A Long Term Integrated Framework Linking Urban Development, Demographic Trends and Technology Changes to Stationary and Mobile Source Emissions

A Progress Report

Alex Anas

October 27, 2008

Future Air Quality with Projected Global Changes: A Progress Review Meeting

Research Triangle Park Campus of the US EPA

Background

- RELU-TRAN was developed by Alex Anas under an award from the National Science Foundation (1999 – 2005); subsequently modified and applied under this STAR award from the USEPA (2006 – present).

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A REGIONAL ECONOMY, LAND USE, AND TRANSPORTATION MODEL (RELU-TRAN)*: FORMULATION, ALGORITHM DESIGN, AND TESTING*

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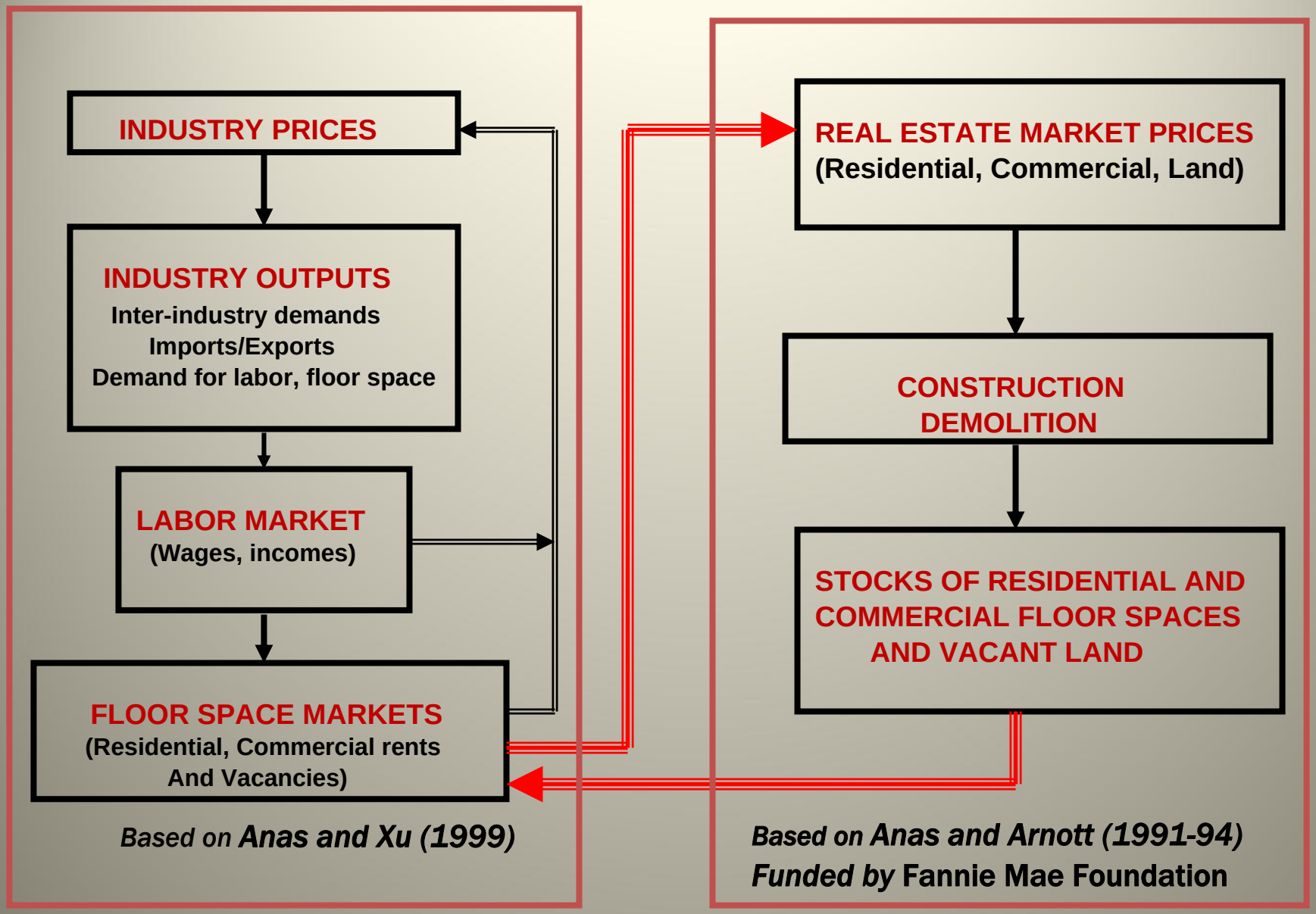
“Model integration in practice is highly demanding of technical personnel. Project deadlines, competition for funding, jitters about job security and results urgently demanded by the users of the modeling work, as well as the lack of quality standards undoubtedly contribute to faulty model integration and to the opaque documentation of the results.”

-- Anas and Liu (2007)

“Difficulties encountered with a prior assistant in the development of RELU-TRAN are highly illustrative of these issues and have been documented in Anas (2005), a project document written as a report to the SUNY Research Foundation that may be made available upon request. The report shows the types of problems that arise when faulty model integration occurs and how such faulty model integration can be presented as not being faulty, slipping by others who are unwilling or unable to scrutinize the results.” – Anas and Liu (footnote).

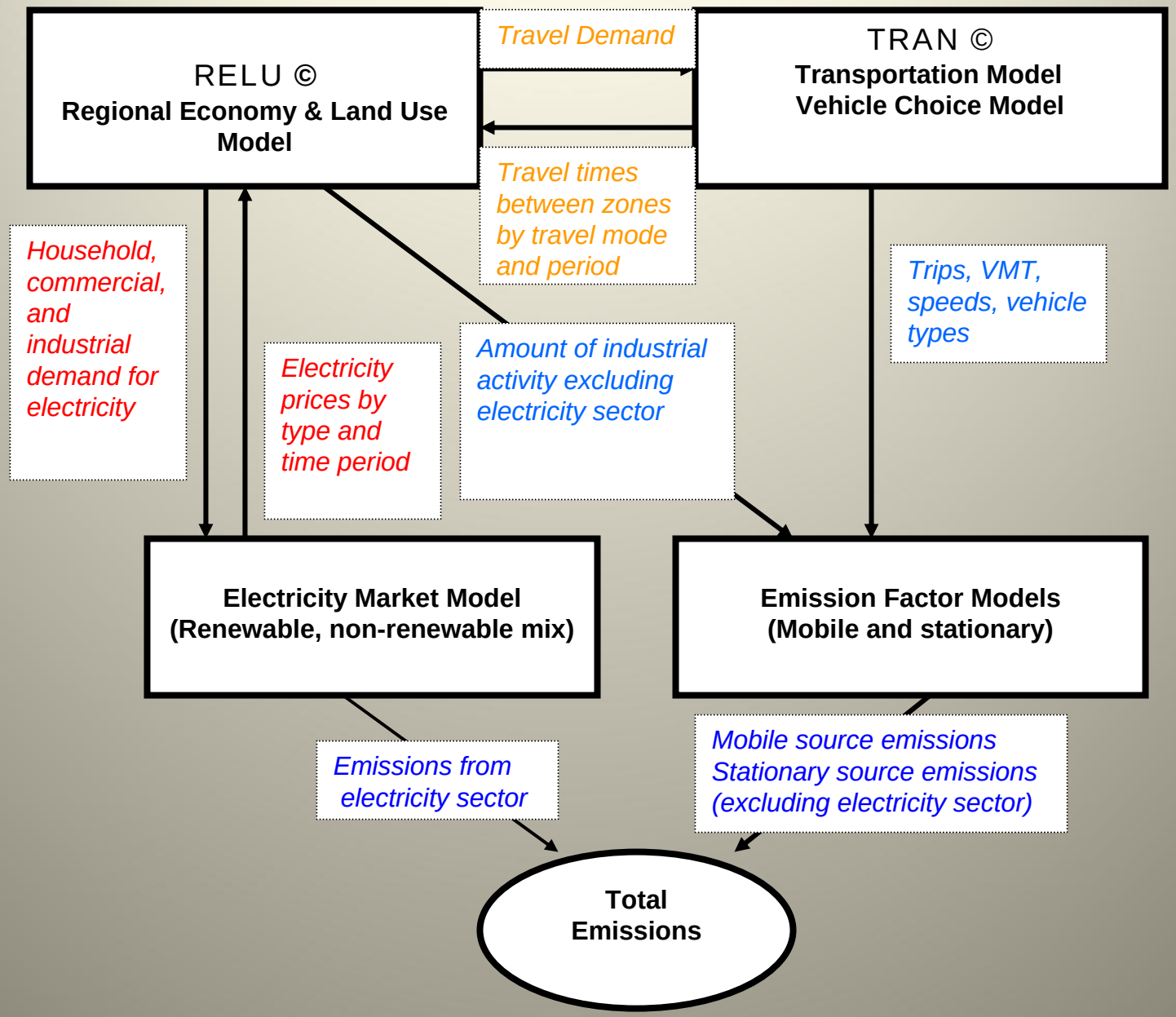
RELU-TRAN

- **RELU-TRAN is an economic equilibrium model simulating the response of real estate, labor and production markets to changes in the transportation system.**
- **It utilizes an integrated transportation and land use modeling framework based on general equilibrium analysis (from microeconomic theory).**
- **It treats income and preference heterogeneity and time and income effects in travel and location decisions.**
- **Time valuation occurs by imputed values determined by the model not assumed by the modeler.**

