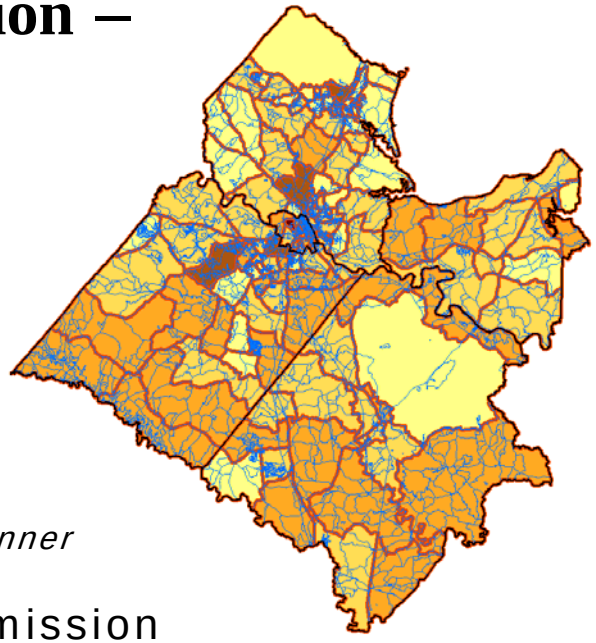
CUSIM-M:

Competing-destinations Urban SImulation Model in MATLAB

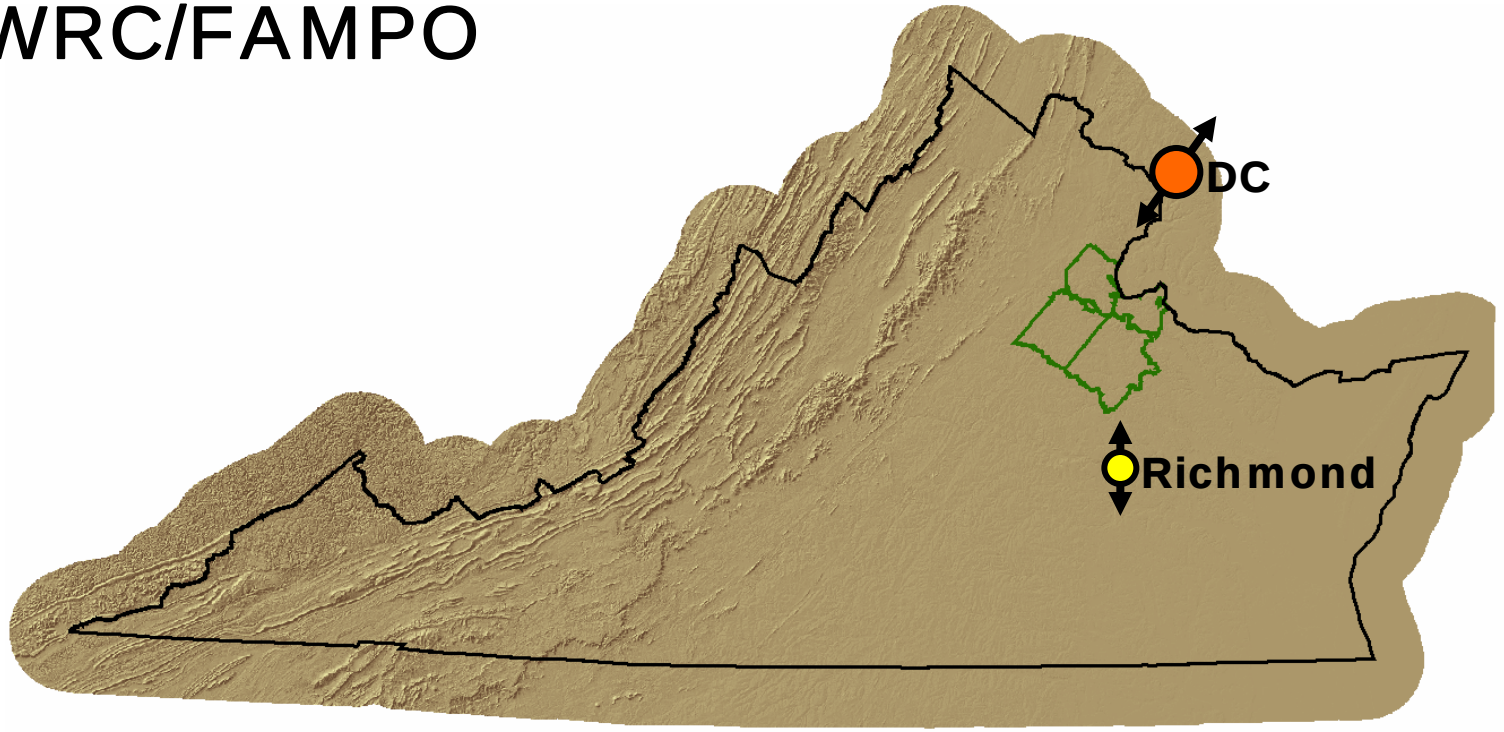
– A Forecasting Tool for Spatial Distribution of Employment and Population –



David Jung-Hwi LEE, *Regional Planner*

George Washington Regional Commission
Fredericksburg Area MPO

GWRC/FAMPO



Virginia: 21 Planning District Commissions
PD16 GWRC PDC vs. FAMPO (Mid/small size MPO)

Stafford, Spotsylvania, King George, Caroline, and Fredericksburg City

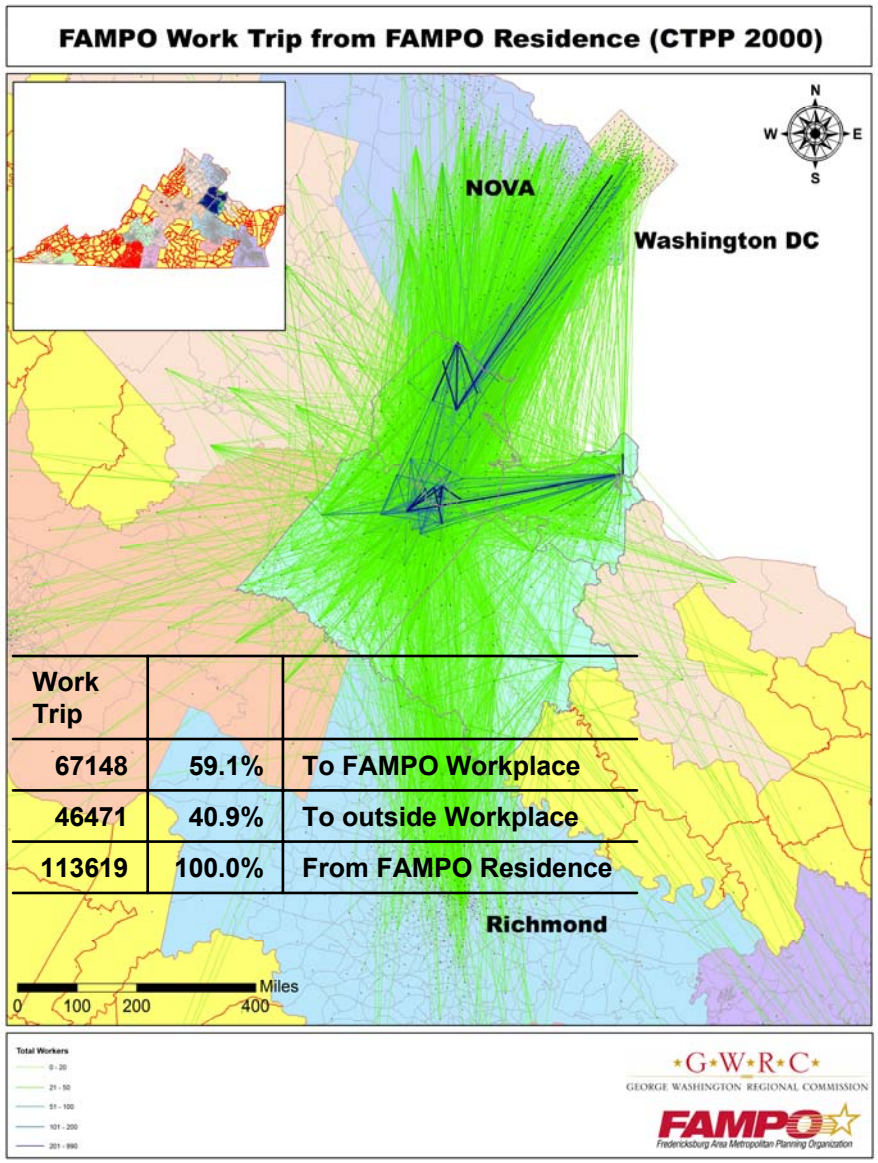
I-95

Population: 309,763 (2006)

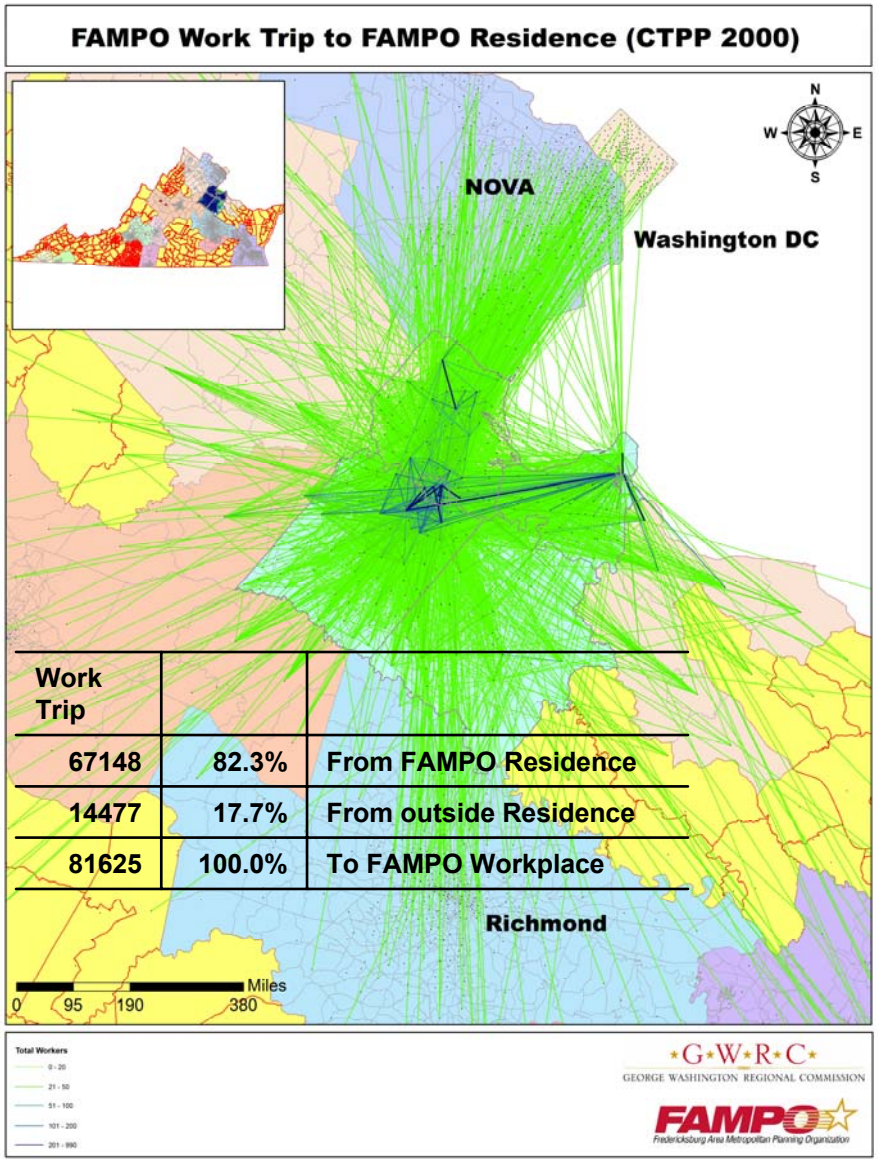
Employment: 113,501 (2006)

