Advanced Modeling System for Forecasting Regional Development, Travel Behavior, and the Spatial Pattern of Emissions

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Presentation outline

- Research team members
- Research questions
- Study area
- Modeling approach
- Progress highlights
- Next steps

THE UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
CENTER FOR URBAN AND REGIONAL STUDIES

ENVIRONMENTAL MODELING for POLICY DEVELOPMENT

ITRE

UNC COLLEGE OF ARTS & SCIENCES

Land use and travel behavior modeling

UNC CTP, NCSU ITRE, ODU

Emissions estimation

NCSU ITRE and CE

Air quality modeling

UNC Institute for the Environment

Outreach and partnerships

UNC

Motivation

- Built form related to how we travel
  - Walking
    - Distance to destinations
    - Mixed uses of land
      - Specific uses
    - Density
  - Miles traveled
  - Trip purpose
    - Shopping trips
    - Work trips

Motivation

- Link development patterns and regional air quality, through travel
  - Develop behavioral models that reflect built form influences
  - Couple travel demand and emissions models at appropriate spatial and temporal scales
  - Improve ability to represent real-world driving cycles and microscale influences at high temporal and spatial resolution
  - Account for advanced technologies and alternative fuels

Key research questions

- Can regional development patterns, over 50 years, influence quantity and spatial pattern of emissions from transportation in the Charlotte (NC) area?
  - Type of development
  - Intensity of development
  - Location of development

- How would different development patterns affect…
  - Ozone
  - Fine PM
  - Other quality of life indicators

Modeling approach

- Classify built environment
  - Walking and transit-supportive environments
- Develop models sensitive to such environments
  - Land demand
  - Travel demand
- In future scenarios compare behaviors, emissions, air quality

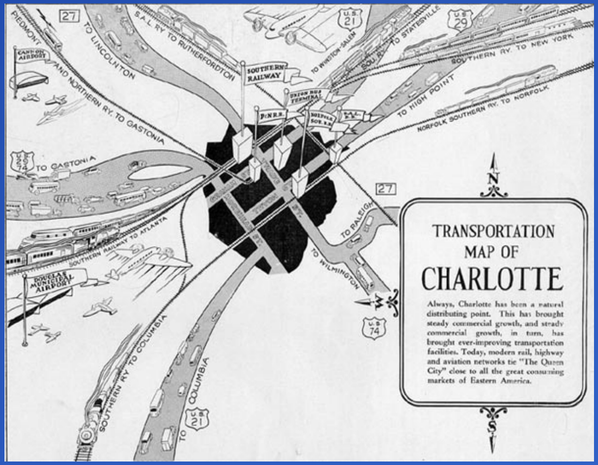
Modeling steps -scenarios

Built form TRANSECT
↓
Integrated transport-land model
↓
Emissions estimates
↓
Air quality

Built form TRANSECT
↓
Integrated transport-land model
↓
Future scenarios
↓
Emissions estimates
↓
Air quality

Study area -Charlotte

- Growing metro area in NC
- Data-rich
- Designated 8-hour ozone non-attainment area
- SEQL + ReVA
- Future transit metropolis?