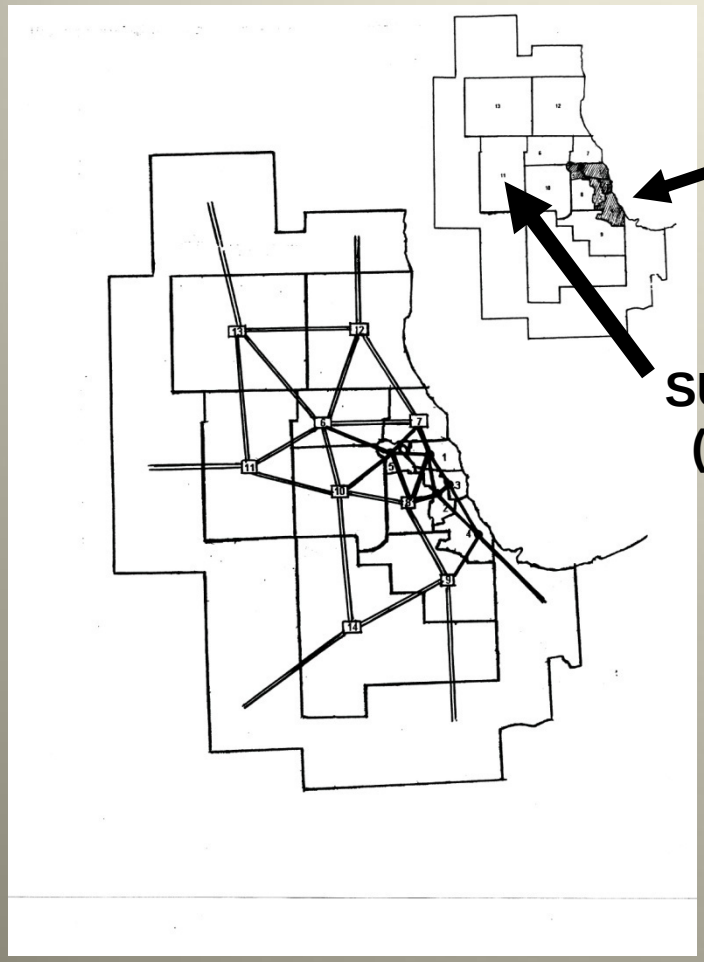


RELU© A Regional Economy and Land Use Model

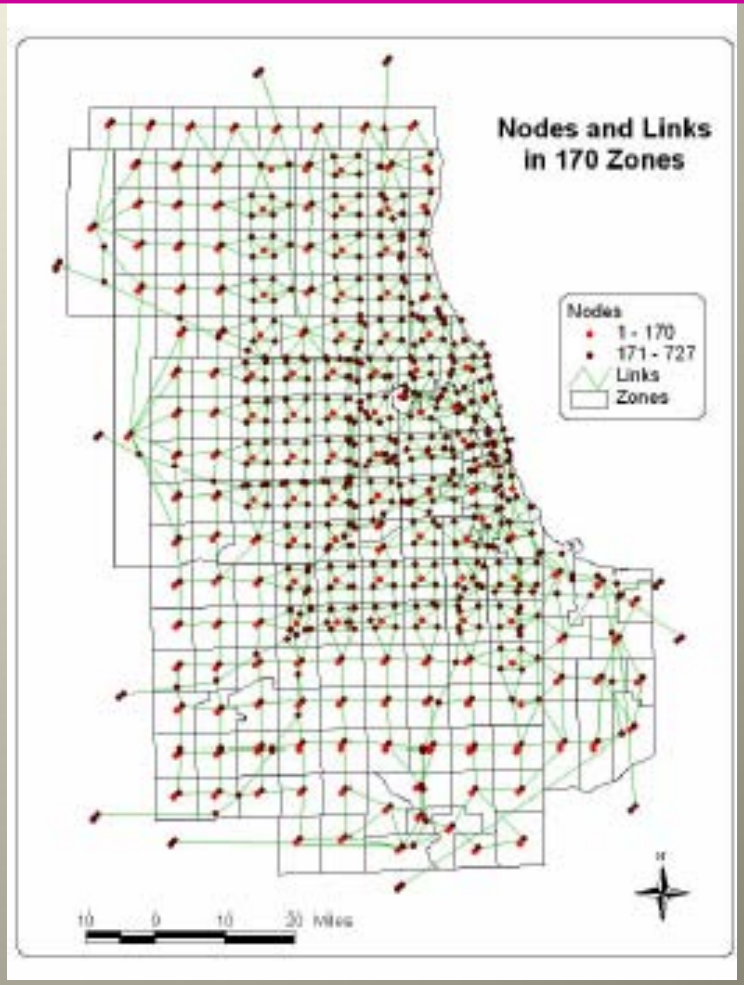
Funded by the National Science Foundation


RELU ©
Regional Economy & Land Use Model
Travel Demand
TRAN ©
Transportation Model
Vehicle Choice Model
Travel times between zones by travel mode and period
Household, commercial, and industrial demand for electricity
Electricity prices by type and time period
Amount of industrial activity excluding electricity sector
Trips, VMT, speeds, vehicle types
Electricity Market Model (Renewable, non-renewable mix)
Emission Factor Models (Mobile and stationary)
Emissions from electricity sector
Mobile source emissions
Stationary source emissions (excluding electricity sector)
Total Emissions

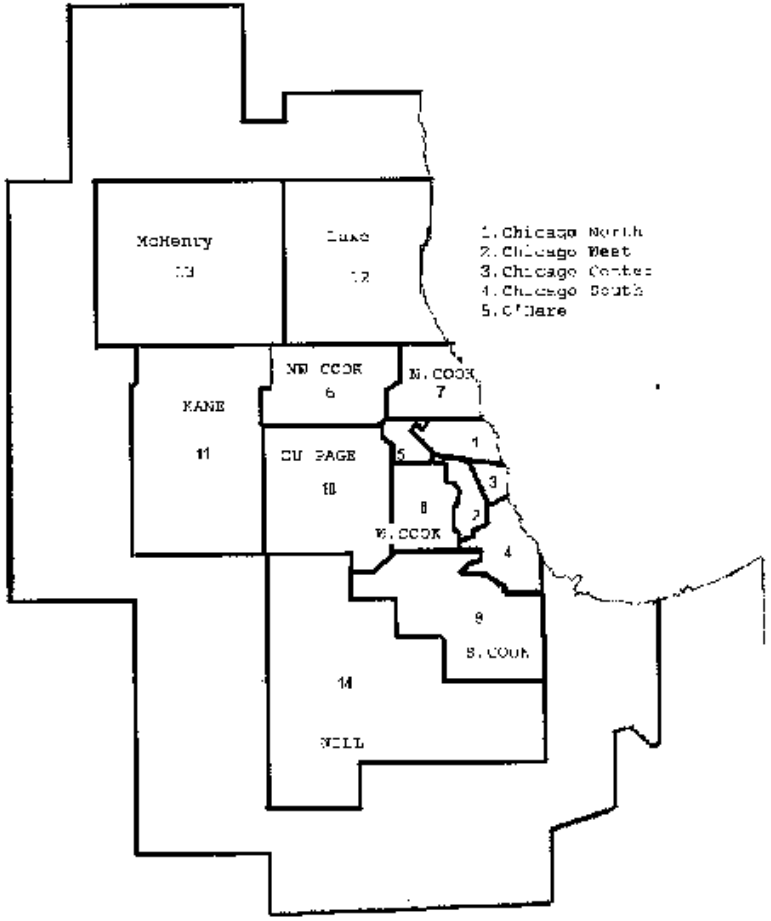
Geography:
Levels of network and zonal aggregation