TAZ: 802 zones

2000 GWRC/FAMPO Work Trip Patterns

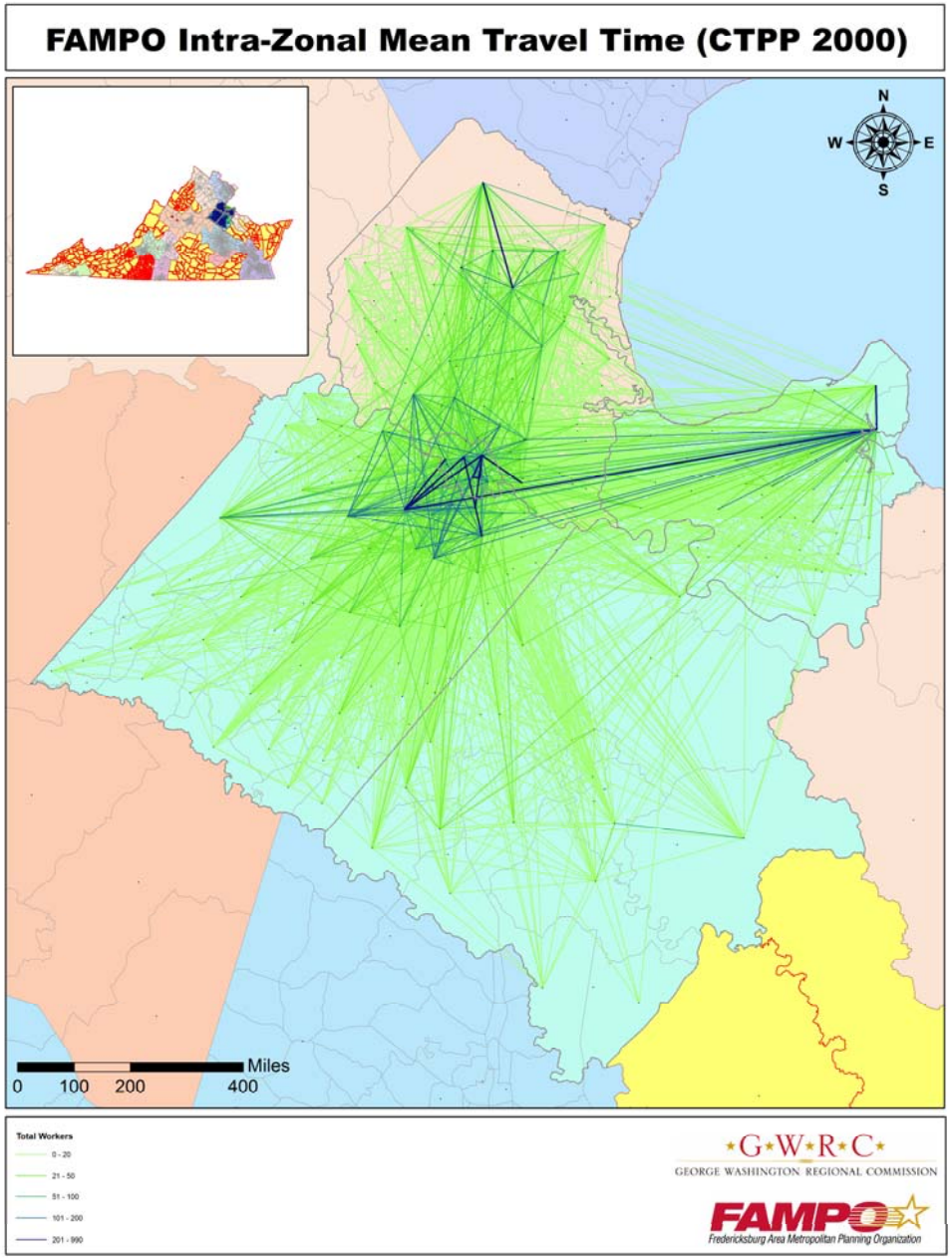


Work Trip		
67148	59.1%	To FAMPO Workplace
46471	40.9%	To outside Workplace
113619	100.0%	From FAMPO Residence

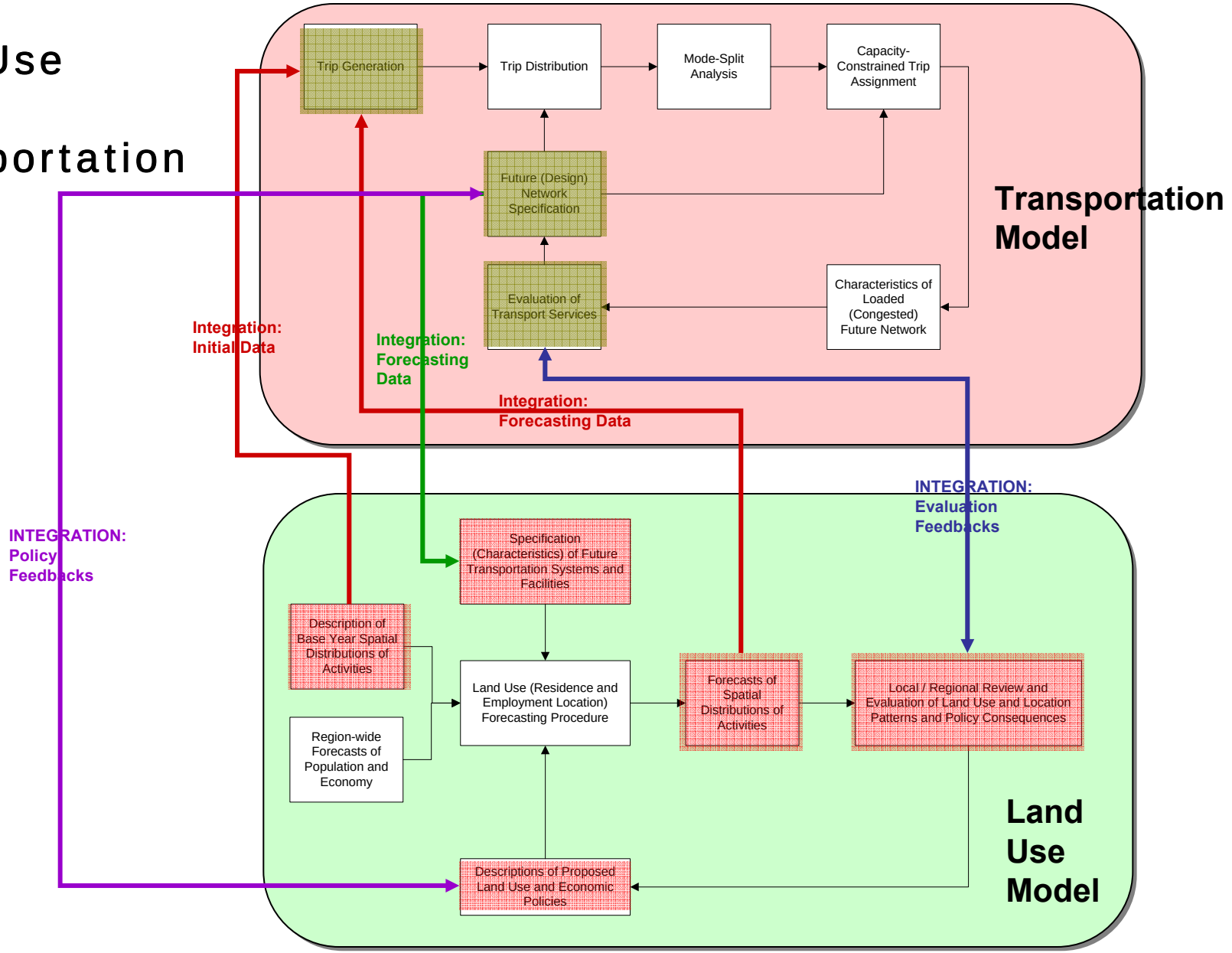


Work Trip		
67148	82.3%	From FAMPO Residence
14477	17.7%	From outside Residence
81625	100.0%	To FAMPO Workplace

2000 GWRC/FAMPO Work Trip Patterns (Intra Only)

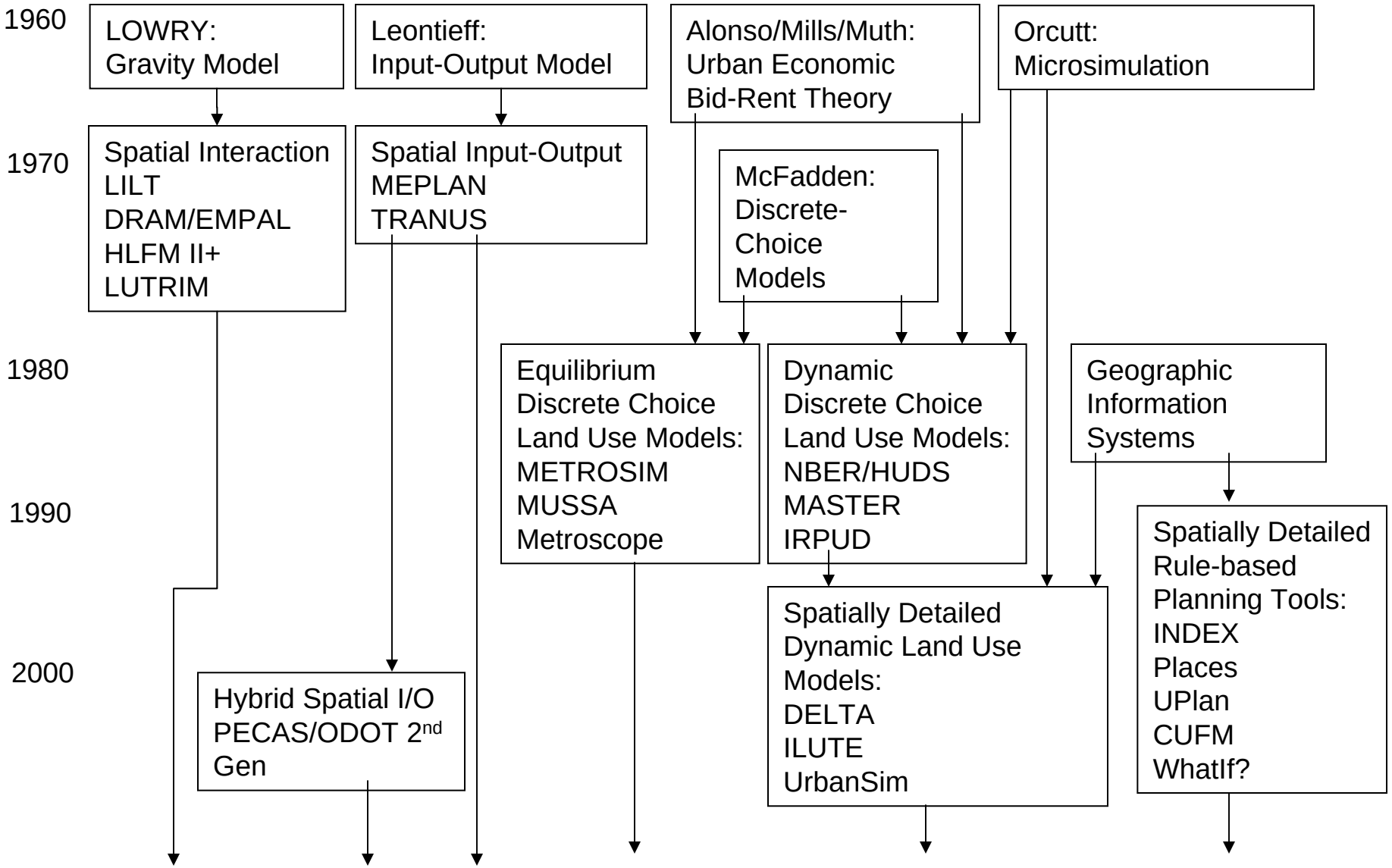


Integration of Land Use and Transportation



Land Use Modeling Frameworks

From Waddell 2005



Integration of Land Use and Transportation

• Land Use

- Macro: Spatial Interaction Models
  - TELUM, Metropilus, ITLUP, DRAM/EMPAL/LANCON (S.H. Putman)
  - CUSIM-M / CUSIM-C++ / CUSIM-G (David J-H. LEE)
- Linear Programming Models
  - TOPAZ
- Input-Output
  - TRANUS (De La Barra)
  - MEPLAN (Echenique)
  - PECAS (J.D. Hunt)
- Micro: Economic Based Approaches
  - MUSSA (Francisco Martinez C.)
  - METROSIM (Alex Anas)
  - METROSCOPE (Portland Metro)
  - UrbanSIM (Paul Waddell)
  - DELTA (D. Simmonds)

• Transportation

- Four Step Modeling
  - CUBE/Voyager Travel Demand Model (TDM)
  - TransCAD Travel Demand Model (TDM)
- Activity Based Approach

MODEL SEARCH :
Aggregate vs. Disaggregate: Zonal System

- TAZ: small enough?