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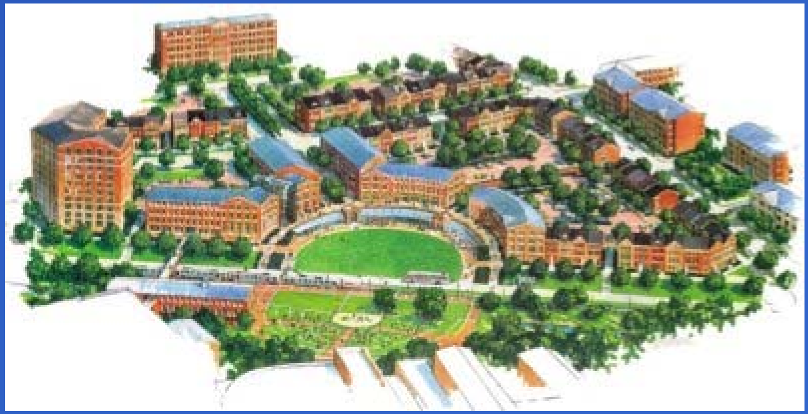
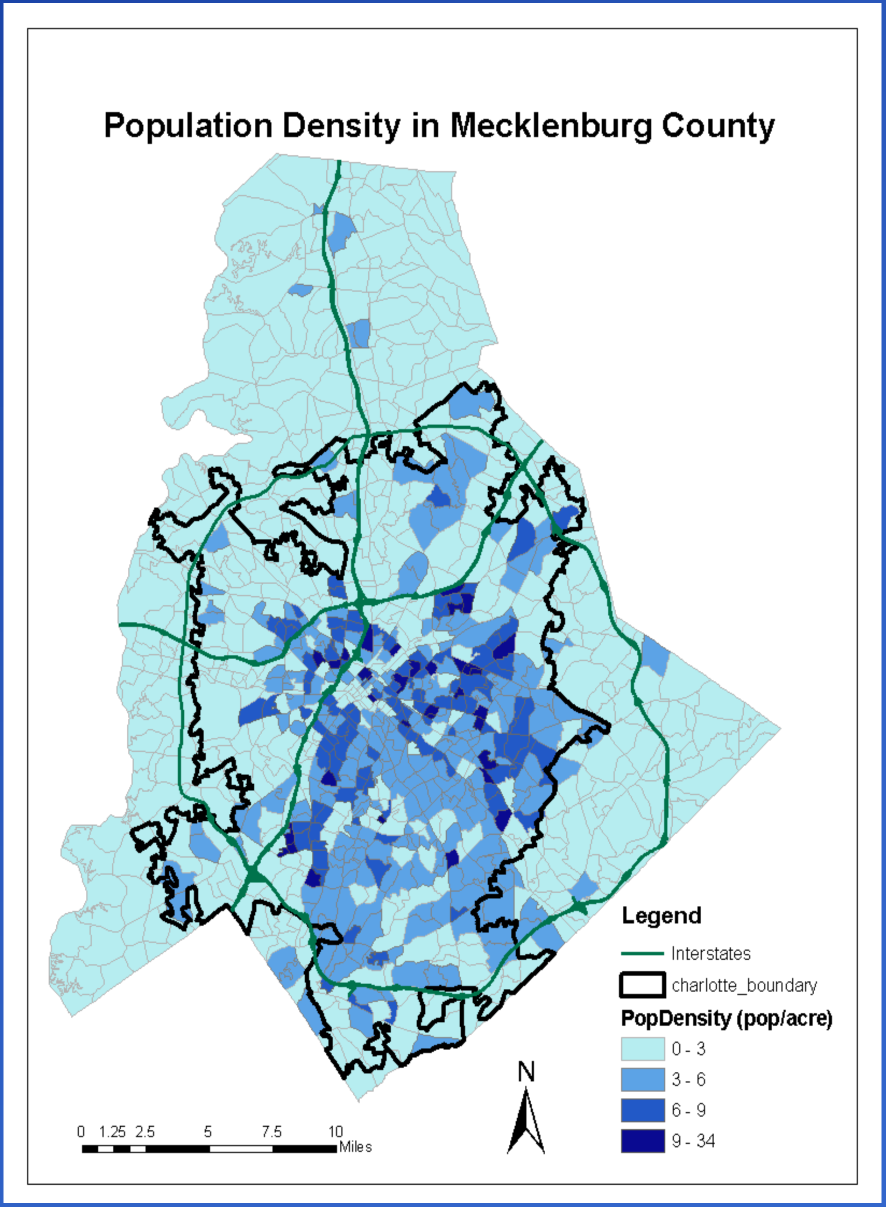
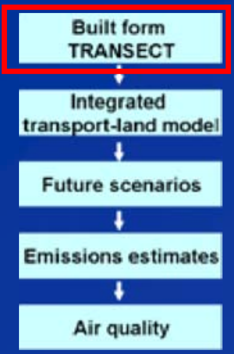


Charlotte in 2050?