CHICAGO 14+1 ZONE TEST VERSION



Larger Chicago 111+6 zones


McHenry
13
Lake
12
1.Chicago North
2.Chicago West
3.Chicago Center
4.Chicago South
5.O'Hare
KANE
11
NW COOK
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N.COOK
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DU PAGE
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S.COOK
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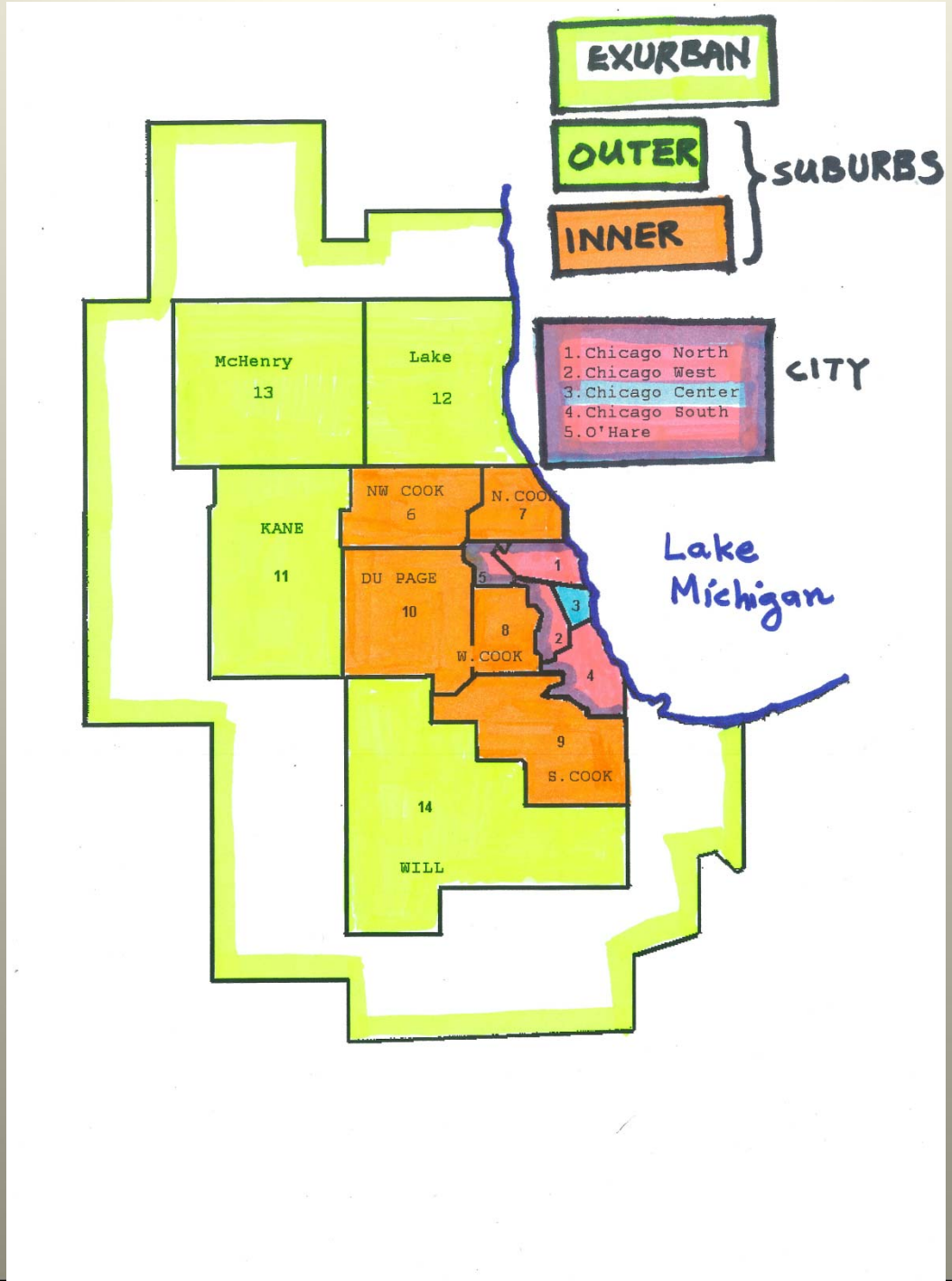
WILL


EXURBAN
OUTER
INNER
SUBURBS
1. Chicago North
2. Chicago West
3. Chicago Center
4. Chicago South
5. O'Hare
CITY
McHenry
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Lake
12
KANE
11
NW COOK
6
N. COOK
7
DU PAGE
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3
8
W. COOK
2
4
9
S. COOK
14
WILL
Lake
Michigan

Results of the RELU-TRAN Model's Application to Chicago

- ✓ Effects of congestion on location
- ✓ The cost of congestion
- ✓ Congestion pricing policies
- ✓ Population growth and urban sprawl's effect on VMT and travel
- ❖ Relationship between congestion, vehicle ownership, VMT, fuel consumption and CO2 emissions

PART I: Congestion

- Effects of congestion on locations
- The cost of congestion delays
- The effects and impacts of congestion pricing

Table 5.5: Population of Employed Residents and Employment by RELU Model Zone: Comparison of U.S. Census and RELU-TRAN Base Case, Year 2000

RELU ZONE	Population of Employed Residents (*thousands*)		Employment (*thousands*)	
	Census Data	Base case (RELU-TRAN)	Census Data	Base case (RELU-TRAN)
(1)	541	534	313	330
(2)	51	52	85	85
CHI. CBD (3)	31	31	543	537
(4)	400	400	247	237
O'HARE (5)	125	131	120	126
SUBURBANCOOK NW(6)	368	361	413	399
SUBURBAN COOK,N(7)	139	165	209	217
SUBURBAN COOK,W(8)	269	274	271	271
SUBURBAN COOK, S(9)	351	357	292	285
DU PAGE(10)	446	464	518	535
KANE (11)	180	180	169	163
LAKE (12)	297	296	313	300
MCHENRY (13)	125	121	92	93
WILL (14)	225	219	154	166
PERIPHERAL	190	159		
TOTAL	3,738	3,745	3,738	3,745

Table 5.6: Eliminating Congestion Versus Optimally Pricing Congestion:
Percentage Impacts on Population of Employed Residents and on Employment
by RELU Zone, Year 2000

RELU ZONE	Population of employed residents		Employment	
	No Congestion	Optimal Pricing	No Congestion	Optimal Pricing
(1)	-1.1	-0.6	-0.3	+1.5
(2)	+5.2	-1.3	+8.6	+3.1
CHI. CBD (3)	-5.5	-2.4	+14.4	+7.4
(4)	+19.6	+2.3	+10.7	+0.8
O'HARE (5)	-6.6	-2.7	+0.2	+1.0
SUBURBANCOOK NW(6)	-6.9	-1.6	-1.0	-4.3
SUBURBAN COOK,N(7)	+1.7	-1.1	+3.3	-1.6
SUBURBAN COOK,W(8)	-3.1	+0.4	-0.5	-2.2
SUBURBAN COOK, S(9)	-2.9	-0.7	-8.5	-1.4
DU PAGE(10)	-9.6	-0.9	-6.3	-2.4
KANE (11)	-15.3	-1.0	-9.8	+0.4LLL
LAKE (12)	-13.9	-2.6	-6.9	-3.4
MCHENRY (13)	-12.8	-1.9	-11.8	-0.6
WILL (14)	- 6.2	-1.4	-1.8	-1.9
PERIPHERAL	+75.3	+13.3		
TOTAL	0.0	0.0	0.0	0.0

Effects of Congestion and "Optimal" Pricing on Locations

- Congestion has caused the share of employment in the CBD to be lower by about 14% and about 7% lower in the Central City, while increasing CBD population.