- Zonal Scale
  - Broadbent's Rule
  - Sikdar (1982, 1984)
  - Steel and Holt (1996)
  - Norner and Murray (2002)
  - Gitlesen (2004)

  as disaggregate as possible

- GIS & Microsimulation:

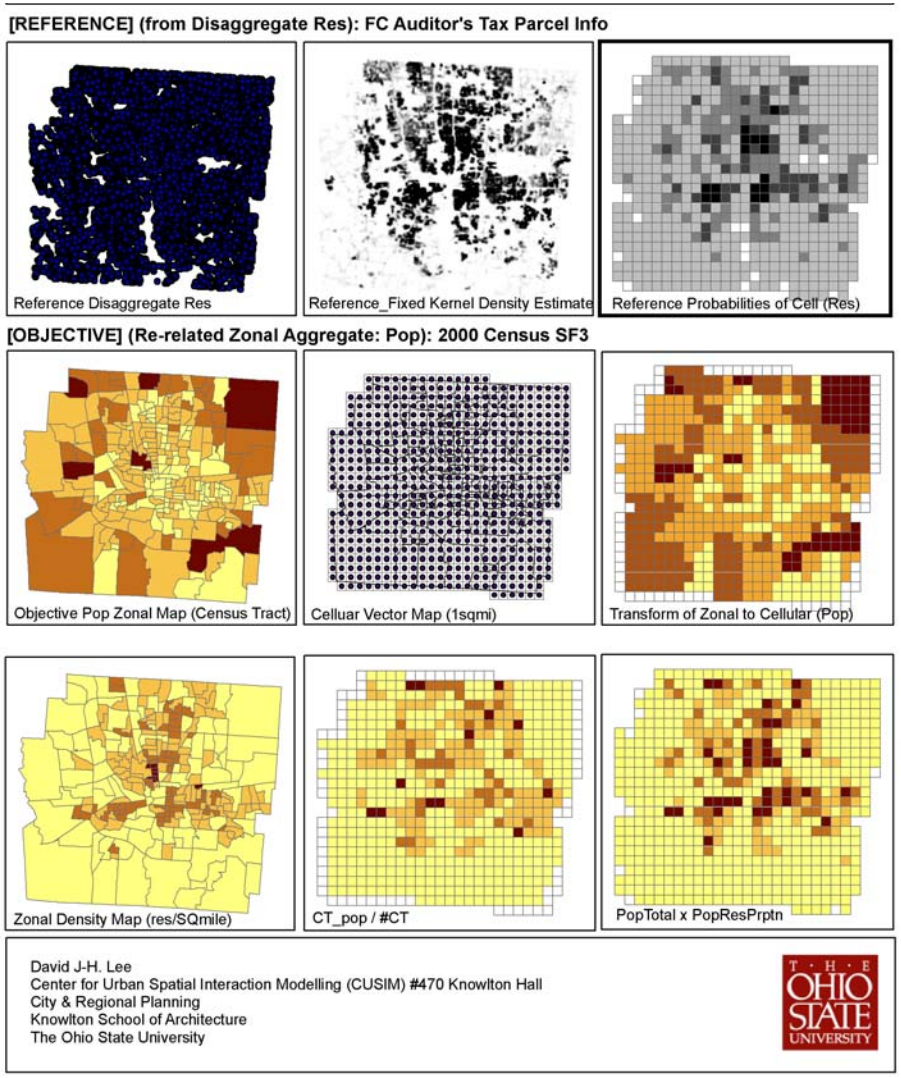
  models the behavior of individuals
  - Dissagregate data; DBMS
  - Fotheringham & Wegener (2000)
  - Spiekermann & Wegener (1996)
  - Landis & Zhang

- GWRC data:

  Limited parcel layer availability

  Geocoding: TAZ level accuracy

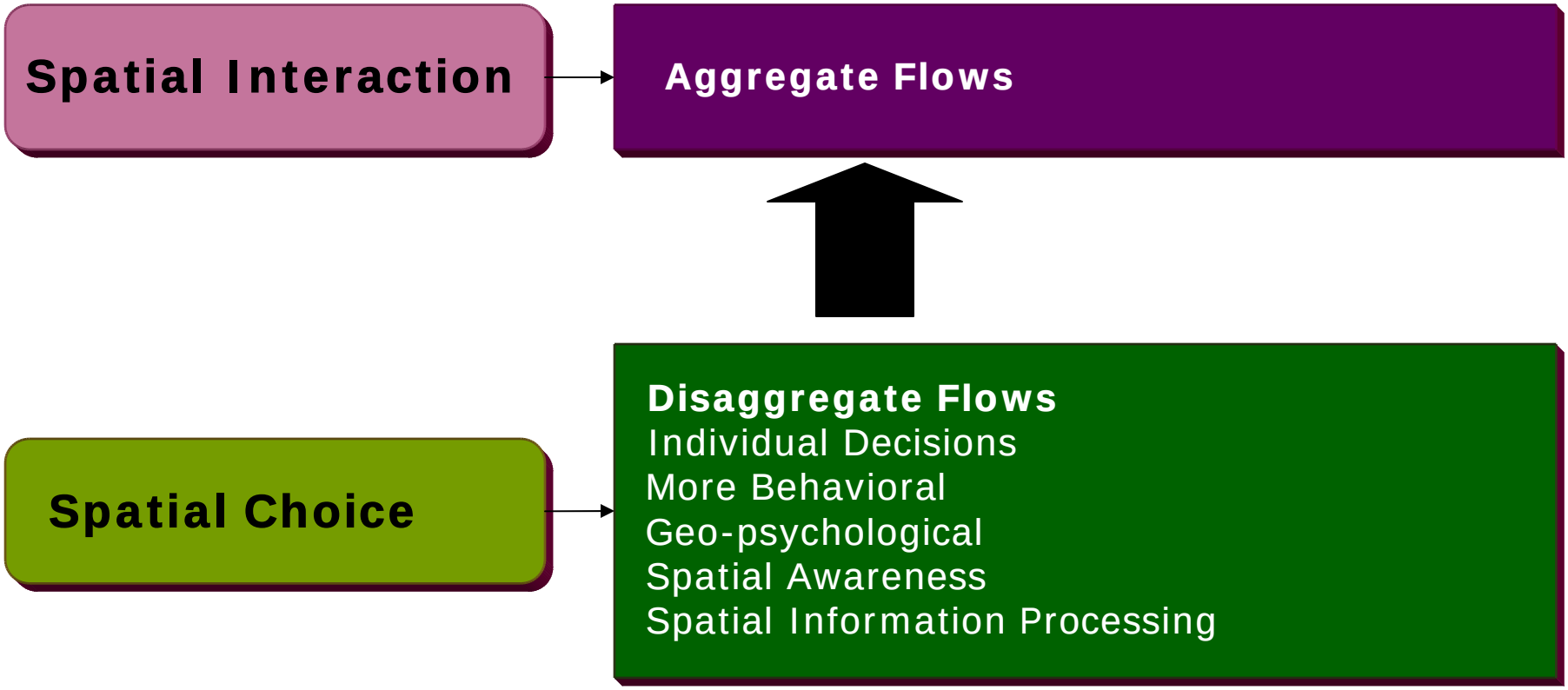
  Thiessen Polygon



Vector grid zonal system example

MODEL SEARCH :
Aggregate or Disaggregate ?

Fotheringham and O'Kelly (1989)



MODEL SEARCH :
Spatial interaction modeling (SIM)

(1) spatial interaction as social physics

Newtonian gravity model
Lowry model
Extensions of Lowry model

(2) spatial interaction as statistical mechanics

Wilson's entropy maximizing procedure
family of spatial interaction models
Alonso's (1973; 1978) framework
Additive Version of Family of SIM by Tobler

(3) spatial interaction as aspatial information processing

(4) spatial interaction as spatial information processing

Fotheringham 2000

MODEL SEARCH :
Spatial interaction modeling (SIM)

(1) spatial interaction as social physics

(2) spatial interaction as statistical mechanics

(3) spatial interaction as aspatial information processing

discrete choice models by McFadden
LOGIT formulation (1974; 1978; 1980)
Two undesirable properties
- independence from irrelevant alternatives (IIA)
- regularity

(4) spatial interaction as spatial information processing

Nested Logit
Competing Destinations model
No more IIA and Regularity

Fotheringham 2000

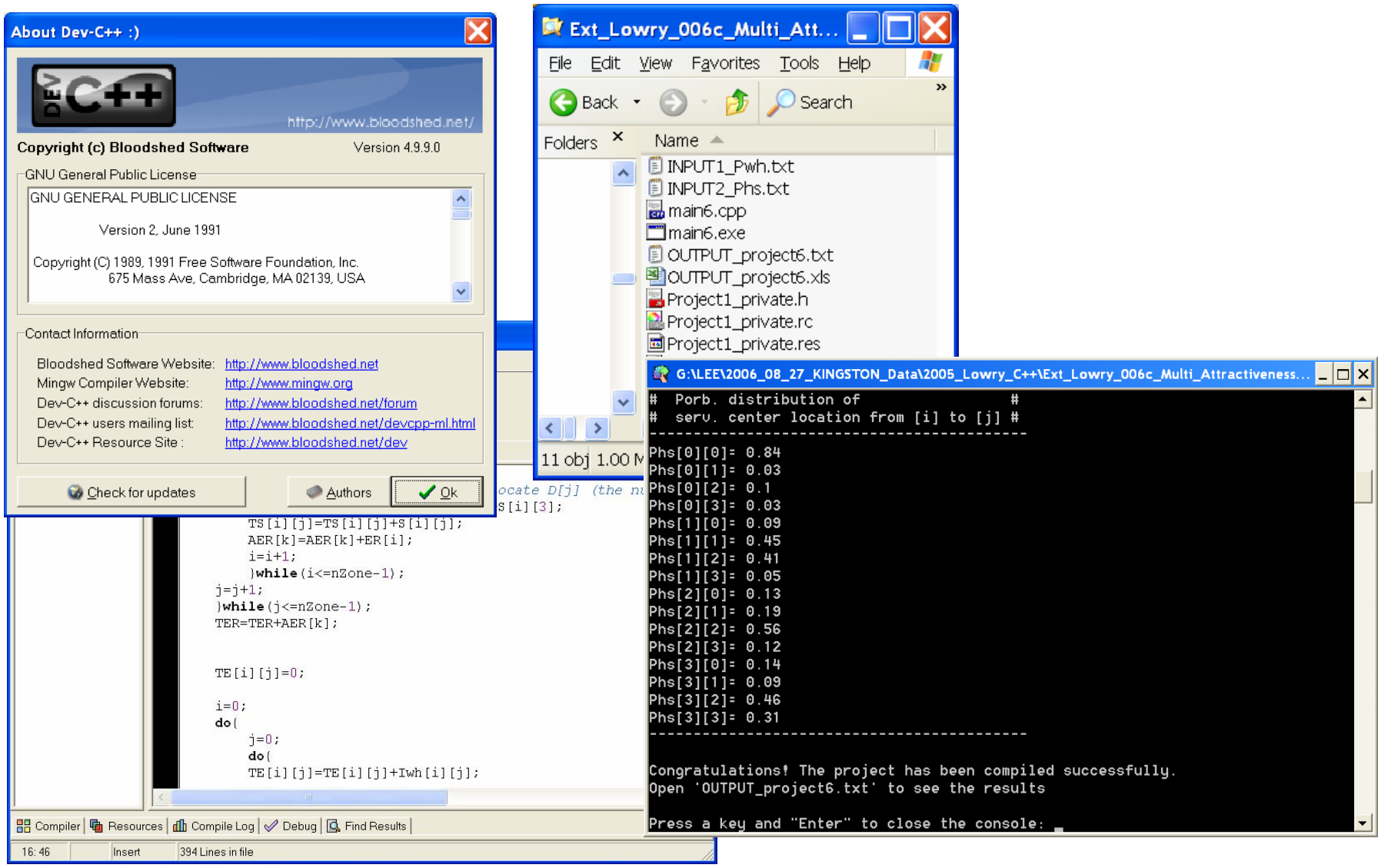
MODEL SEARCH :
Nested Logit vs. Competing Destinations

hierarchical processing
search strategy

Nested Logit	Competing Destinations
assumes that the modeller has knowledge to individual choice sets	considers the likelihood of an alternative being in the true choice set This likelihood is according to the similarity, or position, of that alternative relative to the other alternatives. Pellegrini and Fotheringham (1999)

