desagregar la población que está incubando la enfermedad en los del primer día INC1, los del segundo día INC2 y los del tercer día INC3 como se muestra en la figura.

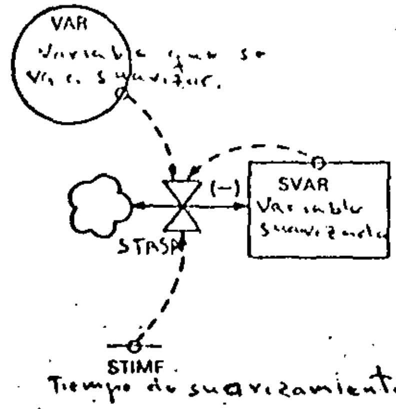


La demora resultante entre estar infectado (la tasa INF) y mostrar los síntomas (la tasa SYMP) se conoce oficialmente como una demora exponencial de tercer orden de materiales y en Dynamo se representa con la función DELAY3.

R SYMP.KL=DELAY3(INF.JK,TSS)

Función SMOOTH

Esta función sirve para suavizar. Suponga que se desea promediar la variable VAR,



las ecuaciones son:

L SVAR.K = SVAR.J + DT * STASA.JK

N SVAR = VAR

R STASA.KL = (VAR.K − SVAR.K) / STIME

La ecuación siguiente hace lo mismo que las tres ecuaciones anteriores:

A SVAR.K = SMOOTH (VAR.K, STIME)

VAR puede ser nivel, Tasa o auxiliar.

OTRAS FUNCIONES

Matemáticas:

$SQRT(X) = \sqrt{X}$

$SIN(X) = \text{seno}(X)$

$COS(X) = \cos(X)$

$EXP(X) = e^{X}$

$LOGN(X) = \log_e X$

Lógicas:

$$MAX(A, B) = \begin{cases} A & \text{si } A \geq B \\ B & \text{si } A < B \end{cases}$$

$$MIN(A,B) = \begin{cases} B & si \quad A \geq B \\ A & si \quad A < B \end{cases} \quad (10)$$

$$CLIP(A,B,X,Y) = \begin{cases} A & si \quad X \geq Y \\ B & si \quad X < Y \end{cases}$$

$$SWITCH(A,B,X) = \begin{cases} A & si \quad X = 0 \\ B & si \quad X \neq 0 \end{cases}$$

Otras funciones que sirven para hacer pruebas al modelo son:

STEP (A, B)

donde A - altura del paso
B - tiempo en que comienza

RAMP (A, B)

donde A - pendiente de la función
B - tiempo de inicio

PULSE (A, B, C)

donde A - altura del pulso
B - tiempo del primer pulso
C - intervalo entre pulsos sucesivos

NOISE() genera números aleatorios de -0.5 a 0.5

A*NOISE() +B genera números aleatorios de B - A/2 a B + A/2

Alfeld, Louis and Alan K. Graham, 1976. *Introduction to Urban Dynamics*. Cambridge, Ma.: The MIT Press.

Britting, Kenneth R., 1973. Correlated Noise Generation Using DYNAMO. System Dynamics Group working paper D-1908, Alfred P. Sloan School of Management, M.I.T., Cambridge, MA. 02139.

Cooper, Kenneth G., 1980. Naval Ship Production: A Claim Settled and a Framework Built. *Interfaces*, 10,6(1980):20-36.

Forrester, Jay W., 1959. Advertising: a Problem in Industrial Dynamics. *Harvard Business Review*, March-April, 1959.

Forrester, Jay W., 1961. *Industrial Dynamics*. Cambridge, Ma.: The MIT Press.

Forrester, Jay W., 1968a. Market Growth as Influenced by Capital Investment. *Industrial Management Review* (now the *Sloan Management Review*), 9(1968):83-105.

Forrester, Jay W., 1968b. *Principles of Systems*. Cambridge, Ma.: The MIT Press.

Forrester, Jay W., 1969. *Urban Dynamics*. Cambridge, Ma.: The MIT Press.

Forrester, Jay W., 1971. Counterintuitive Behavior of Social Systems. *Technology Review* 73(1971):52-68.

Forrester, Jay W., 1973. *World Dynamics*. Cambridge, Ma.: The MIT Press.

Forrester, Jay W., 1975. *Collected Papers of Jay W. Forrester*. Cambridge, Ma.: The MIT Press.

Forrester, Jay W., Gilbert W. Low, and Nathaniel J. Mass. The Debate on *World Dynamics*: A Response to Nordhaus. *Policy Sciences*, 5(1974):169-190.

Forrester, Jay W. and Peter M. Senge, 1980. Tests for Building Confidence in System Dynamics Models. *System Dynamics*. *TIMS Studies in Management Sciences* 14(1980):209-228.

Richardson, George P., 1981. Statistical Estimation of Parameters in a Predator-Prey Model: an Exploration using Synthetic Data. System Dynamics Group working paper D-3314-1, Alfred P. Sloan School of Management, M.I.T., Cambridge, MA. 02139.

Roberts, Edward B., 1964. *The Dynamics of Research and Development*. Cambridge, Ma.: The MIT Press.

Roberts, Edward B., 1980. *Managerial Applications of System Dynamics*. Cambridge, Ma.: The MIT Press.

Roberts, Edward B., 1977. Strategies for Effective Implementation of Complex Corporate Models. *Interfaces*, 8,1(1977)Part 1.

Schroeder, Walter E. and John E. Strongman, 1974. Adapting Urban Dynamics to Lowell, in *Readings in Urban Dynamics*, vol. 1, Nathaniel J. Mass, ed. Cambridge, Ma.: The MIT Press. 197-223.

Senge, Peter M., 1977. Statistical Estimation of Feedback Models. *Simulation*, 28(1977):177-184.

Shaffer, William, 1976. *Court Management and the Massachusetts Criminal Justice System*. Ph.D. dissertation, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Ma. 02139.

Shaffer, William, 1978. *Mini-DYNAMO Users' Guide*. Pugh-Roberts Associates, 5 Lee Street, Cambridge, Ma. 02139.

Wiener, Norbert., 1961. *Cybernetics: or control and communication in the animal and the machine*. Cambridge, Ma.: The MIT Press.

Garn, Harvey A. and Robert H. Wilson, 1972. A Look at Urban Dynamics: The Forrester Model and Public Policy. *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-2(1972):150-155.

(13)

Goodman, Michael R., 1974. *Study Notes in System Dynamics*. Cambridge, Ma.: The MIT Press.

Graham, Alan K., 1977. *Principles on the Relationship Between Structure and Behavior of Feedback Systems*. Ph.D. dissertation. Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, Ma., 02139.

Graham, Alan K., 1980. Parameter Estimation in System Dynamics Modeling, in *Elements of the System Dynamics Method*, Jorgen Randers, ed. Cambridge, Ma.: The MIT Press, 143-161.

Greenberger, Martin, Mathew A. Crensen, and Brian L. Crissy, 1976. *Models in the Policy Process*. New York: Russell Sage Foundation.

Hardin, Garret, 1972. *Exploring New Ethics for Survival; the voyage of the spaceship Beagle*. New York: Viking Press.

Kormondy, Edward J., 1969. *Concepts of Ecology*. Englewood Cliffs, N.J.: Prentice-Hall.

Levin, Gilbert, Edward B. Roberts, and Garry Hirsch, 1975. *The Persistent Poppy*. Cambridge, Ma.: Ballinger.

Lyneis, James M., 1980. *Corporate Planning and Policy Design*. Cambridge, Ma.: The MIT Press.

Malthus, Thomas, 1798. *First Essay on Population*, 1966 edition. New York: MacMillan, Inc.

Mass, Nathaniel J., 1973. *Readings in Urban Dynamics*, vol. 1. Cambridge, Ma.: The MIT Press.

Mass, Nathaniel J. and Peter M. Senge, 1978. Alternative Tests for the Selection of Model Variables. *IEEE Transactions on Systems, Man, and Cybernetics*, July, 1978.

Meadows, Dennis L., 1970. *Dynamics of Commodity Cycles*. Cambridge, Ma.: The MIT Press.

Meadows, Dennis L. and Donella H. Meadows, eds., 1973. *Toward Global Equilibrium*. Cambridge, Ma.: The MIT Press.

(14)

Meadows, Dennis L., William H. Behrens III, Donella H. Meadows, Roger F. Naill, Jorgen Randers, and Erich K.O. Zahn, 1974. *Dynamics of Growth in a Finite World*. Cambridge, Ma.: The MIT Press.

Meadows, Donella H., 1980. The Unavoidable A Priori, in *Elements of the System Dynamics Method*, Jorgen Randers, ed. Cambridge, Ma.: The MIT Press. 23-57.

Meadows, Donella H., Dennis L. Meadows, Jorgen Randers, and William W. Behrens III, 1972. *The Limits to Growth*. New York: Universe Books, A Potomac Associates Book.

Naill, Roger F., 1973. The Discovery Life Cycle of a Finite Resource: A Case Study of U.S. Natural Gas, in *Toward Global Equilibrium*, Dennis L. Meadows and Donella H. Meadows, eds. Cambridge, Ma.: The MIT Press. 213-256.

Nordhaus, William D. World Dynamics: Measurement Without Data. *The Economic Journal*, 83(1973):1156-1183.

Peterson, David W., 1980. Statistical Tools for System Dynamics, in *Elements of the System Dynamics Method*, Jorgen Randers, ed. Cambridge, Ma.: The MIT Press. 224-245.

Pindyck, Robert S. and Daniel L. Rubenfeld, 1976. *Econometric Models and Econometric Forecasts*. New York: McGraw-Hill.

Pugh, Alexander L., III, 1976. *DYNAMO Users' Manual*, 5th ed. Cambridge, Ma.: The MIT Press.

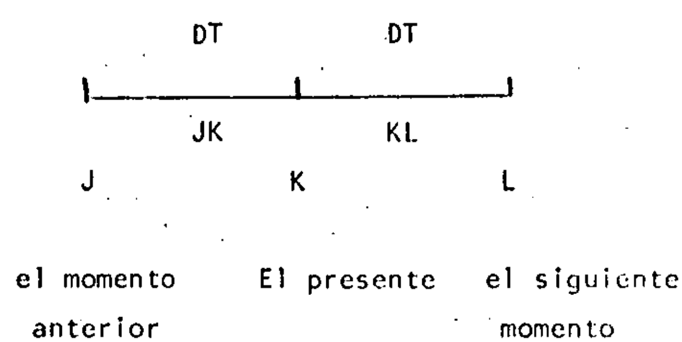
Randers, Jorgen., 1980. *Elements of the System Dynamics Method*. Cambridge, Ma.: The MIT Press.

Randers, Jorgen and Dennis L. Meadows, 1973. The Dynamics of Solid Waste Generation, in *Toward a Global Equilibrium*, Dennis L. Meadows and Donella H. Meadows, eds. Cambridge, Ma.: The MIT Press. 165-211.

INTRODUCCION A DYNAMO

Dynamo es un lenguaje de cómputo para simulación. Su nombre, una fusión de las palabras "dynamics models", indica su uso: modelar sistemas del mundo real de manera que su comportamiento en el tiempo pueda ser generado, (imitado, simulado) por una computadora.

La notación Dynamo ayuda a comunicar precisamente cómo se lleva a cabo el cómputo. Las variables en Dynamo tienen índices indicando su lugar en el tiempo. K representa el presente; J el punto en el tiempo inmediato anterior, y L el punto en el futuro inmediato. El símbolo DT se usa para representar el tiempo que pasa entre J y K o K y L.



UN EJEMPLO:

Para demostrar el esquema de cómputo usado por Dynamo para simular un sistema, se considera el ejemplo simple del enfriamiento del café en una tasa. La ley de Newton del enfriamiento es suficiente para nuestro propósito. Newton postuló que el café se debería enfriar con una tasa directamente proporcional a la diferencia entre la temperatura de la habitación que rodea la tasa y la temperatura del café. Esto es, Cambio en la temperatura del café = constante * (temp. de la habitación- -temp. del café), donde la constante representa cosas tales como la circulación del aire en el cuarto, conductividad de la tasa, etc. Se presentan a continuación los cálculos y las ecuaciones de este ejemplo.

Tiempo	CAFE °C	HAB. °C	HAB.- -CAFE °C	CAMBIO °C/min.	CAMBIO en 0.5 min.
0	90	20	- 70	- 14	- 7
.5	83	20	- 63	- 12.6	- 6.3
1	76.7	20	- 56.7	- 11.3	- 5.7
1.5	71	20	- 51	- 10	- 5.1
2	65.9	20	- 45.9	- 9.2	- 4.6
2.5	61.3	20	- 41.3	- 8.2	- 4.1
3	57.2	20	- 37.2	- 7.4	- 3.7
3.5	53.5	20	- 33.5	- 6.7	- 3.4
4	50.1	20	- 30.1	- 6.	- 3.0

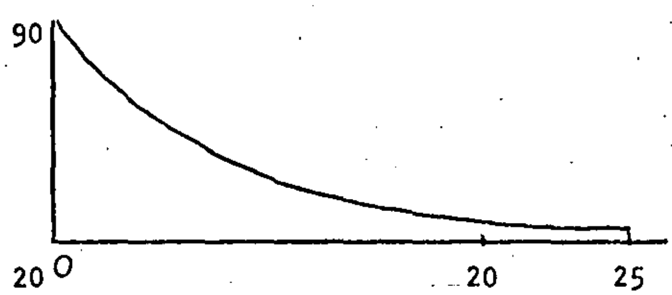
DT = 0.5 minutos   CONST = 0.2 1/min., HAB =20

ECUACIONES DYNAMO.

CAFE.K = CAFE.J + (DT) (CAMBIO. JK)

CAFE = 90

CAMBIO.KL = CONST * (HAB - CAFE.K)



TIPOS DE ECUACIONES

variables: suscritos K, J, KL, o JK.
constantes:
los valores no cambian en todo el curso de la simulación

C   HAB = 20

C   CONST = 0.2

Ecuaciones de Nivel

15

L NIVEL.K = NIVEL.J + DT * (ENT. JK - SAL. JK).
hasta 6 caracteres, el lo. debe ser una letra.

DYNAMO no acepta espacios en sus ecuaciones, ninguna ecuación se puede extender más allá de la columna 72.

Ecuaciones de tasa.

R CAMBIO KL = CONST * (HAB - CAFE.K)
NACIM. KL = TN * POB.K
MUER.KL = POB.K / VPROM

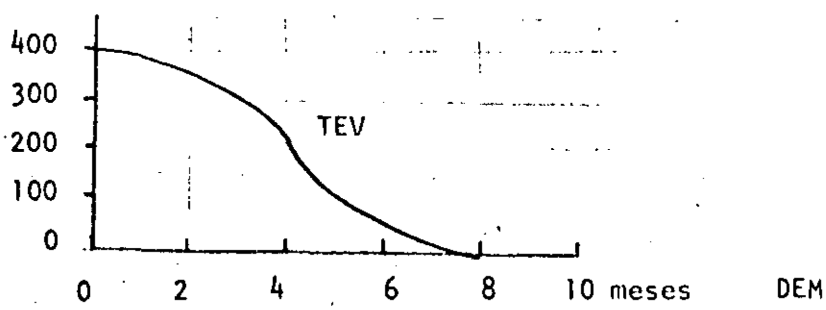
Ecuaciones auxiliares
difícil escribir ecuaciones de tasa.

A DIF.K = HAB - CAFE.K
R CAMBIO.KL = CONST * DIF. K

Funciones tabla

Ejemplo:
R PED. KL = VEN.K * EV.K

se piensa que la EV depende de la demora que la organización tiene para entregar los pedidos.



(podrían ser comas en lugar de /) A EV = TABLE (TEV. DEM.K, 0,10,2)
T TEV = 400/360/220/60/0.
TABLE - valores fuera del rango se reportan
TABHL - no se reportan

Ecuaciones N

L CAFE.K = CAFE.J + (DT) (CAMBIO.JK)

N CAFE (sin suscritos) = 90

Todas las variables de nivel deben inicializarse

N INV = DIC * AVSHIP

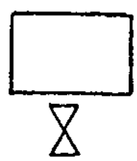
DIC es constante

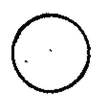
AVSHIP es tasa

Simbolos para diagrama de flujo.

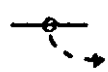
Nivel L

tasa R

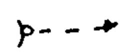


auxiliar A 

función tabla 

Constante 

variable exógena 

variable no definida en el diagrama (

liga de información 

Flujo de materiales 

Obteniendo la salida

SPEC DT=0.5/LENGTH = 100/PRTPER = 10/PLTPER =2

pueden usarse también comas — período de impresión — período de graficación

DINAMICA DE SISTEMAS (FORRESTER)

I N S T R U C C I O N E S

FEBRERO, 1985

D I N A M I C A D E S I S T E M A S

INSTRUCCIONES PARA PROCESAR MODELOS DINAMICOS DE SIMULACION CON EL PAQUETE "DYNAMO" IMPLANTADO EN EL CENTRO DE SERVICIOS DE COMPUTO DE LA UNAM 1981.

NOTAS PRELIMINARES: Todo el modelo debe estar codificado a partir de la séptima columna sin dejar espacios intermedios, con excepción de: RUN,NOTE,PRINT,PLOT SPEC,MACRO,MEND,REMOTE,DYNAMO,o SKIP que se deben iniciar en la ---- columna uno.

La estructura general del modelo es:

```
col.:   1     7
        100REMOTE                   indica que se va a procesar por terminal
        200DYNAMO DLIST NARROW      indica opciones DYNAMO (ver manual)
        300RUN    NOMBRE            NOMBRE puede ser cualquiera
        400
        500
col.:   .   1     7                 Programa
        .
        1600PRINT 1)A/2)B
        1700PLOT  A=*/B=#
        1800SPEC  DT=_/LENGTH=_/PRTPER=_/PLTPER=_
        1900RUN   OTRONOMBRE
        2000      P=8
```

I N S T R U C C I O N E S:

#	OBJETIVO	ACCION	R E S U L T A D O
1.	Prender la pantalla	Conectar el interruptor	La pantalla se ilumina tenuemente.
2.	Solicitar sesión de Trabajo.	Oprimir la tecla "RETURN"	La computadora contesta: #ENTER USERCODE PLEASE
3.	Dar la clave del usuario pedida	Teclear la clave sin caracteres especiales o espacios ejemplo FA83 y después oprimir la tecla "RETURN"	La computadora contesta: #ENTER PASSWORD PLEASE

#	OBJETIVO	ACCION	RESULTADO
4.	Dar la contraseña	Teclear la contraseña del usuario, por ejemplo DM y oprimir la tecla "RETURN"	La computadora puede contestar: a) "INVALID USERCODE, ENTER USERCODE PLEASE" se dió equivocada la clave o contraseña, regresar a 3. b) #RECOVERY DATA:nnn (nombre arch) (fecha). Esto sucede cuando la sesión anterior fue interrumpida por falla del sistema y el usuario tiene la posibilidad de recuperar el archivo de trabajo que tenía creado durante la sesión interrumpida tecleando REC nnn y oprimir RETURN. c) Algún mensaje como suspensión de servicio de fin de semana, remoción de archivos o TECLEE NEWS y oprimir RETURN. d) # B6700:126 CANDE 30.140 ;YOU ARE (identific de la terminal) # DEFAULT PRINT DESTINATION=SITE # SESSION xxx (hora) (fecha)
5.	Crear un archivo de trabajo llamado DYNAMOINPUT	Teclear: MAKE DYNAMOINPUT y oprimir la tecla RETURN	La computadora contesta: #WORKFILE DYNAMOINPUT : SEQ
6.	Ordenar la secuencia automática de 100 en 100	Teclear: SEQ y oprimir RETURN	La computadora coloca un 100 en el primer renglón.
7.	Meter el programa	Teclear: REMOTE y oprimir RETURN	La computadora coloca 200 en el segundo renglón.
		Teclear: DYNAMO DLIST NARROW y oprimir RETURN	La computadora coloca 300 en el tercer renglón.
		Teclear: RUN NOMBRE y oprimir RETURN	La computadora coloca 400 en el cuarto renglón.

JETIVO	ACCION	RESULTADO
8. Corrección de errores	Si se comete un error marcarlo en la hoja de codificación y proseguir inmediatamente con el siguiente renglón	El error oerrores detectados durante la introducción de las ecuaciones se corregiran al final. nota.-al darse cuenta del error suspender lo que sigue en el renglón.
9. Salir de la secuencia automática después del último dato.	Oprimir la tecla RETURN dos veces.	El sistema responde con un # indicando que está listo para recibir ordenes.
10. Corrección de errores	Teclear el número correspondiente al renglón donde se cometió el error y teclear de nuevo el renglón, oprimir RETURN.	El sistema avanza una línea.
11. Verificar que el error se corrigió.	Teclear LIST XXX siendo XXX el número de la secuencia corregida,y oprimir RETURN.	El sistema muestra el renglón XXX
12. Verificar todas las instrucciones.	Teclear L y oprimir la tecla RETURN	Aparecen todas las ecuaciones y datos introducidos,verificar con la hoja de codificación.
13. Guardar el archivo creado en la biblioteca del usuario	Teclear SAVE y oprimir RETURN	El sistema contesta: WORKSOURCE(DYNAMOINPUT) SAVED.
14. Eliminar datos del archivo (opcional)	Teclear DEL dar un espacio y teclear el número del renglón a eliminar y RETURN	El sistema contesta: #
15. Regresar a la secuencia automática a partir del último reng.	Teclear: SEQ END y oprimir RETURN	El sistema contesta con un número igual al último usado más 100.
16. Si se tuvo error al tratar de correr y se corrigió el arch.	Teclear: SAVE y RETURN	El sistema contesta: WORKFILE SAVED OLD FILE REMOVED

…JETIVO	ACCION	R E S U L T A D O
17. Saber hora y día (opcional)	Teclear: ?TIME y OPRIMIR RETURN	Da la hora diá y diá de la semana
18. Mandar un mensaje a otra terminal	Teclear:?TO(CLAVE) (TEXTO) oprimir RETURN	Manda mensaje.
19. Preguntar el estado del sistema (opcional).	Teclear: ?STA y RETURN	Indica el estado del sistema,resp. al usuario.
20. Interrumpir el proceso (opcional)	Teclear ?DS y RETURN	Interrumpe el proceso.
21. Llamar al programa traductor DYNAMO Nota.-La instrucción de poner la C no funciona	Teclear: EXECUTE *SERVICIO/DYNAMO oprimir RETURN	El sistema contesta: #RUNNING XXX #? ENTER IN COLUMNS 1- 15 THE NAME OF THE DISK FILE YOU WISH DYNAMO TO CREATE TO WRITE YOUR ALGOL SOURCE CODE. IF OUTUT IS DESIRED ON THE LINE PRINTER ENTER C IN COLUMN 1 FOLLOWED BY FILENAME
22. Darle nombre al archivo en disco que uno desea que DYNAMO cree para escribir el programa fuente en ALGOL.	Teclear: PREFIJO/SUFIJO siete caractéres max,divid. por un / Ejemplo: A/1 oprimir RETURN	El sistema contesta: OK BURROUGHS B6700/B7700 DYNAMO LEVEL 45 (fecha) INPUT PHASE BEGIN AT (hora) y a continuación si se usó DLIST aparece todo el programa,si hay errores DYNAMO los indica y omite los pasos siguientes. Si no se usó DLIST solo indica los errores si hay. y luego aparece en pantalla: INPUT PHASE CONCLUDED AT (hora) GENERATION PHASE BEGAN AT (hora) RUN PHASE GENERATED AT (hora) PRINT PHASE GENERATED AT (hora) PLOT PHASES GENERATED AT (hora) ELAPSED COMPILATION TIME (tiempo) PLEASE ENTER COMPILE A/1 WITH ALGOL, THEN WAIT UNTIL YOUR TERMINAL REPORTS THAT YOUR COMPILATION IS COMPLETE.

# OBJETIVO	ACCION	RESULTADO
Nota.- En este ejemplo se usó como nombre para el archivo en lugar de : PREFIJO/SUFIJO a A/1.		AFTER GOOD COMPILATION ENTER EXECUTE A/1 #ET= _ PT= _ IO= _
23. Compilar el archivo creado por DYNAMO	Teclear: COMPILE A/1 WITH ALGOL y oprimir RETURN	Contesta: #COMPILING XXX $SET BCL RESET LIST 000010000 WARNING- BCL PROGRAMS ARE NOT PORTABLE TO EBCDIC MACHINES # ET= _ PT=_ IO= _
24. Procesar el programa en ALGOL creado.	Teclear: EXECUTE A/1 y oprimir RETURN	Contesta: #RUNNING XXX aparece el listado ,los valores de las variables y las gráficas. Termina con: FINISHED RUN NUMBER NOMBRE AT (hora) (fecha) #ET=_ PT=_ IO=_
25. Obtener una copia de las ecuaciones del modelo	Teclear: W y oprimir RETURN	Contesta: #RUNNING XXX e imprime por la impresora de línea la copia.
26. Obtener una copia de los resultados	Teclear: EXECUTE A/1;FILE W9900(PRINTER) y oprimir RETURN	Contesta : #RUNNING XXX y sale una copia por la impresora de línea.
27. Borrar el archivo.	Teclear: REMOVE DYNAMOINPUT RETURN REMOVE A/1 RETURN	Contesta: #DYNAMOINPUT REMOVED #A/1 REMOVED

28. Despedirse y terminar la sesión	Teclear:
	BYE y RETURN
		#END SESSION XXX
		ET= PT= IO=
		#USER=CLAVE (hora)(fecha)

SECUENCIA PARA PROCESAR DYNAMO:

9
1,2,3,4,5,6,7,12,13,21,22,23,24,25,26,27,28.

Esta secuencia es válida si no se cometen errores.

P/COPIAR UN ARCHIVO DE UNA CLAVE A OTRA.

HELLO CLAVE 1

SEC NOMBRE 1 PUBLIC

FA

DISK= ALGO OTHERWISE DISK

BYE

HELLO CLAVE 2

G(CLAVE 1) NOMBRE 1, O.N ALGO

SA AS NOMBRE 2

GET NOMBRE 2

P/COPIAR UN ARCHIVO EN LA MISMA CLAVE

GET ARCHIVO 1 ; SAVE AS ARCHIVO 2

P/CAMBIAR TITULO AL ARCHIVO

TITLE ARCHIVO VIEJO TO ARCHIVO NUEVO

DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

DINAMICA DE SISTEMAS (FORRESTER)

FORMULACION DEL MODELO

DR. JOSE DE JESUS ACOSTA FLORES

FEBRERO, 1985

FORMULACION DEL MODELO

La formulación es el proceso de trasladar la estructura del modelo en ecuaciones. El punto de vista conceptual, informal, se traduce a una representación cuantitativa y formal. Se verá primero la formulación de las ecuaciones de tasa, después el arte de desarrollar una función tabla y finalmente se formulará el modelo del ejemplo del proyecto visto en sesiones anteriores.

FORMULACION DE ECUACIONES DE TASA

Se verán ciertas estructuras comunes, no para tomarlas como recetario, sino para evitar el que se tenga que reinventar la rueda.

CONST * NIVEL.K

NIVEL.K / VIDA

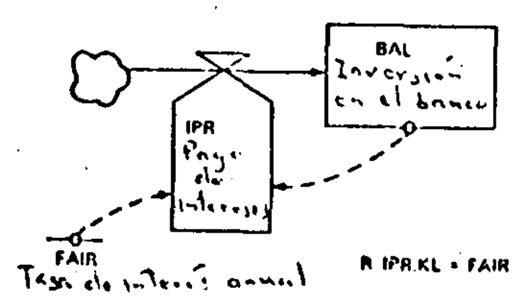
(META - NIVEL.K) /TIDEA

AUX.K * NIVEL.K y NIVEL.K/AUX.K

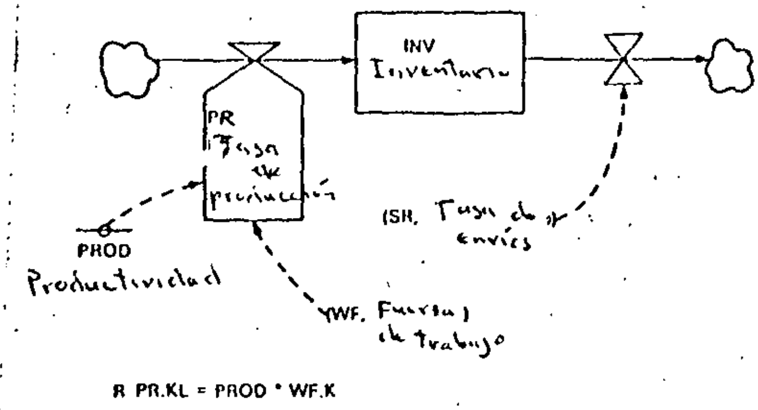
NORM.K + EFECT.K

NORM.K * EFECT.K

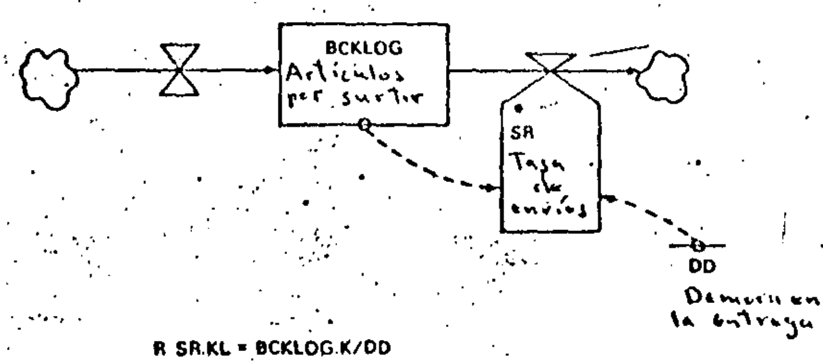
Se presentan dos ejemplos donde es adecuado formular una tasa como CONST * NIVEL.K. Se considera apropiada esta formulación cuando se obtiene una contestación afirmativa a la pregunta: ¿si el nivel aumenta, aumenta proporcionalmente la tasa?



R IPR.KL = FAIR * BAL.K

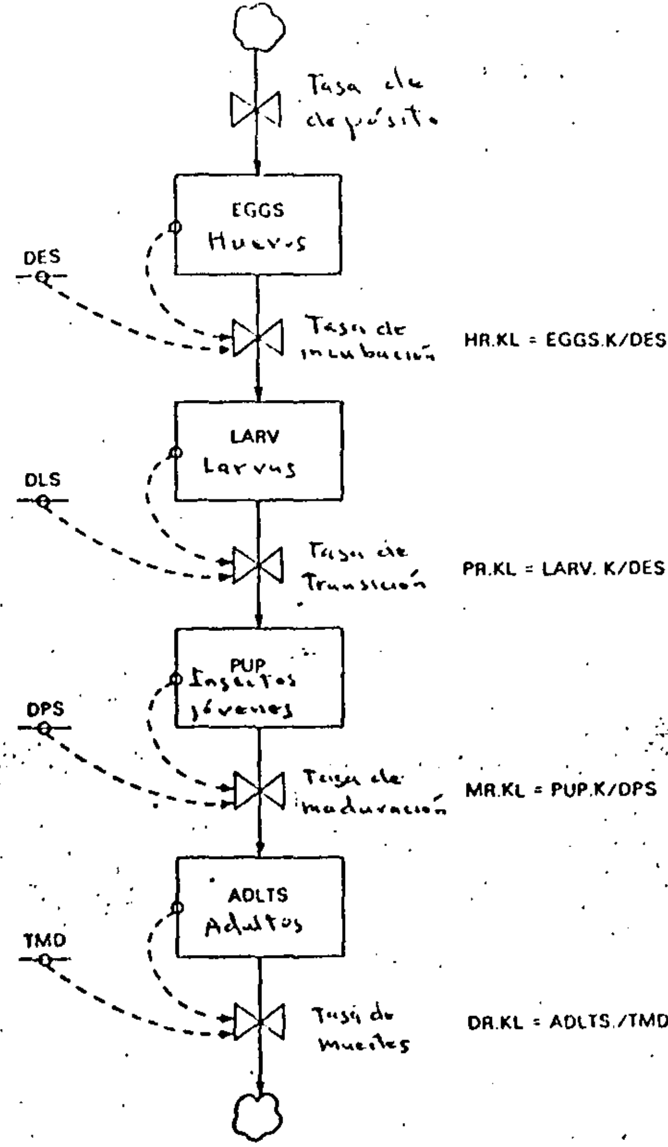


Se exhiben a continuación tres ejemplos donde es adecuado formular la tasa como NIVEL.K / VIDA

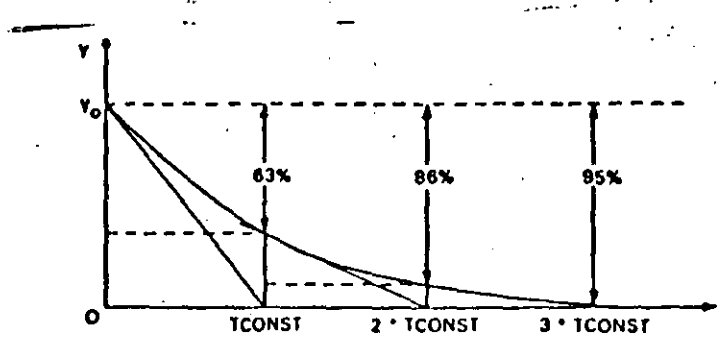


DD es el tiempo promedio que un artículo permanece en BCKLOG antes de que se envíe.

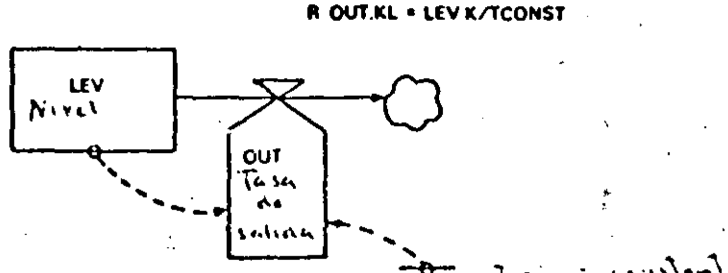
En la figura siguiente se presentan las etapas del desarrollo de un insecto, donde por simplicidad se han omitido las tasas de muerte en los tres primeros niveles,



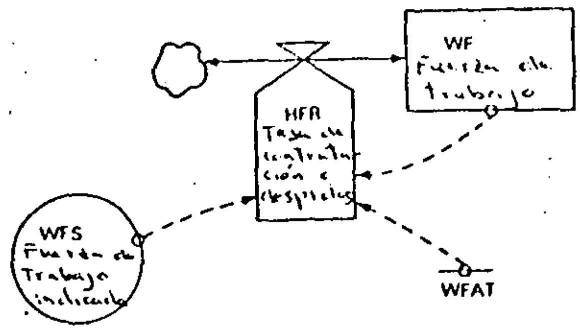
DES, DLS, DPS y TMD es el tiempo promedio que permanece un elemento en el nivel antes de salir.
En la figura siguiente se muestra el comportamiento de este tipo de tasas.



R OUT.KL = LEV.K/TCONST



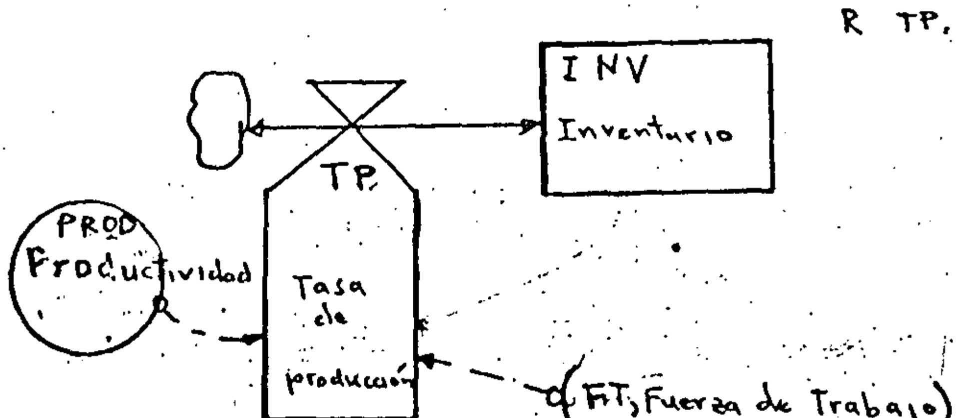
El ejemplo siguiente ilustra el uso de (META - NIVEL.K) / TIMEA

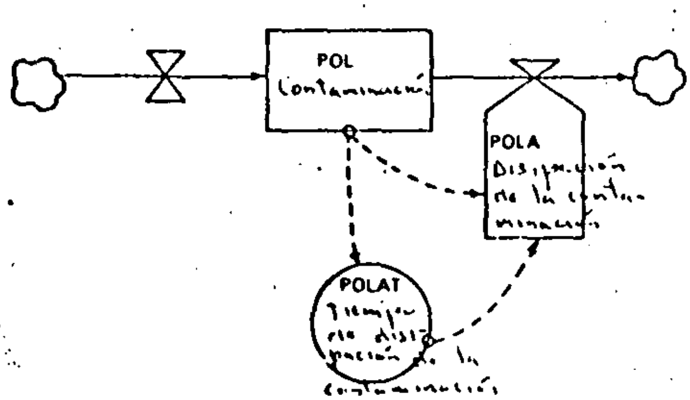


R HFR.KL = (WFS.K-WF.K)/WFAT

Los dos ejemplos siguientes muestran el empleo de AUX.K * NIVEL.K y NIVEL.K / AUX.K respectivamente

R TP.KL = PROD.K * FT.K

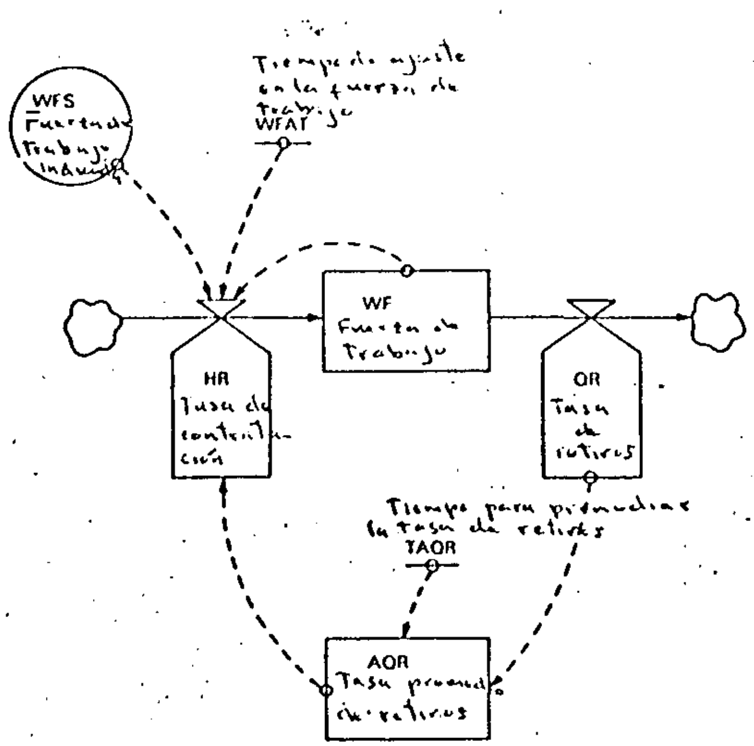




Al aumentar la contaminación aumenta POLAT

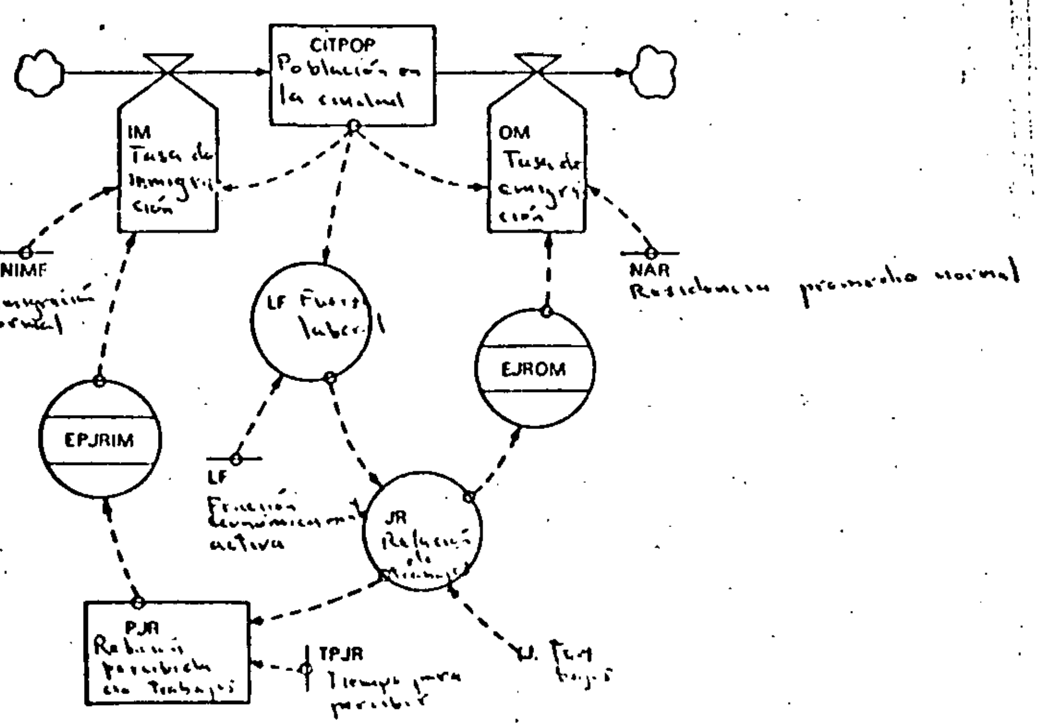
R POLA.KL = POL.K/POLAT.K

NORM.K + EFECT.K se ilustra en :



HR.KL = AQR.K + (WFS.K-WF.K)/WFAT

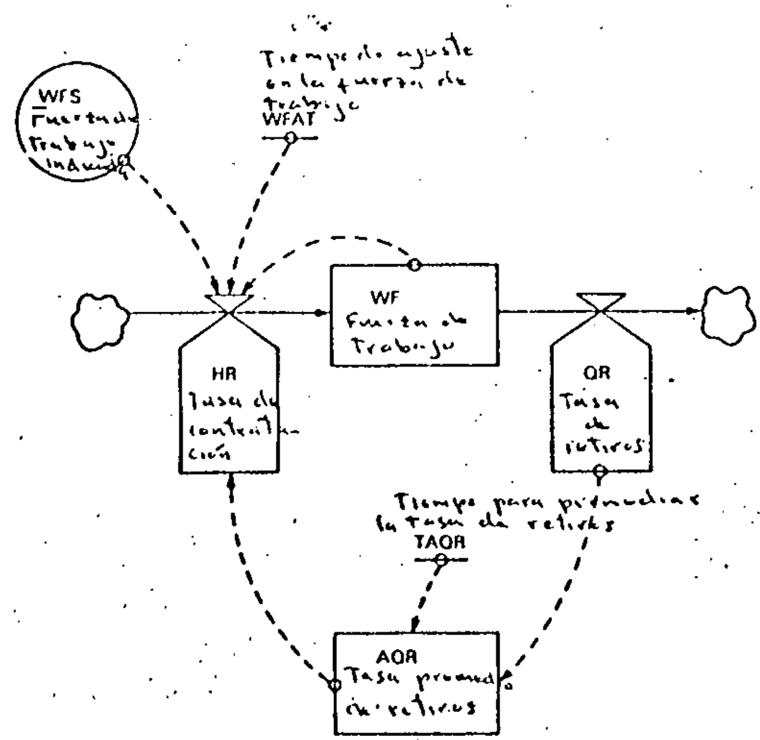
NORM.K * EFECT.K se ilustra en :



R IM.KL = (NIMF * CITPOP.K) * EPJRIM.K

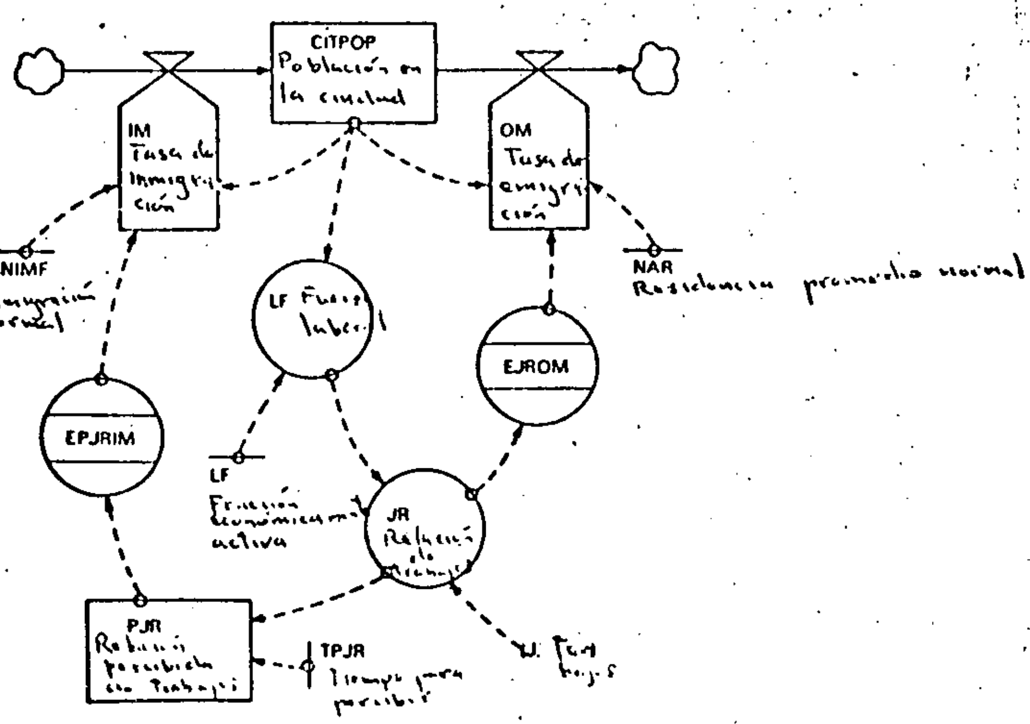
R OM.KL = (CITPOP * K/MAR) * EJROM.K

NORM.K + EFECT.K se ilustra en :



$$HR.KL = AQR.K * (WFS.K - WF.K)/WFAT$$

NORM.K * EFECT.K se ilustra en :

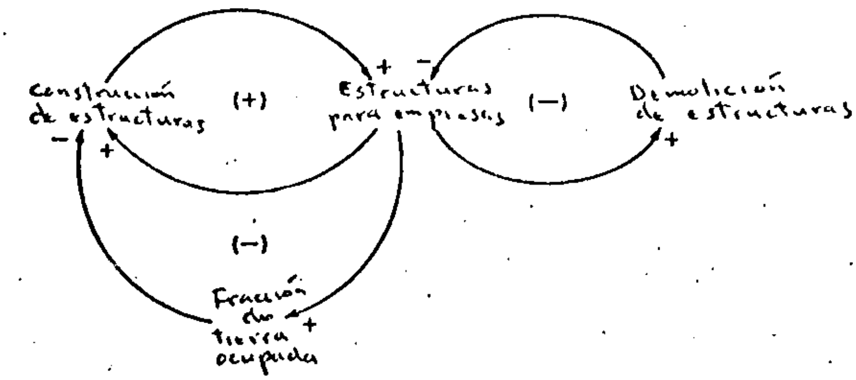


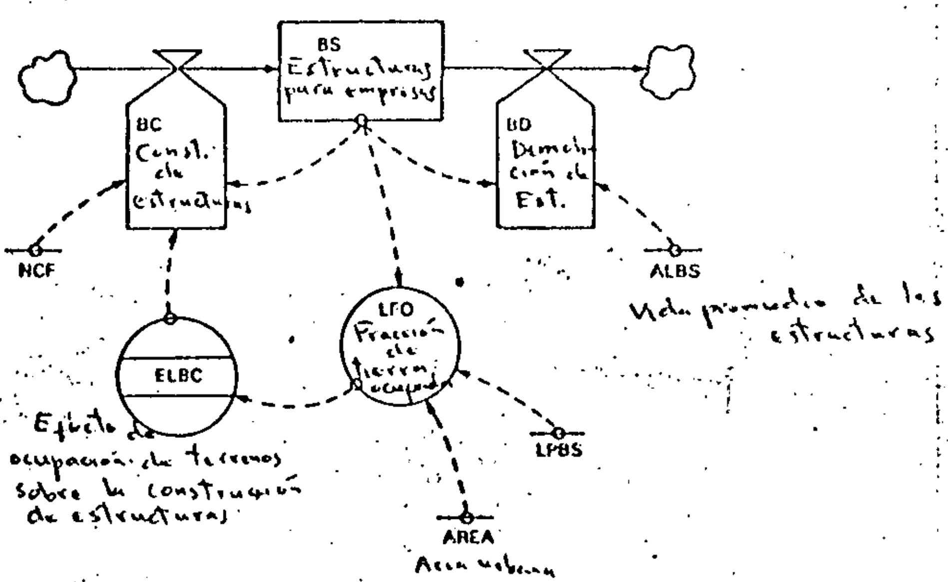
R IM.KL = (NIMF * CITPOP.K) * EPJRIM.K

R OM.KL = (CITPOP.K/NAR) * EJROM.K

ARTE PARA FORMULAR UNA FUNCION TABLA

Se ilustrará mediante un ejemplo



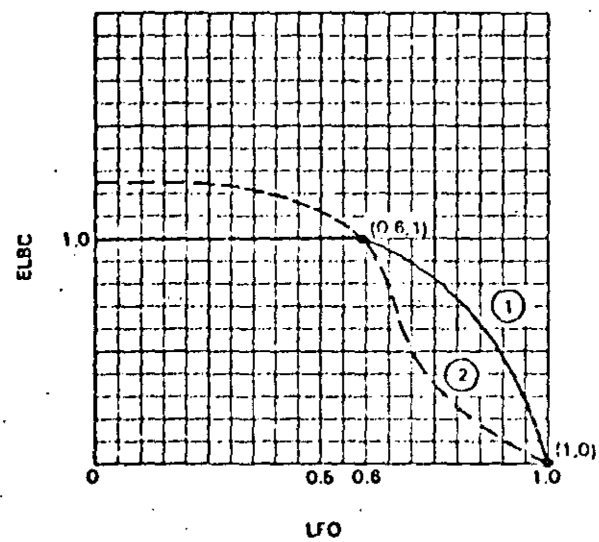


Siendo sus ecuaciones

```
L   BS.K = BS.J + DT*(BC.JK - BD.JK)
R   BC.KL = NCF * BS.K * ELBC.K
R   BD.KL = BS.K/ALBS
A   LFO.K = BS.K*LPBS/AREA
```

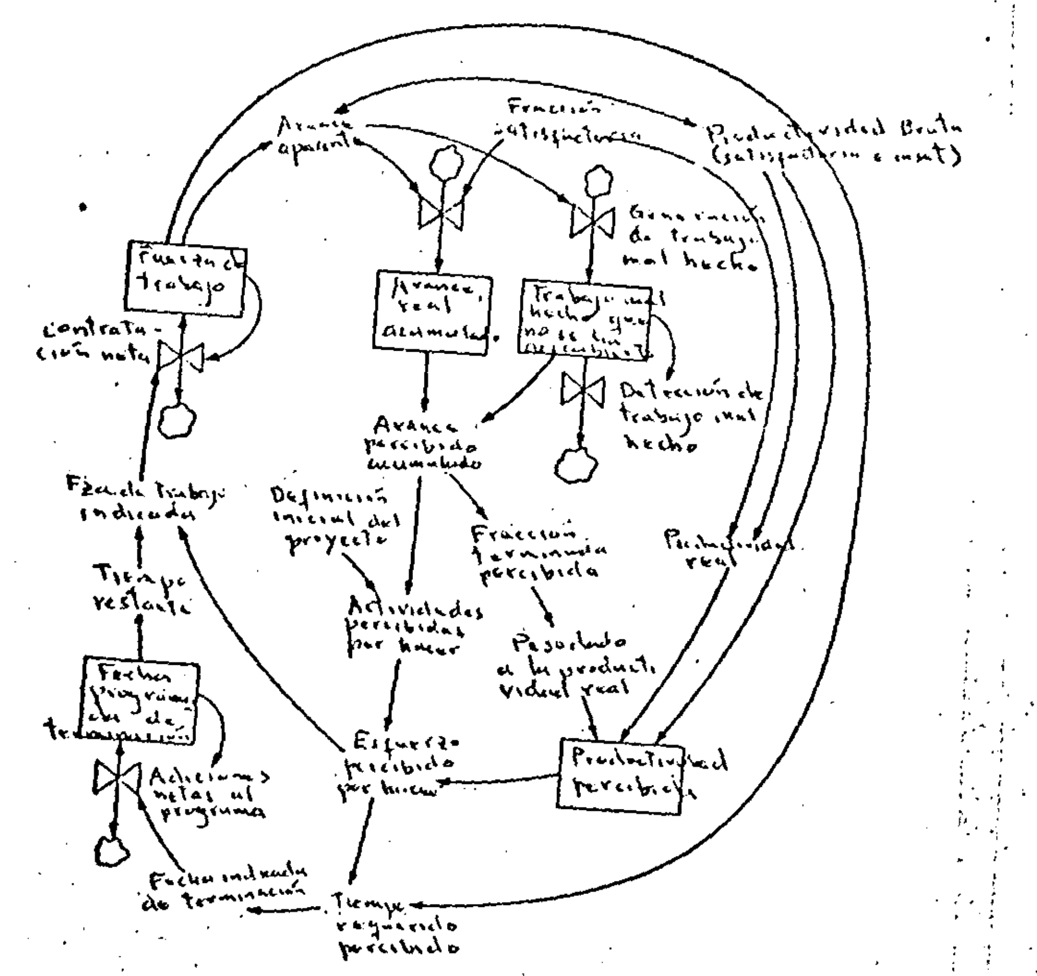
Para considerar el efecto de ocupación de los terrenos en la construcción de estructuras es necesario formular la tabla ELBC.

LFO varía de 0 (area sin personas) a 1 (ciudad totalmente construida)
ELBC debe ser 0 cuando LFO sea 1. También estamos interesados
en el valor de LFO cuando ELBC es 1, ésta es la condición
normal de referencia, donde la tasa de construcción es NCF.
Existen otras dos consideraciones. la pendiente de la tabla y su
forma.



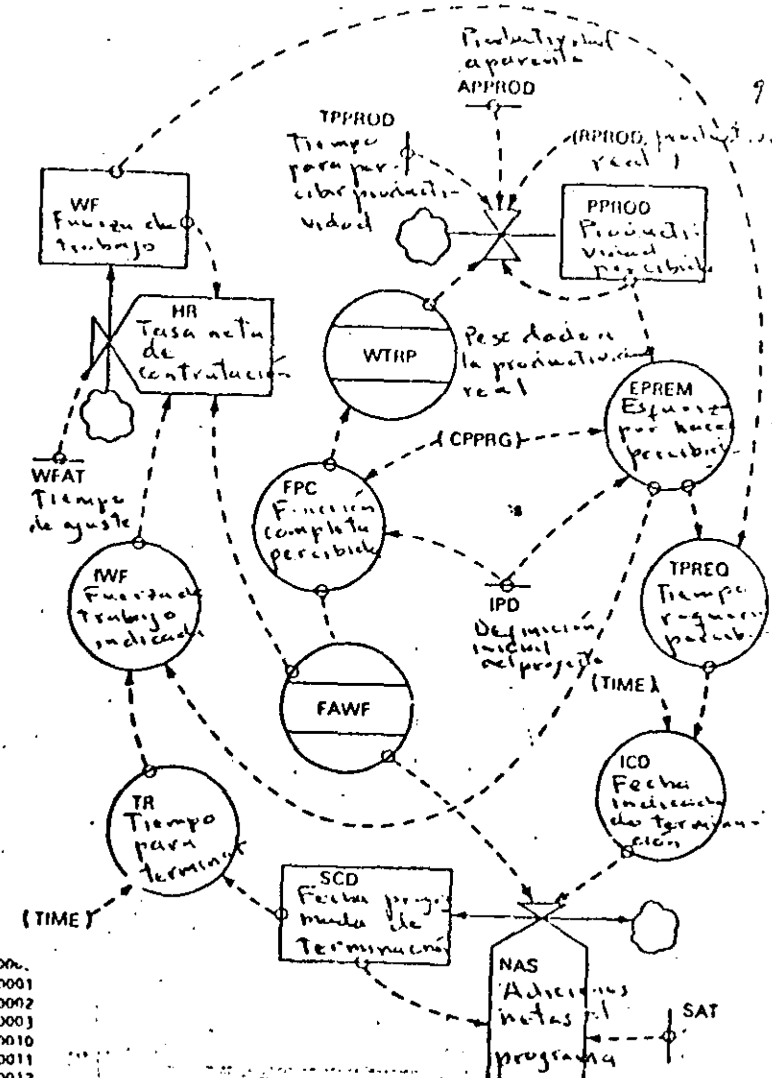
Se muestran en la figura dos posibles comportamientos.
La pendiente es negativa porque al construirse más, cada vez es
más dificil encontrar terrenos, (cuestan más, se dedican a otros usos,
se zonifica, etc).

EJEMPLO. FORMULACION DEL MODELO DEL PROYECTO.
Se presenta su diagrama causal reemplazando las variables que
se piensa son acumulaciones por niveles



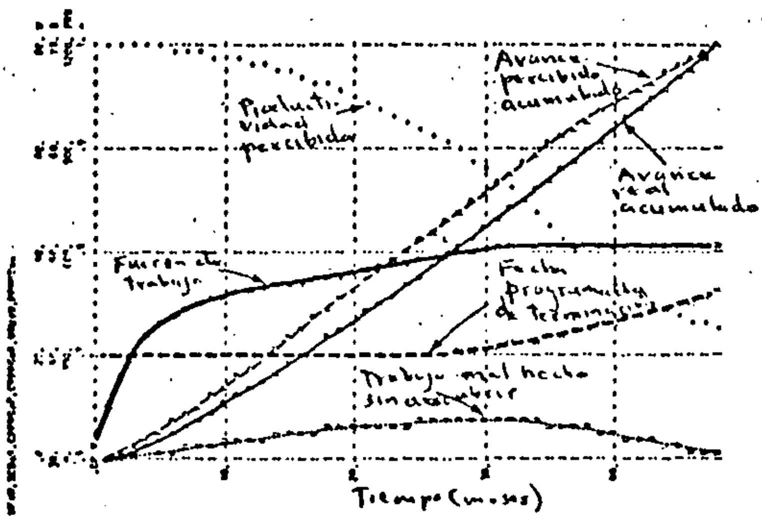
En segundo lugar se identificarán las tasas que afectan a los niveles.

Se presentan a continuación el diagrama de tasas y niveles del ejemplo, sus ecuaciones y los resultados obtenidos en la simulación.




```
NOTE
NOTE
NOTE
A   APPRG.K=WF.K*GPROD
C   GPROD=1

R   RPRG.KL=APPRG.K*FSAT
C   FSAT=0.7

L   CRPRG.K=CRPRG.J+DT*RPRG.JK
N   CRPRG=0
NOTE
NOTE
NOTE
R   GURW.KL=APPRG.K*(1-FSAT)

L   URW.K=URW.J+DT*(GURW.JK-DURW.JK)
N   URW=0
R   DURW.KL=URW.K/TDRW.K

A   TDRW.K=TABLE(TTDRW,FPCOMP.K,0,1,0.2)

T   TTDRW=12/12/12/10/5/.5
NOTE
NOTE
NOTE
A   CPPRG.K=CRPRG.K+URW.K

A   FPCOMP.K=CPPRG.K/IPD

C   IPD=1200
NOTE
NOTE
NOTE
A   EPREM.K=(IPD-CPPRG.K)/PPROD.K

A   PPROD.K=SMOOTH(IPROD.K,TPPROD)

C   TPPROD=5

A   IPROD.K=WTRP.K*RPROD.K+(1-WTRP.K)*GPROD


A   RPROD.K=GPROD*FSAT

A   WTRP.K=TABLE(TWTRP,FPCOMP.K,0,1,0.2)

T   TWTRP=0/.1/.25/.5/.9/1
NOTE
NOTE
NOTE
L   WF.K=WF.J+DT*HR.JK
N   WF=WFN
C   WFN=2
R   HR.KL=(WFS.K-WF.K)/WFAT
C   WFAT=1
A   WFS.K=WCWF.K*IWF.K+(1-WCWF.K)*WF.K
```

```
A   IWF.K=EPREM.K/TREM.K
A   WCWF.K=TABHL(TWCWF,TREM.K,0,21,3)


T   TWCWF=0/0/0/.1/.3/.7/.9/1
NOTE
NOTE
NOTE
A   TREM.K=SCD.K-TIME.K
L   SCD.K=SCD.J+DT*NAS.JK
N   SCD=SCDN
C   SCDN=40
R   NAS.KL=(ICD.K-SCD.K)/SAT

C   SAT=6
A   ICD.K=TIME.K+TPREQ.K
A   TPREQ.K=EPREM.K/WFS.K
NOTE
NOTE
NOTE
SPEC DT=.25,MAXLEN=100,PLTPER=1,PRTPER=0
A   LENGTH.K=CLIP(MAXLEN,0,1,FCOMP.K)
A   FCOMP.K=CRPRG.K/IPD

PLOT WF=W(0,80)/SCD=S(30,70)/CPPRG=P,CRPRG=R,URW=U(0,1200)/PPROD=*(.6,
X        1)
RUN BASE
```



DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

DINAMICA DE SISTEMAS (FORRESTER)

FORMULACION DEL MODELO

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FEBRERO, 1985

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FORMULACION DEL MODELO.

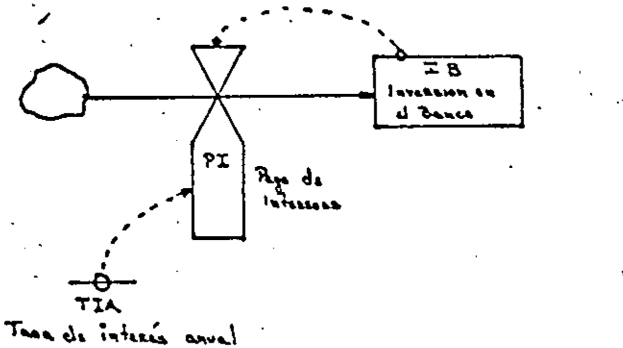
La formulación es el proceso de trasladar la estructura del modelo en ecuaciones. El punto de vista conceptual, informal, se traduce a una representación cuantitativa y formal. Se verá primero la formulación de las ecuaciones de tasa, segundo las ecuaciones auxiliares incluyéndose el arte de desarrollar una función tabla, tercero las ecuaciones de niveles y finalmente se formulará el modelo del ejemplo del proyecto visto en sesiones anteriores.

FORMULACION DE ECUACIONES DE TASA.

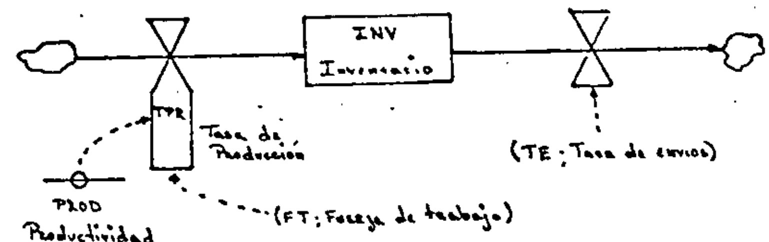
Se verán ciertas estructuras comunes, no para tomarlas como recetario, sino para evitar el que se tenga que reinventar la rueda.

CONST * NIVEL.K
NIVEL.K./VIDA
(META-NIVEL.K)/TIDEA
AUX.K*NIVEL.K y NIVEL.K./AUX.K.
NORM.K + EFECT.K
NORM.K*EFECT.K

Se presentan dos ejemplos donde es adecuado formular una tasa como CONST*NIVEL.K. Se considera apropiada esta forumulación cuando se obtiene una contestación afirmativa a la pregunta ¿si el nivel aumenta, aumenta proporcionalmente la tasa?

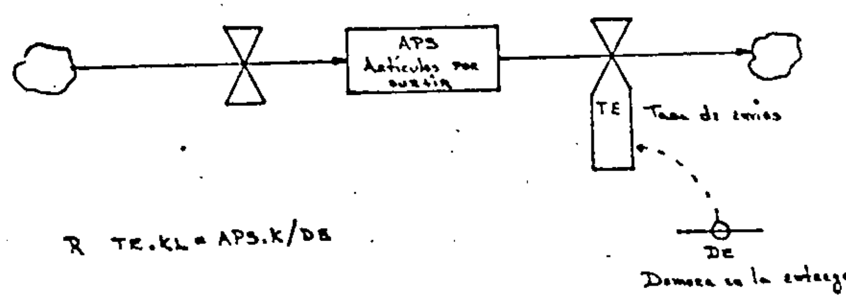


R PI.KL = TIA * IB.K



R TPR.KL = (PROD)(FT.K)

se escriben a continuación tres ejemplos donde es adecuado formular la tasa como NIVEL.K/VIDA.

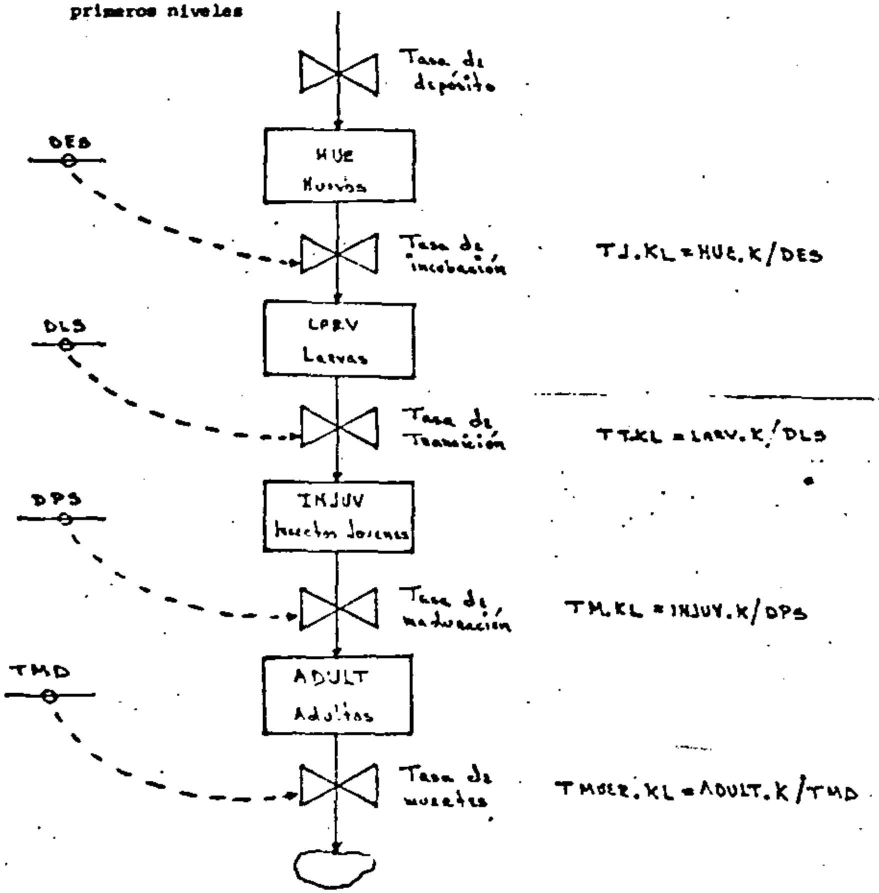


R TE.KL = APS.K/DE

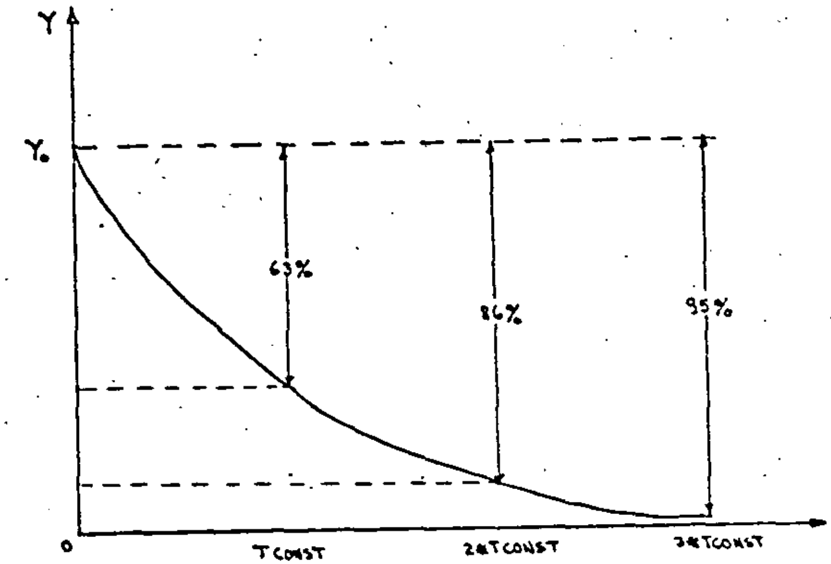
DE es el tiempo promedio en que un artículo puede permanecer en APS antes de que se envíe.

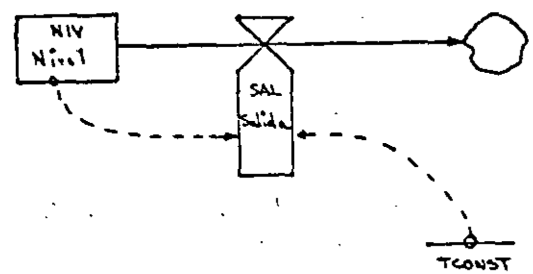
El siguiente ejemplo muestra una propiedad muy importante para las ecuaciones de tasa de la forma NIVEL.K/VIDA, observe la gráfica.

En la figura siguiente se presentan las etapas del desarrollo de un insecto, donde por simplicidad se han omitido las tasas de muerte en los 3 primeros niveles

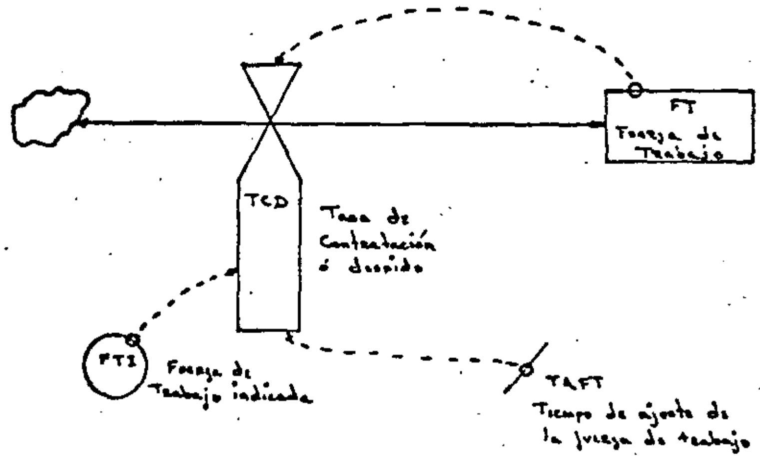


DES, DLS, DPS y TMD representan el tiempo promedio que permanece un elemento en el nivel antes de salir.



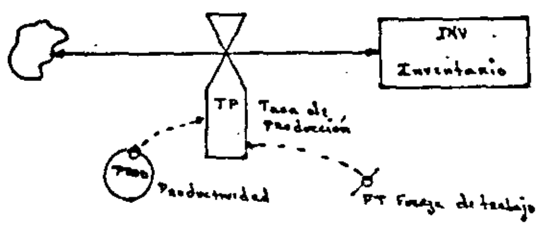


El ejemplo siguiente ilustra el uso de (META-NIVEL.K)/TIDZA

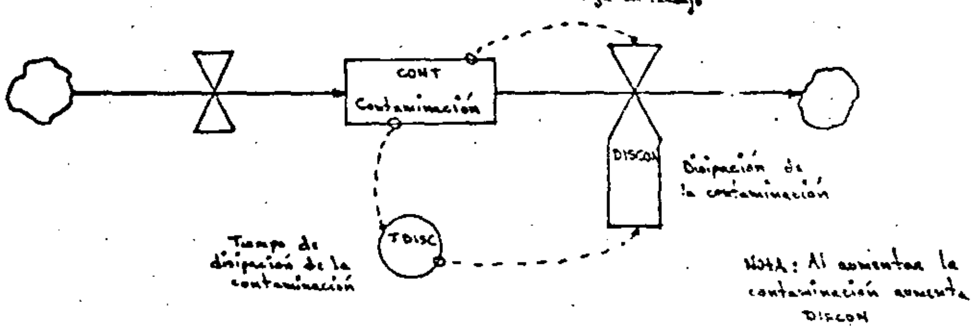


R TCD.KL = (FTI.K - FT.K)/TAFT

Los dos ejemplos siguientes muestran el empleo de AUX.K.*NIVEL.K y NIVEL.K/AUX.K respectivamente.

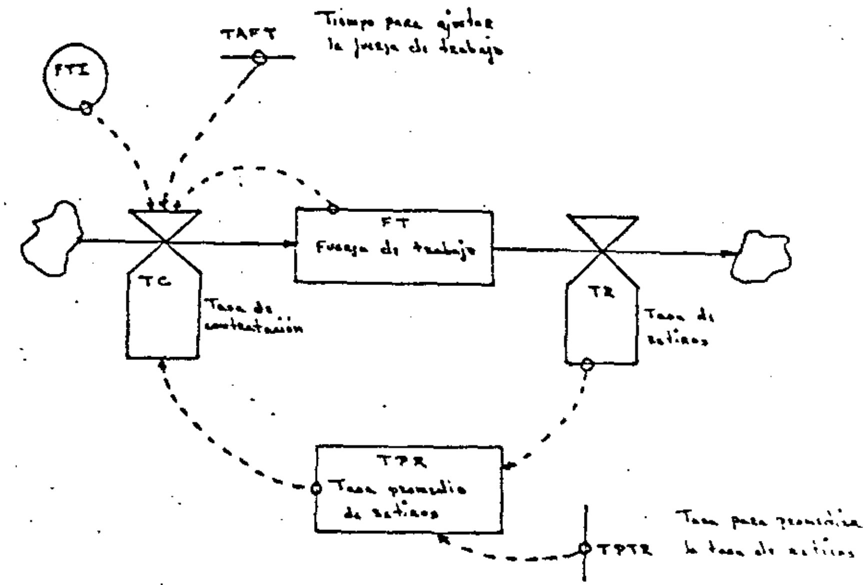


R TP.KL=PROD.K*FT.K



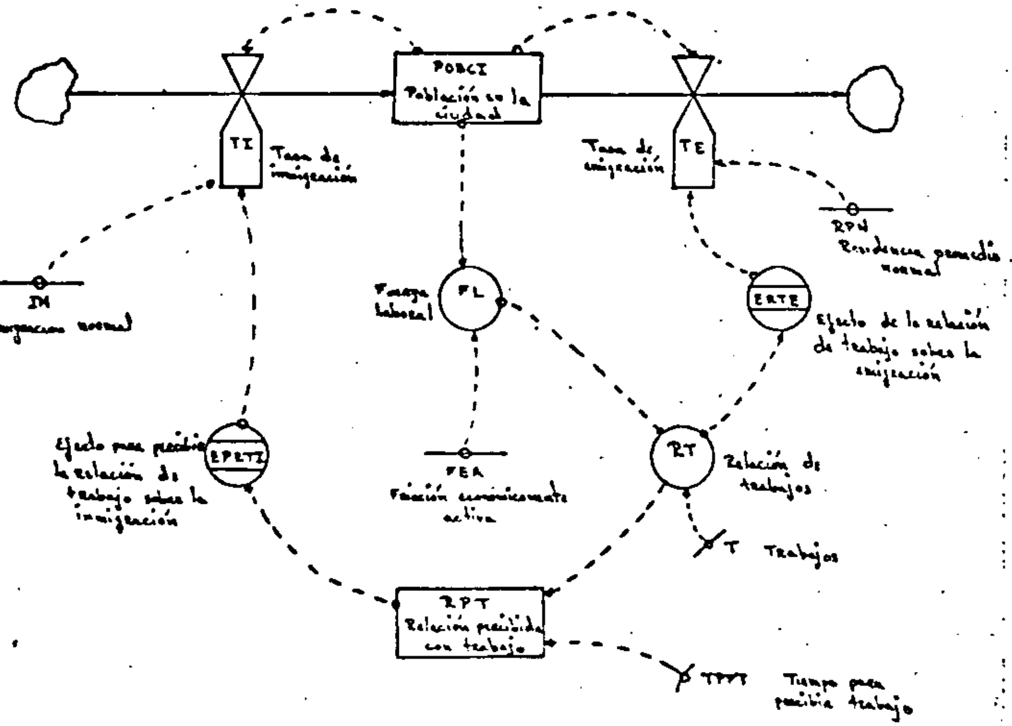
R DISCON.KL = CONT.K/TDISC.K

NORM.K. + EFECT.K se ilustra en:



R TC.KL = TPR.K + (FIJ.K - FI.K)/TAFI.

NORM.K.*EFEC.K se ilustra en



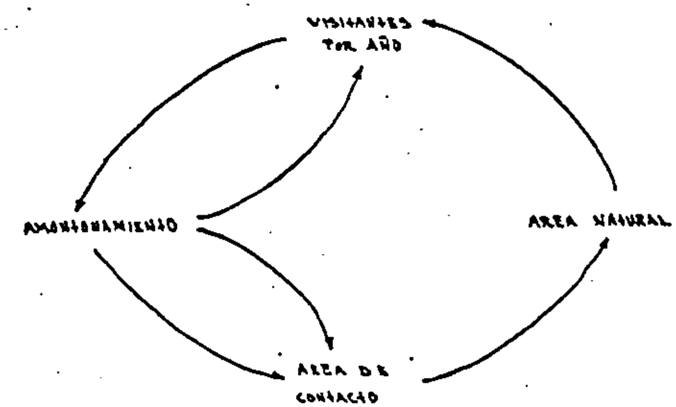
R TI.KL = (IN)(POBCI.K)(EPRII)

R TE.KL = (POBCI.K/RPN)(ERIE)

FORMULACION DE ECUACIONES AUXILIARES

Estas representan información dentro del sistema manejando ésta dentro del modelo como una expresión algebraica. Para desarrollar una ecuación auxiliar deberemos pensar en la información como una cantidad, identificar sus unidades o bien, identificar las unidades de las variables que -- convergen para determinarla.

Ejemplo:



De acuerdo al diagrama causal, es natural pensar en la variable - amontonamiento como la medida de la densidad de visitantes. Se presenta enseguida su ecuación definida como auxiliar.

A DENSV.K=VPA.K/AC.K
DENSV =DENSIDAD DE VISITANTES (PERS/AÑO/HA)
VPA =VISITANTES POR AÑO (PERS/AÑO)
AC +AREA DE CONTACTO (HA)

Otra variable auxiliar puede ser el área natural y su cálculo tiene un carácter diferente. Aparentemente sólo es función del área de contacto, ésto nos sugiere una formulación aditiva, para ello se contemplaron las unidades involucradas.