- "Optimal" congestion pricing would bring back about half of the decentralized CBD employment

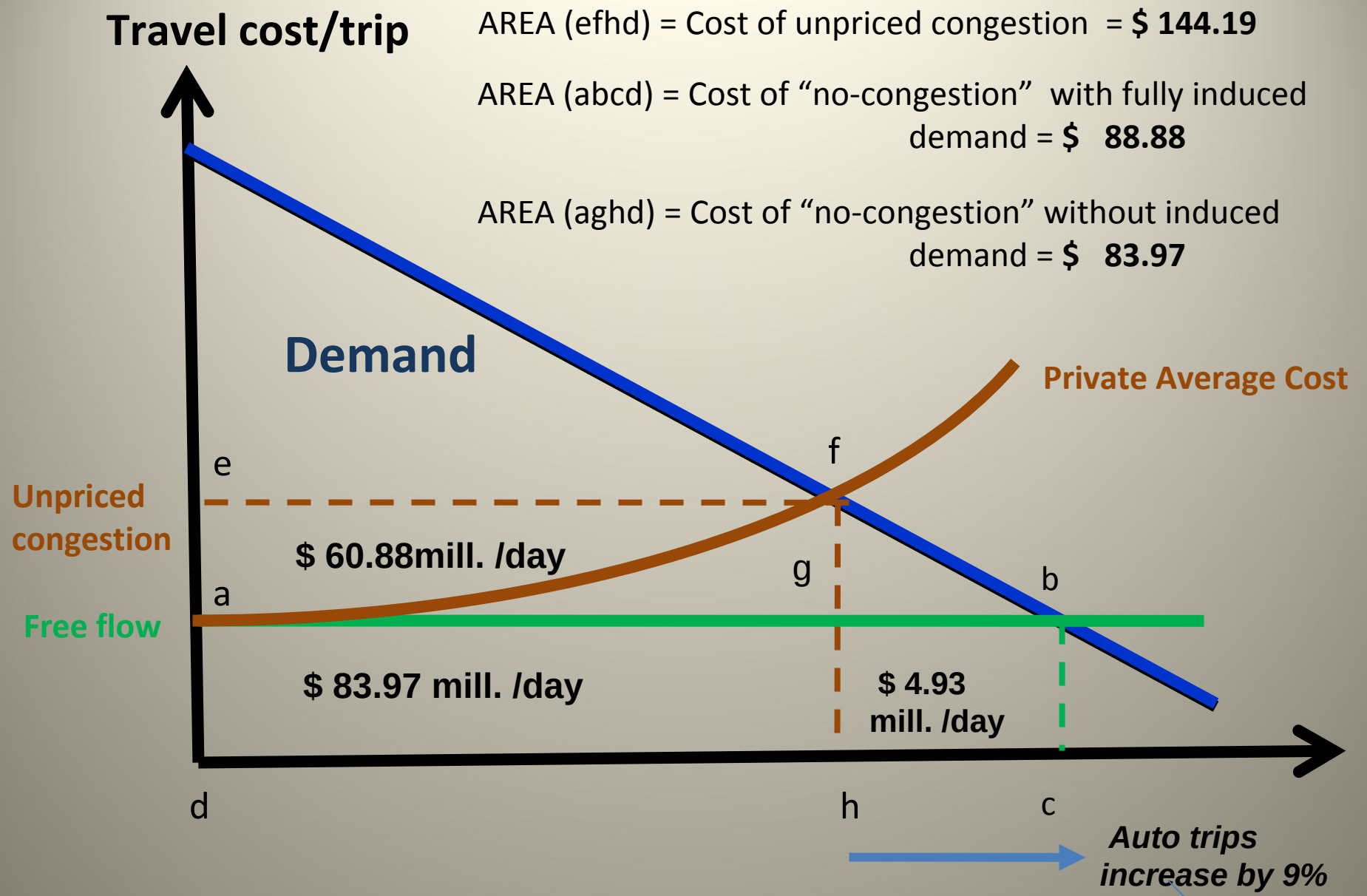

FIGURE 1: Illustration of aggregate delays

Distribution of the cost of delay by auto passenger's income quartile

2000	Shares of total time lost (%)					Shares of total delay costs (%)			
	Q 1	Q 2	Q 3	Q 4		Q 1	Q 2	Q 3	Q 4
Un-priced	8.9	21.3	29.0	40.8	Un-priced	3.2	12.0	22.2	62.6
CBD Cordon	8.8	20.3	28.4	42.5	CBD Cordon	3.1	11.2	21.4	64.3
Tolls	11.5	21.6	28.4	38.5	Tolls	4.3	12.7	22.5	60.5

- **The unequal sharing reflects unequal commuting distances, and wages imputed by the model, as both increase with income, and lower income has a larger share of unemployed who do not commute and use more transit.**

Pricing Policies Tested for 2000

- **Optimized cordon toll around CBD on incoming traffic resulted in a toll of $ 13 per crossing and an annual toll revenue of $497 million per year.**

- **Tolling all major roads resulted in $ 591 average annual tolls per capita, or $ 2.7 billion annual toll revenue, about 10% of the cost of travel by auto and six times more than the cordon case.**

POLICY or SCENARIO, year 2000 CHICAGO, MSA	TOTAL ANNUAL TOLLS ($ million)	PER CAPITA TOLLS ($)	DAILY COST OF AUTO TRIPS (% change from un-priced)		
			TOTAL ($ million)	$ PER WORKER	$ PER CAR PASSENGER
BASE CASE					
UNPRICED CONGESTION	N/A	N/A	144.186	38.50	23.82
POLICIES TESTED					
CBD CORDON	497.305	106.	128.877 (-10.62)	34.42 (-10.59)	21.96 (-7.82)
TOLLING OF MAJOR ROADS	2,772.020	591	109.583 (-24.00)	29.31 (-23.88)	19.73 (-17.17)

PART II: Growth, Sprawl & Travel

- How will the future projected growth affect the development of city and suburbs, congestion, VMT and travel time ?

- How will the burden of congestion evolve with the growth of the area ?