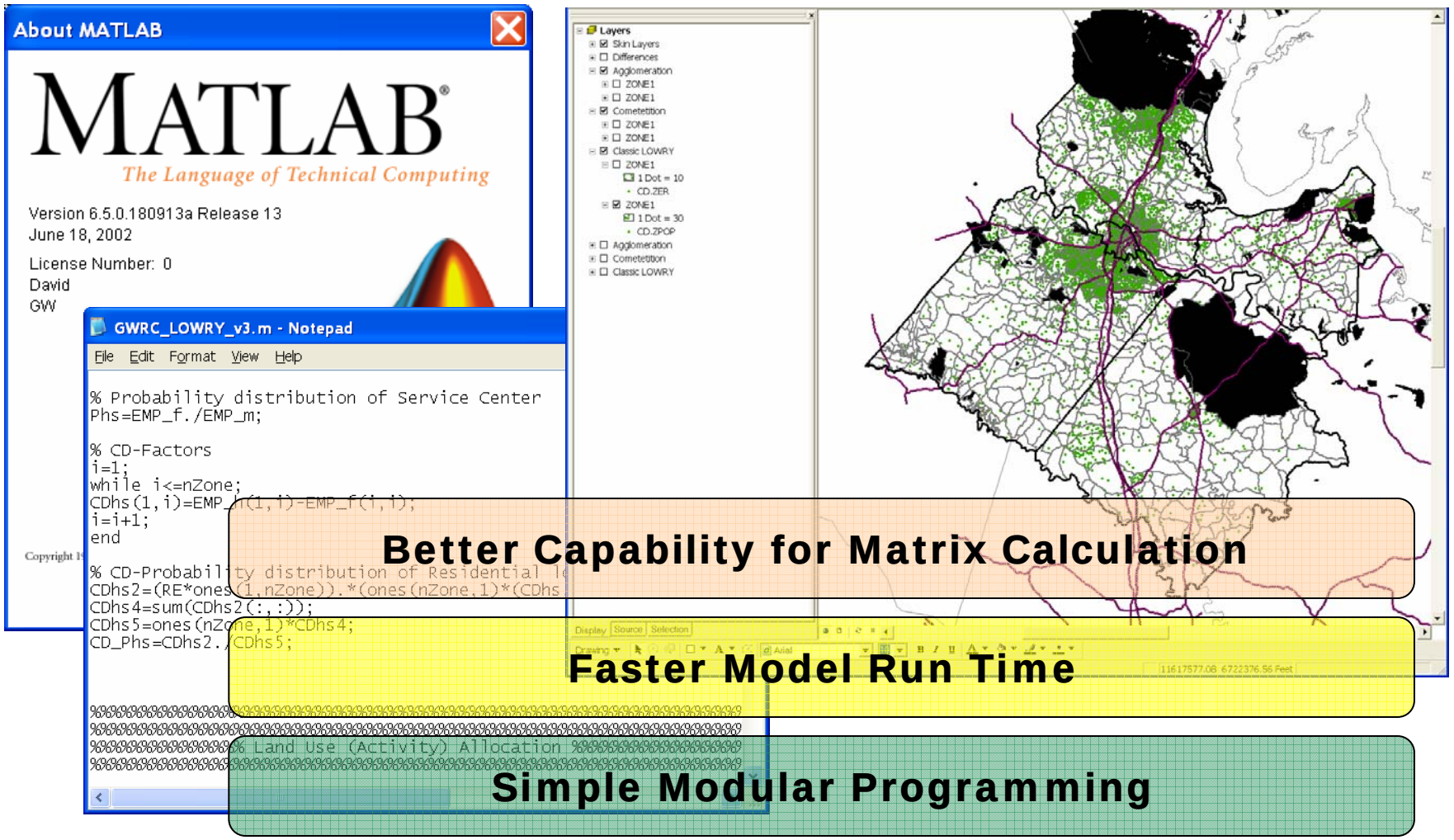
OPERATIONALIZATION

[C++: CUSIM-C++-2005-10 Model]



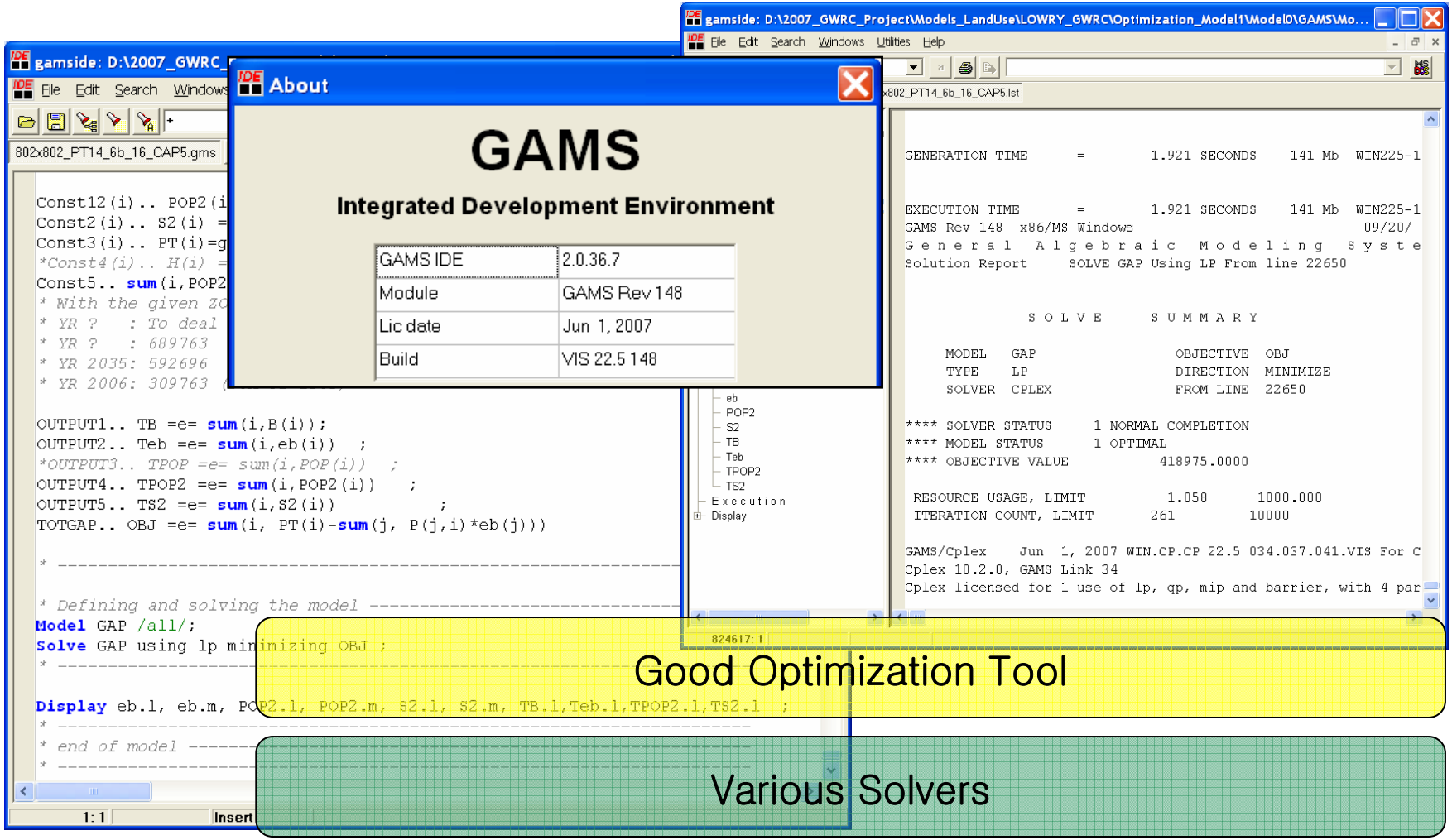
OPERATIONALIZATION

[MATLAB: CUSIM-M-2007-09 Model]

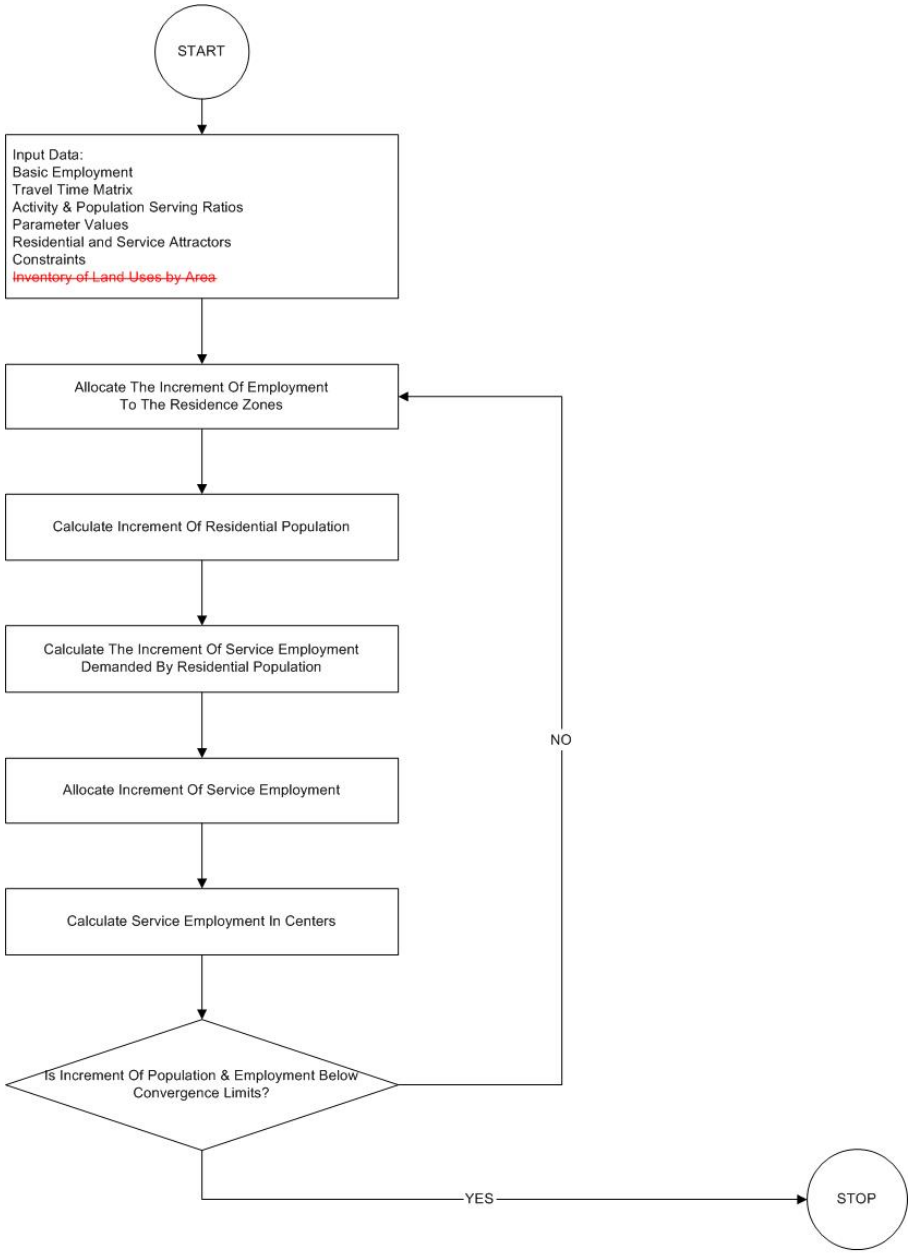


OPERATIONALIZATION

[GAMS: CUSIM-G-2007-09 Model]