A AN.K = AREA - AC.K.
AN = AREA NATURAL (HA)
AREA = AREA TOTAL (HA)
AC = AREA DE CONTACTO (HA)

Las funciones tablas son otra forma de formular las ecuaciones auxiliares, para explicar su formulación daremos primero una guía y posteriormente un ejemplo.

GUIA PARA FORMULAR FUNCIONES TABLA

1.- Existen cuatro consideraciones potenciales en la formulación de funciones tabla: pendiente, forma, uno o más puntos específicos y una o más líneas de referencia.

2.- Defina la pendiente de la tabla conforme al signo del efecto que representa: una liga negativa se representa por una función tabla con pendiente negativa.

3.- Seleccione la forma de la curva, poniendo atención a su pendiente y curvatura en ambos extremos y en la mitad de la tabla. El aplanamiento de la función tabla corresponde a un efecto de saturación. Mientras que una forma empinada representa el fortalecimiento del efecto.

4.- Si es posible, normalice o referencie la tabla formulándola como una función de la razón de entrada con respecto a su valor de referencia. El punto de referencia está entonces claramente indicado para aquella coordenada de X con valor de 1 (uno).

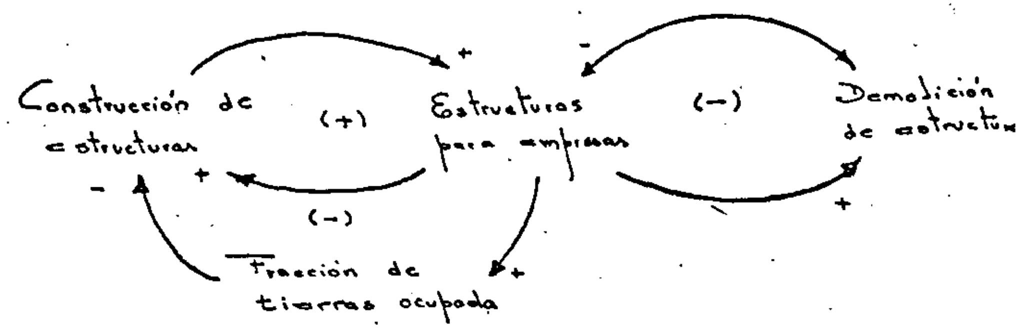
5.- Determine las coordenadas de la mayoría de los siguientes puntos:
- donde el valor de y en la tabla es 0
- donde el valor de y en la tabla es 1
- donde el valor de X en la tabla es 0
- donde el valor de X en la tabla es 1
- los extremos de X e Y en la tabla.

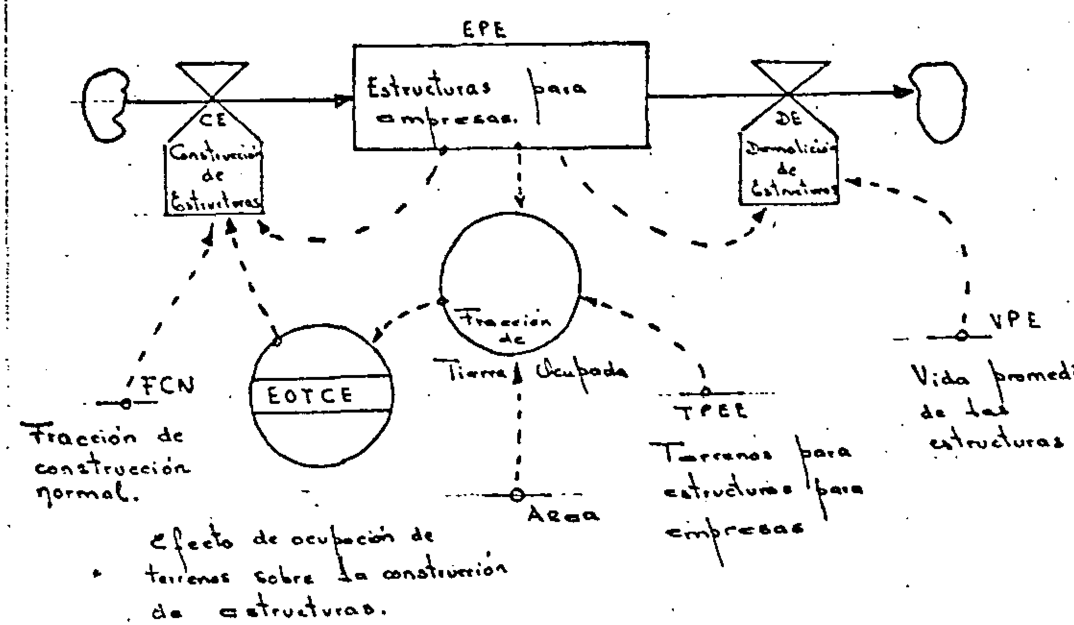
6.- Para una tabla que se utilice como multiplicador, los puntos donde las Y son 1, la variable no tiene efecto. Para una tabla que suma a la formulación, el efecto, el valor o en la tabla, representa como si no existiera la tabla.

7.- Las líneas de referencia como $y = x$, $y = yo$, $y = x_o$ pueden ser útiles para representar las condiciones ideales o deseadas, límites de saturación y otras referencias para la tabla.

Ejemplo:

Arte para formular una función tabla.





Siendo sus ecuaciones

L   EPE.K = EPE.J + (DT)(DE.JK - CE.JK)

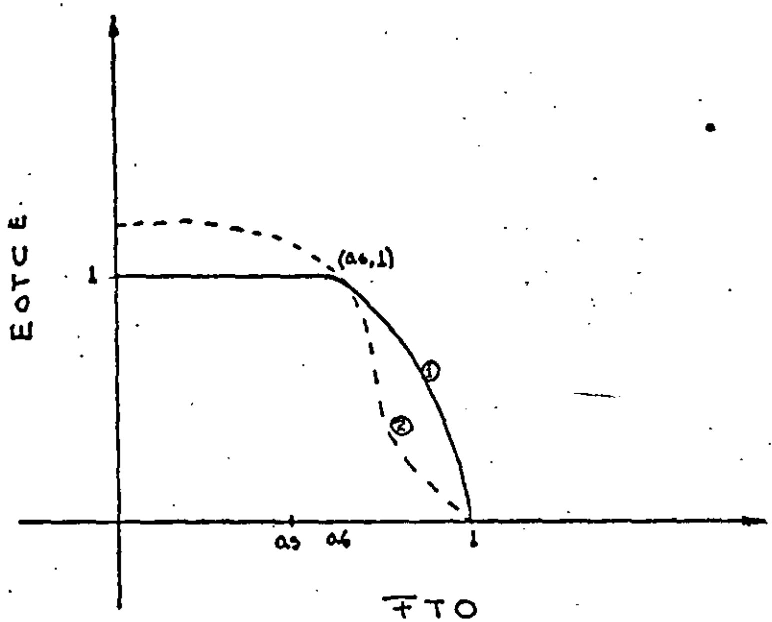
R   CE.KL = (FCN)(EPE.K)(EOTCEK)

R   DE.KL = EPE.K/VPE

A   FTO.K = (EPE.K)(TPEE)/APEA

Para considerar el efecto de ocupación de los terrenos en la construcción de estructuras es necesario formular la tabla EOTCE.FTO varía de 0 (área sin personas) a 1 (ciudad totalmente construída), EOTCE debe ser 0 cuando FIO sea 1, también estamos interesados en el valor de FIO guarda EOTCE es 1, ésta es la condición normal de referencia, donde la tasa de construcción es FCN.

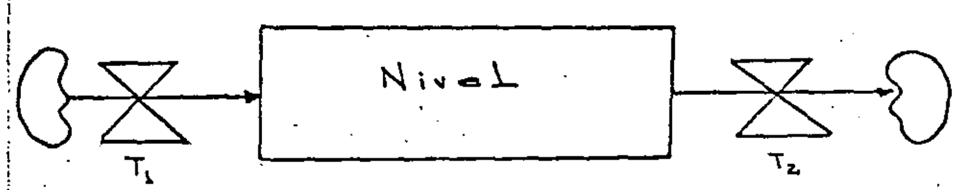
Existen otras dos consideraciones la pendiente de la tabla y su — forma.



Se muestran en la figura dos posibles comportamientos. La pendiente es negativa porque al construirse más, cada vez es más difícil encontrar - terrenos (cuesta más, se dedica a otros usos, se zonifica, etc).

FORMULACION DE ECUACIONES DE NIVEL

Sabemos que una variable de nivel es una acumulación sobre el tiempo, un almacenamiento de material, energía o información. Las tasas crecen o decrecen, el nivel se acumula y por lo tanto las ecuaciones DYNAMO para cualquier nivel tienen una forma predecible.



L   NIVEL.K = NIVEL.J + (DT)(T2.JK - TS.JK)

Cabe resaltar que no todas las acumulaciones son niveles.

Una sencilla manera de determinar los niveles potenciales dentro del sistema es la siguiente: Imagine que el tiempo en el sistema se detiene. Las variables potenciales a ser niveles son aquellas que todavía existen y — tienen un significado en la instantánea (fotografía)

La idea de detener el tiempo del modelo del sistema y tomar una fotografía instantánea nos hace pensar que existe una relación entre el -- tiempo de horizonte del modelo y el tiempo sobre el cual las diferentes variables cambian. Por ejemplo, un cambio muy lentó nos sugiere que la variable es una constante, cabe hacer notar que el tiempo de referencia es el - de la estructura del modelo, es decir, puede ser una acumulación muy lenta.

Por otro lado ya habíamos mencionado que también las variables auxiliares pueden tener acumulación. Para fijar cuáles variables serán auxiliares y cuáles niveles dentro del modelo, no siempre parecerá obvio, también deberemos, en algunos casos, contemplar el aspecto tiempo en la estructura del modelo, puede llegar a suceder que cierta variable sea más conveniente contemplarla como una auxiliar que como un nivel, tal sería el caso de -- aquellas variables que también tienen acumulación pero de manera más rápida respecto al tiempo de modelado.

FORMULACION DE PARAMETROS Y VALORES INICIALES.

Los parámetros dentro de modelos de dinámica de sistemas no requieren de mucha exactitud, esto lo detectaremos en la sesión de prueba del modelo. No se deben colocar parámetros sólo para ajustar unidades.

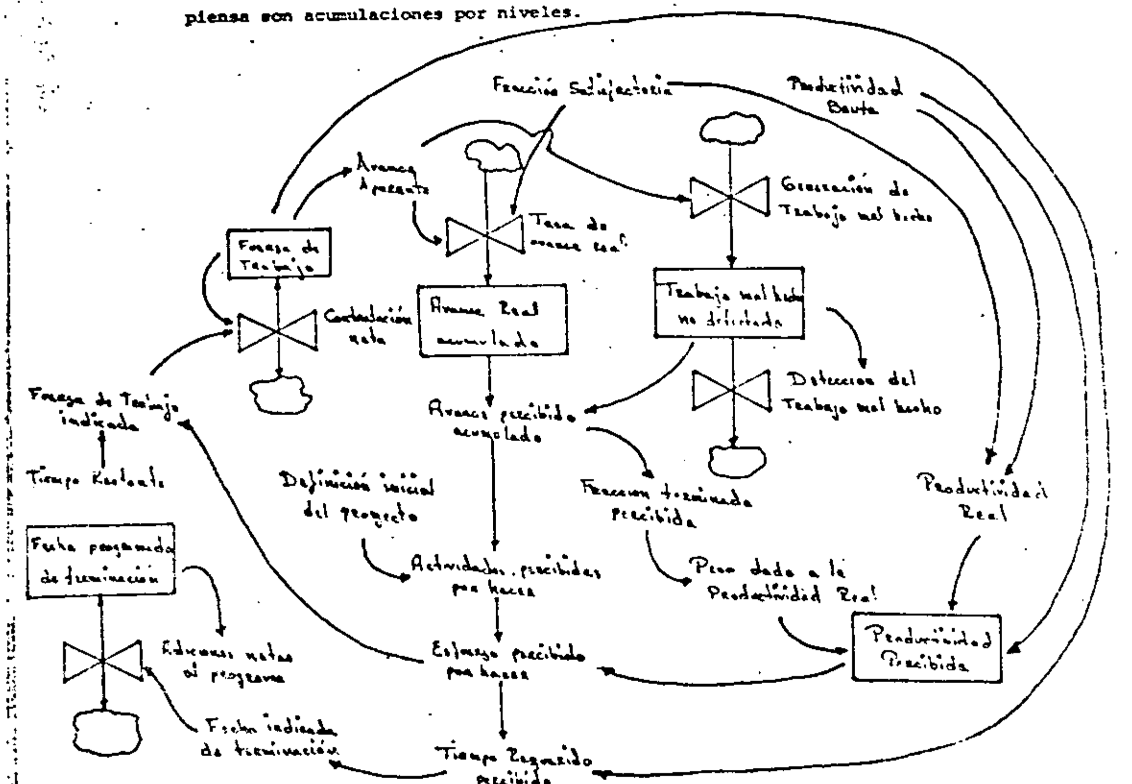
En general, los parámetros pueden estimarse de tres maneras: directamente por conocimiento del proceso, por datos o individuos relacionados con el modelo y por datos que abarcan todo el comportamiento del sistema. Parámetros que impliquen medida tienden a estimarse muy fácil pues se conocen directamente, el área de una ciudad, los habitantes de un país, etc. o bien pueden obtenerse los valores de los parámetros por simple consulta de la fuente apropiada: observación del mismo sitema real, datos, literatura o de personas. Para la tercera manera, habrá que tener cuidado en que los datos usados tengan el significado de las cantidades dentro del modelo. Terreno por vivienda en un modelo urbano es un ejemplo ingenioso, puesto que, terreno por vivienda es más que el terreno en el cual los edificios físicamente se encuentran; se incluyen en él la porción de terreno utilizada para la infraestructura requerida en una vivienda.

Para seleccionar los valores iniciales de los niveles en el modelo existen tres situaciones generales: el modelador puede decidir marcar una situación histórica, iniciar la simulación en el año 1970, o iniciar en equilibrio, ésto se presenta cuando las tasas de entrada son iguales a las tasas de salida; o bien, en algun caso particular de crecimiento (o decaimiento). Las ventajas de cada situación dependen, en sí, de propósitos del modelo. En la sesión de prueba del modelo retomaremos este punto.

Ejemplo:

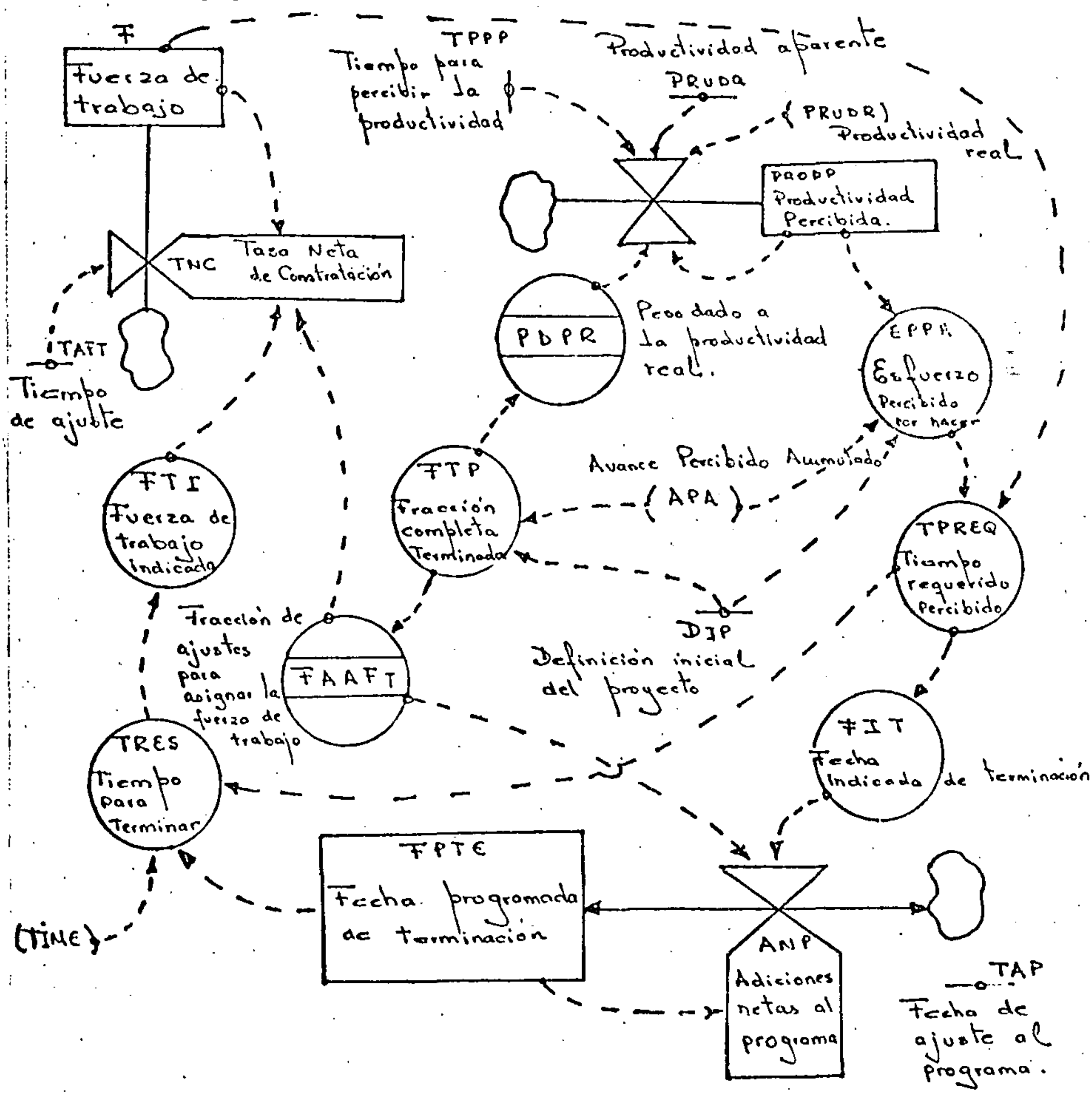
Formulación del modelo del proyecto.

Se presenta su diagrama causal reemplazando las variables que se piensa son acumulaciones por niveles.



En segundo lugar se identificarán las tasas que afectan a los niveles.

Se presentan a continuación el diagrama de tasas y niveles del ejemplo, sus ecuaciones y los resultados obtenidos en la simulación.



```
BY FILENAME

EUREKA/1

OK

BURROUGHS B6700/B7700 DYNAMO LEVEL DYN4541 6/11/82

INPUT PHASE BEGIN AT 20148 33

DYNAMO DLIST NARROW
RUN    MOPROY

       SECCION DE AVANCE REAL

A      AA.K=(F.K)(PB)
       AVANCE APARENTE (ACT/MES)
C      PB=1
       PRODUCTIVIDAD BRUTA (ACT/PERS-MES)
R      AR.KL=(AA.K)(FSAT)
       TASA DE AVANCE REAL (ACT/MES)
C      FSAT=.7
       FRACCION SATISFACTORIA (SU)
L      ARA.K=ARA.J+(DT)(AR.JK)
N      ARA=0
       AVANCE REAL ACUMULADO (ACT)

       SECCION TRABAJO MAL HECHO NO DETECTADO

R      GTMND.KL=(AA.K)(1-FSAT)
       GENERACION DE TRABAJO MAL HECHO NO DETECTADO (ACT/MES)
L      TMND.K=TMND.J+(DT)(GTMND.JK-DTM.JK)
N      TMND=0
       TRABAJO MAL HECHO NO DETECTADO (ACT)
R      DTM.KL=TMND.K/TDTM.K
       DETECCION DE TRABAJO MAL HECHO (ACT/MES)
       FTP=FRACCION TERMINADA PERCIBIDA, ES LA RELACION DE LOS TRABAJOS
       QUE SE CREYERON SATISFACTORIOS CON RESPECTO A EL NUMERO TOTAL DE
       TRABAJOS INICIALMENTE PROGRAMADOS

       SECCION DE AVANCE PERCIBIDO

A      TDTM.K=TABLE(TDTMT,FTP.K,0,1,.2)
       TDTMT*=12/12/12/10/5/.5
       TABLA TIEMPO PARA DETECTAR TRABAJO MAL HECHO (MES)
A      APA.K=ARA.K+TMND.K
       AVANCE PERCIBIDO ACUMULADO (ACT)
A      FTP.K=APA.K/DIP
       FRACCION TERMINADA PERCIBIDA (SU)
```

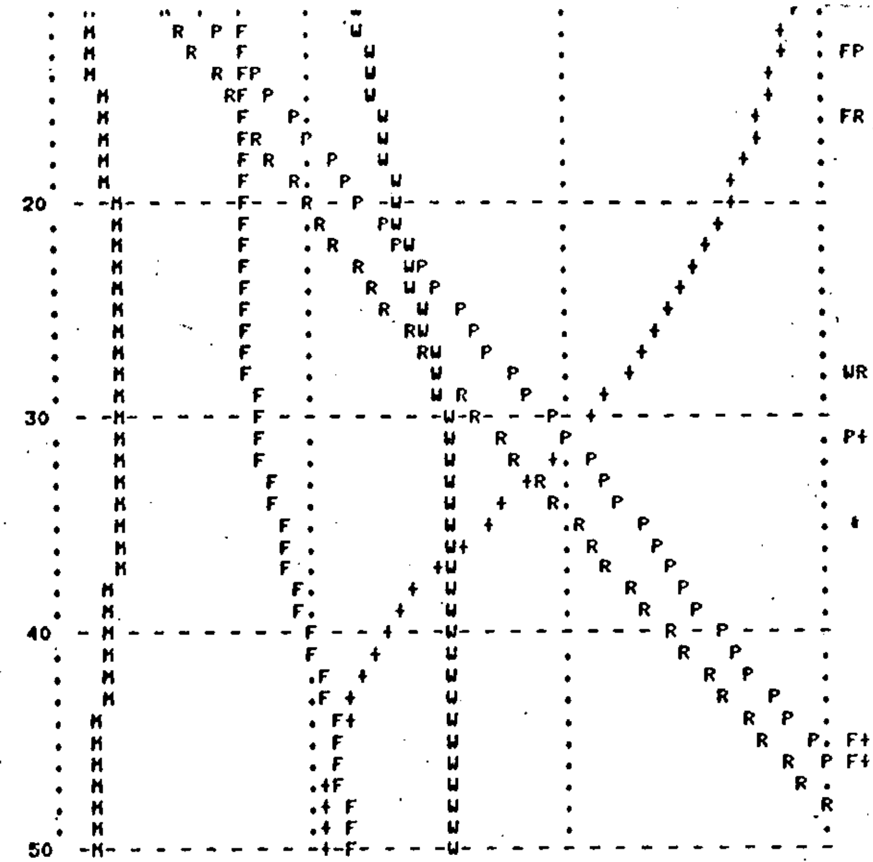


```
DIP=1200
DEFINICION INICIAL DEL PROYECTO (ACT)

SECCION ESFUERZO RESTANTE PERCIBIDO

EPPH.K=(DIP-APA.K)/PRODP.K
ESFUERZO PERCIBIDO POR HACER (HOM*MES)
PRODI.K=(PDPR.K)(PRODR.K)+(1-PDPR.K)(PB)
PRODUCTIVIDAD INDICADA (ACT/HOM-MES)

SUAVIZANDO LA PRODUCTIVIDAD PERCIBIDA

PRODP.K=PRODP.J+(DT)(PRODI.J-PRODP.J)/TPPP
PRODP=PRODI
PRODUCTIVIDAD PERCIBIDA (ACT/HOM-MES)
TPPP=6
TIEMPO PARA PERCIBIR LA PRODUCTIVIDAD (MES)
PRODR.K=AR.K/F.K
PRODUCTIVIDAD REAL (ACT/HOM-MES)
PDPR.K=TABLE(PDPRT,FTP.K,0,1,.2)
PDPRT*=0/.1/.25/.5/.9/1
PDPR=PESO A LA PRODUCTIVIDAD REAL (SU)
TABLA QUE RELACIONA EL PESO A LA PRODUCTIVADAD REAL CON
RESPECTO A LA FRACCION TERMINADA PERCIBIDA

SECCION DE CONTRATACION

F.K=F.J+(DT)(TNC.JK)
FUERZA DE TRABAJO (HOM)
F=FTC
FTC=2
VALOR INICIAL DE LA FUERZA DE TRABAJO (HOM)
TNC.KL=(FTR.K-F.K)/TAFT
TASA NETA DE CONTRATACION (HOM/MES)
TAFT=3
VALOR INICIAL DEL TIEMPO PARA AJUSTAR LA FUERZA DE TRABAJO (HOM)
FTR.K=(DCFT.K)(FTI.K)+(1-DCFT.K)(F.K)
FUERZA DE TRABAJO REQUERIDA (HOM)
FTI.K=EPPH.K/TRES.K
FUERZA DE TRABAJO INDICADA (HOM)
DCFT.K=TABHL(DCFTT,TRES.K,0,21,3)
DISPONIBILIDAD A CAMBIAR LA FUERZA DE TRABAJO (SU)
DCFTT*=0/0/0/.1/.3/.7/.9/1

SECCION DE MODIFICACIONES AL PROGRAMA

TRES.K=FPTE.K-TIME.K
TIEMPO RESTANTE (MES)
FPTE.K=FPTE.J+(DT)(ANP.JK)
FECHA PROGRAMADA DE TERMINACION (MES)
FPTE=FPTEI
```

```
C       FPTEI=40
        VALOR INICIAL DE LA FECHA PROGRAMADA DE TERMINACION (MES)
R       ANP.KL=(FIT.K-FPTE.K)/TAP
        ADICIONES NETAS AL PROGRAMA (SU)
C       TAP=6
        VALOR INICIAL DEL TIEMPO DE AJUSTE AL PROGRAMA (MES)
A       FIT.K=TPREQ.K+TIME.K
        FECHA INDICADA DE TERMINACION (MES)
A.      TPREQ.K=EPPH.K/FTR.K
        TIEMPO PERCIBIDO REQUERIDO (MES)

        ORDENES DE CONTROL

SPEC  DT=.25/LENGTH=50/PLTPER=1/PRTPER=0
PLOT  F=W(0,80)/FPTE=F(30,70)/APA=P,ARA=R,TMND=M(0,1200)/PRODP=+(.6,1)
#7345 (LM70)PROGRAMFILE/DYNAMO REMOVED ON PACK PK117 .

INPUT PHASE CONCLUDED AT  20:50 59

GENERATION PHASE BEGAN AT 20:51  0
#7345 2000 SECT REQ ON PACK PK117 *

?STA
#20:52 2000 SECT REQ ON PACK PK117 * ET=4:58.0 PT=11.7 IO=2.4
?STA
#20:53 2000 SECT REQ ON PACK PK117 * ET=5:23.5 PT=11.8 IO=2.4

??DEL
?STA
#20:55 2000 SECT REQ ON PACK PK117 * ET=7:11.1 PT=12.1 IO=2.4
?STA
#20:56 2000 SECT REQ ON PACK PK117 * ET=8:50.0 PT=13.0 IO=2.4

#7345 GOING


?STA
#20:58 ET=11:00.6 PT=17.4 IO=5.3
RUN  PHASE  GENERATED AT  20:59  5
PRINT PHASE GENERATED AT  20:59  5
PLOT PHASES GENERATED AT  20:59 10

ELAPSED COMPILATION TIME      11  7


PLEASE ENTER COMPILE EUREKA/1          WITH ALGOL.  THEN
WAIT UNTIL YOUR TERMINAL REPORTS THAT YOUR COMPILATION
IS COMPLETE.  AFTER GOOD COMPILATION ENTER  EXECUTE
EUREKA/1
```



```
#ET=11:22.7 PT=20.2 IO=7.7
COMPILE EUREKA/1 WITH ALGOL
#SCHD 7452
#COMPILING 7452
$SET BCL RESET LIST
00001000 WARNING:BCL PROGRAMS ARE NOT PORTABLE TO EBCDIC MACHINES.

#QUEUED
?STA
#21:02 ET=1:59.5 PT=14.2 IO=8.3
#ET=2:06.0 PT=15.7 IO=9.0
#
RUN EUREKA/1
#RUNNING 7464

PAGE  1    MOPROY

                  21:02.6250, 12 JUNE 1982

           STARTED TO RUN CODE AT 21:02.6322, 12 JUNE 1982

#7464 1000 SECT REQ ON PACK PK117 *

?STA
#21:07 1000 SECT REQ ON PACK PK117 * ET=4:30.9 PT=1.4 IO=1.1
?STA
#21:10 1000 SECT REQ ON PACK PK117 * ET=7:55.6 PT=2.0 IO=1.1
#7464 GOING

PAGE  2    MOPROY

           BEGAN PLOTTING AT 21:12.2858, 12 JUNE 1982

      F=W, FPTE=F, APA=P, ARA=R, TMND=M, PRODP=+

      0.0              26.7                53.3                80.0  W
     30.0              43.3                56.7                70.0  F
      0.0             400.0               800.0              1200.0  PRM
      0.6               0.7                 0.9                 1.0  +
    P W - - - - - -F- - - - - - - - - - - - - - - - - - - - - - - + PRM
    P       W     F   .                    .                      + PRM
    MP          W F   .                    .                      + FR
    .RP           FW  .                    .                      + RM
    .MRP          F  W .                   .                      +
    .M RP         F    W                   .                      +
    .M  RP        F    .W                  .                     +.
    . M  R P      F    . W                 .                     +.
    . M   R P     F    .  W                .                     +.
    . M    R P    F    .  W                .                     +.
 10 -M- - R -P- -F- - - - W - - - - - - - - - - - - - - - - - - + -
    . M     R P   F    .   W                                     +
```



FINISHED RUN NUMBER MODPROY AT 21:14.5661, 12 JUNE 1982
#ET=12:11.1 PT=5.0 IO=3.3
SA
#WORKSOURCE ALREADY SAVED

PRUEBA DEL MODELO.-

El proceso de modelado de Dinámica de Sistemas es iterativo, pasando por las secuencias de conceptualización, formulación, prueba (simulación) reconceptualización y refinamiento.

Con objeto de analizar las relaciones entre estructura y comportamiento se considerarán los cambios en parámetros y funciones tabla para desactivar los circuitos de retroalimentación.

Una manera muy general para desactivar lazos es aplicar el principio a ecuaciones de la forma (META-NIVEL.K)/TIDEA. Si hacemos TIDEA muy grande, la tasa se hace cero.

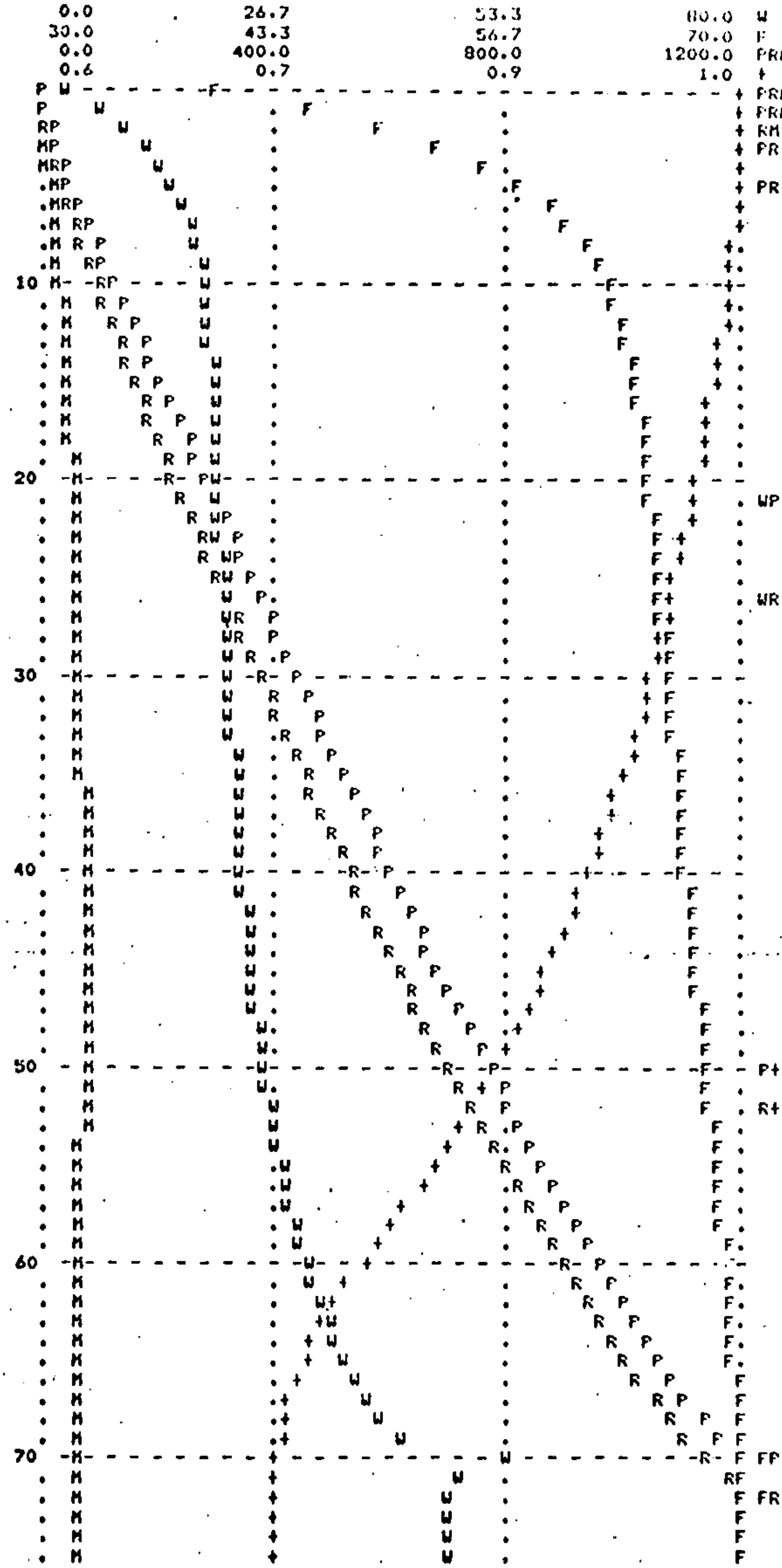
Utilizando el modelo del proyecto realizaremos algunas pruebas para obtener un modelo revisado.

Si en el listado original (el proporcionado en la sesión de formulación del modelo hacemos el siguiente cambio en DCFTT tendremos:

Modelo base	DCFTT*=0/0/0/ .1/.3/.7/.9/1
Modificación	DCFTT*=.5/.5/.5/.5/.5/.5/.5/.5

obtendremos la siguiente simulación.

F=W, FPIC-F, APA-P, ARA-R, INNO-M, PROUP-I



54

FINISHED RUN NUMBER MOPROY AT 0154.9942, 15 JUNE 1982
8A
@QUEUED
@ET=3:46.9 PT=5.2 IO=3.4
@NO WORK FILE

Uso de funciones prueba.

Usualmente estas funciones son usadas para causar un disturbio al modelo, ésto es conveniente realizarlo en alguno de los sectores del modelo.

Considerando la versatilidad de DYNAMO para experimentar, es conveniente planear una sucesión de simulaciones que se enfoquen en un elemento particular de la estructura. Analizando de antemano el comportamiento esperado, escribiendo las hipótesis y comprobándolas en el comportamiento observado. Si aparece comportamiento inesperado, analizarlo. Todo debe anotarse no permitiendo el confiar en la memoria.

Sensibilidad:

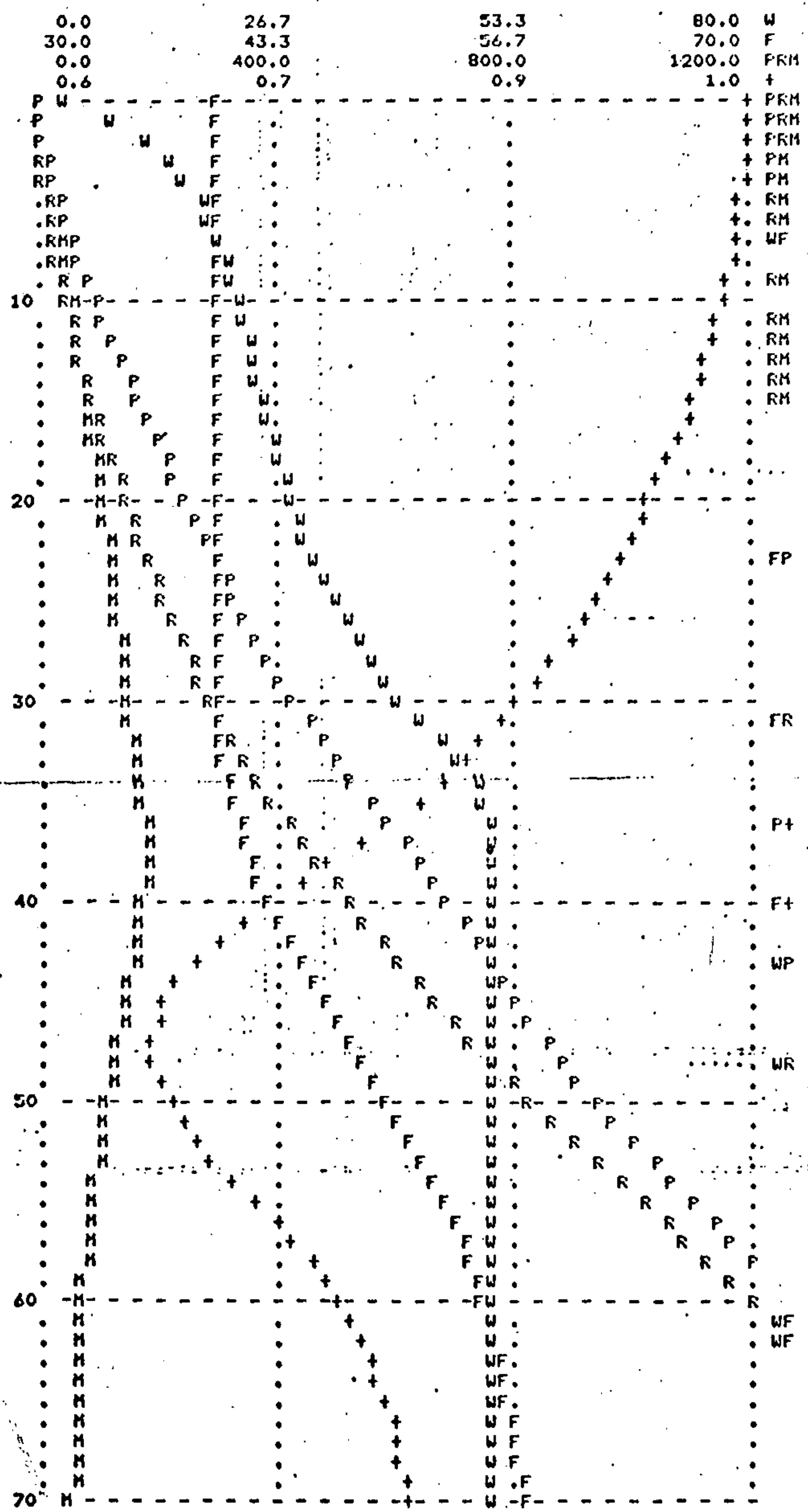
La credibilidad de un modelo basada en el análisis y recomendaciones de políticas se logrará cuando el modelador conozca hasta qué punto dichos cambios no afectan las condiciones basadas en el modelo acerca del sistema real.

En un modelo se pueden analizar tres clases de sensibilidad: La numérica, que se refiere a los cambios de valores que se presentarán en la simulación, en parámetros o estructuras del modelo; la de comportamiento, referida ésta al cambio que se sufre al modificar un parámetro o al formular alguna alternativa; la de políticas, las cuales deberán reflejar el comportamiento del modelo con el mundo real.

Veamos cómo un cambio de valor en FSAT, en el modelo del proyecto, no es muy significativo en la simulación, se cambio FSAT de 0.7 a 0.5

BEGAN PLOTTING AT 17:50.4589, 5 JULY 1982

F=W, FPTE=F, APA=P, ARA=R, TMND=M, PROOP=+



57

FINISHED RUN NUMBER MOPROY AT 17:53.6119, 5 JULY 1982

Es obvio pensar que las estructuras y los parámetros del modelo se encuentran relacionados y para analizar sus relaciones se pueden seguir las siguientes estrategias: cambiando la estructura, modificando los valores de los parámetros; reemplazando las funciones tablas por constantes y utilizando funciones prueba.

En el caso de funciones tabla podemos realizar pruebas alternas ello lo logramos modificando los valores establecidos en el modelo base para aquellas tablas que de alguna manera afectan el comportamiento del modelo en general, para ello se simularía y se analizarían los resultados obtenidos.

En la mayoría de los casos los modelos dinámicos tienden a ser menos sensitivos a cambios en parámetros que a cambios en estructuras debiéndose a dos causas; primera, la existencia de un circuito de retroalimentación dominante y segunda a la existencia de un circuito de retroalimentación compensador.

Refinaiento y Reformulación.

No hay que olvidar que el proceso de modelar es un proceso iterativo y como ya mencionamos en otra sesión incluye los pasos de conceptualización, formulación, simulación y evaluación. El propósito de este proceso iterativo es producir un modelo altamente consistente con el sistema real, con propósitos bien definidos y bien entendidos.

Las estrategias para reformular el modelo pueden ser: descomposición de un nivel en dos o más; transformación de constantes en variables que enriquezcan nuestras hipótesis dinámicas o bien añadiendo nuevos circuitos de ciertas variables, utilizadas en el modelo.

En el caso de la reformulación de un nivel, deberemos hacer las siguientes consideraciones: si nuestro análisis de políticas se beneficia, es decir, si añadimos aquella política que existe en el sistema real a nuestro modelo; el comportamiento del modelo es otra consideración muy importante, si desactivamos el modelo nivel en dos o más niveles podría suceder que sufriéramos cambios significativos en el comportamiento.

Al hacer esta modificación podríamos tener como consecuencia que el número de ecuaciones se nos dupliquen y caer en ciertas consideraciones absurdas como sería el hecho de valores contrarios al comportamiento del sistema real.

En el modelado de Dinámica de Sistemas, como en cualquier otra clase de modelado, nos surge la interrogante de saber hasta cuándo cesar en la reformulación o refinamiento del modelo. Mientras no se afecte la validez del modelo podremos refinarlo en tanto se sienta que es un nivel adecuado al que llegamos. Si los propósitos han sido logrados con un cierto nivel de refinamiento, entonces, podemos suspender y en general, otro grupo de recomendaciones que se hacen sin definir algo conreto, sería el considerar la validez como buen indicador.

Validez.

Ya arriba mencionamos que el propósito del modelo era el permitirnos simular el comportamiento del sistema real. Pero debemos tener presente que el modelo se dirije a un problema y nó al sistema, es decir, sólo esta diseñado para responder a un conjunto bien definido de problemas.

En Dinámica de Sistemas la validación es un grupo de actividades entremezcladas a travês del proceso iterativo de la construcción del modelo.

Para nuestro propósito la validez es más útil llevarla a dos preguntas.

- ¿Es el modelo conveniente hacia los propósitos del problema al que esta dirigido?

- ¿Es el modelo consistente no obstante la realidad que se quiere conseguir?

Ejemplo:

Después de varias pruebas se presenta el modelo revisado del proyecto y las simulaciones correspondientes.

```
L
#NO WORK FILE
L DYNAMOTRE/2DEL
GET DYNAMPODEL
GET DYNAMOTRE/2
#WORKFILE DYNAMOTRE/2: SEQ, 165 RECORDS, SAVED
L
100 REMOTE
200 DYNAMO NARROW
300 RUN   MOPROY
400 NOTE
500 NOTE  SECCION DE AVANCE REAL
600 NOTE
610 L     ARA.K=ARA.J+(DT)(TARA.JK)
620 N     ARA=0
630 NOTE  AVANCE REAL ACUMULADO  (ACT)
640 R     TARA.KL=(TAP.K)(FSAT.K)
650 NOTE  TASA DE AVANCE REAL  (ACT/MES)
660 A     TAP.K=(F.K)(PB.K)(EPPPB.K)
670 NOTE  AVANCE APARENTE  (ACT/MES)
680 A     PB.K-(NPB)(EEPB.K)
690 NOTE  PRODUCTIVIDAD BRUTA  (ACT/HOM/MES)
700 C     NPB=1
710 NOTE  PRODUCTIVIDAD BRUTA NORMAL (ACT/HOM/MES)
720 A     FSAT.K=(FSATN.K)(EEXPFS.K)(EPPFS.K)
730 NOTE  FRACCION SATISFACTORIA
740 A     FSATN.K=TABLE(FSATNT,FT.K,0,1,.2)
750 NOTE  FRACCION SATISFACTORIA NORMAL
760       FSATNT*=.5/.55/.63/.75/.9/1
770 NOTE  TABLA DE LA FSATN
780 NOTE
790 NOTE  EFECTOS DE LA EXPERIENCIA Y LA PRESION EN LA PROGRAMACION
800 NOTE
810 A     EEPB.K=TABLE(EEPBT,FFE.K,0,1,.2)
820 NOTE  EFECTO DE LA EXPERIENCIA SOBRE LA PRODUCTIVIDAD  BRUTA (SU)
830       EEPBT*=.5/.55/.65/.75/.87/1
840 NOTE  TABLA DE  LA EEPB
850 A     FFE.K=FTEX.K/F.K
860 NOTE  FRACCION DE LA FUERZA DE TRABAJO EXPERIMENTADA (SU)
870 A     EEXPFS.K=TABLE(EEXPFT,FFE.K,0,1,.2)
880 NOTE  EFECTO DE LA EXPERIENCIA SOBRE LA FRACCION SATISFACTORIA  (SU)
890       EEXPFT*=.5/.6/.7/.8/.9/1
900 NOTE  TABLA PARA EL EEXPFS
910 A     EPPFS.K=TABLE(EPPFST,FIT.K/FPTE.K,.9,1.2,.05)
920 NOTE  EFECTO DE LA PRESION DE LA PROGRAMACION SOBRE LA FRACCION
930 NOTE  SATISFACTORIA (SU)
940       EPPFST*=1.1/1.06/1/.96/.9/.83/.75
950 NOTE  TABLA PARA EPPFS
960 A     EPPPB.K=TABLE(EPPPBT,FIT.K/FPTE.K,.9,1.2,.05)
970 NOTE  EFECTO DE LA PRESION DE LA PROGRAMACION SOBRE LA
980 NOTE  PRODUCTIVIDAD BRUTA  (SU)
990       EPPPBT*=.9/.92/1/1.1/1.18/1.23/1.25
1000 NOTE  TABLA PARA EPPPB
1800 NOTE
1900 NOTE  SECCION TRABAJO MAL HECHO NO DETECTADO
2000 NOTE
2100 R     GTMND.KL=(TAP.K)(1-FSAT.K)
2200 NOTE  GENERACION DE TRABAJO MAL HECHO NO DETECTADO (ACT/MES)
2300 L     TMND.K=TMND.J+(DT)(GTMND.JK-DTM.JK)
2400 N     TMND=0
2500 NOTE  TRABAJO MAL HECHO NO DETECTADO (ACT)
2600 R     DTM.KL=TMND.K/TDTM.K
2700 NOTE  DETECCION DE TRABAJO MAL HECHO (ACT/MES)
2800 NOTE  FTP=FRACCION TERMINADA PERCIBIDA, ES LA RELACION DE LOS TRABAJOS
2900 NOTE  QUE SE CREYERON SATISFACTORIOS CON RESPECTO A EL NUMERO TOTAL DE
3000 NOTE  TRABAJOS INICIALMENTE PROGRAMADOS
3100 NOTE
3200 NOTE  SECCION DE AVANCE PERCIBIDO
3300 NOTE
3400 A     TDTM.K=TABLE(TDTMT,FTP.K,0,1,.2)
3500       TDTMT*=12/12/12/10/5/.5
3600 NOTE  TABLA TIEMPO PARA DETECTAR TRABAJO MAL HECHO (MES)
3700 A     APA.K=ARA.K+TMND.K
3800 NOTE  AVANCE PERCIBIDO ACUMULADO (ACT)
3900 A     FTP.K=APA.K/DPP.K
4000 NOTE  FRACCION TERMINADA PERCIBIDA (SU)
4100 A     DPP.K=TABLE(DPPT,FT.K,0,1,.2)
4110 NOTE  DEFINICION PREVALECIENTE DEL PROYECTO (ACT)
4120       DPPT*=800/830/900/1000/1140/1200
4130 NOTE  TABLA PARA DPP
4140 N     DFP=1200
4150 NOTE  DEFINICION FINAL DEL PROYECTO (ACT)
4160 A     FT.K=ARA.K/DFP
4170 NOTE  FRACCION TERMINADA (SU)
4300 NOTE
4400 NOTE  SECCION ESFUERZO RESTANTE PERCIBIDO
4500 NOTE
```

```
4600 A      EPPH.K=(DPP.K-APA.K)/PRODP.K
4700 NOTE   ESFUERZO PERCIBIDO POR HACER (HOM*MES)
4800 A      PRODI.K=(PDPR.K)(PRODR.K)+(1-PDPR.K)(NPB)
4810 N      PRODI=NPB
4900 NOTE   PRODUCTIVIDAD INDICADA (ACT/HOM-MES)
5000 NOTE
5100 NOTE   SUAVIZANDO LA PRODUCTIVIDAD PERCIBIDA
5200 NOTE
5300 L      PRODP.K=PRODP.J+(DT)(PRODI.J-PRODP.J)/TPPP
5400 N      PRODP=1
5500 NOTE   PRODUCTIVIDAD PERCIBIDA (ACT/HOM-MES)
5600 C      TPPP=6
5700 NOTE   TIEMPO PARA PERCIBIR LA PRODUCTIVIDAD (MES)
5800 A      PRODR.K=(NPB)(FSAT.K)
5900 NOTE   PRODUCTIVIDAD REAL (ACT/HOM-MES)
6000 A      PDPR.K=TABLE(PDPRT,FTP.K,0,1,.2)
6100        PDPRT*=0/.1/.25/.5/.9/1
6200 NOTE   PDPR=PESO A LA PRODUCTIVIDAD REAL (SU)
6300 NOTE   TABLA QUE RELACIONA EL PESO A LA PRODUCTIVADAD REAL CON
6400 NOTE   RESPECTO A LA FRACCION TERMINADA PERCIBIDA
6500 NOTE
6600 NOTE   SECCION DE CONTRATACION
6700 NOTE
6800 L      F.K=FTEX.K+NFT.K
6900 NOTE   FUERZA DE TRABAJO (HOM)
6910 L      FTEX.K=FTEX.J+(DT)(TAF.JK)
6920 NOTE   FUERZA DE TRABAJO EXPERIMENTADA (HOM)
6930 N      FTEX=FTEXN
6940 C      FTEXN=2
6950 NOTE   VALOR INICIAL DE LA FUERZA DE TRABAJO EXPERIMENTADA
7000 R      TAF.KL=NFT.K/TASM
7010 NOTE   TASA DE ASIMILACION DE LA FUERZA DE TRABAJO  (HOM/MES)
7020 C      TASM=6
7025 NOTE   TIEMPO DE ASIMILACION (MES)
7030 L      NFT.K=NFT.J+(DT)(TNC.JK-TAF.JK)
7040 NOTE    NUEVA FUERZA DE TRABAJO (HOM)
7050 N      NFT=NFTN
7060 C      NFTN=1
7070 NOTE   VALOR INICIAL DE NFT  (HOM)
7300 R      TNC.KL=(FTR.K-F.K)/TAFT
7400 NOTE   TASA NETA DE CONTRATACION (HOM/MES)
7500 C      TAFT=3
7600 NOTE   VALOR INICIAL DEL TIEMPO PARA AJUSTAR LA FUERZA DE TRABAJO (HOM)
7700 A      FTR.K=(DCFT.K)(FTI.K)+(1-DCFT.K)(F.K)
7800 NOTE   FUERZA DE TRABAJO REQUERIDA (HOM)
7900 A      FTI.K=EPPH.K/TRES.K
8000 NOTE   FUERZA DE TRABAJO INDICADA (HOM)
8100 A      DCFT.K=TABHL(DCFTT,TRES.K,0,21,3)
8200 NOTE   DISPONIBILIDAD A CAMBIAR LA FUERZA DE TRABAJO (SU)
8300        DCFTT*=0/0/0/.1/.3/.7/.9/1
8400 NOTE
8500 NOTE   SECCION DE MODIFICACIONES AL PROGRAMA
8600 NOTE
8700 A      TRES.K=FPTE.K-TIME.K
8800 NOTE   TIEMPO RESTANTE (MES)
8900 L      FPTE.K=FPTE.J+(DT)(ANP.JK)
9000 NOTE   FECHA PROGRAMADA DE TERMINACION (MES)
9100 N      FPTE=FPTEI
9200 C      FPTEI=40
9300 NOTE   VALOR INICIAL DE LA FECHA PROGRAMADA DE TERMINACION (MES)
9400 R      ANP.KL=(FIT.K-FPTE.K)/TAPR
9500 NOTE   ADICIONES NETAS AL PROGRAMA (SU)
9600 C      TAPR=6
9700 NOTE   VALOR INICIAL DEL TIEMPO DE AJUSTE AL PROGRAMA (MES)
9800 A      FIT.K=TPREQ.K+TIME.K
9900 NOTE   FECHA INDICADA DE TERMINACION (MES)
10000 A      TPREQ.K=EPPH.K/FTR.K
10100 NOTE   TIEMPO PERCIBIDO REQUERIDO (MES)
10200 NOTE
10300 NOTE   INDICADORES
10400 NOTE
10500 L      EA.K=EA.J+(DT)(F.J)(EPPPB.J)
10600 N      EA=0
10700 NOTE   ESFUERZO ACUMULADO (HOM*MES)
10800 A      COSTO.K=(CPHM)(EA.K)
10900 NOTE   COSTO DEL PROYECTO  (PESOS)
10910 C      CPHM=3000
10920 NOTE   COSTO POR HOMBRE-MES    (PESOS)
10930 NOTE
10940 NOTE   ORDENES DE CONTROL
10950 NOTE
11000 SPEC   DT=.25/LENGTH=70/PLTPER=1/PRTPER=5
11100 PLOT   F=W(0,80)/FPTE=F(30,70)/APA=P,ARA=R,TMND=M(0,1200)/PRODP=+(.6,1)
11300 PLOT   EPPPB=1,EEPD=2,EPPPS=3,EEXPPS=4(.5,1.5)/FFE=X(0,1)
11400 PRINT 1)PRODP/2)PRODI/3)TAP/4)TAPR
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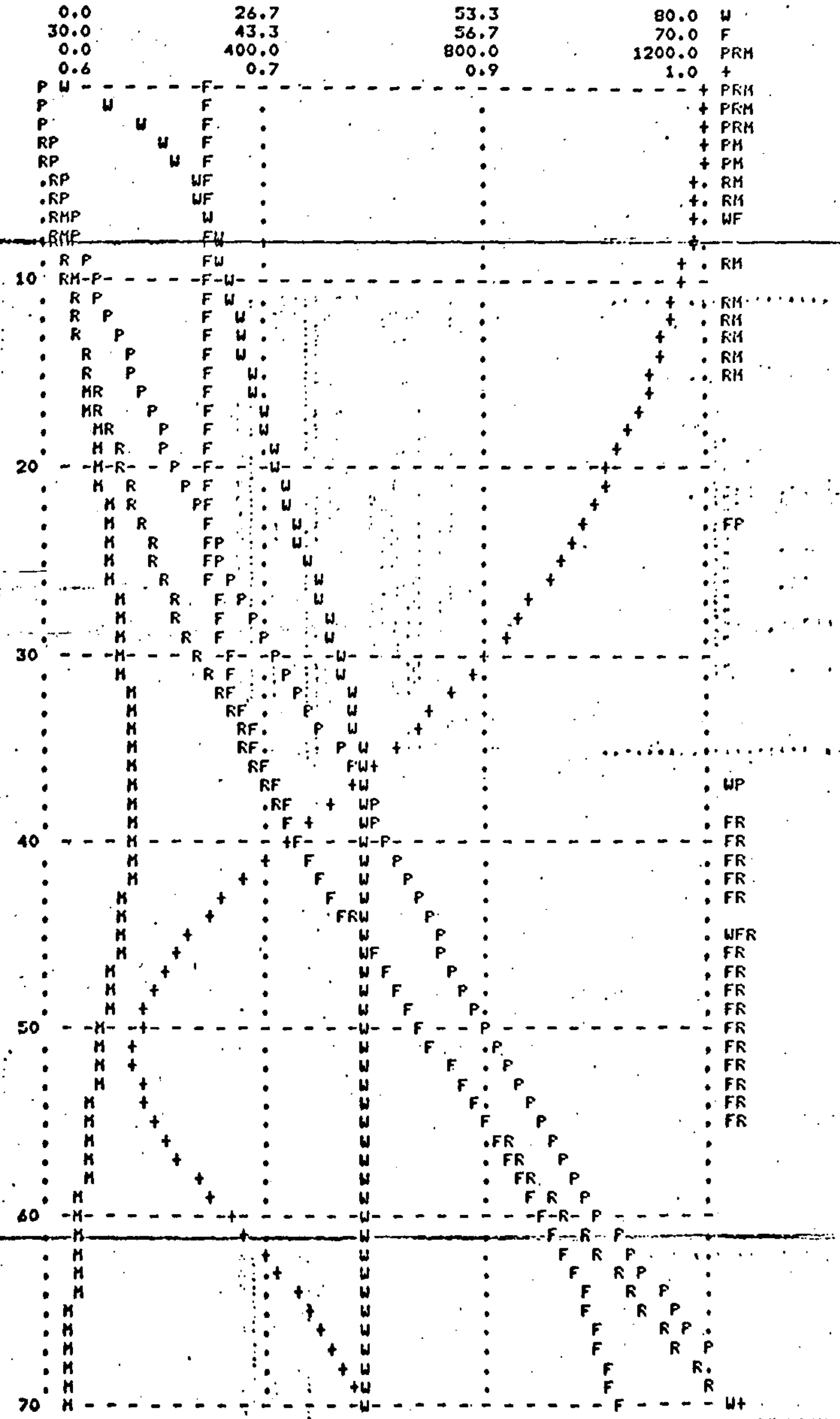

63

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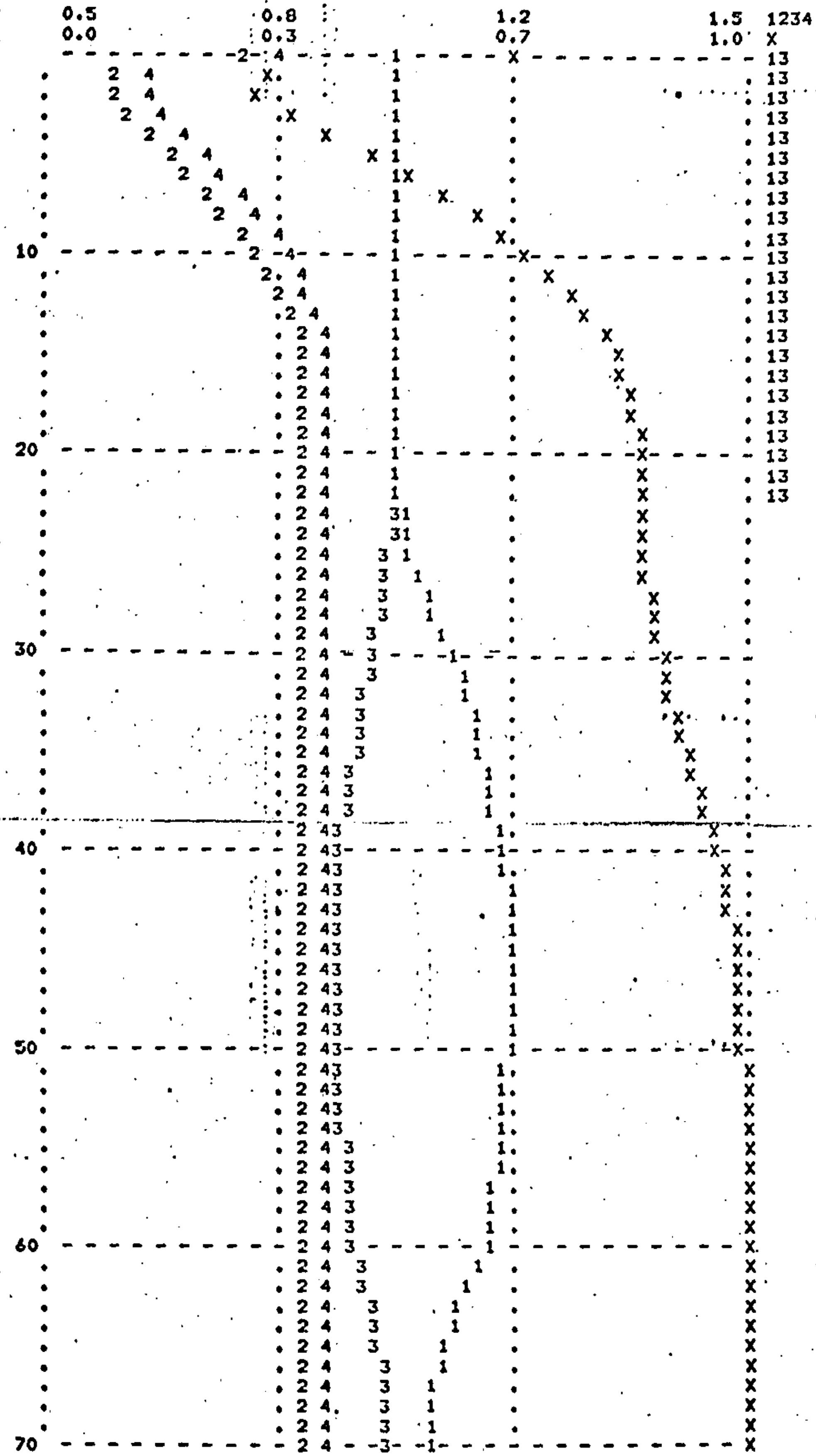

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BIBLIOGRAFIA.

Alfeld, Louis and Alan K Graham- 1976 - Introduction to Urban Dynamics Cambridge, Ma.: The MIT Press.

Britting, Kennet R., - 1973 - Correlated Noise Generation Using DYNAMO - System Dynamics Group Working Paper D-1908 - Alfred P. Sloan School of Management, M.I.T., Cambridge, Ma. - 02139

Cooper, Kenneth G., - 1980 - Naval Ship Production: A Claim Settled and a Framework Built. Interfaces, 10,6(1980):20-36.

Forrester, Jay W. 1959 - Advertising: a Problem in Industrial Dynamics - Harvard Business Review - March-April.

Forrester, Jay W. 1961 - Industrial Dynamics - Cambridge, Ma.: the MIT Press.

Forrester, Jay W. 1968a - Market Growth as Influenced by Capital Investment. Industrial Management Review (now the Sloan Management Review), 9 (1968):83-105.

Forrester, Jay W., 1968b - Principles of Systems - Cambridge, Ma.: The MIT Press.

Forrester, Jay W., 1969 - Urban Dynamics - Cambridge Ma.: The MIT Press.

Forrester, Jay W., 1971 -Counterintuitive Behavior of Social Systems. - Technology Review 73(1971):52-68

Forrester, Jay W., 1973 - World Dynamics - Cambridge, Ma.: The MIT Press.

Forrester, Jay W., 1975 - Collected Papers of Jay W. Forrester - Cambridge, Ma.: The MIT Press.

Forrester, Jay W., Gilbert W. Low, and Nathaniel J. Mass. - The Debate on World Dynamics: A response to Nordhaus. - Policy Sciences - 5(1974):169-190

Forrester, Jay W. and Peter M. Senge - 1980 - Tests for Building Confidence in System Dynamics Models. ·ystem Dynamics. TIMS Studies in Management Sciences - 14(1980):209-228

Richardson, George P., Pugh., 1981 - Introduction to System Dynamics Modeling with DYNAMO - The MIST Press.

Richardson, George P., 1981 - Statistical Estimation of Parameters in a Predator-Prey Model: and Exploration using Synthetic Data. System Dynamics Group working paper D-3314-1, Alfred P. Sloan School of Management, M.I.T. Cambridge, Ma - 02139.

Roberts, Edward B - 1964 - The Dynamics of Research and Development - Cambridge, Ma.: The MIT Press.

Roberts, Edward B., 1980 - Managerial Applications of System Dynamics - Cambridge, Ma.: The MIT Press

Roberts, Edward B., 1977 - Strategies for Effective Implementation of Complex Corporate Models - Interfaces, 8,1(1977) Part 1.

Schroeder, Walter E. and John E. Strongman, 1974 - Adapting Urban Dynamics to Lowell, in Readings in Urban Dynamics, vol 1, Nathaniel J. Mass, ed. Cambridge, Ma.: The MIT Press. 197-223

Senge, Peter M. - 1977 - Statistical Estimation of Feedback Models - Simulation, 28 (1977):177-184

Shaffer, William - 1976 - Mini-DYNAMO Users' Guide - Pugh Roberts Associates 5 Lee Street - Cambridge, Ma. 02139

Wiener, Norbert, 1961 - Cybernetics: or control and communication in the animal and the machine - Cambridge, Ma.: The MIT Press.

Shaffer, William - 1976 - Court Management and the Massachusetts Criminal Justice System. Ph.D. Dissertation, - Alfred P. Sloan School of Management Massachusetts Institute of Technology, Cambridge. Ma. 02139.

Garn, Harvey A. and Robert H. Wilson, 1972 - A Look at Urban Dynamics: - The Forrester Model and Public Policy, IEEE Transacions on Systems, Man and Cybernetics - SMC-2(1972):150:155

Goodman, Michael R., 1974. Study Notes in System Dynamics, Cambridge, Ma.: The MIT Press

Graham, Alan K., 1977 - Principles of the Relationship Between Structure and Behavior of Feedback Systems. Ph.D. dissertation. Department of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, - Cambridge, Ma., 02139.

Graham, Alan K., 1980 - Parameter Estimation in System Dynamics Modeling, in Elements of the System Dynamics Method, Jorgen Randers, ed. Cambridge, Ma.: The MIT Press, 143-161.

Greenberger, Martin, Matehw A. Crensen, and Brian L. Crissy, 1976. Models in the Policy Process. New York. Russell Sage Foundation.

Hardin, Garret, 1972 - Exploring New Ethics for Survival; the voyage of the spaceship Beagle. New York. Viking Press.

Kormondy, Edward J., 1969. Concepts of Ecology. Englewood Cliffs, N.J. - Prentice-Hall.

Levin, Gilbert, Edward B. Roberts, and Garry Hirsch, 1975. The Persistent Poppy. Cambridge, Ma.: Ballinger.

Lyneis, James M., 1980 - Corporate Planning and Policy Design. Cambridge Ma.: The MIT Press.

Malthus, Thomas, 1798 - First Essay on Population, 1966 edition New York. MacMillan, Inc.

Mass, Nathaniel J., 1973 - Readings in Urban Dynamics - vol. 1 - Cambridge Ma.: The MIT Press

Mass, Nathaniel J. and Peter M. Senge, 1978 - Alternative Tests for the Selection of Model Variables - IEEE Transactions on Systems, Man, and Cybernetics, July 1978.

Meadows, Dennis L., 1970 - Dynamics of Commodity Cycles. Cambridge, Ma.: The MIT Press

Meadows, Dennis L. and Donella H. Meadows, eds., 1973 - Toward Global Equilibrium Cambridge, Ma.: The MIT Press.

Meadows, Dennis L., William H. Behrens III, Donella H. Meadows, Roger F. Naill, Jorgen Randers, and Erich K.O. Zahn, 1974 - Dyanmics of Growth in a Finite World. Cambridge, Ma.: The MIT Press

Meadows, Donella H., 1980 - The Unavoidable A Priori, in Elements of the System Dynamics Method, Jorgen Randers, ed. Cambridge, Ma.: The MIT Press.

Meadows, Donella H., Dennis L. Meadows, Jorgen Randers, and William W. Behrens III, 1972. The Limits to Growth. New York. Universe Books, A Potomac Associates Book.

Naill, Roger F., 1973 - The Discovery Life Cycle of a Finite Resource: A Case Study of U.S. Natural Gas, in Toward Global Equilibrium, Dennis L. Meadows and Donella H. Meadows, eds. Cambridge, Ma.: The MIT Press. 213-256

Nordhaus, William D. World Dynamics: Measurement Without Data. The Economic Journal, 83(1973): 1156-1183

Peterson, David W., 1980 - Statistical Tools for System Dynamics, in Elements fot the System Dynamics Method, Jorgen Randers, Ed. Cambridge, Ma.: The MIT Press - 224-245

Pindyck, Robert S. and Daniel L. Rubenfeld - 1976 - Econometric Models and Econometric Forecasts - New York - McGraw-Hill

Pugh, Alexander L., III - 1976 - DYNAMO Users' Manual - 5th. ed. Cambridge, Ma.: The MIT Press

Randers, Jorgen and Dennis L. Meadows, 1973 - The Dynamics of Solid Waste Generation, in toward a Global Equilibrium, Dennis L. Meadows and Donella H. Meadows, eds. Cambridge, Ma.: The MIT Press - 165-211

DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

DINAMICA DE SISTEMAS (FORRESTER)

CRECIMIENTO DEL MERCADO

DR. JOSE DE JESUS ACOSTA FLORES

FEBRERO,1985

Palacio de Minería Calle de Tacuba 5 primer piso Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

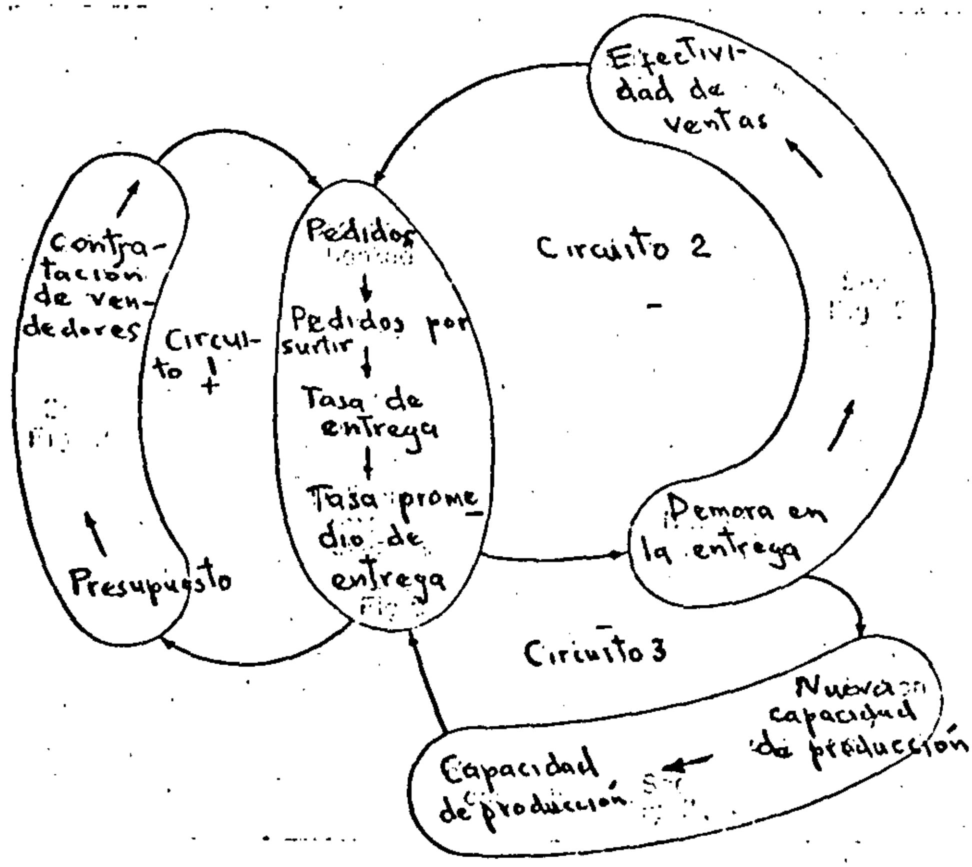
CRECIMIENTO DEL MERCADO INFLUENCIADO POR LA INVERSION DE CAPITAL.

Industrial Management Review (Sloan Management Review) 9 No. 2 1968. Resumen del artículo de Jay W. Forrester.

Se trata del crecimiento de un nuevo producto.

OBJETIVO: Identificar y explicar uno de los sistemas que pueden causar el estancamiento del crecimiento de ventas aún en la presencia de un mercado ilimitado.

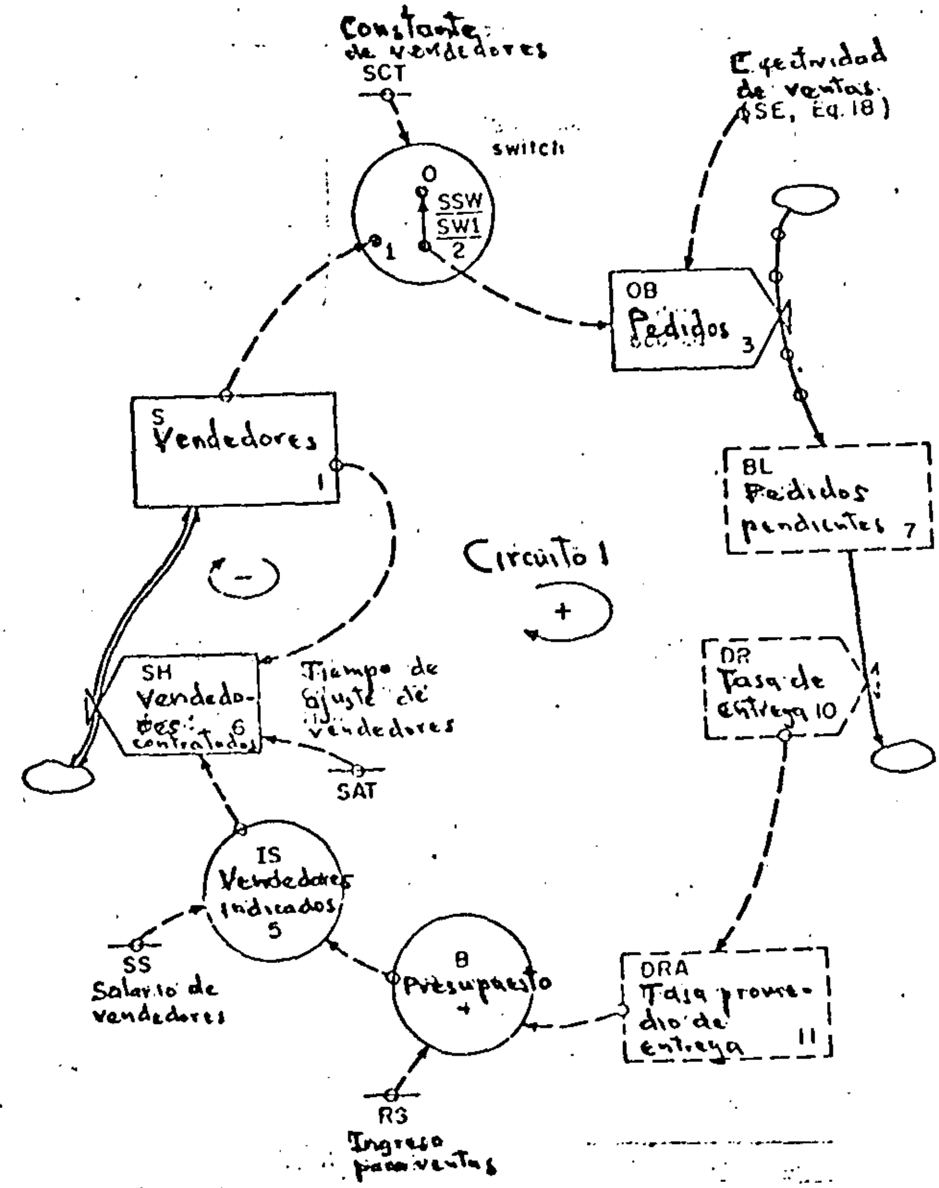
Se presenta a continuación el diagrama causal del modelo



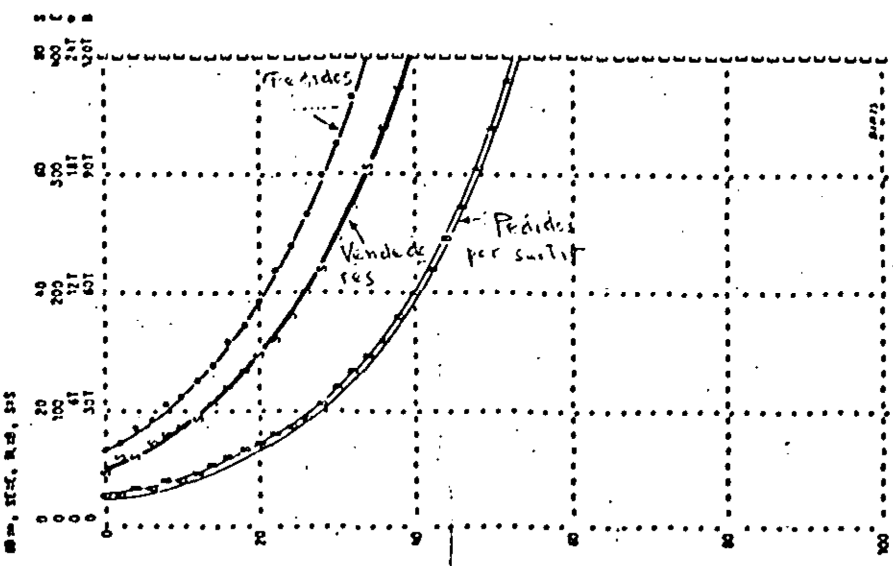
El circuito 1 genera crecimiento y el 2 busca una meta: tiende a igualar la tasa de pedidos a la capacidad de producción.

CIRCUITO DE CONTRATACION DE VENDEDORES

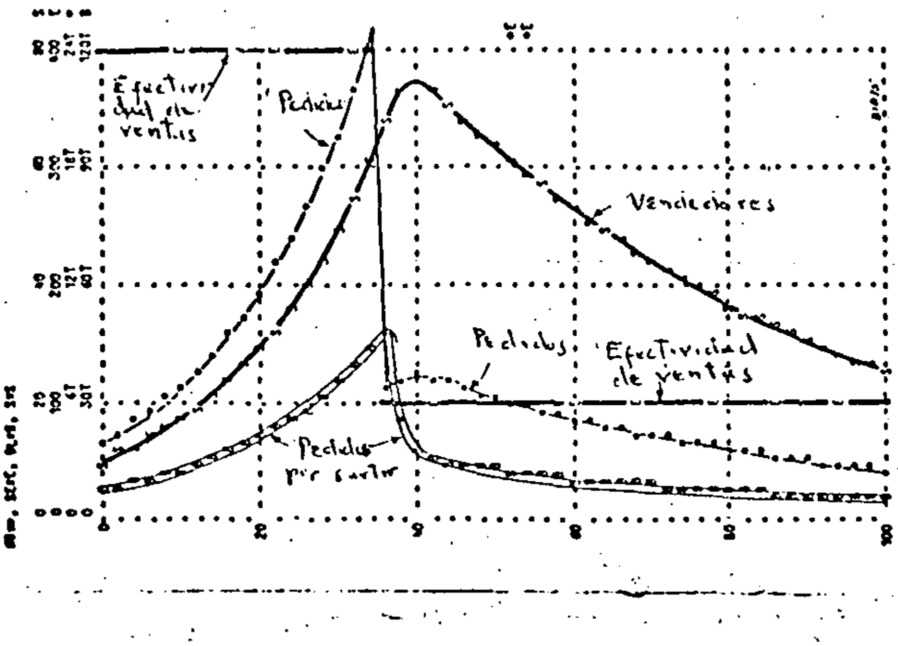
A continuación se muestra el diagrama de niveles y tasa para este circuito. Al final se presentarán todas sus ecuaciones respectivas.



En la figura siguiente se exhibe el crecimiento exponencial ilimitado de este circuito



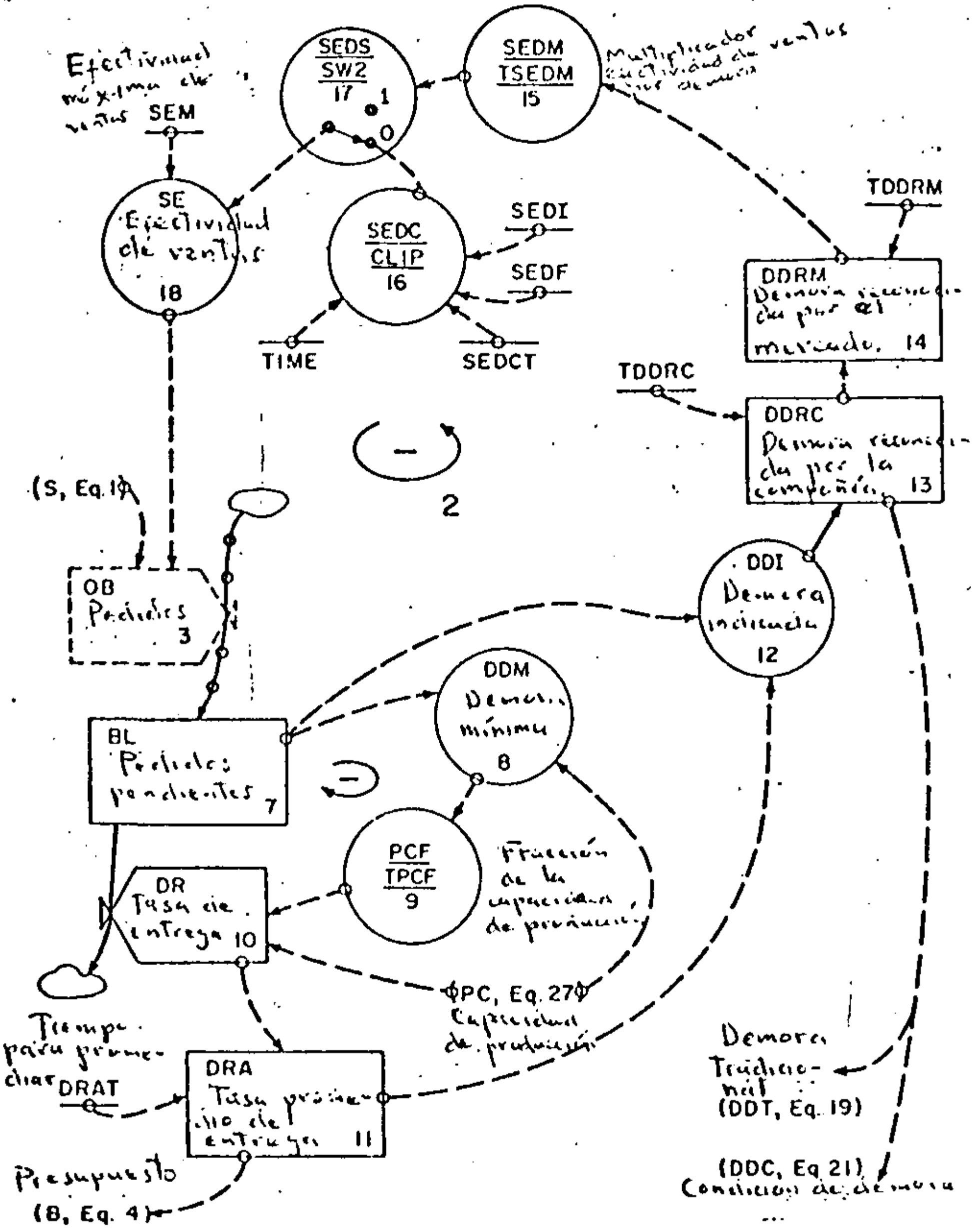
Si se reduce la efectividad de ventas de 400 unidades/hombre-mes a 100 unidades/hombre-mes, los resultados cambian a



CIRCUITO DEL MERCADO

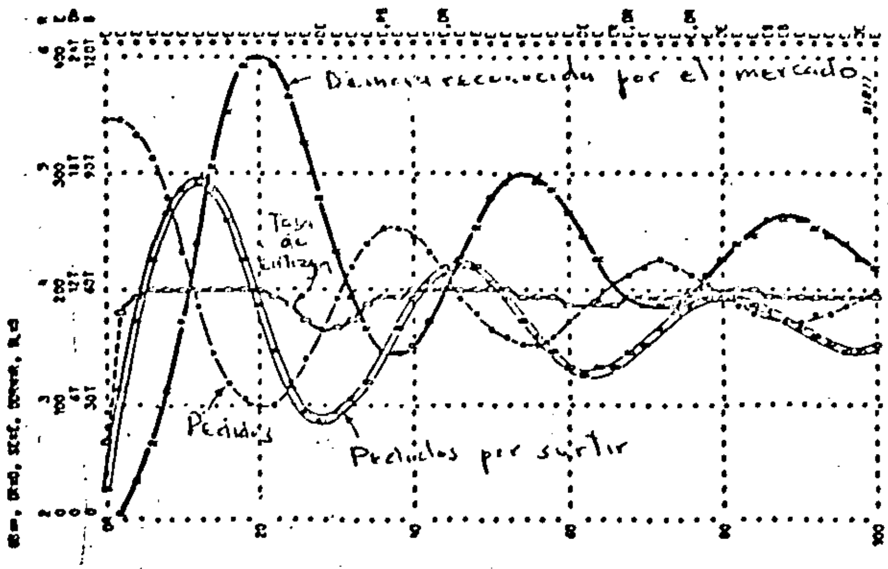
4

El diagrama de niveles y tasas para este circuito es



Si la tasa de pedidos es demasiado alta, se elevan los pedidos por surtir y disminuye la tasa de pedidos.

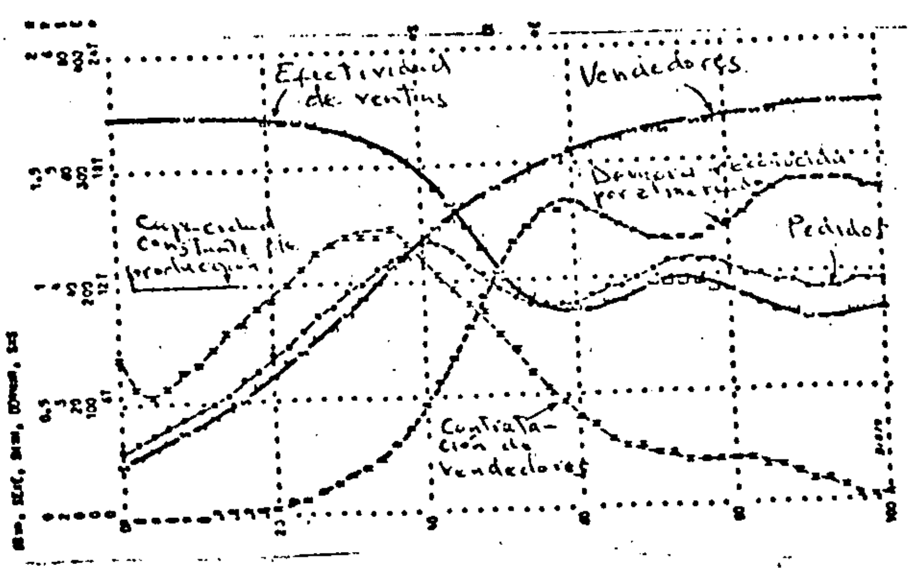
El comportamiento de las variables cuando el número de vendedores y la capacidad de producción son constantes es:



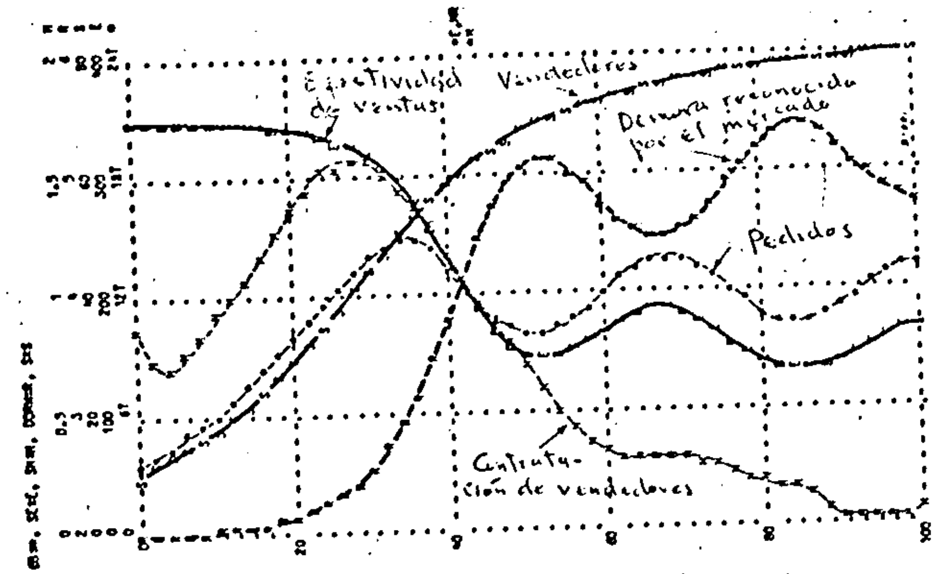
Aquí los vendedores pasan la mayor parte del tiempo explicando a sus clientes por qué llegan tarde los artículos y se desmoralizan porque sienten que no tiene sentido tratar de vender un artículo que no está disponible.

CIRCUITOS COMBINADOS DE VENDEDORES Y MERCADO

Se considera que la capacidad de producción es constante los resultados obtenidos son:



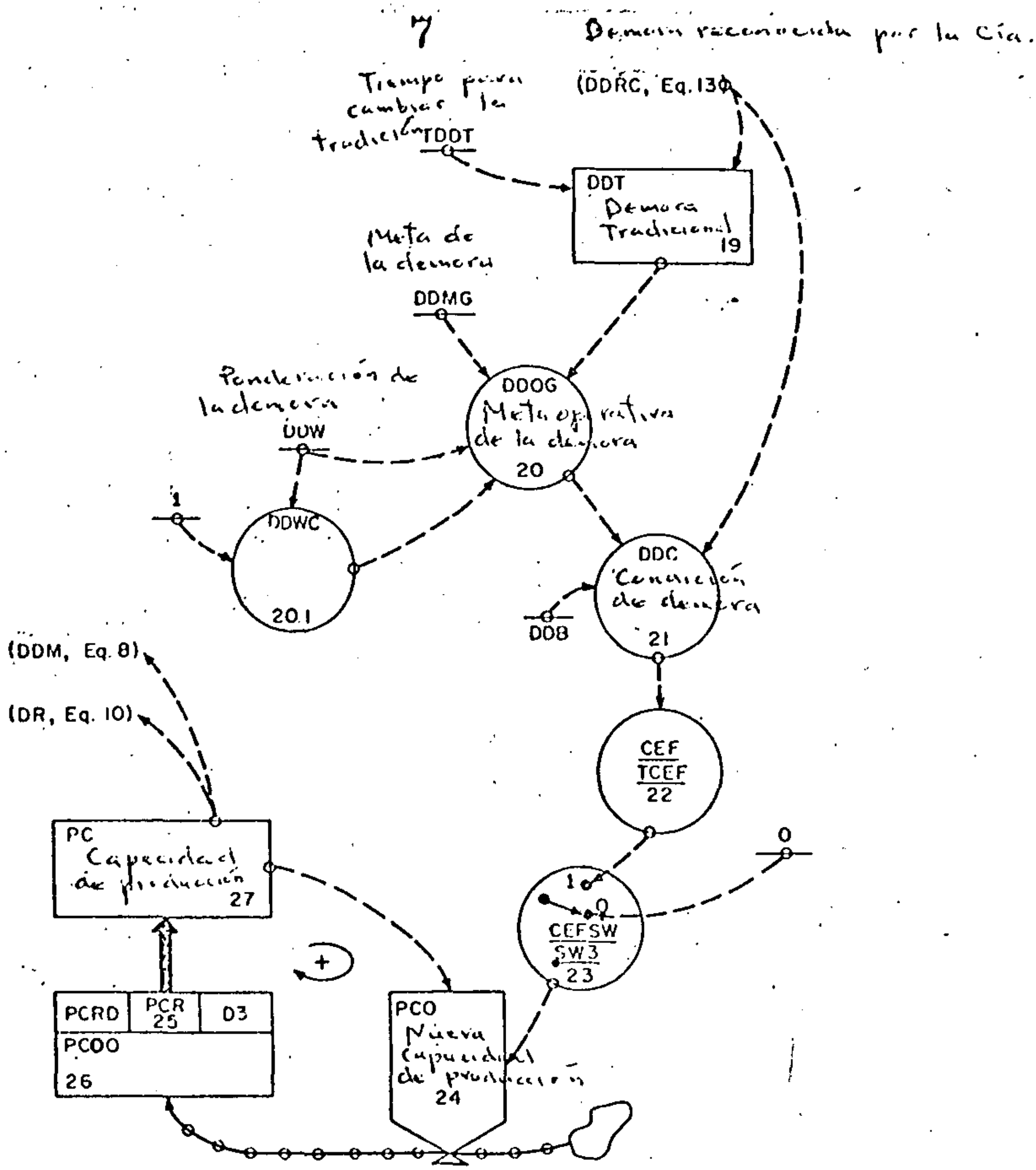
Vamos a suponer ahora que no estuviéramos conscientes de la influencia de la demora en la entrega de manera que aumentáramos el esfuerzo de mercadeo (aumentar RS en el modelo). Los resultados que se obtendrían serían



Se observa que a largo plazo aumenta el número de vendedores y disminuye la efectividad de ventas hasta igualar la capacidad de producción. Se tiene el mismo nivel de ventas pero con ganancias reducidas. El cambio en política no logró lo deseado.

INVERSION DE CAPITAL

La capacidad de producción fija no es típica, por lo que se presenta el circuito 3 en su diagrama de tasas y niveles.



La política de cambiar la producción es la que puede incrementar el crecimiento del mercado.

A continuación se presentan las ecuaciones del modelo.