Mecklenburg County

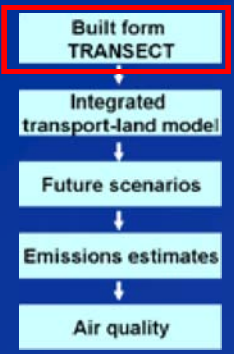
- Rapid population increase
  - 22 % from 1990 to 2000
  - > 600k in 2005
- Even faster land consumption
  - Density
    - 1950: 6.98 person/acre
    - 2000: 3.60 person/acre





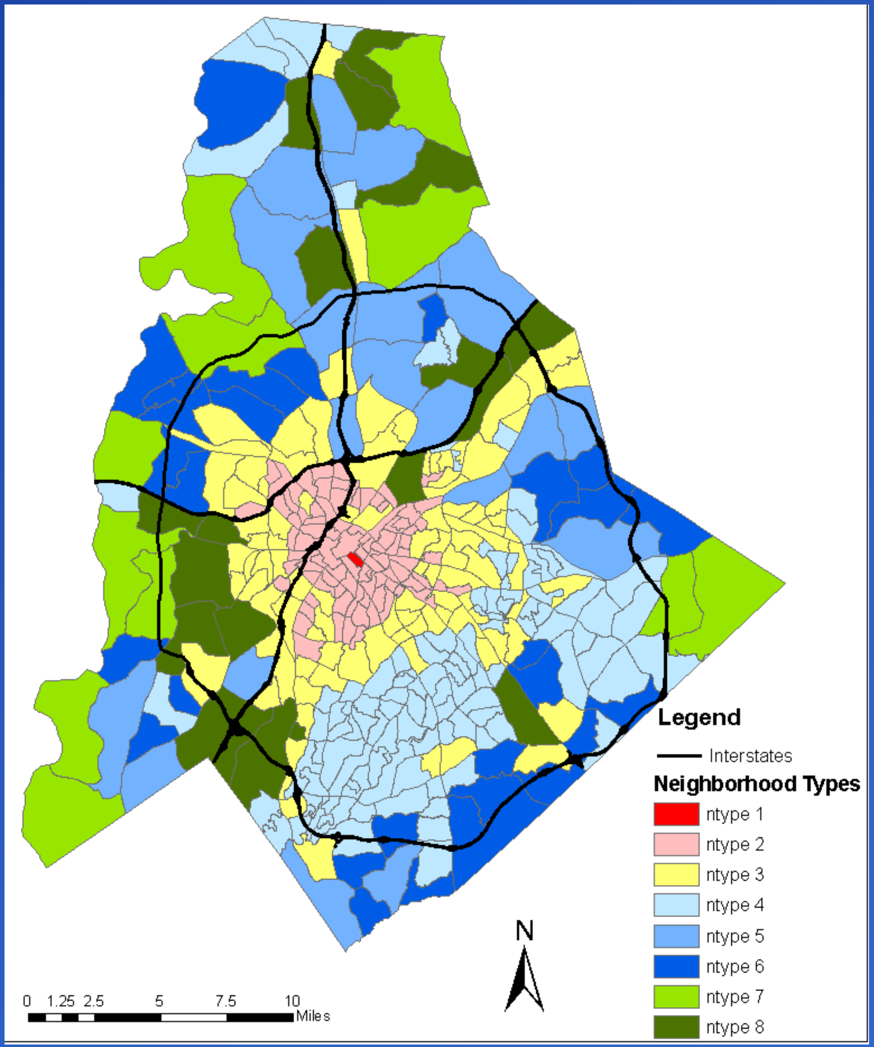
Built form Transect

- Provides continuum of built environments and development possibilities
- Classifies neighborhoods based on
  - Land use (uses, densities, open space)
  - Demographics + employment
  - Travel (street design and circulation, accessibility, and alternative modes)
  - Housing
  - Recreation