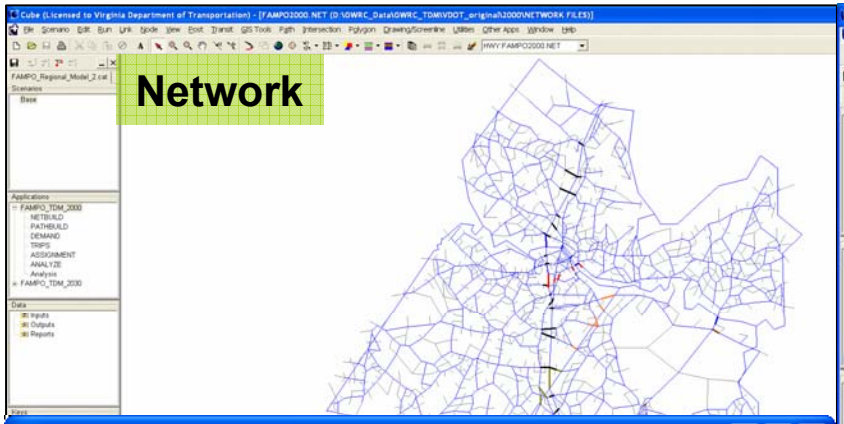
COMPONENT :
Economic Base Theory

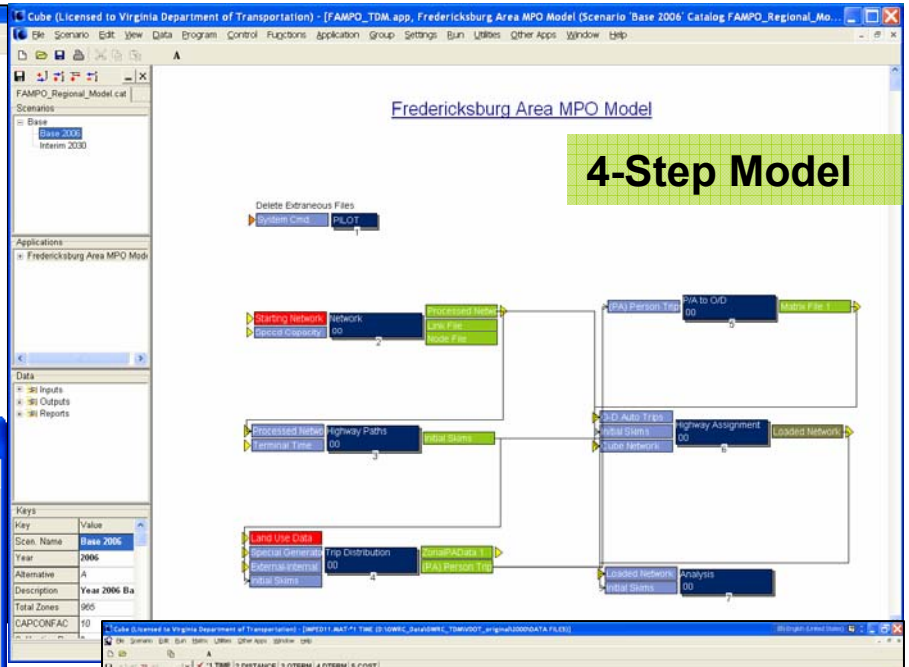


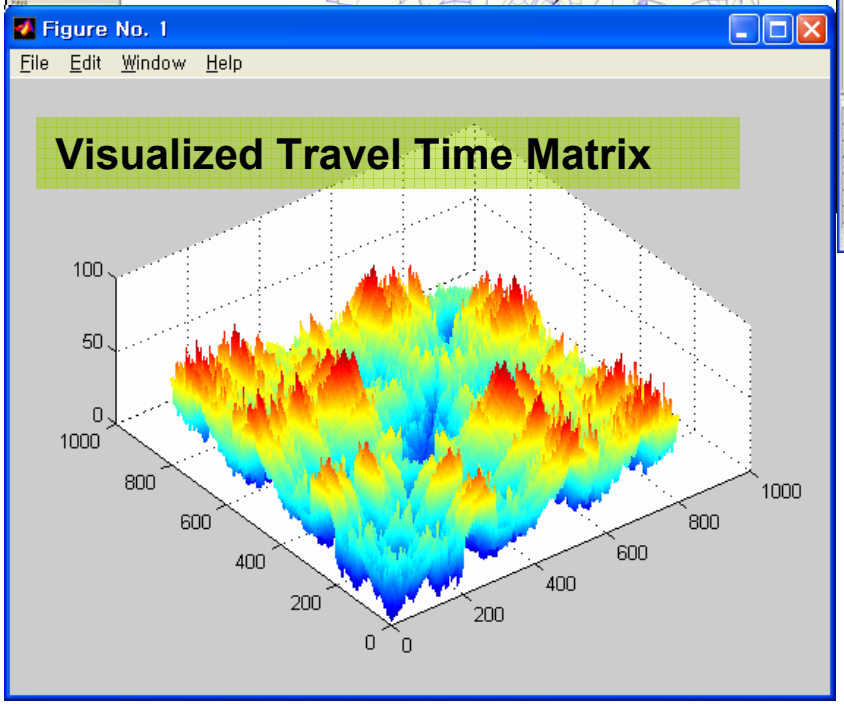
Garin-Lowry Model
Source: Batty 1972

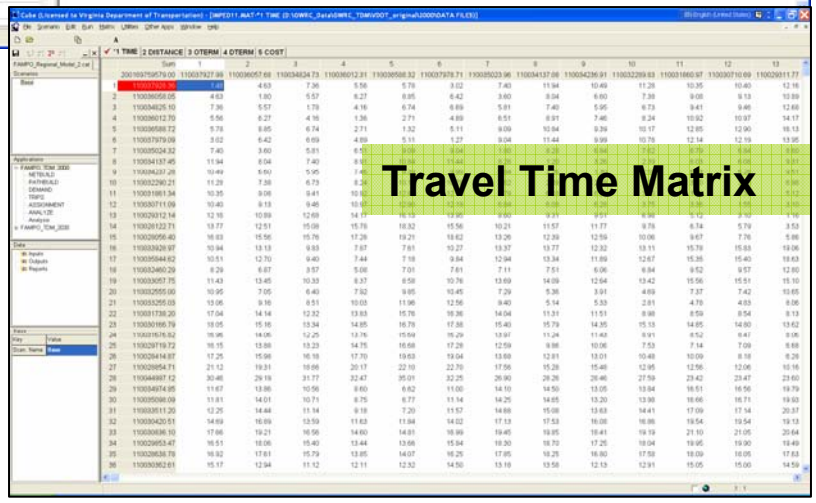
COMPONENT :

Deterrence Function [Travel Time Matrix] : From FAMPO Travel Demand Model









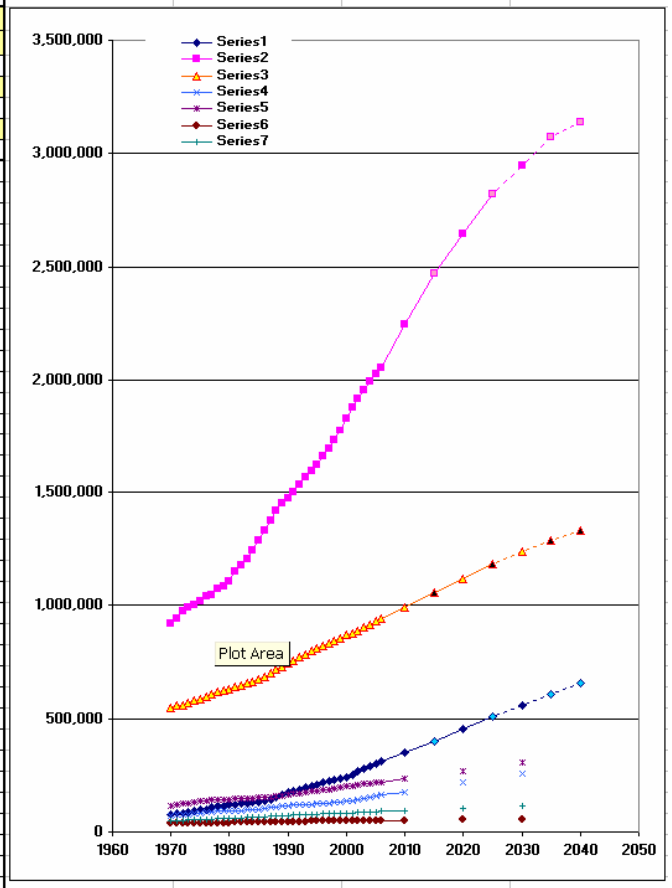
INPUT :
Control Totals

	2000	2005	2006	2010	2015	2020	2025	2030	2035
BAS	Virginia Employment Commission Virginia's Electronic Labor Market Access		73,042	82,891	94,658	107,137	119,616	131,766	143,917
NBAS			37,742	42,831	48,911	55,359	61,808	68,086	74,364
EMP			110,784	125,722	143,569	162,496	181,424	199,852	218,281
POP	US Census Bureau Estimates Annual Population Data		State Demographer Projections Population Data						

		2004	2005	2006
Activity Rate	a=TTP/TTE	a	2.878	2.984	2.794
Population Serving Ratio	b=TSE/TTP	b	0.137	0.108	0.122

INPUT :
Control Totals (Population)

SOURCE: VEC	YEAR	George Washington Regional Commission PD 16	Northern Virginia PD 08	Richmond Regional PD 15	Rappahannock-Rapidan PD 9	Thomas Jefferson PD 10	Northern Neck PD 17	Middle Peninsula PD 18
	2040	657,616	3,140,553	1,332,690				
	2035	609,784	3,071,422	1,288,913				
State Demographer Projections Population Data	2030	558,302	2,946,911	1,235,288	259,409	305,612	57,072	116,838
	2025	506,819	2,822,400	1,181,663				
	2020	453,945	2,647,224	1,119,542	216,460	268,261	54,300	105,411
	2015	401,070	2,472,047	1,057,422				
	2010	351,213	2,247,960	993,633	176,584	234,606	51,721	94,630
US Census Bureau Estimates Annual Population Data	2006	309,483	2,055,014	944,820	163,348	221,504	50,669	91,009
	2005	301,355	2,023,872	929,844	158,442	218,444	50,808	89,494
	2004	290,436	1,994,586	915,482	152,308	214,351	50,442	88,136
	2003	278,733	1,953,932	902,298	147,924	211,195	50,318	87,143
	2002	267,179	1,916,526	890,059	143,762	207,805	49,799	85,733
	2001	254,229	1,878,846	878,927	139,299	204,244	49,384	84,825
	2000	243,505	1,829,041	868,785	135,617	200,477	49,351	83,878
	1999	234,780	1,777,048	856,807	132,666	196,918	49,189	83,147
	1998	227,679	1,730,285	845,466	130,356	192,589	48,921	82,001
	1997	222,435	1,693,959	834,045	128,183	188,571	48,528	81,134
	1996	217,125	1,656,907	820,855	126,128	185,008	48,334	79,958
	1995	209,644	1,622,565	809,481	124,532	181,432	47,943	79,038
	1994	202,785	1,594,484	797,445	122,247	178,356	47,155	77,883
	1993	194,508	1,564,497	784,637	121,327	175,323	45,870	77,080
	1992	187,245	1,533,809	770,881	120,371	171,460	45,623	75,420
	1991	180,310	1,500,416	757,171	118,841	168,399	44,927	74,216
	1990	173,781	1,472,561	744,063	117,209	165,490	44,331	73,302
	1989	162,273	1,448,876	728,968	114,082	161,456	43,686	72,442
	1988	153,289	1,418,991	715,399	110,616	158,191	43,241	71,474
	1987	145,042	1,377,277	699,499	107,271	155,494	42,807	70,005
	1986	138,771	1,332,057	683,700	103,590	152,675	42,245	68,423
	1985	133,870	1,287,634	671,741	100,711	152,331	41,693	66,836
	1984	130,158	1,246,062	662,876	98,349	149,739	41,509	64,889
	1983	126,593	1,206,577	655,087	96,460	148,586	41,213	63,238
	1982	124,056	1,176,553	648,593	95,347	147,466	41,333	61,956
	1981	121,615	1,148,665	641,702	94,356	146,316	41,183	61,109
	1980	118,674	1,105,714	632,015	92,897	143,597	40,950	59,987
	1979	117,200	1,085,700	626,100	92,500	143,400	41,000	59,700
	1978	113,100	1,071,600	616,600	90,800	141,700	41,000	58,700
	1977	107,200	1,048,300	609,400	88,000	140,200	40,300	57,500
	1976	101,000	1,039,400	596,800	85,700	138,700	39,600	56,000
	1975	96,700	1,019,000	586,400	83,300	136,200	39,500	55,300
	1974	92,500	1,001,600	578,300	81,900	131,300	38,500	54,200
	1973	87,300	992,400	571,200	78,500	127,400	38,400	52,200
	1972	83,900	976,300	560,600	76,800	123,700	37,600	50,600
	1971	81,000	939,600	558,000	75,200	118,100	38,200	48,700
	1970	77,425	921,237	547,542	72,222	115,235	37,011	47,609



INPUT :

Basic vs Non-Basic (Location Quotients)

$$\frac{e_{ir} / \sum e_{ir}}{E_i / \sum E_i}$$

- e_{ir} = employment in some industry (i) in some region (r)
- Σe_{ir} = total employment in the region
- E_i = national employment in some industry (i)
- ΣE_i = total national employment

INPUT :
Basic vs Non-Basic (Location Quotients)

- Location quotient = 1
  - Local production can just satisfy local consumption.
- Location quotient > 1
  - Local production can satisfy local consumption, and the excess is exported. This is a “basic” industry.
- Location quotient < 1
  - Local production can not satisfy local consumption, and the difference must be imported.