```
                        CRECIMIENTO DEL MERCADO
0.1
0.2    RUN    STD
0.3    NOTE
0.4    NOTE
0.5    NOTE   CIRCUITO POSITIVO - VENDEDORES
0.6    NOTE
1      1L     S.K=S.J+(DT)(SH.JK+0)
1.1    6N     S=10
2      49A    SSW.K=SWITCH(SCT,S.K,SW1)
2.1    C      SCT=60
2.2    C      SW1=0
3      12R    OB.KL=(SSW.K)(SE.K)
4      12A    B.K=(DRA.K)(RS)
4.1    C      RS=12
5      20A    IS.K=B.K/SS
5.1    C      SS=2000
6      21R    SH.KL=(1/SAT)(IS.K-S.K)
6.1    C      SAT=20
6.4    NOTE
6.5    NOTE   CIRCUITO NEGATIVO - MERCADO
6.6    NOTE
7      1L     BL.K=BL.J+(DT)(OB.JK-DR.JK)
7.1    6N     BL=8000
8      20A    DDM.K=BL.K/PC.K
9      58A    PCF.K=TABHL(TPCF,DDM.K,0,5,.5)
9.1    C      TPCF*=0/.25/.5/.67/.8/.87/.93/.95/.97/.98/1
10     12R    DR.KL=(PC.K)(PCF.K)
11     3L     DRA.K=DRA.J+(DT)(1/DRAT)(DR.JK-DRA.J)
11.1   6N     DRA=DR
11.2   C      DRAT=1
12     20A    DDI.K=BL.K/DRA.K
13     3L     DDRC.K=DDRC.J+(DT)(1/TDDRC)(DDI.J-DDRC.J)
13.1   6N     DDRC=DDI
13.2   C      TDDRC=4
14     3L     DDRM.K=DDRM.J+(DT)(1/TDDRM)(DDRC.J-DDRM.J)
14.1   6N     DDRM=DDRC
14.2   C      TDDRM=6
15     58A    SEDM.K=TABHL(TSEDM,DDRM.K,0,10,1)
15.1   C      TSEDM*=1/.97/.87/.73/.53/.38/.25/.15/.08/.03/.02
16     51A    SEDC.K=CLIP(SEDF,SEDI,TIME.K,SEDCT)
16.1   C      SEDF=1
16.2   C      SEDI=1
16.3   C      SEDCT=36
17     49A    SEDS.K=SWITCH(SEDC.K,SEDM.K,SW2)
17.1   C      SW2=0
18     12A    SE.K=(SEDS.K)(SEM)
18.1   C      SEM=400
18.4   NOTE
18.5   NOTE   INVERSION EN CAPITAL
18.6   NOTE
19     3L     DDT.K=DDT.J+(DT)(1/TDDT)(DDRC.J-DDT.J)
19.1   6N     DDT=DDRC
19.2   C      TDDT=12
20     15A    DDOG.K=(DDT.K)(DDW)+(DDMG)(DDWC)
20.1   7N     DDWC=1-DDW
20.2   C      DDW=0
20.3   C      DDMG=2
21     27A    DDC.K=(DDRC.K/DDOG.K)-DDB
```

```
21.1    C      DDB=.3
22      58A    CEF.K=TABHL(TCEF,DDC.K,0,2.5,.5)
22.1    C      TCEF*=-.07/-.02/0/.02/.07/.15
23      49A    CEFSW.K=SWITCH(0,CEF.K,SW3)
23.1    C      SW3=0
24      12R    PCO.KL=(PC.K)(CEFSW.K)
25      39R    PCR.KL=DELAY3(PCO.JK,PCRD)
25.1    C      PCRD=12
26      1L     PCOO.K=PCOO.J+(DT)(PCO.JK-PCR.JK)
26.1    12N    PCOO=(PCO)(PCRD)
27      1L     PC.K=PC.J+(DT)(PCR.JK+0)
27.1    6N     PC=PCI
27.2    C      PCI=12000
27.5    NOTE
27.6    NOTE   TARJETAS DE CONTROL
27.7    NOTE
27.8    PLOT   OB=*,PC=C(0,24000)/SE=E(0,400)/S=S(0,80)
27.9    NOTE
28      NOTE
28.1    RUN    A
28.2    NOTE   CRECIMIENTO EXPONENCIAL ILIMITADO
28.3    SPEC   DT=.5/LENGTH=100/PRTPER=100/PLTPER=2
28.4    PRINT  1)S
29      C      SW1=1
29.1    C      PCI=100000
29.4    PLOT   OB=*(0,24000)/SE=E(0,400)/BL=B(0,120000)/S=S(0,80)
29.5    RUN    B
29.6    NOTE
30      C      SW1=1
30.1    C      SEDF=.25
30.2    C      PCI=100000
30.5    RUN    C
30.6    NOTE
31      C      SW2=1
31.3    PLOT   OB=*,DR=D(0,24000)/SE=E(0,400)/DDRM=R(2,6)/BL=B(0,120000)
31.4    RUN    D
31.5    NOTE
32      C      SW1=1
32.1    C      SW2=1
32.4    PLOT   OB=*(0,24000)/SE=E(0,400)/SH=H(0,2)/DDRM=R(2,6)/S=S(0,80)
32.5    RUN    E
32.6    NOTE
33      C      SW1=1
33.1    C      SW2=1
33.2    C      RS=13.6
33.5    RUN    F
33.6    NOTE   EXPANSIÓN EN CAPACIDAD
34      C      SW1=1
34.1    C      SW2=1
34.2    C      SW3=1
34.5    PLOT   OB=*,PC=C(0,24000)/SE=E(0,400)/DDRM=R,DDOG=G(2,6)/S=S(0,80)/CEF=F(
34.6    X1     -.06,.18)
34.7    RUN    G
34.8    NOTE
35      C      SW1=1
35.1    C      SW2=1
35.2    C      SW3=1
35.3    C      DDW=1
```

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FACULTAD DE INGENIERIA U.N.A.M.

DINAMICA DE SISTEMAS (FORRESTER)

LA DINAMICA DE LA MATRIZ INSUMO PRODUCTO (I-O)

M. EN I. JORGE SILVA MIDENCES

FEBRERO, 1985

LA DINAMICA DE LA MATRIZ INSUMO PRODUCTO (I-O)

M. en I. SILVA MIDENCES

1984

I N D I C E

I. INTRODUCCION

II. MARCO DE REFERENCIA

Las Cuentas Nacionales

La Matriz I-O

III. ALGUNOS CONCEPTOS BASICOS

Terminología de la Matriz I-O

Tasa-Nivel: Expresiones Matematicas y en Dynamo.

IV. MANIPULACIONES DE LA MATRIZ I-O

Formulación Estática

Formulación Dinámica

Modelo Causal

V. EJEMPLOS

Validación y análisis de la capacidad de respuesta

Un modelo regional

Bibliografía

"EL ANALISIS INSUMO-PRODUCTO NO ES MAS QUE UNA CONSECUENCIA PRACTICA DE AQUELLA TEORIA CLASICA QUE POSTULA LA INTERDEPEN DENCIA GENERAL DE LAS VARIABLES ECONOMICAS. CONSIDERA ESTA TEORIA QUE EL CONJUNTO DE LA ECONOMIA DE UNA REGION, UN PAIS O EL MUNDO CONSTITUYE UN SISTEMA UNICO, Y SE ESFUERZA POR EXPRESAR LA TOTALIDAD DE SUS FUNCIONES EN TERMINOS DE AQUELLAS, DE SUS PROPIEDADES ESTRUCTURALES QUE SON SUSCEPTIBLES DE CUAN TIFICAR..."

Wassili LEONTIEF

"LAS EMPRESAS ESTADOUNIDENSES INVIERTEN CADA AÑO MILLONES DE DOLARES EN ELABORAR PREVISIONES DE VENTAS, BUSCANDO CON ELLO PERFECCIONAR SUS ESTIMACIONES CON RESPECTO A LOS MERCADOS FU TUROS DE SUS PRODUCTOS (estimaciones que necesitan para poder elaborar sus programas internos de producción y sus planes - de inversión)... DESGRACIADAMENTE, ESTAS PREVISIONES SON MAS CONOCIDAS POR SUS FRACASOS QUE POR SUS EXITOS..."

LEONTIEF

LA INDUSTRIA SIDERURGICA PROCURA ESTIMAR SUS VENTAS DE PLANCHAS DE ACERO DURANTE EL PROXIMO AÑO O DURANTE EL PROXIMO QUINQUENIO A PARTIR DEL VOLUMEN DE PEDIDOS QUE ESPERA QUE LE HAGAN LAS DISTINTAS EMPRESAS DEDICADAS A LA CONSTRUCCION NAVAL.

LAS EMPRESAS DE CONSTRUCCION NAVAL PROCURAN ESTIMAR, - al mismo tiempo, QUE LA INDUSTRIA SIDERURGICA HACE SUS PREVISIONES, LA DEMANDA FUTURA DE GASOLINA CON OBJETO DE PODER DETERMINAR EL NUMERO DE "PETROLEROS" QUE LES ENCARGARAN PROBABLEMENTE EL PROXIMO AÑO.

A SU VEZ, A LOS ANALISTAS DE MERCADO DE LA INDUSTRIA DEL PETROLEO LES INTERESA CONOCER LOS NIVELES DE PRODUCCION DE LOS PRINCIPALES SECTORES DE LA ECONOMIA QUE CONSUMEN PRODUCTOS PETROLIFEROS, CON OBJETO DE DETERMINAR LA POSIBLE DEMANDA DE LOS MISMOS.

"SIMULTANEAMENTE, AUNQUE CON INDEPENDENCIA LAS UNAS DE LAS OTRAS TODAS LA EMPRESAS, GRANDES, MEDIANAS Y PEQUEÑAS, DE LOS DIFERENTES SECTORES QUE COMPONEN LA ECONOMIA DE UN PAIS, ESTAN COMPROMETIDAS EN UN juego de conjeturas extremadamente costoso e inútil." (Leontief)

LA MATRIZ DE INSUMO-PRODUCTO NOS DA EL FLUJO DE BIENES Y SERVICIOS QUE SE HA ESTABLECIDO ENTRE LOS DIFERENTES SECTORES DE UNA ECONOMIA DURANTE UN DETERMINADO PERIODO DE TIEMPO.

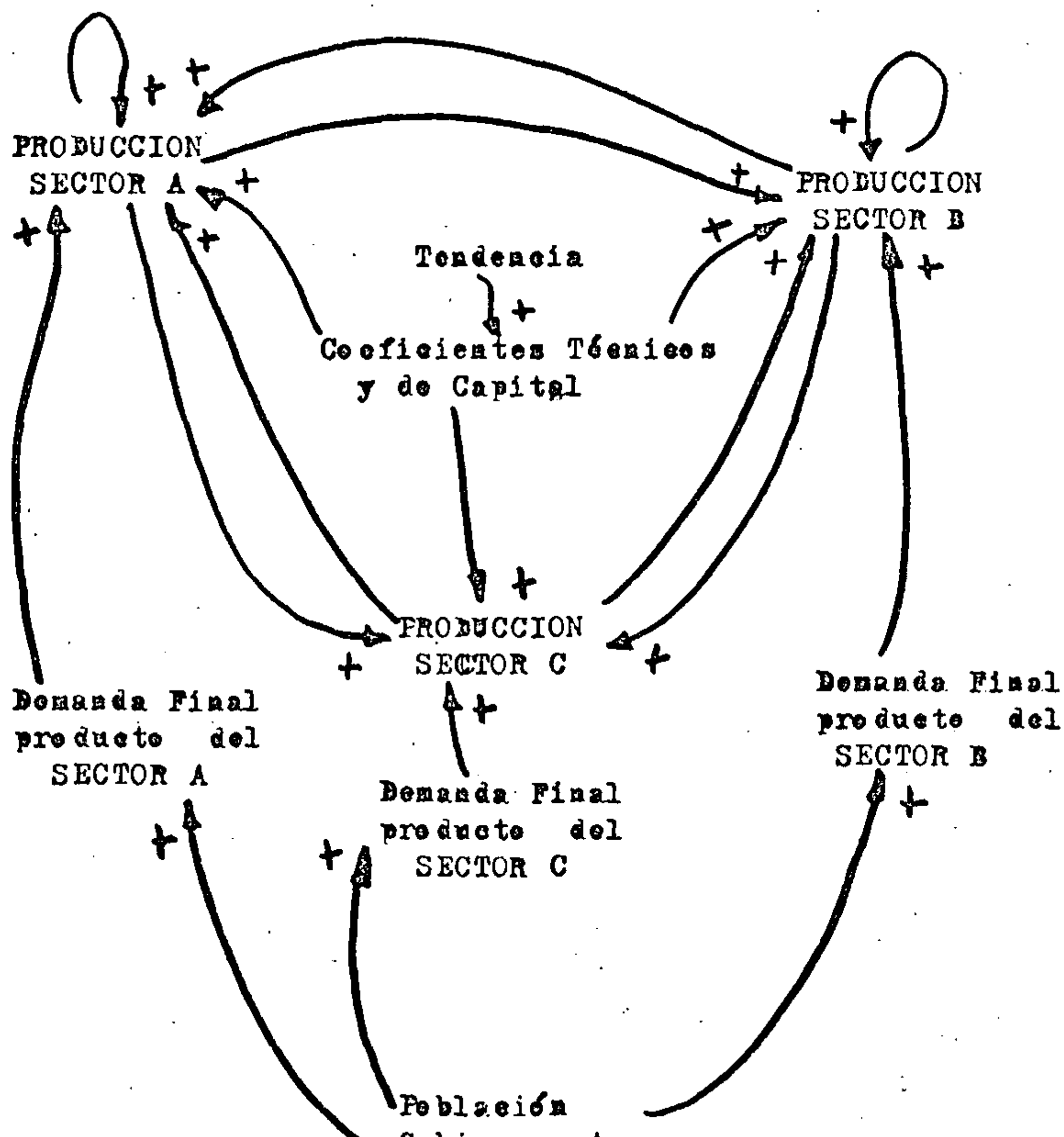


DIAGRAMA CAUSAL GENERAL

LA DINAMICA DE LA MATRIZ INSUMO-PRODUCTO (I-O)

I. INTRODUCCION

"SI HOY EN DIA, JAMES CLERK MAXWELL, UNO DE LOS FISICOS MAS EMINENTES DEL SIGLO XIX, ASISTIERA A ALGUNAS DE LAS REUNIONES QUE REGULARMENTE CELEBRA LA *American Phisical Society* LE SERIA SEGURAMENTE MUY DIFICIL SEGUIR EL HILO DE LAS DISCUSIONES. ESTO, SIN EMBARGO, LE HABRIA RESULTADO MUY FACIL SI EN LUGAR DE HABERSE DEDICADO A LA FISICA SE HUBIERA DEDICADO A LA ECONOMIA, COMO SU CONTEMPORANEO JOHN STUART MILL. LA FISICA, AL TRAVES DE LA APLICACION DEL METODO INDUCTIVO A LOS HECHOS OBSERVADOS Y EXPRESADOS EN FORMA CUANTITATIVA, HA RENOVADO TOTALMENTE SUS PREMISAS. LA ECONOMIA, EN CAMBIO, CONTINUA SIENDO ESENCIALMENTE UNA CIENCIA DEDUCTIVA FUNDADA EN UN GRUPO ESTATICO DE PREMISAS, QUE EN SU MAYORIA ERAN YA CONOCIDAS POR STUART MILL Y ALGUNAS DE LAS CUALES ENCONTRAMOS YA EN *La Riqueza de las Naciones*, DE ADAM SMITH."

EN LA ACTUALIDAD NO TODOS LOS ECONOMISTAS SE MUESTRAN SATISFECHOS DEL ESTADO EN QUE ENCUENTRA LA ECONOMIA. LOS NOMBRES DE ALGUNOS DE LOS MAS IMPORTANTES ECONOMISTAS ENTRE LOS FALLECIDOS DENTRO DE LA PRIMERA MITAD DEL SIGLO XX, *León Walras*, *Vilfredo Pareto*, *Irving Fisher*, APARECEN ASOCIADOS AL ESFUERZO REALIZADO POR ENCONTRAR METODOS CUANTITATIVOS APLICABLES A LA ENORME CANTIDAD DE DATOS EMPIRICOS INVOLUCRADOS EN LAS SITUACIONES ECONOMICAS REALES. SIN EMBARGO, BUENA PARTE DE LOS ECONOMISTAS PROFESIONALES TODAVIA SE MUESTRAN REACIOS A ACEPTAR ESTOS METODOS. LA RAZON DE ELLO NO ES SOLO QUE LES RESULTA ANTIPATICO EL RIGOR MATEMATICO QUE CARACTERIZA A LOS MISMOS, SINO EL QUE ESTOS RARAS

RON LAS COMPUTADORAS Y EN LOS APARATOS GUBERNAMENTALES Y PRIVADOS SE SINTIERON INCLINADOS A ACUMULAR DATOS.

AHORA BIEN, LA TEORIA ECONOMICA SE ESFUERZA POR EXPLICAR AQUELLOS ASPECTOS Y OPERACIONES MATERIALES DE NUESTRA SOCIEDAD EN FUNCION de las interacciones que se dan entre variables tales como la oferta y la demanda o los salarios y los precios. POR REGLA GENERAL, LOS ECONOMISTAS HABIAN FUNDADO SUS DEDUCCIONES ANALITICAS EN DATOS RELATIVAMENTE SIMPLES, COMO SON EL PRODUCTO NACIONAL BRUTO, LOS TIPOS DE INTERES O LOS NIVELES DE SALARIOS. PERO, EN LA REALIDAD, LAS COSAS NO SON TAN SIMPLES. Entre el instante en que se modifican los salarios y aquel en el que dicha modificación se deja sentir en los precios, TIENE LUGAR UNA COMPLEJA SERIE DE TRANSACCIONES A TRAVES DE LAS CUALES LAS PERSONAS reales SE INTERCAMBIAN ENTRE SI BIENES Y SERVICIOS. POR REGLA GERAL, LA FORMULA CLASICA QUE RELACIONA LAS DOS VARIABLES MENCIONADAS (los salarios y los precios), NO DICE NADA ACERCA DE ESTOS PASOS INTERMEDIOS. NATURALMENTE, ES CIERTO QUE LAS TRANSACCIONES PARTICULARES, AL IGUAL QUE LOS ATOMOS Y LAS MOLECULAS QUE ESTUDIA LA FISICA, SON DEMASIADO NUMEROSAS PARA QUE PODAMOS OBSERVARLAS Y DESCRIBIRLAS CON DETALLE. PERO PODEMOS Y TAMBIEN PODEMOS EN EL CASO DE LAS PARTICULAS FISICAS, ORDENARLAS DE ALGUN MODO CLASIFICANDOLAS Y FORMANDO GRUPOS CON ELLAS. ESTE ES EL PROCEDIMIENTO EMPLEADO POR EL ANALISIS I-O CON OBJETO DE AUMENTAR LA COMPRESION DE LA TEORIA ECONOMICA CON RESPECTO A LOS HECHOS A LOS QUE DEBE ENFRENTARSE EN LAS SITUACIONES REALES.

II. MARCO DE REFERENCIA

EN NUESTRO PAIS Y BAJO LA RESPONSABILIDAD DE LA Secretaría de Programación y Presupuesto, LAS CUENTAS NACIONALES CONSTITUYEN "LA

ESTRUCTURA CONCEPTUALMENTE ORGANIZADA EN QUE SE INSERTA LA INFORMACION ESTADISTICA DE QUE DISPONEMOS. LAS CUENTAS NACIONALES PERMITEN CONOCER LA ESTRUCTURA Y FORMA EN QUE ESTA OPERANDO LA ECONOMIA: QUE PRODUCE, CUANTO SE PRODUCE, PARA QUIEN O PARA QUE SE PRODUCE, A QUE SE DESTINA EL INGRESO, ESTO ES, QUE Y CUANTO SE CONSUME, CUANTO SE AHORRA Y CUANTO SE INVIERTE"

"EL CONOCIMIENTO DE LA ESTRUCTURA DE LA ECONOMIA Y SU COMPORTAMIENTO RESULTA FUNDAMENTAL PARA LA TOMA DE DECISIONES Y PARA LA PROGRAMACION DE ACTIVIDADES DE LOS SECTORES PUBLICO, PRIVADO Y SOCIAL DEL PAIS, ASI COMO PARA EVALUAR EL EFECTO DE ESAS ACCIONES Y DECISIONES"

"LA MATRIZ I-O, PARTE INTEGRANTE DEL SISTEMA DE CUENTAS NACIONALES, MUESTRA LAS RELACIONES QUE EXISTEN ENTRE LOS DISTINTOS SECTORES DE LA ECONOMIA, POR EJEMPLO, PERMITE CONOCER LAS ADQUISICIONES QUE UN SECTOR HACE DE LOS OTROS SECTORES, ASI COMO LO QUE LES PROVEE"

"COMO HERAMIENTA DE ANALISIS ECONOMICO, UNA MATRIZ I-O ES DE MUCHA UTILIDAD. PERMITE APRECIAR, POR EJEMPLO, LA ESTRUCTURA DE COSTOS DE UNA DETERMINADA RAMA O IDENTIFICAR A LOS DEMANDANTES DE LOS BIENES Y SERVICIOS PRODUCIDOS EN TODA LA ECONOMIA"

"ES, SIN EMBARGO, COMO INSTRUMENTO DE PLANEACION, EN DONDE LOS USOS SON MAYORES. SU EMPLEO PERMITE RESPONDER A MULTIPLES INTERROGANTES:

¿ QUE REPERCUSIONES SE ESPERARIAN EN LA PRODUCCION DEL CONJUNTO DE SECTORES SI SE QUIERE AUMENTAR LA PRODUCCION DE CIERTO TIPO DE BIENES Y SERVICIOS?

¿ CUAL SERIA EL IMPACTO DE UN AUMENTO EN LOS PRECIOS DE LOS PRODUCTOS DE UNA RAMA INDUSTRIAL, SOBRE EL NIVEL GENERAL DE LOS PRECIOS?

¿QUE REQUERIMIENTOS DE IMPORTACION MOTIVARIA LA EXPANSION DE LAS EXPORTACIONES DE UNA RAMA INDUSTRIAL DETERMINADA?

¿ANTE ALTERNATIVAS DE PRODUCCION, QUE EFECTOS SOBRE EL EMPLEO EN LA ECONOMIA PUEDEN ESPERARSE?

¿QUE NIVELES DE PRODUCCION DEBE ALCANZAR CADA SECTOR PARA CUMPLIR CON LAS METAS PROPUESTAS DE CONSUMO DE LA POBLACION?

"LAS MATRICES I-O SIRVEN TAMBIEN PARA EXAMINAR LAS REPERCUSIONES QUE EN LA PRODUCCION DE BIENES Y SERVICIOS DE LA ECONOMIA TIENEN POR EJEMPLO, LOS PROGRAMAS Y PROYECTOS DE INVERSION PUBLICA Y - PRIVADA; TAMBIEN PERMITE CONOCER EL IMPACTO DE LOS CAMBIOS TECNOLOGICOS EN EL PROCESO DE PRODUCCION DE BIENES Y SE VICIOS. POR OTRA PARTE POSIBILITA EXAMINAR, POR SEPARADO O EN CONJUNTO, LAS REPERCUSIONES DE LOS INCREMENTOS EN SALARIOS, IMPUESTOS INDIRECTOS Y SUBSIDIOS"

TODO ELLO, PERMITE DETECTAR A TIEMPO LOS POSIBLES CUELLOS DE BOTELLA QUE PUDIERAN OBSTACULIZAR EL DESARROLLO ECONOMICO FUTURO, AL TRAVES DE:

1. LA SERIE DE CUENTAS CONSOLIDADES DE LA NACION

   Cuenta de Producto y Gasto Interno Bruto
   Cuenta de Ingreso Nacional Disponible y su Asignación
   Cuenta de Acumulación y Financiamiento del Capital, y:
   Cuenta de Transacciones con el Exterior

2. LA CUENTA DE PRODUCCION, CONSUMO Y ACUMULACION DE CAPITAL POR RAMA DE ACTIVIDAD y:

3. LA MATRIZ I-O

"LA MATRIZ I-O SE PUEDE CONSIDERAR COMO UNA EXTENSION DE LAS CUENTAS DE PRODUCCION, CONSUMO Y FORMACION DE CAPITAL DE LA ECONOMIA, DONDE LA PARTE REFERIDA A LA DEMANDA INTERMEDIA SE DETALLA PARA HACER EXPLICITAS LAS RELACIONES DE ABASTECIMIENTO Y USO DE BIENES Y SERVICIOS QUE SE DAN ENTRE LAS DIFERENTES ACTIVIDADES ECONOMICAS QUE PARTICIPAN EN LA PRODUCCION INTERNA. A SU VEZ, TAMBIEN MUESTRA LA PARTE DE LA PRODUCCION QUE SE DESTINA AL ABASTECIMIENTO DE LA DEMANDA FINAL"

PARA CUMPLIR CON SU PROPOSITO LA MATRIZ I-O SE DISEÑA EN FORMA DE CUADRO DE DOBLE ENTRADA, DONDE LOS CRUCES DE LAS FILAS Y LAS COLUMNAS SIRVEN PARA REGISTRAR EN UN SOLO ASIENTO LAS TRANSACCIONES, DEBIDO A QUE LAS FILAS MUESTRAN EL DESTINO DE LOS BIENES Y SERVICIOS PRODUCIDOS POR UNA ACTIVIDAD ECONOMICA Y LAS COLUMNAS LA COMPOSICION DE LOS COSTOS DE PRODUCCION EN BASE A LAS ACTIVIDADES ECONOMICAS DE LAS CUALES PROVIENEN LOS BIENES Y SERVICIOS UTILIZADOS, PERO VEAMOS UN ESQUEMA SIMPLE:

CUADRO DE RELACIONES INTERSECTORIALES

Composición de insumos / Distribución de la producción	Agric.	Indus.	Serv.	Total de ventas intermediarias	Demanda Final: Total	Bienes y Serv. de Cons.	Bienes y Serv. de Capital	V. B. P.
Agricultura	5	30	—	35	65	65	—	100
Industria	10	40	5	55	95	50	45	150
Servicios	10	10	5	25	115	115	—	140
Total Insumos	25	80	10	115				
Salarios	40	40	75					
Intereses	5	5	10					
Ingresos	15	5	5					
Ganancias	15	20	40					
V. A.	75	70	130		275			
V. B. P.	100	150	140					390

EN EL ESQUEMA ANTERIOR SE DISTINGUEN TRES CAMPOS:

EL PRIMERO:(A),PRESENTA EN FORMA INTEGRAL TODA LA PRODUCCION DE BIENES INTERMEDIOS EN LA ECONOMIA. SE HACE NOTAR QUE AQUI SE TORNA CLARO EL FENOMENO GENERICO DE QUE LAS "SALIDAS" DE UN SECTOR CONSTITUYEN "ENTRADAS" DE OTROS (O DEL MISMO SECTOR)

EL SEGUNDO (B),NOS MUESTRA TODOS LOS BIENES FINALES PRODUCIDOS POR EL SISTEMA ECONOMICO EN UN PERIODO DETERMINADO.

Y EN EL CAMPO (C) EN FORMA GENERICA: LOS RENDIMIENTOS QUE SE PAGAN AL TRABAJO Y A LOS PROPIETARIOS DE LOS FACTORES CAPITAL Y RECURSOS NATURALES, etc, PERO AMPLIEMOS LA VISION:

La Matriz de Insumo-Producto

RAMA NUMERO		DEMANDA INTERMEDIA							DEMANDA FINAL						VALOR BRUTO DE PRODUCCION
		SECTORES DE PRODUCCION							INTERNA				EXPORTACIONES	TOTAL	
	SECTORES DE BIENES Y SERVICIOS	1	2	3	......	71	72	TOTAL	CONSUMO PRIVADO	CONSUMO GOBIERNO GENERAL	INVERSION INTERNA	SUBTOTAL			
1	AGRICULTURA														
2	GANADERIA														
3	SILVICULTURA														
4	CAZA Y PESCA														
5	CARBON Y DERIVADOS														
.	.....														
.	.....														
.	.....														
.	.....														
.	.....														
.	.....														
.	.....														
70	SERVICIOS MEDICOS														
71	SERVICIOS DE ESPARCIMIENTO														
72	OTROS SERVICIOS														
	IMPORTACIONES														
	SUBTOTAL	INSUMOS DE BIENES Y SERVICIOS							CONSUMO FINAL		INVERSION BRUTA INTERNA	BIENES Y SERVICIOS DISPONIBLES	EXPORTACIONES	DEMANDA FINAL TOTAL	VALOR BRUTO DE PRODUCCION MAS IMPORTACIONES
	VALOR AGREGADO BRUTO														
1	REMUNERACION DE ASALARIADOS														
2	SUPERAVIT BRUTO DE EXPLOTACION														
3	IMPUESTOS INDIRECTOS NETOS DE SUBSIDIOS														
		VALOR BRUTO DE PRODUCCION													

III. ALGUNOS CONCEPTOS BASICOS

VALOR BRUTO DE LA PRODUCCION: SUMA TOTAL DE LOS VALORES DE LOS BIENES Y SERVICIOS PRODUCIDOS POR UNA SOCIEDAD, INDEPENDIENTEMENTE DE QUE SE TRATE DE Insumos, ES DECIR, BIENES INTERMEDIOS.

PRODUCTO INTERNO BRUTO: SUMA DE LOS VALORES MONETARIOS DE LOS BIENES Y SERVICIOS PRODUCIDOS POR UN PAIS EN UN AÑO

Ejemplo:

	Valor de la Venta	Valor Agregado
TRIGO	100	100
HARINA	150	50
PAN	200	50
	450	200
	(VBP)	(PIB)

T A S A - N I V E L

Ejemplo: Crecimiento poblacional. Hipótesis: La Tasa Neta de Crecimiento (TNC) de la población P, es propocional a ésta

1) $TNC = \frac{dP}{dt} = kP$ o bien: $\frac{dP}{P} = k\, dt$

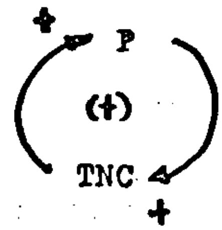
integrando:

2) $\ln P = kt + \ln C \Rightarrow P = C e^{kt}$

si $t = 0$, $P = P_o$ y de 2) $C = P_o \Rightarrow$

3) $P_t = P_o e^{kt}$

Formulación causal del ejemplo anterior:



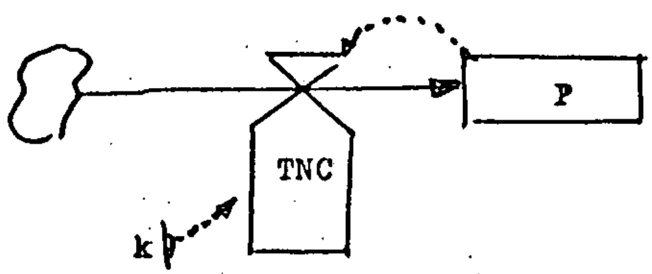
$$P.K = P.J + (DT)(TNC.JK)$$

$$\frac{P.K - P.J}{DT} = TNC.JK$$

$$\frac{dP}{dt} = TNC_t \quad \text{pero:} \quad TNC = kP \qquad \frac{dP}{dt} = k\,P$$

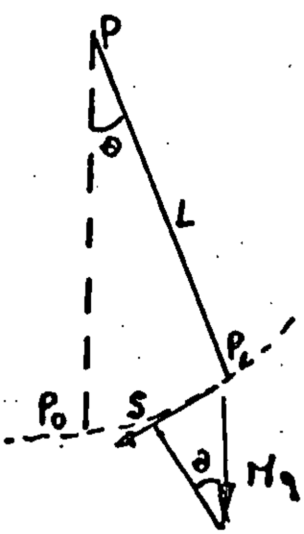
siguiendo el proceso anterior:

$$P_t = P_o e^{kt}$$



Hagamos otro ejemplo:

UN PENDULO, DE LONGITUD L Y MASA M, SUSPENDIDO DEL PUNTO P SE MUEVE EN UN PLANO VERTICAL BAJO P. ENCUENTRE LA ECUACION DEL MOVIMIENTO



HIPOTESIS: EL CENTRO DE GRAVEDAD DEL PENDULO SE MUEVE EN FORMA CIRCULAR CON CENTRO P Y CON RADIO L. SEA ϕ EL ANGULO POSITIVO MEDIDO EN SENTIDO CONTRARIO DE LAS MANECILLAS DEL RELOJ Y CUYA MAGNITUD ES FUNCION DEL TIEMPO t. LA UNICA FUERZA ES LA GRAVEDAD (SENTIDO POSITIVO HACIA ABAJO) Y SU COMPONENTE, TANGENTE AL CIRCULO ES: $Mg \operatorname{sen}\phi$. SI S ES IGUAL AL ARCO P_oP_1, ENTONCES $S = L\phi$ Y LA ACELERACION A LO LARGO DEL ARCO ES:

$$\frac{d^2S}{dt^2} = L \frac{d^2\phi}{dt^2}$$

$$ML \left(\frac{d^2\phi}{dt^2} \right) = - Mg \operatorname{sen}\phi \quad \Longrightarrow \quad L \frac{d^2\phi}{dt^2} = -g \operatorname{sen} \phi \quad \ldots.(1)$$

multiplicando por $2 \frac{d\phi}{dt}$ e integrando:

$$L \left(\frac{d\phi}{dt}\right)^2 = 2g \cos \phi + C_1$$

o bien: $$\frac{d\phi}{\sqrt{2g \cos\phi + C_1}} = \pm \frac{dt}{\sqrt{L}}$$

cuando ϕ es pequeño, SEN $\phi \doteq \phi$

$$L \frac{d^2\phi}{dt^2} + g \phi = 0 \qquad \phi = C_1 \cos \sqrt{\frac{g}{L}}\, t + C_2 \operatorname{sen} \sqrt{\frac{g}{L}}\, t$$

O LO QUE ES IGUAL: ES UN EJEMPLO DEL MOVIMIENTO ARMONICO SIMPLE

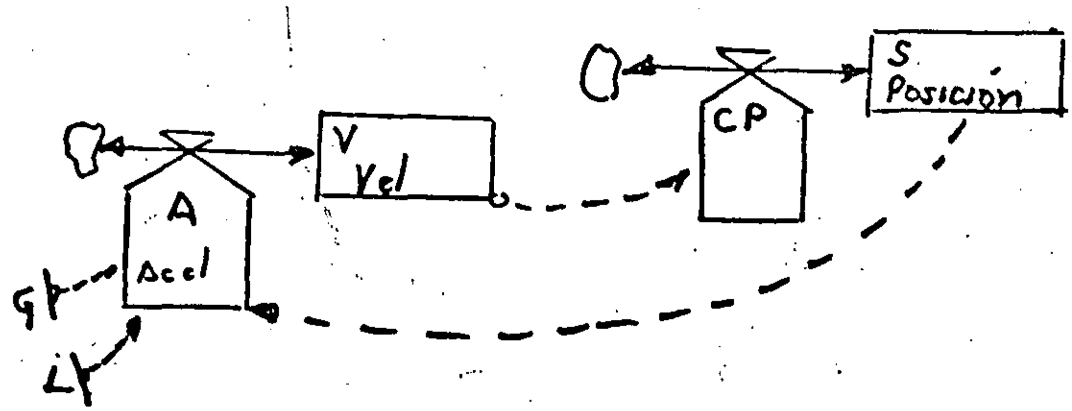
$$S_t = C_1 L \cos \sqrt{\frac{g}{L}}\, t + C_2 L \operatorname{sen} \sqrt{\frac{g}{L}}\, t$$

¡ CONTINUANDO !

$A = \frac{G}{L} (-S)$ $\qquad$ A.KL = ($\frac{G}{L}$)(- S.K)

V = A dt $\qquad$ V.K = V.J + (DT)(A.JK)

S = V dt $\qquad$ CP.KL = V.K
S.K = P.J + (DT)(PC.JK)



IV. MANIPULACIONES DE LA MATRIZ I-O

Formulación Estática: COMO HEMOS VISTO, LA MATRIZ I-O NOS DA EL FLUJO DE BIENES Y SERVICIOS QUE SE HA ESTABLECIDO ENTRE LOS DIFERENTES SECTORES DE UNA ECONOMIA DURANTE UN DETERMINADO PERIODO DE TIEMPO, DIGAMOS DE UN AÑO. REPRESENTEMOS UN EJEMPLO MUY SIMPLE CONSTITUIDO POR UNA ECONOMIA TRISECTORIAL:

	S_1	S_2	S_3	VBP
S_1	x_{11}	x_{12}	x_{13}	X_1
S_2	x_{21}	x_{22}	x_{23}	X_2
S_3	x_{31}	x_{32}	x_{33}	X_3

EN QUE:

S_i = SECTOR DE PRODUCCION $\quad i = 1,2,3$

x_{ij} = VENTAS DEL SECTOR S_i AL SECTOR S_j

X_i = VALOR BRUTO DE LA PRODUCCION

AHORA BIEN: $\boxed{\text{SI } x_{ij} = a_{ij} X_j} \Longrightarrow$

$$a_{ij} = \frac{\text{CANTIDAD DE PRODUCCION DEL } S_i \text{ ABSORBIDA POR } S_j}{\text{PRODUCCION DE } S_j}$$

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

ES DECIR, a_{ij} = COEFICIENTE TECNICO QUE REPRESENTA LA COMPRA DE PRODUCTOS INTERMEDIOS DEL SECTOR j AL SECTOR i, PARA CONCRETAR UNA UNIDAD DE PRODUCCION BRUTA DEL SECTOR j. POR LO TANTO, LA MATRIZ DE COEFICIENTES TECNICOS SERA:

PARA ESTE EJEMPLO:

	S_1	S_2	S_3	VBP
S_1	$x_{11} = 50$	$x_{12} = 40$	$x_{13} = 110$	200
S_2	$x_{21} = 70$	$x_{22} = 30$	$x_{23} = 150$	250
S_3	$x_{31} = 80$	$x_{32} = 180$	$x_{33} = 40$	300

	S_1	S_2	S_3
S_1	0.25	0.16	0.3666 (a_{13})
S_2	0.35	0.12	0.5000
S_3	0.40	0.70 (a_{32})	0.1333

Y REGRESANDO: SI LA PRODUCCION BRUTA X_j DEL S_j ES IGUAL A SUS VENTAS DE DEMANDA FINAL (Y_j), MAS SUS VENTAS A LOS OTROS SECTORES PRODUCTORES ENTONCES:

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + Y_1$$
$$X_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + Y_2$$
$$X_3 = a_{31}X_1 + a_{32}X_2 + a_{33}X_3 + Y_3$$

- -

$$\begin{array}{lllll} (1 - a_{11})X_1 & -a_{12}X_2 & -a_{13}X_3 & & Y_1 \\ -a_{21}X_1 & +(1 - a_{22})X_2 & -a23X_3 & & Y_2 \\ -a_{31}X_1 & -a_{32}X_2 & +(1-a_{33})X_3 & = & Y_3 \end{array}$$

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

EXPRESION GENERAL:

$$\left[X_i\right] = \left[a_{ij}\right]^{-1} \left[Y_i\right] = \left[A_{ij}\right] \left[Y_i\right]$$

SI SUPONEMOS CONOCIDAS LAS DEMANDAS FINALES, EL SISTEMA TIENE SOLUCION.

LA MATRIZ I-O DINAMICA SE DESARROLLA A PARTIR DE LA ESTATICA DESDE EL MOMENTO EN QUE CONSIDERAMOS QUE LA INTERDEPENDENCIA SECTORIAL PRESENTA DESFASES, O SUPONEMOS QUE LA MISMA EXPERIMENTA VARIACIONES A LO LARGO DEL TIEMPO. LAS RELACIONES ESTRUCTURALES ENTRE LOS STOKS Y LAS CORRIENTES DE BIENES CONSTITUYEN LA BASES TEORICA DEL ENFOQUE I-O DEL ANALISIS EMPIRICO DEL PROCESO DE ACUMULACION Y DE LA PLANEACION DEL DESARROLLO.

EL STOCK DE BIENES PRODUCIDOS POR EL SECTOR i QUE EL SECTOR j DEBE ABSORBER POR unidad DE SU PRODUCTO, CORRESPONDIENTE A LA PLENA CAPACIDAD, ES DENOMINADO COEFICIENTE DE CAPITAL DEL BIEN i EN EL SECTOR j Y ACOSTUMBRA DESIGNARSE POR b_{ij}

EL EQUILIBRIO ENTRE EL PRODUCTO Y LA CAPACIDAD DISPONIBLE DE UN SECTOR CARACTERISTICO, POR EJEMPLO EL i, Y SU UTILIZACION EN UN AÑO PARTICULAR t, PODRIA SER DESCRITO POR LA SIGUIENTE ECUACION LINEAL DIFERENCIAL, QUE IMPLICA LA EXISTENCIA DE INTERRELACIONES ESTRUCTURALES ENTRE LOS INSUMOS Y PRODUCTOS DE LOS DIVERSOS SECTORES Y SUS tasas de cambio, $\dot{X}_1(t)$, $\dot{X}_2(t)$, $\dot{X}_3(t)$,.......

$$X_i(t) - a_{i1}X_1(t) - a_{i2}X_2(t) - \ldots\ldots - a_{in}X_n(t) -$$
$$- b_{i1}X_1(t) - b_{i2}X_2(t) - \ldots\ldots - b_{in}X_n(t) = Y_i(t)$$

LA MAYOR PARTE DEL TRABAJO EMPIRICO EN ESTE CAMPO SE LLEVA A CABO EMPLEANDO EL ANALISIS DE PERIODOS DISCRETOS QUE SE FUNDA EN SISTEMAS DE ECUACIONES EN DIFERENCIAS DEL TIPO QUE INDICAMOS A CONTINUACION

$$X_i^t - a_{i1}X_1^t - a_{i2}X_2^t - \ldots\ldots - a_{in}X_n^t -$$
$$-b_{i1}(X_1^{t+1}-X_1^t) - b_{i2}(X_2^{t+1}-X_2^t) - \ldots\ldots - b_{in}(X_n^{t+1}-X_n^t) = Y_i^t$$

LA FORMULACION EN DYNAMO SE PRESENTA EN LAS SIGUIENTES HOJAS, PERO PODEMOS AFIRMAR LO SIGUIENTE:

- EN UN MODELO REGIONAL, LAS DEMANDAS FINALES SON TAMBIEN VARIABLES ENDOGENAS Y POR LO TANTO, EXISTE UNA INTERACCION ENTRE LAS VARIABLES RELEVANTES, TAL Y COMO SE PLANTEARA EN LA PROXIMA CONFERENCIA LO ANTERIOR PERMITIRA DESCRIBIR PARA CADA POLITICA, POR EJEMPLO: EL RITMO DEL PIB, NIVEL DE EMPLEO etc., EN CADA DIFERENCIAL DE TIEMPO dt.

- LOS COEFICIENTES TECNICOS Y DE CAPITAL PUEDEN VARIAR INTERNAMENTE A TODO LO LARGO DEL HORIZONTE DE PLANEACION Y PARA CADA SIMULACION A REALIZAR

E J E M P L O S:

ACADEMIA
NACIONAL
DE INGENIERIA, A.C.

México, D.F., mayo, 1983.

Señor (es)
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Tengo el agrado de informarle(s) que su trabajo: "LA MATRIZ INSUMO-PRODUCTO EN UN MODELO DE SIMULACION DINAMICA PARA EL ANALISIS REGIONAL".

Ha sido aceptado para su presentación ante el IX Congreso de la Academia Nacional de Ingenieria, que tendrá lugar en León, Gto., del 28 al 30 de Septiembre del presente año.

A fin de que dicho trabajo pueda incluirse en las Memorias del Congreso, le(s) ruego escribirlo en las hojas especiales anexas, siguiendo las instrucciones que también se acompañan. Juntamente con el manuscrito, deberá(n) Ud(s) devolver firmada la declaración de no publicación.

Es muy importante que los autores presenten sus trabajos personalmente, por lo que será muy apreciada su participación en el Congreso. En el caso de no poder asistir, le(s) ruego encargar la presentación a un participante que Ud(s) considere(n) capacitado para ello.

Agradeciéndole(s) su colaboración, le(s) saludo atentamente.

POR EL COMITE TECNICO

Presidente del Comite

Dr. Alejandro F. Romero López.

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LA MATRIZ INSUMO-PRODUCTO EN UN MODELO DE SIMULACION DINAMICA PARA EL ANALISIS REGIONAL

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Abstract

This paper is devote of the General System Theory. Hipothesis: the real world can be described by a set of simultaneous differential equations and the model can be simulated on a digital computer with a set of nonsimultaneous difference equations, according with Forrester, by languaje DYNAMO (DYNAmics MOdels).

The purpose is to include the Input-Output (I-O) matrix in a model of dynamics simulation for regional analysis, solving the subsystem I-O by a set of simultaneous difference equations, with the demands (exogenous variable) like endogenous and with no necessarily fixed technical and capital coefficients over the time. This lend us to generate easily alternative sets of projections and to incorporate policies within the framework used for projection so as to test their potential impact in more realistic form.

Resumen

Este documento se apoya en la Teoría General de Sistemas. Hipótesis: el mundo real puede ser representado por un conjunto de ecuaciones diferenciales simultáneas y el modelo puede ser simulado en una computadora digital con un conjunto no simultáneo de ecuaciones de diferencias, de acuerdo a Forrester, por medio del lenguaje DYNAMO (DYNAmics MOdels).

El propósito de este trabajo es incluir la matriz Insumo-Producto (I-O), en un modelo de simulacion dinámico para el análisis regional, resolviendo el subsistema I-O como un conjunto de ecuaciones de diferencias simultáneas y manipulando las demandas (variable exógenas) como endógenas así como sin tener necesariamente fijos los coeficientes técnicos y de capital a lo largo del tiempo. Lo anterior permite generar fácilmente conjuntos alternos de proyecciones, incorporando políticas y estimando sus impactos potenciales en forma más realista.

Introducción

Las investigaciones científicas son una exposición de la estructura de los sistemas naturales, la tecnología ha producido complejos sistemas de producción, pero aún así a partir de la Teoría General de los Sistemas (1), no hemos entendido completamente sus principios respecto al comportamiento de los Sistemas, aún aceptando el concepto de sistema: "conjunto de partes coordinadas con objeto de lograr un conjunto de metas" (2). Conforme a lo anterior, una componente interactuante del desarrollo nacional, es el desarrollo regional en la cual también existen prácticamente, las mismas variables. Huelga decir la importancia que actualmente cobra en nuestro país el análisis regional, debido a problemas tales como migración, contraste en actividad económica, nivel de infraestructura, contaminación, etc.

Estado del Arte

Ahora bien, dentro de los modelos a gran escala realizados sobre desarrollo regional del tipo base económica, como son los que se han utilizado en Estados Unidos sobre las regiones de San Diego, Nueva York, Cuenca del río Ohio, California o el de la Cuenca Lehigh, todos se han caracterizado por realizar dos proyecciones independientes; población y fuerza laboral (3), manipulando en forma separada la matriz I-O y como variable exógena la demanda. Una excepción en cuanto a proyecciones independientes es el modelo de la Cuenca del río Susquehanna, aunque éste no emplea como instrumento de análisis económico dicha matriz.
El presente trabajo propone una interacción dinámica para la utilización de la matriz I-O en el análisis regional, o bien, a nivel nacional, apoyándose directamente en la conceptualización teórica y matemática de Forrester (4,5), lo cual permite, baja manipulación especial, describir paso a paso las fluctuaciones de cada variable en el tiempo para cada simulación realizada.

El Subsistema I-O Dinámico

"el análisis I-O no es más que una consecuencia práctica de aquella teoría clásica que postula la interdependencia general de las variables económicas. "Considera esta teoría que el conjunto de la economía de una región, un país o el mundo costituye un sistema único, y se esfuerza por expresar la totalidad de sus funciones en términos de sus propiedades estructurales que son susceptibles de cuantificación". (Leontief). La conceptualización de la interacción dinámica representada por el diagrama causal de la fig. 1, se ilustra en la página siguiente. Lo anterior arroja como consecuencia los siguientes aspectos relevantes:

Contribución

-En un modelo regional, las demandas finales son también variables endógenas y por lo tanto, existe una interacción entre todas las variables relevantes (fig2), lo anterior permite describir para cada política asumida, por ejemplo: el ritmo del PIB, empleo, etc., y en cada diferencia del tiempo dt.
-Los coeficientes técnicos y de capital pueden variar intercamunto a todo lo largo del horizonte de análisis y para cada simulación realizar

-Las entregas que el sector A se hace a sí mismo y a los demás sectores en respuesta a las respectivas necesidades de la capacidad productiva, y de acuerdo a Forrester (4,5), se mide por la diferencia existente entre el nivel de producción del tiempo presente K, y el tiempo pasado J, es decir en cada diferencial de tiempo dt, (6) o bien, como diferencia entre un pronóstico de evento futuro y tiempo presente.
Como ejemplo de cómputo, sea la variable Inventario (I) es como las Tasas de entrada y salida E y S respectivamente:

$$I_{\text{"ahora"}} = I_{\text{"anterior"}} + \int_0^t (E-S)\,dt \text{ ----------- (0)}$$

$$I_k = I_j + (E_{jk} - S_{jk})DT \text{ -------- (0')}$$

en que DT se usa para definir el lapso entre J y K o K y E de acuerdo a la fig. 3

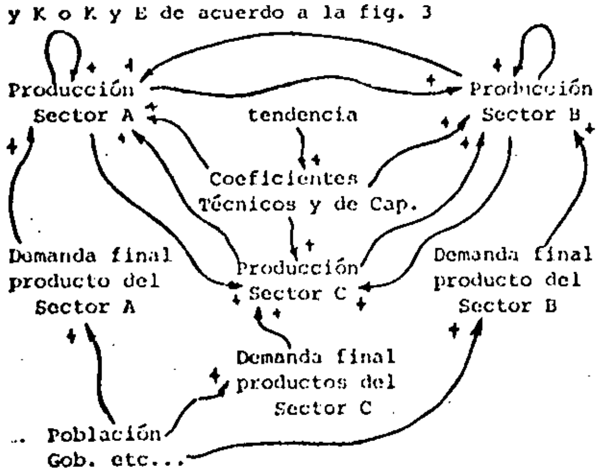


Figura 1

"La descripción análitica general y al mismo tiempo realista de las relaciones I-O de índole dinámica sería utilizando diferentes variables para designar las corrientes de insumo y producción efectuadas o absorbidas por la misma industria en años diferentes. El equilibrio entre lo producido y la capacidad disponible de un sector característico por ejemplo el x_i y su utilización en un año particular t, podría ser descrito por la siguiente ecuación lineal diferencial que implica la existencia de interrelaciones estructurales entre los insumos y su producción de los diversos sectores y sus tasas de cambio: $\dot{x}_1(t), \dot{x}_2(t)$" (7)

$$x_i(t) - a_{i1}x_1(t) - a_{i2}x_2(t) - \ldots - a_{in}x_n(t) - b_{i1}\dot{x}_1(t) - b_{i2}\dot{x}_2(t) - \ldots - b_{in}\dot{x}_n(t) = y_i(t) \text{ ---------------------------- (1)}$$

$$x_i^t - a_{i1}^t x_1^t - a_{i2}^t x_2^t - \ldots - a_{in}^t x_n^t - b_{i1}^t(x_1^{t+1} - x_1^t) - b_{i2}^t(x_2^{t+1} - x_2^t) - \ldots - b_{in}^t(x^{t+1} - x_n^t) = y_i^t \text{ ---------- (2)}$$

en que:

$x_i(t) = x_i^t$ = cantidad de producción del sector

$\dot{x}_i(t)$ = tasa de cambio del sector i en el tiempo t

a_{ij}^t = coeficiente técnico del producto del sector i en el sector j, en el tiempo t

b_{ij}^t = coeficiente de capital del bien i en el sector j, en el tiempo t

$y_i(t) = y_i^t$ = cantidad de la demanda final del producto del sector i en el tiempo t

t = unidad de tiempo

y la formulación general en lenguaje Dynamo:

$PT_i.K = PT_i.J + (DT)(1/T)(TX_i.J - PT_j.J)$ --- (3)

$TX_i.K = (1/(1-A_{ii}.K))(STCK_i.K + \sum_{j \neq i}^{n}((A_{ij}.K)(PT_j.K)) + \sum_{j \neq i}^{n}((B_{ij}.K)(PT_j.K)) + Y_i.K)$ -------- (4)

$DPROP_i.K = (A_{ii}.K)(PT_i.K)$ ó bien ---------- (5)

$(A_{ii}.K)(TX_i.K)$ si $REALS_i.K = f(\text{pronóstico})$ - (5')

$STCK_i.K = (B_{ii}.K)(REALS_i.K)$ --------------- (6)

$REALS_i.K = CLIP(IP_i.K, 0, IP_i.K, 0)$ ------------ (7)

$IP_i.K = PT_i.K - A_i.J$ ó bien ------------- (8)

$(\text{Pronósticos})_i.K - TX_i.K$ ------------------ (8')

$A_i.K = A_i.J + (DT)(1/T)(TA_i.J - A_i.J)$ ------ (9)

$PT_i = 0$ ---------------------------------- (10)

$A_i = 0$ ---------------------------------- (11)

$TA_i.K = PT_i.J$ ---------------------------- (12)

Si $REALS_i.K$ se define en función de un pronóstico (6), entonces desaparecen las ecuaciones 3), 9), 10), 11) y 12), siendo la notación la siguiente:

$PT_i.K = TX_i.K$ = cantidad de producción del sector i en el tiempo presente K.

PT_i = valor de inicialización

$PT_i.J = TX_i.J$ = cantidad de producción del sector i en el tiempo pasado J

DT = diferencial de tiempo

T = tiempo promedio de demora

$A_{ij}.K$ = coeficiente técnico del producto del sector i en el sector j, en el tiempo presente K

$B_{ij}.K$ = coeficiente de capital del bien i en el sector j, en el tiempo presente K

$DPROP_i.K$ = demanda propia del sector i en el tiempo presente K

$STCK_i.K$ = adiciones al stock de capital productivo del sector i en el tiempo presente K

$A_i.K$, A_i, $TA_i.K$, $IP_i.K$ = variables auxiliares

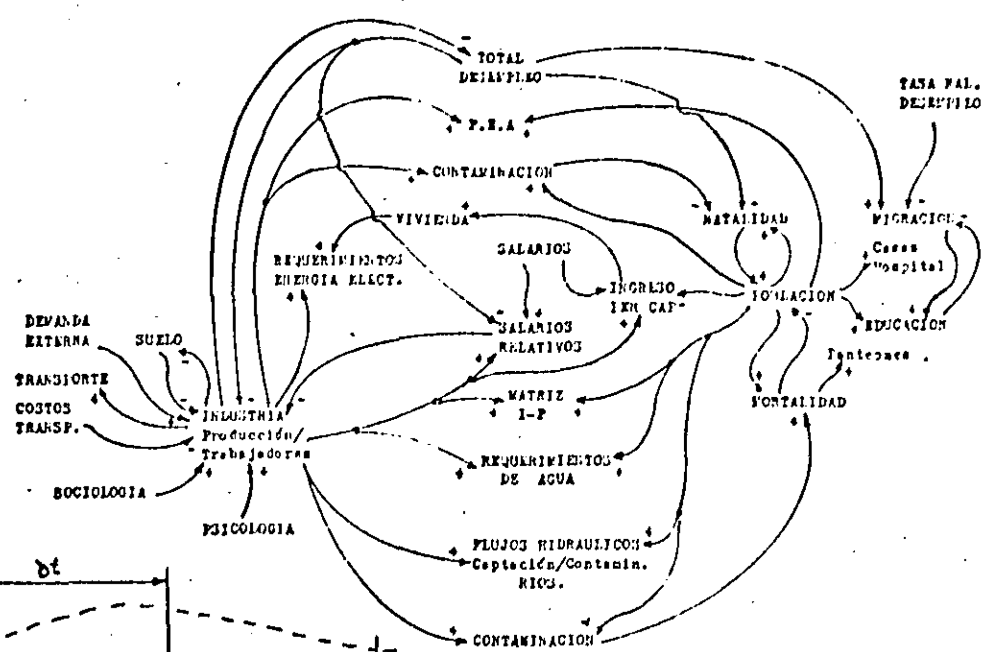


Figura 2

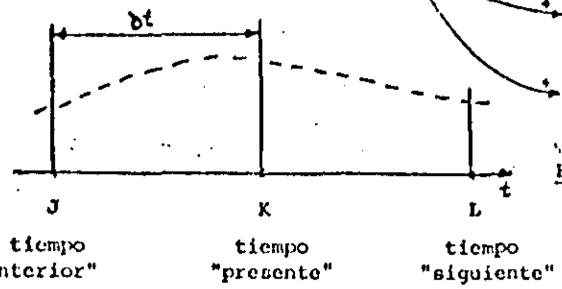


Figura 3

EJEMPLOS

Ejemplo 1: (validación)
En la tabla 1 se presenta un ejemplo sencillo tomado del artículo Análisis I-O, 1965 de Leontief (7) en el cual primero hizo un análisis de consistencia interna, para lo cual mantiene constante las demandas Y_1 y Y_2 (variable exógenas) en 55 Hl de trigo y 30 m^2 de paño. El producto total de trigo se mantiene constante en 100 Hl y el de productos manufacturados en 50 m de paño; es decir, la economía se mantuvo invariable.

TABLA 1 Ejemplo del artículo "Análisis I-O/1965" pg 208, ...(7)

Hacia / A partir	Sect 1 Agric.	Sect 2 Indust	Sect 3 Familias	Output ($)
Sector 1				
Agricultura	50	40	110	200
Sector 2:	70	30	150	250
Sector 3:	80	180	40	300
Input Total	200	250	300	

En dynamo, las Listas 1 y 2 se presentan los listados por computadora, en la 3, los valores asumidos por las variables asumidos por las variables. En la fig. 3 se presenta la gráfica por computadora obtenida con una DT=0.125 en que, efectivamente, la economía se mantiene invariable

Lista 1

```
[illegible]

[illegible]
[illegible]

[illegible]
[illegible]

ENTER IN COLUMNS 1-15 THE NAME OF THE DISK FILE YOU WISH
DYNAMO TO CREATE TO WRITE YOUR ALGOL SOURCE CODE. IF OUTPUT
IS DESIRED ON THE LINE PRINTER ENTER C IN COLUMN 1 FOLLOWED
BY FILENAME

LEONT/O

OK

BURROUGHS B6700/B7700 DYNAMO LEVEL DYN454: 7/16/03

INPUT PHASE BEGIN AT  7:14 11

DYNAMO BLIST NARROW
RUN   LEONTIEF

        EJEMPLO DE ANALISIS INPUT/OUTPUT (LEONTIEF 1965)

            SECTOR (1): AGRICULTURA

      PT1.K=PT1.J+(DT)((1/T)(TX1.J-PT1.J))
      PT1=0
      TX1.K=(1/(1-A11))(STOCK1.K+DSECT2.K+DSTOC2.K+Y1.K)
      DPROP1.K=(A11)(PT1.J)
      STOCK1.K=(B11)(REALS1.K)
.PAGE.
      REALS1.K=CLIP(IP1.K,0,IP1.K,0)
      IP1.K=PT1.J-A1.J
      DSECT2.K=(A12)(PT2.J)
      DSTOC2.K=(B12)(REALS2.K)

      A1.K=A1.J+(DT)((1/T)(TA1.J-A1.J))
      A1=0
      TA1.K=PT1.J

      Y1=DEMANDA FAMILIAR AL SECTOR (1)

      Y1.K=TABLE(TY1T,TIME.K,0,5,.5)
      TY1T=0/55/55/55/55/55/55/55/55/55

            SECTOR (2): INDUSTRIA

      PT2.K=PT2.J+(DT)((1/T)(TX2.J-PT2.J))
      PT2=0
      TX2.K=(1/(1-A22))(DSECT1.K+DSTOC1.K+STOCK2.K+Y2.K)
      DSECT1.K=(A21)(PT1.J)
.PAGE.
      DSTOC1.K=(B21)(REALS1.K)
      DPROP2.K=(A22)(PT2.J)
      STOCK2.K=(B22)(REALS2.K)
      REALS2.K=CLIP(IP2.K,0,IP2.K,0)
```

```
      A2.K=A2.J+(DT)(1/T1)(TA2.J-A2.J)
      A2=0
      TA2.K=...
                                                   Lista 2
                                                   (cont'n)
      Y2=DEMANDA FAMILIAR AL SECTOR (2)

      Y2.K=TABLE(TY2T,TIME.K,0,5,.5)
      TY2T=0/20/20/30/20/30,30/30/30/30/30

      COEFICIENTES   TECNICOS   =  A11
      COEFICIENTES DE CAPITAL   =  B11
      A11=0.25
      A12=0.40
      A21=0.14
.PAGE.
      A22=0.12
      B11=0.20
      B12=0.05
      B21=0.01
      B22=0.07

      T=0.125
PRINT 1)DEMOP1/2)STOCK1/3)DSECT2/4)DSTOC2/5)Y1/6)PT1
PRINT 1)DSECT1/2)DSTOC2/3)DEMOP2/4)STOCK2/5)Y2/6)PT2
PLOT  PT1=1(0,150)/PT2=2(0,100)/Y1=X(0,75)/Y2=Y(0,50)
SPEC  DT=0.125
SPEC  LENGTH=5
SPEC  PRTPER=0.5
SPEC  PLTPER=0.125
#1215 (JSU9)PROGRAMFILE/DYNAMO REMOVED ON PACK PK33.