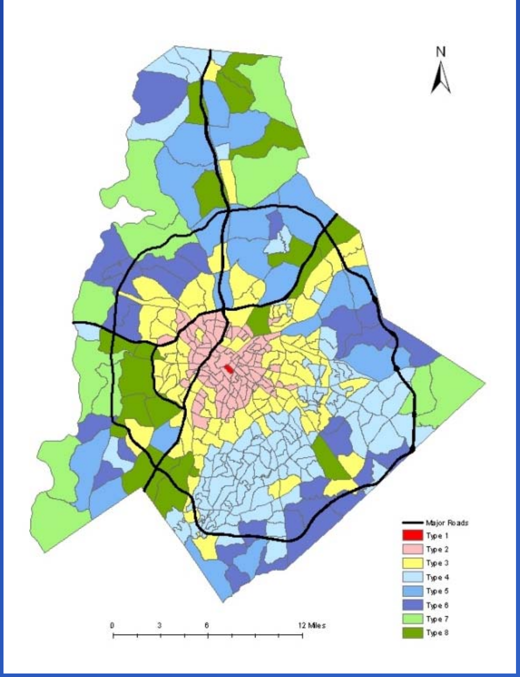
Built form Transect

- Data factor-analyzed
  - walkability
  - accessibility
  - agglomeration
  - property value
  - industry
- Cluster analysis of factors

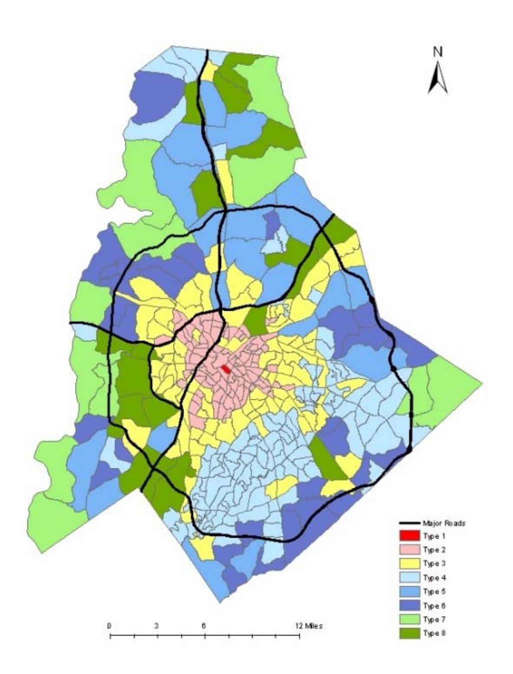


Cluster types

- Type 1 (Red)
  - One, unique CBD block group
  - Mostly office
  - High local/regional accessibility
  - High improvements to total parcel value ratio