Figure 6.1: Drivers of Growth 2000-2030

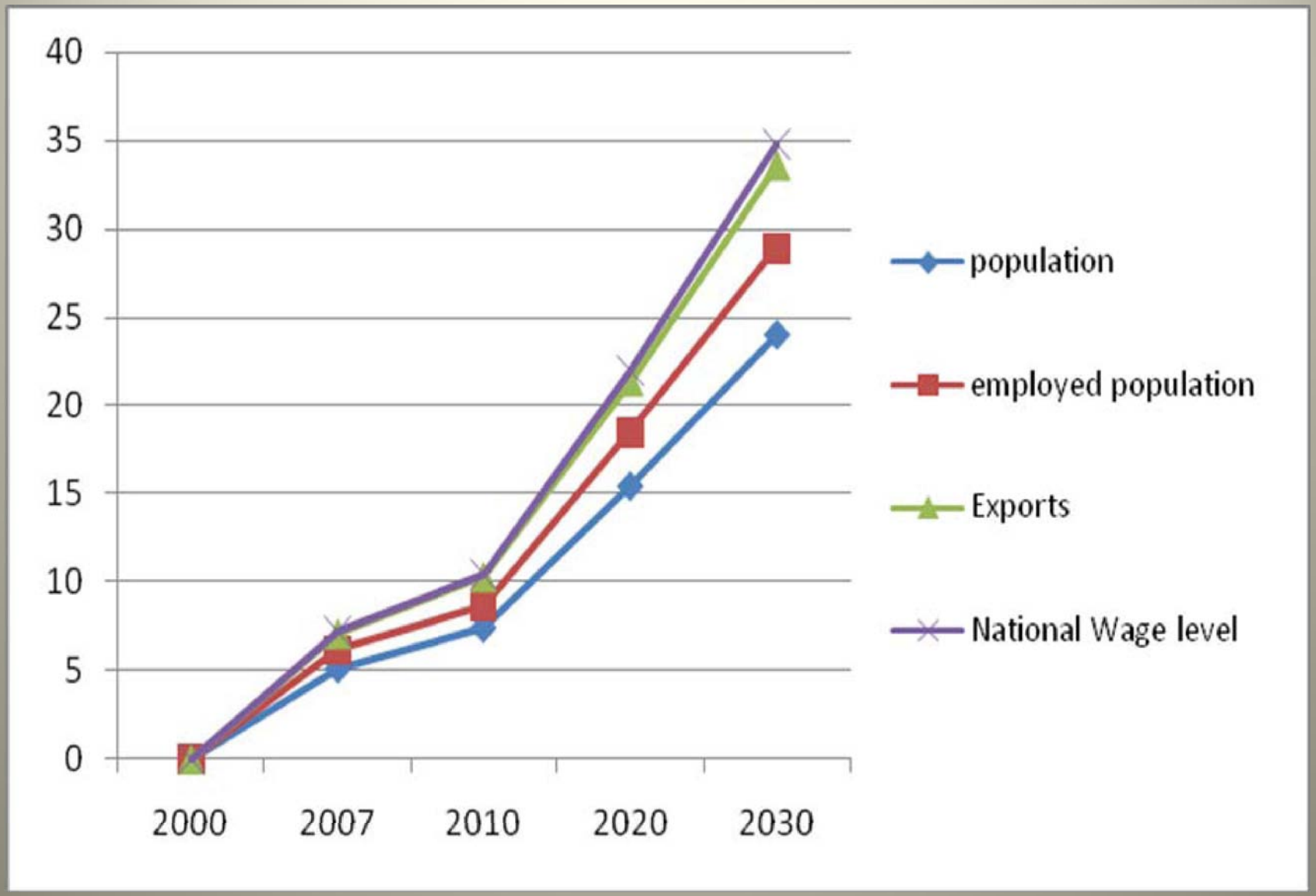

FIGURE 3: GROWTH BY YEAR 2000-2030

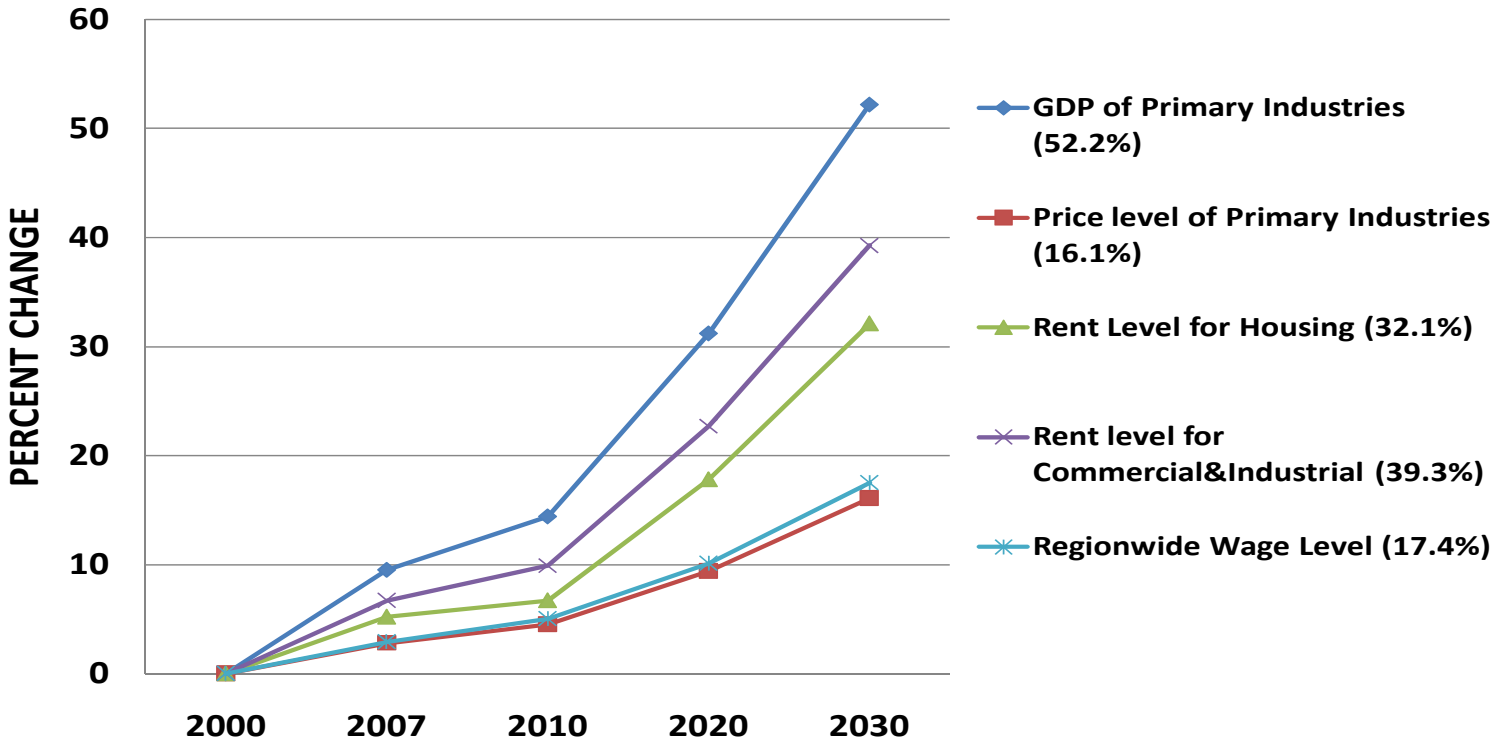

Figure 6.6: The Effect of Growth on Residence Location

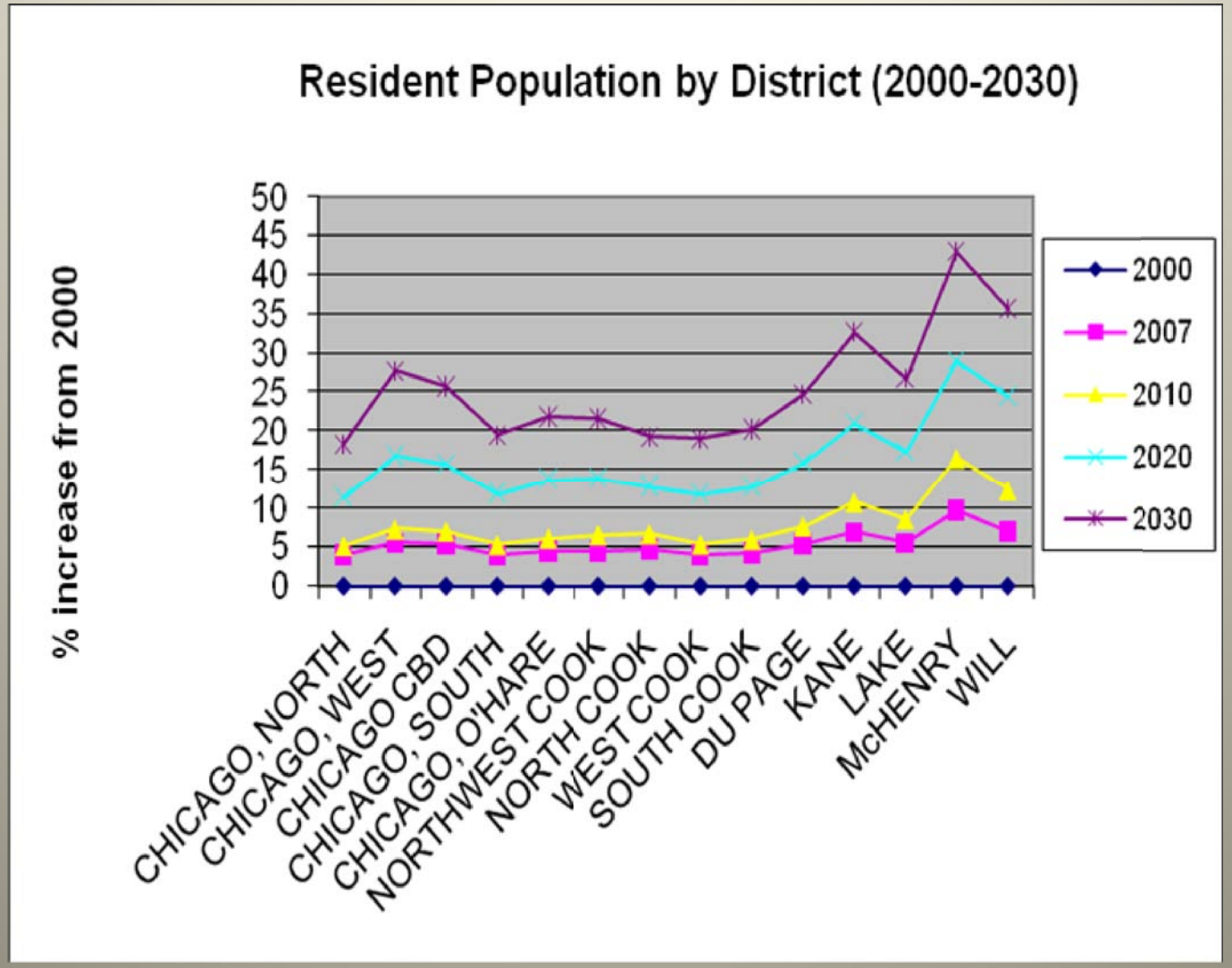