INPUT :
Basic vs Non-Basic (Location Quotients)

- Not all of a basic industry is “basic.”
- Only that part of the industry that serves the export market is considered basic.
- It is that part of the industry that raises the location quotient above 1.0

INPUT :

Basic vs Non-Basic (Location Quotients)

Calculating Basic Employment Using Location Quotients

	PD16	United States
NAICS 236xx	2,050	1,721,661
Total Private Sector Employment	105,167	131,640,225
Employment Ratio	.019492	.013078

Location Quotient = (.019492 / .013078) = 1.49

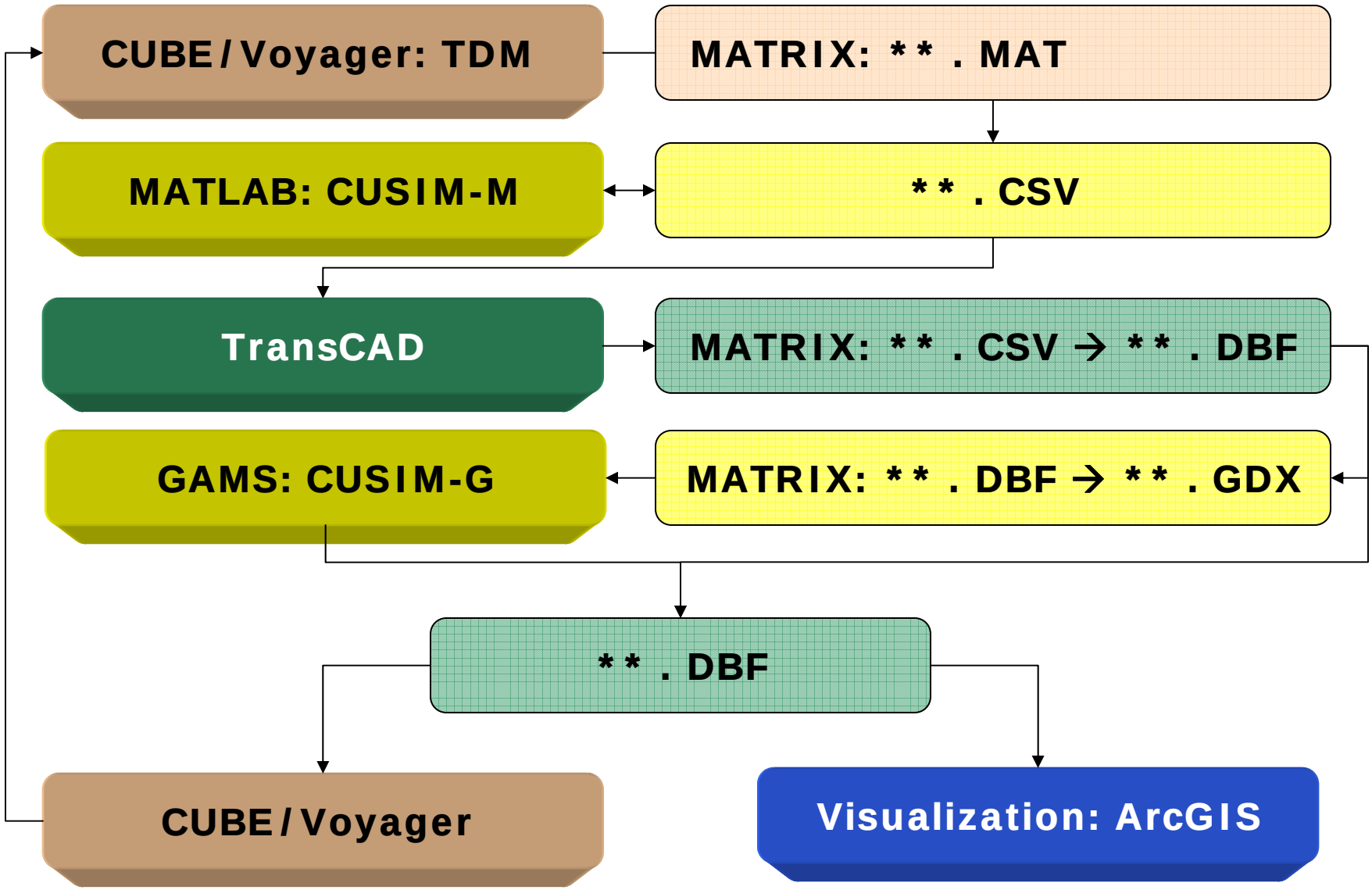
Non-basic Employment = (.013078) * 105,167 = 1,375

Basic Employment = 2,050 – 1,375 = 675

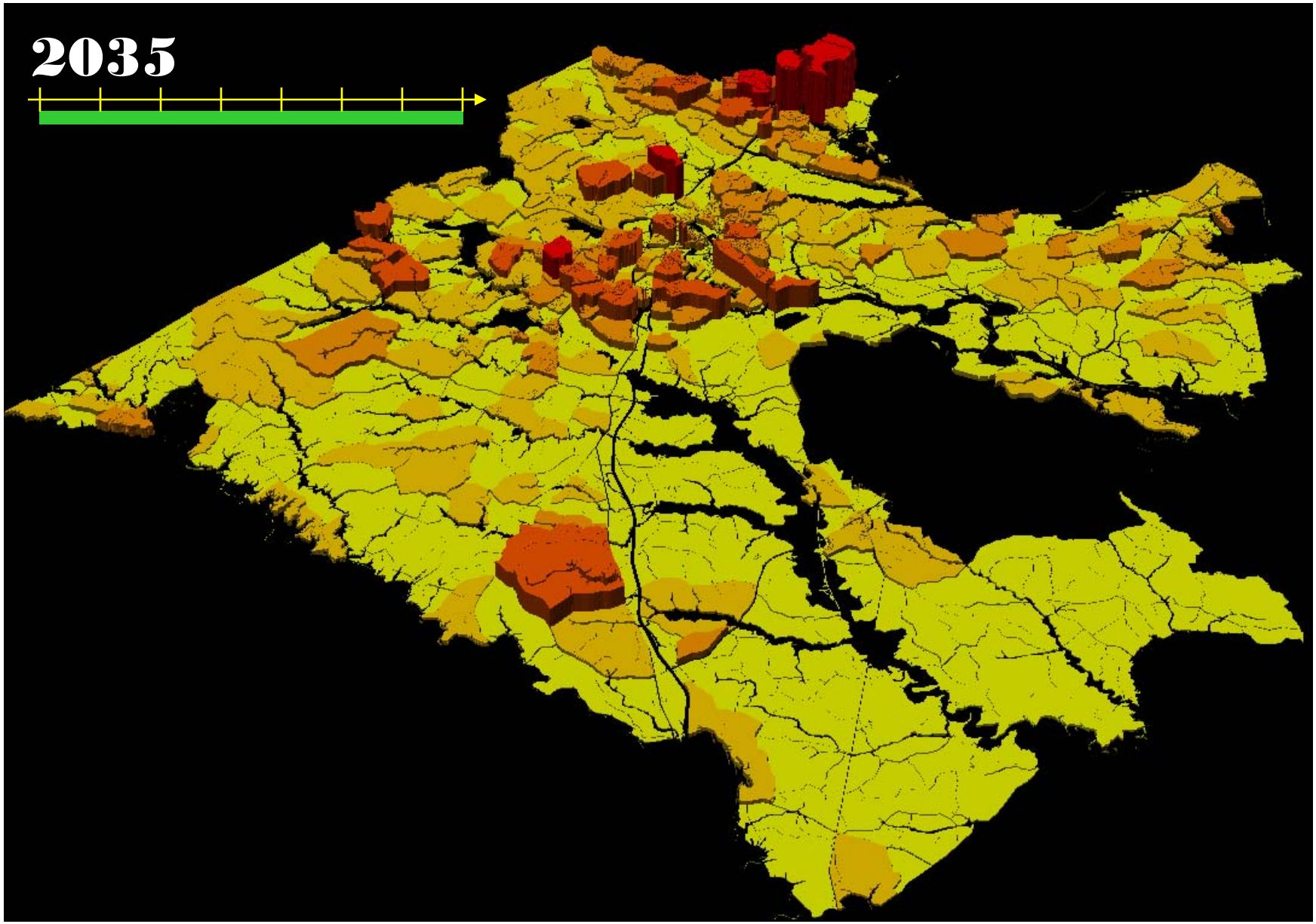
INPUT :
Zonal Basic Employment (exogenous)

2			2006							2010				2015			
3	LEE_TAZ		BAS_06	NBAS_06	EMP_06		PV_BAS_06	PV_NBAS_06	PV_EMP_06	BAS_10	NBAS_10	EMP_10	POP_10	BAS_15	NBAS_15	EMP_15	POP_
783	780		29	0	29		0.00040	0.00000	0.00027	33	0	33		38	0	38	
784	781		0	0	0		0.00000	0.00000	0.00000	0	0	0		0	0	0	
785	782		0	0	0		0.00000	0.00000	0.00000	0	0	0		0	0	0	
786	783		10	1	11		0.00014	0.00003	0.00010	11	1	13		13	1	14	
787	784		3	2	5		0.00004	0.00005	0.00005	3	2	6		4	3	7	
788	785		2	0	2		0.00003	0.00000	0.00002	2	0	2		3	0	3	
789	786		30	3	33		0.00042	0.00008	0.00030	34	3	38		39	4	43	
790	787		10	0	10		0.00014	0.00000	0.00009	11	0	12		13	0	13	
791	788		25	5	30		0.00035	0.00014	0.00028	29	6	35		33	7	39	
792	789		13	0	13		0.00018	0.00000	0.00012	15	0	15		17	0	17	
793	790		10	1	11		0.00014	0.00003	0.00010	11	1	13		13	1	14	
794	791		20	13	33		0.00028	0.00035	0.00030	23	15	38		26	17	43	
795	792		3	1	4		0.00004	0.00003	0.00004	3	1	5		4	1	5	
796	793		7	5	12		0.00010	0.00014	0.00011	8	6	14		9	7	16	
797	794		3	0	3		0.00004	0.00000	0.00003	3	0	3		4	0	4	
798	795		75	5	80		0.00104	0.00014	0.00073	86	6	92		98	7	105	
799	796		63	14	77		0.00087	0.00038	0.00071	72	16	89		83	19	101	
800	797		91	171	262		0.00126	0.00462	0.00240	105	198	302		120	226	345	
801	798		414	113	527		0.00574	0.00305	0.00483	476	131	607		544	149	694	
802	799		166	223	389		0.00230	0.00603	0.00357	191	258	448		218	295	512	
803	800		50	8	58		0.00069	0.00022	0.00053	57	9	67		66	11	76	
804	801		0	0	0		0.00000	0.00000	0.00000	0	0	0		0	0	0	
805	802		101	14	115		0.00140	0.00038	0.00105	116	16	133		133	19	151	
806	TOTAL		72,080	37,007	109,087		1	1	1	82,891	42,831	125,722	351,213	94,658	48,911	143,569	401,070
807	PD08 (803)		829,744	286,649	1,116,393	2,055,014				907,649	313,562	1,221,211	2,247,960	998,128	344,820	1,342,948	2,472,047
808	PD15 (804)		312,648	207,742	520,390	944,820				328,800	218,475	547,275	993,633	349,908	232,500	582,409	1,057,422