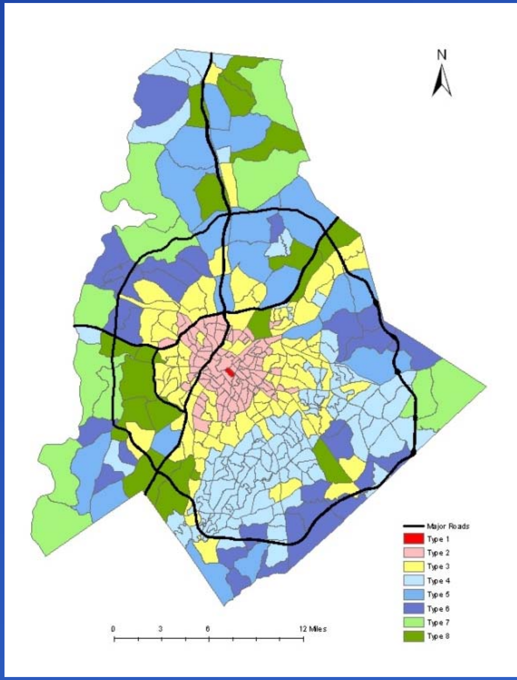


Cluster types

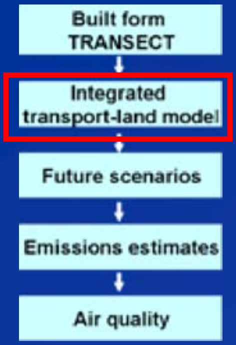


- Type 3 (Yellow Blue)
  - Some mixing of land uses
  - High local/regional accessibility
  - Roughly the second ring

Cluster types

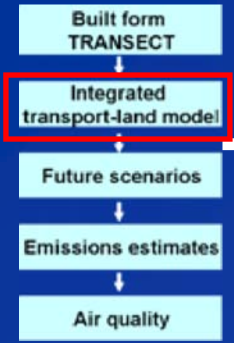


- Type 6 (Dark Blue)
  - Single family residential is dominant
  - High levels of green space
  - Limited local/regional accessibility
  - Bridge between rural and suburban