Figure 6.7: The Effect of Growth on Job Locations

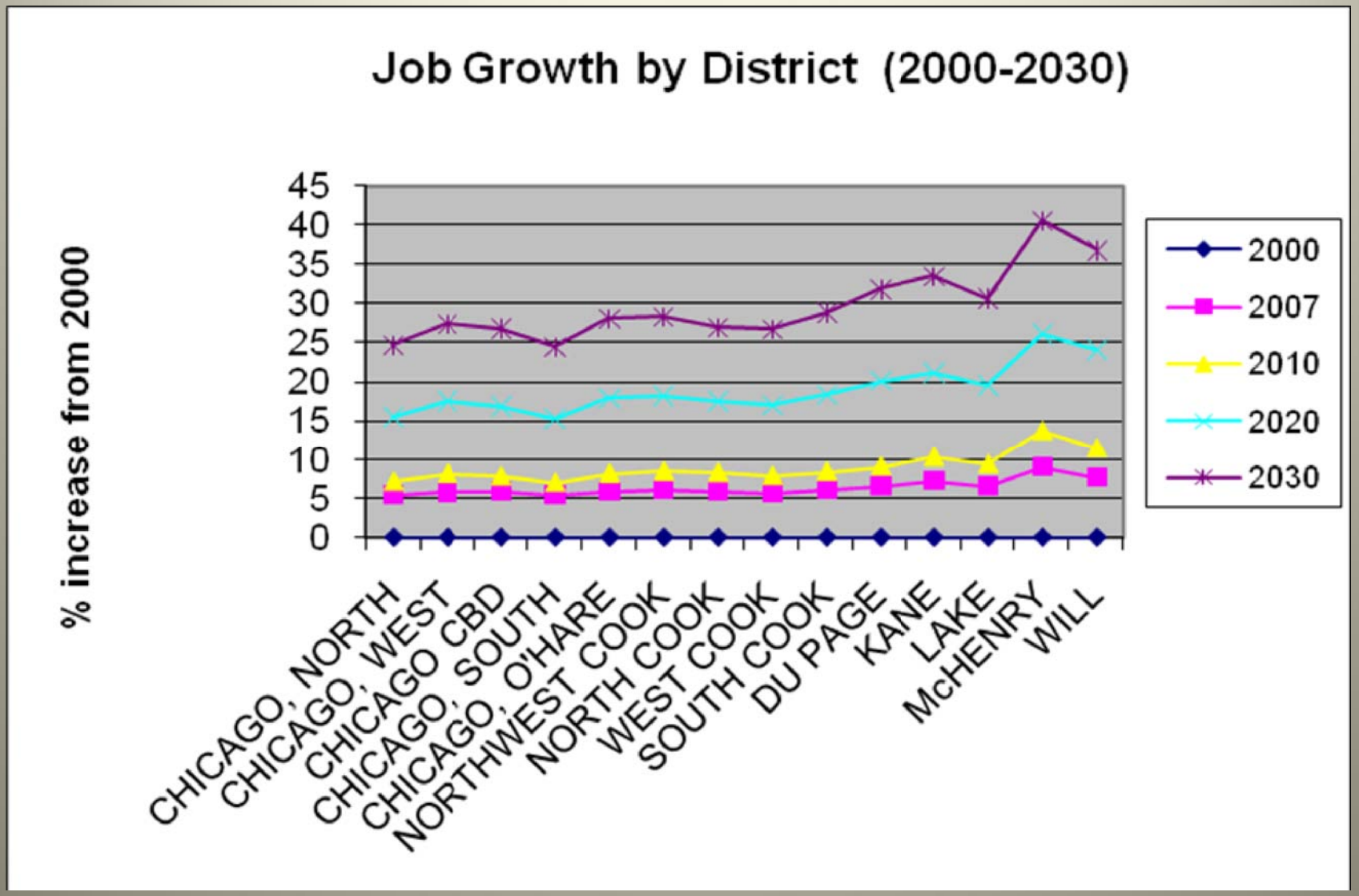

Figure 6.4: Real Estate Growth (2000-2030)

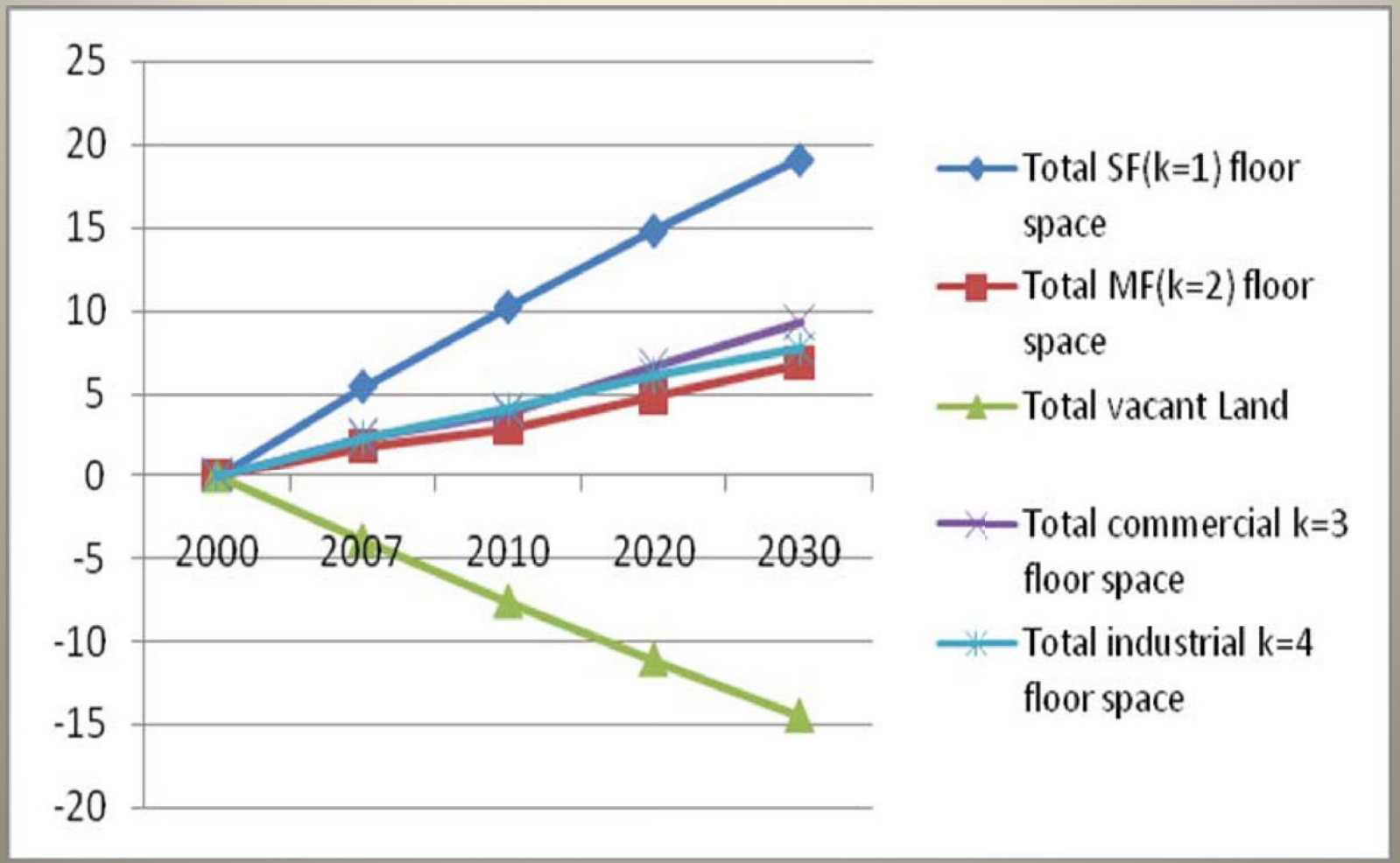

Figure 6.5: Income Growth (2000-2030)