INPUT PHASE CONCLUDED AT    7115 35

GENERATION PHASE BEGAN AT   7115 37
RUN  PHASE  GENERATED AT    7115 42
.PAGE.
PRINT PHASE GENERATED AT    7115 43
PLOT PHASES GENERATED AT    7115 44

ELAPSED COMPILATION TIME      1 48

PLEASE ENTER COMPILE LEONTZO          WITH ALGOL.  THEN
WAIT UNTIL YOUR TERMINAL REPORTS THAT YOUR COMPILATION
IS COMPLETE.  AFTER GOOD COMPILATION ENTER  EXECUTE
LEONTZO

#ET=2101.4 PT=4.5 IO=5.2

COMPILE LEONTZO WITH ALGOL
#COMPILING 1216
#SET BCL RESET LIST
00001000 WARNING:BCL PROGRAMS ARE NOT PORTABLE TO EBCDIC MACHINES
#ET=14.5 PT=2.4 IO=6.1
                                                    Lista 3
  EXECUTE LEONTZO
  RUNNING 1217

   PAGE  1     LEONTI

                      7116.0150, 16 JULY 1983

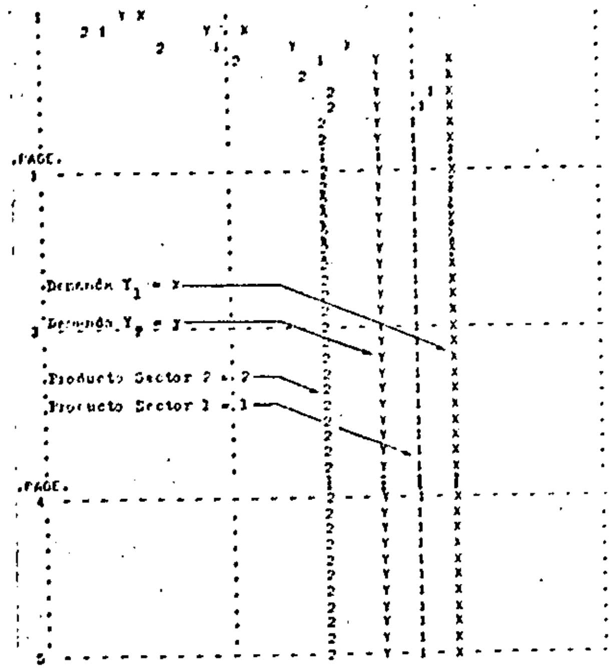
            STARTED TO RUN CODE AT  7116.0164, 16 JULY 1983