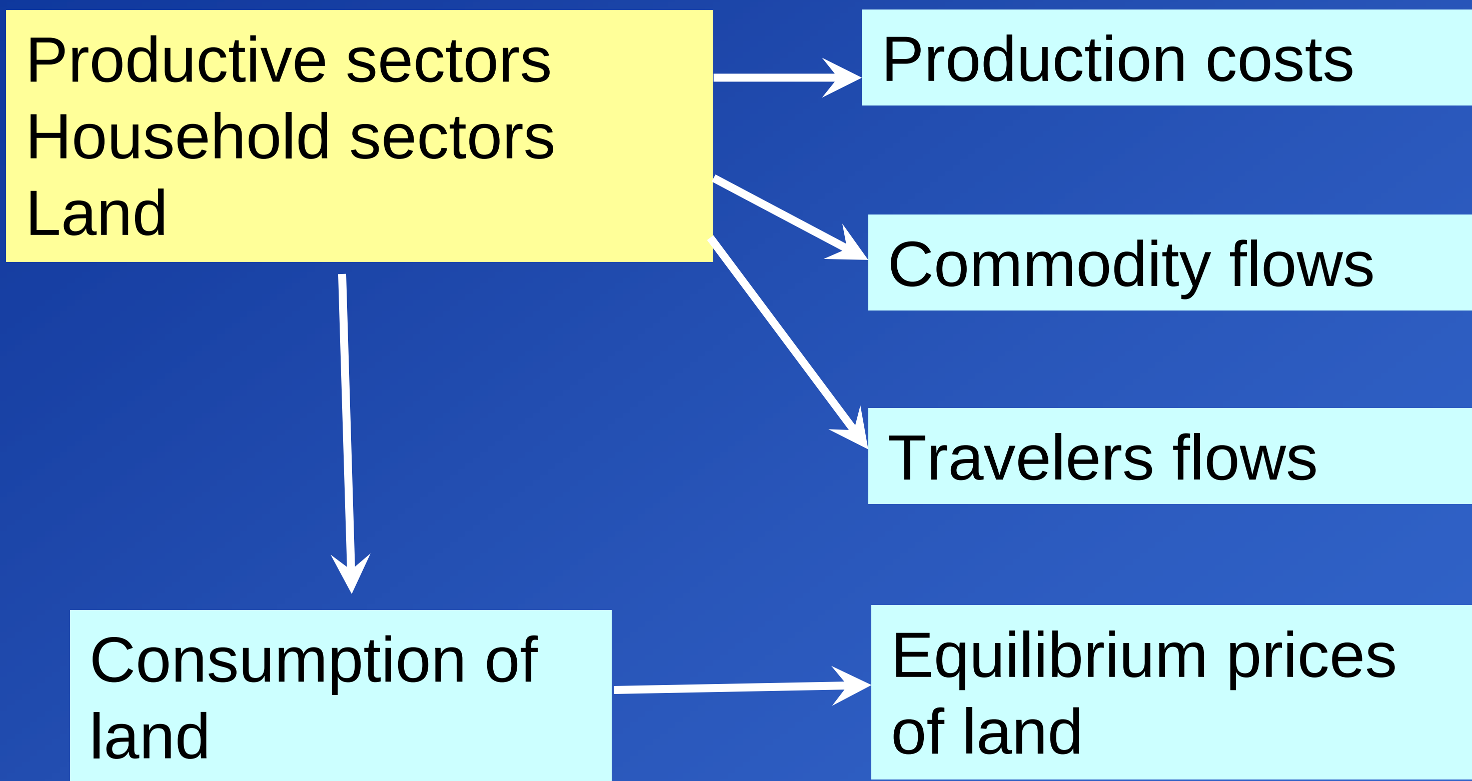


TRANUS

- Integrated transportation-land development model
  - Cross-sectional equilibrium, spatial input-output
  - Production, household, land sectors