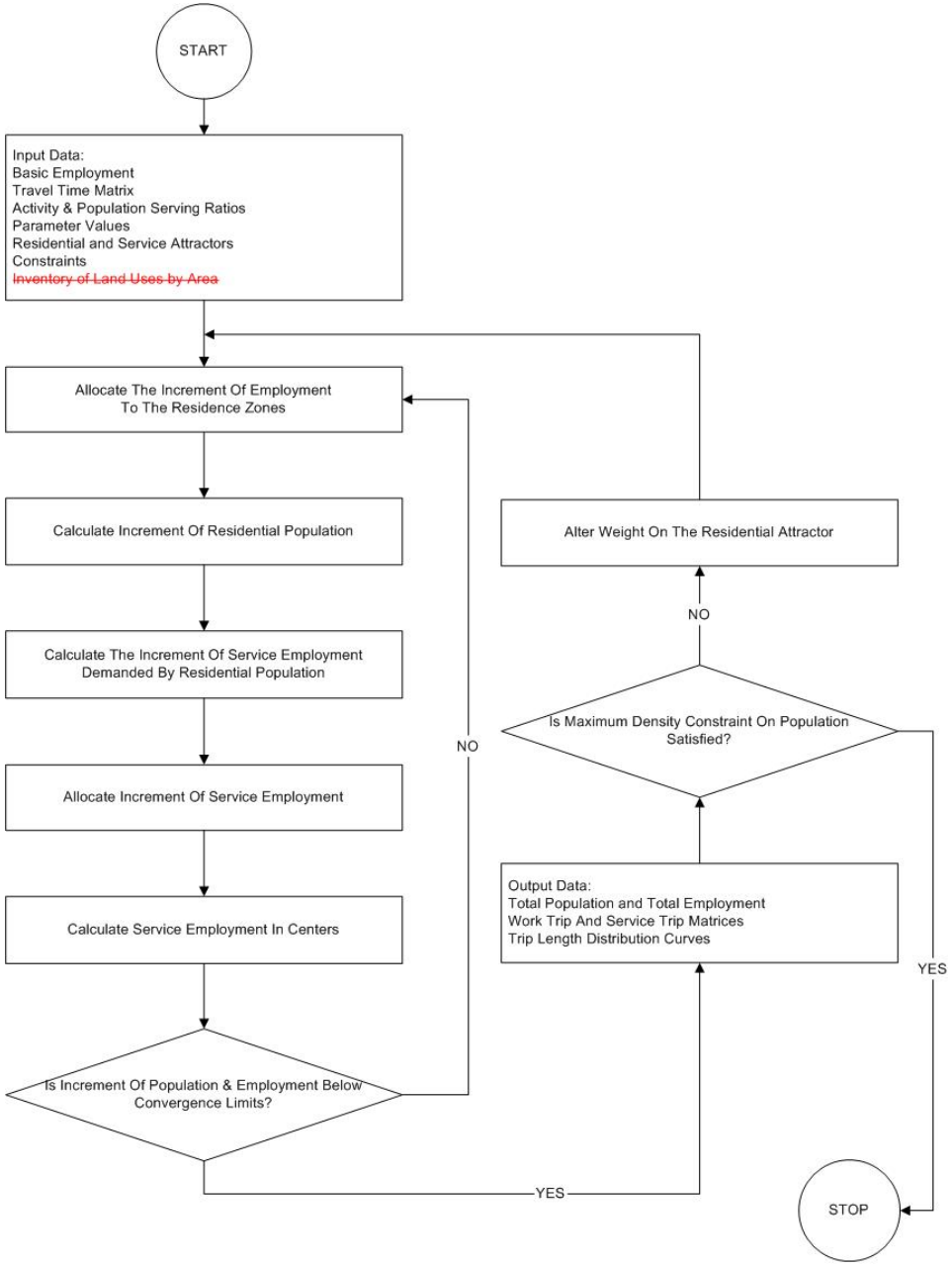
APPLICATIONS & FILE FORMAT



CUSIM-M-2007-09 Model : Forecasting



Density Constraint



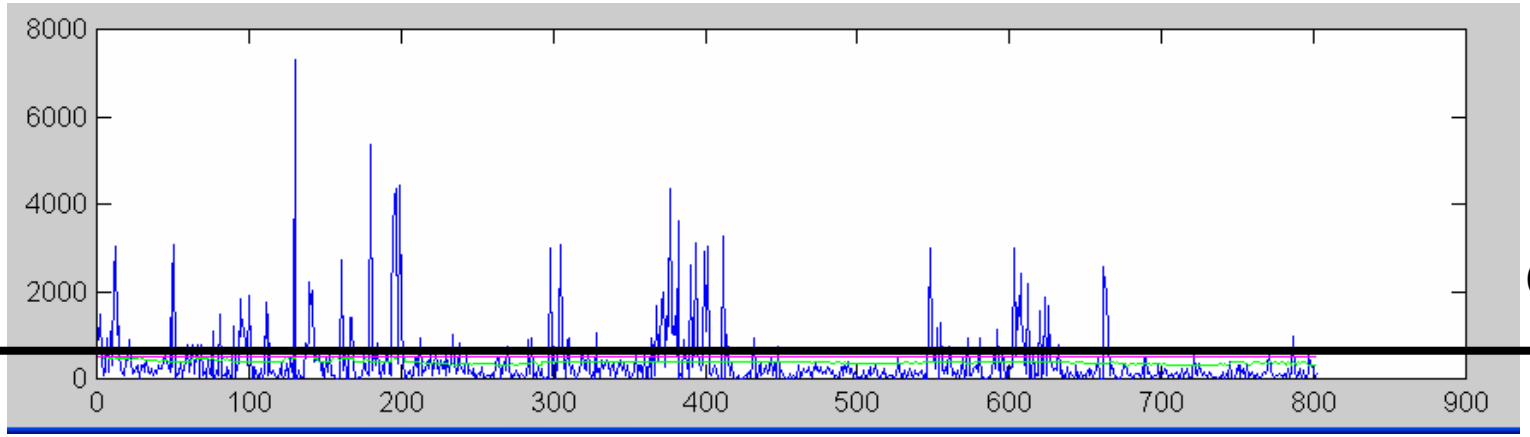
Modification I of the Garin-Lowry Model
Source: Batty 1972

Density Constraint

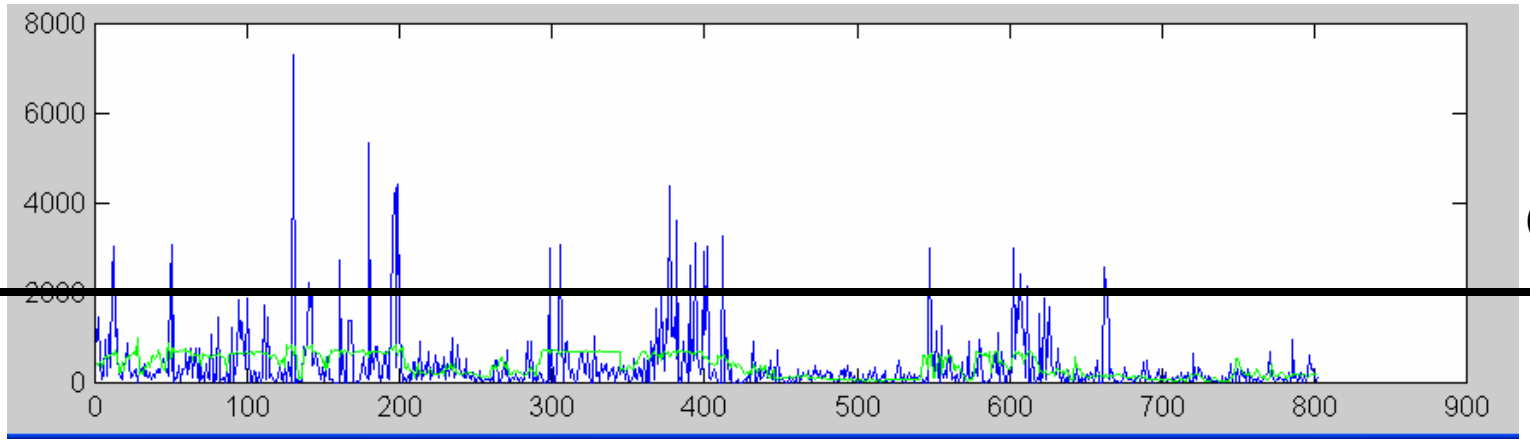
Wt_POP:

$$CD\_P_{ij}^{wh} = \frac{(Wt\_POP * A_i^R) X_i^{\gamma} \exp(-\beta d_{lj})}{\sum_l (Wt\_POP * A_l^R) X_l^{\gamma} \exp(-\beta d_{lj})}$$

weighting factor
A vector of the ratio of the zonal maximum constrained population over the zonal estimated population

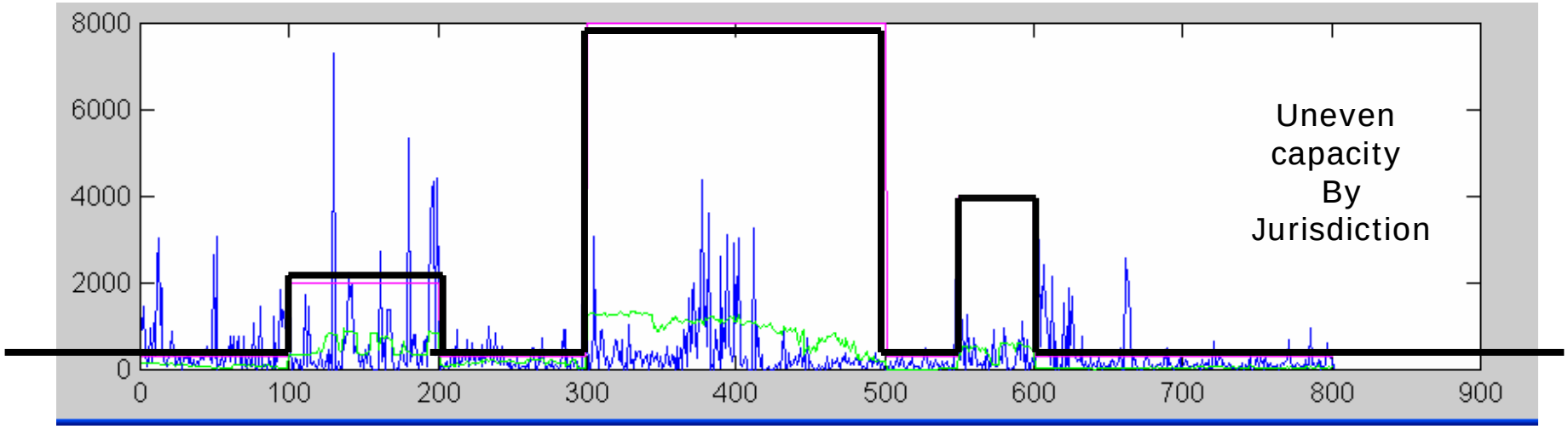


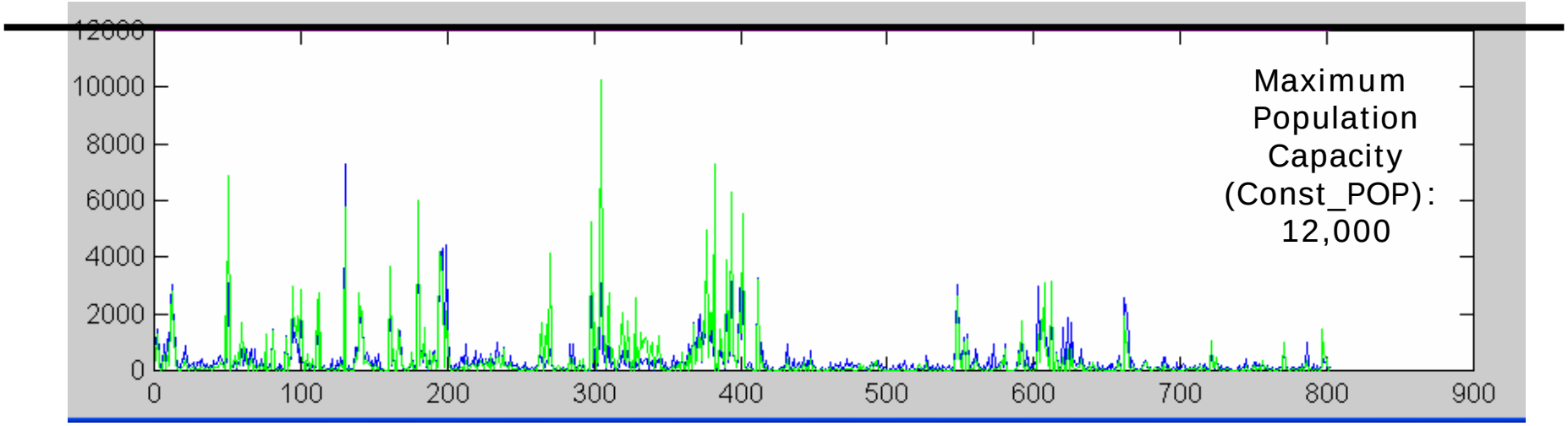
Maximum Population Capacity (Const_POP): 500



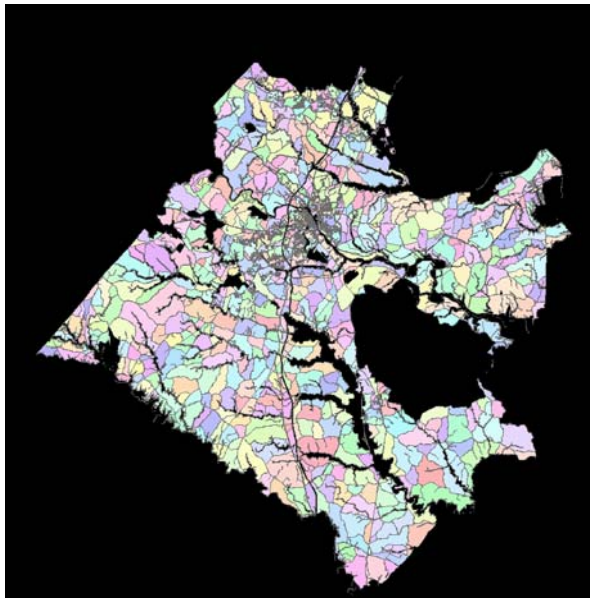
Maximum Population Capacity (Const_POP): 2,000