   PAGE  2     LEONTI

            STARTED PRINTING AT  7116.9044, 16 JULY 1983
```

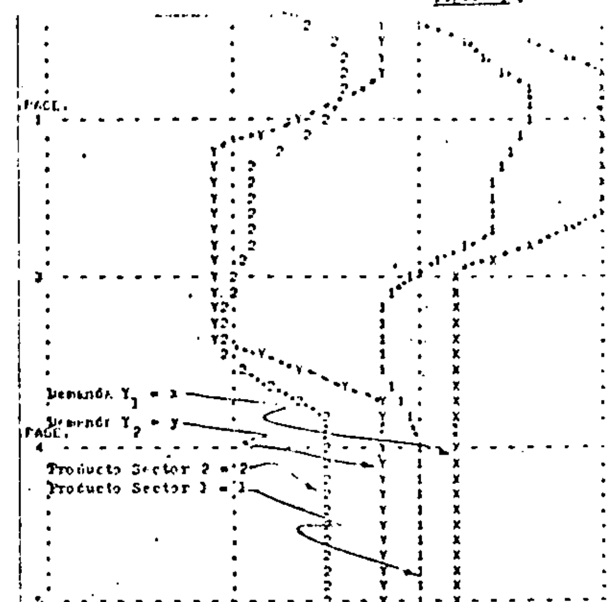
TIME	DEMOP1 DSECT1	STOCK1 DSTOC2	DSECT2 DEMOP2	DSTOC2 STOCK2	Y1 Y2	PT1 PT2
E+00	E+00 E+00	E+00 E+00	E+00 E+00	E+00 E+00	E+00 E+00	E+00 E+00
0.0000	0.000 0.000	0.0000 0.00000	0.000 0.0000	0.00000 0.00000	0.000 0.000	0.00 0.000
0.5000	18.624 10.470	5.5656 0.67234	13.710 4.1154	0.67234 0.94128	55.000 30.000	74.50 34.295
1.0000	25.105 14.104	0.0000 0.00000	20.170 6.0511	0.00000 0.00000	55.000 30.000	100.74 50.424
1.5000 .PAGE.	25.001 14.001	0.0000 0.00000	20.001 6.0004	0.00000 0.00000	55.000 30.000	100.01 50.003
2.0000	25.000 14.000	0.0000 0.00000	20.000 6.0000	0.00000 0.00000	55.000 30.000	100.00 50.000
2.5000	25.000 14.000	0.0000 0.00000	20.000 6.0000	0.00000 0.00000	55.000 30.000	100.00 50.000
3.0000	25.000 14.000	0.0000 0.00000	20.000 6.0000	0.00000 0.00000	55.000 30.000	100.00 50.000
3.5000	25.000 14.000	0.0000 0.00000	20.000 6.0000	0.00000 0.00000	55.000 30.000	100.00 50.000
4.0000	25.000 14.000	0.0000 0.00000	20.000 6.0000	0.00000 0.00000	55.000 30.000	100.00 50.000
4.5000	25.000 14.000	0.0000 0.00000	20.000 6.0000	0.00000 0.00000	55.000 30.000	100.00 50.000

En la fig. 4: una nueva gráfica computarizada, pero ahora incrementando la demanda Y_1 y decrementando la Y_2. Lo anterior permite visualizar la cantidad y capacidad de respuesta del sistema.



FINISHED RUN NUMBER LEONTI AT 7120.0956, 16 JULY 1983
#ET=3127.2 PT=0.0 IO=1.6

Figura 3



FINISHED RUN NUMBER LEONTI AT 7129.9806, 16 JULY 1983
#ET=3130.2 PT=0.0 IO=1.6

Figura 4

En la fig. 5 se realiza otra simulación, ahora con una DT=0.0625 año

Ejemplo 2:

Dentro del análisis regional (8), un diagrama causal general puede ser como el de la fig 2 anterior, y cuyos resultados se visualizan en las gráficas por computadora de las figs. 6 y 7 y se puede apreciar las fluctuaciones de algunas de las 72 variables consideradas.

Agradecimientos

Este trabajo fue posible gracias a la beca otor

gada por la ex-Secretaría de Asentamientos Humanos y Obras Públicas, siendo Subsecretario el Ing. Rodolfo Félix Valdes, así como por la asesoría del Dr. José de Jesús Acosta Flores, Subjefe de Ingeniería de Sistemas de la DEPFI. UNAM.

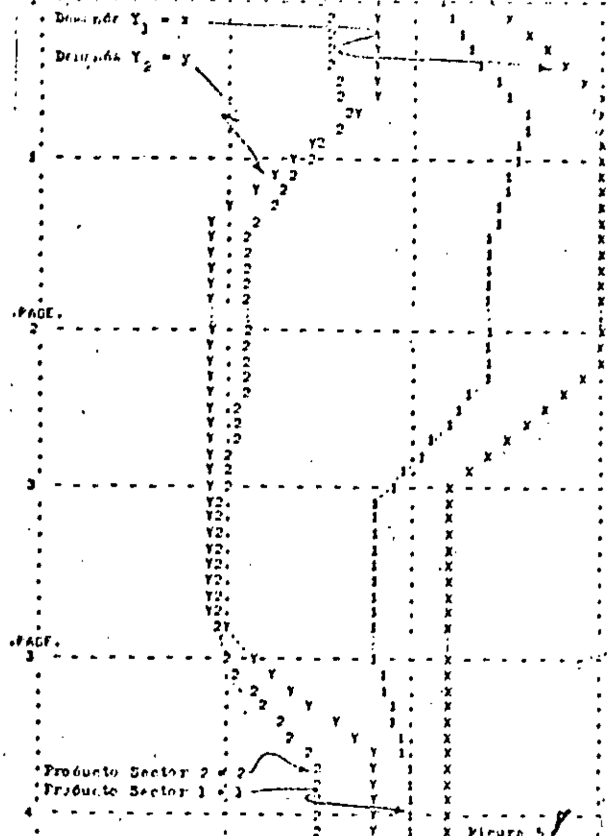


Figura 5

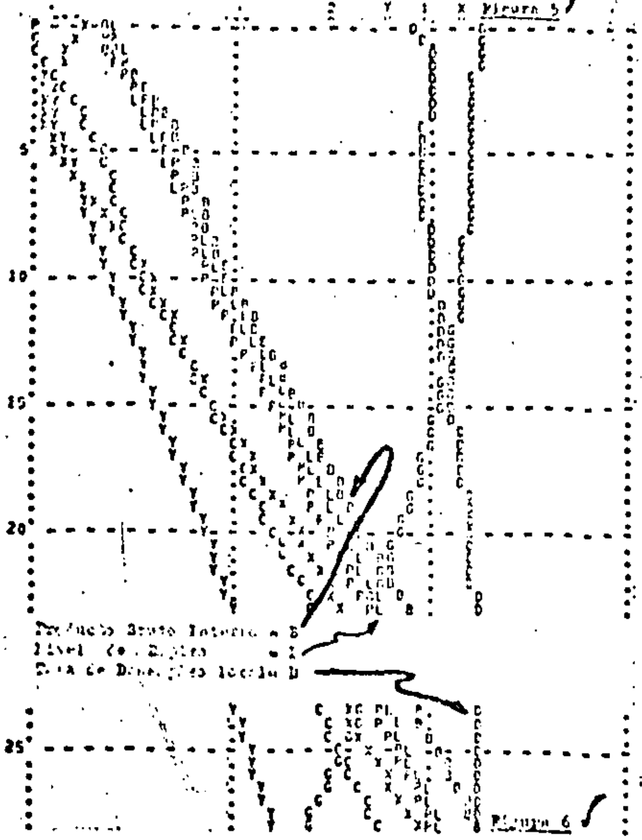
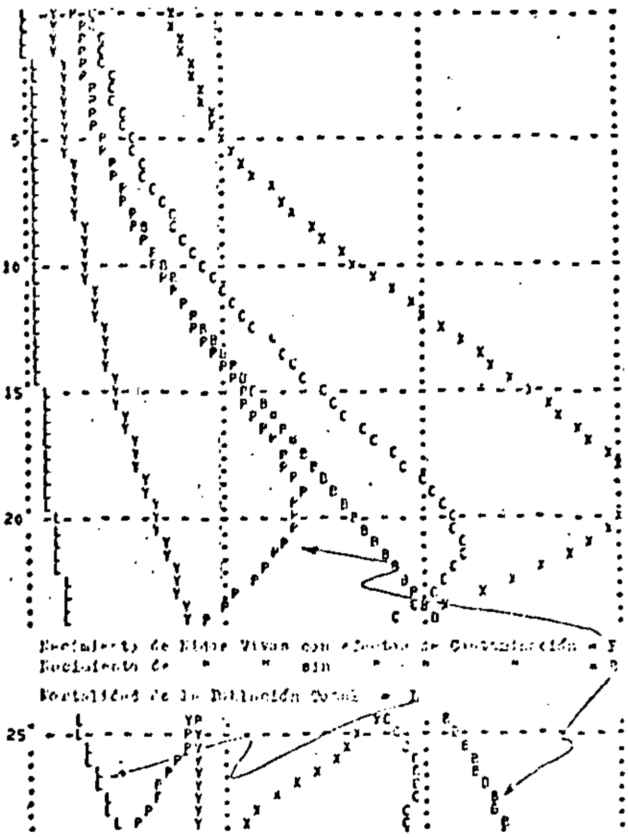


Figura 6



Bibliografía

1. Bertalanffy L, "General System Theory-Foundations, Development, Aplications" Ed. Braziller, New York, 1968

2. Jauffred F, "El enfoque de sistemas en la planeación urbana", Seminario Planeación del Sistema Urbano. División de Educación Continua, México D.F, 1976.

3. Hamilton J, Systems Simulation for Regional Analysis. An Application to River-Basin Planning, M.I.T Press, U.S.A, 1969. pp 54-87

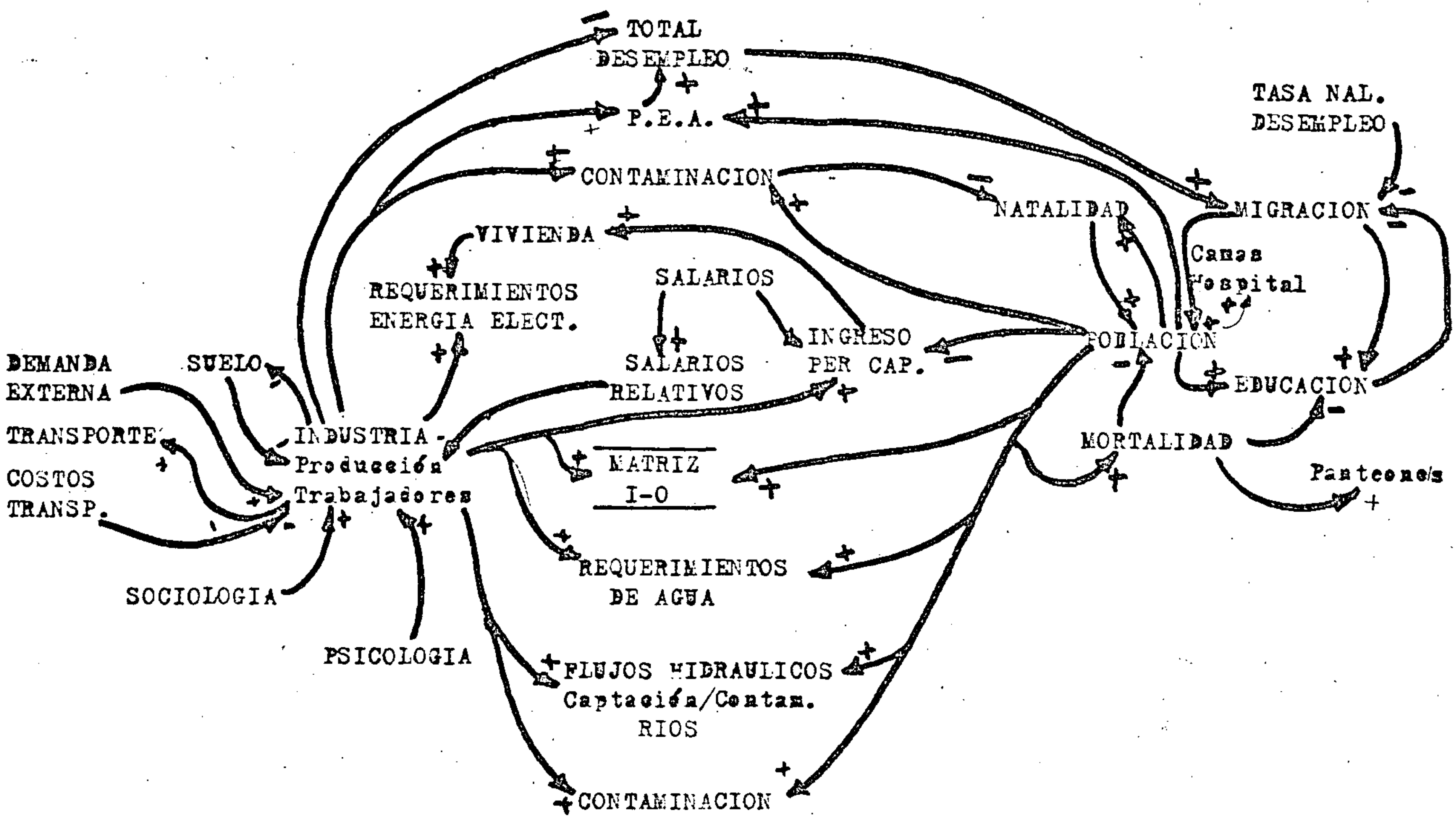
4. Forrester J, Principles of Systems, Wright-Allen Press Inc, U.S.A., 1968

5. Goodman M, Study Notes in Systems Dynamics, Wright-Allen Press Inc, U.S.A., 1974, pp 43-44.

6. Lyneis J, Corporate Planning and Policy Design: A System Dynamics Approach, M.I.T. Press, U.S.A., 1980

7. Leontief W, Análisis Económico Input-Output, Editorial Ariel, España, 1973, pp 207-226

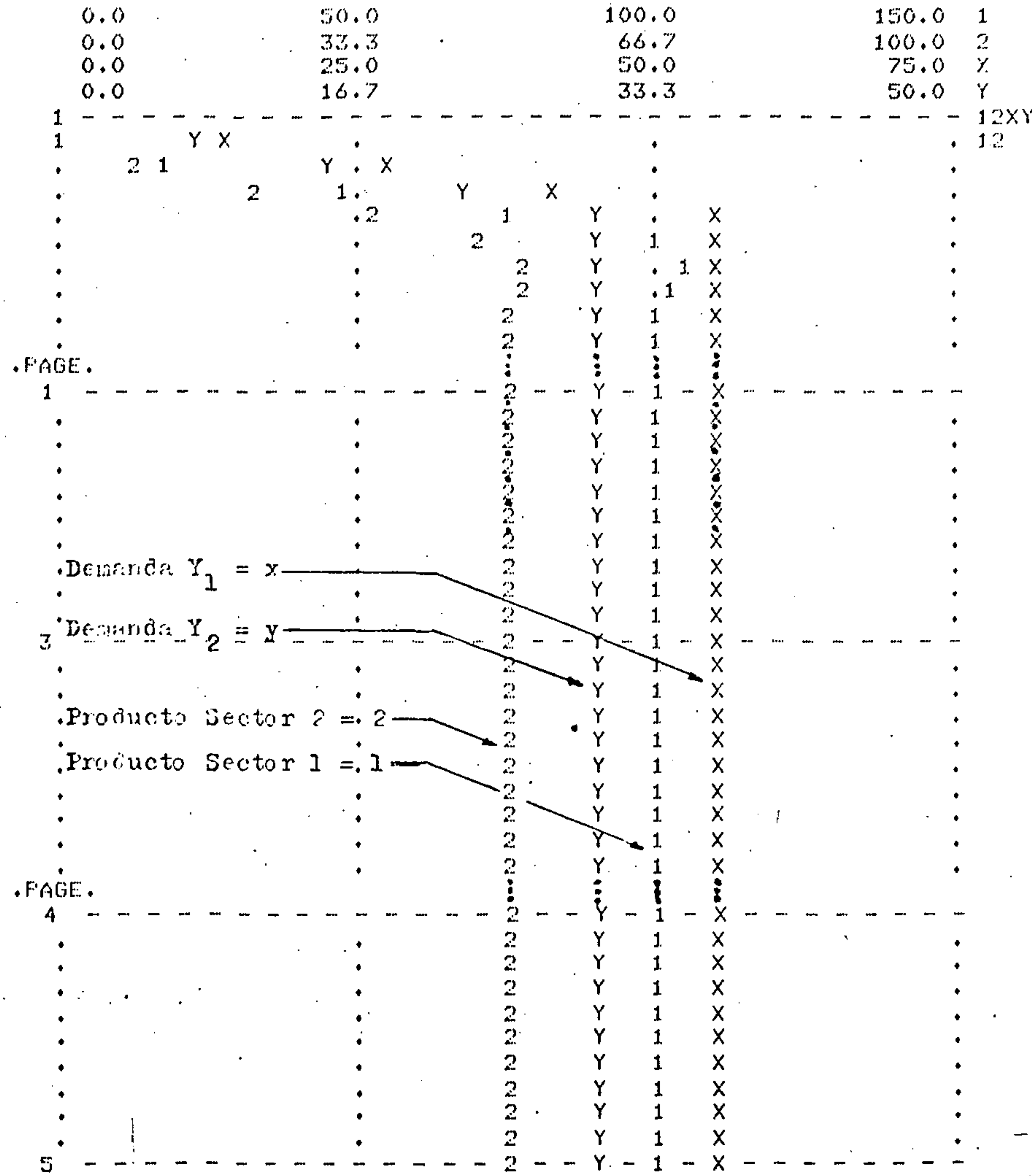
8. Silva J, "Un modelo sistémico en la planeación regional", Tesis DEPFI-UNAM, México, 1982.



UN MODELO REGIONAL

BEGAN PLOTTING AT 7:18.1825, 16 JULY 1983

PT1=1, PT2=2, Y1=X, Y2=Y



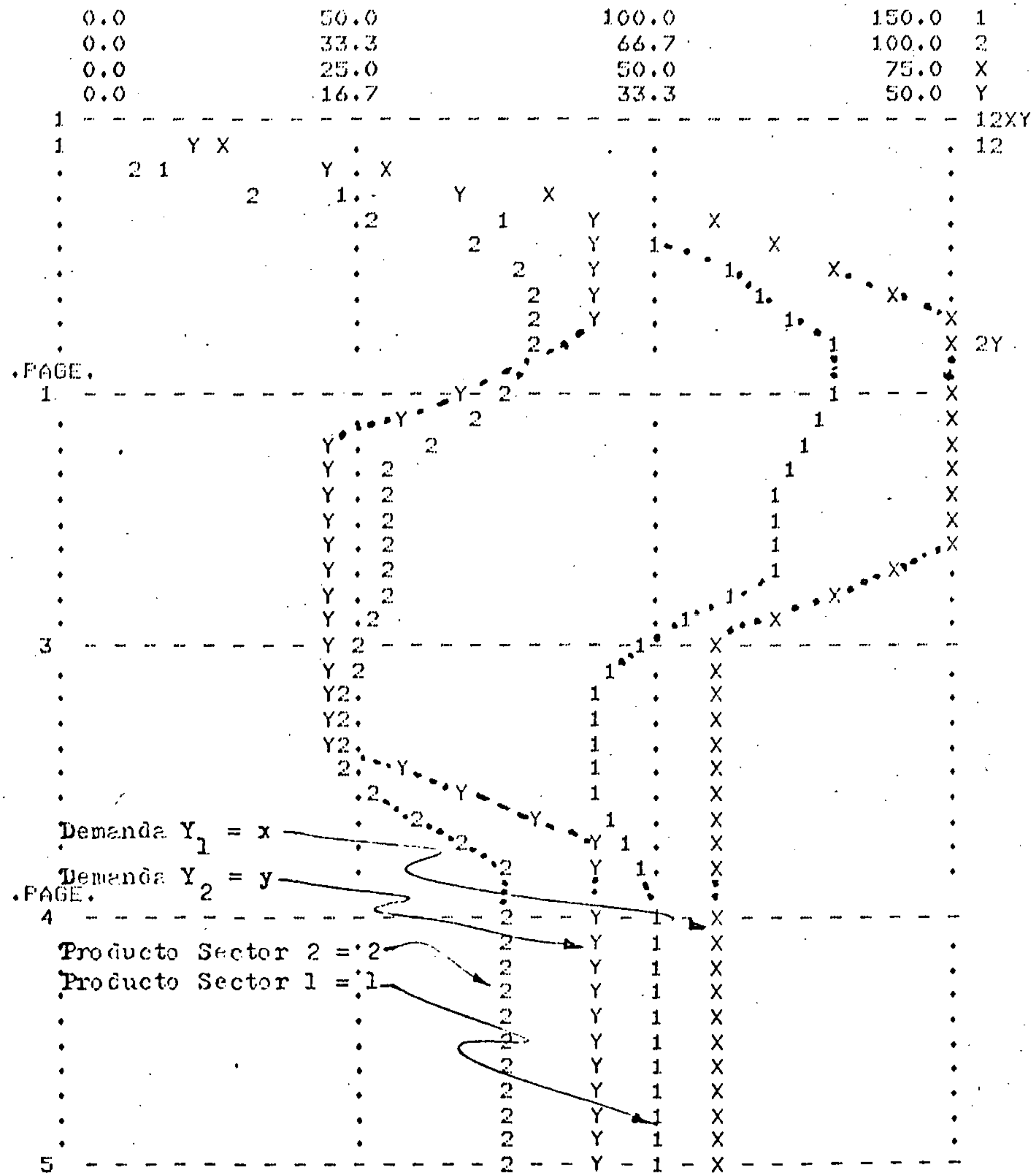
FINISHED RUN NUMBER LEONTI AT 7:20.0956, 16 JULY 1983
$ET=3:27.2 PT=0.8 IO=1.6

Figura 3

GET DYNAMOINPUT

BEGAN PLOTTING AT 7:28.0231, 16 JULY 1983

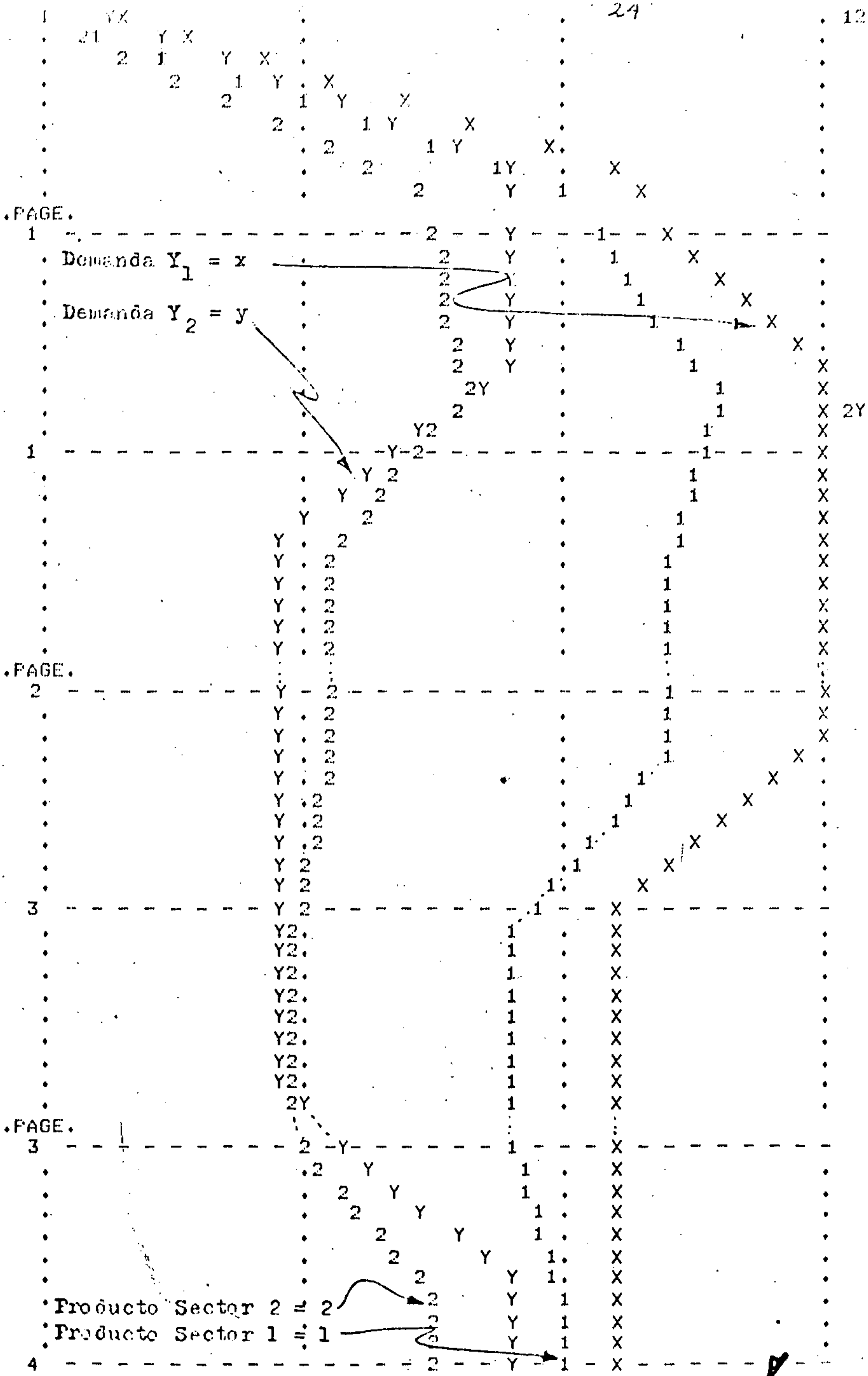
PT1=1, PT2=2, Y1=X, Y2=Y



FINISHED RUN NUMBER LEONTI AT 7:29.9806, 16 JULY 1983
#ET=3:30.2 PT=0.8 IO=1.6

Figura 4

SA
#UPDATING
#WORKSOURCE DYNAMOINPUT SAVED; OLD SOURCE REMOVED



.PAGE.
Demanda Y_1 = x
Demanda Y_2 = y
Producto Sector 2 = 2
Producto Sector 1 = 1

Figura 5

DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

DINAMICA DE SISTEMAS (FORRESTER)

DESARROLLO DEL PETROLEO EN MEXICO

M. EN C. LUIS MARIO LEON ESTRADA

FEBRERO, 1985

Palacio de Minería Calle de Tacuba 5 primer piso Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

ALTERNATIVE POLICIES FOR MEXICAN OIL

LUIS MARIO LEON ESTRADA

POLITICS OF MEXICAN DEVELOPMENT

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MAY 1982

(1)

TABLE OF CONTENTS

Introduction.

Oil and economic development in Mexico.

Debates, plans, and projections.

Simulation model: approach and methodology.

System Dynamics methodology

Model description

Simulation of policies.

Additional directions for energy policy.

INTRODUCTION

(2)

The discovery and initial exploitation of vast oil and gas reserves within Mexico during the 1970's precipitated a large variety of hopes and expectations regarding the benefits that oil development could bring to Mexico. Some people expected that ample domestic energy supplies combined with foreign exchange earnings derived from oil export would become an intrument for rapid growth and elevating the income and job prospects of unemployed or underemployed. Oil resources promised a mechanism for eliminating chronic balance of payments and government deficits, while providing additional revenues to the government to control inflation. In contrast to these high expectations, another group of people pointed out the difficulties ahead in effecting judicious use of Mexico's oil resources, and further pointed to the experience of other oil exporting countries that counselled extreme caution in the allocation and disbursément of oil revenues. Venezuela for example, had failed to use oil wealth wisely; it had suffered rampant inflation and had become increasingly dependent on imports of food and consumer goods, without simultaneously developing a strong domestic economic base.

The impacts of oil development on the Mexican economy to date give some justification to both viewpoints expressed above. On the one hand, growth in real GDP accelerated from 3.3% per year in 1977 to 7.3% per year in 1978 and nearly 8% in 1979. But on the other side, inflation has simultaneously risen to the range of 30% per year, domestic credit availability remains tight, and nominal interest rates have increased along with inflation. Moreover, balance of payments on the current account worsened from -2% of GDP in 1977 to -4% of GDP in 1979 and again in 1980, despite revenues from oil exports of over 10 billion dollars in 1980.

In many respects, it is too early to appreciate the significant ramifications of future oil development and export for Mexico. National energy policy is still evolving along the tenent of the Global Development

Plan and National Energy Plan, and significant delays will intervene between policy implementation and eventual consequences. (3)

The purpose of this paper is to discuss the important role that oil has in the Mexican economy, and based on a simulation model, show the long term consequences of the policies stated in the plans developed by the government. To finalize, there are some further policies that could be implemented to solve some of the problems that oil alone does not.

OIL AND ECONOMIC DEVELOPMENT IN MEXICO

Oil started its development during the Diaz regime by giving concessions to foreign companies, and allowing importation of drilling and refining equipment duty free, and exemption of oil company capital stock from taxes. With these benefits and the discoveries of large oil reserves, oil production rised enough to supply 25% of world oil production by 1917. Despite the revolutionary war, from 1917 to 1921 the production incresed from 55.3 to 193.4 million barrels. With the approval of the article 27 of the constitution that considered the natural resources in the subsoil property of the Mexican nation, and the companies were granted a lease to exploit them, plus the protection given to the workers in article 123, generated adverse feelings in the oil companies that leaded them to look for new sources of oil as Venezuela, and decrease the production in Mexico.

Despite the great oil wealth in the country, Mexicans gain very little from it, because literally all the oil industry was in foreign hands. They had tax excemptions so the government could not benefit, they had foreigners in the top possitions of the companies, and wage discrimination against Mexicans, so labor could not benefit, and finally, the huge profits went abroad to the home countries of the owners.

During the post-revolutionary period, the Mexican state was in formation, and the economy was recovering from the war. Oil production was declining and its role in the economy was not as important as its role in politics. The attitude of the oil companies, the increasing demands from the workers, and the nationalistic trend in the government, lead to the expropiation in 1938. From then, oil has had an incresing role in the economy and politics of Mexico.

The recent economic history of Mexico falls into three clearly defined stages. The first of these, characterized by development with inflation, covers the period from the late 1930's until 1956, with annual price increases of 11%, government deficits financed with currency issues, foreign exchange instability -the peso was devaluated in 1948 and 1954- and a rapid agricultural development. In fact, agricultural output had a higher rate of growth than that of the gross national product (6.2 percent) and brought about a considerable expansion in agricultural exports and foreign trade in general. In short, this was a period of externally-oriented growth. During this period Pemex had to face embargo of spares and equipment, and blocade of shipments. This situation was alleviated with WW II. Internally, it faced strugles from the union workers to get control of the new company, and to get the managerial and technical expertise that was lost with the departure of oil companies. From the experience gained from the nationalization of the rail roads, the government decided not to make the same mistake again, and manage to keep control of Pemex. Its role in the economy was limited to supply domestic demand, and a decreasing amount for exports. The director of Pemex during that period Antonio J. Bermudez, considered that Pemex should not get involve in the national politics, and kept the role of Pemex to fulfill its objectives: exploration, exploitation, refining, transportation, storage, distribution, and first hand sale of basic petrochemicals.

The second stage was inwardly-oriented, based on substitution for imports of manufactured goods, the proportion of which decreased from 8 percent of GDP in the first period to 5 percent in the second. Relative stagnation also became evident in the agricultural sector, the rate of growth of which fell below that of the gross national product, which remained 6.2 percent. The exchange rate of the peso was maintained at 12.50 to the dollar. Prices rose 1.9 percent per year on the average (less than in the United States, with which Mexico has 70 percent of its foreign trade).

As a result of the diminished vitality of the agricultural sector, the rate of increase of agricultural exports declined considerably, and in general receipts of foreign exchange increased at a slower rate than expenditures abroad. This produced a large deficit in the current account of the balance of payments and an increase in the foreign debt. The slowing down of investment in social overhead capital and in agricultural research and development, as well as the distortion of cost structure resulting from the effects of protectionism on the prices of industrial inputs, had an adverse effect on the competitive position of agricultúral exports and constitute a factor in the slowdown in growth of merchandise exports. On the other hand, the parity prices for goods destined for domestic consumption rose in order to stimulate their output.

One characteristic of the period of price stability as the growth of domestic savings, which played an important role in the accelerated expansion of the banking system and, in fact, in a general financial boom of unusual magnitude, brougth about by factors such as transfers from the non-financial market to the institutional sector. The process facilitated the placement of government securities by the central bank among the financial intermediaries-especially the non-monetary ones- so that the government deficits no longer represented a mere creation money by the central bank, as they did in the first period.

During this period Pemex continued its solidification as company, it gained the technical expertice, to become self sufficient and proved to be a success of nationalization. It became an instrument of the government to encourage industrialization by supplying the increasing demand for hydrocarbons and to give subsidies through low prices. In 1958 it was granted a state monopoly on basic petrochemicals, becoming an active participant in the industrialization process by reducing imports and supplying feedstock for private manufacturing companies. Production of secondary petrochemicals was left to private companies whose share capital is at least 60% Mexican owned.

The third stage has been characterized by development with inflation and a higher deppendency on oil. This characteristics are a consequence of the problems of the second stage. The increasing deficits in foreign trade and government budget, plus the change in the stability in the international economy, created a sudden decline in GDP growth and in order to reactivate the domestic economy and to correct some of the deficiencies of the economic model, the government started a series of social and investment programs which were financed with money issues and borrowing. This generated high inflation rates and worsened the balance of trade, that eventually made it impossible to sustain the parity of 12.50 pesos per dollar and forced a major devaluation in 1976. This measure worsened the inflation and combined with expectations of oil revenues, made the government to follow a policy of rapid expantion and increasingly larger government budget deficits which lead to minidevaluations during 1980 and

1981, and a major one in 1982.

Through the 1960s and until 1971, the money supply was limited to an average annual growth of 10.4 percent, which, in conjunction with an annual real GDP growth rate of 6.8 percent and stable prices of imported goods, kept inflation at a 2.7 percent average annual rate. Since the end of 1972, however, Mexico has experienced a sharply higher inflation rate, mainly because of substantial increases in the money supply, the rapid growth of Government expenditures, the expansion of aggregate demand, bottlenecks inhibiting increased production and higher import prices. The removal of the fixed exchanged rate of the peso on August 31 of 1976, the subsequent decontrol of prices on many items and the adjustment of certain public utility and transport rates also contributed to high inflation. In addition, speculation concerning the imposition of the Value Added Tax on January 1 of 1980 contributed to the sharp increases in price levels during the begining of 1980.

With the discoveries of the huge hydrocarbon deposits of the Southeast of Mexico in the early 1970s, oil and Pemex changed ist role in the economic arena. On the economic side, Pemex became the largest enterprise in Latin America and in Mexico. It is responsible on an exclusive basis for the operation and development of Mexico's oil, natural gas and basic petrochemical industries. It has total assets of 1,188,000 millions of pesos equivalent to $48,462 millions at December 31, 1981 and net sales of $ 461,000 millions of pesos equivalen to $18,806 millions (converted at 24.514 pesos per dollar which was the average exchange rate for 1981).

On the political side, the role has become more active because ist actions generate strong debates, and from the retoric of the polititians that have built a lot of expectations from oil to the population.

In 1981, Pemex produced an average of 2,312,144 BPD of crude oil and condensate, 239,777 BPD of natural gas liquids and 4,060.8 million of cubic feet of natural gas per day. This represented an increase over 1976 production levels of 189%, 157%, and 92% respectively.

The continous rise in production has allowed Mexico to increase its exports of crude oil which started in 1974 with 15,902 BPD, and rose to

1,098,021 BPD in 1981. During 1980, exports amounted to $10,401.9 million and imports reached $765.9 million, resulting in a net surplus of $9,636 million. For 1981 it was expected that the total exports would reach $20,405.5 million and imports would be reduced to $552 million producing a net surplus of $19,853.5 million, a 106% increase over the previous year.

Due to the world surplus of oil, in the middle of 1981, there was a sudden fall of mexican oil exports to about half of the target, and up to the beginning of 1982, it has not been possible a full recovery despite of three reductions in price.

At December 31 of 1980 the export prices of Istmo crude oil was $38.50 per barrel and the export price of Maya crude oil was $34.50 per barrel. At the end of 1981 the prices were $35.00 and $28.50 per barrel respectively. In January of 1982 there was another price reduction of $2.00 to the Maya crude oil.

The shortage of export oil revenues made it necessary to increase foreign borrowing heavyly to a total of $16,234 million, paying $6,758 million, resulting in a net increase in debt of $9,476 million. This magnitude represents one fifth of the total public foreign debt outstanding at the end of 1981.

Domestic prices for Pemex's products are fixed by the Government with a view to generating sufficient revenues to cover operating costs, debt service and a portion of capital expenditures. The balance of capital expenditures is financed by borrowing and, when necessary, by capital contributions from the Government. Prices for products exported by Pemex are set by market supply and demand conditions.

As sole owner of Pemex, the Government is entitled to any distribution of profits. To date, no such distribution has been made.

Pemex is required to pay taxes based on total revenues at a rate of 15% for petrochemicals and 27% for all other products. Pemex's export sales of crude oil are subject to a 58% tax plus a 2% ad valorem tax.

The income by sales represented 55% and 45% was made by borrowing. The expenditure was:

Federal Taxes	238,193	(28%)
Investment	230,773	(27%)
Payment on Debt	165,657	(19%)
Operation Expenses	134,217	(15%)
Interest of Debt	61,740	(7%)
Operaciones Ajenas	30,901	(4%)

The taxes were paid for the following concepts: 37,193 for internal sales, 200,117 export tax and 883 other taxes. This figures represented an increase of 47% over 1980.

In brief, the nation's economic development requires more money and more energy, and Pemex will be the source of both, as its sales and production increase. This implies that Pemex is destined to generate sufficient production to diminish imports, increase exports, and earn money abroad to balance necessary purchases. Then the continued expansion of Pemex will make it richer and more powerful.

The rebirth of the oil industry during the last decade, generated a series of debates, plans and policies regarding the uses, abuses, and implications of the new wealth. Who should benefit? To whom would the money go? What purposes would it eventually serve? To what extent?

After the discovery and confirmation of increasingly larger oil reserves in the Southeast of Mexico, there was also increasing concern and public discussion about the alternative policies that the Government should follow regarding oil exploitation and uses of oil revenue. For the first time in Mexico there were open discussions in all the arenas, at all levels, and from all political affiliations. So from several government agencies plans came out including the role of oil. Several organizations like the CTM proposed the creation of a National Fund for Employment (Fondo del Empleo), in which all oil revenue were to be allocated to create jobs. The main speackeman of the oposission in oil matters, Ing. Herberto Castillo, became very popular by its constant critics to the official programs, basically showing inconsistencies and political implications that were not always on the side of the government. For example in for the construction of the gaseoducto to the U.S. border, he talked against it on the grounds of higher dependency, and that the benefit of the natural resources were not for the Mexicans. Also he pointed out the big losses of burning the natural gas that came associated with the oil, and that Pemex should produce at a rate that could take advantage of all the resources, instead of loosing gas at the expense of high oil export growth.

The government retoric to sustain its policies and actions came from everyplace in the system. The most utopic of all was former director of Pemex, Diaz Serrano, which stated "Mexico's new oil wealth makes it possible to see in the future the chreation of a new country ...,permanently prosperous ...,a rich country where the right to work will be a reality, with a better style and quality of life in general...". There were other public officials that were more cautious in their statements, but that deffitelly took a clear position. Like the ministers of Patrimony, de la Pena and Oteyza, have consistently shown a nationalistic point of view and want to keep the oil for the Mexicans, while Diaz Serrano wants to sell it to the U.S.

Another point which was considered very important in the discusion was the amount of oil that should be produced, the so called the optimum rate of production. Due to the structural restrictions of the mexican economy, the amuont of foreign revenue that it can absorb is limited, and above a certain point all the additional revenues are transformed into inflation. The basic cause is that the additional revenues are added into the monetary base, creating an increase in demand, but as the production is limited, the additional demand causes rise in prices.

Traditionally the main restrictions for economic growth in Mexico had been the lack of foreign resources to import capital goods, and the lack of domestic savings that limited the amount of internal resources to finance investment. With the sudden increment of oil resources, the new restrictions have switched to: lack of skilled labor force, lack of development and implementation of projects (lack of entreprenurship), and the need for stability in peso exchange rate and inflation.

The objectives in economic policy then should be: to absorbe the growing labor force; and to guarrantee the transfer of oil wealth into permanent sources of income. The first objective requires high GDP growth and the second the need of even higher investment.

Eventually all those economic considerations and public debates, were transformed into concrete plans, that for the first time showed hints of intended productive uses of oil wealth, in a planned manner, and in some cases, looking into the long term perspective. The two more important plans are: the Global Development Plan (Plan Global de Desarrollo) and the National Energy Plan (Plan Nacional de Energia). The most relevant issues of these plans are:

Plan Global de Desarrollo.

Oil resources should be allocated in the following manner:

32% for Pemex investment

68% for investment in the prioritary sectors

25% agriculture

16% industry (excluding Pemex)

20% comunications and transports

24% social development

15% support to the states and municipalities

Oil resources are defined as Pemex current savings.

Plan de Energia.

-domestic energy prices should correspond to 70% of the international prices, and they should be adjusted during ten years to avoid strong inflationary impacts.

-25% of the investment in the electricity sector should be made with its own resources.

-The targets for exports of oil are 1.5 MMBD and 300 million cubic feet of natural gas. (There is a 10% margin to cover eventual needs).

-It will be encourage the development of nuclear energy. 20 nuclear power plants should be installed by the year 2000, that will generate 2000MW (25% of energy requirements)

-Encouragement of science and technology.

-Measures to enforce the rational use of resources.

The combination of both documents determine the official possition. The Global Plan has a very short term horizon 1980-1982, and concentrates on the allocation of oil resources. While the Energy Plan is long term strategy and focuses on the prices of energy, development of alternative sources, and conservation of oil.

SIMULATION MODEL: APPROACH AND METHODOLOGY

(13)

SYSTEM DYNAMICS METHODOLOGY.

This model was built using the System Dynamics approach, which has been developed by Jay Forrester at the Massachusetts Institute of Technology, since the 1950's.

System Dynamics is a technique for broad policy analysis of complex systems. It started as Industrial Dynamics, focusing on problems arising in the corporate setting. It was concerned with management problems like instabilities in production and employment, slack or inconsistent corporate growth, and declining market share. During the 1960's, it started to be applied to a broader class of problems and in different areas such as urban planning, and implications of population growth in a limited resource world. With these expansions in applicatons, the name was changed to System Dynamics.

Although System Dynamics has been applied in several fields, it is in social systems, which are characterised by: its complexity, the multiple-contradicting objectives, the imperfect knowledge of the variables and its relationships; that constitute the ideal field for applications of this approach.

The problem that one addresses from the perspective of System Dynamics have at least two features in common. First, they are dynamic: they involve quantities which change over time. Being the variables of the system and their interrelationships (the structure of the system) which determine the behavior. Second, they are feedback systems. The term feedback is used in engineering for servomechanisms and closed loop control systems, in psychology for homeostasis, in social science for vicious circles and self-fulfilling prophesies.

The System Dynamics approach applies to dynamic problems arising in feedback systems.

Feedback is the transmission and return of information. The emphasis, inherent in the word feedback itself, is on the return. A heating system produces heat to warm a room. A thermostat in the room, connected to the heating system, returns information about the room's temperature back to the heating system, turning it on and off and thereby controlling the room's temperature. A thermostat is a feedback device. Together with the furnace, pumps, and radiators or vents, it forms a feedback system.

Feedback systems characteristically form loops of interconnections-loops of causes and effects. Without resorting to the broad intrepretation of the word information implicit in the definition above: A feedback loop is a closed sequence of causes and effects, a closed path of action and information. An interconnected set of feedback loops is a feedback system. There is a growing awareness that biological environmental, industrial, economic, and societal systems are feedback systems. Understanding the dynamic behavior of such systems requires acknowledging the role of feedback.

Feedback loops form the central structures that control change in real systems. Likewise, they are the organizing structure around which system dynamics models are constructed. Although feedback has become a word in the public vocabulary, there is little appreciation of its full significance. The usual approach to problem solving is,as shown in figure #1: a problem is perceived; an action is proposed; a result is expected.

Information about problem ⟶ Action ⟶ Result

Figure #1

But the result often does not occur. The reason lies in the more realistic structure of figure #2, as extended to more complexity in figure #3. Symptom, action, and solution are not isolated in a linear cause-to-effect relationship, but exist in a nest of circular and interlocking structures wherein an action can induce not only correction but also fluctuation, counterpressures, and even accentuation of the forces that produced the original symptoms of distress.

All change takes place within the control of feedback loops. Growth, goal seeking, and oscillation are a consequence of feedback loop dynamics. Some loops tend to gennerate growth or decay, and others are self regulatory or goal seeking. The results are not always evident because the influence of one loop can vary when the rest of the variables in the system also change.

So many times the actions to solve problems in socioeconomic systems do not produce the intended results, not just due to lack of control in the implementation of the policy but as result of the so called counterintuitive behavior of dynamic systems, or the conflict between the short term and long term consequences of a policy change. A policy which produces improvement in the short run, within 5 to 10 years, is usually one which degrades the system in the long run, Beyond 10 years. For example a policy to export oil and import food in order to improve food consumption and nutrition in the short run may create an apparent improvement, but it also may cause the stagnation of the agricultural sector, dependency on oil resources to alleviate the problem and higher imports of food. When the oil reserves are depleted, there is not enough food produced domestically and the food shortage and malnutrition in worse than original. Anyway, the short run is more visible and more compelling. Administrations in Mexico last six years. It speaks loudly for immediate attention. But a series of actions all aimed at short run improvement can eventually burden a system with long run depressants so severe that even heroic short run measures no longer suffice. With these concepts in mind there was a concern to build a model that show the main variables of the Mexican economy, their interrelationship and their implications.

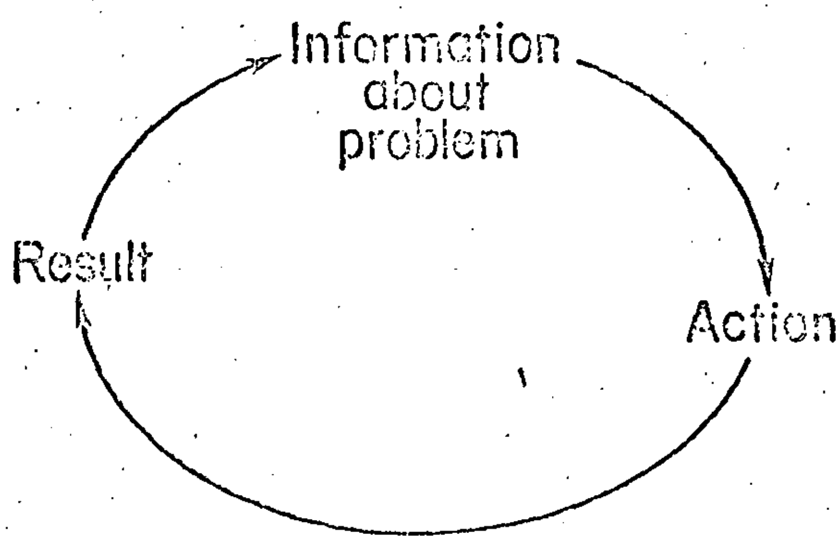


Figure 2 Basic loop structure within which all policies exist.

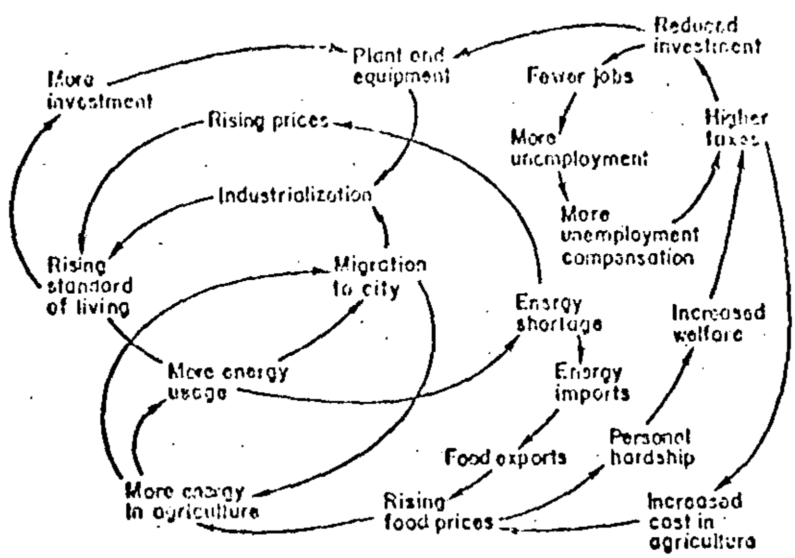


Figure 3. Interconnected loops produce growth, instability and goal-seeking as policies interact.

Models have become idealy accepted as a means for studying complex phenomena. A model is a substitute for real equipment or system. The value of the model arises from its improving our understanding of obscure behavior characteristics more effectively than could be done by observing the real system. A model compared to the real system it represents, can yield information at lower cost.Knowledge can be obtained more quickly and for conditions not observable in real life.

Perhaps the most feasible feature of the system dynamics approach is its use of formal, quantitative computer models. The term model stands for representation, essentially a simplification, of some slice of reality. A a system dynamics model is a laboratory tool. It allows repeated experimentation with the system, testing assumptions or altering management policies. The purpose is to gain understanding, so that the problem to which the model is addressed may be solved or minimized.

A formal model has two advantages over the informal so-called mental models on which most human decisions are based. First, formal models are more explicit and communicable. A system dynamics model exposes its assumptions about a problem for criticisms, experimentation, and reformulation. A mental model, on the other hand, is fuzzy and implicit. Its fuzziness is a result of its rich intuitive detail and is a source of its range and adaptability. The implicit nature of mental models, however, is the cause of occasional misunderstanding, miscommunication, and misapplication. Second, a formal model handles complexity more easily. Unlike a mental model, a system dynamics computer model can reliably trace through time the implications of any messy maze of assumptions and interactions, without stumbling over phraseology, emotional bias, or gaps in intuition. Computer models have these two advantages not because computers are so smart but, in a sense, because they are so dumb: they love the boring, repetitive computations involved in tracing a model through time, and they require absolutely every assumption to be spelled out in computer code, explicitly.

It is attractive, indeed, to think that experimentation with appropiate computer models might lead to the understandings we require to solve or minimize the host of complex problems we face. But the history of the application of formal models to policy problems does not produce great confidence.

In contrast to traditional approaches, this model emphasizes:

-a long time horizon, not limited to the conventional planning horizon in government of less than six years, but long enough to encompass the period influenced by current decisions and to anticipate future undesired effects in time to avoid them

- a wide perspective, not limited to one sector or one discipline, but including all the variables and social mechanisms bearing on the problem; and

- a flexible conceptual framework, not unnecessary limited to traditional variables, but based on open-minded observation of the real world and on the willingness to define new concepts to avoid excessive emphasis on what is already measured or easy to measure.

MODEL DESCRIPTION.

Figure #4 overviews the principal interactions between the various model sectors. At the top, the production sectors are linked to each other through orders and payments for factors of production. Also, the production sectors are connected to the financial sector through various channels, including domestic and foreign borrowing, payment of interest on debt, and holdings of money. The production sectors are tied to the foreign trade sector through imports and exports of various goods and services, including an explicit representation of the competitiveness of Mexican non-oil exports. The production sectors pay wages and dividends to the household sector and generate a demand for labor from the household; in the opposite direction, the household demands food, goods, housing, and energy from the production sectors, make payments for these factors of utility and offers a

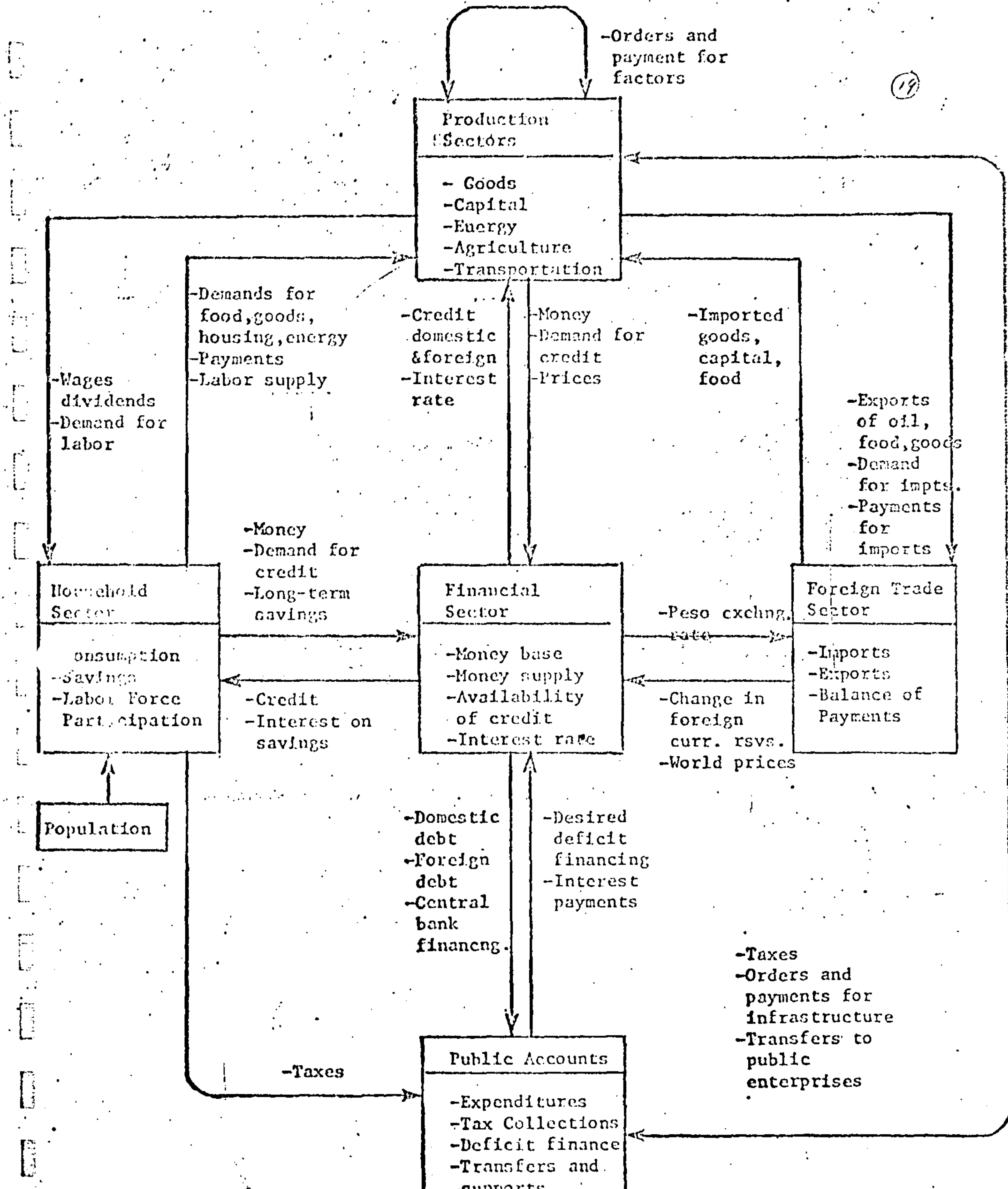


Figure 4.

OVERVIEW OF INTERACTIONS BETWEEN MODEL SECTORS supply of labor. Also, the production sectors are linked to the public sector through tax collections, production of infraestructure, and net revenues and transfers between the public sector and those public enterprises that reside within each aggregate production sector.

At the left of the figure #4, the household sector interacts with the production sectors as described earlier, with the financial sector through borrowing, savings, and interest payments, and with the public sector through income tax payments and receipt of and payment for social services (such as health, and social security). Population is an exogenous input to labor supply within the household sector, although the actual labor supply is affected both by population and by relative wage rates and employment opportunities; the model can also incorporate various assmptions about future population growth.

In the center of the figure #4, the financial sector portrays explicitly the main components of the monetary base such as foreign currency holdings and the Treasury debt held by the Central Bank. The financial sector also represents the supply of money and liquidity, and the availability and cost of credit. The financial sector interacts with the production, household, and public sectors through flows of money and credit. Additionally, the financial sector interacts with the foreign trade sector through determining the peso exchange rate that affects the competitiveness of Mexican exports as well as incentives to import, and through changes in the foreign currency reserves that affect the monetary base.

Because the major focus of the model is energy policies, it incorporates a number of different policy options in the area of domesting pricing of oil and gas, export levels, and allocation of oil revenues, the model incorporates a number of different policy options in each of these areas. For example, domestic oil prices can be set in any relationship to the world oil price, including the possibility of increasing domestic energy price up to levels near the world energy price over some time span, as called for the in the National Energy Plan. Finally, the model includes a policy variable representing the fraction of Pemex current savings which goes as export taxes to the government and the remaining fraction which is retained by Pemex for its own internal expansion. That tax rate on oil exports can be changed in the model to show the impact of different tax rates on the general disposition of Federal revenues, and on the financial structure and availability of liquidity to Pemex.

The model was also designed to represent a variety of different allocations on earmarkings of the government share of oil export revenues. The major possibilities incorporated in the model are, imports of food, imports of capital goods and technology, reduction of government deficit, increase of social expenditures, stimulus of particular production sectors, and so on. The model can incorporate any desired distributions of the government's share of oil export revenues between these uses in order to examine their impacts on sectoral output levels and on overall macroeconomic indicators such as inflation, unemployment, and the federal deficit.

The model is based on an energy-economy model for the United States, and it was addapted to represent the mexican case. The approach was to replicate the decision making processes and the physical and technical relationships of a single firm and generalize them to represent a sector of the economy. In other words, there is a generalitation of the microeconomic behavior into the macroeconomy. There were simplifications, being the most important, the representation of the agricultural sector, but in the real Mexico there are two sub-sectors: one that behaves according to the economic theory, and second, the traditional agriculture, that does not. The energy and public sectors in the model were changed to represent the Mexican case, in which the energy is concentrated into two government agencies, and the public sector that is much larger than its American counterpart.

The model represents both the physical structure of the national economy (people, capital, goods, money) and the decision-making structure of the various actors in the system (the decision rules and the information sources for decisions).

There are five major sectors: production, household, financial, government, and foreign trade.

The production sector.

The production sector actually consists on five distinct production sectors: the goods sector, representing consumer goods and services; the capital sector, representing capital plant and equipment and housing; the agriculture sector, representing all the food industry; the transport sector; the energy sector, which is divided into Pemex and the electricity sector consisting of the Comision Federal de Electricidad and of the Compania de Luz y Fuerza.

Each of the five production sectors in the model represents many firms producing similar types of output. The five sectors all have the same structure which constitutes a dynamic behavioral theory of the firm. Investment and capacity aquisition, labor management and wage bargaining, pricing, production scheduling, and financial management are all represented explicitly.

Each sector is composed of ten major subsectors. The subsectors are divided into those concerned with the physical or real aspects of production (the determination of output, factor use, and flow of materials, people, and energy) and those responsible for financial management (wage, prices, and the balance sheet and income statement).

The household sector.

The household sector supplies labor to the production sectors, and in turn receives wages which are used to purchase goods, housing, food, and energy. The household also supplies savings, through the financial sector, to the production sectors, and receives the profits of the production sectors in return. It also pays taxes to the Government Sector. Though the household does not sell physical output or set a price, it must make many of the decisions faced by production sectors: housing, goods, and energy must be ordered in the proper proportions; labor utilized; revenues and expenditures must be balanced, taxes paid, and debt managed. These decisions are, to a large degree, modeled in a manner analogous to their treatment in the production sectors. The basic difference from the production sector is that it maximizes utility instead of profit and labor represents leisure time and household employment.

The financial sector.

The financial sector represents the monetary and financial linkage between all model sectors, including the Government Sector and the Foreign Trade Sector. This sector represents the operations of financial institutions by setting interest rates and directing the flow of funds between lenders and borrowers. The financial sector is considered an intermediary, allocating savings among competing demands for credit and channeling interest payments, dividends, and capital gains among the various savers. The financial sector does not accumulate funds or employ factors of production. It also represents the Central Bank operations and policies regarding legal deposits, passive interest rates and the Peso exchange rate.

The government sector.

The Government Sector reperesents the expenditures and receipts of the Federal Government as it relates to public enterprises, households, and private producers. The receipts included in the model are:

Tax collections

- personal income
- corporate income
- excise
- value added

export

Revenue from social expenditures

Domestic Borrowing

Foreign Borrowing

Financing from Central Bank

The expenditures are:

Social Expenditures

Investment in Infraestructure

Administrative Expense

Net Transfers to public enterprises

Repayment of domestic debt

Repayment of foreign debt

Interest on domestic debt

Interest on foreign debt

Imports of food, capital, goods

The government role is to collect taxes and to spend the money according to certain goals or plans. Then the major expenditures of the government come from trying to accomplish those goals, for example: one goal may be to increase the social government expenditure per capita at 4 % per year, meaning more education and health for the population, or a similar goal for investment in infraestructure, meaning more roads, drainage and water supply per capita. Then the government sets the budget trying to accomplish the goals, but this generates a deficit that has to be financed from any of the following sources:

Financing from the Banco de Mexico

Foreign Borrowing

Domestic Borrowing

Accounts Payable (representing a delay between the time government is billed for services and its actual subsequent payment; these payables correspond approximately to ADEFAS)

The formulation of the domestic borrowing assumes that the Federal government attempts to avoid excessive loads on domestic capital markets, and that borrowing request from domestic banks will therefore be deliberately limited somewhat if credit is in short supply. Foreign borrowing provides a substancial net source of government funds. The model assumes that if government debt and interest obligations are high in relation to tax collections, expenditures will need to be limited as a consequence of diminished access to new financing. Government expenditures may also be limited on the base of total public sector debt relative to GDP as a policy option. Treasury financing from the Central Bank makes up the residual of financing requirements that cannot be met by boorowing or delaying payments.

Government social expenditures (health, education, social security, etc.) and expenditures for infraestructure (dams, roads, public buildings, etc.) have a similar formulation in the model. Target real social expenditures per capita and target infraestructure per capita are translated into nominal spending amounts by adjusting for the price level. Change in the targets from year to year can be represented (1) through an exogenous growth rate in nominal spending, (2) through an exogenous target real growth in expenditures per capita, or (3) by endogenously linking real expenditures to average growth in real GDP.

Real social expenditures contribute to labor productivity and therefore to growth in overall GDP, representing effects of expenditures for health and education; a delay exists in achieving the full productivity benefits of higher expenditures. Analogously, infraestructure development contributes to national productivity through allocating a portion of the infraestructure to the agricultural and transportation sectors to supplement their capital stocks; in turn, higher capital productivity will stimulate more employment help to lower production costs. The remainder of public infraestructure represents public buildings, schools, and other governmental facilities. Administrative expenses are linked to the overall volume of government activity.