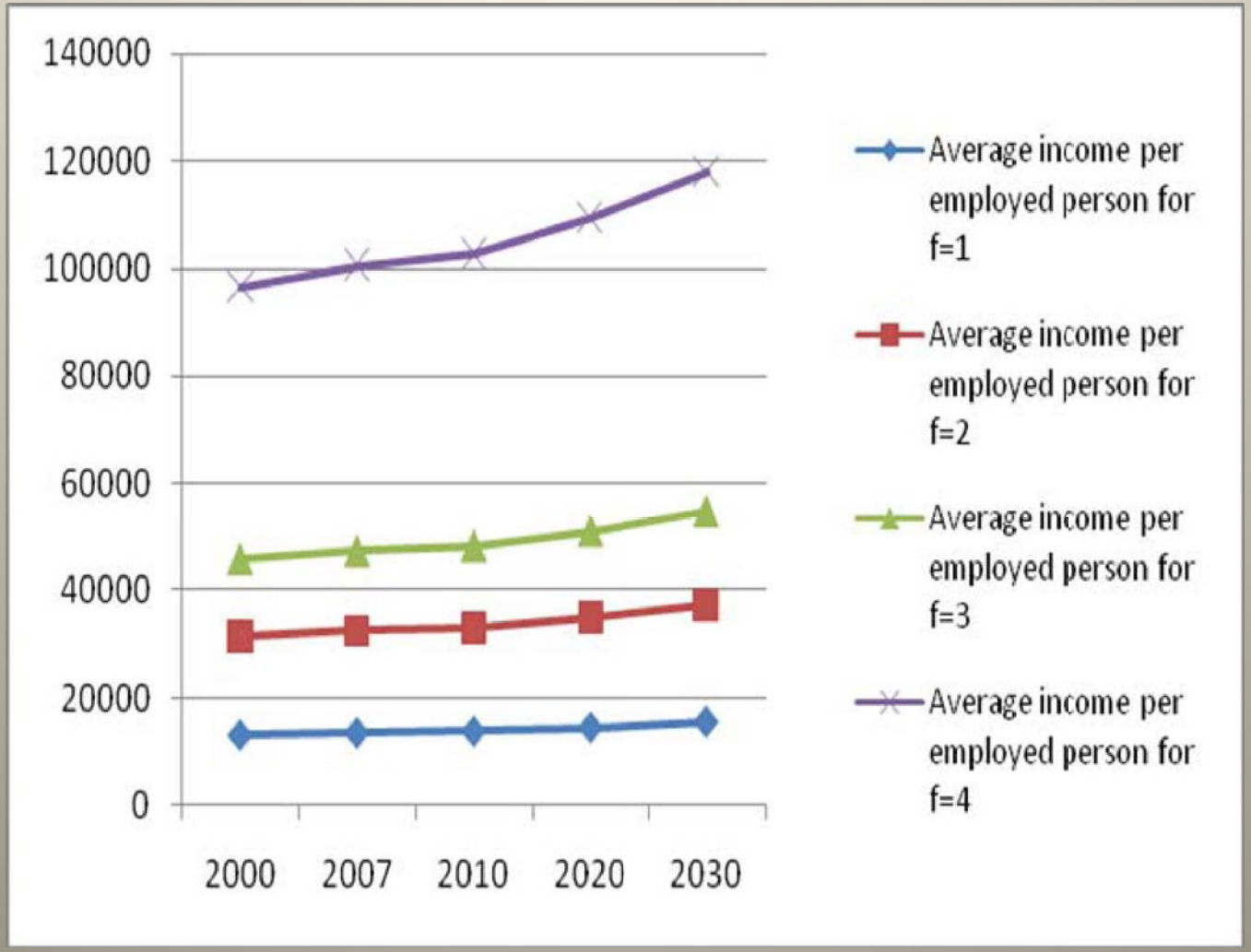

Figure 6.8: The Change in the Aggregate and Per Capita VMT Traveled Without Highway Capacity Additions

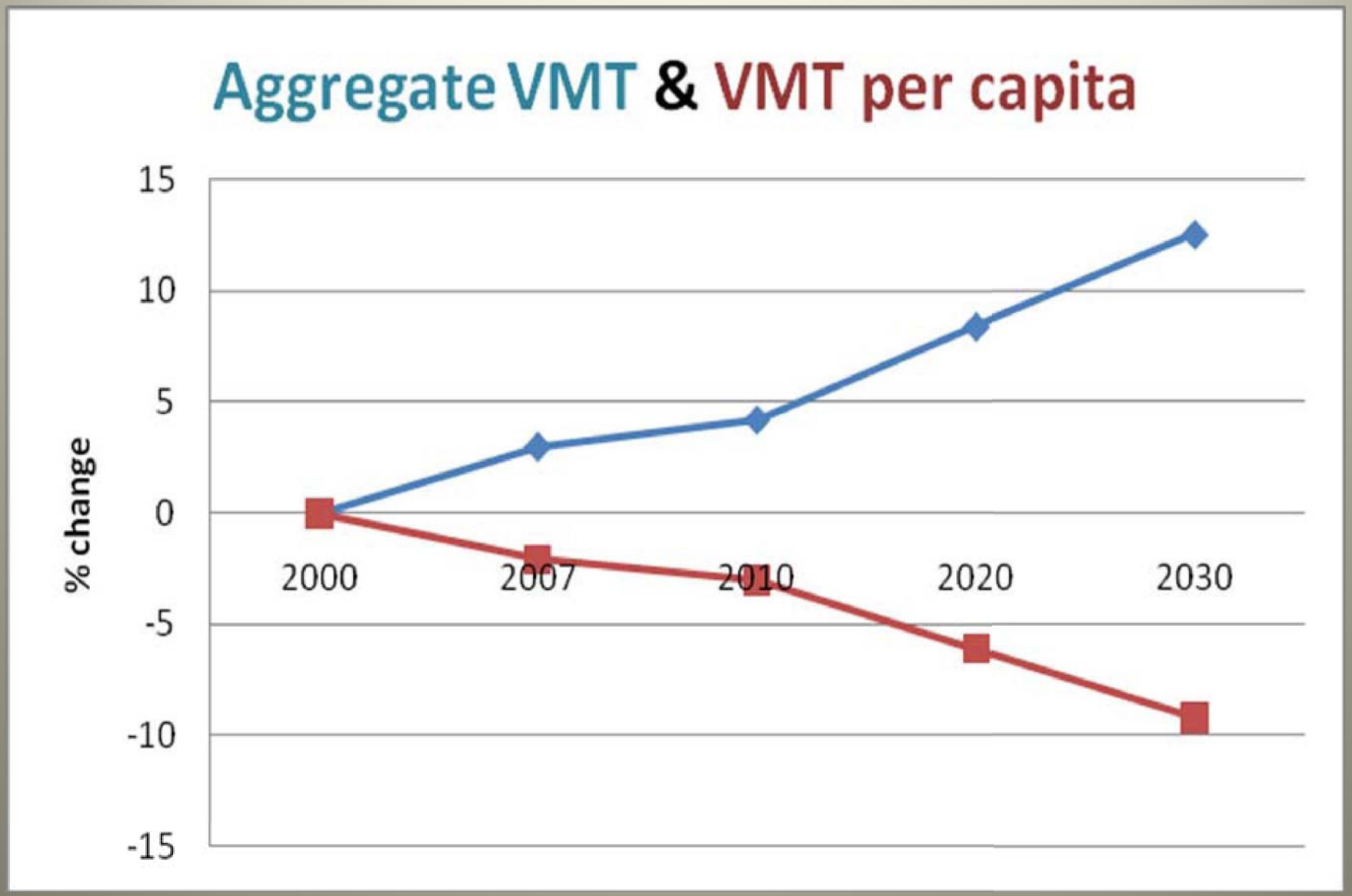

Figure 6.9: The Change in the Aggregate and Per Capita VMT Traveled With Highway Capacity Additions