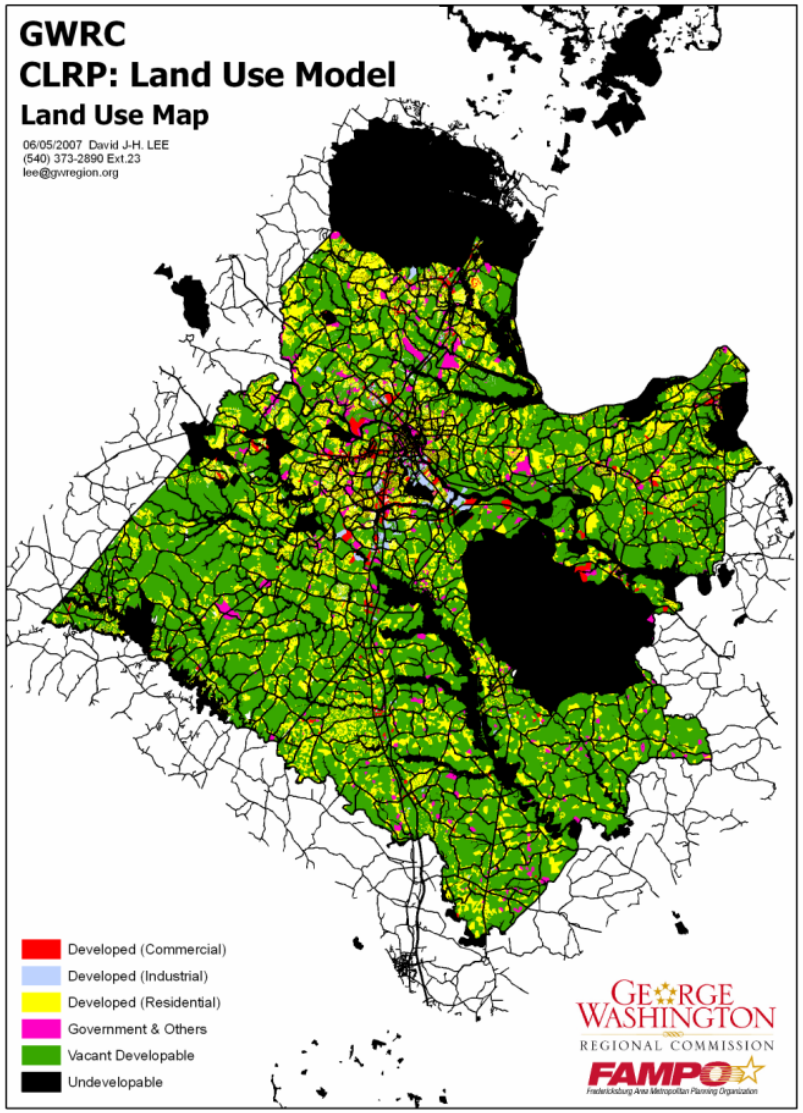
Density Constraint





Density Constraint w/ Land Use





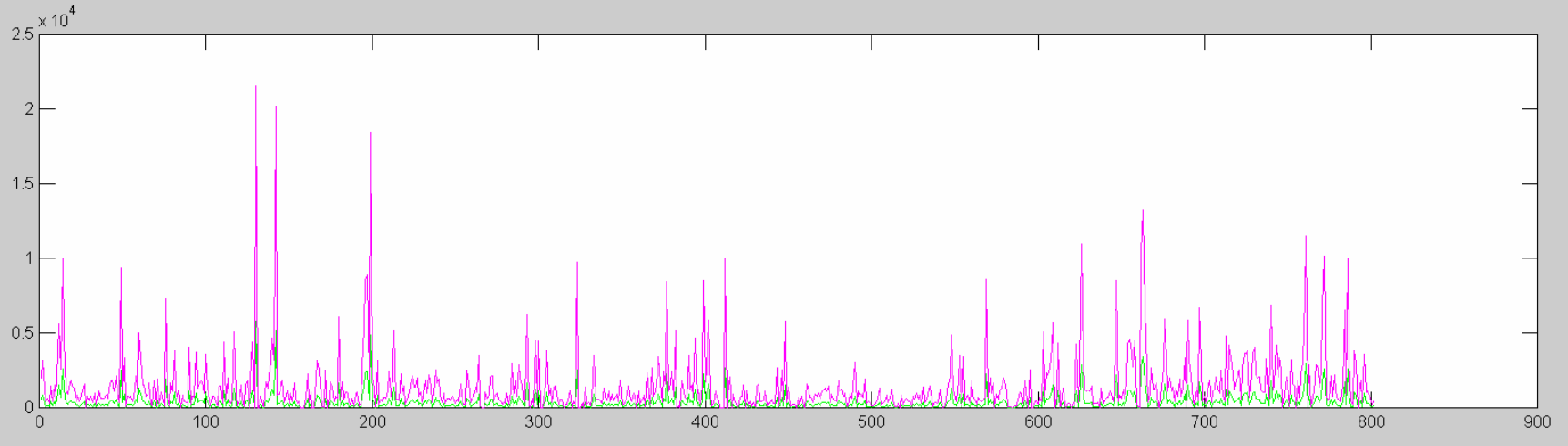
Current Land Use for George Washington Region, 2006

Density Constraint

Zonal Specific Population Capacity Constraints

ZONE	TOTAL_ACRE	ACRE_DVPB	ACRE_UnDVPB	ACRE_DvdCOM	ACRE_DvdIND	ACRE_DvdRES	ACRE_DvdGov	ACRE_DvdOther	ACRE_DVPB_VAC	TOTPop_2006	Unit ACRE*	A_PSB_RES*	POP_CAP*
1	1203.03	1077.32	125.71	18.84	5.08	455.33	0.00	193.53	404.54	1048	0.434	859.87	1979
2	1003.75	866.31	137.44	2.56	3.56	469.44	0.00	2.71	388.04	1720	0.273	857.48	3142
3	1041.24	905.32	135.92	0.00	0.00	378.30	0.00	0.00	527.02	546	0.693	905.32	1307

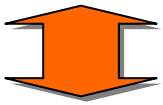
Zonal Population Capacity vs. Estimated Population



Hybrid Modeling Approach

MATLAB Simulation (Descriptive) Model

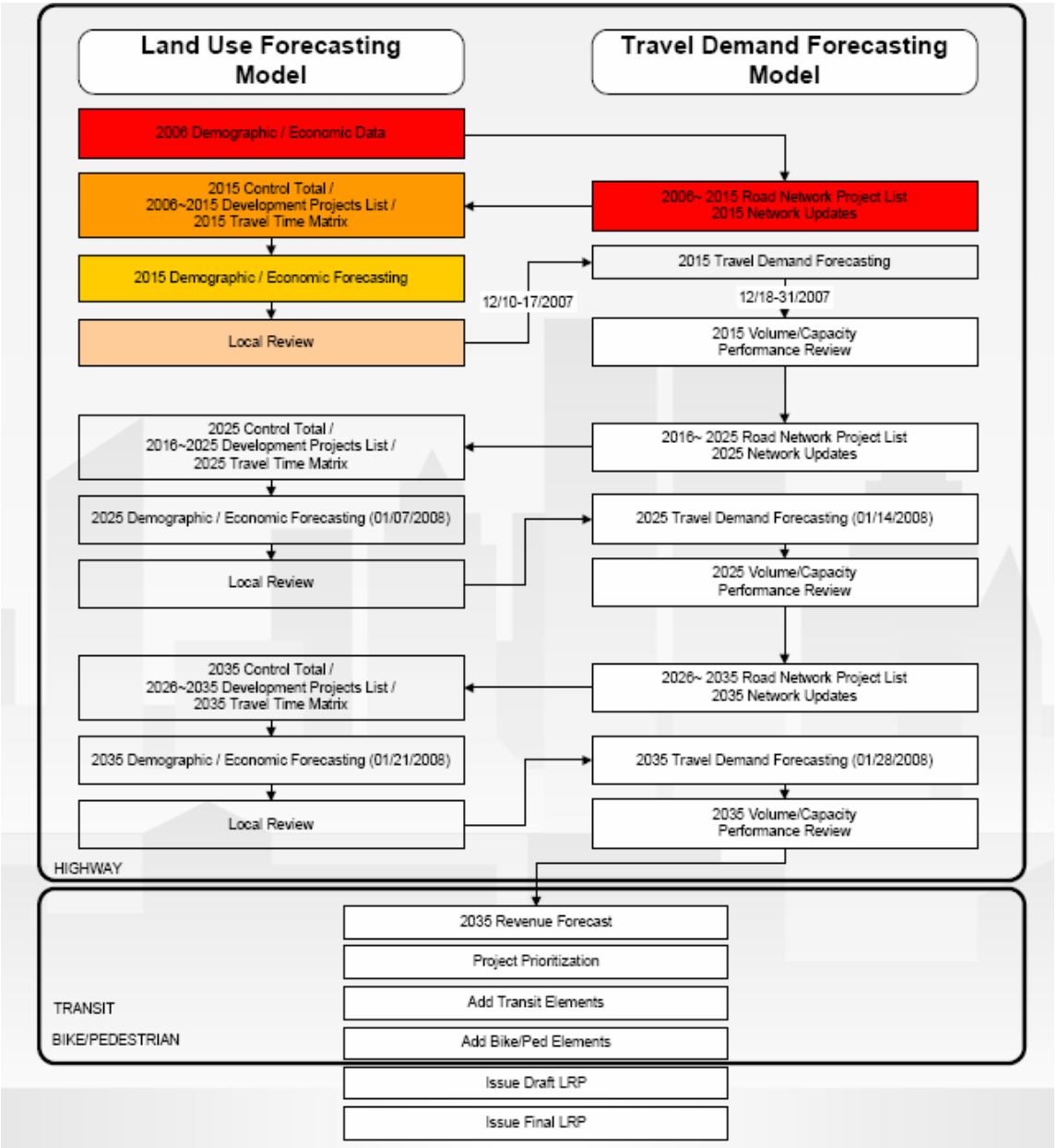
characterizing the general operations and mechanics of land use changes and development patterns

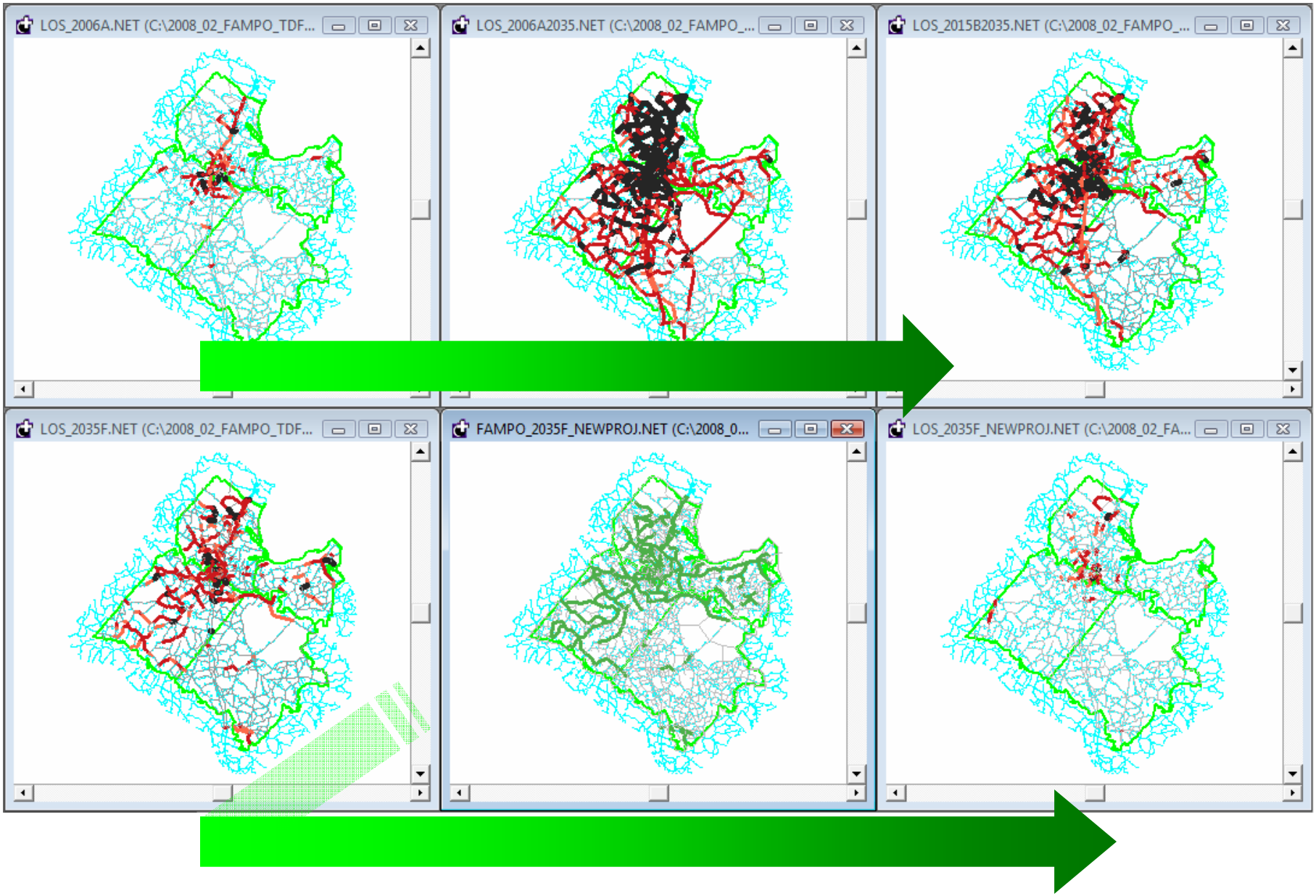


GAMS Optimization (Prescriptive) Model

prescribing optimal urban development patterns with minimal concerns associated

Land Use and Transportation in LRTP

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Thank you very much!!

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GEORGE WASHINGTON
REGIONAL COMMISSION

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Fredericksburg Area Metropolitan Planning Organization