Transfers to public enterprises are the final major category of Federal government expense in the model. The trahsfers represent an additional source of income to each recipient production sector besides revenues from product sales. Depending on the receiving sector's need for liquidity, transfers to public enterprises will have a mixture of two effects: direct stimulus of investment and output, and price reduction.

Thus, for example, transfers to the Federal Electricity Commission and to the agricultural sector through Conasupo allow sale prices to consumers to be lower than otherwise, and elicit more investment than would otherwise be called for by a given output price. In the model, transfers can either be specified as covering a given fraction of a sectors production costs, or generated endogenously to provide transfers when a given sector is falling short of meeting output demand. The model thus attempts to capture the shifting investment priorities of the government depending on individual sectoral conditions.

SIMULATION OF POLICIES

The model is strategically oriented, and is designed to span a time horizon of 50 years, beginning with the significant initial exploitation of Mexican oil reserves around 1977. The purpose of the 50 year time horizon of the model is twofold: first, along time horizon is required to evaluate both short term (5 to 10 year) and long term consequences of energy policies such as accelerated development of alternative energy sources, whose implementation will take a long amount of time due to long development and start-up lead times and whose effects will be felt even long after initial policy implementation. Second, a relative long time frame is also needed to span the full life cycle of Mexico's oil and gas reserves, given a range of estimates for potential production. For example, current estimates of likely potentially recoverable reserves from oil and gas in Mexico amount to 250,000 million barrels. During 1978, production of oil and gas for domestic use amounted to over one million barrels per day, and domestic consumption was growing at over 10% annually in real terms. At this rate of growth, even without any exports, Mexico's oil reserves would be depleted within 40 years. The model has not being designed to answer operational questions or to generate short term forecasting over less than 10 years.

In order to analize the impact of alternative oil policies, it is necesary to define one alternative as point of departure. For this purpose the case of low exports of oil was taken. With that reference, the policies of the National Energy Plan and the Global Plan are analized. To finalize, an alternative policy is included, that seems to have a positive effect in the economy. This is just a limited set of alternatives that are possible to simulate with the model, but is enough to give an idea of the possibilities and the effects of the official policies.

<u>test # 1: low oil exports and continuation of energy subsidy.</u>

This level of exports was achieved during 1978, and this simulation assumes that this is the level of hydrocarbons that is sustained thereafter. The purpose of this scenario is not to represent a most likely case of oil export, but rather to provide a reference point embodying sustained low export levels, against which results of the export targets provided for in the National Plans can be compared to understand their incremental effect.

The initial conditions for the model are those of Mexico at the end of 1977 and the begining of 1978, like: inflation is 26%, peso exchange rate is 21 pesos per dollar,population growing at 3.2%, technological progress is assumed to enhance productivity of labor and capital at an external rate of 3% per year, external inflation is assumed to be 10% per year, external real GDP that affects demand for Mexican exports (other than oil) is assumed to grow at 3% per year, mexican oil exports are not assumed to be limited by demand, as long as exports are made at the prevailing world oil price. Pemex is taxed at 68 % of current savings, and the allocation of oil resources is made according to the Global Development Plan. In addition it is assumed that the low pricing for energy continues in Mexico with the idea of ecouraging industrialitation, and give competitiveness of manufactured goods with low cost imputs.

The results are shown in the following figures. Figure 2-1a shows that real GDP growth averages 7-7.5% for the first thirty years. However, real GDP growth slackens dramatically after year 30, and averages only about 4% per year from years 30 to 50. It also shows stable unemployment toward 30% between years 30 to 50. Inflation rate increases from 26% per year to nearly 40 % per year by the end of the simulation (year 2027). The remaining graphs help to explain the major shifts occurring in GDP growth, inflation, and unemployment. For example figure 2-1c shows the profile of energy production. Conventional production by Pemex rises rapidly to a peak of about 20 million barrels per day at year 37. By year 50, conventional production has fallen bellow 14 MMBD, while production of unconventional energy has risen to 7 MMBD.

Figure 2-1b shows one of the reasons for slow development of

Figure 2-1: Sustained Low Oil Exports

(29)

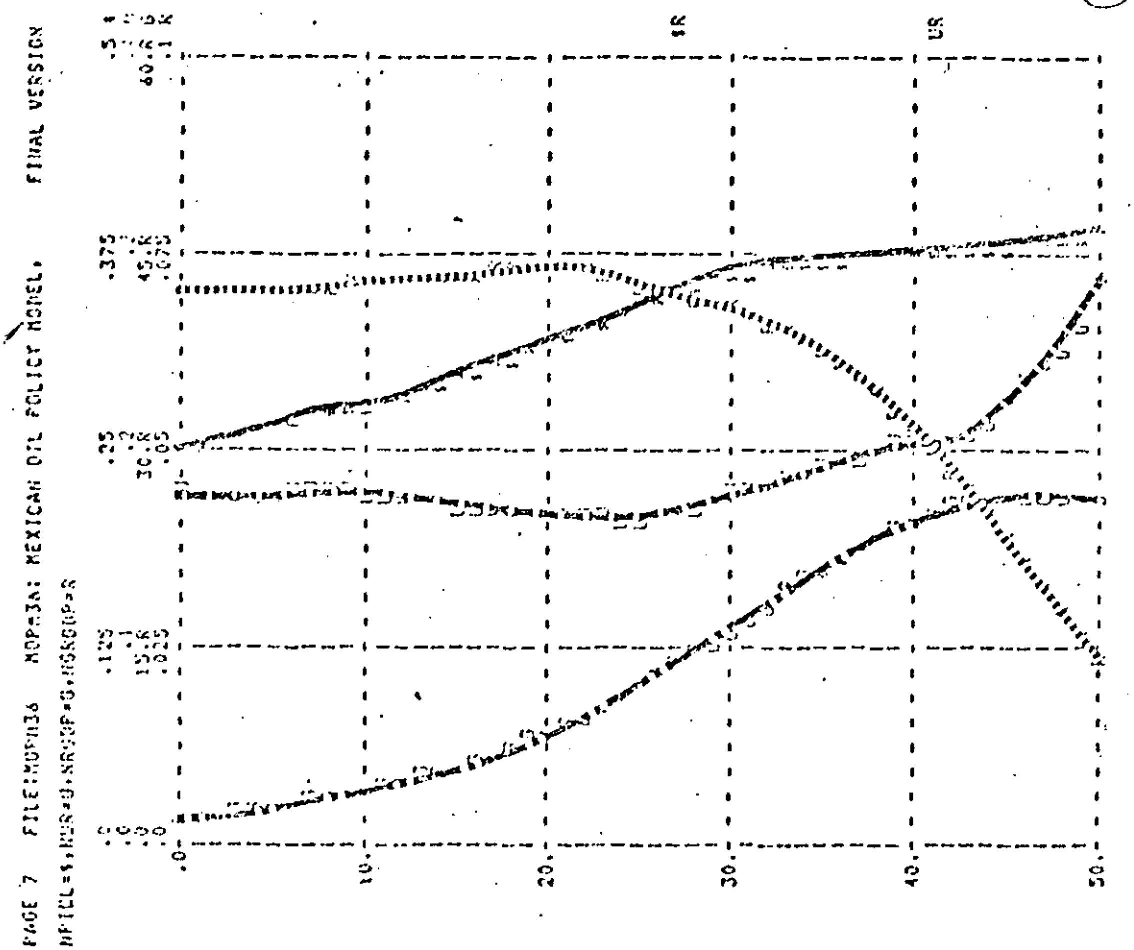


Figure 2-1a

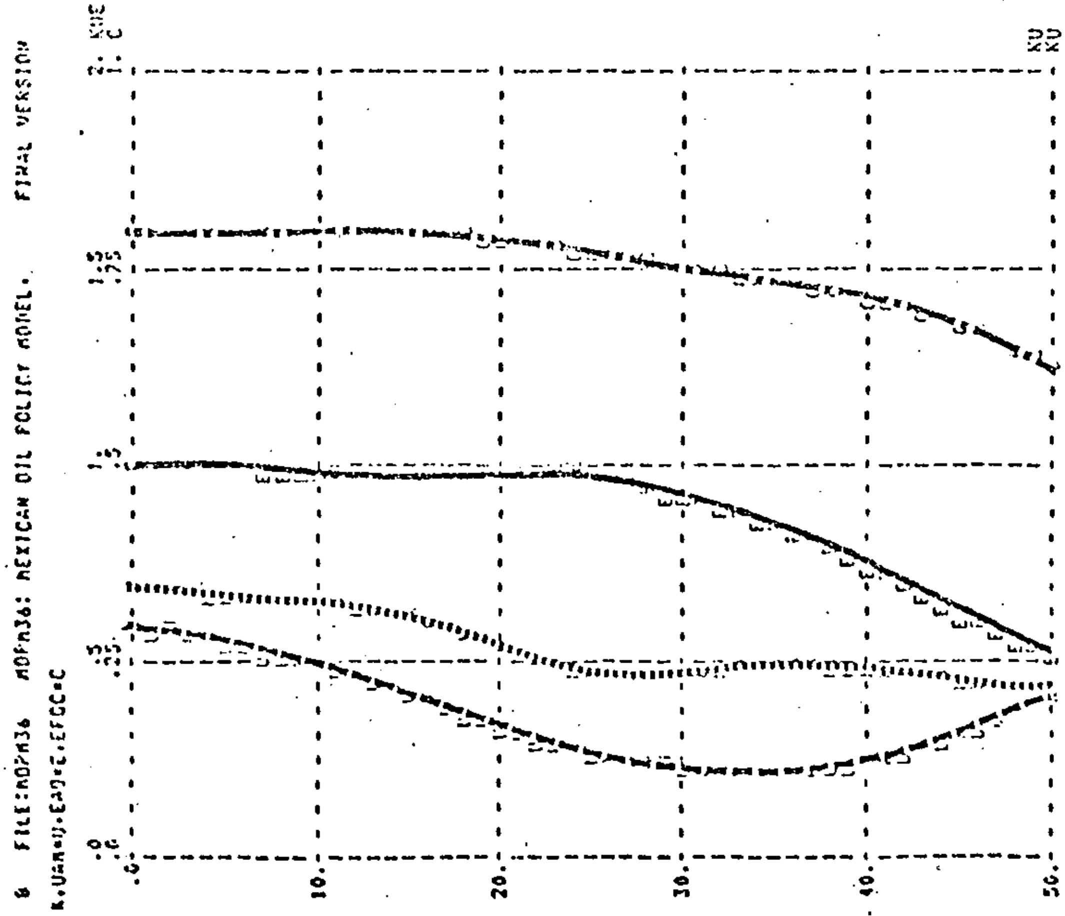
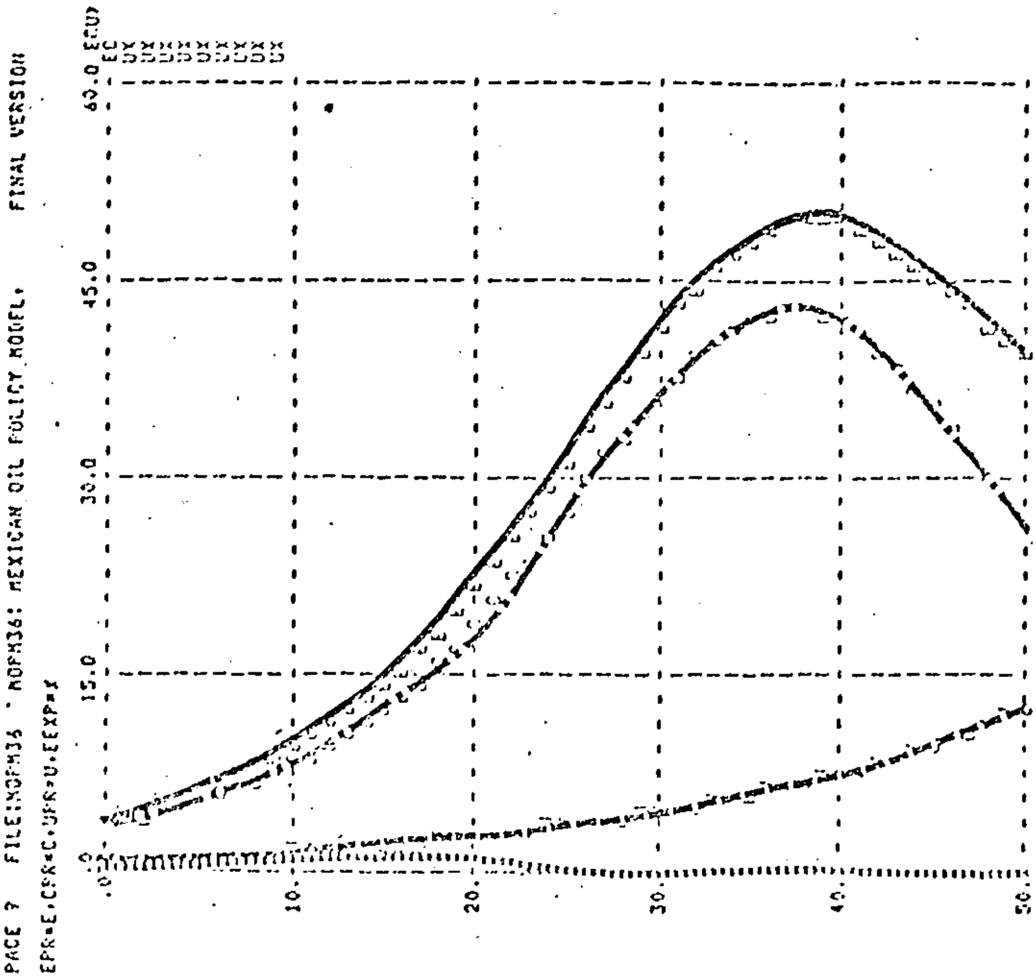


Figure 2-1b

Figure 2-1: Sustained Low Oil Exports

(30)



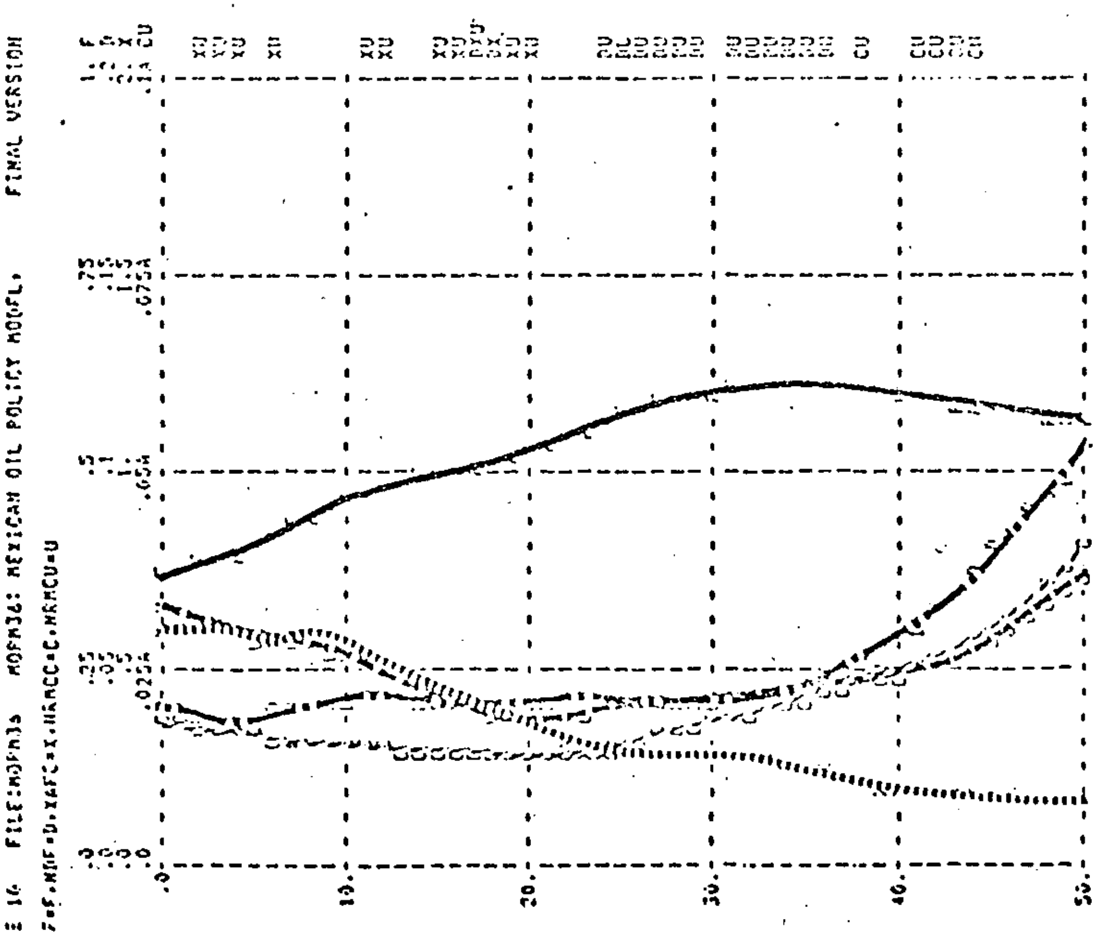
Energy production

Pemex production

Unconventional production

Energy exports

Figure 2-1c



Foreign debt fraction

Deficit fraction

Adequacy of foreign currency

Real Pemex marginal cost

Real unconventional marginal cost

Figure 2-1d

unconventional energy. Despite a high subsidy from the Federal government of more than 30% of its production costs, the unconventional energy sector (representing production of electricity by the CFE and production of energy from alternatives to hydrocarbons, such as nuclear or solar) is suffering a severe liquidity shortage. Adequacy of liquidity in the unconventional sector starts at about 60% and declines to below 30% by year 30, during which time unconventional production is being called upon to supplant depleting hydrocarbons. The low liquidity, and consequent high debt loads and weakened financial position of the unconventional energy sector, are the consequence of two forces: first, a rapid attempted rate of expansion of conventional energy, with long lead times and consequent high cost of capital projects in the construction phase; and second, increasing general inflation that raises both nominal interest rates and nominal financing requirements of the unconventional energy sector. Although not shown, there is a weakening financial position of Pemex as a consequence of rising marginal cost of producing energy in the face of resource depletion (figure 2-1d). In other words, increasing amounts of labor and capital and progressively deeper wells are necessary to continue producing oil and gas.

Figure 2-1b shows that adequacy of energy supply falls off sharply between years 30 and 50, indicating that Mexico suffers from a general shortage of energy relative to domestic demands. Such energy shortages early in the next century would most likely have to be met through substancial imports of energy by the government at high real energy prices due to worl wide depletion of oil and gas resources (although such imports are not explicitly represented in the model). Declining rates of real GDP growth seen in figure 2-1a between years 30 to 50 are a consequence of weakening liquidity positions through the economy due to mounting inflation, compounded by the emerging energy shortage. For example, figure 2-1b shows declining adequacy of liquidity in the capital goods producing sector, thereby retarding production of capital goods and contributing to capital shortages throughout the Mexican economy. Moreover, significant development of unconventional energy is being delayed due to relatively lower prices of conventional oil and gas, and consequent high consumer and industry demands for energy end uses that are most suitable met by conventional production by Pemex.

Inflation is a consequence of several self reinforcing processes (possitive feedback) as shown in the figure 2-2. For example considering the inner loops of this figure . Both loops originate with a higher inflation that leads to additional (nominal) spending by the federal government in order to accomplish the government's real development objectives for social programs and infrastructure. More government spending leads to higher deficits, which in turn, tend to be financed primarly through a mix of foreign borrowing and treasury financing from the central bank. Both sources add to the monetary base, which eventually results in higher rates of inflation through expanded liquidity and credit availability. In the middle loop in figure 2-2, high inflation also supplements demand for credit, both by increasing nominal transaction requirements, as well as by lowering the real interest on debt. In other words, in the face of higher inflation, the real cost of debt is reduced since debt can be repaid at time of maturity in depreciating currency. Increased credit demand reduces the relative availability of domestic credit from commercial banks and other financial institutions and intermediaries. In turn, lower domestic credit availability induces corporations and public enterprises to take on additional foreign debt,thereby increasing the monetary base and adding to total liquidity and consequent pressure on prices. Finally, in the outer loop of the figure, higher inflation reduces the incentive for household savings, which reduces domestic credit supply, leading to more foreign borrowing, greater increase in foreign currency holdings from external debt, and compounding pressures for more inflation. Accompanying the trend toward greater inflation, figure 2-1d shows the increasing dependence on foreign debt, which provides more than 50% of total financing by the turn of the century.

Figure 2-1d also shows a rising government deficit as a fraction of GDP. The deficit fraction rises slowly during the first 30 years of the simulation, generally remaining near 4%, but then more than doubles between years 30 and 50. During this time, slowing GDP growth due to rising energy prices, diminishing liquidity, and energy shortages, reduce the growth rate of the economy and hence lower growth in tax collections. In the model, the government is assumed to adjust its expenditure patterns over time so as to avoid excessive drains on the real output capabilities of the economy. In other words, during a period of declining real growth rates, real growth in government expenditures is eventually lowered as well, but with a perception and reaction delay for several years during which time deficit spending is exercised in an effort to stimulate growth. Thus, for a significant period of time, real government expenditures are increasing more rapidly than tax collections, leading to accelerating deficits and still higher inflation.

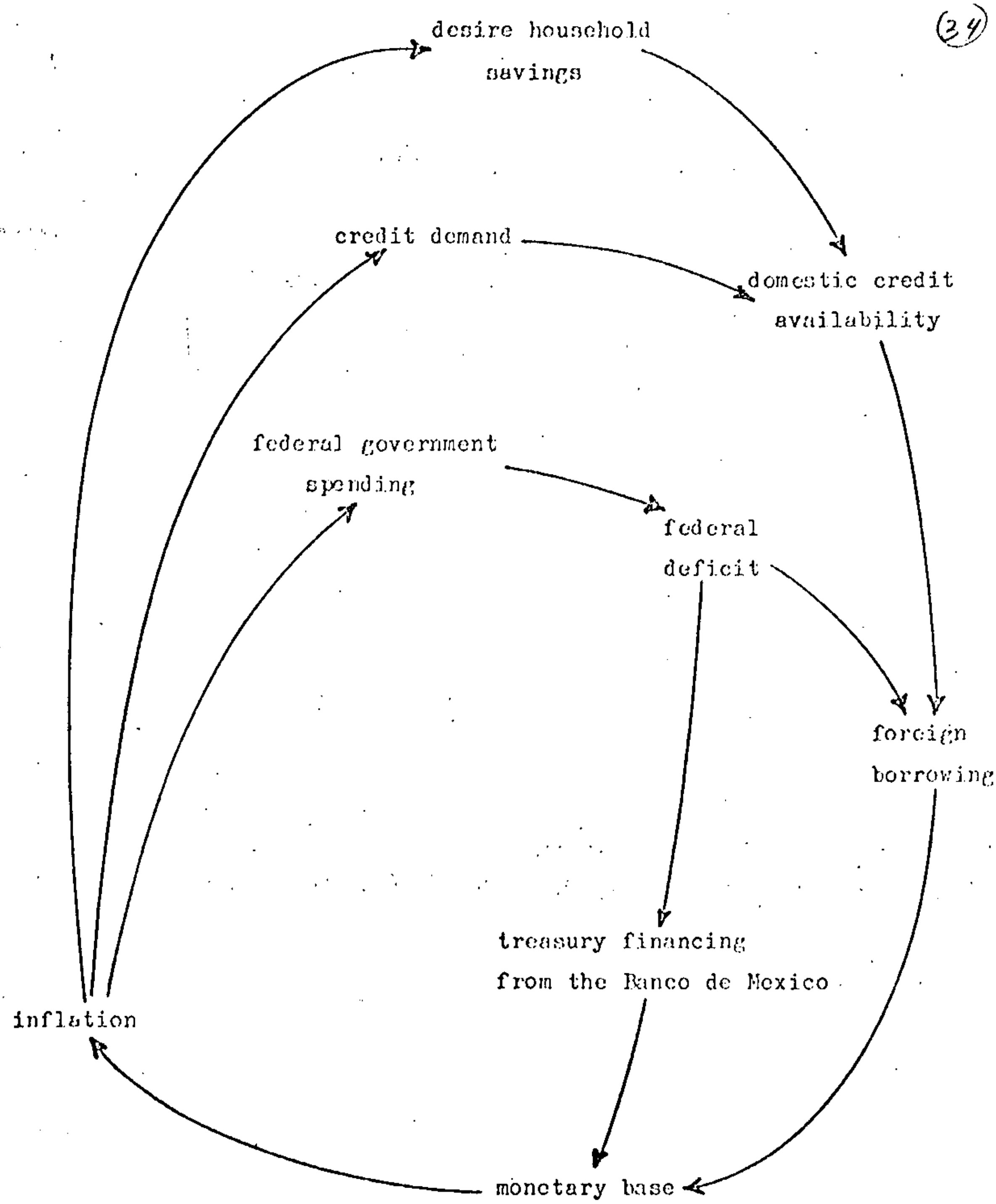

desire household savings
credit demand
domestic credit availability
federal government spending
federal deficit
foreign borrowing
treasury financing from the Banco de Mexico
inflation
monetary base

Figure 2-2

test #2: low oil exports and reduction of pricing subsidy.

(35)

This simulation represents a policy change in addition to the low export scenario depicted in test #1. Here, domestic price of oil is raised to 70% of the world price in a graduated manner between 1982 and 1992, as proposed in the National Energy Plan.

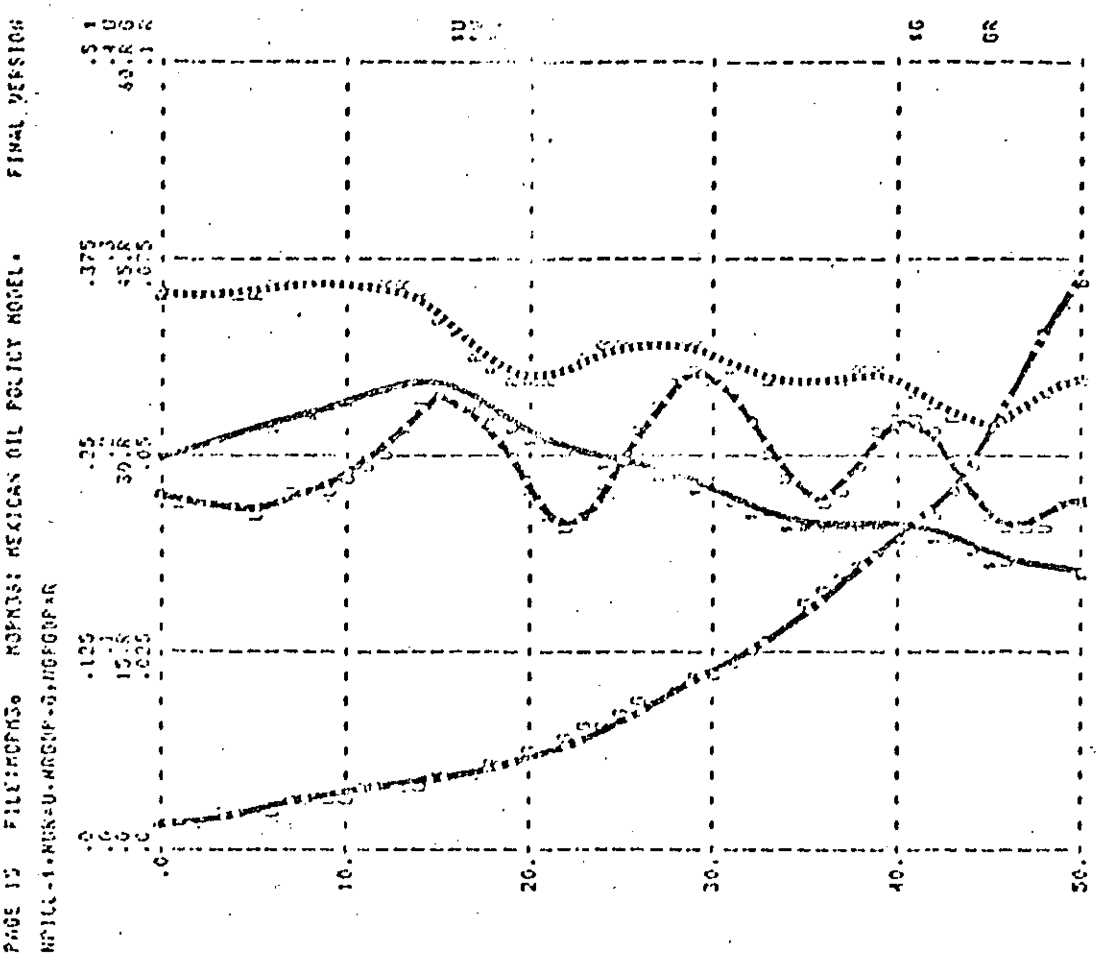
Figure 2-3a shows slowly rising inflation, from 26% to 29%, from years 0 to 15. Thereafter, inflation slowly declines to about 18% per year at year 50. The dominant reason for the reduction in long term inflation is the stable ratio of federal deficit to GDP (at below 5%) as seen in figure 2-3d, in contrast to the more than doubling in the deficit ratio in figures 2-1 without the relative increase in domestic oil price. In turn, a major source of the deficit reduction lies in the revenue feedback deriving from increased taxes paid by Pemex due to higher revenues. As noted earlier, in the low export case with a continued pricing subsidy for domestic use of oil and gas, the financial structure of Pemex deteriorates along several dimensions, including diminishing relative liquidity and increasing debt ratio. In contrast, with a higher domestic price for oil and gas products, Pemex current savings improve dramatically, enabling a relative reduction in debt and a removal of liquidity induced constraints on capacity expansion. Consequently, taxes paid by Pemex based on current savings become a significant fraction of total government tax collections, even without substancial oil export revenues. For example, in the yest underlying figure 2-3, tax on Pemex based on current savings becomes more than 20% of total government tax collections by year 15. The higher tax collections are alloted to the uses described in the Plan Global. Hence, there is no immediate reduction in the government deficit as a result of Pemex's increased tax contribution since the tax stream is fully recirculated to expenditures and investments. However, the additional transfers to the agricultural, industrial, and transportation sectors are retained within those sectors for investment to a significant extent. Expansion in activity of those sectors yields an indirect revenue feedback to the government. Moreover, improved adequacy of output due to allocation of tax revenues derived from Pemex production reduces the pressures for transfers to public enterprises, and thereby diminishes the need for federal deficits to subsidize production in public enterprises. Low deficits also slow growth in the money supply and in inflation. In turn, lower inflation tends to improve liquidity in all production sectors, including public enterprises, thereby further rising adequacy of output and diminishing the ongoing need for transfers from the government. A long term process of relative deficit stabilization is thereby set in motion, with significant benefits in the form of lower inflation.

Figure 2-3a shows a reduction in real GDP growth in the early years as a consequence of higher oil price. For example, in figure 2-1a, growth rate in GDP declines from 7.5% to 6% per year between years 10 and 20 (1987-97), and real growth thereafter remains stable at an average of about 6% per year. Figure 2-1a showed continued growth in the range of 7.5% per year for the first 30 years. As a consequence of real higher energy price, real GDP is lower for the first 40 years with the relative increase in oil price. But this policy shows a smoother long term growth and does not exhibit the substancial reduction in the real growth rate as a consequence of emerging energy shortages and strained general liquidity. In fact, by year 50, real GDP is significantly above its corresponding value in the previous simulation.

The long term improvement in the real economic growth results from the longer lasting of oil reserves as a consequences of lower consumption due to higher price. Following an adjustment period in which energy intensities and energy growth rate of the economy must be brought into line with a higher real price of energy, improved adequacy of energy enables sustains long term GDP growth without the problem of rapid depletion of domestic reserves and consequent dependence on imported energy. There is also an improvement in relative liquidity, as a consequence of lower inflation, which reduces nominal financing charges on debt, and more importantly, lowers the interest cost of capital under construction as a fraction of sales revenues.

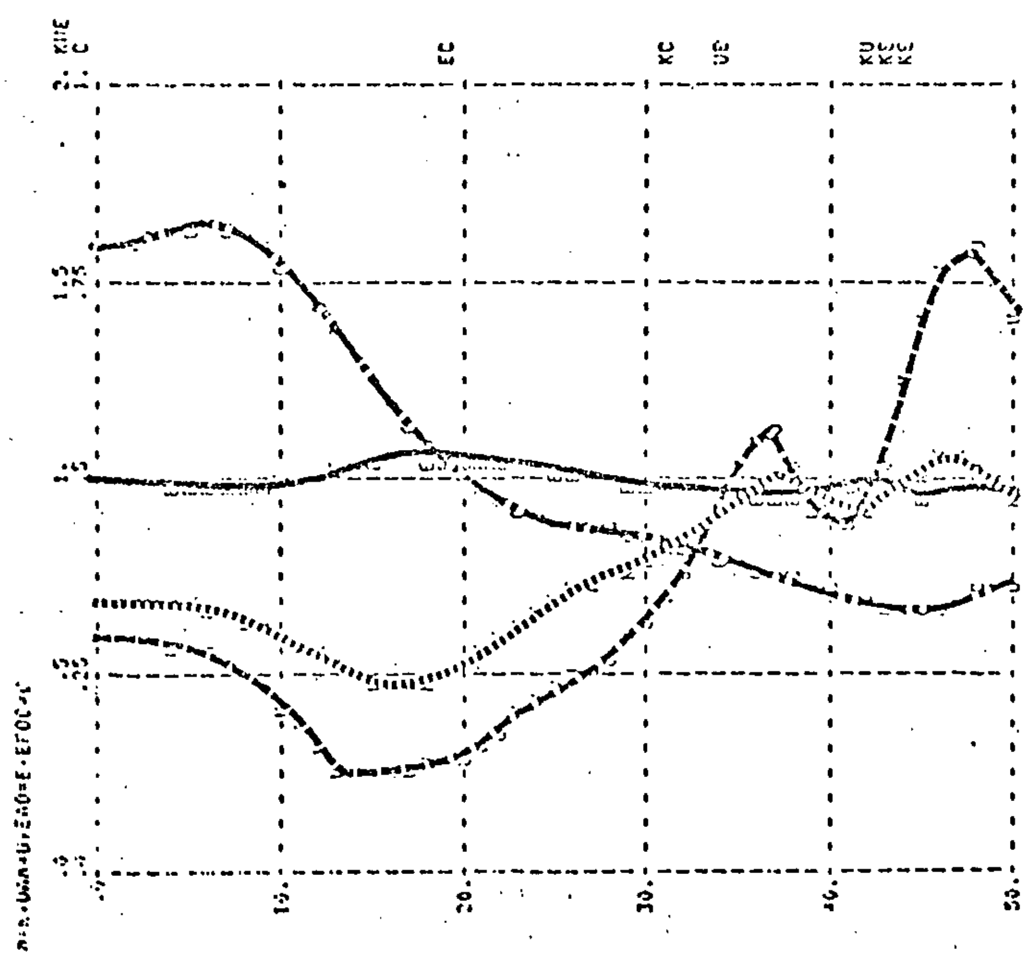
The results of this simulation suggest significant long term benefits from increasing the real domestic oil price, including eventually higher GDP and lowered inflation. However, there are some short term costs, particullarly in terms of diminished GDP growth during the 1980s and short

Figure 2-1: ... Oil Exports and 70% Domestic Price Parity



Inflation
Unemployment
Real GDP
Real GDP growth

Figure 2-3a



Capital sector liquidity
Unconventional sector liquidity
Energy adequacy
Pemex fraction of energy demand

Figure 2-3b

Figure 2-3: Low Oil Exports and 70% Domestic Price Parity

(38)

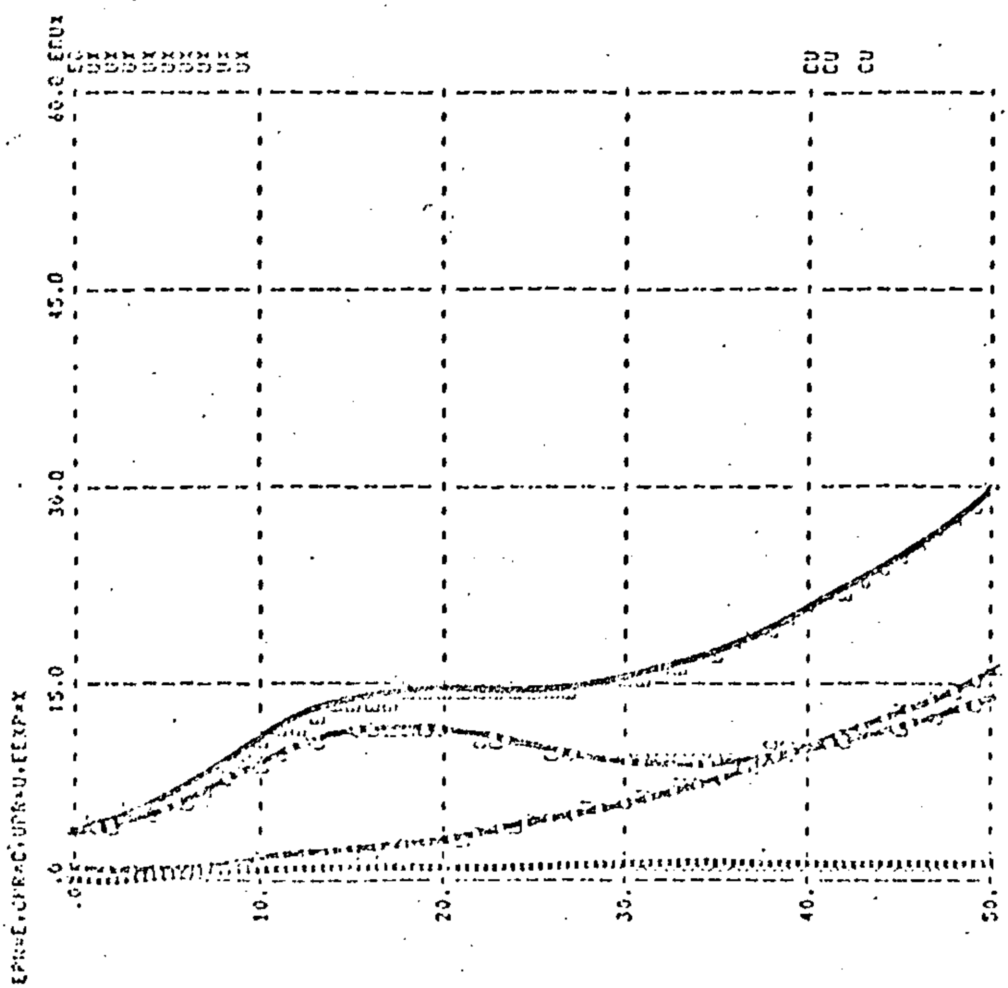


Figure 2-3c

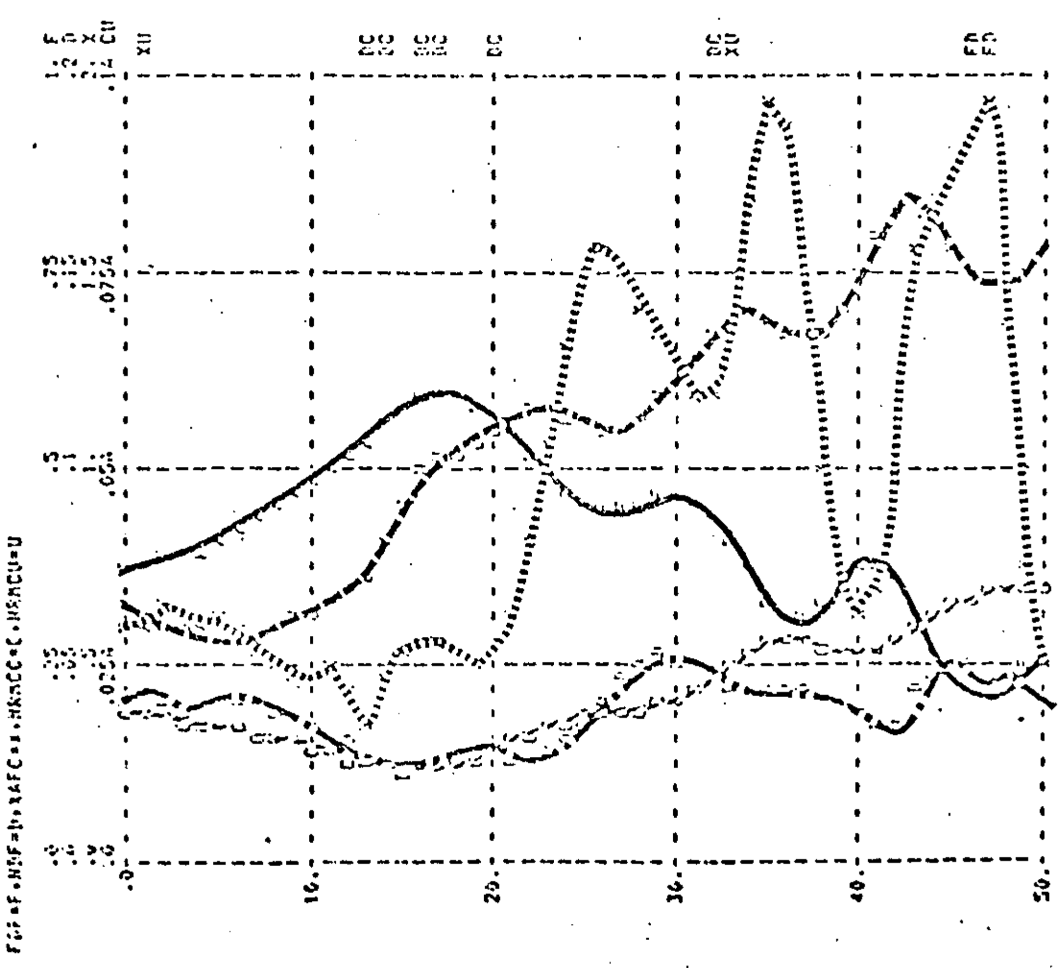


Figure 2-3d

term increase in unemployment. Additional benefits are: less dependence on foreign debt, competitiveness of Mexican exports is improved due to lower inflation, even a small net balance of payments surplus after the year 30. Savings rate and domestic availability of credit are improved due to lower inflation. There is also a reduction in the potential dependence on costly foreign energy supplies once Mexico's domestic reserves are depleted.

test #3: oil exports of 1.5 MMBD.

This simulation test the implications of rising exports of oil to the official target of 1.5 MMBD, and the continued subsidies throgh low energy prices are maintained. This results are comparable to test #1, except for the increase in exports. The purpose of this test is to isolate the macroeconomic effects of higher exports of oil and gas. The results are shown in figures 3-1.

The results show mixed benefits. There is a short term improvement of 2% in GDP for 10 years, but later is lower till year 35, and then is an improvement till the end of the simulation, and does not decline as before. Figures 3-1 also show a level of inflation that is consistently below its corresponding values in the low export case. In particular, the inflation rate rises to a peak of less than 28% before year 10, then declines just below 25% by year 20, eventually rising to a peak of around 32% per year inflation, in contrast of 40%.

The results summarized above present a more complex picture of the impact of oil exports than that underlying popular impressions. A common expectation is that increased oil exports should provide powerful stimulus to real growth but at the cost of higher inflation. In fact figure 3-1 represents three periods of differing impact on real economic growth: in the first period (years 0-10) real growth is slightly higher; in the intermediate period (years 10-30) real growth is slightly lowered; and in the long term, there is a renewed stimulus to growth. Moreover, inflation is consistently below values that would prevailed in the face of low oil exports due to an improvement in the foreign exchange position, which helps to maintain the value of the peso, and then alleviates that pressure on inflation.

One consequence of the improved foreign currency position during the period of oil exports is that it enables more imports of capital and consumer goods. High rates of growth generate large demand, while high interest rates and inflation limit the capacity of domestic capital producers to keep up with demand.

At a generic level of policy perspectives, the above results suggest that to the extent that oil exports are used to import food, consumer goods, capital goods, or other items that could be domestically produced, there is less impetus for domestic producing sectors to evolve to satisfy demand. Such effect may be difficult to discern, especially in the face of rapid general economic growth such as has occurred in Mexico in recent years. In other words, when economic sectors are growing it is hard to know what their potential really is. But the experience of petrolization in countries such as Venezuela seems consistent with the idea that substancial imports financed by oil exports can stultify internal sectoral and macroeconomic development and rise external dependence. It is important to note that the stimulus of capital imports due to improved adequacy of foreign exchange exhibited in figure 3-1 was not part of a deliberate attempt to import capital goods using oil export revenues, but a consequence of the improved foreign exchange position and greater supply of foreign currency to enable imports. The foreign exchange earnings derived from oil exports accumulate in foreign currency holdings and therefore in the monetary base. If these currency holdings were to remain in the domestic economy, they could have an inflationary effect. But the diversion of foreign currency earnings to pay for capital goods imports means that a significant portion of the increase in foreign exchange from oil export revenues is being quickly recirculated into imports that retain growth in foreign currency holdings. Improved adequacy of output due to higher transfers and more capital imports tends to have a reinforcing effect towards restoring inflation over time: greater adequacy of output reduces pressures for inflationary government finance due to supply shortages and bottlenecks, thereby yielding lower inflation, improved relative liquidity and lower interest rates, and consequently still further improved adequacy of output.

Figure 3-1: Effects of Target Oil Exports

(111)

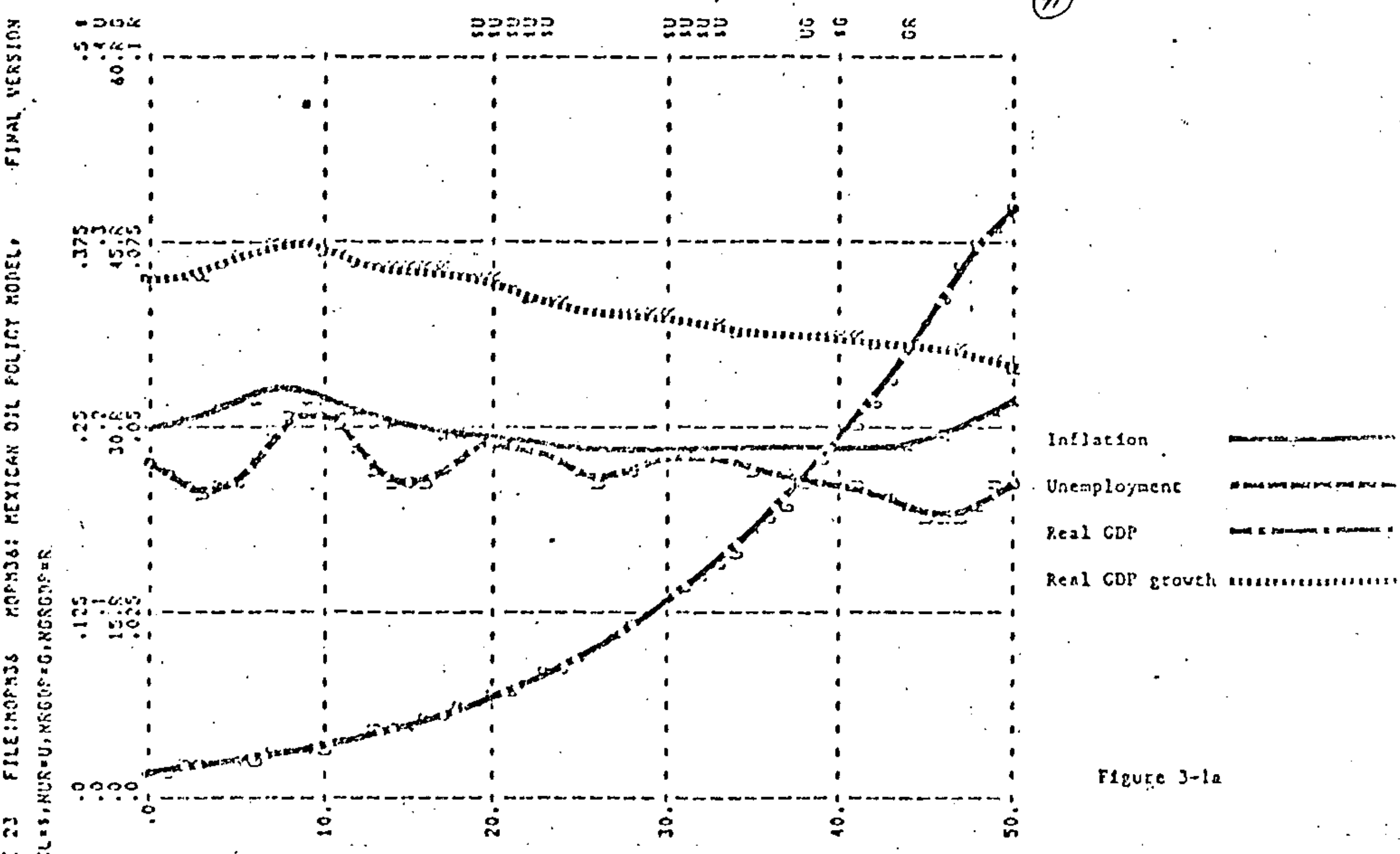


Figure 3-1a

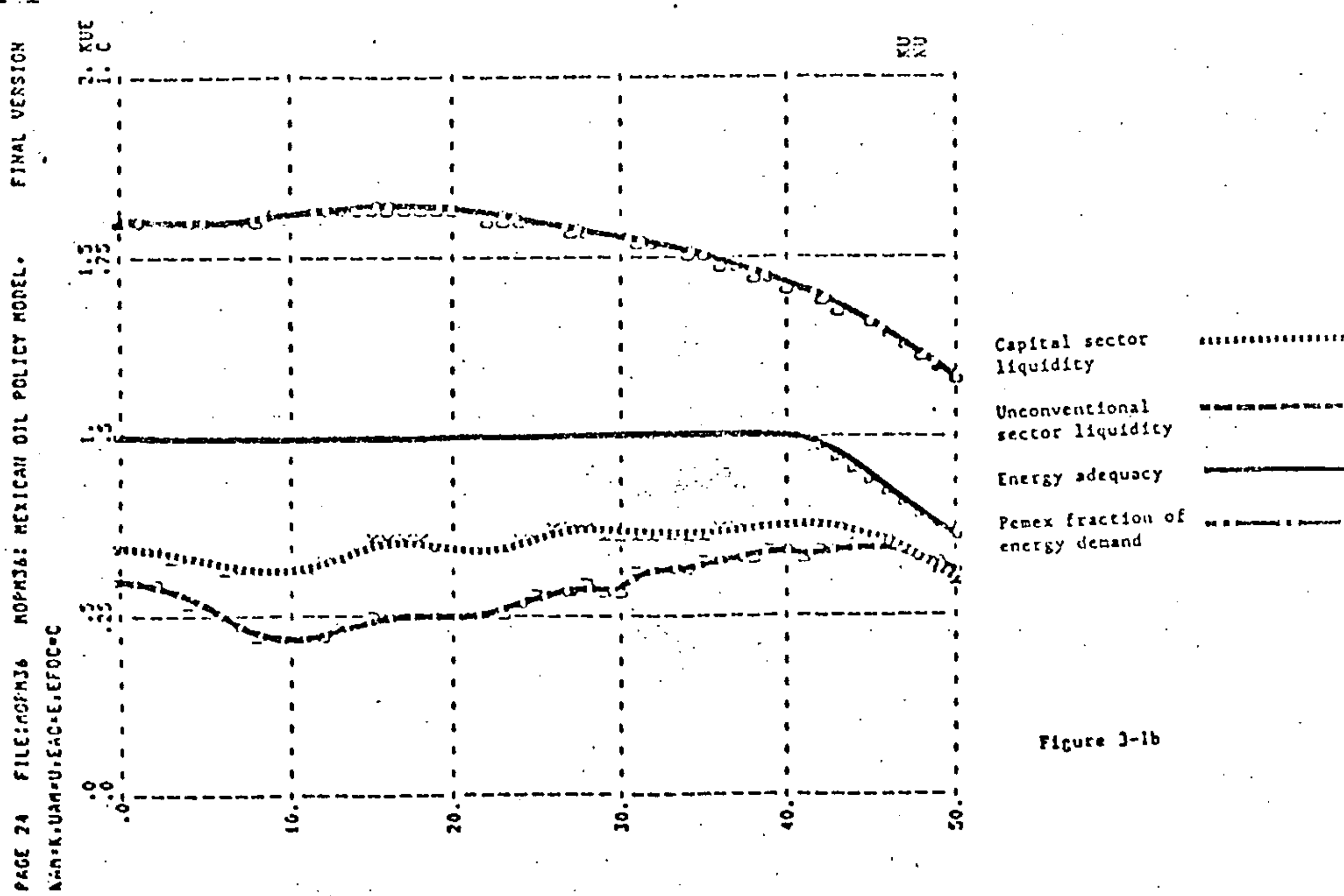


Figure 3-1b

Figure 3-1: Effects of Target Oil Exports

(42)

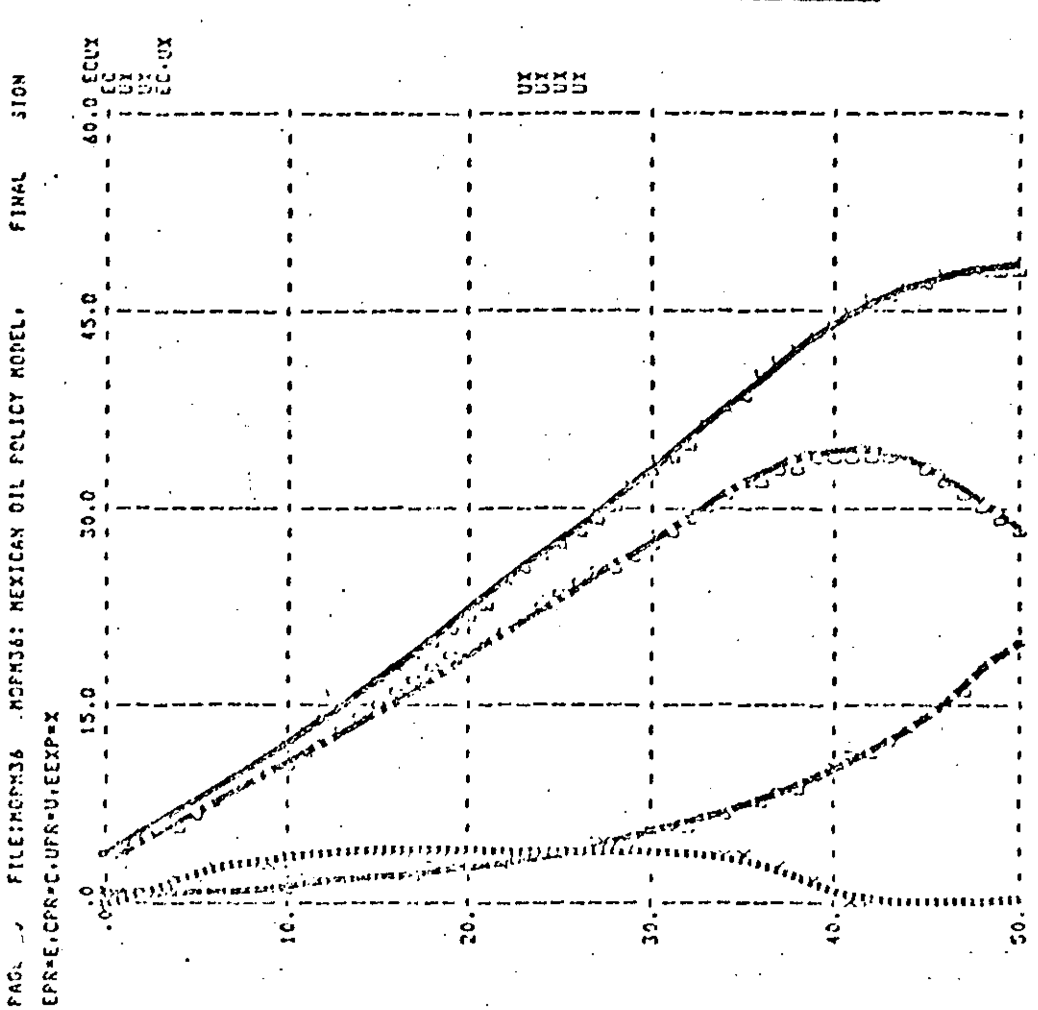


Figure 3-1c

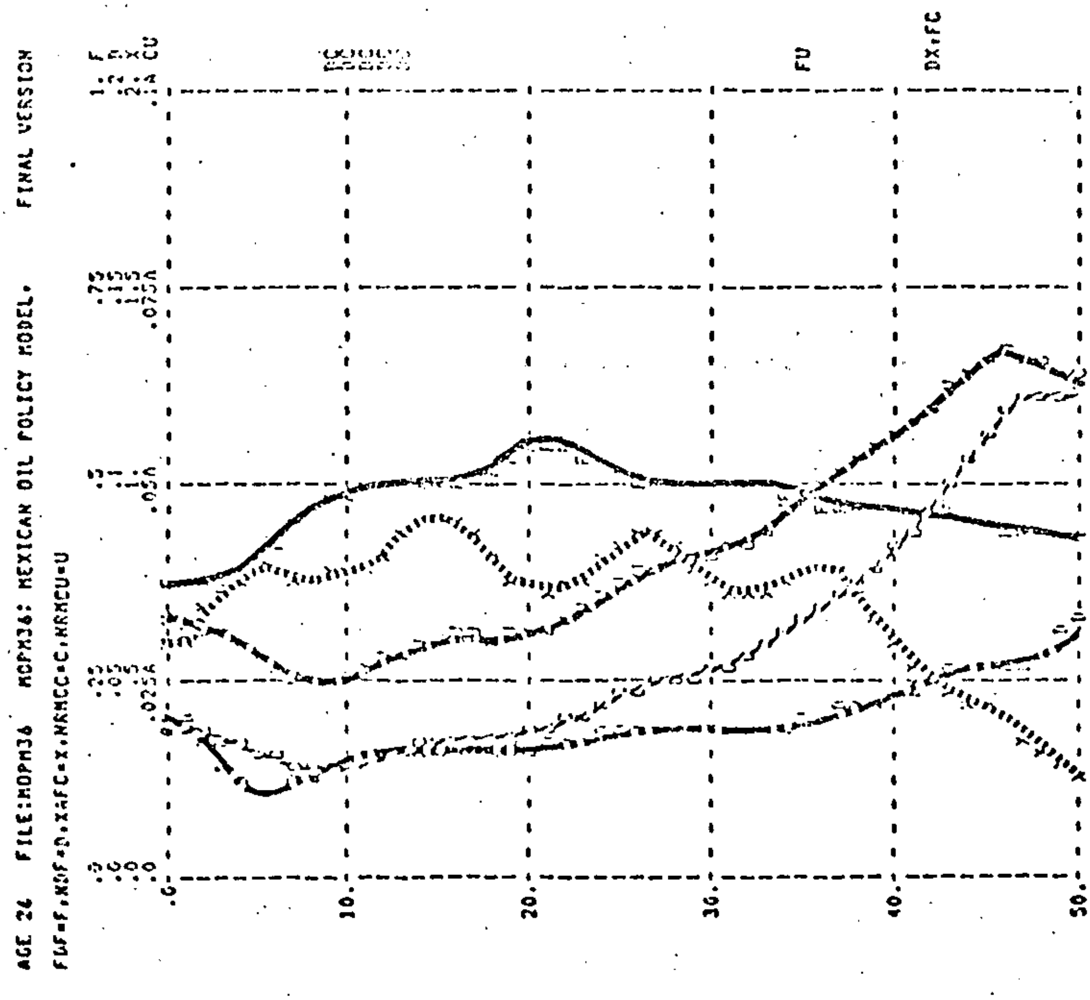


Figure 3-1d

test #4: oil exports of 1.5 MMBD and reduction of pricing subsidy.

This test is a combination of tests #2 and #3. Domestic price for oil is raised to 70% of the world oil price, and the target for oil exports is implemented.

Figure 3-2 shows that growth in total energy use is slowed dramatically by the relative increase in domestic energy prices. In figure 3-2c, between years 10 and 30, domestic energy use by households and production sectors is actually lower than the real growth rate of GDP. Due to a higher price of conventional oil and gas, production of energy from alternative sources is accelerated. Unconventional energy production rises by 35% of total energy supply by year 30, compared with 15% in figure 3-1. Figure 3-2c also shows that exports of oil and gas sustained at target levels for the full 50 years, instead of 35, due to the greater longevity of energy resources resulting from diminished domestic energy growth and consequent reduced competition for energy sources between domestic and export uses. Energy shortages are avoided compared with the previous case.

In summary, figure 3-2 indicates the same relative benefits and trade-offs from reduction of the existing pricing subsidy for domestic energy use as analyzed previously: intermediate term real GDP growth is lower with slightly higher unemployment; but inflation is continually lowered by up to 15 points, liquidity is improved and general interests rates are lowered, long term economic growth is enhanced due to greater longevity of energy supplies, Pemex exports are stabilized for at least an additional 15 years, and long term dependence on oil exports, external energy supplies, and foreign debt is reduced.

test #5: 1.5 MMBD exports, low subsidies and development of alternatives sources of energy.

In addition to the attainment of 70% price parity for domestic oil prices versus world oil prices, the national Energy Plan also calls for accelerated development of unconventional energy. Nuclear electric generating capacity is expected to grow to 2,500MW by 1990 and to 20,000MW by the end of the century.

Figure 3-2: Target Oil Exports and 70% Domestic Pricing Parity

(44)

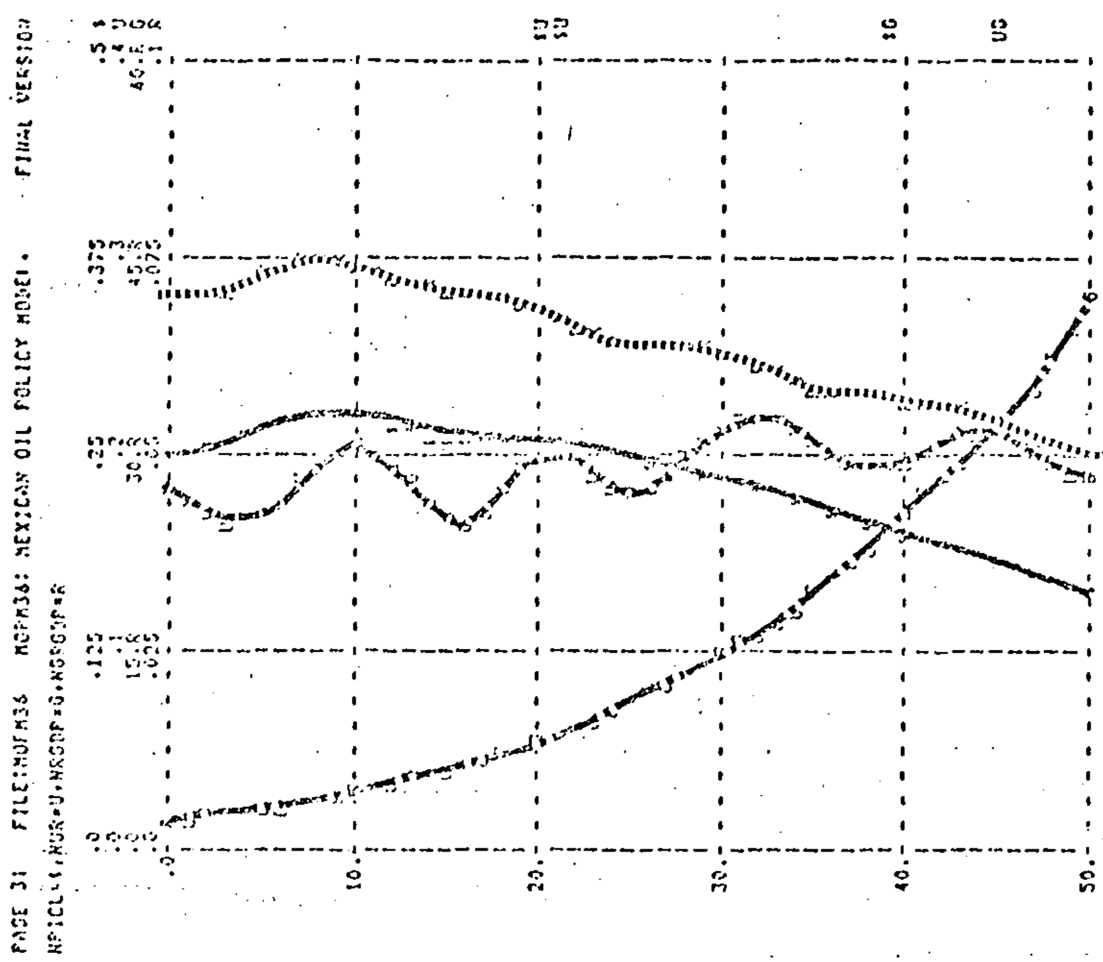


Figure 3-2a

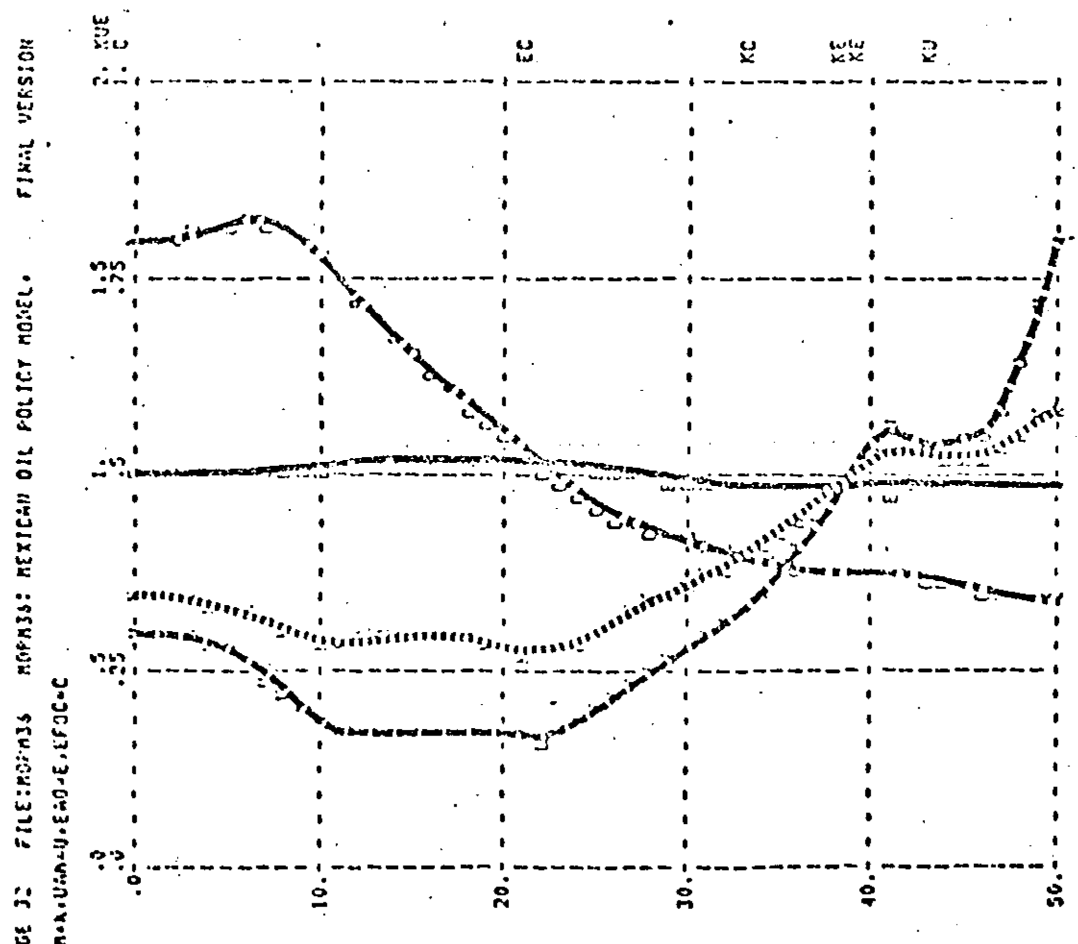


Figure 3-2b

Figure 3-2: Target Oil Exports and 70% Domestic Pricing Parity

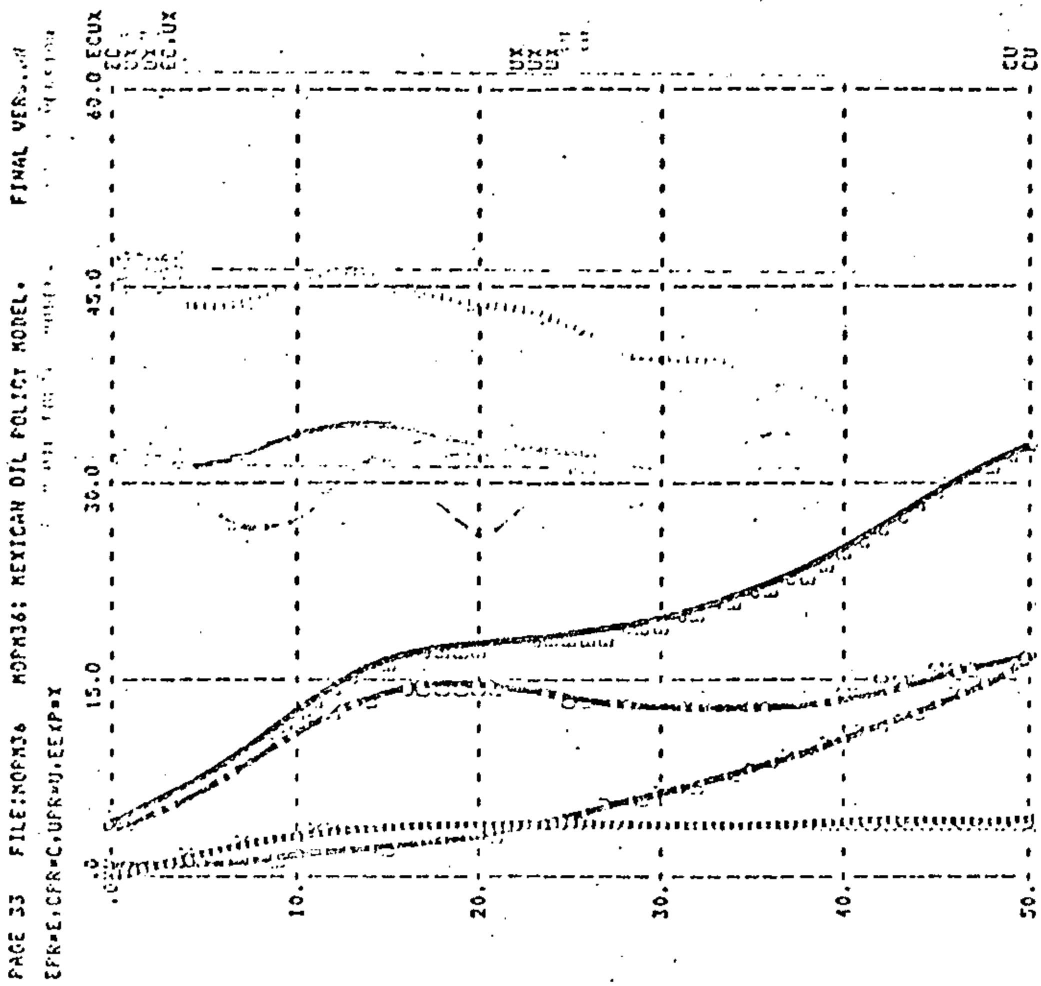


Figure 3-2c

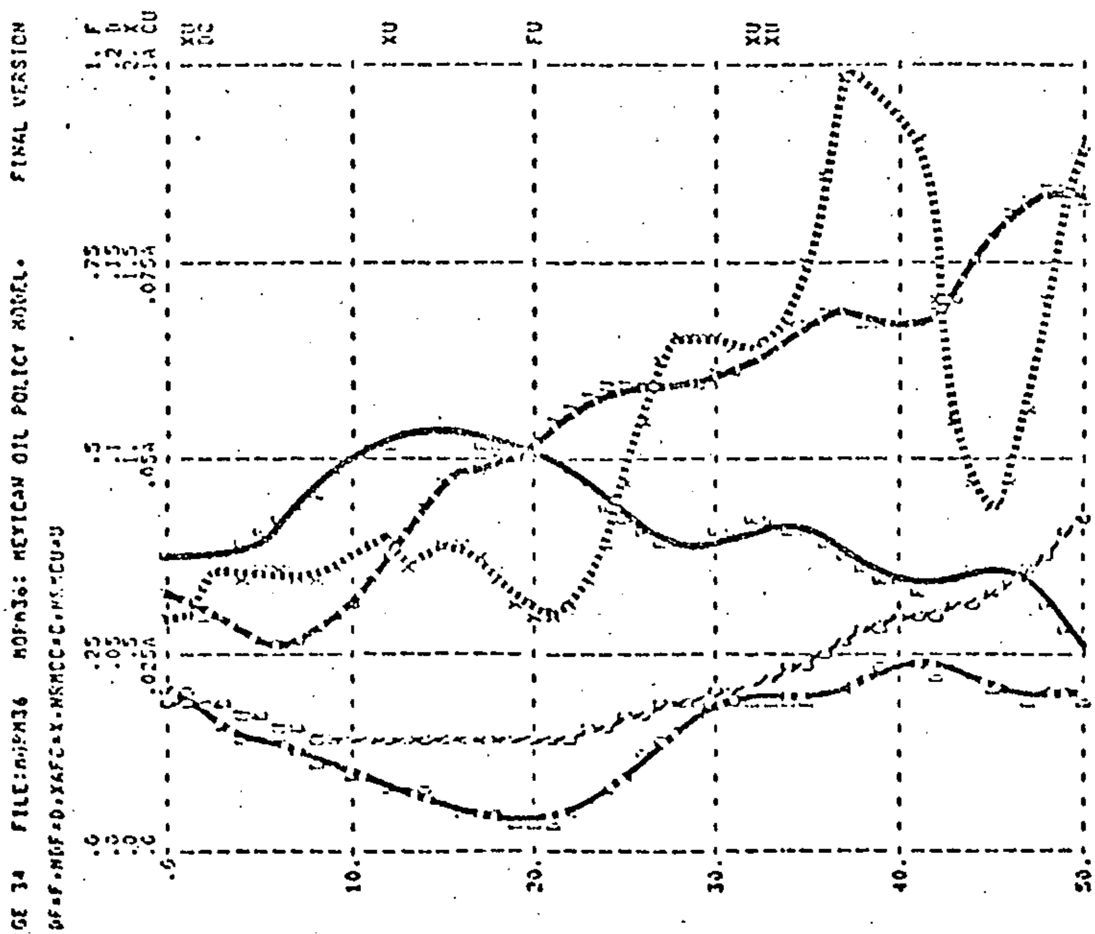
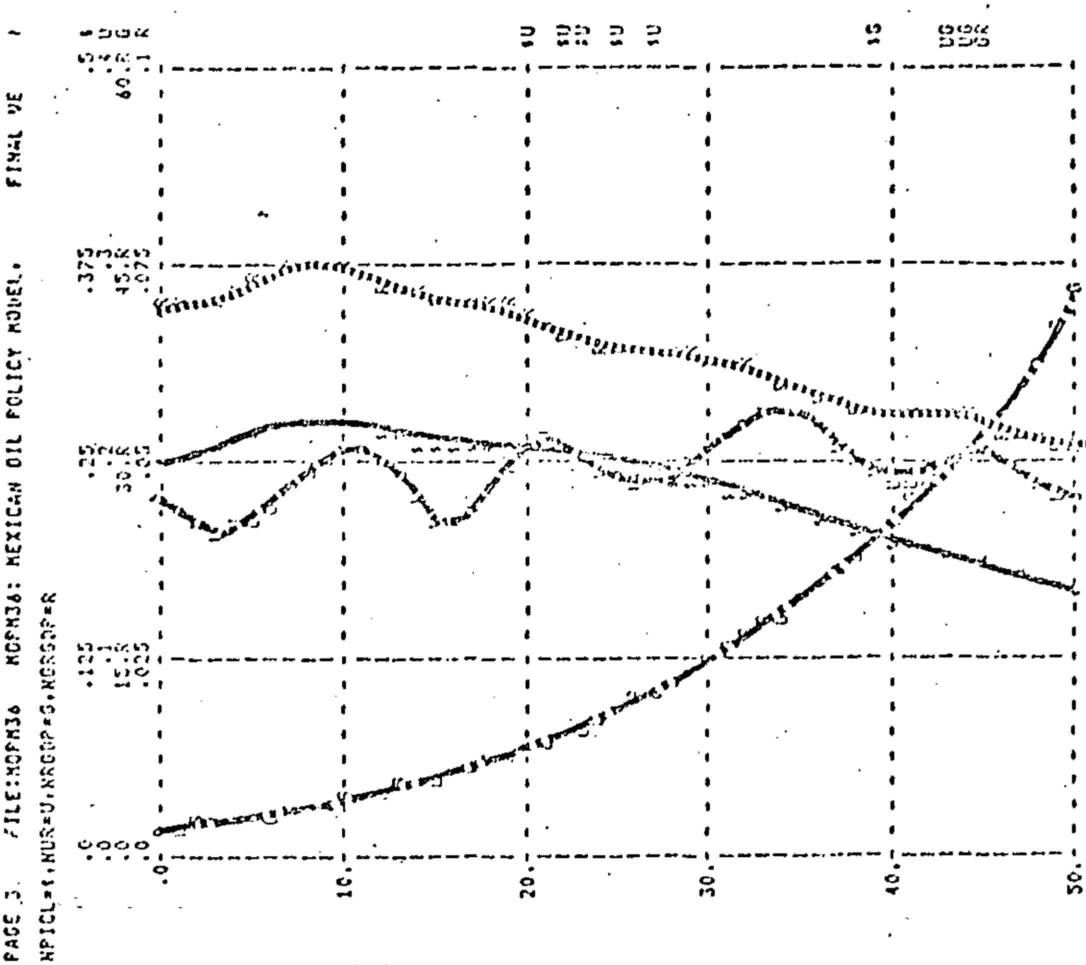


Figure 3-2d

Overall, the results of the policy tests embodied in this section suggest that stimulus of unconventional energy production can have a significant benefit within the energy sector toward increasing stability of Pemex exports and diminishing the possibility of eventual dependence on external energy sources when domestic oil and gas reserves within Mexico become more costly to exploit. On the other side, general macroeconomic effects tend to be small, with the impacts on real growth and inflation depending on how the encouragement of unconventional production is financed from a governmental and federal deficit point of view.

The results are shown in figure 3-3.

Figure 3-3: Allocating Oil Revenues to Develop Alternative Energy



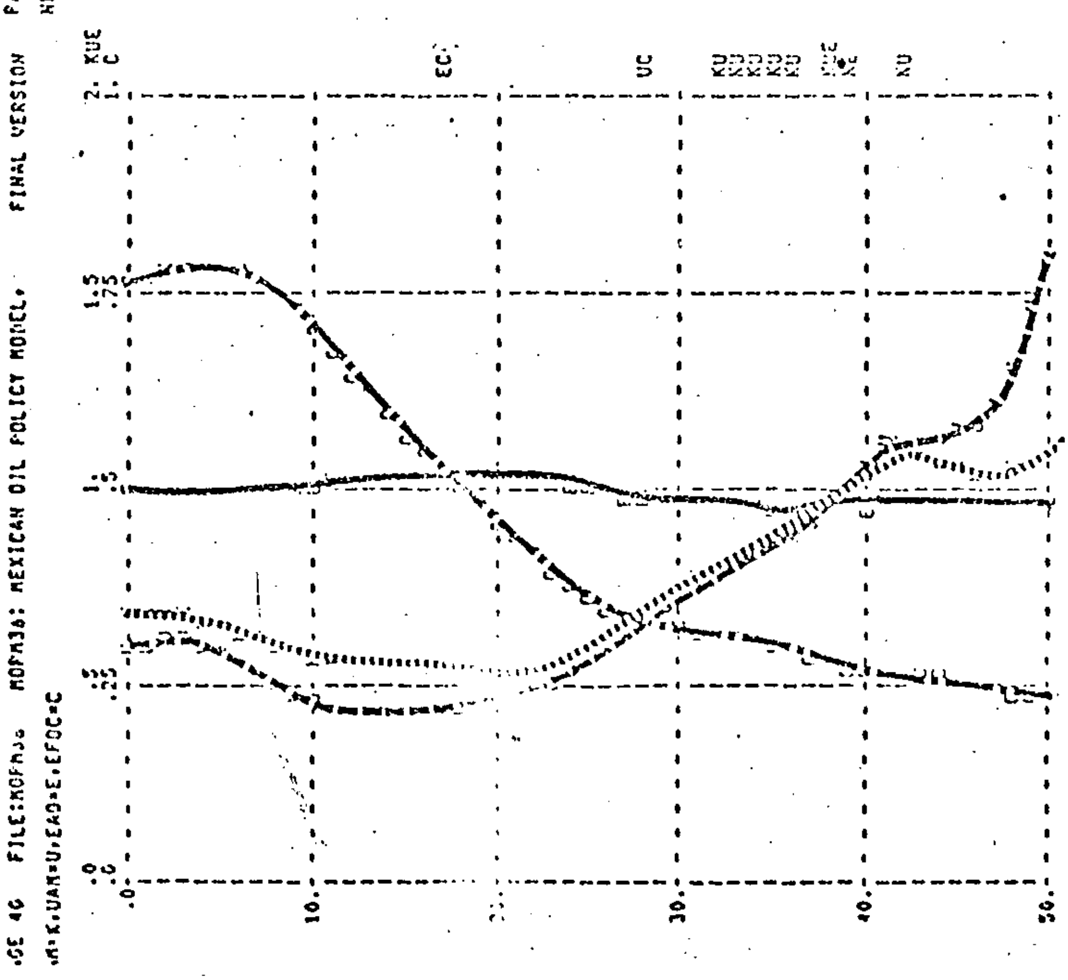
Inflation

Unemployment

Real GDP

Real GDP growth

Figure 3-3a



Capital sector liquidity

Unconventional sector liquidity

Energy adequacy

Pemex fraction of energy demand

Figure 3-3b

Figure 3-3: Allocating Oil Revenues to Develop Alternative Energy

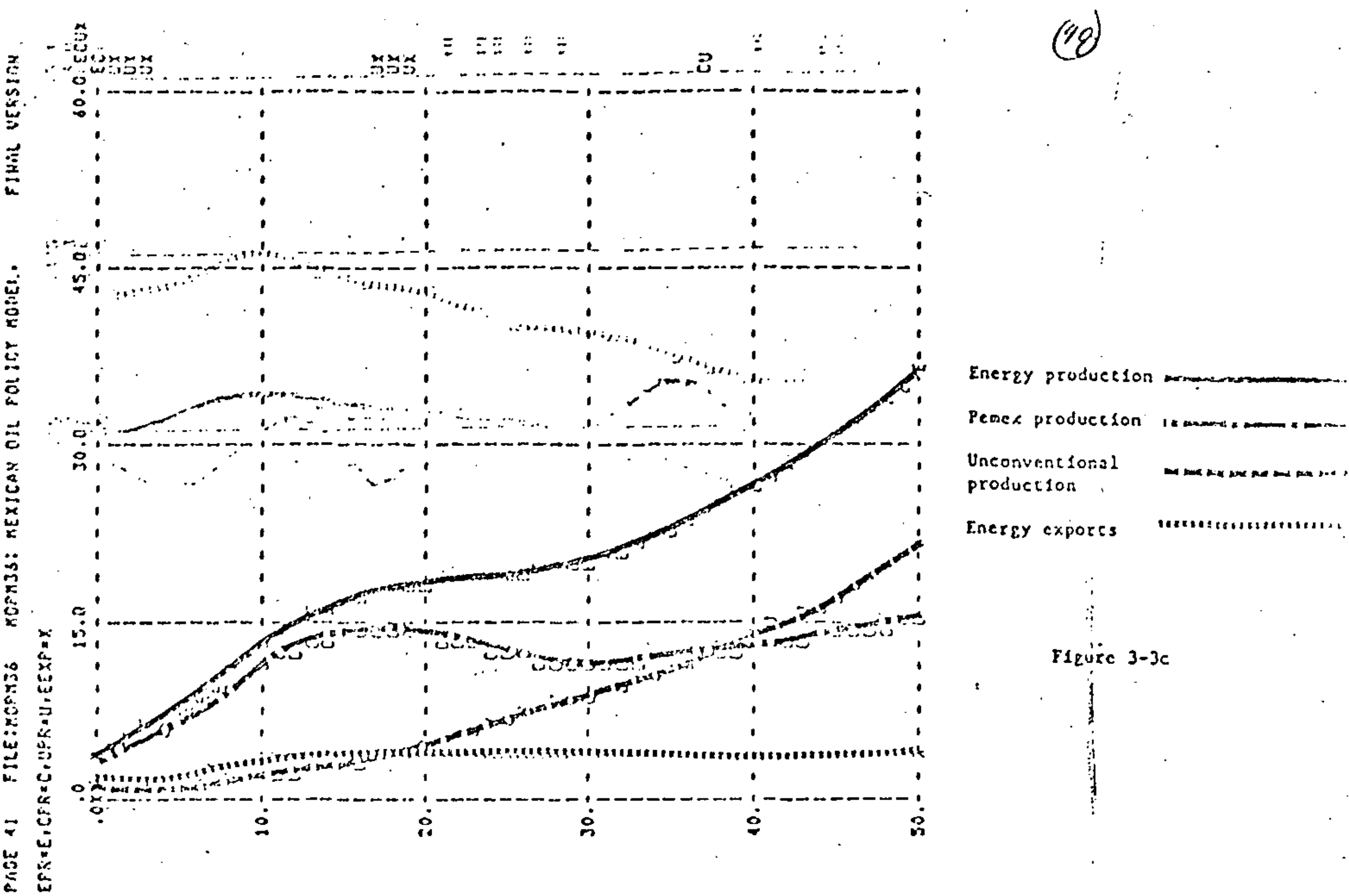


Figure 3-3c

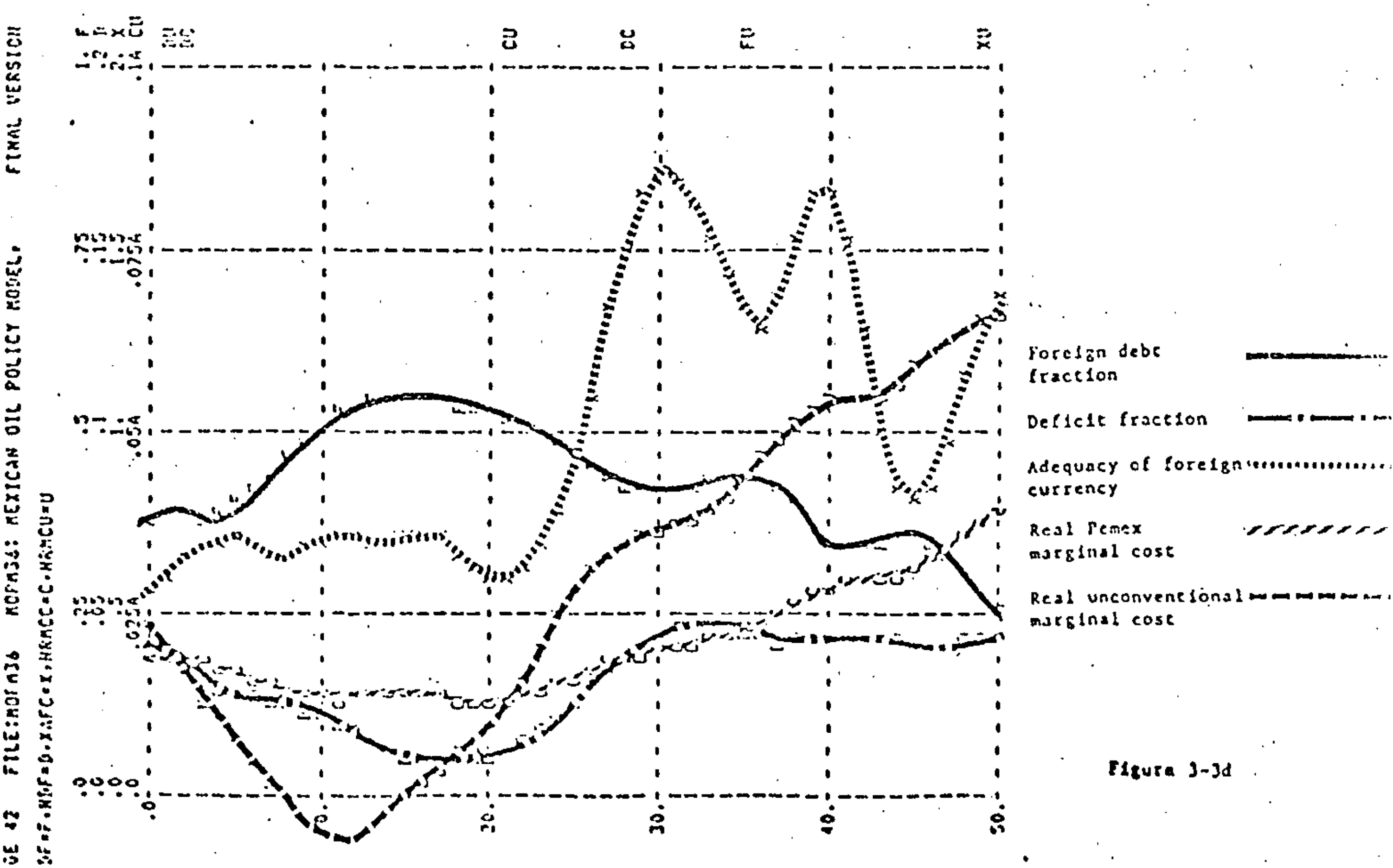


Figure 3-3d

ADDITIONAL DIRECTIONS FOR NATIONAL ENERGY POLICY

The preceding analysis has shown that the major elements of the National Energy Plan and Global Development Plan within the energy arena achieve a number of benefits. Rising the domestic price of oil and gas to 70% parity with world prices tends to lower inflatio by several points and to conserve long term energy supplies, although at the cost of some real growth due to higher average costs and relatively lower labor productivity. Accelerated development of alternative energy sources to supplement, and eventually replace, Pemex conventional production of oil and gas also helps to maintain long term energy supplies, diminish vulnerability to potential energy shortages, yet has a relatively minor impact on inflation.

On the other hand, the analysis also suggests that the real economic benefits of energy export may not be as substancial as expected by some analysts and policy makers. For example, model results suggest that a policy of raising Pemex exports up to a level of 1.5 MMBD of crude oil and some additional exports of petrochemicals and refined products, coupled with reduction in the subsidy for domestic use and encouragement of alternative energy sources, tends to raise real GDP by a total of 10-12% by the end of the century, implying an annual growth increment of less than 0.5% per year compared with a policy of sustained low oil exports and 70% domestic price parity to international prices. Another important mechanism that tends to lower growth is the imports of capital goods, because although they add to the national productive capacity and thus enhance productivity, but at the same time they reduce the pressures to develop a strong domestic capital goods sector within Mexico. Basing economic development on a substancial fraction of imported consumer goods and capital goods financed by oil exports may be a necessary short term strategy, but posses long term risks in terms of external dependence and slower development of internal production capacity and techniques than is possible given Mexico's substancial oil wealth. One important complication from a policy stand point is that even if imports of consumer and producer goods were to be limited, the additional accumulation of money within Mexico before real production capacity can catch up with nominal purchasing power will yield additional inflation. From this perspective, the conversion of oil revenues into imports that diminish foreign currency holdings tends to restrain the inflationary thrust of buildup of foreign exchange from oil export.

The policy examined here incorporates the target export levels set in the National Energy Plan, the increase in relative domestic oil prices, and the stimulus to production of alternative energy sources. It also includes:

-In order to stimulate internal development of capital production capacity within Mexico and to lower dependence on external sources of capital goods from a long term standpoint, the policy limits imported capital goods to 75% of desired levels based on the shortfall of domestic production capacity compared with desired capital investment rate.

-In order to limit the inflationary impact from retention of a higher percentage of oil revenues within foreign currency reserves and domestic money supply, the policy also shifts the allocation of oil export revenues compared with that laid out in the Global Plan: 50% of oil export taxes go to economic development, and the remaining 50% go to reduce the government deficit and therefore lower foreign debt and money creation by financing through the central bank.

Figure 4-1 shows the impacts of the policy on real growth and other macroeconomic indicators. There is a significant stimulus to real economic growth from the policy. The major source of the increase is due to the substitution of domestic capital production for imported capital goods.

Unemployment tends to be less during the first 10 years of the policy as a consequence of pressures to subtitute labor for capital goods in the face of higher real GDP. Over the long term, unemployment tends to held down by higher real GDP growth surrounding the multiplier effect from development of domestic capital production.

Regarding inflation none of the tests examined indicate a significant improvement in reducing price increases. These results may suggest that energy policies will need to be complemented by monetary and fiscal policies that lower federal deficits and rates of monetary growth in order to control inflation.

Figure 4-1: Limited Capital Imports and Deficit Reduction

(51)

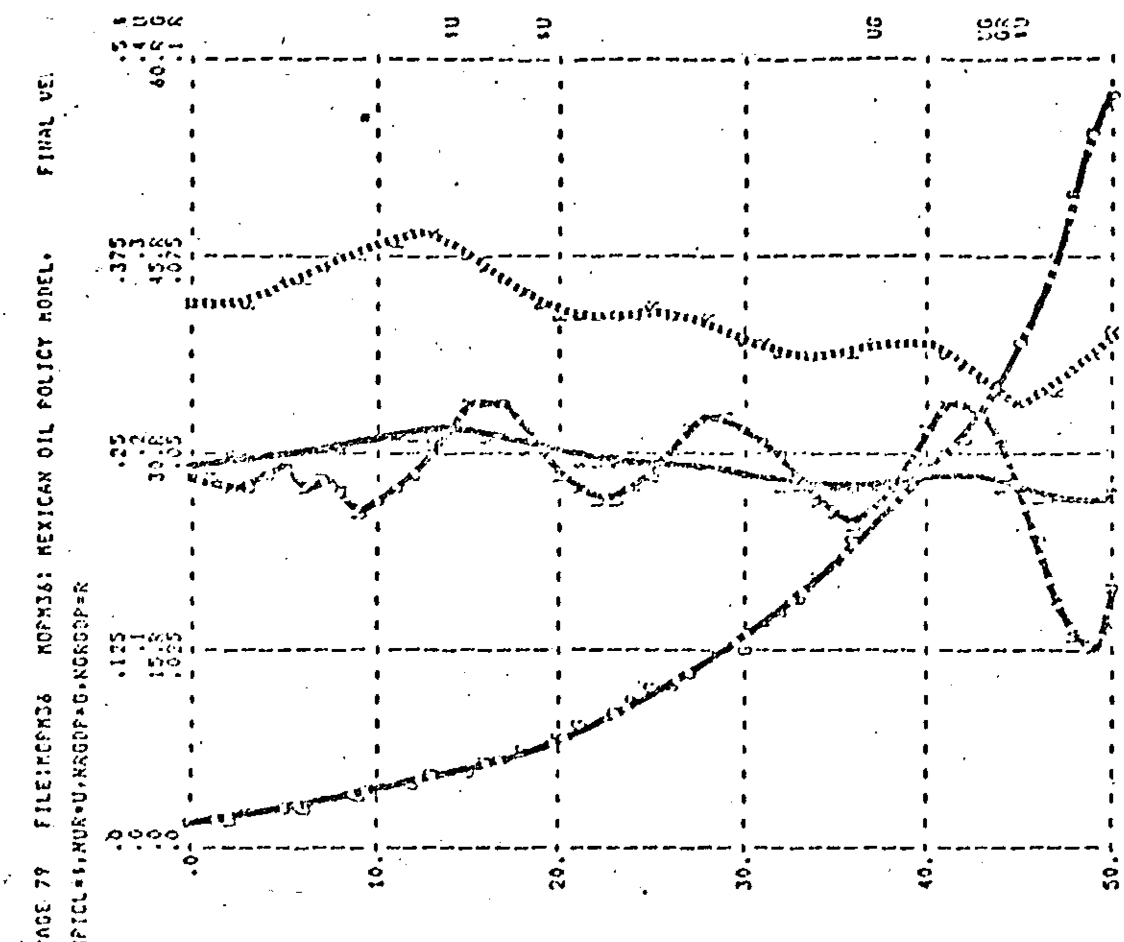


Figure 4-1a

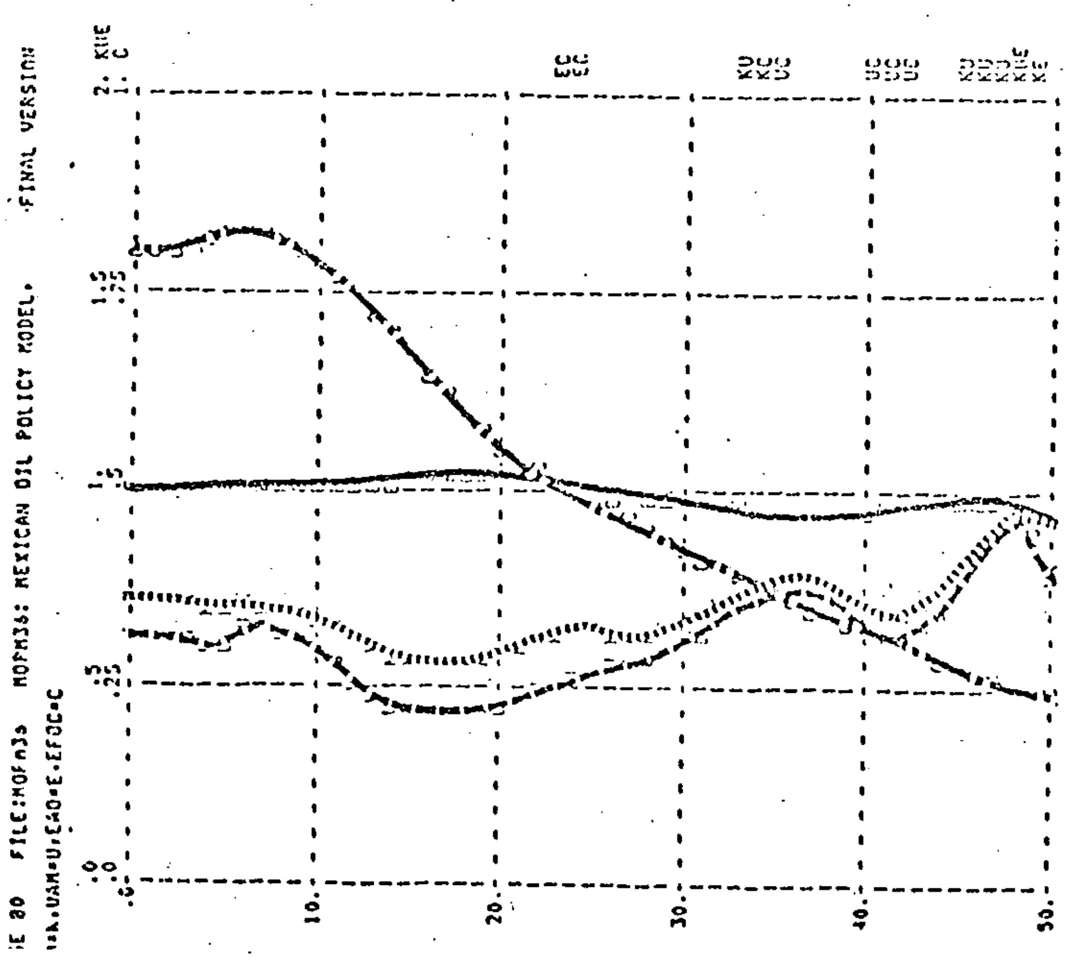


Figure 4-1b

Figure 4-1: Limited Capital Imports and Deficit Reduction

(52)

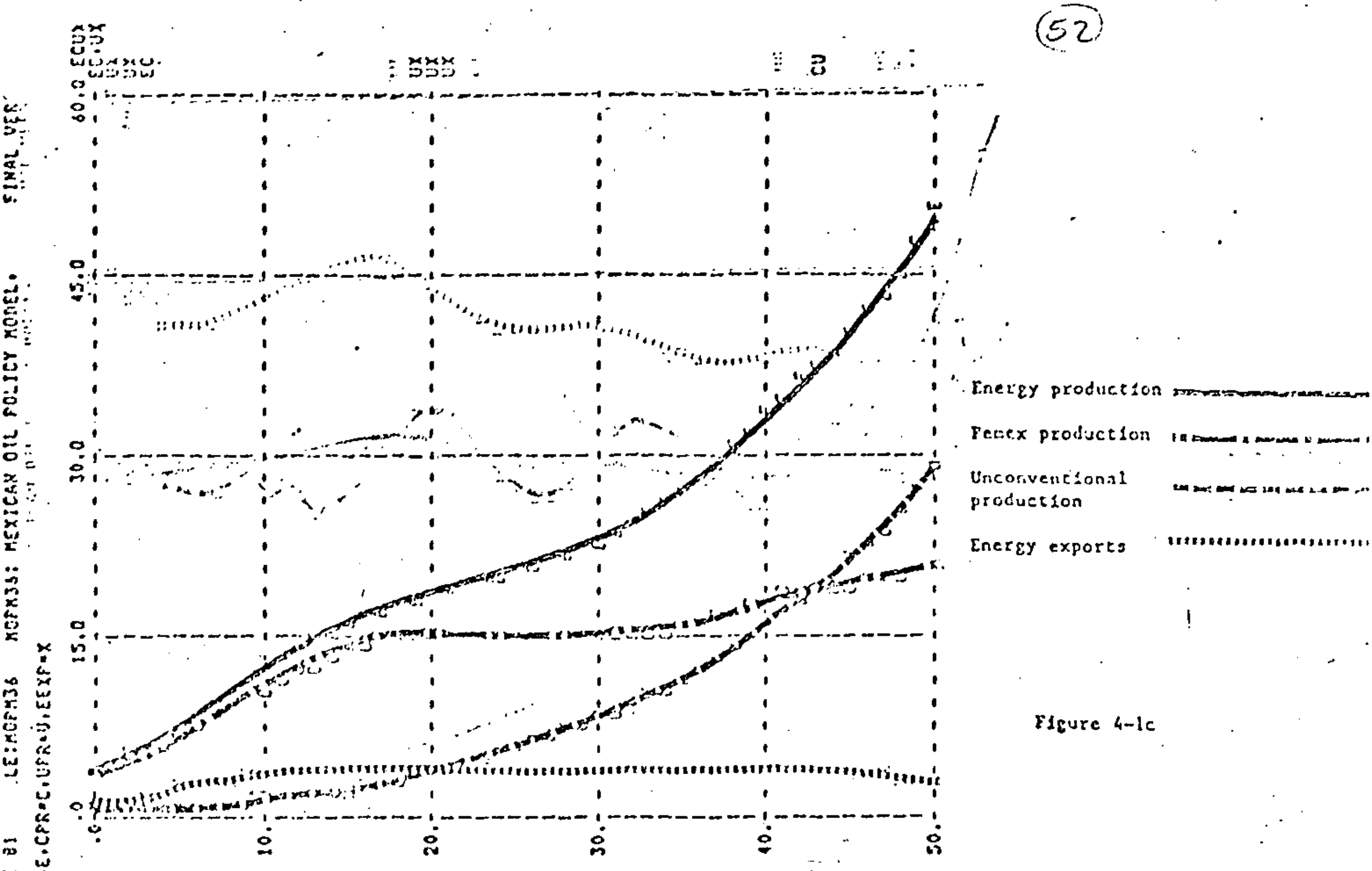


Figure 4-1c

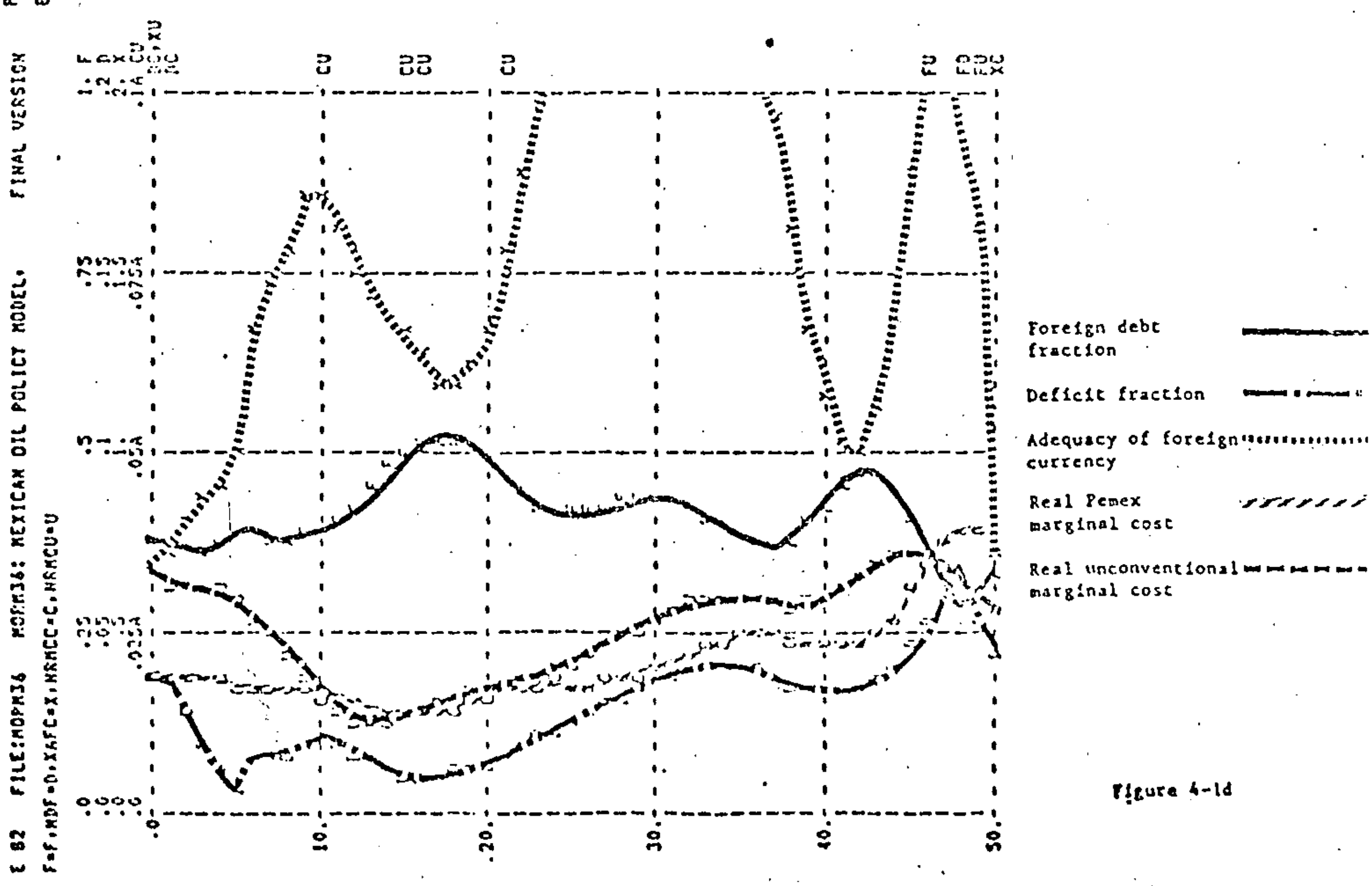


Figure 4-1d

FINAL REPORT:
HONEYWELL CUSTOMER SERVICES DIVISION
SYSTEM DYNAMICS MODELING PROJECT

by

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MAY 1982

FINAL REPORT:
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SYSTEM DYNAMICS MODELING PROJECT

CONTENTS

1. INTRODUCTION

1.1 Purpose of Pilot Project in System Dynamics
1.2 Review of Problem Area
1.3 Discussion of Alternative Policies

2. OVERVIEW OF MODEL

2.1 Honeywell Customer Service Division
2.2 The Marketplace

3. SIMULATION ANALYSIS

3.1 Simulation #1: Mainframe Growth
3.2 Simulation #2: Mini-Computer Growth
3.3 Simulation #3: Establishing a Reference Mode - Combined Growth

4. POLICY ANALYSIS

4.1 Summary of Policy Tests
4.2 Simulation #4: Service Policy Toward Resellers
4.3 Simulation #5: Man-In-The-Van Program
4.4 Simulation #6: Discount Service Price for Resellers
4.5 Simulation #7: Third Party Maintainer Service Quality

5. CONCLUSIONS

5.1 Recommendations from Model Analysis
5.2 Considerations abd Extensions

Outline, Documentation, and Model Description

APPENDIX 1: Presentation Outline

APPENDIX 2: Policy Structure Diagrams

APPENDIX 3: Documented Model Listing

APPENDIX 4: Model Equations with Reruns

1. INTRODUCTION

1.1 Purpose of Pilot Project in System Dynamics

The System Dynamics approach is a technique to further the understanding of complex systems through policy structure analysis. This formalzed approach uses dynamic simulation models. The ultimate objective is an incresed insight into the dynamics of the system at hand. Much knowledge is obtained in going through the exercise of building the model. In some aspects the modeling process is more valuable of an asset to the parties involved than the actual model itself! -- for building a model requires hard and clear thinking. It requires that all assumptions be rigorously justified. It is quite an intellectual challenge with definite practical applications. The lessons learned and the information uncovered in the process of conceptualizing and reconceptualizing a system's dynamic structure are well worth the work it demands.

This project has attempted to expand and clarify ideas about modeling the relationships between the Honeywell Customer Service Division and the Market. A picture of the organization is developed in terms of decision making processes. That picture of organizational structure is then translated into a set of precise mathematical equations to be used as a simulation model.

Once enough confidence is built up in the model, it is possible to develop many new insights into the system as well as confirm prior knowledge. This System Dynamics model can be used to explore the short- and long-term consequences of policy changes in the Customer Service Division. It can also be very valuable as a policy and strategy tool in the analysis of current bsiness problems.

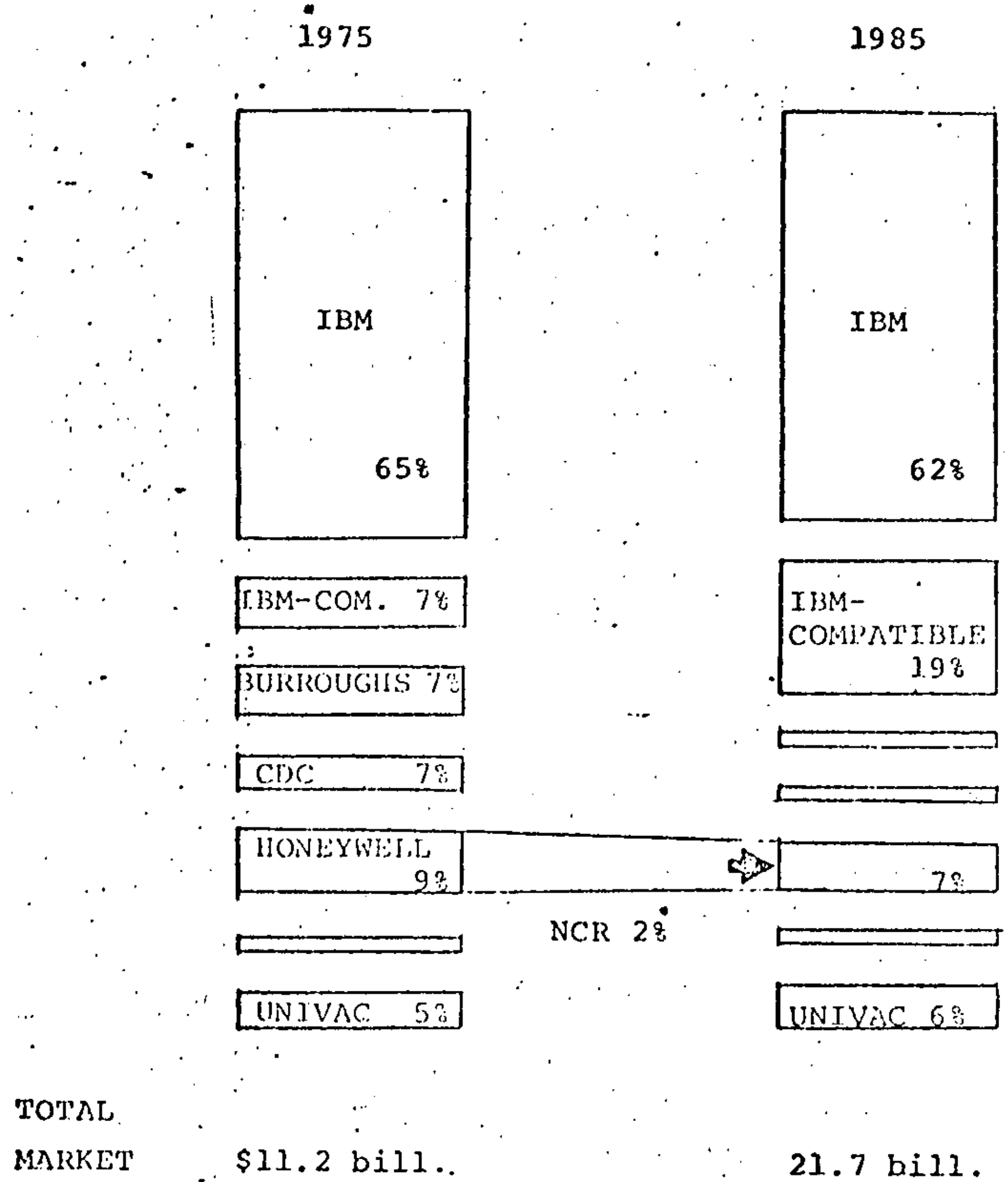
System Dynamics seeeks qualitative conclusions about the potential impacts of policy and decision-making upon a system. We aim to understand the structural underpinnings of a complex system and consequentially establish the relationships by which the actual system behavior is finally influenced. System Dynamics does not attempt to predict anything. It is merely a very powerful and unique tool by which to facilitate understanding of phenomena which are not readily comprehensible.

1.2 Review of Problem Area

Upon initial inspection there did not exist one clearly distinct "problem" for us to "solve" within the Customer Service Division. Honeywell has definately been experiencing a loss of market share in relation to its competitors (see Figure #1). The current situation cannot simply be broken down into a "problem and answer" scenario. It is our view that what is going on within Honeywell, and in fact within the whole information processing industry at this time, is an acute transformation. There is a tremendous market opening up for relatively low cost, small scale computers such as Honeywell's Level 6, as opposed to the large scale mainframe computers.

FIGURE #1

HONEYWELL MARKET SHARE



As illustrated in Figure #2, the trend is clear. Whereas in 1975 mainframe computer sales occupied an overwhelming 83 per-cent of the overall computer market ($13 billion), in 1985 that figure is projected to decrease by more than one-half to 36 per-cent of a total computer market which will increase five fold to $63 billion. In contrast, mini-computer sales as a percentage of the market are projected to increase by one and one-half times between 1975 and 1985, from 9.5 per-cent to 13 per-cent. We expect to see mini-computer sales for the entire computer industry to increase by eight times their 1975 level to $8 billion by 1985. Indications are that this will be only the beginning of a long period of exponential growth in the mini-computer market.

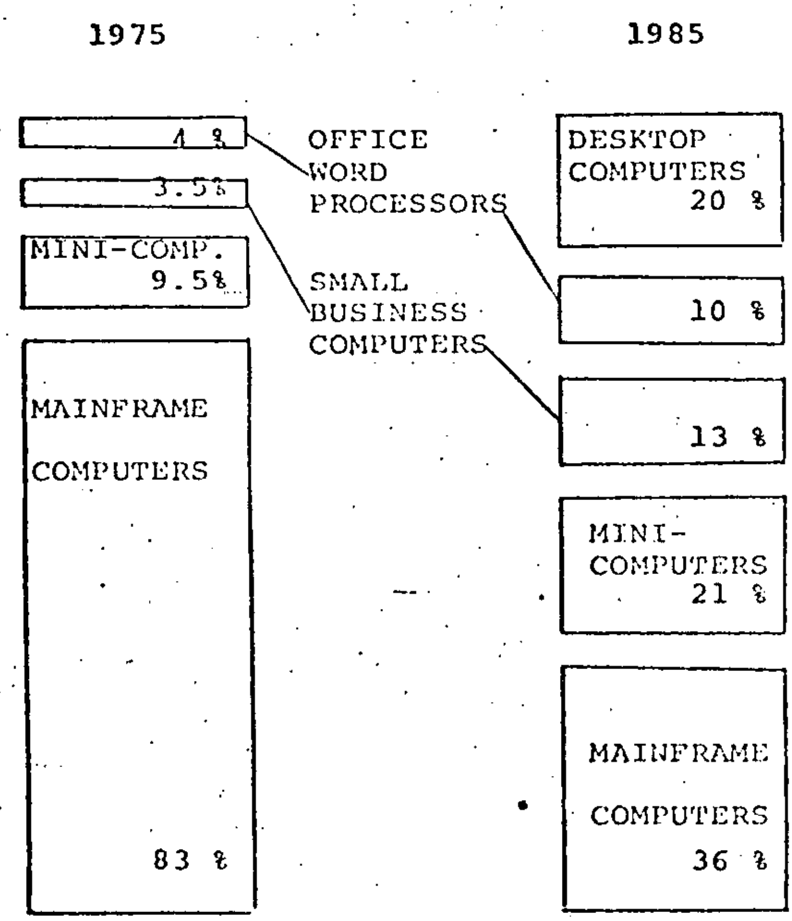
When the above observations are put more in the perspective of Honeywell, it means that mini-computer sales will double to fifty percent of overall service revenue. It is in just this particular case that the numbers can be quite deceiving (see Figure #3). Mini-computer sales which were $210 million in 1980 will more than quadruple to a projected $925 million in 1985 because the overall market is growing so fast. This type of growth characteristic, the phenomenon of exponential growth, has the capability of producing unexpected and unintuitive behavior within an organization.

1.3 Discussion of Alternative Policies

Unprecedented increases in the sales of mini-computers during the next five to ten years will necessitate new ways of thinking about

FIGURE # 2

MAINFRAME COMPUTER MARKET SHARE

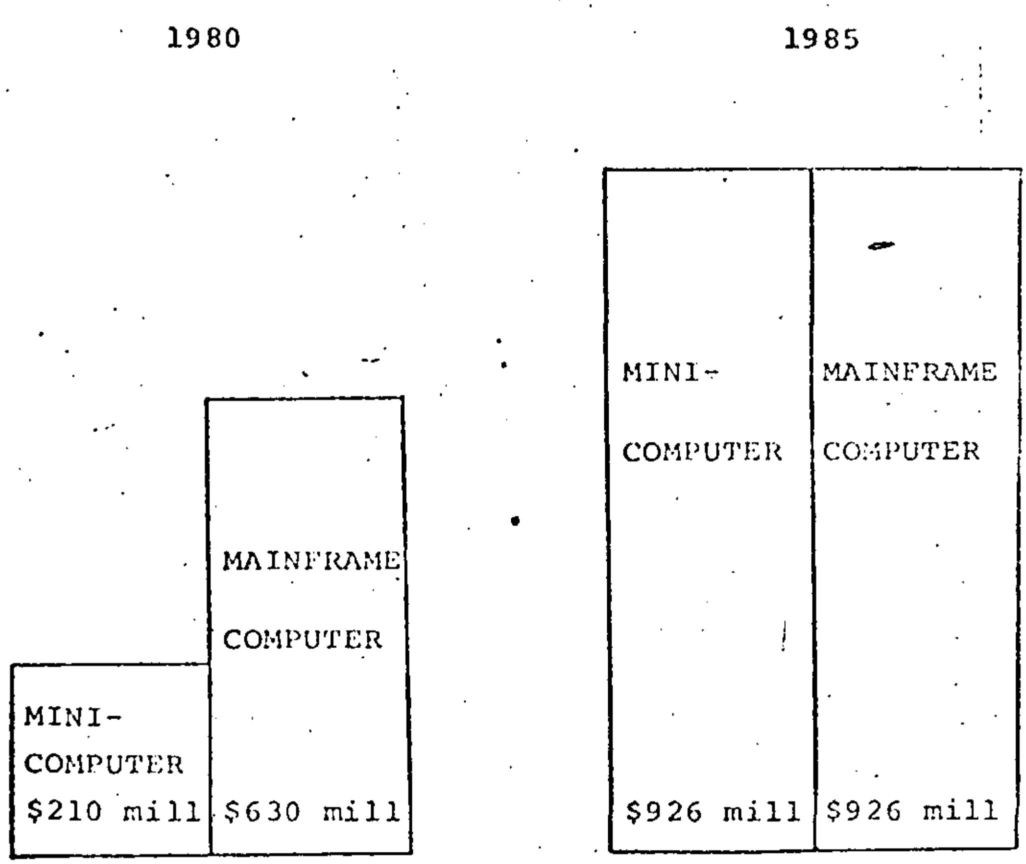


TOTAL MARKETS $12.83 billions $63.31 billions

8

FIGURE # 3

HONEYWELL REVENUE



and providing service. In the past Honeywell has refrained extensively from obligating itself to maintain Honeywell mini-computers sold by resellers. There is a different cost and profit structure associated with servicing minis as opposed to mainframes. The profit margin per mini installation, at least initially, is much less than large scale computers. Replacement parts, spares, and circuit boards for new mini equipment are very capital intensive.

In light of these financial considerations, there is uncertainty as to encouraging further reseller and third party maintenance of Honeyell equipment. Price discounts on service contracts for resellers are one means of inciting growth, but such measures might tend to reduce profit even further. Non-traditional maintenance policies such as the man-in-the-van program would seem to cut down on costs by making more effective use of existing assets and labor, but its ultimate effect is not quite known.

Honeywell is looking to increase market share in the coming years with the influx of mini and micro products. Therefore, high service quality is also a topic of concern. It is important to assess the impact of the above policies upon service quality and the market, while keeping in mind the new financial structure associated with mini-computers. Leverage points can be found within the Honeywell Service organization through which policy decisions will have the greatest effect upon the organization while generating the least amount of internal resistance.

2. OVERVIEW OF MODEL

This study involves Honeywell Customer Service Division and its relationships to a changing market. HCSD has to provide service to two different types of equipment: minicomputers and large scale systems. Traditionally it has been providing service to the latter, but there has been a change in the computer market, due to the maturation of large scale systems and fast growth in minicomputers. This creates a problem because the requirements, costs, and prices of mini service are different, so there is the need to look for new methodologies.

2.1 Honeywell Customer Service Division

The Honeywell Customer Service Division can be thought of as having two primary and sometimes conflicting goals: to provide service and also to make a profit. We have represented the CSD by the Service Subsystem, which is composed of a Service Sector and a Financial Sector, in order to capture these two distinct goals and the processes associated with them.

The Service Sector provides service by aquiring the necessary resources, namely Labor and Assets. The desired levels of these resources are calculated by forecasting expected service requirements. Labor is especially more intricate than Assets in that Average Experience of Labor and Overtime Policies are also necessary to be taken into consideration. A Backlog of service calls is generated by the number of installations serviced by Honeywell. These calls then must be answered using the available resources. If the required Assets and/or Labor are not available, then Backlog will build up and Honeywell Service Quality consequently will decline.

The Financial Sector is a mechanism for keeping track of the cost and revenue of the Service Division. Based upon these figures, Service Profit Margin can be calculated. When Profit Margin differs from its historically expected target, then financial constraints will be imposed upon the Service Division in order to reduce costs and increase profit. These are simplified budgetary processes. As a result, Asset and Labor aquisition will decrease which will then leave the Service Sector short of resources. The two sectors are truly conflicting.

2.2 The Marketplace

The Marketplace can be thought of as two distinct sectors: the Sales Market and the Service Market.

Honeywell and Reseller Sales are both represented in the Sales Market. Each grows at a rate proportional to its own size; as they get bigger, then they grow at faster rates. Price and Service Quality are the two main factors which influence rate of growth in the market. Therefore, Service Subsystem performance in terms of Service Quality will influence market growth. The market will then feed back and influence Service once again.

The Service Market is meant to differentiate between these Honeywell installations which are serviced by Honeywell and those which are serviced by Third Party Maintainers. When Honeywell Service Quality declines in relation to TPM Service quality, then Third party Maintainers are liable to receive more service contracts. Conversely, when Honeywell Service Quality increases, then they are likely to get more business.

The Market and the Service Division interact in a unique way. The two feed back to one another. If Honeywell Service Quality were to decline, then market growth would also slow down. A decrease in sales would increase the installations which need to be serviced, and so Service Quality would eventually rise back up. This increase would cause growth which in turn would decrease Service Quality and start the whole cycle all over again. (See Figures #4, #5, #6, #7)

3. SIMULATION ANALYSIS

3.1 Simulation #1: Mainframe Growth

Our first major concern when testing the model was that it correctly portray the behavioral characteristics of normal mainframe growth. We have assumed for this purpose a maturing linear growth of large scale installations beginning at 12,500 in 1978 and increasing to 25,000 over a period of ten years. The simulation is begun in equilibrium; it therefore requires almost a 24 month period for the transient effects of growth to die away. The same will be true of all subsequent simulations.

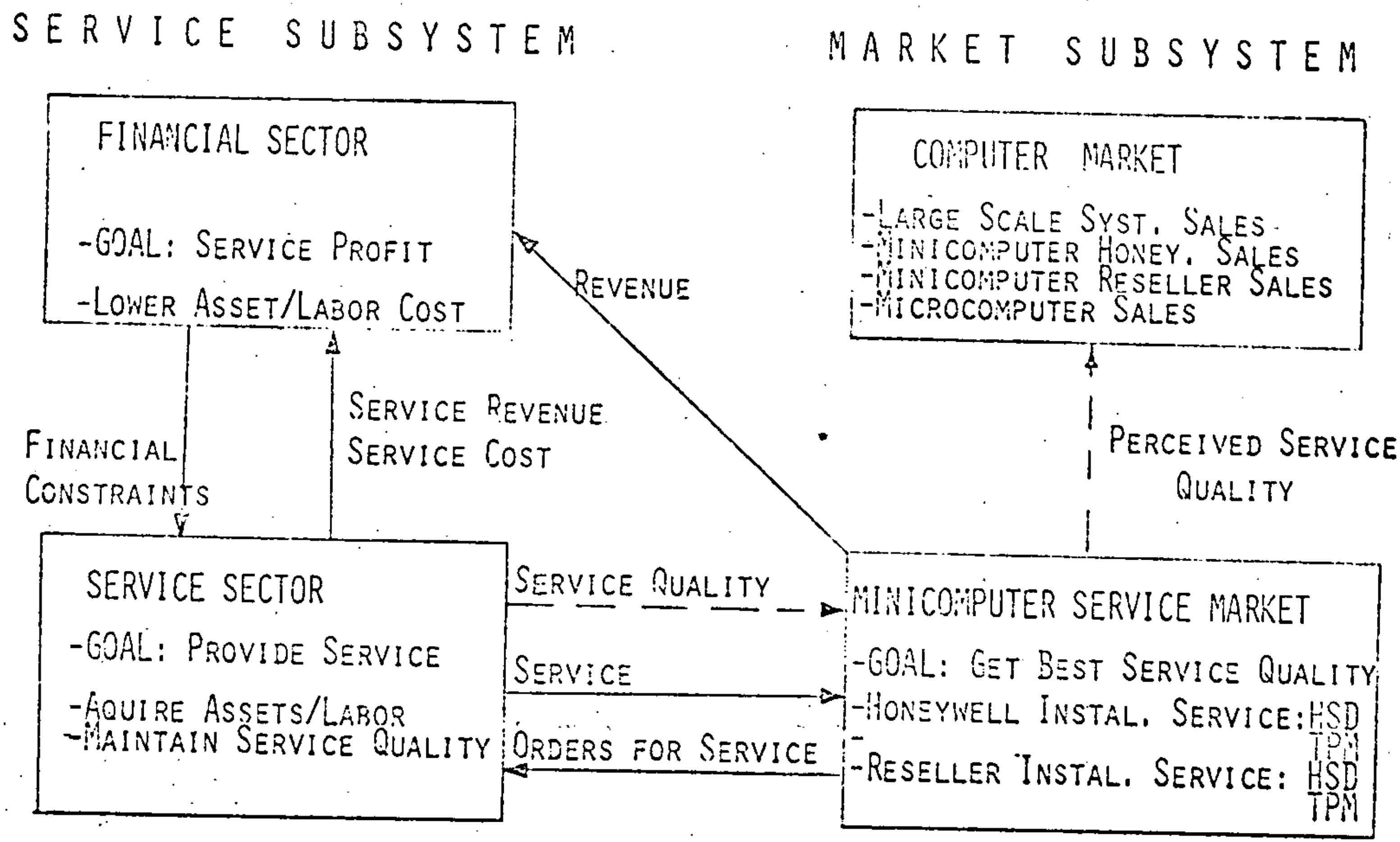

SERVICE SUBSYSTEM
MARKET SUBSYSTEM
FINANCIAL SECTOR
-GOAL: SERVICE PROFIT
-LOWER ASSET/LABOR COST
REVENUE
COMPUTER MARKET
-LARGE SCALE SYST. SALES
-MINICOMPUTER HONEY. SALES
-MINICOMPUTER RESELLER SALES
-MICROCOMPUTER SALES
FINANCIAL CONSTRAINTS
SERVICE REVENUE
SERVICE COST
PERCEIVED SERVICE QUALITY
SERVICE SECTOR
-GOAL: PROVIDE SERVICE
-AQUIRE ASSETS/LABOR
-MAINTAIN SERVICE QUALITY
SERVICE QUALITY
SERVICE
ORDERS FOR SERVICE
MINICOMPUTER SERVICE MARKET
-GOAL: GET BEST SERVICE QUALITY
-HONEYWELL INSTAL. SERVICE: HSD
TPM
-RESELLER INSTAL. SERVICE: HSD
TPM

FIGURE # 5

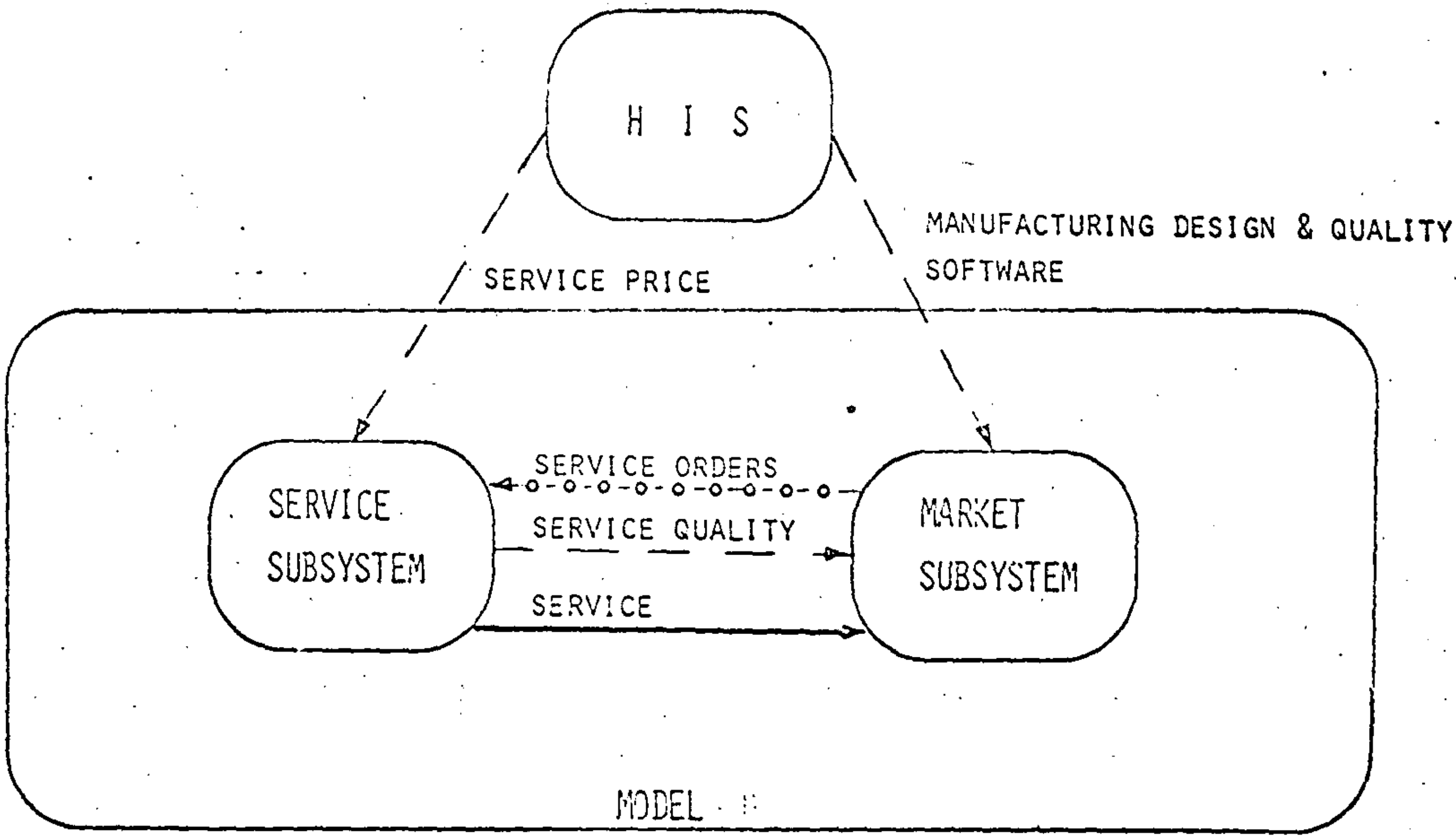
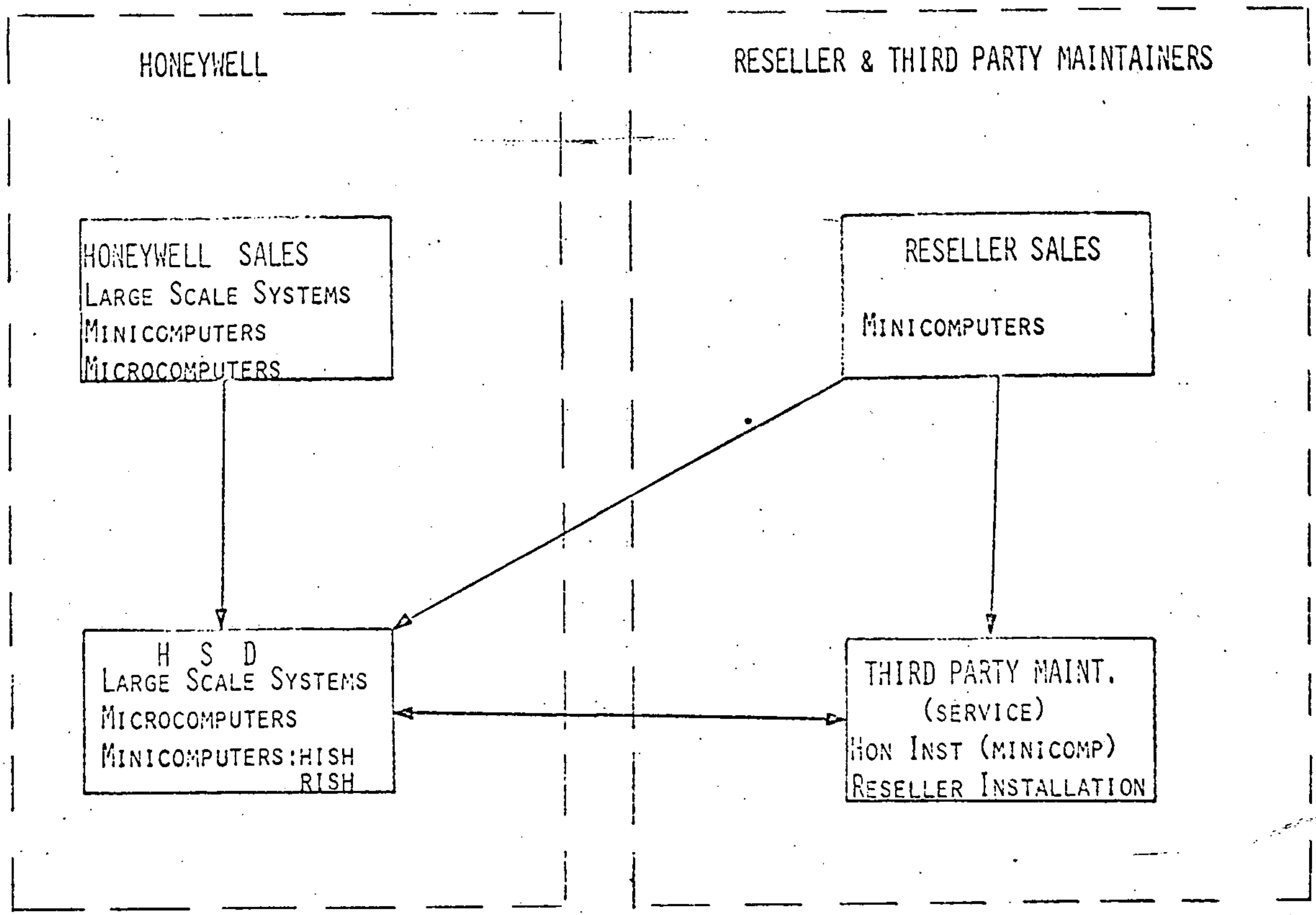

H I S
MANUFACTURING DESIGN & QUALITY
SOFTWARE
SERVICE PRICE
SERVICE SUBSYSTEM
SERVICE ORDERS
SERVICE QUALITY
SERVICE
MARKET SUBSYSTEM
MODEL

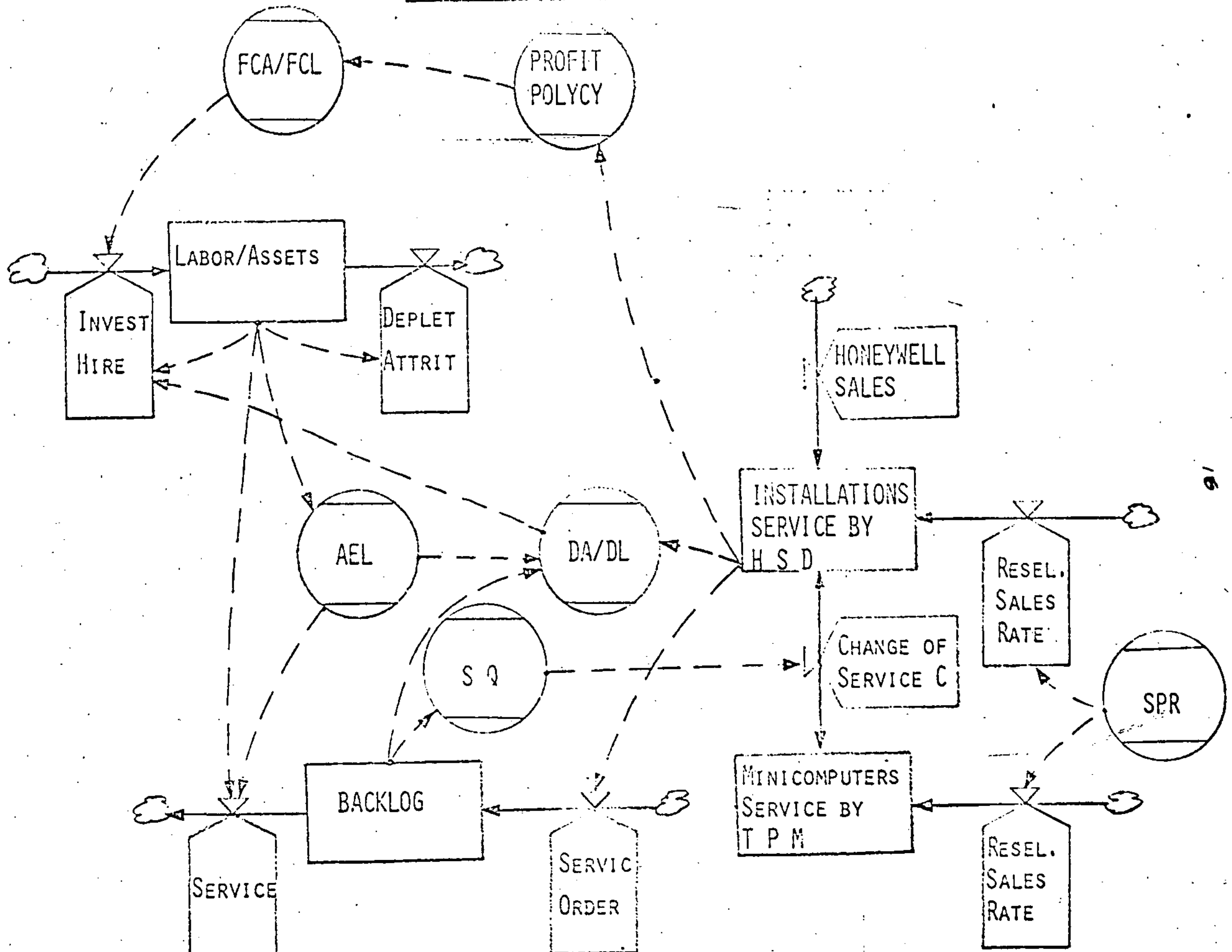
FIGURE # 4



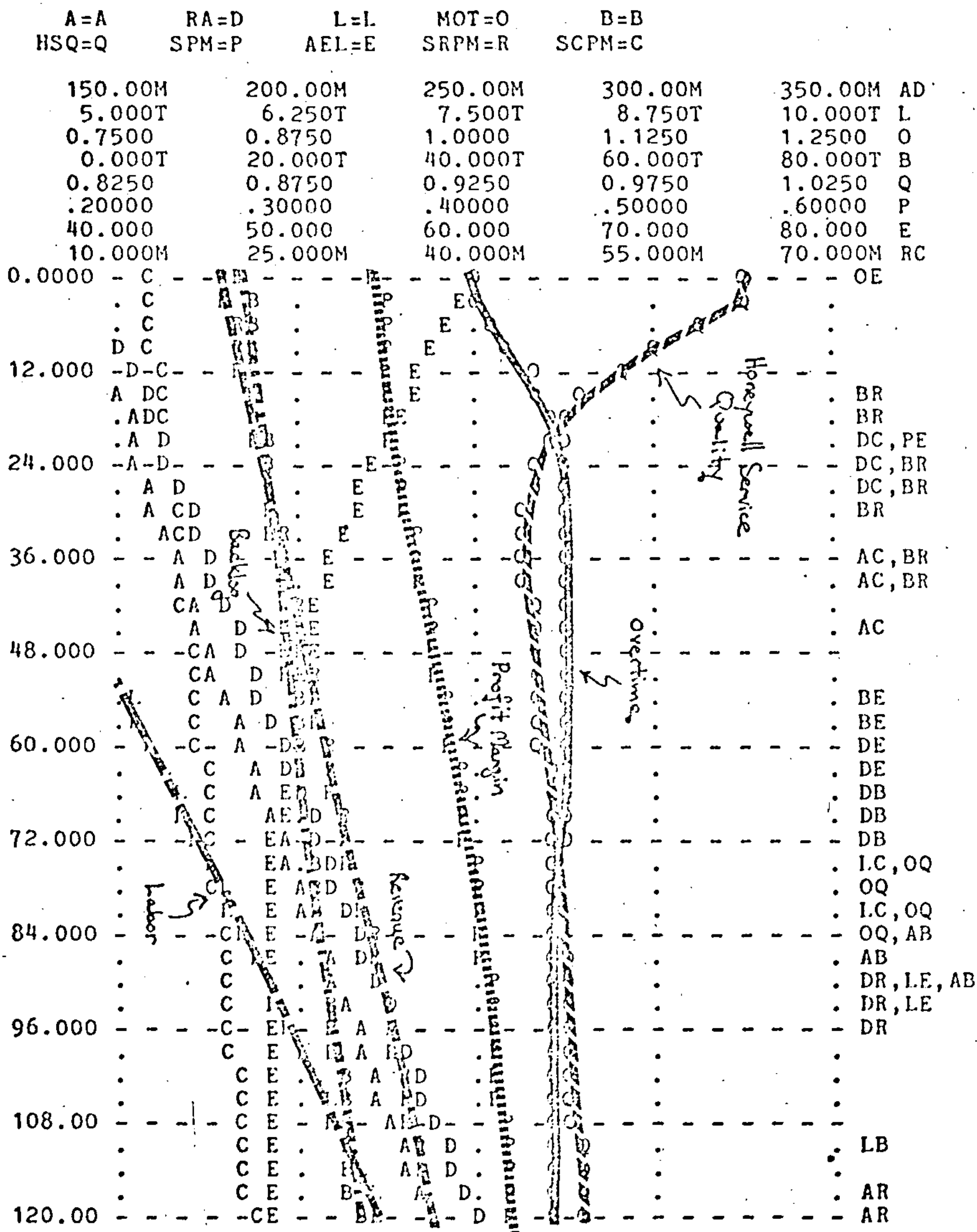
HONEYWELL
RESELLER & THIRD PARTY MAINTAINERS
HONEYWELL SALES
LARGE SCALE SYSTEMS
MINICOMPUTERS
MICROCOMPUTERS
RESELLER SALES
MINICOMPUTERS
H S D
LARGE SCALE SYSTEMS
MICROCOMPUTERS
MINICOMPUTERS:HISH
RISH
THIRD PARTY MAINT.
(SERVICE)
HON INST (MINICOMP)
RESELLER INSTALLATION

FIGURE # 6

POLICY STRUCT DIAGRAM



P- 7 RUN-TEST#5 TEST#5: NON-MINI GROWTH



SIMULATION #1: MAINFRAME GROWTH

An increase in Mainframes implies an increase in total installations service by Honeywell. In this case, total installations serviced raises the service requirement which influences three areas:

1] Revenue increases due to a greater number of installations serviced;

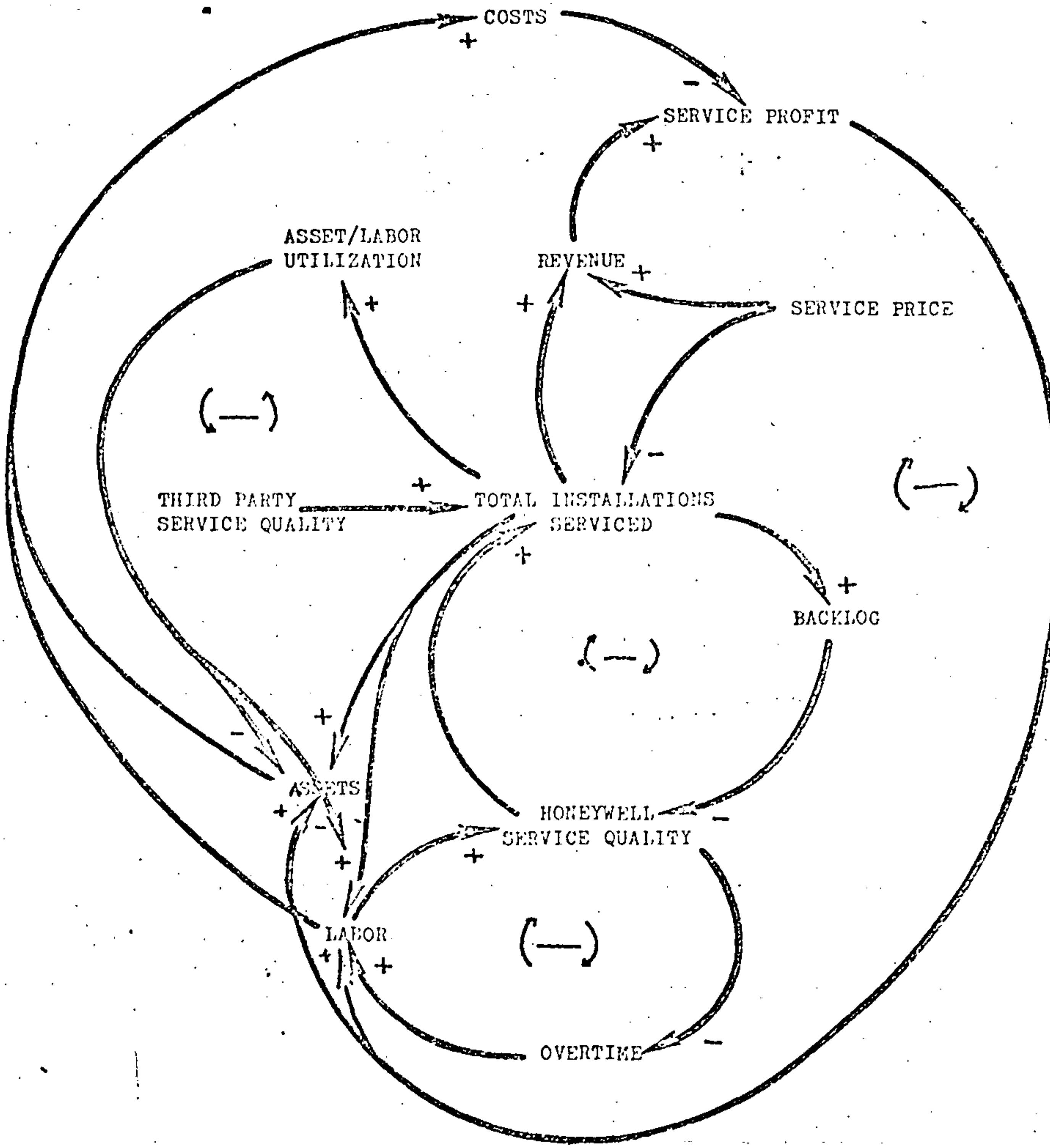
2] Backlog of service calls increases also for the same reason;

3] Required Assets and Labor rises as well.

Overtime increases due to a lag in the aquisition of Labor and Assets. It is necessary to both make up for deficiencies in Labor and to compensate for the decrease in Labor productivity that insufficient Assets causes. Service Profit Margin increases during this same period on account of this aquisition lag as well. Since expenses do not keep pace with the increase in Revenue, a greater Profit Margin is realized.

Honeywell Service Quality decreases because the greater Backlog imposes an increased service requirement upon the Service Division, but again due to lags in aquisition, Assets and Labor are not maintained at required levels. Consequently, Service Quality falls.

Overtime and Service Quality are plotted as mirror images of one another. This outcome is not suprising since they are linked by a directly by an inverse relationship, a negative causal link. Both are representative of the overall state of the organization. Asset and Labor Utilization, Average Experience of Labor, Backlog of service calls, and Required Labor and Assets all directly feed into Service Quality and Overtime (see Causal Loop Diagram).



CAUSAL LOOP DIAGRAM

3.2 Simulation #2: Minicomputer Growth

The focus of this study deals with Mini-Computer growth and the potential problems which such growth may create. We have assumed a fairly rapid doubling time for mini installations in the market of approximately 15 to 25 months. The Reseller growth has been purposely differentiated from Honeywell by its tendency to increases at a faster rate.

Mini-Computer growth can be divided into two distinct regions:

1] <60 months - approximate linear growth;

2] >60 months - clearly exponential growth.

Exponential growth is present all the time, but for the first half of the simulation it's approximately linear. As the number of Honeyell Mini Installations increases, growth increases as well. This result is due to a positive feedback loop in which the growth of installations is dependant upon the total number of installations! As they increase, the loop becomes much stronger and exhibits clear exponential behavior which until then has remained rather hidden.

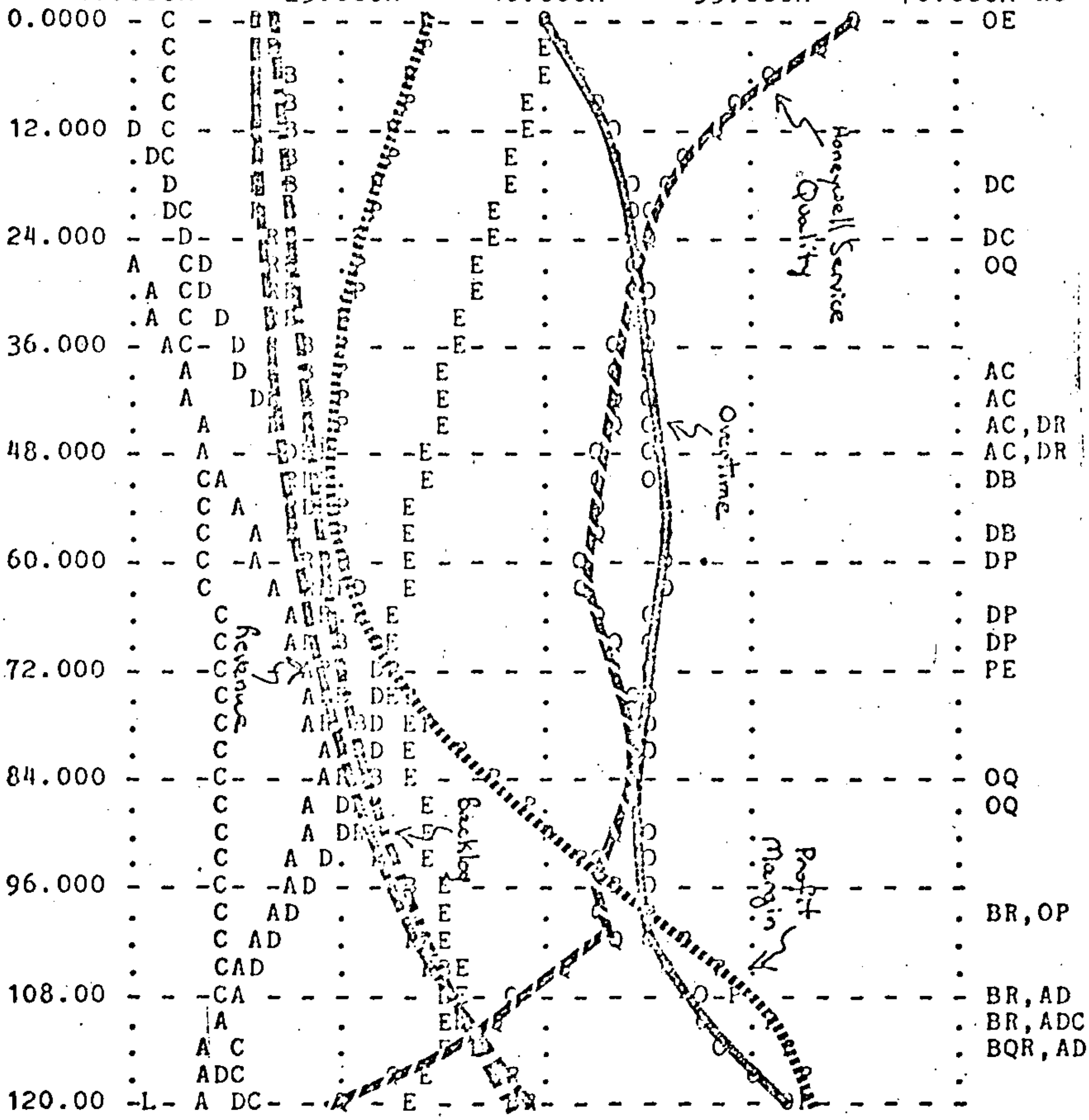
Service Profit Margin initially declines because minis, during their early stage of growth, are not as profitable to service as mainframes. As growth continues, utilization of Assets and Labor increases. Therefore, Profit Margin rises due to the lowering of Service Cost per installation serviced.

The aquisition lag for Labor and Assets is present in this case as well, but it is not a dominating effect. The change in Utilization due to service volume has a much more direct impact upon profits and service quality than does the aquisition lag.

P- 8 RUN-TEST#6 HONEYWELL CUSTOMER SERVICE DIVISION 05/15/82