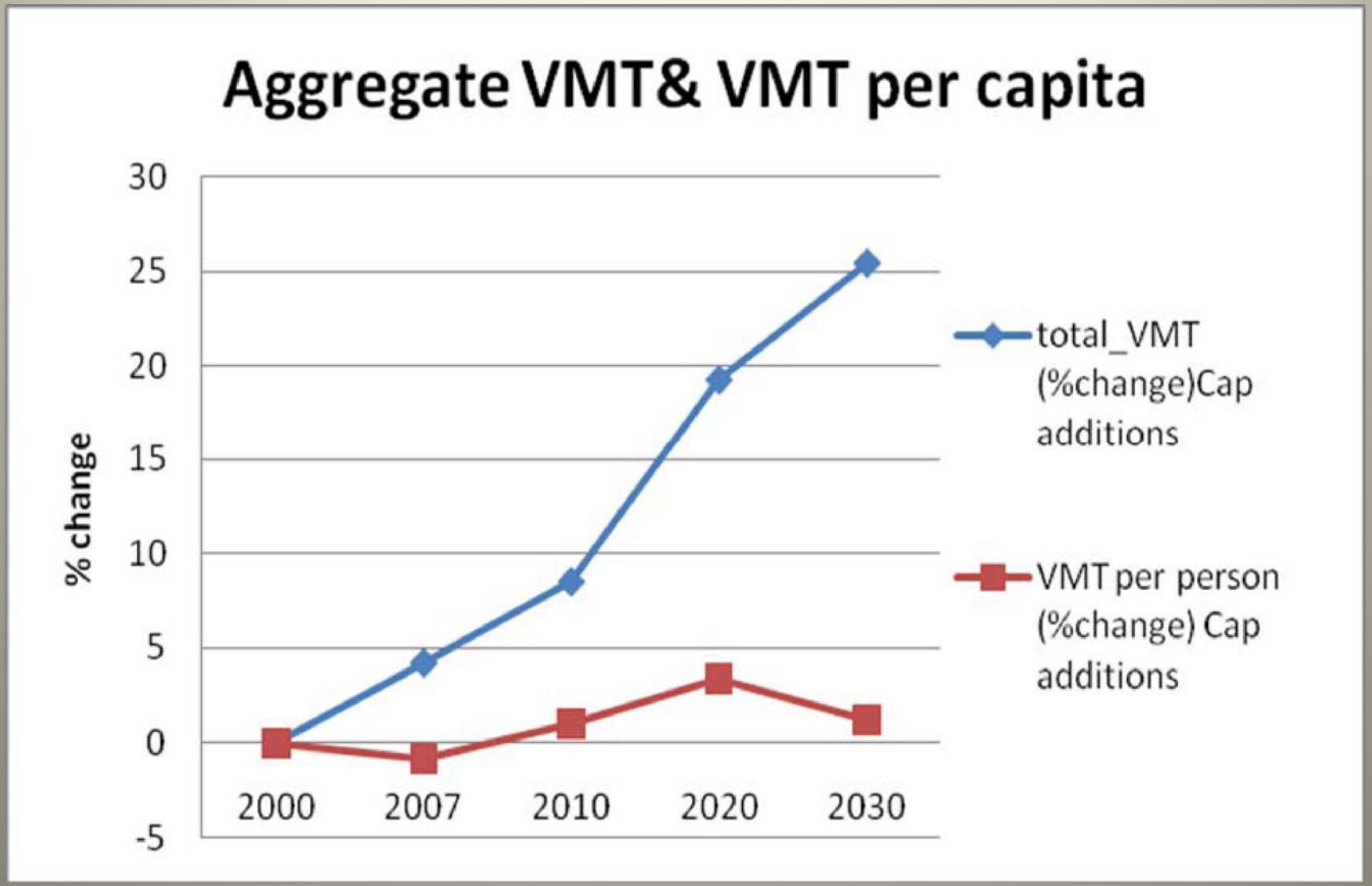

Figure 6.7: The Constancy of Average Commuting Travel Time by Car, Despite Population Growth and Increasing Sprawl

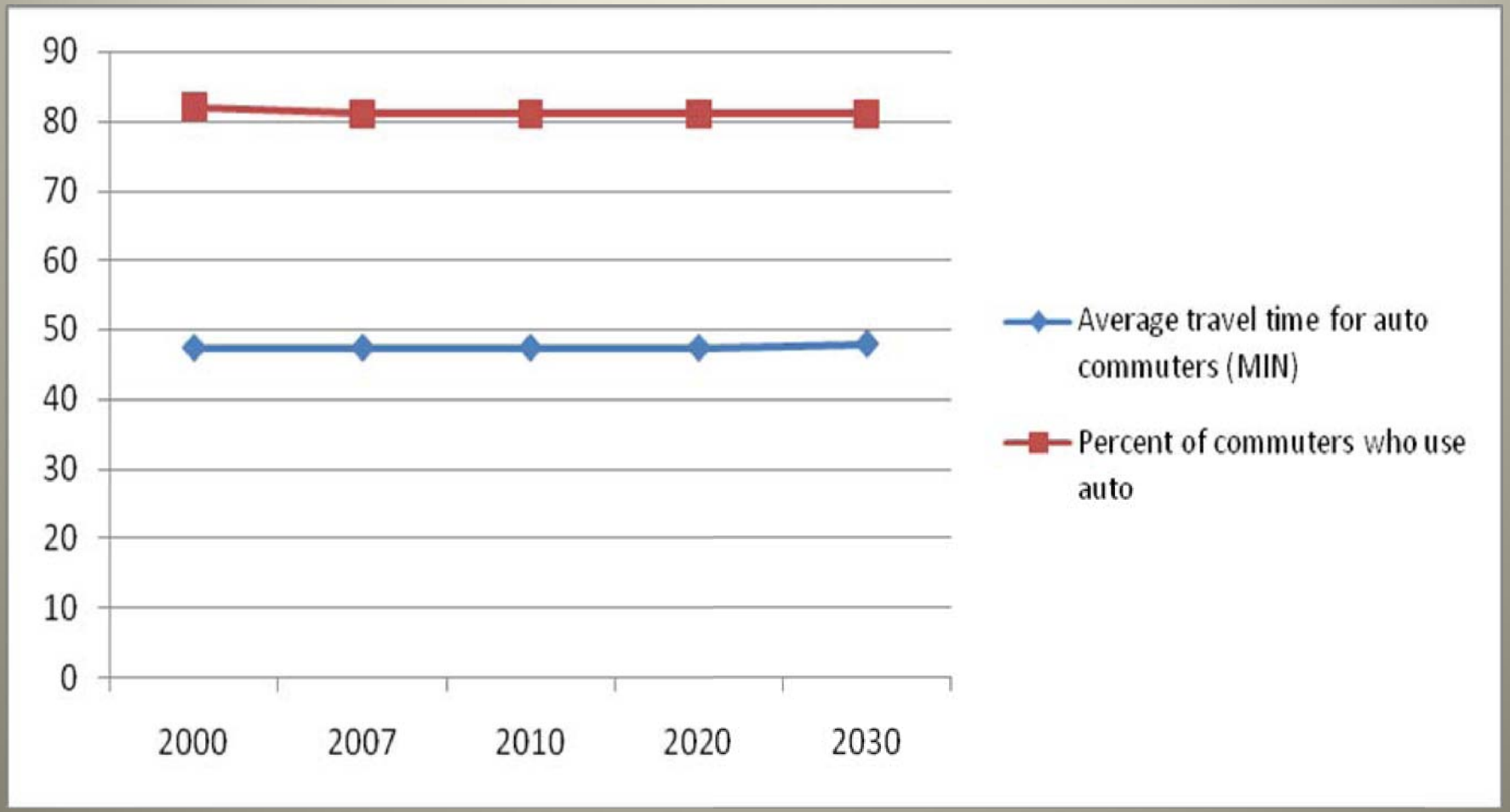

Table 6.5: The Daily Cost of Congestion on Chicago Region Roads Over Time (2000-2030): Estimates and Forecasts (*$ million/day*)

Cost of travel	2000	2007	2010	2020	2030
Free-flow	89.00	96.72	100.91	114.79	132.8
Optimal Tolls	109.71	119.18	124.15	140.93	162.62
Cordon Toll	129.73	141.76	147.12	167.25	195.34
Base	144.36	157.9	164.02	186.78	218.09
Cost of congestion					
Cost of Base relative to Optimal tolling	34.65	38.72	39.87	45.85	55.47
As % of income	**5.6%**	**5.7%**	**5.7%**	**5.7%**	**5.9%**
Cost of Base relative to Cordon Tolling	14.63	16.14	16.90	19.53	22.75
As % of income	1.5%	1.5%	1.5%	1.5%	1.6%

Table 6.6: Revenues From Tolls Under the Two Policies by Year

	OPTIMAL TOLLING OF MAJOR ROADS		OPTIMIZED CORDON TOLL ($ 13/crossing in year 2000 dollars)	
	$year/1000	$ per cap/year	$ year/1000	$ per Cap/year
2000	2,771,788	590.89	498,667	106.31
2007	2,961,168	600.36	518,532	105.13
2010	3,010,840	597.44	529,507	105.07
2020	3,265,682	603.17	563,881	104.15
2030	3,582,800	615.96	589,393	101.33