```
   A=A       RA=D       L=L      MOT=O       B=B
 HSQ=Q      SPM=P     AEL=E     SRPM=R     SCPM=C

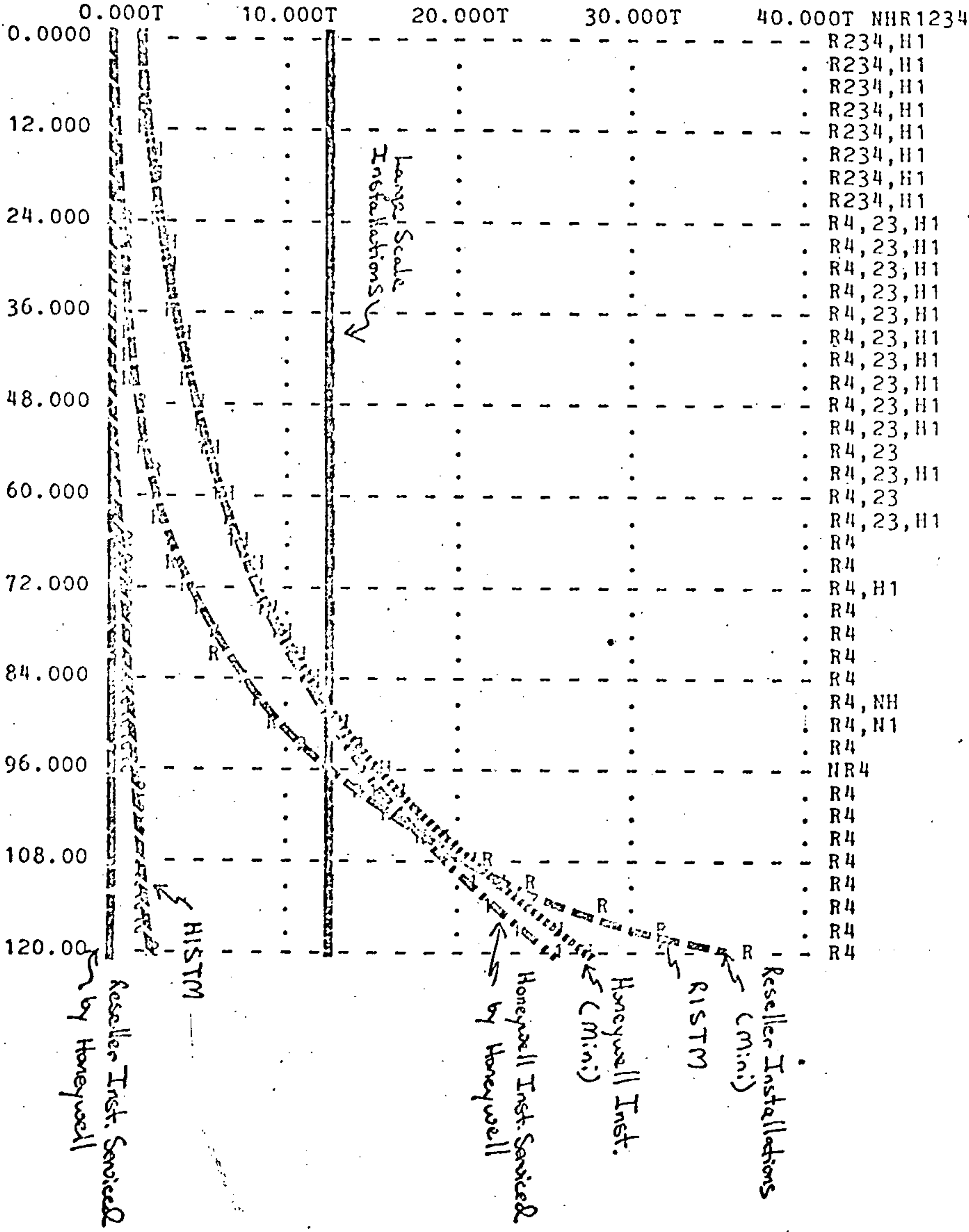
  150.00M    200.00M   250.00M    300.00M    350.00M AD
  5.000T     6.250T    7.500T     8.750T     10.000T L
  0.7500     0.8750    1.0000     1.1250     1.2500  O
  0.000T     20.000T   40.000T    60.000T    80.000T B
  0.8250     0.8750    0.9250     0.9750     1.0250  Q
  .20000     .30000    .40000     .50000     .60000  P
  40.000     50.000    60.000     70.000     80.000  E
  10.000M    25.000M   40.000M    55.000M    70.000M RC
```



SIMULATION #2: MINI-COMPUTER GROWTH

P- 12 RUN-TEST#6 TEST#6: MINI GROWTH

NMI=N HI=H RI=R HISH=1 HISTM=2
RISH=3 RISTM=4



SIMULATION #2: MINI-COMPUTER GROWTH

Service Quality and Overtime again move in opposite directions as they did in mainframe growth. This result makes sense. A decline in Quality is most often caused by a deficiency in Labor or/and Assets. As Quality deteriorates, Overtime is steps up in order to counteract any downward movement as much as possible.

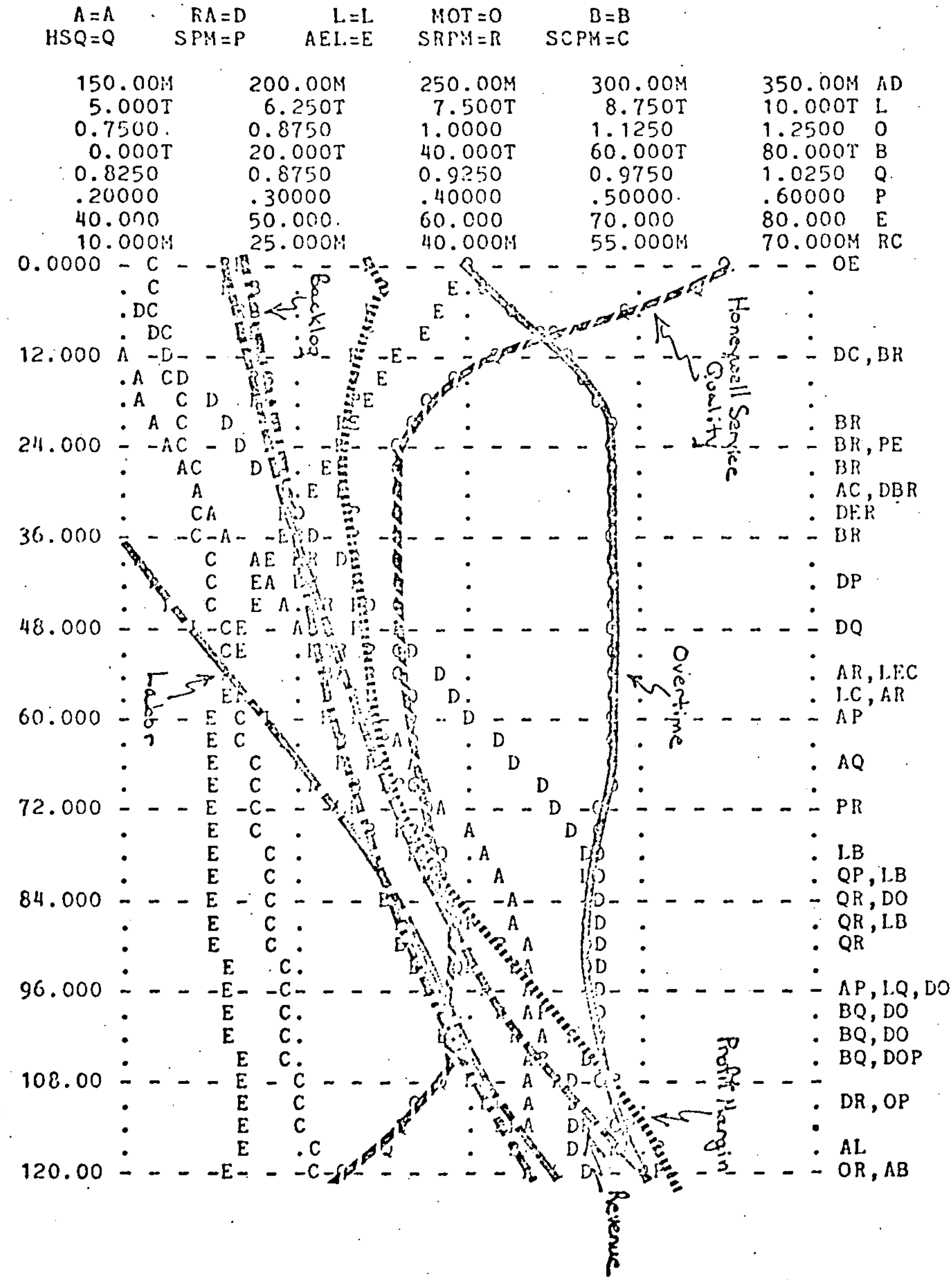
3.3 Simulation #3: Establishing a Reference Mode - Combined Growth

We combine mainframe and mini growth together in persuit of a meaningful reference mode. At this time Honeywell is not servicing any reseller installations. We will use this mode as a point of reference from which to evaluate alternative policies.

Superposition seems to apply to combined growth, although not absolutely. Overtime, Service Quality, Profit Margin, etc. possess a composite of behavioral characteristics from Simulations #1 and #2. Each of the two types of installations contribute to the overall Service Division behavior according to their relative size. As Mini Installations Serviced by Honeywell increases, then minis will have a greater impact on total behavior. The superposition effect is weighted according to the relative size of the respective installations.

There is a distinct change in the behavior of Labor, Overtime, Service Quality, and Profit Margin circa month 60. At this time more favorable Asset and Labor Utilization is realized. This unambiguous change in utilization has profound effects throughout the system. Utilization

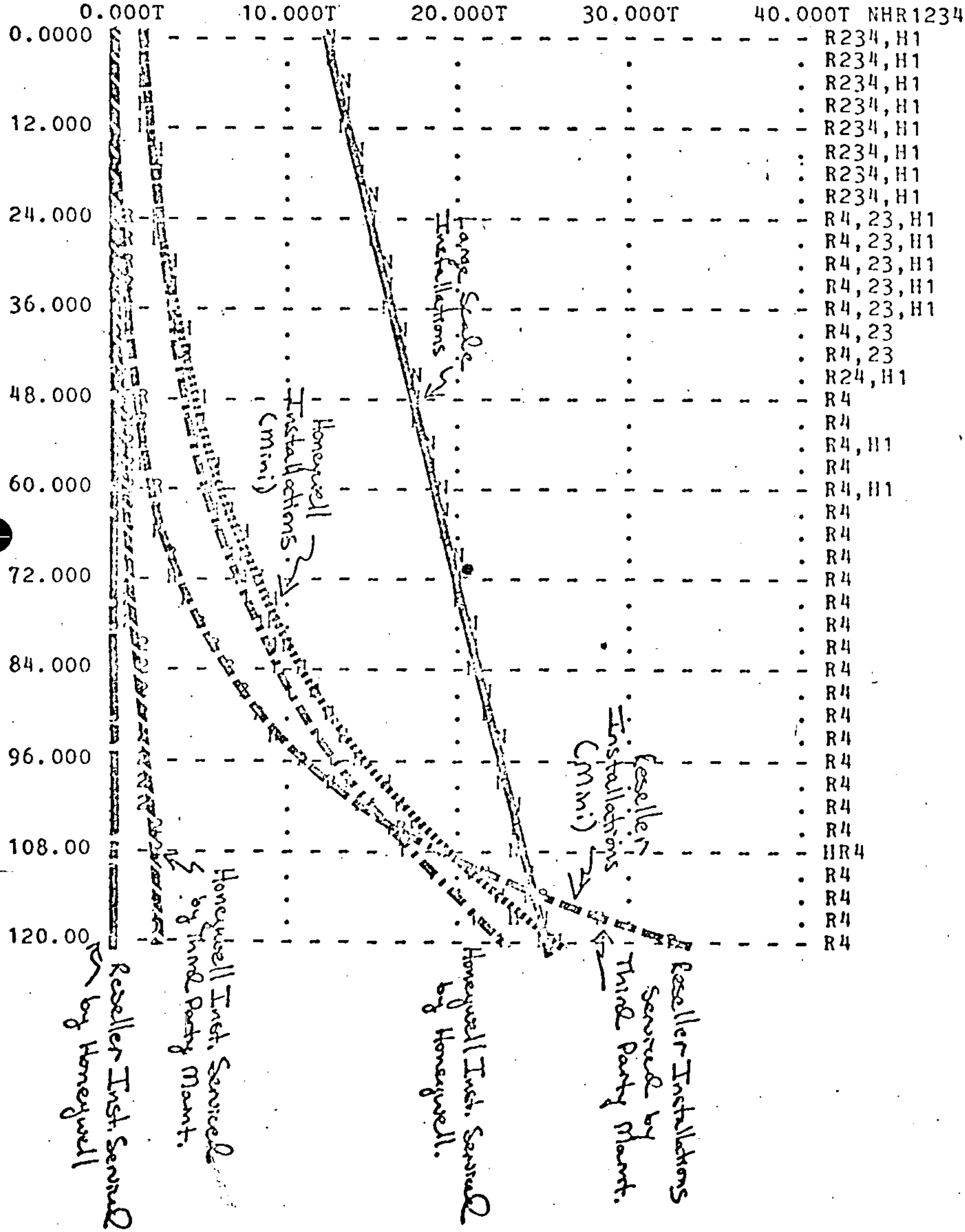
P- 7 RUN-TEST#1 TEST#1: LARGE SCALE AND MINI GROWTH - HONEYWELL CS



SIMULATION #3: COMBINED MINI AND MAINFRAME GROWTH

P- 8 RUN-TEST#1 TEST#1: LARGE SCALE AND MINI GROWTH - HONEYWELL CS

NMI=N HI=H RI=R HISH=1 HISTM=2
RISH=3 RISTM=4



SIMULATION #3: COMBINED MINI AND MAINFRAME GROWTH saturates as Total Installations Serviced surpasses 21,000. We would expect that the beneficial effects of increasing utilization would cease at some point, and this characteristic is indeed encorporated into the model. Because this saturation is unexpected by the rest of the organization, Service Quality jackknifes downward circa month 100.

Combined growth results in a level of total Mini Installations which is less than Simulation #2. Minis decline because of a lower Service Quality than experienced in the pervious simulation. This result is due mainly to the superposition effect of mainframes. At month 48 (equivalent to 1982) total Mini Installations equals approximately 6000, which is about the amount that it actually is at this time. This result occured as a result of model structure. It was not contrived. Also, Overtime remains consistenly around 10 percent similar to the actual level of overtime in the CSD. This result was also an output of the model, but not an assumption which went into it.

4. POLICY ANALYSIS

4.1 Summary of Policy Tests

Alternative policies are sought in order to make servicing Mini-Computers a more profitable and successful venture. These policies basically regard resellers and non-traditional forms of maintenance:

1] Honeywell service 75 percnet of subsequent reseller Mini-Computer Installations;

2] Implementation of Man-In-The-Van Program in order to raise Service Quality and reduce Service Cost;

3] Implementation of discount price policy to resellers of 15 percent in order to encourage reseller growth;

4] Reduction in Third Party Maintainers' Service Quality by 25 percent.

It is not totally clear whether or not any of these policies will benefit or impair Honeywell Service Quality, Service Profit, or Mini-Computer growth in the long run.

4.2 Simulation #4: Service Policy Toward Reseller

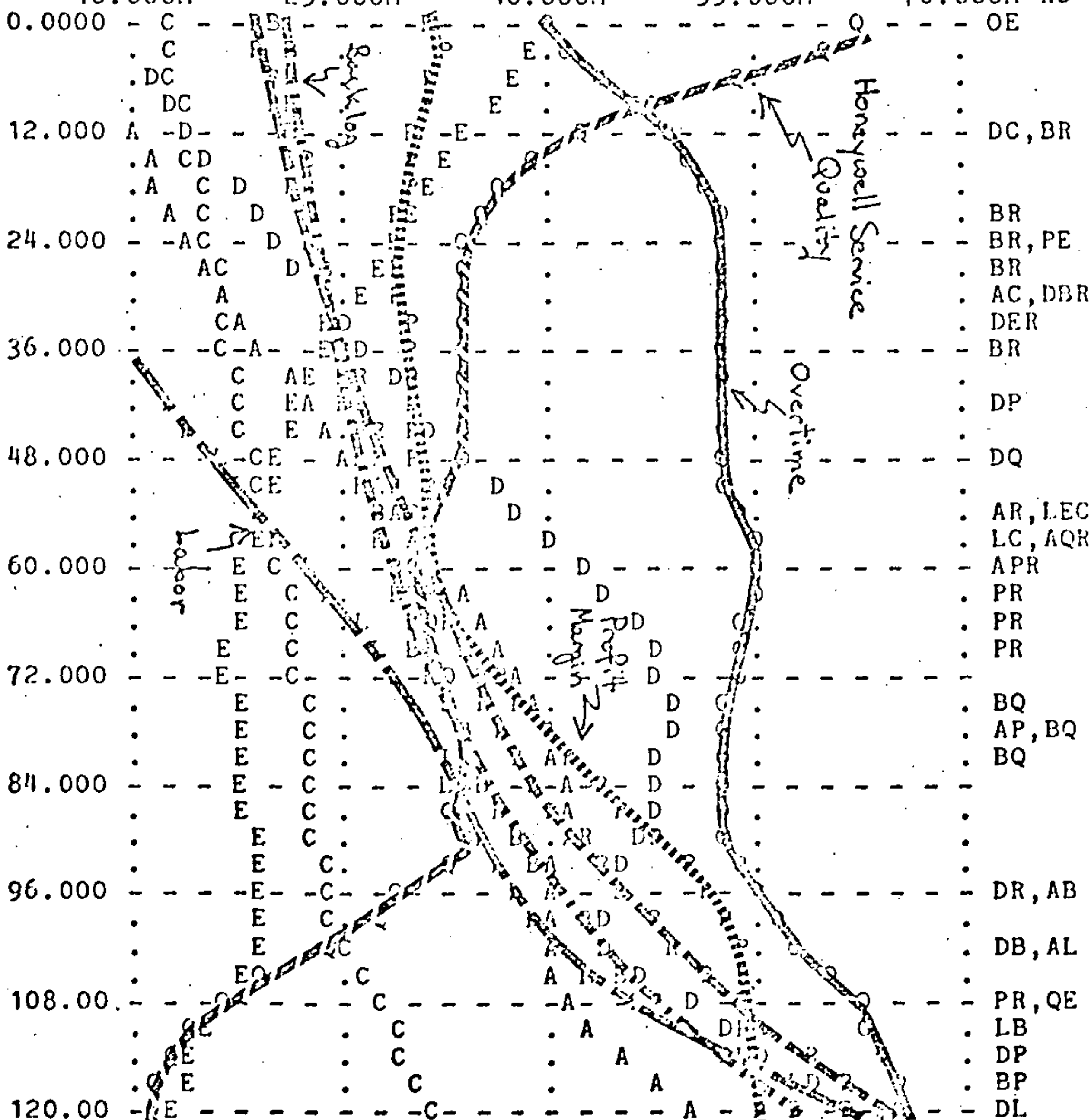
The purpose of this policy test is to determine the consequences for Honeywell of aggressive pursuit of reseller service contracts. We assumed the reference growth mode, and then added the condition that Honeywell will service 75 percnet of all subsequent reseller sales.

There is no change in behavior up until month 48 because the level of reseller installations is small and growth is slow. Profit Margin increases faster than the inital growth case because the number of installations which Honeywell is obligated to service is increasing faster. Therefore Utilization increases at a swifter rate. Profit Margin and Utilization both saturate sooner also on account of augmented growth.

P- 11 RUN-TEST#2 TEST#2: GROWTH & SERVICE POLICY FOR RESELLER 75%

A=A	RA=D	L=L	MOT=O	B=B
HSQ=Q	SPM=P	AEL=E	SRPM=R	SCPM=C

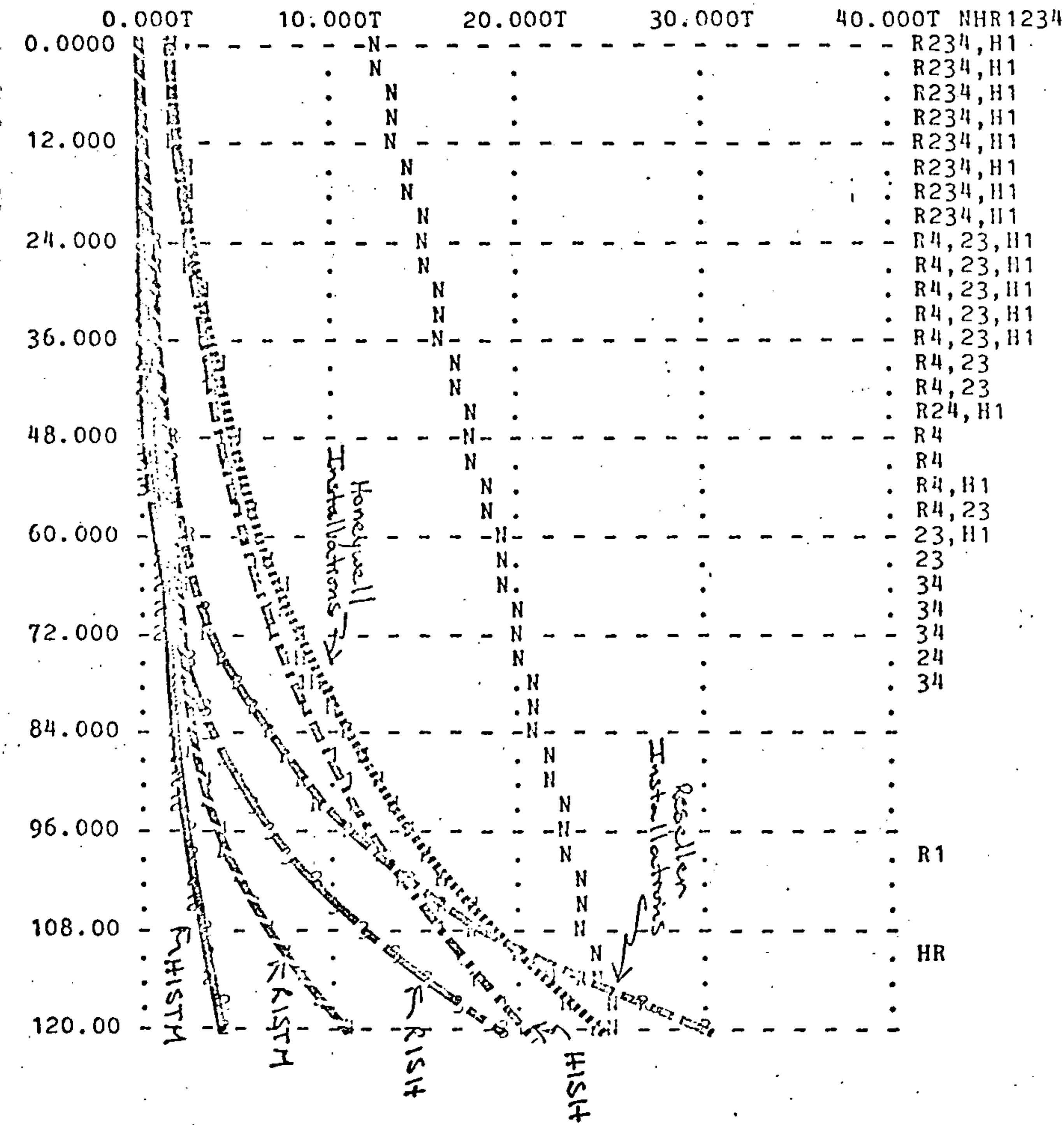
150.00M	200.00M	250.00M	300.00M	350.00M	AD
5.000T	6.250T	7.500T	8.750T	10.000T	L
0.7500	0.8750	1.0000	1.1250	1.2500	O
0.000T	20.000T	40.000T	60.000T	80.000T	B
0.8250	0.8750	0.9250	0.9750	1.0250	Q
.20000	.30000	.40000	.50000	.60000	P
40.000	50.000	60.000	70.000	80.000	E
10.000M	25.000M	40.000M	55.000M	70.000M	RC



SIMULATION #4: SERVICE POLICY TOWARD RESELLERS AT 75 PERCENT

P- 12 RUN-TEST#2 TEST#2: GROWTH & SERVICE POLICY FOR RESELLER 75%

NMI=N HI=H RI=R HISH=1 HISTM=2
ISH=3 RISTM=4



SIMULATION #4: SERVICE POLICY TOWARD RESELLERS AT 75 PERCENT

As a consequence of Utilization saturating sooner than in the reference mode, there is less flexibility within the system to be able to meet an increasing demand to service installations. Service Quality therefore declines, and Overtime exceeds its previous levels. Because Overtime is more expensive than ordinary labor, Profit Margin decreases below its comparable value for reference growth. Revenue increases by 5 percent.

Accumulated Profit over the entire simulation is 10 percent higher than with ordinary growth. This increase is due to higher overall Revenues. Service Qulaity declines to lower values than ever before because the growth of service contracts is higher than previously. The greater the rate of growth of Total Installations Serviced, the lower Service Quality will fall. There is a "give-and-take" between Revenue and Service Quality. An increase in installations forces Revenue up, but at the same time it drives Service Quality down. The optimal course would steer between these two option in order to maximize total profit over time.

Although during reference growth Honeywell does make a 300 percent profit on spares which are sold to resellers and third party maintainers, a much greater Profit and Revenue is realized when the maintenance is performed by Honeywell directly.

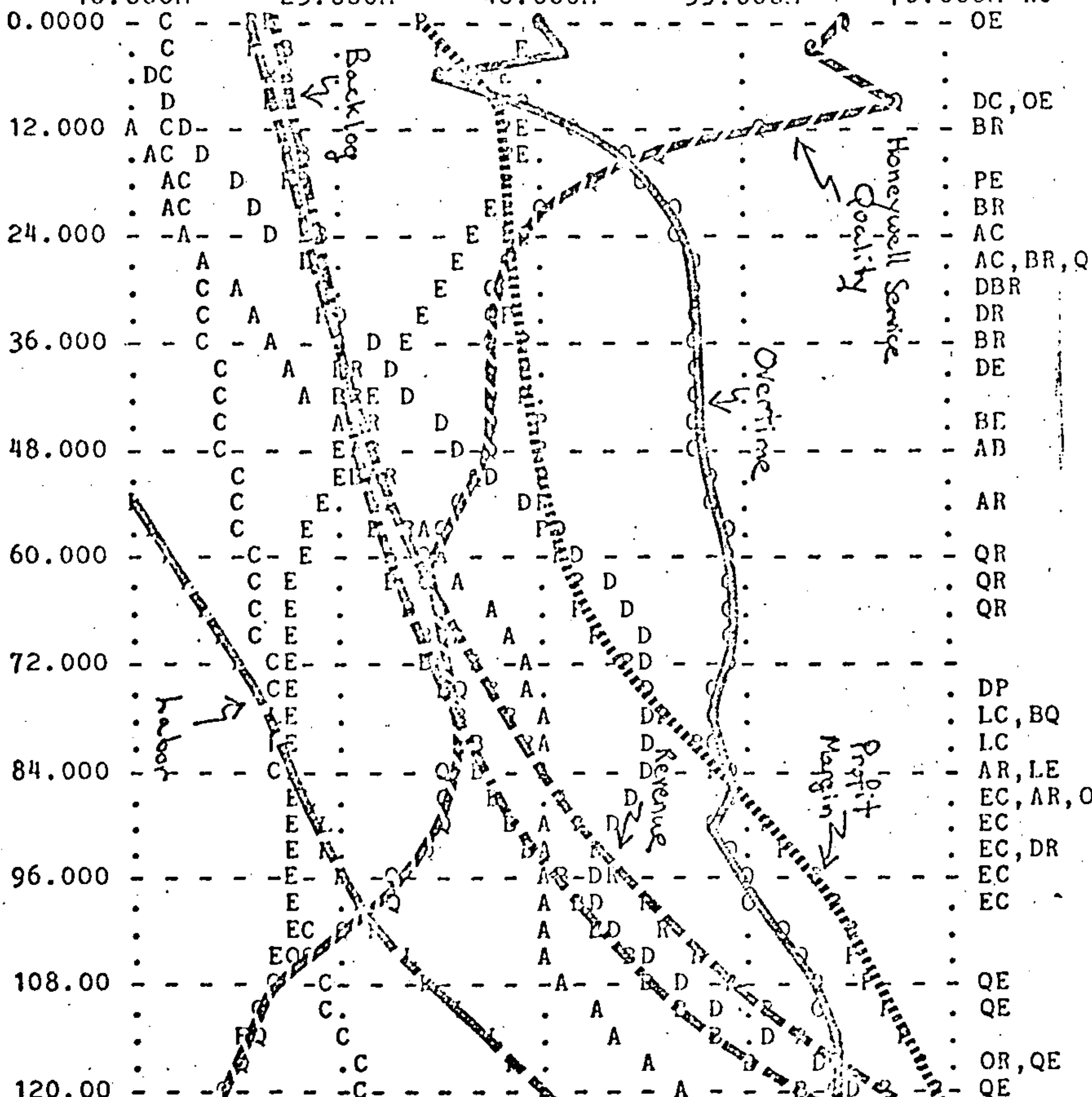
4.3 Simulation #5: Man-In-The-Van Program

It looks as though the previous Service Policy for Resellers may be a favorable policy to enact; although Accumulated Profit and Revenue is

P- 15 RUN-TEST#3 TEST#3: GROWTH, SPR=75%, & MAN-IN-VAN PROGRAM

A=A	RA=D	L=L	MOT=O	B=B
HSQ=Q	SPM=P	AEL=E	SRPM=R	SCPM=C

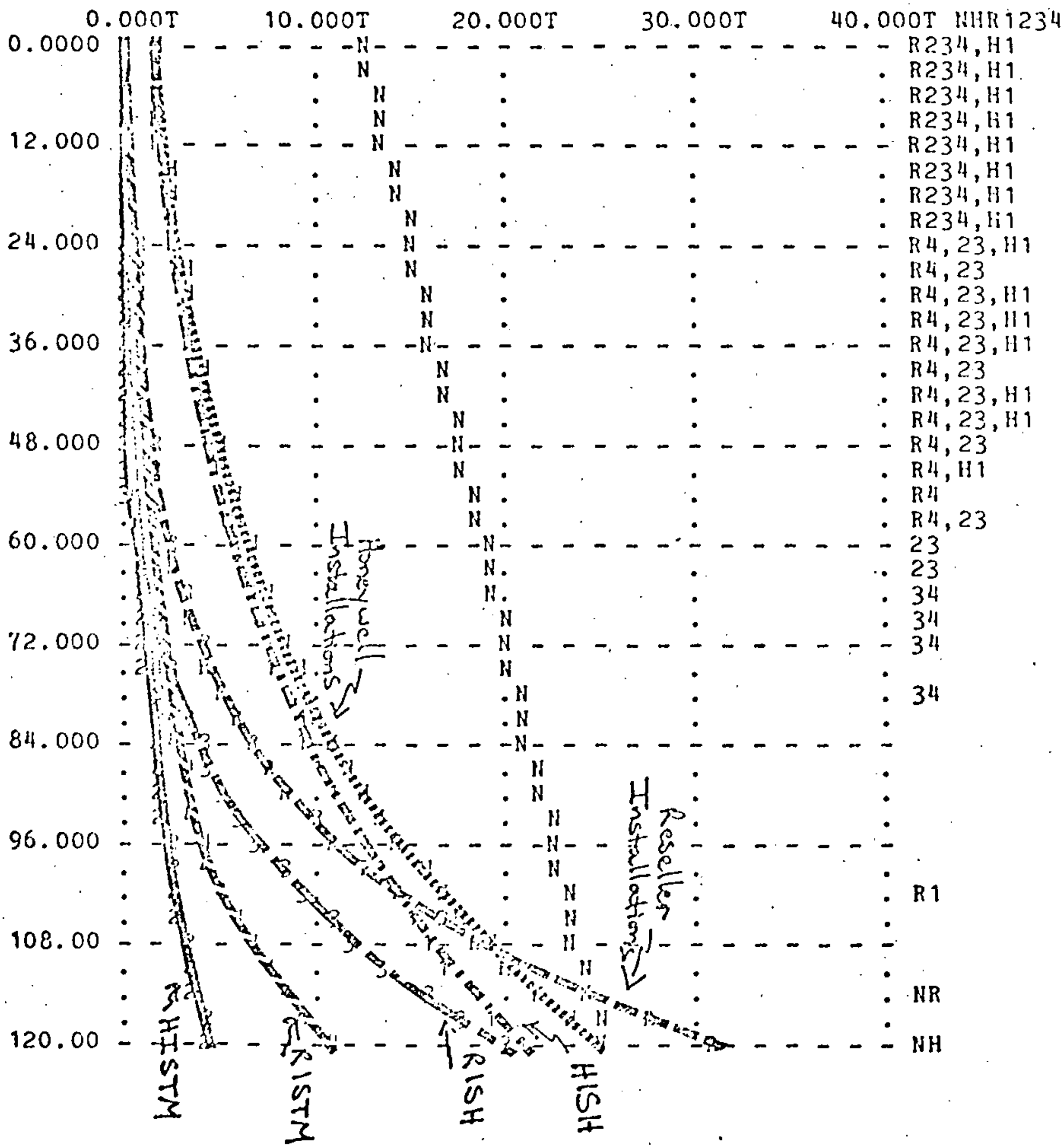
150.00M	200.00M	250.00M	300.00M	350.00M	AD
5.000T	6.250T	7.500T	8.750T	10.000T	L
0.7500	0.8750	1.0000	1.1250	1.2500	O
0.000T	20.000T	40.000T	60.000T	80.000T	B
0.8250	0.8750	0.9250	0.9750	1.0250	Q
.20000	.30000	.40000	.50000	.60000	P
40.000	50.000	60.000	70.000	80.000	E
10.000M	25.000M	40.000M	55.000M	70.000M	RC



SIMULATION #5: MAN-IN-THE-VAN PROGRAM

P- 16 RUN-TEST#3 TEST#3: GROWTH, SPR=75%, & MAN-IN-VAN PROGRAM

NMI=N HI=H RI=R HISH=1 HISTM=2
RISH=3 RISTM=4



SIMULATION #5: MAN-IN-THE-VAN PROGRAM

up, Service Quality erodes. We will test the consequences of implementing the Man-In-The-Van program in addition to the reseller policy. This policy increases the productivity and effectiveness of field Labor. Therefore, it may affect Service Quality.

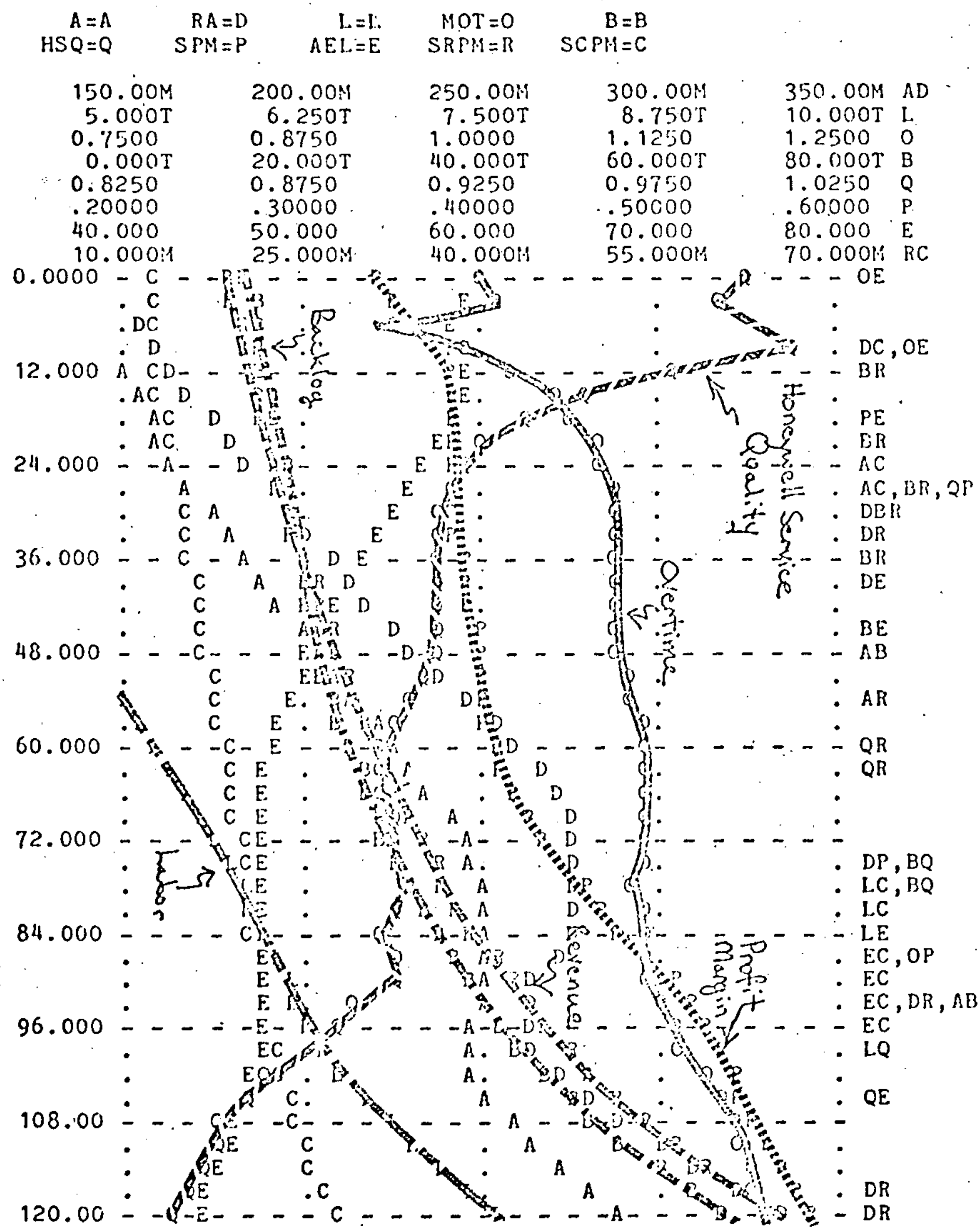
We immediately discover upon performing the simulation that the resultant behavior is quite on the contrary to what we might have had expected. Almost all behavior remains unchanged. The Man-In-the-Van does not improve Service Quality over the long run because it allows for the reduction of Labor which has exactly the opposite effect upon quality.

Since this policy reduces the Required labor, it decreases the Cost per-Installations Serviced. Also, the percentage of Overtime is the same, but the actual number of Overtime hours is reduced because the Labor force is smaller due to increased productivity. This decline in hours of Overtime reduces cost as well. The decrease in expenses logically increases Profit Margin while Service Quality et alia remains unaffected.

4.4 Simulation #6: Discount Price Policy of 15 Percent Toward Resellers

The introduction of a discount price policy toward resellers has been proposed as a means of encouraging reseller growth. The uncertainty surrounding this policy is whether or not the Revenue lost by the Price decrease can be made up by an increase in sales, and what the impact upon Service Quality and overall Market growth in the long run will be. We have imposed a discount policy of 15 percent in addition to two policies which were tested in the previous simulation in order to see their cumulative effect.

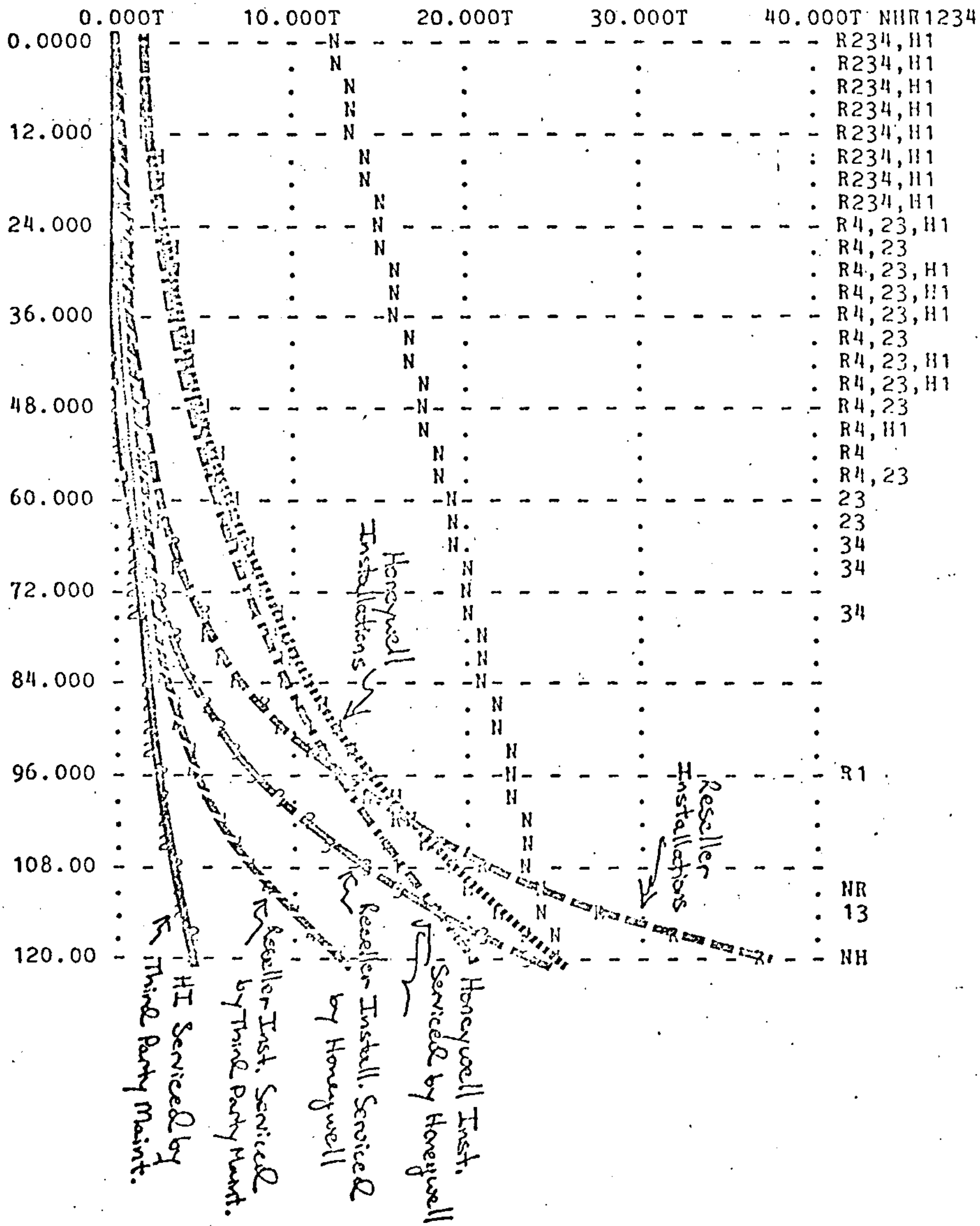
P- 19 RUN-TEST#4 TEST#4: GROWTH, SPR=75%, MAN-IN-VAN, & DISC. PRICE



SIMULATION #6: DISCOUNT PRICE POLICY OF 15 PERCENT FOR RESELLERS

P- 20 RUN-TEST#4 TEST#4: GROWTH, SPR=75%, MAN-IN-VAN, & DISC. PRICE

NMI=N HI=H RI=R HISH=1 HISTM=2
RISH=3 RISTM=4



SIMULATION #6: DISCOUNT PRICE POLICY OF 15 PERCENT FOR RESELLERS

The net effect on Service Division behavior is not very great. Service Profit Margin declines slightly due to a decrease in Revenue per Installation Serviced, but Revenue remains basically unchanged. Although Price per sale is down, the number of sales is up to compensate for a loss in Revenue. Accumulated Profit over the time of simulation decreases by a mere 1 percent (not a very significant change).

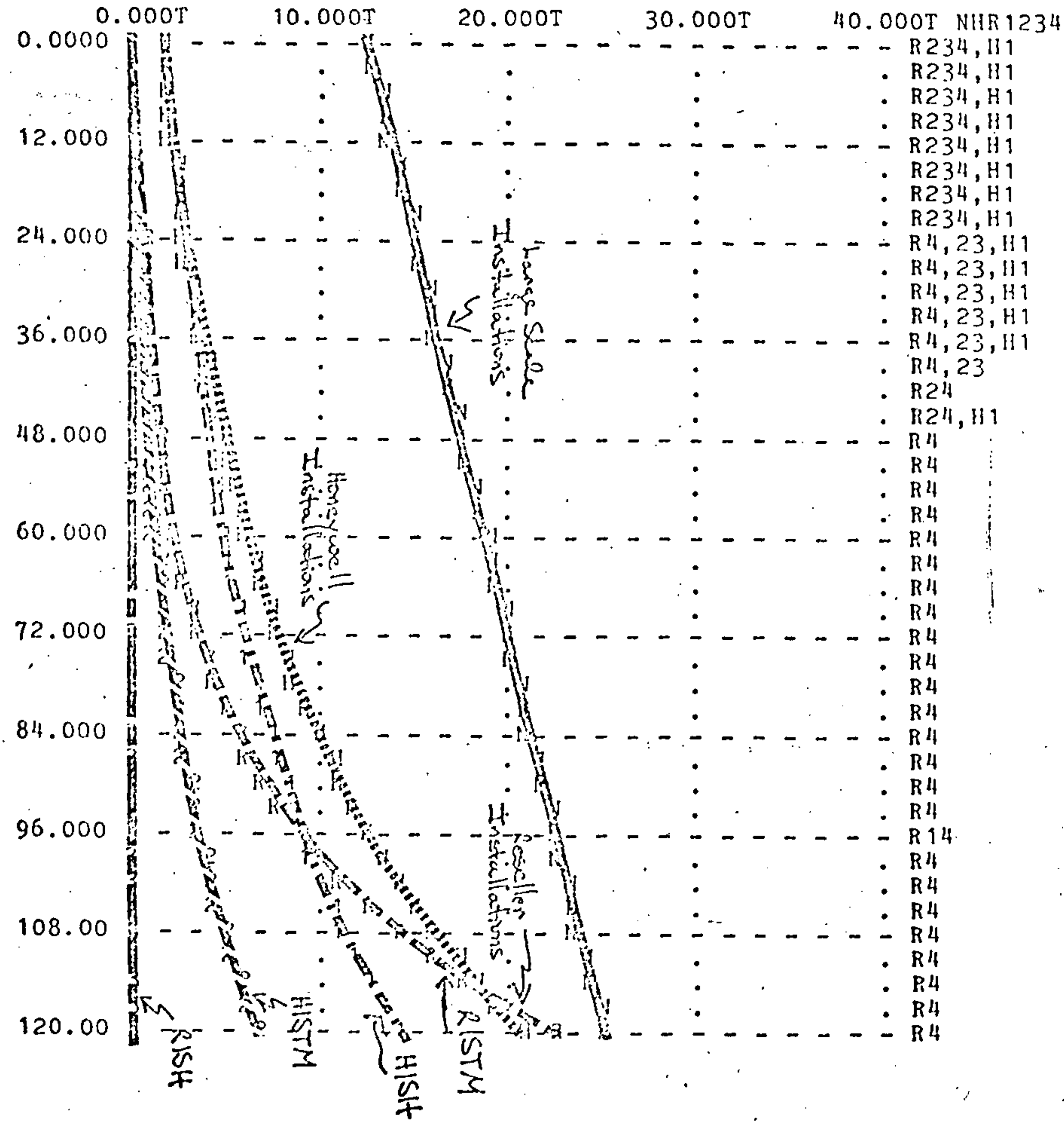
Discount Prices to resellers do not seem to affect the overall Profit structure of the organization. The result which the policy undoubtedly achieves is encouraging reseller growth. Service Quality decreases due to the increases in volume, but growth is not very sensitive to such a small decline in Service Quality at this point. The reinforcing (positive feedback) character of growth is very strong toward the latter half of the simulation.

4.5 Simulation #7: Decline in Third Party Maintainer Service Quality

This test was performed in order to see the importance of Third Party and Reseller Service Quality upon the Service Division. We have only assumed the reference growth mode plus this decrease in quality. Initially, it may be expected that Third Parties do not have that much of an effect upon the behavior of the Service Division itself, but as the size of installations serviced by TPM grows in relation to those service by Honeywell, then TPM Service Quality has a much greater effect.

P- 21 RUN-TEST37 TEST#7: GROWTH PLUS THIRD PARTY MAINT. SERVICE QUA

NMI=N HI=H RI=R HISH=1 HISTM=2
RISH=3 RISTM=4



SIMULATION #7: DECLINE OF 25 PERCENT IN THIRD PARTY SERVICE QUALITY

The decrease in TPM Service Quality results in a generally perceived decline of Honeywell Service Qualtiy. Growth is impaired. Utilization of Labor and Assets does not approach saturation as it would otherwise have done. A higher Service Profit Margin is not realized on account of the lack of improvement in Utilization. Honeywell Service Quality increases, and inversely Overtime decreases due to the slower rate of overall growth.

It seems as though Honeywell Customer Service Division and the Marketplace may be very sensitive to TPM Service Quality. We are left with a paradoxical situation:

- When TPM Service Quality is high, Honeywell stands a chance of losing service contracts to TPM and resellers;
- When TPM Service Quality is ailing, its association with the Honeywell name tends to cause Honeywell to lose service contracts anyhow.

In our opinion it is more important for TPM Service Quality to remain high in order to assure growth, than it would be to discourage TPM competition. The benefits of greater Utilization which is afforded by growth far outweighs the disadvantages of Third Party competition.

TABLE # 1

SHORT RUN (1983)

	TEST # 3 GROWTH	TEST # 4 SPR=.75	TEST # 5 4 & MIV	TEST # 6 5 & DPPR	TEST # 7 TPMSQ=.75
ASSETS (M$)	222	222	225	225	220
LABOR	6000	6031	5243	5244	5941
HI (MINI)	6194	6192	6316	6316	5963
RI (MINI)	2207	2206	2279	2344	2072
HSD (MINI)	5427	6165	6428	6476	4795
TMMH (MINI)	8401	8397	8595	8660	8035
HSQ	90%	89%	90%	90%	92%
SPM (%)	34	34	41	41	35
PROFIT (M$/m)	10	10	12	13	10
REVENUE (M$/m)	30	31	31	31	30
ACCUMULATED PROFIT (M$)	485	485	563	563	485
ACCUMULATED REVENUE (M$)	1447	1450	1455	1454	1443

TABLE # 2

LONG RUN (1988)

	TEST # 3 GROWTH	TEST # 4 SPR=.75	TEST # 5 4 & MIV	TEST # 6 5 & DPPR	TEST # 7 TPMSQ=.75
ASSETS (M$)	266	282	284	288	289
LABOR	8104	9290	7527	7615	7956
HI (MINI)	25,509	24,298	24,854	24,773	20,548
RI (MINI)	32,329	29,823	30,964	36,389	22,585
HSD (MINI)	22,774	39,154	40,577	43,947	13,993
TMMH (MINI)	57,838	54,121	55,819	61,162	43,133
HSQ	88%	83%	85%	84%	93%
SPM (%)	50	50	59	58	47
PROFIT (M$/m)	27	32	38	39	22
REVENUE (M$/m)	54	63	65	65	48
ACCUMULATED PROFIT (M$)	1,517	1,656	1,922	1,904	1,392
ACCUMULATED REVENUE (M$)	3,861	4,069	4,099	4,092	3,708

5. CONCLUSIONS

The basic problem with servicing minicomputers with the present organization of the CSD is that minis are not as profitable as the large scale systems which have been the traditional market. Even so, it is possible to make a good business out of it. It is necesary to reduce cost, and that can be done by reducing the service requirements per installation, particullarly in terms of labor, or by increasing the number of installations serviced which would increase Utilization.

5.1 Recommendations from Model Analysis

The most important recomendations of the analysis are:

-Servicing reseller installations improves business through increased volume and reduced service cost per installation. It generates higher revenue and profit margin, but creates problems in keeping service quality at a high level during times of rapid growth. The way to implement this policy would be to sell the equipment to the reseller under the condition that it will be serviced by Honeywell, so at the time of sale, he should sell the equipment with a CSD service contract. It is not necesary that all computers are serviced by CSD, so if this restriction is valid for areas in which CSD already has an office, the proportion to be serviced could be high, without representing a big increase in the operating cost. The reseller can use the Honeywell name to back up his sales, and CSD can get more customers without any additional marketing effort.

-High rates of growth create pressure on the system to keep a high level of Service Quality. The greater the rate of growth, the lower the Service Quality. Because in many cases there is a tendency to behave very conservatively, particularly for hiring and investing for future requirements, the system tends to have a persistent shortage of assets and labor. The problems caused by these shortages are exacerbated during periods of exponential growth. The main result is low Service Quality which eventually slows growth and encourages customers to change service over to Third Party Maintainers. Although there is a forecasting policy in the model, it is a linear extrapolation of the data (as many organizations do), and it under estimates consistantly the necessary This is a case of a reactive organization rather than a planning organization. The justification for this conservative policy is that it increases profit margin by keeping service costs low.

-Man-in-the-van program proves to be an effective policy to reduce Service Cost and increase Profit Margin, but it does not seem to help raise the level of Honeywell Service Quality. As stated in the first recommendation, any policy that reduces cost per installation is a good policy. The reason that service quality stops improving is the rationale for hiring labor. When the program is implemented, the amount of installations that each field engineer can service is duplicated, and this reduces the need for Labor. The system instead of keeping an "excess" of labor for future growth and to keep a high service quality, it just reduces the amount of labor according to the new productivity. Behaving as before, but at lower unit service cost, the same problems persist.

-The implementation of discount service price for resellers is a favourable policy to encourage and generate growth. Although discounting prices does reduce revenue, the added growth compensates for such a loss while providing greater sales volume for Honeywell Information Systems as a whole. On the other hand, the reduction is very small and if it is combined with a policy of servicing a certain proportion of reseller installations, reduction in profits can be compensated for.

-The service quality of third party maintainers and resellers has a strong effect upon perceived Honeywell Service Quality within the marketplace. It is necessary that resellers offer high quality service in order to avoid a negative impact upon growth. In the case that third party maintainers may be encouraged through franchices, it is very important that there exists a strong supervision by Honeywell.

5.2 Considerations and Extensions.

Some of the results of the model seem to fit very well into with the actual data, although it was never designed to accomplish that purpose. This result creates some confidence about the behavior and structure of the model. Nonetheless, the numerical values of the results should never be considered as forecasts. They are just an indication of the impact that certain policies could have on the system if they are implemented.

The policies tested are programs which are already designed and partially implemented. The results of the model confirm the expectations built from real situations. There are some assumptions that should be further analyzed because they seem to have a big impact on the behavior of the model.

For any continuation of the project, it is necessary that some people within Honeywell learn the details of the model, and its operation, to be able to use it internally. From the discussions of the use of the model, they can come out with the most relevant extensions

The present structure of the model allows to make a large number of tests involving many combinations of policies simultaneusly. They can be from a simple change in service requirement per installation to a more sophisticated variable change in demand for each of the products. This approach should be followed and exhausted before going into more disagregation. The size of the model is large enough to create many problems when modifications are made to it without completely understanding the present version.

During the construction of the model, on several occasions, there were themes that seem to have relevance with the operations of the CSD and that were not included in the model for lack of time and information. It could be very productive to extend the model into such areas as: micro-computers, software development and service, disagregation of labor and assets for minicomputers and non-minicomputers, more detail in the financial sector.

APPENDIX #1 (44)

PURPOSE OF PILOT PROJECT IN SYSTEM DYNAMICS WITH HONEYWELL CSD

A. EXPAND AND CLARIFY IDEAS ABOUT MODELING THE RELATIONSHIPS BETWEEN HONEYWELL CUSTOMER SERVICE DIVISION AND THE MARKET.

B. DEVELOP A PICTURE OF THE ORGANIZATION IN TERMS OF DECISION MAKING PROCESSES.

C. TRANSLATE THE PICTURE OF ORGANIZATIONAL STRUCTURE INTO A SET OF PRECISE MATHEMATICAL EQUATIONS TO BE USED AS A SIMULATION MODEL.

D. EXPLORE THE SHORT- AND LONG-TERM CONSEQUENCES OF POLICY CHANGES IN THE CSD.

E. SEE HOW SYSTEM DYNAMICS CAN BE USED AS A POLICY AND STRATEGY TOOL IN THE ANALYSIS OF CURRENT BUSINESS PROBLEMS.

MOTIVATION FOR STUDY

A. UNPRECEDENTED INCREASE IN SALES OF MINI-COMPUTERS OVER THE NEXT 5 - 10 YEARS WILL NECESSITATE NEW WAYS OF THINKING ABOUT AND PROVIDING SERVICE.

B. DIFFERENT COST AND PROFIT STRUCTURE ASSOCIATED WITH THE INCREASING SERVICE OF MINIS AS OPPOSED TO MAINFRAMES.

C. UNCERTAINTY TOWARD ENCOURAGING FURTHER RESELLER AND THIRD-PARTY MAINTENANCE OF HONEYWELL EQUIPMENT.

D. EXPERIMENTATION WITH NON-TRADITIONAL FORMS OF MAINTENANCE FOR MINIS.

MODEL TESTING 46

SIMULATION #1: MAINFRAME GROWTH . . .

ASSUMPTIONS: A. MATURING LINEAR GROWTH OF LARGE SCALE INSTALLTIONS FROM 12,500 IN 1978 TO 25,000 TEN YEARS LATER.

RESULTS:

A. SERVICE CALLS INCREASE DUE TO INCREASE IN INSTALLATIONS.

B. OVERTIME AND PROFIT MARGIN INCREASE DUE TO LAG IN AQUIRING LABOR AND ASSETS.

C. HONEYWELL SERVICE QUALITY DECREASES DUE TO INCREASE INSTALLATIONS AND LAG IN AQUIRING ASSETS AND LABOR.

D. OVERTIME AND SERVICE QUALITY ARE MIRROR IMAGES OF ONE ANOTHER. THEY BOTH ARE REPRESENTATIVE OF THE OVERALL STATE OF THE ORGANIZATION:
- -ASSET & LABOR UTILIZATON
- -AVERAGE EXPERIENCE OF LABOR
- -BACKLOG OF SERVICE CALLS
- -REQUIRED LABOR AND ASSETS

SI. ATION #2: MINI-COMPUTER GROWTH . . . . (47)

ASSUMPTIONS: A. GROWTH IN HONEYWELL AND RESELLER INSTALLATIONS WHERE PERCENTAGE OF RESELLER GROWTH IS GREATER.

RESULTS: A. MINI GROWTH CAN BE DIVIDED INTO TWO DISTINCT REGIONS

1] <60 MONTHS - APPROXIMATE LINEAR GROWTH;

2] >60 MONTHS - CLEARLY EXPONENTIAL GROWTH.

B. PROFIT MARGIN INITIALLY DECLINES. MINIS ARE NOT AS PROFITABLE AS NON-MINIS DURING EARLY STAGES OF GROWTH.

C. AS GROWTH CONTINUES, UTILIZATION OF ASSETS AND LABOR INCREASES. THEREFORE, PROFIT MARGIN RISES DUE TO LOWER COST/INSTALLATION SERVICED.

D. THE LAG TO AQUIRE ASSETS AND LABOR IS PRESENT AS IN SIMULATION #1, BUT IT IS BY FAR NOT A DOMINATING EFFECT.

E. SERVICE QUALITY AND OVERTIME AGAIN MOVE IN OPPOSITE DIRECTIONS. THIS RESULT MAKES SENSE -- AS QUALITY DECLINES, OVERTIME STEPS UP IN ORDER TO COUNTERACT IT.

ESTABLISHING A REFERENCE MODE (48)

SIMULATION #3: COMBINED MINI AND MAINFRAME GROWTH . . .

ASSUMPTIONS: A. ACTIVE GROWTH MODES FOR RUNS #1 AND #2.

B. HONEYELL DOES NOT SERVICE RESELLER INSTALLATIONS.

ESULTS: A. SUPERPOSITION SEEMS TO APPLY THOUGH NOT ABSOLUTELY. OVERTIME, SERVICE QUALITY, PROFIT MARGIN, ETC. POSSESS A COMPOSITE OF CHARACTERISTICS FROM RUNS #1 AND #2.

B. CIRCA MONTH 60 THERE IS A DISTINCT CHANGE IN LABOR, OVERTIME, SERVICE QUALITY, AND PROFIT MARGIN AS INCREASED GROWTH RESULTS IN BETTER ASSET AND LABOR UTILIZATION.

C. TOTAL MINI INSTALLATIONS IS LESS THAN RUN #2 BECAUSE OF A LOWER SERVICE QUALITY THAN PREVIOUSLY EXPERIENCED. THIS RESULT IS DUE TO SUPERPOSITION.

D. AT MONTH 48 (EQUIVALENT TO 1982) TOTAL MINIS EQUALS (148) APPROXIMATELY 6000 INSTALLATIONS, WHICH IS ABOUT WHAT IT ACTUALLY WILL IS. THIS RESULT WAS NOT PURPOSELY CONTRIVED, IT HAPPENED AS A CONSEQUENCE OF MODEL. THERE WAS NO WAY TO ACTUALLY KNOW THAT THIS WOULD OCCUR BEFOREHAND.

E. OVERTIME REMAINS CONSISTENTLY AROUND 10 PERCENT SIMILAR TO THE ACTUAL OVERTIME IN THE CSD. AGAIN, THIS RESULT WAS ALSO AN OUTPUT OF THE MODEL, BUT NOT AN ASSUMPTION WHICH WENT INTO IT.

F. SERVICE QUALITY JACKKNIFES DOWNWARD CIRCA MONTH 100 DUE DUE TO SATURATION IN IMPROVEMENT OF ASSET AND LABOR UTILIZATION WHICH THE SYSTEM IS NOT EXPECTING.

SUMMARY OF POLICY TESTS (5d)

A. HONEYWELL SERVICES 75 PERCENT OF SUBSEQUENT RESELLER MINI INSTALLATIONS.

B. IMPLEMENTATION OF MAN-IN-THE-VAN PROGRAM IN ORDER TO RAISE SERVICE QUALITY AND REDUCE COSTS.

C. IMPLEMENTATION OF DISCOUNT PRICE POLICY TO RESELLERS OF 15 PERCENT IN ORDER TO ENCOURAGE RESELLER GROWTH.

D. REDUCTION IN THIRD PARTY MAINTAINERS' SERVICE QUALITY BY 25 PERCENT.

SIMULATION #4: SERVICE POLICY TOWARD RESELLERS AT 75 PERCENT

ASSUMPTIONS: A. GROWTH MODE AS IN RUN #3 PLUS HONEYWELL SERVICE OF 75 PERCENT OF ALL SUBSEQUENT RESELLER SALES.

RESULTS: A. UP TO MONTH 48 THERE IS NO EFFECT BECAUSE THE LEVEL OF RESELLER INSTALLATIONS IS SMALL AND GROWTH IS SLOW.

B. PROFIT MARGIN INCREASES FASTER BECAUSE THE NUMBER OF INSTALLATIONS WHICH HONEYWELL IS OBLIGATED TO SERVICE IS INCREASING AT A FASTER RATE. PROFIT MARGIN SATURATES SOONER AS DOES UTILIZATION.

C. PROFIT MARGIN SATURATES FASTER BECAUSE OF UTILIZATION, BUT, SATURATION OCCURS AT A LOWER LEVEL DUE TO EXCESSES IN OVERTIME.

D. ACCUMULATED PROFIT OVER THE ENTIRE SIMULATION IS 10 PERCENT HIGHER THAN WITH ORDINARY GROWTH. REVENUE AT THE COMPLETION OF THE SIMULATION IS 5 PERCENT GREATER THAN FOR REFERENCE GROWTH.

E. SERVICE QUALITY DECLINES LOWER THAN EVER BEFORE BECAUSE GROWTH OF SERVICE CONTRACTS IS GREATER THAN EVER BEFORE. THE GREATER THE RATE OF GROWTH, THE LOWER GOES HONEYWELL SERVICE QUALITY.

F. ALTHOUGH IN PURE GROWTH (RUN #3) HONEYWELL DOES MAKE A 300 PERCENT PROFIT ON SPARES WHICH ARE SOLD TO RESELLERS AND THIRD PARTY MAINTAINERS, MUCH GREATER PROFIT AND REVENUE IS REALIZED WHEN THE MAINTENANCE IS PERFORMED BY HONEYELL DIRECTLY.

G. THERE EXISTS A "GIVE AND TAKE" BETWEEN THE LEVEL OF SERVICE QUALITY AND REVENUE.

MULATION #5: MAN-IN-THE-VAN PROGRAM . . .

63

ASSUMPTIONS: A. GROWTH AND RESELLER SERVICE POLICY AT 75 PERCENT AS IN RUN #5.

B. IMPLEMENTATION OF MAN-IN-THE-VAN PROGRAM WHICH INCREASES PRODUCTIVITY AND EFFECTIVENESS OF FIELD LABOR.

RESULTS: A. ALMOST ALL BEHAVIOR REMAINS UNCHANGED.

B. MAN-IN-THE-VAN DOES NOT IMPROVE SERVICE QUALITY OVER THE LONG RUN BECAUSE IT ALLOWS FOR THE REDUCTION OF LABOR WHICH HAS EXACTLY THE OPPOSITE EFFECT ON QUALITY.

C. PERCENTAGE OF OVERTIME IS THE SAME, BUT THE ACTUAL NUMBER OF OVERTIME HOURS IS REDUCED BECAUSE THE LABOR FORCE IS SMALLER DUE TO INCREASED PRODUCTIVITY. THE SYSTEM NATURALLY TENDS TOWARD OVERTIME.

D. BECAUSE THE MAN-IN-THE-VAN PROGRAM REDUCES THE REQUIRED LABOR, IT DECREASES THE COST/INSTALLATION SERVICED. THIS DECREASE IN EXPENSE LOGICALLY INCREASES PROFIT MARGIN.

IULATION #6: DISCOUNT PRICE POLICY TOWARD RESELLERS . . . (54)

ASSUMPTIONS: A. GROWTH, SPR=75%, AND IMPLEMENTATION OF MAN-IN-THE-VAN.

B. DECREASE IN PRICE OF SERVICE CONTRACTS SOLD BY RESELLER BY 15 PERCENT.

RESULTS: A. PROFIT MARGIN DECLINES SLIGHTLY DUE TO A DECREASE IN REVENUE/INSTALLATION SERVICED.

B. REVENUE REMAINS BASICALLY CONSTANT. ALTHOUGH PRICE PER SALE IS DOWN, THE NUMBER OF SALES IS UP TO COMPENSATE FOR A LOSS OF REVENUE.

C. ACCUMULATED PROFIT OVER THE TIME OF SIMULATION DECREASES BY A MERE 1 PERCENT (NOT A VERY SIGNIFICANT CHANGE). DISCOUNT PRICES TO RESELLERS DO NOT SEEM TO AFFECT THE OVERAL PROFIT STRUCTURE OF THE ORGANIZATION.

D. SERVICE QUALITY DECREASES DUE TO THE INCREASES IN VOLUME, BUT GROWTH IS NOT VERY SENSITIVE TO SUCH A SMALL DECLINE IN SERVICE QUALITY AT THIS POINT.

E. EFFECTIVE AT ENCOURAGING RESELLER GROWTH

IMULATION #7: DECLINE IN THIRD PARTY SERVICE QUALITY . . . 55

ASSUMPTIONS: A. GROWTH MODE AS IN RUN #3 PLUS DECLINE IN THIRD PARTY SERVICE QUALITY OF 25 PERCENT.

RESULTS: A. DECREASE IN THIRD PARTY SERVICE QUALITY RESULTS IN A GENERALLY PERCEIVED DECLINE OF HONEYWELL SERVICE QUALITY. GROWTH IS IMPAIRED.

B. DUE TO LOWER GROWTH, UTILIZATION OF LABOR AND ASSETS DOES NOT APPROACH SATURATION AS IT WOULD DO OTHERWISE. A HIGHER PROFIT MARGIN IS NOT REALIZED ON ACCOUNT OF THE LACK OF IMPROVEMENT IN UTILIZATION.

C. SERVICE QUALITY INCREASES AND INVERSELY OVERTIME DECREASES DUE TO THE SLOWER RATE OF OVERALL GROWTH.

D. PARADOXICAL SITUATION:

- WHEN THIRD PARTY SERVICE QUALITY IS HIGH, HONEYWELL STANDS A CHANCE OF LOSING SERVICE CONTRACTS TO THIRD PARTY MAINTAINERS AND RESELLERS.
- WHEN THIRD PARTY SERVICE QUALITY IS LOW, ITS ASSOCIATION WITH THE HONEYWELL NAME MAY TEND TO CAUSE HONEYWELL TO LOSE SERVICE CONTRACTS ANYHOW.

CONCLUSIONS

INSIGHTS INTO ALTERNATIVE POLICIES . . .

A. SERVICING RESELLER INSTALLATIONS IMPROVES BUSINESS THROUGH INCREASED VOLUME AND REDUCED SERVICE COST PER INSTALLATION. IT GENERATES HIGHER REVENUE AND PROFIT MARGIN , BUT CREATES PROBLEMS IN KEEPING SERVICE QUALITY AT A HIGH LEVEL DURING TIMES OF RAPID GROWTH.

B. THE MAN-IN-THE-VAN PROGRAM PROVES TO BE AN EFFECTIVE POLICY TO REDUCE SERVICE COST AND INCREASE PROFIT MARGIN, BUT IT DOES NOT SEEM TO HELP RAISE THE LEVEL OF HONEYWELL SERVICE QUALITY.

C. IMPLEMENTATION OF A DISCOUNT SERVICE PRICE FOR RESELLERS IS A FAVORABLE POLICY TO ENCOURAGE AND GENERATE GROWTH. ALTHOUGH DISCOUNTING PRICES DOES REDUCE REVENUE, THE ADDED GROWTH COMPENSATES FOR SUCH A LOSS WHILE PROVIDING GREATER SALES VOLUME FOR HONEYWELL INFORMATION SYSTEMS ON THE WHOLE.

D. THE SERVICE QUALITY OF THIRD PARTY MAINTAINERS AND RESELLERS HAS A STRONG EFFECT UPON PERCEIVED HONEYWELL SERVICE QUALITY WITHIN THE MARKETPLACE. IT IS NECESSARY THAT THEY OFFER HIGH QUALITY SERVICE IN ORDER TO AVOID A NEGATIVE IMPACT UPON GROWTH.

(57)

E. THERE IS CONCERN WITHIN THE HONEYWELL ORGANIZATION THAT THE ENCOURAGEMENT OF RESELLER AND THIRD PARTY MAINTAINERS WOULD BE AIDING A POTENTIAL COMPETITOR. ON THE CONTRARY, IT SEEMS FAR MORE IMPORTANT TO ENCOURAGE RESELLERS IN ORDER TO SPUR GROWTH THAN TO WORRY ABOUT COMPETITIVE FACTORS.

INSIGHTS INTO SYSTEM BEHAVIOR . . . (58)

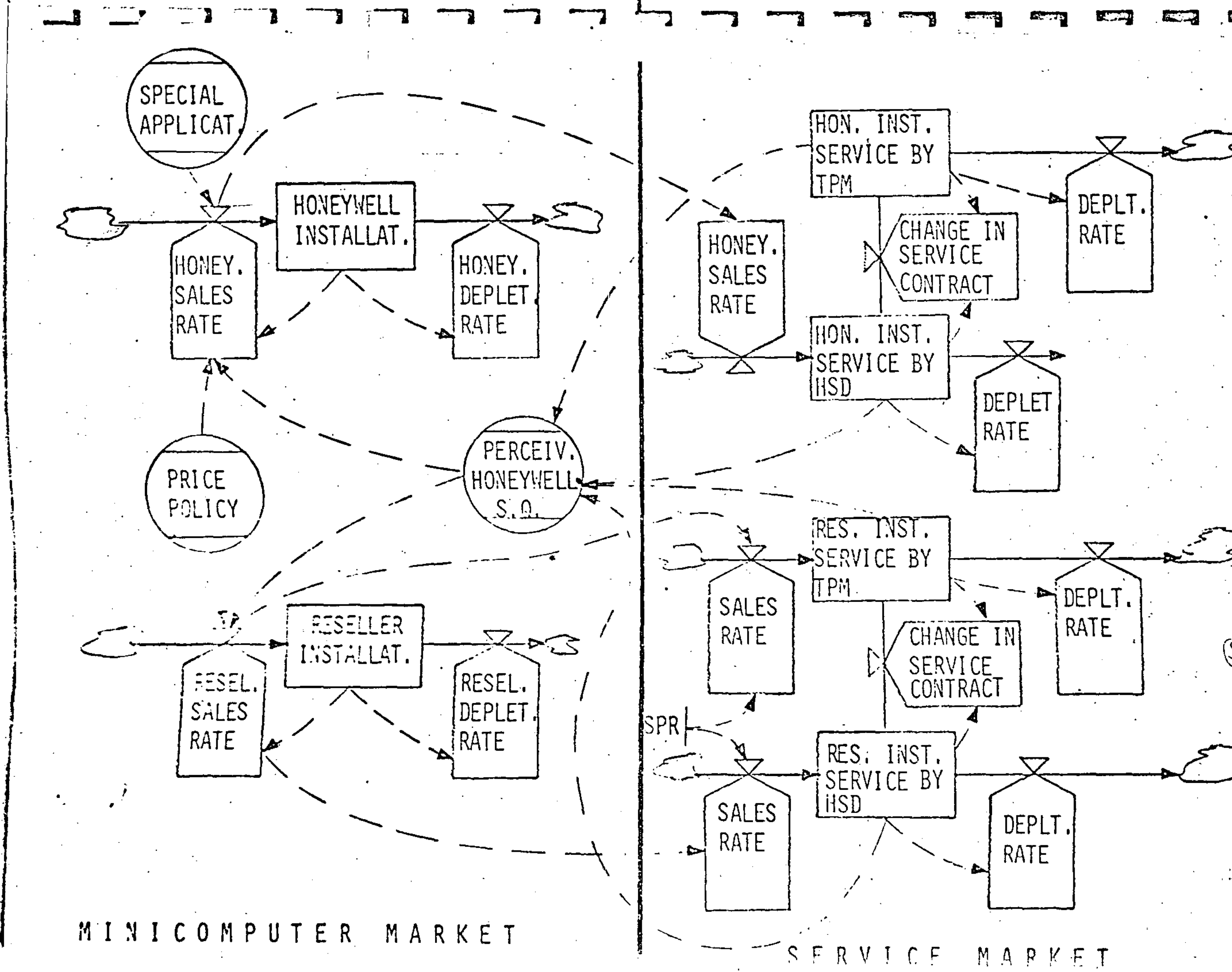
A. OVERTIME IS A REASONABLY GOOD INDICATOR OF THE OVERALL STATE OF THE ORGANIZATION. IT IS REPRESENTATIVE OF SERVICE QUALITY AND CAN BE OBJECTIVELY MEASURED AND COMPARED.

B. AQUISITION LAG IN LABOR AND ASSETS CONTRIBUTES SIGNIFICANTLY TO DECLINING SERVICE QUALITY, INCREASING OVERTIME AND PROFIT MARGIN.

C. EXPONENTIAL GROWTH IS A CHARACTERISTIC OF THIS SYSTEM WHICH MAY REMAIN UNNOTICED DURING PERIODS OF SLOW GROWTH DURING WHICH LINEAR BEHAVIOR IS APPROXIMATED. AS THE LEVEL OF INSTALLATIONS INCREASES, TRUE EXPONENTIAL BEHAVIOR IS EXHIBITED. FORECASTING MECHANISMS ARE LINEAR, AND THEY BREAKDOWN IN PERIODS OF SUCH GROWTH CAUSING SERVICE QUALITY TO DECLINE, ETC.

D. CHANGES IN ASSET AND LABOR UTILIZATION DUE TO EXPONENTIAL GROWTH MARKEDLY AFFECT THE DYNAMIC BEHAVIOR OF THE SYSTEM.

E. THERE IS A TRADE-OFF, A "GIVE AND TAKE", BETWEEN SERVICE QUALITY AND REVENUE.


SPECIAL APPLICAT.
HONEYWELL INSTALLAT.
HONEY. SALES RATE
HONEY. DEPLET. RATE
PRICE POLICY
PERCEIV. HONEYWELL S.Q.
RESELLER INSTALLAT.
RESEL. SALES RATE
RESEL. DEPLET. RATE
MINICOMPUTER MARKET
HON. INST. SERVICE BY TPM
DEPLT. RATE
HONEY. SALES RATE
CHANGE IN SERVICE CONTRACT
HON. INST. SERVICE BY HSD
DEPLET RATE
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RES. INST. SERVICE BY HSD
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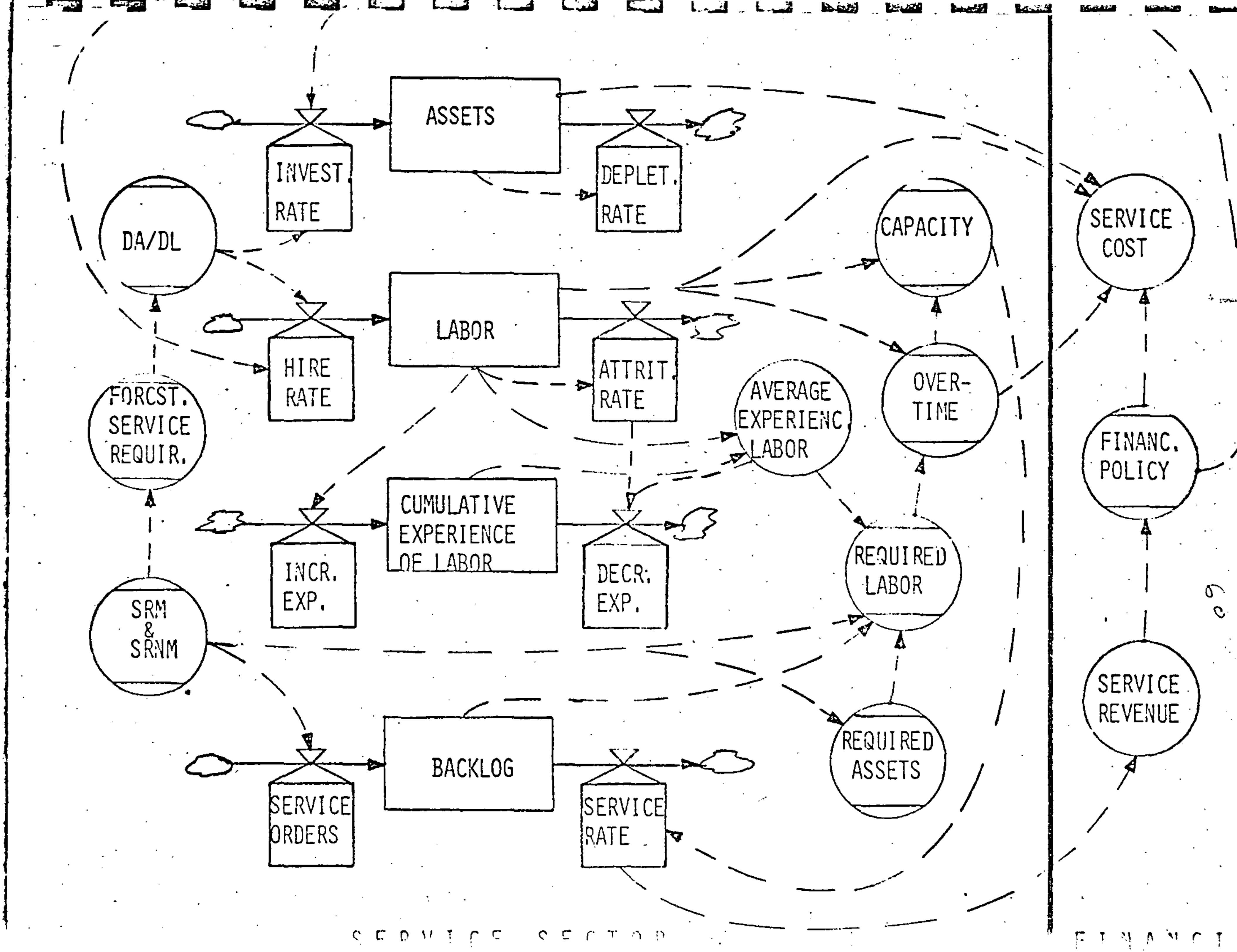
DEPLT. RATE
SERVICE MARKET


ASSETS
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AVERAGE EXPERIENC LABOR
OVER-TIME
FINANC. POLICY
CUMULATIVE EXPERIENCE OF LABOR
INCR. EXP.
DECR. EXP.
REQUIRED LABOR
SRM & SRNM
SERVICE REVENUE
BACKLOG
SERVICE ORDERS
SERVICE RATE
REQUIRED ASSETS
SERVICE SECTOR

SYSTEM DYNAMICS MODEL
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CAMBRIDGE, MA 02139
MAY 1982

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TABLE OF CONTENTS

1.0 MARKET SUBSYSTEM

1.1 HONEYWELL SALES
1.2 RESELLER SALES
1.3 SERVICE MARKET

2.0 SERVICE SUBSYSTEM

2.1.0 FINANCIAL SECTOR

2.1.1 SERVICE REVENUE
2.1.2 SERVICE COST
2.1.3 SERVICE PROFIT MARGIN

2.2.0 SERVICE SECTOR

2.2.1 ASSETS
2.2.2 LABOR
2.2.3 SERVICE PERFORMANCE
2.2.4 SERVICE REQUIREMENTS:
2.2.4.1 NON-MINI INSTALLATIONS
2.2.4.2 MINI INSTALLATIONS

3.0 SUPPLEMENTARY EQUATIONS

4.0 CONTROL CARDS

5.0 RERUN STATEMENTS

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1.0 MARKET SUBSYSTEM

1.1 HONEYWELL SALES

```
HI.K=HI.J+DT*(HSR.JK-HDR.JK)                                    L,6
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>
    DT     - SOLUTION TIME INTERVAL <112>
    HSR    - HONEYWELL SALES RATE (MINICOMPUTERS/MONTH) <7>
    HDR    - HONEYWELL DEPLETION RATE (MINICOMPUTERS/MONTH)
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 =1500                                                    N,6.1     >HSR,R,7/HDR,R,17/TMHM,A,19/HISH,N,29.1/PLOT,114/
                                                                      PRINT,116
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>

HSR.KL=HI.K*MHSA.K*MHSP.K*MPHSQ.K/DTHI.K                  R,7       >HI,L,6/HISH,L,29
    HSR    - HONEYWELL SALES RATE (MINICOMPUTERS/MONTH) <7>
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>
    MHSA   - MULTIPLIER FOR HONEYWELL SPECIAL APPLICATIONS
              (DIMENSIONLESS) <12>
    MHSP   - MULTIPLIER FOR HONEYWELL SERVICE PRICE
              (DIMMENSIONLESS) <9>
    MPHSQ  - MULTIPLIER FOR PERCEIVED HONEYWELL SERVICE
              QUALITY (DIMENSIONLES <14>
    DTHI   - (MONTHS)DOUBLING TIME FOR HONEYWELL
              INSTALLATIONS <8>

DTHI.K=120*(1-STEP(SDTHI,0))                              A,8       >HSR,R,7
SDTHI=0                                                   C,8.1     >DTHI,A,8
    DTHI   - (MONTHS)DOUBLING TIME FOR HONEYWELL
              INSTALLATIONS <8>
    SDTHI  - STEP TEST FOR DTHI (FRACTION) <8>

MHSP.K=TABLE(TMHSP,HSP.K/CSP.K,0,1.5,.25)                 A,9       >HSR,R,7
TMHSP=3,2,1.5,1.1,1,.9,0                                  T,9.1     >MHSP,A,9
    MHSP   - MULTIPLIER FOR HONEYWELL SERVICE PRICE
              (DIMMENSIONLESS) <9>
    TABLE  - TABLE FUNCTION
    TMHSP  - TABLE FOR MULTIPLIER FOR HONEYWELL SERVICE PRICE
              <9>
    HSP    - HONEYWELL SERVICE PRICE (DOLLARS/MONTH) <10>
    CSP    - COMPETITORS SERVICE PRICE (DOLLARS/MONTH) <11>

HSP.K=CSP.K+STEP(STHSP,12)                                A,10      >MHSP,A,9/DHSP,A,27/SRHISH,A,44
STHSP=0                                                   C,10.1    >HSP,A,10
    HSP    - HONEYWELL SERVICE PRICE (DOLLARS/MONTH) <10>
    CSP    - COMPETITORS SERVICE PRICE (DOLLARS/MONTH) <11>
    STHSP  - STEP TEST FOR HSP (FRACTION) <10>

CSP.K=700                                                 A,11      >MHSP,A,9/HSP,A,10/MRSP,A,23/RSP,A,24
    CSP    - COMPETITORS SERVICE PRICE (DOLLARS/MONTH) <11>

MHSA.K=TABLE(TMHSA,SA.K,0,1.5,.25)                        A,12      >HSR,R,7
TMHSA=.1/.3/.5/.75/1/1.15/1.25                            T,12.1    >MHSA,A,12
    MHSA   - MULTIPLIER FOR HONEYWELL SPECIAL APPLICATIONS
              (DIMENSIONLESS) <12>
    TABLE  - TABLE FUNCTION
    TMHSA  - TABLE FOR HONEYWELL SPECIAL APPLICATIONS <12>
    SA     - HONEYWELL SPECIAL APPLICATIONS (FRACTION) <13>

SA.K=TABLE(TSA,TIME.K,0,120,60)                           A,13      >MHSA,A,12
TSA=1/1/1                                                 T,13.1    >SA,A,13
    SA     - HONEYWELL SPECIAL APPLICATIONS (FRACTION) <13>
    TABLE  - TABLE FUNCTION
    TSA    - TABLE FOR HONEYWELL SPECIAL APPLICATIONS <13>
```

```
MPHSQ.K=TABLE(TMPHSQ,PHSQ.K,0,1.25,.25)              A,14     >HSR,R,7/RSR,R,21
TMPHSQ=.25,.25,.4,.8,1,1.2                           T,14.1   >MPHSQ,A,14
    MPHSQ  - MULTIPLIER FOR PERCEIVED HONEYWELL SERVICE
               QUALITY (DIMENSIONLES <14>
    TABLE  - TABLE FUNCTION
    TMPHSQ - TABLE FOR MULTIPLIER FOR PERCEIVED HONEYWELL
               SERVICE QUALITY <14>
    PHSQ   - PERCEIVED HONEYWELL SERVICE QUALITY (FRACTION)
               <15>

PHSQ.K=DELAY3(WSQ.K,TPHSQ)                           A,15     >MPHSQ,A,14/MMAHSD,A,32/MMTHSD,A,34
TPHSQ=12                                             C,15.1   >PHSQ,A,15
    PHSQ   - PERCEIVED HONEYWELL SERVICE QUALITY (FRACTION)
               <15>
    DELAY3 - THIRD ORDER AVERAGING MACRO
    WSQ    - WEIGHTED SERVICE QUALITY (FRACTION) <16>
    TPHSQ  - (MONTHS) TIME TO PERCEIVE HONEYWELL SERVICE
               QUALITY <15>

WSQ.K=((RISH.K+HISH.K)*(HSQ.K)+(TPMSQ.K)*(HISTM.K+RISTM.K))/  A,16   >PHSQ,A,15
 TMHM.K
    WSQ    - WEIGHTED SERVICE QUALITY (FRACTION) <16>
    RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
               (MINICOMPUTERS) <36>
    HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
               (MINICOMPUTERS) <29>
    HSQ    - HONEYWELL SERVICE QUALITY (SQ) <96>
    TPMSQ  - THIRD PARTY MAINTAINER SERVICE QUALITY (SQ) <18>
    HISTM  - HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC <35>
    RISTM  - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1
               SERVICE REVENUE <40>
    TMHM   - TOTAL MARKET OF HONEYWELL MINICOMPUTERS
               (MINICOMPUTERS) 1.2 RESELLER SALES <19>

HDR.KL=HI.K/ALI                                      R,17     >HI,L,6
    HDR    - HONEYWELL DEPLETION RATE (MINICOMPUTERS/MONTH)
               <17>
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>
    ALI    - (MONTHS) AVERAGE LIFE OF MINICOMPUTER
               INSTALLATIONS <18>

TPMSQ.K=1+STEP(STPMSQ,24)                            A,18     >WSQ,A,16
STPMSQ=0                                             C,18.1   >TPMSQ,A,18
ALI=120                                              C,18.2   >HDR,R,17/RDR,R,28/HISH,L,29/HISTM,L,35/RISH,L,36/
                                                                RISTM,L,40
    TPMSQ  - THIRD PARTY MAINTAINER SERVICE QUALITY (SQ) <18>
    STPMSQ - STEP TEST FOR TPMSQ (FRACTION) <18>
    ALI    - (MONTHS) AVERAGE LIFE OF MINICOMPUTER
               INSTALLATIONS <18>

TMHM.K=HI.K+RI.K                                     A,19     >WSQ,A,16/PRINT,116
    TMHM   - TOTAL MARKET OF HONEYWELL MINICOMPUTERS
               (MINICOMPUTERS) 1.2 RESELLER SALES <19>
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>
    RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>
```

1.2 RESELLER SALES

```
RI.K=RI.J+DT*(RSR.JK-RDR.JK)                               L,20      >TKHM,A,19/RSR,R,21/RDR,R,23/RISH,N,36.1/RISTM,N,40.1/
RI=150                                                     N,20.1      PLOT,114/PRINT,116
    RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>
    DT     - SOLUTION TIME INTERVAL <112>
    RSR    - RESELLER SALES RATE (MINICOMPUTERS/MONTH) <21>
    RDR    - RESELLER DEPLETION RATE (MINICOMPUTERS/MONTH)
               1.3 SERVICE MARKET <28>

RSR.KL=RI.K*MRSP.K*MPHSQ.K*PERG/DTRI.K                     R,21      >RI,L,20/RISH,L,36/RISTM,L,40
PERG=1                                                     C,21.1    >RSR,R,21
    RSR    - RESELLER SALES RATE (MINICOMPUTERS/MONTH) <21>
    RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>
    MRSP   - MULTIPLIER FOR RESELLER SERVICE PRICE
               (DIMENSIONLESS) <23>
    MPHSQ  - MULTIPLIER FOR PERCEIVED HONEYWELL SERVICE
               QUALITY (DIMENSIONLES <14>
    PERG   - POLICY TO ENCOURAGE RESELLER GROWTH (FRACTION)
               <21>
    DTRI   - DOUBLING TIME FOR RESELLER INSTALLATIONS
               (MONTHS) <22>

DTRI.K=120*(1-STEP(SDTRI,0))                               A,22      >RSR,R,21
  SDTRI=0                                                  C,22.1    >DTRI,A,22
    DTRI   - DOUBLING TIME FOR RESELLER INSTALLATIONS
               (MONTHS) <22>
    SDTRI  - STEP TEST FOR DTRI (FRACTION) <22>

MRSP.K=TABLE(THRSP,WARSP.K/CSP.K,0,1.5,.25)                A,23      >RSR,R,21
THRSP=3,2,1.5,1.1,1,.9,0                                   T,23.1    >MRSP,A,23
    MRSP   - MULTIPLIER FOR RESELLER SERVICE PRICE
               (DIMENSIONLESS) <23>
    TABLE  - TABLE FUNCTION
    THRSP  - TABLE FOR MULTIPLIER FOR RESELLER SERVICE PRICE
               <23>
    WARSP  - WEIGHTED AVERAGE RESELLER SERVICE PRICE (DOLLRS/
               MONTH) <25>
    CSP    - COMPETITORS SERVICE PRICE (DOLLARS/MONTH) <11>

RSP.K=CSP.K                                                A,24      >WARSP,A,25
    RSP    - RESELLER SERVICE PRICE (DOLLARS /MONTH) <24>
    CSP    - COMPETITORS SERVICE PRICE (DOLLARS/MONTH) <11>

WARSP.K=(DHSP.K*SPR.K)+((1-SPR.K)*RSP.K)                   A,25      >MRSP,A,23
    WARSP  - WEIGHTED AVERAGE RESELLER SERVICE PRICE (DOLLRS/
               MONTH) <25>
    DHSP   - DISCOUNT HONEYWELL SERVICE PRICE (DOLLARS/MONTH)
               <27>
    SPR    - SERVICE POLICY FTO RESELLER (FRACTION) <26>
    RSP    - RESELLER SERVICE PRICE (DOLLARS /MONTH) <24>

SPR.K=STEP(STSPR,48)                                       A,26      >WARSP,A,25/RISH,L,36/RISH,N,36.1/RISTM,L,40/RISTM,N,4
STSPR=0                                                    C,26.1    >SPR,A,26
    SPR    - SERVICE POLICY FTO RESELLER (FRACTION) <26>
    STSPR  - STEP TEST FOR SPR (FRACTION) <26>
```

```
DHSP.K=HSP.K*(1-DPPR)                                   A,27        >WARSP,A,25/SRRISH,A,43
I[illegible]0                                           C,27.1      >DHSP,A,27
    DHSP   - DISCOUNT HONEYWELL SERVICE PRICE (DOLLARS/MONTH)
              <27>
    HSP    - HONEYWELL SERVICE PRICE (DOLLARS/MONTH) <10>
    DPPR   - DISCOUNT PRICING POLICY TO RESELLER (FRACTION)
              <27>

RDR.KL=RI.K/ALI                                         R,28        >RI,L,20
    RDR    - RESELLER DEPLETION RATE (MINICOMPUTERS/MONTH)
              1.3 SERVICE MARKET <28>
    RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>
    ALI    - (MONTHS) AVERAGE LIFE OF MINICOMPUTER
              INSTALLATIONS <18>


              1.3 SERVICE MARKET

HISH.K=HISH.J+DT*(HSR.JK-(HISH.J/ALI))-DT*HICSCR.JK     L,29        >WSQ,A,16/HISHLR,A,31/SRHISH,A,44/SRM,A,97/MLUTIL,A,1(
HISH=HI                                                 N,29.1       ANSRM,A,106/PLOT,114/PRINT,116
    HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
    DT     - SOLUTION TIME INTERVAL <112>
    HSR    - HONEYWELL SALES RATE (MINICOMPUTERS/MONTH) <7>
    ALI    - (MONTHS) AVERAGE LIFE OF MINICOMPUTER
              INSTALLATIONS <18>
    HICSCR - HONEYWELL INSTALLATIONS CHANGE OF SERVICE
              CONTRACT RATE (MINICOM <30>
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>

HICSCR.KL=(HISHLR.K-HISTLR.K)/ATCSC                     R,30        >HISH,L,29/HISTM,L,35
ATCSC=12                                                C,30.1      >HICSCR,R,30/RICSCR,R,37
    HICSCR - HONEYWELL INSTALLATIONS CHANGE OF SERVICE
              CONTRACT RATE (MINICOM <30>
    HISHLR - HONEYWELL INSTALLATIONS SERVICE BY HSD LEAVING
              RATE (MINICOMPUTE <31>
    HISTLR - HONEYWELL INSTALLTIONS SERVICE BY THIRD PARTY
              MAINTAINERS LEAVIN <33>
    ATCSC  - (MONTHS) AVERAGE TIME TO CHANGE SERVICE CONTRACT
              <30>

HISHLR.K=HISH.K*MMAHSD.K                                A,31        >HICSCR,R,30
    HISHLR - HONEYWELL INSTALLATIONS SERVICE BY HSD LEAVING
              RATE (MINICOMPUTE <31>
    HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
    MMAHSD - MULTIPLIER FOR MOVING AWAY FROM HSD
              (DIMENSIONLESS) <32>

MMAHSD.K=TABLE(TMMAHS,PHSQ.K,.5,1.5,.25)                A,32        >HISHLR,A,31/RISHLR,A,38
[illegible]MAHS.K=.5,.25,0,0,0                          T,32.1      >MMAHSD,A,32
    MMAHSD - MULTIPLIER FOR MOVING AWAY FROM HSD
              (DIMENSIONLESS) <32>
    TABLE  - TABLE FUNCTION
    TMMAHS - TABLE FOR MULTIPLIER FOR MOVING AWAY OF HSD <32>
    PHSQ   - PERCEIVED HONEYWELL SERVICE QUALITY (FRACTION)
              <15>
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[illegible].K=HISTM.K*MMTHSD.K                               A,33     >HICSCR,R,30
    [illegible]STLR - HONEYWELL INSTALLTIONS SERVICE BY THIRD PARTY
               MAINTAINERS LEAVIN <33>
    HISTM  - HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC <35>
    MMTHSD - MULTIPLIER FOR MOVING TOWARDS HSD
               (DIMENSIONLESS) <34>

MMTHSD.K=TABLE(TMMTHS,PHSQ.K,.5,1.5,.25)                     A,34     >HISTLR,A,33/RISTLR,A,39
TMMTHS=0,0,0,.25,.5                                          T,34.1   >MMTHSD,A,34
    MMTHSD - MULTIPLIER FOR MOVING TOWARDS HSD
               (DIMENSIONLESS) <34>
    TABLE  - TABLE FUNCTION
    TMMTHS - TABLE FOR MULTIPLIER FOR MOVING TOWARDS HSD <34>
    PHSQ   - PERCEIVED HONEYWELL SERVICE QUALITY (FRACTION)
               <15>

HISTM.K=HISTM.J+DT*(HICSCR.JK-HISTM.J/ALI)                   L,35     >WSQ,A,16/HISTLR,A,33/SRSP,A,45/CSTMPM,A,51/PLOT,114/
HISTM=0                                                      N,35.1     PRINT,116
    HISTM  - HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC <35>
    DT     - SOLUTION TIME INTERVAL <112>
    HICSCR - HONEYWELL INSTALLATIONS CHANGE OF SERVICE
               CONTRACT RATE (MINICOM <30>
    ALI    - (MONTHS) AVERAGE LIFE OF MINICOMPUTER
               INSTALLATIONS <18>

RISH.K=RISH.J+DT*(RSR.JK*SPR.J-(RISH.J/ALI)-RICSCR.JK)       L,36     >WSQ,A,16/RISHLR,A,38/SRRISH,A,43/SRM,A,97/MLUTIL,A,1
RISH=RI*SPR                                                  N,36.1     ANSRM,A,105/PLOT,114/PRINT,116
    RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
               (MINICOMPUTERS) <36>
    DT     - SOLUTION TIME INTERVAL <112>
    RSR    - RESELLER SALES RATE (MINICOMPUTERS/MONTH) <21>
    SPR    - SERVICE POLICY FTO RESELLER (FRACTION) <26>
    ALI    - (MONTHS) AVERAGE LIFE OF MINICOMPUTER
               INSTALLATIONS <18>
    RICSCR - RESELLER INSTALLATIONS CHANGE OF SERVICE
               CONTRACT RATE (MINICOMP <37>
    RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>

RICSCR.KL=(RISHLR.K-RISTLR.K)/ATCSC                          R,37     >RISH,L,36/RISTM,L,40
    RICSCR - RESELLER INSTALLATIONS CHANGE OF SERVICE
               CONTRACT RATE (MINICOMP <37>
    RISHLR - RESELLER INSTALLATIONS SERVIVE BY HSD LEAVING
               RATE (MINICOMPUTER <38>
    RISTLR - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS LEAVIN <39>
    ATCSC  - (MONTHS) AVERAGE TIME TO CHANGE SERVICE CONTRACT
               <30>

RISHLR.K=RISH.K*MMAHSD.K                                     A,38     >RICSCR,R,37
    RISHLR - RESELLER INSTALLATIONS SERVIVE BY HSD LEAVING
               RATE (MINICOMPUTER <38>
    RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
               (MINICOMPUTERS) <36>
    MMAHSD - MULTIPLIER FOR MOVING AWAY FROM HSD
               (DIMENSIONLESS) <32>
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```
  R.K=RISTM.K*MMTHSD.K                                        A,39     >RICSCR,R,37
   RISTLR - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
              MAINTAINERS LEAVIN <39>
   RISTM  - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
              MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1
              SERVICE REVENUE <40>
   MMTHSD - MULTIPLIER FOR MOVING TOWARDS HSD
              (DIMENSIONLESS) <34>

RISTM.K=RISTM.J+DT*(RSR.JK*(1-SPR.J)-(RISTM.J/ALI)+RICSCR.JK)  L,40     >WSQ,A,16/RISTLR,A,39/SRSP,A,45/CSTMPM,A,51/PLOT,114/
RISTM=RI*(1-SPR)                                               N,40.1     PRINT,116
   RISTM  - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
              MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1
              SERVICE REVENUE <40>
   DT     - SOLUTION TIME INTERVAL <112>
   RSR    - RESELLER SALES RATE (MINICOMPUTERS/MONTH) <21>
   SPR    - SERVICE POLICY FTO RESELLER (FRACTION) <26>
   ALI    - (MONTHS) AVERAGE LIFE OF MINICOMPUTER
              INSTALLATIONS <18>
   RICSCR - RESELLER INSTALLATIONS CHANGE OF SERVICE
              CONTRACT RATE (MINICOMP <37>
   RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>


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              2.0.0 SERVICE SUBSYSTEM

              2.1.0 FINANCIAL SECTOR

              2.1.1 SERVICE REVENUE

SRPM.K=SRRISH.K+SRHISH.K+SRSP.K+SRNMSH.K                       A,42     >SPM,A,55/AR,L,110/P,A,111/PLOT,113/PRINT,115
   SRPM   - SERVICE REVENUE PER MONTH (DOLLARS) <42>
   SRRISH - SERVICE REVENUE FOR RESELLER INSTALLATIONS
              SERVICED BY HONEYWELL <43>
   SRHISH - SERVICE REVENUE FOR HONEYWELL INSTALLATIONS
              SERVICED BY HONEYWEL <44>
   SRSP   - SERVICE REVENUE DUE TO SPARES (DOLLARS) <45>
   SRNMSH - SERVICE REVENUE FOR NON-MINIS SERVICED BY HONEY.
              (DOLLARS) <47>

SRRISH.K=DHSP.K*RISH.K                                         A,43     >SRPM,A,42
   SRRISH - SERVICE REVENUE FOR RESELLER INSTALLATIONS
              SERVICED BY HONEYWELL <43>
   DHSP   - DISCOUNT HONEYWELL SERVICE PRICE (DOLLARS/MONTH)
              <27>
   RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <36>

SRHISH.K=HSP.K*HISH.K                                          A,44     >SRPM,A,42
   SRHISH - SERVICE REVENUE FOR HONEYWELL INSTALLATIONS
              SERVICED BY HONEYWEL <44>
   HSP    - HONEYWELL SERVICE PRICE (DOLLARS/MONTH) <10>
   HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
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SRSP.K=(HISTM.K+RISTM.K)*PSPPM.K                        A,45      >SRPM,A,42
    SRSP   - SERVICE REVENUE DUE TO SPARES (DOLLARS) <45>
    HISTM  - HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC <35>
    RISTM  - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1
               SERVICE REVENUE <40>
    PSPPM  - PRICE OF SPARES PER MONTH PER INSTALLATION
               (DOLLARS) <46>

PSPPM.K=100                                             A,46      >SRSP,A,45
    PSPPM  - PRICE OF SPARES PER MONTH PER INSTALLATION
               (DOLLARS) <46>

SRNMSH.K=NMI.K*PNMISH.K                                 A,47      >SRPM,A,42
    SRNMSH - SERVICE REVENUE FOR NON-MINIS SERVICED BY HONEY.
               (DOLLARS) <47>
    NMI    - NON-MINI INSTALLATIONS (INSTALLATIONS) <88>
    PNMISH - PRICE OF NON-MINI INSTALLATIONS SERVICED BY
               HONEYWELL (DOLLARS) 2.2 SERVICE COST <48>

PNMISH.K=1400                                           A,48      >SRNMSH,A,47
    PNMISH - PRICE OF NON-MINI INSTALLATIONS SERVICED BY
               HONEYWELL (DOLLARS) 2.2 SERVICE COST <48>


                2.1.2 SERVICE COST

SCPM.K=CLPM.K+CSTMPM.K+CAPM.K+DEP.K                     A,49      >SPM,A,55/PLOT,113/PRINT,115
    SCPM   - SERVICE COST PER MONTH (DOLLARS) <49>
    CLPM   - COST OF LABOR PER MONTH (DOLLARS) <50>
    CSTMPM - COST OF SPARES SOLD TO THIRD PARTY MAINTAINERS
               PER MONTH (DOLLAR <51>
    CAPM   - COST OF ASSETS PER MONTH (DOLLARS) <53>
    DEP    - DEPRETIATION (DOLLARS/MONTH) 2.3 SERVICE PROFIT
               MARGIN <54>

CLPM.K=L.K*AWPM.K+MAX(0,OT.K)*1.5*AWPM.K                A,50      >SCPM,A,49
    CLPM   - COST OF LABOR PER MONTH (DOLLARS) <50>
    L      - LABOR (PERSONS) <65>
    AWPM   - AVERAGE WAGE PER MONTH (DOLLARS/MONTH) <74>
    MAX    - LOGICAL MAXIMUM FUNCTION
    OT     - OVERTIME (PERSONS) <65>

CSTMPM.K=(HISTM.K+RISTM.K)*CSPPM.K                      A,51      >SCPM,A,49
    CSTMPM - COST OF SPARES SOLD TO THIRD PARTY MAINTAINERS
               PER MONTH (DOLLAR <51>
    HISTM  - HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC <35>
    RISTM  - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
               MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1
               SERVICE REVENUE <40>
    CSPPM  - COST OF SPARES PER MONTH (DOLLARS) <52>

CSPPM.K=25                                              A,52      >CSTMPM,A,51
    CSPPM  - COST OF SPARES PER MONTH (DOLLARS) <52>
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M.K=ADR.K                                               A,53     >SCPM,A,49
    CAPM   - COST OF ASSETS PER MONTH (DOLLARS) <53>
    ADR    - ASSET DEPLETION RATE (DOLLARS/MONTH) <64>

DEP.K=2250E3                                            A,54     >SCPM,A,49
    DEP    - DEPRETIATION (DOLLARS/MONTH) 2.3 SERVICE PROFIT
              MARGIN <54>


           2.1.3 SERVICE PROFIT MARGIN

SPM.K=(SRPM.K-SCPM.K)/SRPM.K                            A,55     >SPMT,A,56/SPMR,A,58/P,A,111/PLOT,113/PRINT,115
    SPM    - SERVICE PROFIT MARGIN (PERCENT) <55>
    SRPM   - SERVICE REVENUE PER MONTH (DOLLARS) <42>
    SCPM   - SERVICE COST PER MONTH (DOLLARS) <49>

SPMT.K=MAX(0.1,DELAY3(SPM.K,TCSPMT.K))                  A,56     >SPMR,A,58
    SPMT   - SERVICE PROFIT MARGIN TARGET (PERCENT) <56>
    MAX    - LOGICAL MAXIMUM FUNCTION
    DELAY3 - THIRD ORDER AVERAGING MACRO
    SPM    - SERVICE PROFIT MARGIN (PERCENT) <55>
    TCSPMT - (MONTHS) TIME TO CHANGE SPMT <57>

TCSPMT.K=36                                             A,57     >SPMT,A,56
    TCSPMT - (MONTHS) TIME TO CHANGE SPMT <57>

SPMR.K=SPM.K/SPMT.K                                     A,58     >FCA,A,59/FCL,A,60
SPMR=1                                                  N,58.1
    SPMR   - SERVICE PROFIT MARGIN RATIO (DIMENSIONLESS) <58>
    SPM    - SERVICE PROFIT MARGIN (PERCENT) <55>
    SPMT   - SERVICE PROFIT MARGIN TARGET (PERCENT) <56>

FCA.K=TABLE(TFCA,SPMR.K,0.5,1.5,0.25)                   A,59     >AIR,R,62
TFCA=0.75,0.85,1,1.05,1.1                               T,59.1   >FCA,A,59
    FCA    - FINANCIAL CONSTRAINT ON ASSETS (DIMENSIONLESS)
              <59>
    TABLE  - TABLE FUNCTION
    TFCA   - TABLE FOR FCA <59>
    SPMR   - SERVICE PROFIT MARGIN RATIO (DIMENSIONLESS) <58>

FCL.K=TABLE(TFCL,SPMR.K,0.5,1.5,0.25)                   A,60     >LHR,R,66
TFCL=0.75,0.85,1,1.05,1.1                               T,60.1   >FCL,A,60
    FCL    - FINANCIAL CONSTRAINT ON LABOR (DIMENSIONLESS)
              <60>
    TABLE  - TABLE FUNCTION
    TFCL   - TABLE FOR FCL 3.1 ASSET SECTOR <60>
    SPMR   - SERVICE PROFIT MARGIN RATIO (DIMENSIONLESS) <58>
```

2.2.0 SERVICE SECTOR

2.2.1 ASSETS

```
A.K=A.J+DT*(AIR.JK-ADR.JK)                               L,61     >AIR,R,62/ADR,R,64/MEAS,A,80/PLOT,113/PRINT,115
A=142.5E6                                                N,61.1
    A      - ASSETS (DOLLARS) <61>
    DT     - SOLUTION TIME INTERVAL <112>
    AIR    - ASSET INVESTMENT RATE (DOLLARS/MONTH) <62>
    ADR    - ASSET DEPLETION RATE (DOLLARS/MONTH) <64>

AIR.KL=(((DA.K-A.K)/ATAI)+LTADR.K)*FCA.K                 R,62     >A,L,61
ATAI=6                                                   C,62.1   >AIR,R,62
    AIR    - ASSET INVESTMENT RATE (DOLLARS/MONTH) <62>
    DA     - DESIRED ASSETS (DOLLARS) 4.0 SUPPLEMENTARY
              EQUATIONS <108>
    A      - ASSETS (DOLLARS) <61>
    ATAI   - (MONTHS) AVERAGE TIME TO AQUIRE ASSET <62>
    LTADR  - LONG TERM ASSET DEPLETION RATE (DOLLARS/MONTH)
              <63>
    FCA    - FINANCIAL CONSTRAINT ON ASSETS (DIMENSIONLESS)
              <59>

    R.K=SMOOTH(ADR.K,TSADR)                              A,63     >AIR,R,62
TSADR=12                                                 C,63.1   >LTADR,A,63
    LTADR  - LONG TERM ASSET DEPLETION RATE (DOLLARS/MONTH)
              <63>
    SMOOTH - FIRST ORDER AVERAGING MACRO
    ADR    - ASSET DEPLETION RATE (DOLLARS/MONTH) <64>
    TSADR  - (MONTHS) TIME TO SMOOTH ADR <63>

ADR.KL=A.K/ALA                                           R,64     >CAPM,A,53/A,L,61/LTADR,A,63
ALA=60                                                   C,64.1   >ADR,R,64
    ADR    - ASSET DEPLETION RATE (DOLLARS/MONTH) <64>
    A      - ASSETS (DOLLARS) <61>
    ALA    - (MONTHS) AVERAGE LIFE OF ASSETS 3.2 LABOR SECTOR
              <64>
```

2.2.2 LABOR

```
L.K=L.J+DT*(LHR.JK-LAR.JK)                               L,65     >CLPM,A,50/LHR,R,66/LAR,R,68/CEL,L,72/AEL,A,73/EL,A,8?
L=3792.2                                                 N,65.1     MOT,A,83/OT,A,85/NCAP,A,87/PLOT,113/PRINT,115
    L      - LABOR (PERSONS) <65>
    DT     - SOLUTION TIME INTERVAL <112>
    LHR    - LABOR HIRE RATE (PERSONS/MONTH) <66>
    LAR    - LABOR ATTRITION RATE (PERSONS/MONTH) <68>
```

```
LHR.KL=(((DL.K-L.K+LTOT.K+LCB.K)/ATHL)+LTLAR.K)*FCL.K          R,66      >L,L,65
ATHL=6                                                         C,66.1    >LHR,R,66
    LHR    - LABOR HIRE RATE (PERSONS/MONTH) <66>
    DL     - DESIRED LABOR (PERSONS) <107>
    L      - LABOR (PERSONS) <65>
    LTOT   - LONG TERM OVERTIME (PERSONS) <69>
    LCB    - LABOR CORRECTION FOR LABOR (PEOPLE/MONTH) <70>
    ATHL   - (MONTHS) AVERAGE TIME TO HIRE LABOR <66>
    LTLAR  - LONG TERM LABOR ATTRITION RATE (PERONS/MONTH)
              <67>
    FCL    - FINANCIAL CONSTRAINT ON LABOR (DIMENSIONLESS)
              <60>

LTLAR.K=SMOOTH(LAR.K,TSLAR)                                    A,67      >LHR,R,66
TSLAR=12                                                       C,67.1    >LTLAR,A,67
    LTLAR  - LONG TERM LABOR ATTRITION RATE (PERONS/MONTH)
              <67>
    SMOOTH - FIRST ORDER AVERAGING MACRO
    LAR    - LABOR ATTRITION RATE (PERSONS/MONTH) <68>
    TSLAR  - (MONTHS) TIME TO SMOOTH LAR <67>

LAR.KL=L.K/ALL                                                 R,68      >L,L,65/LTLAR,A,67/CEL,L,72
ALL=60                                                         C,68.1    >LAR,R,68
    LAR    - LABOR ATTRITION RATE (PERSONS/MONTH) <68>
    L      - LABOR (PERSONS) <65>
    ALL    - (MONTHS) AVERAGE LIFE OF LABOR <68>

LTOT.K=SMOOTH(OT.K,TSOT)                                       A,69      >LHR,R,66
TSOT=3                                                         C,69.1    >LTOT,A,69
    LTOT   - LONG TERM OVERTIME (PERSONS) <69>
    SMOOTH - FIRST ORDER AVERAGING MACRO
    OT     - OVERTIME (PERSONS) <85>
    TSOT   - (MONTHS) TIME TO SMOOTH OVERTIME <69>

LCB.K=SMOOTH((DB.K-B.K)/LUTIL.K,3)                             A,70      >LHR,R,66
    LCB    - LABOR CORRECTION FOR LABOR (PEOPLE/MONTH) <70>
    SMOOTH - FIRST ORDER AVERAGING MACRO
    DB     - DESIRED BACKLOG (SERVICE CALLS) <71>
    B      - BACKLOG (SERVICE CALLS) <75>
    LUTIL  - LABOR UTILIZATION (SERVICE CALLS/PERSON) <77>

DB.K=NCAP.K                                                    A,71      >LCB,A,70
    DB     - DESIRED BACKLOG (SERVICE CALLS) <71>
    NCAP   - NORMAL CAPACITY (SERVICE CALLS/MONTH) <87>

CEL.K=CEL.J+DT*(L.J-AEL.K*LAR.JK)                              L,72      >AEL,A,73
CEL=227532                                                     N,72.1
    CEL    - CUMULATIVE EXPERIENCE OF LABOR (MONTHS) <72>
    DT     - SOLUTION TIME INTERVAL <112>
    L      - LABOR (PERSONS) <65>
    AEL    - AVERAGE EXPERIENCE OF LABOR (MONTHS/PERSON) 3.3
              SERVICE PERFORMANCE <73>
    LAR    - LABOR ATTRITION RATE (PERSONS/MONTH) <68>
```

```
AEL.K=CEL.K/L.K                                            A,73     >CEL,L,72/MAEL,A,78/PLOT,113/PRINT,115
    AEL    - AVERAGE EXPERIENCE OF LABOR (MONTHS/PERSON) 3.3
               SERVICE PERFORMANCE <73>
    CEL    - CUMULATIVE EXPERIENCE OF LABOR (MONTHS) <72>
    L      - LABOR (PERSONS) <65>

AWPM.K=2000                                                A,74     >CLPM,A,50
    AWPM   - AVERAGE WAGE PER MONTH (DOLLARS/MONTH) <74>


               2.2.3 SERVICE PERFORMANCE

B.K=B.J+DT*(SRNM.K+SRM.K-CAP.K)                            L,75     >LCB,A,70/RL,A,76/HSQ,A,86/PLOT,113/PRINT,115
B=14000                                                    N,75.1
    B      - BACKLOG (SERVICE CALLS) <75>
    DT     - SOLUTION TIME INTERVAL <112>
    SRNM   - SERVICE REQUIREMENT FOR NON-MINIS (SERVICE CALLS/
               MONTH) <89>
    SRM    - SERVICE REQUIREMENT FOR MINIS (SERVICE CALLS/
               MONTH) <97>
    CAP    - CAPACITY (SERVICE CALLS/MONTH) <84>

RL.K=(B.K/LUTIL.K)                                         A,76     >MOT,A,83
    RL     - REQUIRED LABOR (PERSONS) <76>
    B      - BACKLOG (SERVICE CALLS) <75>
    LUTIL  - LABOR UTILIZATION (SERVICE CALLS/PERSON) <77>

LUTIL.K=((MLUTIL.K*DLM.K)+(NMLUTL.K*DLNM.K))/DL.K          A,77     >LCB,A,70/RL,A,76/CAP,A,84/NCAP,A,87
    LUTIL  - LABOR UTILIZATION (SERVICE CALLS/PERSON) <77>
    MLUTIL - MINI LABOR UTILIZATION (SERVICE CALLS/PERSON)
               <103>
    DLM    - DESIRED LABOR FOR MINIS (PERSONS) <102>
    NMLUTL - NON-MINI LABOR UTILIZATION (SERVICE CALLS/
               PERSON) <95>
    DLNM   - DESIRED LABOR FOR NON-MINIS (PERSONS) <94>
    DL     - DESIRED LABOR (PERSONS) <107>

MAEL.K=TABLE(TMAEL1,AEL.K,0,96,12)*SWMAEL.K+TABLE(TMAEL2,  A,78     >NMLUTL,A,95/MLUTIL,A,103
 AEL.K,0,96,12)*(1-SWMAEL.K)
TMAEL1=.5,.8,1,1.05,1.08,1.1,1.1,1.1,1.1                   T,78.1   >MAEL,A,78
TMAEL2=.5,1,1.05,1.08,1.1,1.1,1.1,1.1,1.1                  T,78.2   >MAEL,A,78
    MAEL   - MULTIPLIER FOR AEL (DIMENSIONLESS) <78>
    TABLE  - TABLE FUNCTION
    TMAEL1 - TABLE#1 FOR MAEL <78>
    AEL    - AVERAGE EXPERIENCE OF LABOR (MONTHS/PERSON) 3.3
               SERVICE PERFORMANCE <73>
    SWMAEL - SWITCH FOR MULTIPLIER FOR AEL (DIMENSIONLESS)
               <79>
    TMAEL2 - TABLE#2 FOR MAEL <78>

SWMAEL.K=1-STEP(1,TSMAEL)                                  A,79     >MAEL,A,78
TSMAEL=1000                                                C,79.1   >SWMAEL,A,79
    SWMAEL - SWITCH FOR MULTIPLIER FOR AEL (DIMENSIONLESS)
               <79>
    TSMAEL - TIME TO TURN ON SWMAEL (MONTHS) <79>
```

```
MEAS.K=TABLE(TMEAS,A.K/RA.K,0,2,0.25)                      A,80      >NMLUTL,A,95/MLUTIL,A,103
TMEAS=0,0.2,0.5,0.9,1,1,1,1,1                              T,80.1    >MEAS,A,80
    MEAS   - MULTIPLIER FOR ASSET EFFECT OF SERVICE
              (DIMENSIONLESS) <80>
    TABLE  - TABLE FUNCTION
    TMEAS  - TABLE FOR MEAS <80>
    A      - ASSETS (DOLLARS) <61>
    RA     - REQUIRED ASSETS (DOLLARS) <81>

RA.K=SRNM.K*ANSRNM+SRM.K*ANSRM.K                           A,81      >MEAS,A,80/PLOT,113/PRINT,115
    RA     - REQUIRED ASSETS (DOLLARS) <81>
    SRNM   - SERVICE REQUIREMENT FOR NON-MINIS (SERVICE CALLS/
              MONTH) <89>
    ANSRNM - (ASSETS-MONTH/SERVICE CALLS) ASSETS NEEDED FOR
              SRNM <96>
    SRM    - SERVICE REQUIREMENT FOR MINIS (SERVICE CALLS/
              MONTH) <97>
    ANSRM  - ASSETS NEEDED PER SRM (DOLLARS-MONTH/SERVICE
              CALL) <106>

EL.K=L.K*MOT.K                                             A,82      >CAP,A,84/OT,A,85
    EL     - EQUIVALENT LABOR (PERSONS) <82>
    L      - LABOR (PERSONS) <65>
    MOT    - MULTIPLIER FOR OVERTIME (DIMENSIONLESS) <83>

MOT.K=TABLE(TMOT,RL.K/L.K,0,1.25,0.25)                     A,83      >EL,A,82/PLOT,113/PRINT,115
TMOT=0,.25,.5,.75,1,1.25                                   T,83.1    >MOT,A,83
    MOT    - MULTIPLIER FOR OVERTIME (DIMENSIONLESS) <83>
    TABLE  - TABLE FUNCTION
    TMOT   - TABLE FOR MOT <83>
    RL     - REQUIRED LABOR (PERSONS) <76>
    L      - LABOR (PERSONS) <65>

CAP.K=EL.K*LUTIL.K                                         A,84      >B,L,75
    CAP    - CAPACITY (SERVICE CALLS/MONTH) <84>
    EL     - EQUIVALENT LABOR (PERSONS) <82>
    LUTIL  - LABOR UTILIZATION (SERVICE CALLS/PERSON) <77>

OT.K=EL.K-L.K                                              A,85      >CLPM,A,50/LTOT,A,69
    OT     - OVERTIME (PERSONS) <85>
    EL     - EQUIVALENT LABOR (PERSONS) <82>
    L      - LABOR (PERSONS) <65>

HSQ.K=NCAP.K/B.K                                           A,86      >WSQ,A,16/PLOT,113/PRINT,115
    HSQ    - HONEYWELL SERVICE QUALITY (SQ) <86>
    NCAP   - NORMAL CAPACITY (SERVICE CALLS/MONTH) <87>
    B      - BACKLOG (SERVICE CALLS) <75>

NCAP.K=L.K*LUTIL.K                                         A,87      >DB,A,71/HSQ,A,86
    NCAP   - NORMAL CAPACITY (SERVICE CALLS/MONTH) <87>
    L      - LABOR (PERSONS) <65>
    LUTIL  - LABOR UTILIZATION (SERVICE CALLS/PERSON) <77>
```

2.2.4 SERVICE REQUIREMENTS

2.2.4.1 NON-MINI INSTALLATIONS

```
NMI.K=TABLE(TNMI,TIME.K,0,120,120)                          A,88      >SRNMSH,A,47/SRNM,A,89/PLOT,114
TNMI=12500,12500                                            T,88.1    >NMI,A,88
   NMI    - NON-MINI INSTALLATIONS (INSTALLATIONS) <88>
   TABLE  - TABLE FUNCTION
   TNMI   - TABLE FOR NON MINI INSTALLATIONS <88>

SRNM.K=NMI.K/ER.K                                           A,89      >B,L,75/RA,A,81/ASRNM,A,91/TRSRNM,A,92
   SRNM   - SERVICE REQUIREMENT FOR NON-MINIS (SERVICE CALLS/
              MONTH) <89>
   NMI    - NON-MINI INSTALLATIONS (INSTALLATIONS) <88>
   ER     - (DIMENSIONLESS) EQUIPMENT RELIABILITY <90>

ER.K=1+STEP(STER,TSTER)                                     A,90      >SRNM,A,89
STER=0                                                      C,90.1    >ER,A,90
TSTER=6                                                     C,90.2    >ER,A,90
   ER     - (DIMENSIONLESS) EQUIPMENT RELIABILITY <90>
   STER   - STEP TEST FOR ER (FARCTION) <90>
   TSTER  - (MONTHS) TIME FOR STEP TEST FOR ER <90>

ASRNM.K=SMOOTH(SRNM.K,TASRNM)                               A,91      >FSRNM,A,93
TASRNM=12                                                   C,91.1    >ASRNM,A,91/TRSRNM,A,92
   ASRNM  - AVERAGE SERVICE REQUIREMENT FOR NON-MINIS (CALLS/
              MONTH) <91>
   SMOOTH - FIRST ORDER AVERAGING MACRO
   SRNM   - SERVICE REQUIREMENT FOR NON-MINIS (SERVICE CALLS/
              MONTH) <89>
   TASRNM - (MONTHS) TIME TO AVERAGE SRNM <91>

TRSRNM.K=TREND(SRNM.K,TASRNM,TETRNM,ITSRNM)                 A,92      >FSRNM,A,93
TETRNM=18                                                   C,92.1    >TRSRNM,A,92
ITSRNM=0                                                    C,92.2    >TRSRNM,A,92
   TRSRNM - TREND FOR SRNM (CALLS/MONTH) <92>
   TREND  - TREND MACRO
   SRNM   - SERVICE REQUIREMENT FOR NON-MINIS (SERVICE CALLS/
              MONTH) <89>
   TASRNM - (MONTHS) TIME TO AVERAGE SRNM <91>
   TETRNM - (MONTHS) TIME TO ESTABLISH TREND FOR SRNM <92>
   ITSRNM - (SERVICE CALLS PER MONTH) INITIAL TREND FOR SRNM
              <92>

FSRNM.K=ASRNM.K+FP*TRSRNM.K                                 A,93      >DLNM,A,94/DANM,A,96
FP=6                                                        C,93.1    >FSRNM,A,93/FSRM,A,101
   FSRNM  - FORECAST OF SRNM (SERVICE CALLS/MONTH) <93>
   ASRNM  - AVERAGE SERVICE REQUIREMENT FOR NON-MINIS (CALLS/
              MONTH) <91>
   FP     - (MONTHS) FORECAST PERIOD <93>
   TRSRNM - TREND FOR SRNM (CALLS/MONTH) <92>

DLNM.K=FSRNM.K/NMLUTL.K                                     A,94      >LUTIL,A,77/DL,A,107
   DLNM   - DESIRED LABOR FOR NON-MINIS (PERSONS) <94>
   FSRNM  - FORECAST OF SRNM (SERVICE CALLS/MONTH) <93>
   NMLUTL - NON-MINI LABOR UTILIZATION (SERVICE CALLS/
              PERSON) <95>
```

```
NMLUTL.K=3.5*MAEL.K*MEAS.K                              A,95     >LUTIL,A,77/DLNM,A,94
   NMLUTL - NON-MINI LABOR UTILIZATION (SERVICE CALLS/
              PERSON) <95>
   MAEL   - MULTIPLIER FOR AEL (DIMENSIONLESS) <78>
   MEAS   - MULTIPLIER FOR ASSET EFFECT OF SERVICE
              (DIMENSIONLESS) <80>

DANM.K=FSRNM.K*ANSRNM                                   A,96     >DA,A,108
ANSRNM=9E3                                              C,96.1   >RA,A,81/DANM,A,96
   DANM   - DASIRED ASSETS FOR NON-MINIS (DOLLARS) <96>
   FSRNM  - FORECAST OF SRNM (SERVICE CALLS/MONTH) <93>
   ANSRNM - (ASSETS-MONTH/SERVICE CALLS) ASSETS NEEDED FOR
              SRNM <96>
```

2.2.4.2 MINI INSTALLATIONS

```
SRM.K=(HISH.K+RISH.K)/CIS.K                             A,97     >B,L,75/RA,A,81/ASRM,A,99/TRSRM,A,100
   SRM    - SERVICE REQUIREMENT FOR MINIS (SERVICE CALLS/
              MONTH) <97>
   HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
   RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <36>
   CIS    - (DIMENSIONLESS) CUSTOMER INITIATED SERVICE <98>

CIS.K=1+STEP(STCIS,TSTCIS)                              A,98     >SRM,A,97
STCIS=0                                                 C,98.1   >CIS,A,98
TSTCIS=6                                                C,98.2   >CIS,A,98
   CIS    - (DIMENSIONLESS) CUSTOMER INITIATED SERVICE <98>
   STCIS  - STEP TEST FOR CIS (FRACTION) <98>
   TSTCIS - (MONTHS) TIME FOR STEP TEST FOR CIS <98>

ASRM.K=SMOOTH(SRM.K,TSSRM)                              A,99     >FSRM,A,101
TSSRM=12                                                C,99.1   >ASRM,A,99/TRSRM,A,100
   ASRM   - AVERAGE SERVICE REQUIREMENT FOR MINIS (CALLS/
              MONTH) <99>
   SMOOTH - FIRST ORDER AVERAGING MACRO
   SRM    - SERVICE REQUIREMENT FOR MINIS (SERVICE CALLS/
              MONTH) <97>
   TSSRM  - (MONTHS) TIME TO SMOOTH SRM <99>

TRSRM.K=TREND(SRM.K,TSSRM,TETSRM,ITSRM)                 A,100    >FSRM,A,101
TETSRM=18                                               C,100.1  >TRSRM,A,100
ITSRM=0                                                 C,100.2  >TRSRM,A,100
   TRSRM  - TREND FOR SRM (CALLS/MONTH) <100>
   TREND  - TREND MACRO
   SRM    - SERVICE REQUIREMENT FOR MINIS (SERVICE CALLS/
              MONTH) <97>
   TSSRM  - (MONTHS) TIME TO SMOOTH SRM <99>
   TETSRM - (MONTHS) TIME TO SETABLISH TREND FOR SRM <100>
   ITSRM  - (SERVICE CALLS /MONTH) INITIAL TREND FOR SRM
              <100>
```

```
FSRM.K=ASRM.K+TRSRM.K*FP                                    A,101      >DLM,A,102/DAM,A,105
    FSRM   - FORECAST FOR SRM (SERVICE CALLS/MONTH) <101>
    ASRM   - AVERAGE SERVICE REQUIREMENT FOR MINIS (CALLS/
              MONTH) <99>
    TRSRM  - TREND FOR SRM (CALLS/MONTH) <100>
    FP     - (MONTHS) FORECAST PERIOD <93>

DLM.K=FSRM.K/MLUTIL.K                                       A,102      >LUTIL,A,77/DL,A,107
    DLM    - DESIRED LABOR FOR MINIS (PERSONS) <102>
    FSRM   - FORECAST FOR SRM (SERVICE CALLS/MONTH) <101>
    MLUTIL - MINI LABOR UTILIZATION (SERVICE CALLS/PERSON)
              <103>

MLUTIL.K=TABLE(TMLUT,(RISH.K+HISH.K),1.5E3,21.5E3,5E3)*MMIV.K* A,103   >LUTIL,A,77/DLM,A,102
 MAEL.K*MEAS.K
TMLUT=2.5,4.0,6.5,9,10                                      T,103.1    >MLUTIL,A,103
    MLUTIL - MINI LABOR UTILIZATION (SERVICE CALLS/PERSON)
              <103>
    TABLE  - TABLE FUNCTION
    TMLUT  - TABLE FOR MLUTIL <103>
    RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <36>
    HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
    MMIV   - (DIMENSIONLESS) MULTIPLIER FOR MAN IN THE VAN
              PROGRAM <104>
    MAEL   - MULTIPLIER FOR AEL (DIMENSIONLESS) <78>
    MEAS   - MULTIPLIER FOR ASSET EFFECT OF SERVICE
              (DIMENSIONLESS) <80>

MMIV.K=1+STEP(STMMIV,TMMIV)                                 A,104      >MLUTIL,A,103
STMMIV=0                                                    C,104.1    >MMIV,A,104
TMMIV=6                                                     C,104.2    >MMIV,A,104
    MMIV   - (DIMENSIONLESS) MULTIPLIER FOR MAN IN THE VAN
              PROGRAM <104>
    STMMIV - (FRACTION) STEP TEST FOR MAN IN THE VAN PROGRAM
              <104>
    TMMIV  - (MONTHS) TIME FOR STEP TESTR FOR MAN IN THE VAN
              PROGRAM <104>

DAM.K=FSRM.K*ANSRM.K                                        A,105      >DA,A,108
    DAM    - DESIRED ASSETS FOR MINIS (DOLLARS) <105>
    FSRM   - FORECAST FOR SRM (SERVICE CALLS/MONTH) <101>
    ANSRM  - ASSETS NEEDED PER SRM (DOLLARS-MONTH/SERVICE
              CALL) <106>

ANSRM.K=TABLE(TLANM,(RISH.K+HISH.K),1.5E3,21.5E3,5E3)       A,106      >RA,A,81/DAM,A,105
TLANM=20E3,14E3,7.5E3,4.0E3,2.5E3                           T,106.1    >ANSRM,A,106
    ANSRM  - ASSETS NEEDED PER SRM (DOLLARS-MONTH/SERVICE
              CALL) <106>
    TABLE  - TABLE FUNCTION
    TLANM  - TABLE FOR ANSRM <106>
    RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <36>
    HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
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DL.K=DLM.K+DLNM.K                                          A,107    >LHR,R,66/LUTIL,A,77
    DL     - DESIRED LABOR (PERSONS) <107>
    DLM    - DESIRED LABOR FOR MINIS (PERSONS) <102>
    DLNM   - DESIRED LABOR FOR NON-MINIS (PERSONS) <94>

DA.K=DAM.K+DANM.K                                          A,108    >AIR,R,62
    DA     - DESIRED ASSETS (DOLLARS) 4.0 SUPPLEMENTARY
               EQUATIONS <108>
    DAM    - DESIRED ASSETS FOR MINIS (DOLLARS) <105>
    DANM   - DASIRED ASSETS FOR NON-MINIS (DOLLARS) <96>


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            3.0  SUPPLEMENTARY  EQUATIONS

AP.K=AP.J+DT*P.J                                           L,109    >PRINT,116
AP=0                                                       N,109.1
    AP     - ACCUMULATED PROFIT (DOLLARS) <109>
    DT     - SOLUTION TIME INTERVAL <112>
    P      - PROFIT PER MONTH (PERCENT) 5.0 DYNAMO
               DEFINITIONS <111>

AR.K=AR.J+DT*SRPM.J                                        L,110    >PRINT,116
AR=0                                                       N,110.1
    AR     - ACCUMULATED REVENUE (DOLLARS) <110>
    DT     - SOLUTION TIME INTERVAL <112>
    SRPM   - SERVICE REVENUE PER MONTH (DOLLARS) <42>

P.K=SRPM.K*SPM.K                                           A,111    >AP,L,109/PRINT,116
    P      - PROFIT PER MONTH (PERCENT) 5.0 DYNAMO
               DEFINITIONS <111>
    SRPM   - SERVICE REVENUE PER MONTH (DOLLARS) <42>
    SPM    - SERVICE PROFIT MARGIN (PERCENT) <55>


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                4.0  CONTROL CARDS

SPEC DT=0.25/LENGTH=24/PLTPER=0/PRTPER=3                    112
    DT     - SOLUTION TIME INTERVAL <112>
    LENGTH - LENGTH OF SIMULATION <112>
    PLTPER - PLOT PERIOD <112>
    PRTPER - PRINT PERIOD <112>
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PLOT A=A,RA=D(150E6,350E6)/L=L(5E3,10E3)/MOT=O(0.75,1.25)/        113
 B=B(0,80E3)/HSQ=Q(0.825,1.025)/SPM=P(0.2,0.6)/AEL=E(40,80)/
 SRPM=R,SCPM=C(10E6,70E6)
    A      - ASSETS (DOLLARS) <61>
    RA     - REQUIRED ASSETS (DOLLARS) <81>
    L      - LABOR (PERSONS) <65>
    MOT    - MULTIPLIER FOR OVERTIME (DIMENSIONLESS) <83>
    B      - BACKLOG (SERVICE CALLS) <75>
    HSQ    - HONEYWELL SERVICE QUALITY (SQ) <86>
    SPM    - SERVICE PROFIT MARGIN (PERCENT) <55>
    AEL    - AVERAGE EXPERIENCE OF LABOR (MONTHS/PERSON) 3.3
              SERVICE PERFORMANCE <73>
    SRPM   - SERVICE REVENUE PER MONTH (DOLLARS) <42>
    SCPM   - SERVICE COST PER MONTH (DOLLARS) <49>

PLOT NMI=N,HI=H,RI=R,HISH=1,HISTM=2,RISH=3,RISTM=4(0,40E3)          114
    NMI    - NON-MINI INSTALLATIONS (INSTALLATIONS) <88>
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>
    RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>
    HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
    HISTM  - HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
              MAINTAINERS (MINIC <35>
    RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <36>
    RISTM  - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
              MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1
              SERVICE REVENUE <40>

PRINT A,RA,L,MOT,B,HSQ,SPM,AEL,SRPM,SCPM                            115
    A      - ASSETS (DOLLARS) <61>
    RA     - REQUIRED ASSETS (DOLLARS) <81>
    L      - LABOR (PERSONS) <65>
    MOT    - MULTIPLIER FOR OVERTIME (DIMENSIONLESS) <83>
    B      - BACKLOG (SERVICE CALLS) <75>
    HSQ    - HONEYWELL SERVICE QUALITY (SQ) <86>
    SPM    - SERVICE PROFIT MARGIN (PERCENT) <55>
    AEL    - AVERAGE EXPERIENCE OF LABOR (MONTHS/PERSON) 3.3
              SERVICE PERFORMANCE <73>
    SRPM   - SERVICE REVENUE PER MONTH (DOLLARS) <42>
    SCPM   - SERVICE COST PER MONTH (DOLLARS) <49>
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PRINT HI,RI,HISH,RISH,HISTM,RISTM,AP,AR,P,THHM                         116
    HI     - HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>
    RI     - RESELLER INSTALLTIONS (MINICOMPUTERS) <20>
    HISH   - HONEYWELL INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <29>
    RISH   - RESELLER INSTALLATIONS SERVICE BY HSD
              (MINICOMPUTERS) <36>
    HISTM  - HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
              MAINTAINERS (MINIC <35>
    RISTM  - RESELLER INSTALLATIONS SERVICE BY THIRD PARTY
              MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1
              SERVICE REVENUE <40>
    AP     - ACCUMULATED PROFIT (DOLLARS) <109>
    AR     - ACCUMULATED REVENUE (DOLLARS) <110>
    P      - PROFIT PER MONTH (PERCENT) 5.0 DYNAMO
              DEFINITIONS <111>
    THHM   - TOTAL MARKET OF HONEYWELL MINICOMPUTERS
              (MINICOMPUTERS) 1.2 RESELLER SALES <19>

OPT TXI=4/PLW=50/P                                                     117
RUN BASE                                                               118
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LIST OF VARIABLES

SYMBOL	T	WHR-CMP	DEFINITION
A	L	61	ASSETS (DOLLARS) <61>
	N	61.1	
ADR	R	64	ASSET DEPLETION RATE (DOLLARS/MONTH) <64>
AEL	A	73	AVERAGE EXPERIENCE OF LABOR (MONTHS/PERSON) 3.3 SERVICE PERFORMANCE <73>
AIR	R	62	ASSET INVESTMENT RATE (DOLLARS/MONTH) <62>
ALA	C	64.1	(MONTHS) AVERAGE LIFE OF ASSETS 3.2 LABOR SECTOR <64>
ALI	C	18.2	(MONTHS) AVERAGE LIFE OF MINICOMPUTER INSTALLATIONS <18>
ALL	C	68.1	(MONTHS) AVERAGE LIFE OF LABOR <68>
ANSRM	A	106	ASSETS NEEDED PER SRM (DOLLARS-MONTH/SERVICE CALL) <106>
ANSRNM	C	96.1	(ASSETS-MONTH/SERVICE CALLS) ASSETS NEEDED FOR SRNM <96>
AP	L	109	ACCUMULATED PROFIT (DOLLARS) <109>
	N	109.1	
AR	L	110	ACCUMULATED REVENUE (DOLLARS) <110>
	N	110.1	
ASRM	A	99	AVERAGE SERVICE REQUIREMENT FOR MINIS (CALLS/ MONTH) <99>
ASRNM	A	91	AVERAGE SERVICE REQUIREMENT FOR NON-MINIS (CALLS/ MONTH) <91>
ATAI	C	62.1	(MONTHS) AVERAGE TIME TO AQUIRE ASSET <62>
ATCSC	C	30.1	(MONTHS) AVERAGE TIME TO CHANGE SERVICE CONTRACT <30>
ATHL	C	66.1	(MONTHS) AVERAGE TIME TO HIRE LABOR <66>
AWPM	A	74	AVERAGE WAGE PER MONTH (DOLLARS/MONTH) <74>
B	L	75	BACKLOG (SERVICE CALLS) <75>
	N	75.1	
CAP	A	84	CAPACITY (SERVICE CALLS/MONTH) <84>
CAPM	A	53	COST OF ASSETS PER MONTH (DOLLARS) <53>
CEL	L	72	CUMULATIVE EXPERIENCE OF LABOR (MONTHS) <72>
	N	72.1	
CIS	A	98	(DIMENSIONLESS) CUSTOMER INITIATED SERVICE <98>
CLPM	A	50	COST OF LABOR PER MONTH (DOLLARS) <50>
CSP	A	11	COMPETITORS SERVICE PRICE (DOLLARS/MONTH) <11>
CSPPM	A	52	COST OF SPARES PER MONTH (DOLLARS) <52>
CSTMPM	A	51	COST OF SPARES SOLD TO THIRD PARTY MAINTAINERS PER MONTH (DOLLAR <51>
DA	A	108	DESIRED ASSETS (DOLLARS) 4.0 SUPPLEMENTARY EQUATIONS <108>
DAM	A	105	DESIRED ASSETS FOR MINIS (DOLLARS) <105>
DANM	A	96	DASIRED ASSETS FOR NON-MINIS (DOLLARS) <96>
DB	A	71	DESIRED BACKLOG (SERVICE CALLS) <71>
DELAY3			THIRD ORDER AVERAGING MACRO
DEP	A	54	DEPRETIATION (DOLLARS/MONTH) 2.3 SERVICE PROFIT MARGIN <54>
DHSP	A	27	DISCOUNT HONEYWELL SERVICE PRICE (DOLLARS/MONTH) <27>
DL	A	107	DESIRED LABOR (PERSONS) <107>
DLM	A	102	DESIRED LABOR FOR MINIS (PERSONS) <102>

DLNM	A	94	DESIRED LABOR FOR NON-MINIS (PERSONS) <94>
DPPR	C	27.1	DISCOUNT PRICING POLICY TO RESELLER (FRACTION) <27>
DT	C	112	SOLUTION TIME INTERVAL <112>
DTHI	A	8	(MONTHS)DOUBLING TIME FOR HONEYWELL INSTALLATIONS <8>
DTRI	A	22	DOUBLING TIME FOR RESELLER INSTALLATIONS (MONTHS) <22>
EL	A	82	EQUIVALENT LABOR (PERSONS) <82>
ER	A	90	(DIMENSIONLESS) EQUIPMENT RELIABILITY <90>
FCA	A	59	FINANCIAL CONSTRAINT ON ASSETS (DIMENSIONLESS) <59>
FCL	A	60	FINANCIAL CONSTRAINT ON LABOR (DIMENSIONLESS) <60>
FP	C	93.1	(MONTHS) FORECAST PERIOD <93>
FSRM	A	101	FORECAST FOR SRM (SERVICE CALLS/MONTH) <101>
FSRNM	A	93	FORECAST OF SRNM (SERVICE CALLS/MONTH) <93>
HDR	R	17	HONEYWELL DEPLETION RATE (MINICOMPUTERS/MONTH) <17>
HI	L	6	HONEYWELL INSTALLATIONS (MINICOMPUTERS) <6>
	N	6.1	
HICSCR	R	30	HONEYWELL INSTALLATIONS CHANGE OF SERVICE CONTRACT RATE (MINICOM <30>
HISH	L	29	HONEYWELL INSTALLATIONS SERVICE BY HSD
	N	29.1	(MINICOMPUTERS) <29>
HISHLR	A	31	HONEYWELL INSTALLATIONS SERVICE BY HSD LEAVING RATE (MINICOMPUTE <31>
HISTLR	A	33	HONEYWELL INSTALLTIONS SERVICE BY THIRD PARTY MAINTAINERS LEAVIN <33>
HISTM	L	35	HONEYWELLINSTALLATIONS SERVICE BY THIRD PARTY
	N	35.1	MAINTAINERS (MINIC <35>
HSP	A	10	HONEYWELL SERVICE PRICE (DOLLARS/MONTH) <10>
HSQ	A	86	HONEYWELL SERVICE QUALITY (SQ) <86>
HSR	R	7	HONEYWELL SALES RATE (MINICOMPUTERS/MONTH) <7>
ITSRM	C	100.2	(SERVICE CALLS /MONTH) INITIAL TREND FOR SRM <100>
ITSRNM	C	92.2	(SERVICE CALLS PER MONTH) INITIAL TREND FOR SRNM <92>
L	L	65	LABOR (PERSONS) <65>
	N	65.1	
LAR	R	68	LABOR ATTRITION RATE (PERSONS/MONTH) <68>
LCB	A	70	LABOR CORRECTION FOR LABOR (PEOPLE/MONTH) <70>
LENGTH	C	112	LENGTH OF SIMULATION <112>
LHR	R	66	LABOR HIRE RATE (PERSONS/MONTH) <66>
LTADR	A	63	LONG TERM ASSET DEPLETION RATE (DOLLARS/MONTH) <63>
LTLAR	A	67	LONG TERM LABOR ATTRITION RATE (PERONS/MONTH) <67>
LTOT	A	69	LONG TERM OVERTIME (PERSONS) <69>
LUTIL	A	77	LABOR UTILIZATION (SERVICE CALLS/PERSON) <77>
MAEL	A	78	MULTIPLIER FOR AEL (DIMENSIONLESS) <78>
MAX			LOGICAL MAXIMUM FUNCTION
MEAS	A	80	MULTIPLIER FOR ASSET EFFECT OF SERVICE (DIMENSIONLESS) <80>
MHSA	A	12	MULTIPLIER FOR HONEYWELL SPECIAL APPLICATIONS (DIMENSIONLESS) <12>

MHSP	A	9	MULTIPLIER FOR HONEYWELL SERVICE PRICE (DIMENSIONLESS) <9>
MLUTIL	A	103	MINI LABOR UTILIZATION (SERVICE CALLS/PERSON) <103>
MMAHSD	A	32	MULTIPLIER FOR MOVING AWAY FROM HSD (DIMENSIONLESS) <32>
MMIV	A	104	(DIMENSIONLESS) MULTIPLIER FOR MAN IN THE VAN PROGRAM <104>
MMTHSD	A	34	MULTIPLIER FOR MOVING TOWARDS HSD (DIMENSIONLESS) <34>
MOT	A	83	MULTIPLIER FOR OVERTIME (DIMENSIONLESS) <83>
MPHSQ	A	14	MULTIPLIER FOR PERCEIVED HONEYWELL SERVICE QUALITY (DIMENSIONLES <14>
MRSP	A	23	MULTIPLIER FOR RESELLER SERVICE PRICE (DIMENSIONLESS) <23>
NCAP	A	87	NORMAL CAPACITY (SERVICE CALLS/MONTH) <87>
NMI	A	88	NON-MINI INSTALLATIONS (INSTALLATIONS) <88>
NMLUTL	A	95	NON-MINI LABOR UTILIZATION (SERVICE CALLS/ PERSON) <95>
OT	A	85	OVERTIME (PERSONS) <85>
P	A	111	PROFIT PER MONTH (PERCENT) 5.0 DYNAMO DEFINITIONS <111>
PERG	C	21.1	POLICY TO ENCOURAGE RESELLER GROWTH (FRACTION) <21>
PHSQ	A	15	PERCEIVED HONEYWELL SERVICE QUALITY (FRACTION) <15>
PLTPER	C	112	PLOT PERIOD <112>
PNMISH	A	48	PRICE OF NON-MINI INSTALLATIONS SERVICED BY HONEYWELL (DOLLARS) 2.2 SERVICE COST <48>
PRTPER	C	112	PRINT PERIOD <112>
PSPPM	A	46	PRICE OF SPARES PER MONTH PER INSTALLATION (DOLLARS) <46>
RA	A	81	REQUIRED ASSETS (DOLLARS) <81>
RDR	R	28	RESELLER DEPLETION RATE (MINICOMPUTERS/MONTH) 1.3 SERVICE MARKET <28>
RI	L	20	RESELLER INSTALLTIONS (MINICOMPUTERS) <20>
	N	20.1	
RICSCR	R	37	RESELLER INSTALLATIONS CHANGE OF SERVICE CONTRACT RATE (MINICOMP <37>
RISH	L	36	RESELLER INSTALLATIONS SERVICE BY HSD (MINICOMPUTERS) <36>
	N	36.1	
RISHLR	A	38	RESELLER INSTALLATIONS SERVIVE BY HSD LEAVING RATE (MINICOMPUTER <38>
RISTLR	A	39	RESELLER INSTALLATIONS SERVICE BY THIRD PARTY MAINTAINERS LEAVIN <39>
RISTM	L	40	RESELLER INSTALLATIONS SERVICE BY THIRD PARTY MAINTAINERS (MINIC FINANCIAL SUBSYSTEM 2.1 SERVICE REVENUE <40>
	N	40.1	
RL	A	76	REQUIRED LABOR (PERSONS) <76>
RSP	A	24	RESELLER SERVICE PRICE (DOLLARS /MONTH) <24>
RSR	R	21	RESELLER SALES RATE (MINICOMPUTERS/MONTH) <21>
SA	A	13	HONEYWELL SPECIAL APPLICATIONS (FRACTION) <13>
SCPM	A	49	SERVICE COST PER MONTH (DOLLARS) <49>
SDTHI	C	8.1	STEP TEST FOR DTHI (FRACTION) <8>
SDTRI	C	22.1	STEP TEST FOR DTRI (FRACTION) <22>
SMOOTH			FIRST ORDER AVERAGING MACRO

SPM	A	55	SERVICE PROFIT MARGIN (PERCENT) <55>
SPMR	A	58	SERVICE PROFIT MARGIN RATIO (DIMENSIONLESS) <58>
	N	58.1	
SPMT	A	56	SERVICE PROFIT MARGIN TARGET (PERCENT) <56>
SPR	A	26	SERVICE POLICY FTO RESELLER (FRACTION) <26>
SRHISH	A	44	SERVICE REVENUE FOR HONEYWELL INSTALLATIONS SERVICED BY HONEYWEL <44>
SRM	A	97	SERVICE REQUIREMENT FOR MINIS (SERVICE CALLS/ MONTH) <97>
SRNM	A	89	SERVICE REQUIREMENT FOR NON-MINIS (SERVICE CALLS/ MONTH) <89>
SRNMSH	A	47	SERVICE REVENUE FOR NON-MINIS SERVICED BY HONEY. (DOLLARS) <47>
SRPM	A	42	SERVICE REVENUE PER MONTH (DOLLARS) <42>
SRRISH	A	43	SERVICE REVENUE FOR RESELLER INSTALLATIONS SERVICED BY HONEYWELL <43>
SRSP	A	45	SERVICE REVENUE DUE TO SPARES (DOLLARS) <45>
STCIS	C	98.1	STEP TEST FOR CIS (FRACTION) <98>
STER	C	90.1	STEP TEST FOR ER (FARCTION) <90>
STHSP	C	10.1	STEP TEST FOR HSP (FRACTION) <10>
STMMIV	C	104.1	(FRACTION) STEP TEST FOR MAN IN THE VAN PROGRAM <104>
STPMSQ	C	18.1	STEP TEST FOR TPMSQ (FRACTION) <18>
STSPR	C	26.1	STEP TEST FOR SPR (FRACTION) <26>
SWMAEL	A	79	SWITCH FOR MULTIPLIER FOR AEL (DIMENSIONLESS) <79>
TABLE			TABLE FUNCTION
TASRNM	C	91.1	(MONTHS) TIME TO AVERAGE SRNM <91>
TCSPMT	A	57	(MONTHS) TIME TO CHANGE SPMT <57>
TETRNM	C	92.1	(MONTHS) TIME TO ESTABLISH TREND FOR SRNM <92>
TETSRM	C	100.1	(MONTHS) TIME TO SETABLISH TREND FOR SRM <100>
TFCA	T	59.1	TABLE FOR FCA <59>
TFCL	T	60.1	TABLE FOR FCL 3.1 ASSET SECTOR <60>
TLANM	T	106.1	TABLE FOR ANSRM <106>
TMAEL1	T	78.1	TABLE#1 FOR MAEL <78>
TMAEL2	T	78.2	TABLE#2 FOR MAEL <78>
TMEAS	T	80.1	TABLE FOR MEAS <80>
THHM	A	19	TOTAL MARKET OF HONEYWELL MINICOMPUTERS (MINICOMPUTERS) 1.2 RESELLER SALES <19>
TMHSA	T	12.1	TABLE FOR HONEYWELL SPECIAL APPLICATIONS <12>
TMHSP	T	9.1	TABLE FOR MULTIPLIER FOR HONEYWELL SERVICE PRICE <9>
TMLUT	T	103.1	TABLE FOR MLUTIL <103>
TMMAHS	T	32.1	TABLE FOR MULTIPLIER FOR MOVING AWAY OF HSD <32>
TMMIV	C	104.2	(MONTHS) TIME FOR STEP TESTR FOR MAN IN THE VAN PROGRAM <104>
TMMTHS	T	34.1	TABLE FOR MULTIPLIER FOR MOVING TOWARDS HSD <34>
TMOT	T	83.1	TABLE FOR MOT <83>
TMPHSQ	T	14.1	TABLE FOR MULTIPLIER FOR PERCEIVED HONEYWELL SERVICE QUALITY <14>
TMRSP	T	23.1	TABLE FOR MULTIPLIER FOR RESELLER SERVICE PRICE <23>
TNMI	T	88.1	TABLE FOR NON MINI INSTALLATIONS <88>
TPHSQ	C	15.1	(MONTHS) TIME TO PERCEIVE HONEYWELL SERVICE QUALITY <15>
TPMSQ	A	18	THIRD PARTY MAINTAINER SERVICE QUALITY (SQ) <18>

TREND			TREND MACRO
TRSRM	A	100	TREND FOR SRM (CALLS/MONTH) <100>
TRSRNM	A	92	TREND FOR SRNM (CALLS/MONTH) <92>
TSA	T	13.1	TABLE FOR HONEYWELL SPECIAL APPLICATIONS <13>
TSADR	C	63.1	(MONTHS) TIME TO SMOOTH ADR <63>
TSLAR	C	67.1	(MONTHS) TIME TO SMOOTH LAR <67>
TSMAEL	C	79.1	TIME TO TURN ON SWMAEL (MONTHS) <79>
TSOT	C	69.1	(MONTHS) TIME TO SMOOTH OVERTIME <69>
TSSRM	C	99.1	(MONTHS) TIME TO SMOOTH SRM <99>
TSTCIS	C	98.2	(MONTHS) TIME FOR STEP TEST FOR CIS <98>
TSTER	C	90.2	(MONTHS) TIME FOR STEP TEST FOR ER <90>
WARSP	A	25	WEIGHTED AVERAGE RESELLER SERVICE PRICE (DOLLARS/ MONTH) <25>
WSQ	A	16	WEIGHTED SERVICE QUALITY (FRACTION) <16>

WHERE-USED LIST

SYMBOL	WHERE-USED
A	AIR,R,62/ADR,R,64/MEAS,A,80/PLOT,113/PRINT,115
ADR	CAPM,A,53/A,L,61/LTADR,A,63
AEL	CEL,L,72/MAEL,A,78/PLOT,113/PRINT,115
AIR	A,L,61
ALA	ADR,R,64
ALI	HDR,R,17/RDR,R,28/HISH,L,29/HISTM,L,35/RISH,L,36/RISTM,L,40
ALL	LAR,R,68
ANSRM	RA,A,81/DAM,A,105
ANSRNM	RA,A,81/DANM,A,96
AP	PRINT,116
AR	PRINT,116
ASRM	FSRM,A,101
ASRNM	FSRNM,A,93
ATAI	AIR,R,62
ATCSC	HICSCR,R,30/RICSCR,R,37
ATHL	LHR,R,66
AWPM	CLPM,A,50
B	LCB,A,70/RL,A,76/HSQ,A,86/PLOT,113/PRINT,115
CAP	B,L,75
CAPM	SCPM,A,49
CEL	AEL,A,73
CIS	SRM,A,97
CLPM	SCPM,A,49
CSP	MHSP,A,9/HSP,A,10/MRSP,A,23/RSP,A,24
CSPPM	CSTMPM,A,51
CSTMPM	SCPM,A,49
DA	AIR,R,62
DAM	DA,A,108
DANM	DA,A,108
DB	LCB,A,70
DELAY3	PHSQ,A,15/SPMT,A,56
DEP	SCPM,A,49
DHSP	WARSP,A,25/SRRISH,A,43
DL	LHR,R,66/LUTIL,A,77
DLM	LUTIL,A,77/DL,A,107
DLNM	LUTIL,A,77/DL,A,107
DPPR	DHSP,A,27
DTHI	HSR,R,7
DTRI	RSR,R,21
EL	CAP,A,84/OT,A,85
ER	SRNM,A,89
CA	AIR,R,62
CL	LHR,R,66
FP	FSRNM,A,93/FSRM,A,101
SRM	DLM,A,102/DAM,A,105
SRNM	DLNM,A,94/DANM,A,96
HDR	HI,L,6
"I	HSR,R,7/HDR,R,17/THRM,A,19/HISH,N,29.1/PLOT,114/PRINT,116
ICSCR	HISH,L,29/HISTM,L,35
HISH	WSQ,A,16/HISHLR,A,31/SRHISH,A,44/SRM,A,97/MLUTIL,A,103/ ANSRM,A,106/PLOT,114/PRINT,116
ISHLR	HICSCR,R,30
ISTLR	HICSCR,R,30
HISTM	WSQ,A,16/HISTLR,A,33/SRSP,A,45/CSTMPM,A,51/PLOT,114/PRINT,116

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HSP      MHSP,A,9/DHSP,A,27/SRHISH,A,44
 SQ      WSQ,A,16/PLOT,113/PRINT,115
 SR      HI,L,6/HISH,L,29
ITSRM    TRSRM,A,100
 TSRNM   TRSRNM,A,92
         CLPM,A,50/LHR,R,66/LAR,R,68/CEL,L,72/AEL,A,73/EL,A,82/MOT,A,83/
          OT,A,85/NCAP,A,87/PLOT,113/PRINT,115
LAR      L,L,65/LTLAR,A,67/CEL,L,72
 CB      LHR,R,66
 HR      L,L,65
LTADR    AIR,R,62
 TLAR    LHR,R,66
 TOT     LHR,R,66
LUTIL    LCB,A,70/RL,A,76/CAP,A,84/NCAP,A,87
 AEL     NMLUTL,A,95/MLUTIL,A,103
 AX      CLPM,A,50/SPMT,A,56
MEAS     NMLUTL,A,95/MLUTIL,A,103
MHSA     HSR,R,7
 HSP     HSR,R,7
 LUTIL   LUTIL,A,77/DLM,A,102
MMAHSD   HISHLR,A,31/RISHLR,A,38
 AIV     MLUTIL,A,103
 MTHSD   HISTLR,A,33/RISTLR,A,39
MOT      EL,A,82/PLOT,113/PRINT,115
 PHSQ    HSR,R,7/RSR,R,21
 RSP     RSR,R,21
NCAP     DB,A,71/HSQ,A,86
NMI      SRNMSH,A,47/SRNM,A,89/PLOT,114
 MLUTL   LUTIL,A,77/DLNM,A,94
 T       CLPM,A,50/LTOT,A,69
P        AP,L,109/PRINT,116
 ERG     RSR,R,21
 HSQ     MPHSQ,A,14/MMAHSD,A,32/MMTHSD,A,34
PNMISH   SRNMSH,A,47
 SPPM    SRSP,A,45
 A       MEAS,A,80/PLOT,113/PRINT,115
RDR      RI,L,20
RI       TMHM,A,19/RSR,R,21/RDR,R,28/RISH,N,36.1/RISTM,N,40.1/PLOT,114/
          PRINT,116
 ICSCR   RISH,L,36/RISTM,L,40
RISH     WSQ,A,16/RISHLR,A,38/SRRISH,A,43/SRM,A,97/MLUTIL,A,103/
          ANSRM,A,106/PLOT,114/PRINT,116
 ISHLR   RICSCR,R,37
RISTLR   RICSCR,R,37
 ISTM    WSQ,A,16/RISTLR,A,39/SRSP,A,45/CSTMPM,A,51/PLOT,114/PRINT,116
 L       MOT,A,83
RSP      WARSP,A,25
 SR      RI,L,20/RISH,L,36/RISTM,L,40
 A       MHSA,A,12
 CPM     SPM,A,55/PLOT,113/PRINT,115
SDTHI    DTHI,A,8
 DTRI    DTRI,A,22
 MOOTH   LTADR,A,63/LTLAR,A,67/LTOT,A,69/LCB,A,70/ASRNM,A,91/ASRM,A,99
SPM      SPMT,A,56/SPMR,A,58/P,A,111/PLOT,113/PRINT,115
 PMR     FCA,A,59/FCL,A,60
 PMT     SPMR,A,58
SPR      WARSP,A,25/RISH,L,36/RISH,N,36.1/RISTM,L,40/RISTM,N,40.1
SRHISH   SRPM,A,42
```

SRM	B,L,75/RA,A,81/ASRM,A,99/TRSRM,A,100
SRNM	B,L,75/RA,A,81/ASRNM,A,91/TRSRNM,A,92
SRNMSH	SRPM,A,42
SRPM	SPM,A,55/AR,L,110/P,A,111/PLOT,113/PRINT,115
SRRISH	SRPM,A,42
SRSP	SRPM,A,42
STCIS	CIS,A,98
STEP	DTHI,A,8/HSP,A,10/TPMSQ,A,18/DTRI,A,22/SPR,A,26/SWMAEL,A,79/ ER,A,90/CIS,A,98/MMIV,A,104
STER	ER,A,90
STHSP	HSP,A,10
STMMIV	MMIV,A,104
STPMSQ	TPMSQ,A,18
STSPR	SPR,A,26
SWMAEL	MAEL,A,78
TABLE	MHSP,A,9/MHSA,A,12/SA,A,13/MPHSQ,A,14/MRSP,A,23/MMAHSD,A,32/ MMTHSD,A,34/FCA,A,59/FCL,A,60/MAEL,A,78/MEAS,A,80/MOT,A,83/ NMI,A,88/MLUTIL,A,103/ANSRM,A,106
TASRNM	ASRNM,A,91/TRSRNM,A,92
TCSPMT	SPMT,A,56
TETRNM	TRSRNM,A,92
TETSRM	TRSRM,A,100
TFCA	FCA,A,59
TFCL	FCL,A,60
TIME	SA,A,13/NMI,A,88
TLANM	ANSRM,A,106
TMAEL1	MAEL,A,78
TMAEL2	MAEL,A,78
TMEAS	MEAS,A,80
TMHM	WSQ,A,16/PRINT,116
TMHSA	MHSA,A,12
TMHSP	MHSP,A,9
TMLUT	MLUTIL,A,103
TMMAHS	MMAHSD,A,32
TMMIV	MMIV,A,104
TMMTHS	MMTHSD,A,34
TMOT	MOT,A,83
TMPHSQ	MPHSQ,A,14
TMRSP	MRSP,A,23
TNMI	NMI,A,88
TPHSQ	PHSQ,A,15
TPMSQ	WSQ,A,16
TREND	TRSRNM,A,92/TRSRM,A,100
TRSRM	FSRM,A,101
TRSRNM	FSRNM,A,93
TSA	SA,A,13
TSADR	LTADR,A,63
TSLAR	LTLAR,A,67
TSMAEL	SWMAEL,A,79
TSOT	LTOT,A,69
TSSRM	ASRM,A,99/TRSRM,A,100
TSTCIS	CIS,A,98
TSTER	ER,A,90
WARSP	MRSP,A,23
WSQ	PHSQ,A,15

(88)

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*          HONEYWELL CUSTOMER SERVICE DIVISION                     000000
NOTE                 SYSTEM DYNAMICS MODEL                         000000
NOTE                           BY                                  000000
NOTE                      DAVID DANIELS                            000000
NOTE                        LUIS LEON                              000000
NOTE        MASSACHUSETTS  INSTITUTE OF TECHNOLOGY                 000000
NOTE              SLOAN SCHOOL OF MANAGEMENT                       000000
NOTE                 CAMBRIDGE, MA 02139                           000000
NOTE                       MAY 1982                                000000
NOTE                                                               000000
NOTE*******************************************************************000000
NOTE                                                               000000
NOTE                     TABLE OF CONTENTS                         000000
NOTE                                                               000000
NOTE            1.0     MARKET SUBSYSTEM                           000000
NOTE                                                               000000
NOTE                       1.1   HONEYWELL SALES                   000000
NOTE                       1.2   RESELLER SALES                    000000
NOTE                       1.3   SERVICE MARKET                    000000
NOTE                                                               000000
NOTE            2.0     SERVICE SUBSYSTEM                          000000
NOTE                                                               000000
NOTE                    2.1.0  FINANCIAL SECTOR                    000000
NOTE                                                               000000
NOTE                          2.1.1  SERVICE REVENUE               000000
NOTE                          2.1.2  SERVICE COST                  000000
NOTE                          2.1.3  SERVICE PROFIT MARGIN         000000
NOTE                                                               000000
NOTE        -- ---      2.2.0  SERVICE SECTOR                      000000
NOTE                                                               000000
NOTE                          2.2.1  ASSETS                        000000
NOTE                          2.2.2  LABOR                         000000
NOTE                          2.2.3  SERVICE PERFORMANCE           000000
NOTE                          2.2.4  SERVICE REQUIREMENTS:         000000
NOTE                                    2.2.4.1 NON-MINI INSTALLATIONS 000000
NOTE                                    2.2.4.2 MINI INSTALLATIONS 000000
NOTE                                                               000000
NOTE            3.0     SUPPLEMENTARY EQUATIONS                    000000
NOTE                                                               000000
NOTE            4.0     CONTROL CARDS                              000000
NOTE                                                               000000
NOTE            5.0     RERUN STATEMENTS                           000000
NOTE                                                               000000
NOTE*******************************************************************000000
NOTE                                                               000000
NOTE            1.0     MARKET SUBSYSTEM                           000000
NOTE                                                               000000
NOTE              1.1 HONEYWELL SALES                              000000
NOTE                                                               000000
L   HI.K=HI.J+DT*(HSR.JK-HDR.JK)                                   000000
N   HI=1500                                                        000000
R   HSR.KL=HI.K*MHSA.K*MHSP.K*MPHSQ.K/DTHI.K                       000000
A   DTHI.K=120*(1-STEP(SDTHI,0))                                   000000
C   SDTHI=0                                                        000000
A   MHSP.K=TABLE(TMHSP,HSP.K/CSP.K,0,1.5,.25)                      000000
T   TMHSP=3,2,1.5,1.1,1,.9,0                                       000000
A   HSP.K=CSP.K+STEP(STHSP,12)                                     000000
C   STHSP=0                                                        000000
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```
A   CSP.K=700
A   MHSA.K=TABLE(TMHSA,SA.K,0,1.5,.25)
T   TMHSA=.1/.3/.5/.75/1/1.15/1.25
A   SA.K=TABLE(TSA,TIME.K,0,120,60)
T   TSA=1/1/1
A   MPHSQ.K=TABLE(TMPHSQ,PHSQ.K,0,1.25,.25)
T   TMPHSQ=.25,.25,.4,.8,1,1.2
A   PHSQ.K=DELAY3(WSQ.K,TPHSQ)
C   TPHSQ=12
A   WSQ.K=((RISH.K+HISH.K)*(HSQ.K)+(TPMSQ.K)*(HISTM.K+RISTM.K))/TMHM.K
R   HDR.KL=HI.K/ALI
A   TPMSQ.K=1+STEP(STPMSQ,24)
C   STPMSQ=0
C   ALI=120
A   TMHM.K=HI.K+RI.K
NOTE
NOTE          1.2  RESELLER SALES
NOTE
L   RI.K=RI.J+DT*(RSR.JK-RDR.JK)
N   RI=150
R   RSR.KL=RI.K*MRSP.K*MPHSQ.K*PERG/DTRI.K
C   PERG=1
A   DTRI.K=120*(1-STEP(SDTRI,0))
C   SDTRI=0
A   MRSP.K=TABLE(TMRSP,WARSP.K/CSP.K,0,1.5,.25)
T   TMRSP=3,2,1.5,1.1,1,.9,0
A   RSP.K=CSP.K
A   WARSP.K=(DHSP.K*SPR.K)+((1-SPR.K)*RSP.K)
A   SPR.K=STEP(STSPR,48)
C   STSPR=0
A   DHSP.K=HSP.K*(1-DPPR)
C   DPPR=0
R   RDR.KL=RI.K/ALI
NOTE
NOTE          1.3 SERVICE MARKET
NOTE
L   HISH.K=HISH.J+DT*(HSR.JK-(HISH.J/ALI))-DT*HICSCR.JK
N   HISH=HI
R   HICSCR.KL=(HISHLR.K-HISTLR.K)/ATCSC
C   ATCSC=12
A   HISHLR.K=HISH.K*MMAHSD.K
A   MMAHSD.K=TABLE(TMMAHS,PHSQ.K,.5,1.5,.25)
T   TMMAHS.K=.5,.25,0,0,0
A   HISTLR.K=HISTM.K*MMTHSD.K
A   MMTHSD.K=TABLE(TMMTHS,PHSQ.K,.5,1.5,.25)
T   TMMTHS=0,0,0,.25,.5
L   HISTM.K=HISTM.J+DT*(HICSCR.JK-HISTM.J/ALI)
N   HISTM=0
L   RISH.K=RISH.J+DT*(RSR.JK*SPR.J-(RISH.J/ALI)-RICSCR.JK)
N   RISH=RI*SPR
R   RICSCR.KL=(RISHLR.K-RISTLR.K)/ATCSC
A   RISHLR.K=RISH.K*MMAHSD.K
    RISTLR.K=RISTM.K*MMTHSD.K
    RISTM.K=RISTM.J+DT*(RSR.JK*(1-SPR.J)-(RISTM.J/ALI)+RICSCR.JK)
N   RISTM=RI*(1-SPR)
NOTE
NOTE*****************************************************************
NOTE
```

```
NOTE            2.0.0 SERVICE SUBSYSTEM
NOTE
NOTE            2.1.0 FINANCIAL SECTOR
NOTE
NOTE            2.1.1 SERVICE REVENUE
NOTE
A   SRPM.K=SRRISH.K+SRHISH.K+SRSP.K+SRNMSH.K
A   SRRISH.K=DHSP.K*RISH.K
A   SRHISH.K=HSP.K*HISH.K
A   SRSP.K=(HISTM.K+RISTM.K)*PSPPM.K
A   PSPPM.K=100
A   SRNMSH.K=NMI.K*PNMISH.K
A   PNMISH.K=1400
NOTE
NOTE            2.1.2 SERVICE COST
NOTE
A   SCPM.K=CLPM.K+CSTMPM.K+CAPM.K+DEP.K
A   CLPM.K=L.K*AWPM.K+MAX(0,OT.K)*1.5*AWPM.K
A   CSTMPM.K=(HISTM.K+RISTM.K)*CSPPM.K
A   CSPPM.K=25
A   CAPM.K=ADR.K
A   DEP.K=2250E3
NOTE
NOTE        2.1.3 SERVICE PROFIT MARGIN
NOTE
A   SPM.K=(SRPM.K-SCPM.K)/SRPM.K
A   SPMT.K=MAX(0.1,DELAY3(SPM.K,TCSPMT.K))
A   TCSPMT.K=36
A   SPMR.K=SPM.K/SPMT.K
N   SPMR=1
A   FCA.K=TABLE(TFCA,SPMR.K,0.5,1.5,0.25)
T   TFCA=0.75,0.85,1,1.05,1.1
A   FCL.K=TABLE(TFCL,SPMR.K,0.5,1.5,0.25)
T   TFCL=0.75,0.85,1,1.05,1.1
NOTE
NOTE           2.2.0 SERVICE SECTOR
NOTE
NOTE               2.2.1  ASSETS
NOTE
L   A.K=A.J+DT*(AIR.JK-ADR.JK)
N   A=142.5E6
R   AIR.KL=(((DA.K-A.K)/ATAI)+LTADR.K)*FCA.K
C   ATAI=6
A   LTADR.K=SMOOTH(ADR.K,TSADR)
C   TSADR=12
R   ADR.KL=A.K/ALA
C   ALA=60
NOTE
NOTE               2.2.2  LABOR
NOTE
L   L.K=L.J+DT*(LHR.JK-LAR.JK)
N   L=3792.2
R   LHR.KL=(((DL.K-L.K+LTOT.K+LCB.K)/ATHL)+LTLAR.K)*FCL.K
C   ATHL=6
A   LTLAR.K=SMOOTH(LAR.K,TSLAR)
C   TSLAR=12
R   LAR.KL=L.K/ALL
C   ALL=60
```

```
A  LTOT.K=SMOOTH(OT.K,TSOT)
C  TSOT=3
A  CB.K=SMOOTH((DB.K-B.K)/LUTIL.K,3)
A  DB.K=NCAP.K
L  CEL.K=CEL.J+DT*(L.J-AEL.K*LAR.JK)
N  CEL=227532
A  AEL.K=CEL.K/L.K
A  AWPM.K=2000
NOTE
NOTE          2.2.3 SERVICE PERFORMANCE
NOTE
L  B.K=B.J+DT*(SRNM.K+SRM.K-CAP.K)
N  B=14000
A  RL.K=(B.K/LUTIL.K)
A  LUTIL.K=((MLUTIL.K*DLM.K)+(NMLUTL.K*DLNM.K))/DL.K
A  MAEL.K=TABLE(TMAEL1,AEL.K,0,96,12)*SWMAEL.K+TABLE(TMAEL2,AEL.K,0,96,
X       12)*(1-SWMAEL.K)
T  TMAEL1=.5,.8,1,1.05,1.08,1.1,1.1,1.1,1.1
T  TMAEL2=.5,1,1.05,1.08,1.1,1.1,1.1,1.1,1.1
A  SWMAEL.K=1-STEP(1,TSMAEL)
C  TSMAEL=1000
A  MEAS.K=TABLE(TMEAS,A.K/RA.K,0,2,0.25)
T  TMEAS=0,0.2,0.5,0.9,1,1,1,1,1
A  RA.K=SRNM.K*ANSRNM+SRM.K*ANSRM.K
A  EL.K=L.K*MOT.K
A  MOT.K=TABLE(TMOT,RL.K/L.K,0,1.25,0.25)
T  TMOT=0,.25,.5,.75,1,1.25
A  CAP.K=EL.K*LUTIL.K
A  OT.K=EL.K-L.K
A  HSQ.K=NCAP.K/B.K
A  NCAP.K=L.K*LUTIL.K
NOTE
NOTE          2.2.4 SERVICE REQUIREMENTS
NOTE
NOTE          2.2.4.1 NON-MINI INSTALLATIONS
NOTE
A  NMI.K=TABLE(TNMI,TIME.K,0,120,120)
T  TNMI=12500,12500
A  SRNM.K=NMI.K/ER.K
A  ER.K=1+STEP(STER,TSTER)
C  STER=0
C  TSTER=6
A  ASRNM.K=SMOOTH(SRNM.K,TASRNM)
C  TASRNM=12
A  TRSRNM.K=TREND(SRNM.K,TASRNM,TETRNM,ITSRNM)
C  TETRNM=18
C  ITSRNM=0
A  FSRNM.K=ASRNM.K+FP*TRSRNM.K
C  FP=6
A  DLNM.K=FSRNM.K/NMLUTL.K
A  NMLUTL.K=3.5*MAEL.K*MEAS.K
   DANM.K=FSRNM.K*ANSRNM
   ANSRNM=9E3
NOTE
NOTE          2.2.4.2 MINI INSTALLATIONS
NOTE
A  SRM.K=(HISH.K+RISH.K)/CIS.K
A  CIS.K=1+STEP(STCIS,TSTCIS)
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010000
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010000
010000
010000
010000   [illegible]
[illegible]
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(93)

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C  STPMSQ=-0.25
RUN TEST#4
NOTE                            # TEST#5: GROWTH & SERVICE POLICY
                                 FOR RESELLER 75%
CP STSPR=0.75
RUN TEST#5
NOTE                            # TEST#6: GROWTH, SPR=75%, & MAN-IN-
                                 VAN PROGRAM
CP STMMIV=2
RUN TEST#6
NOTE                            # TEST#7: GROWTH, SPR=75%, MAN-IN-
                                 VAN, & DISC. PRICE 15%
CP DPPR=0.15
RUN TEST#7
```

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