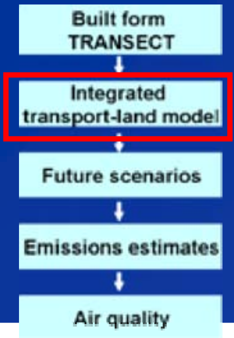


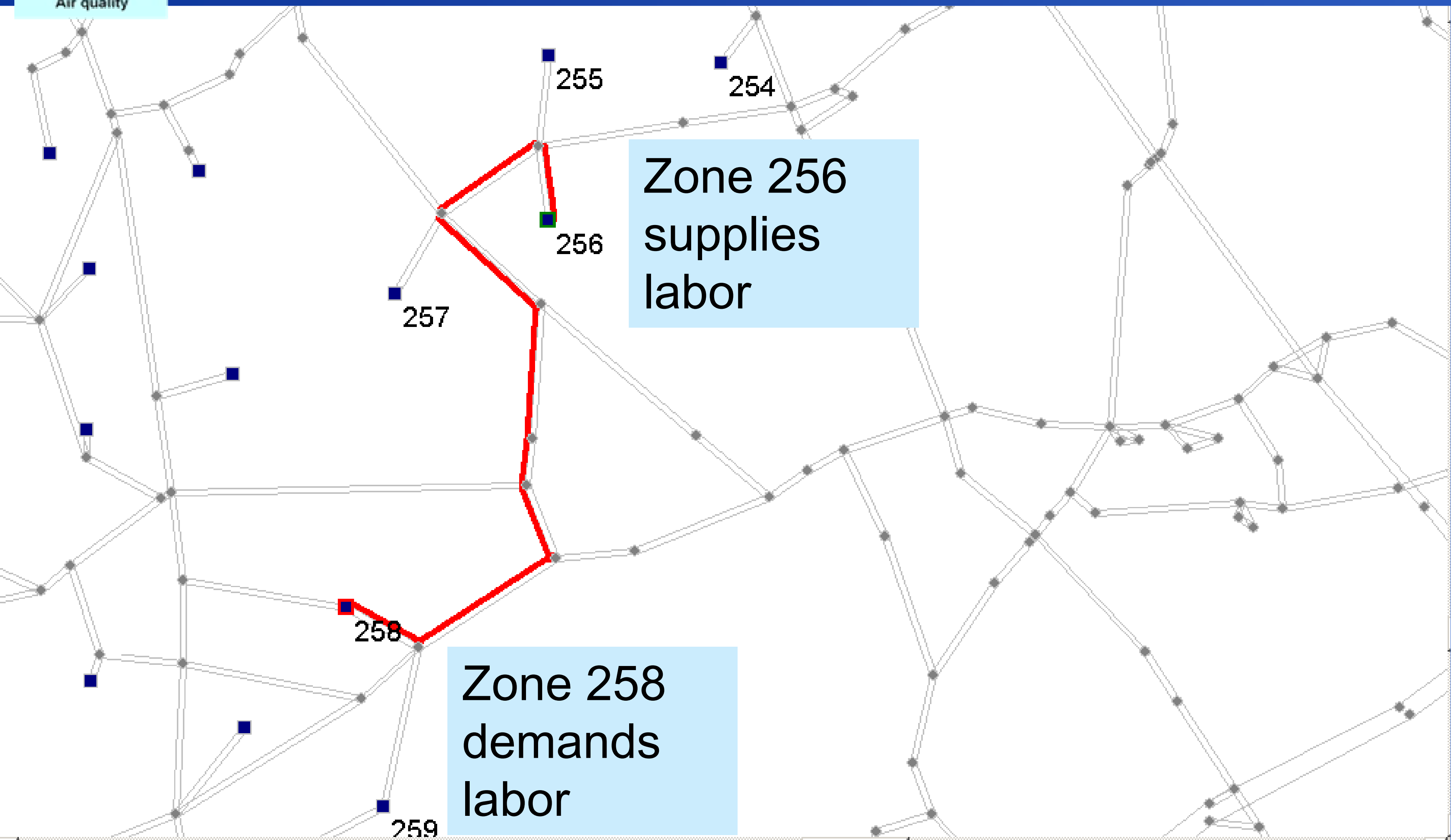
The activities-land use system



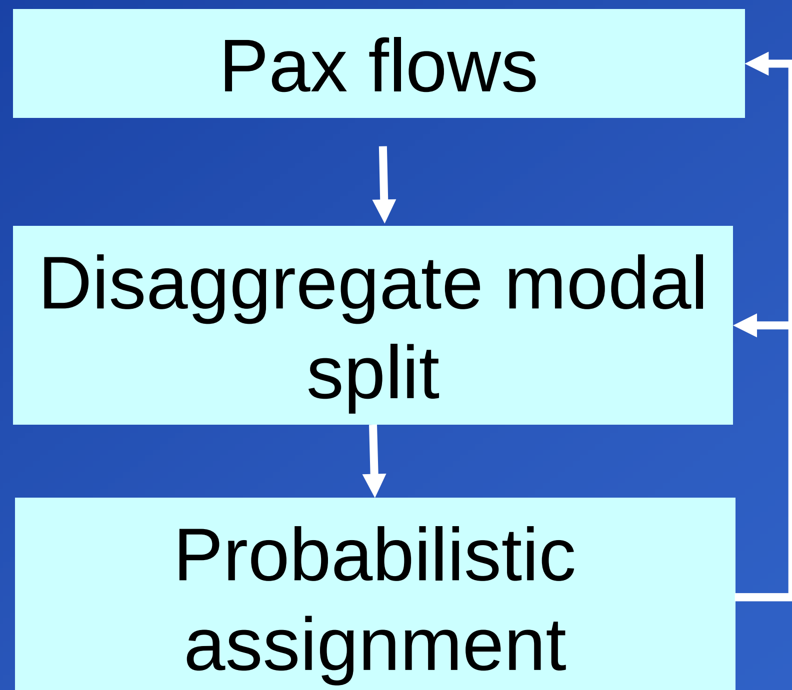
Source: Modelistica, 2004

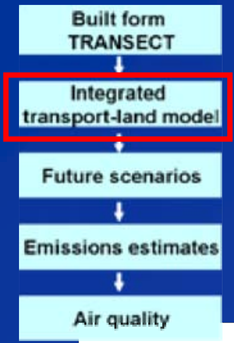
Economic flows generate transportation flows



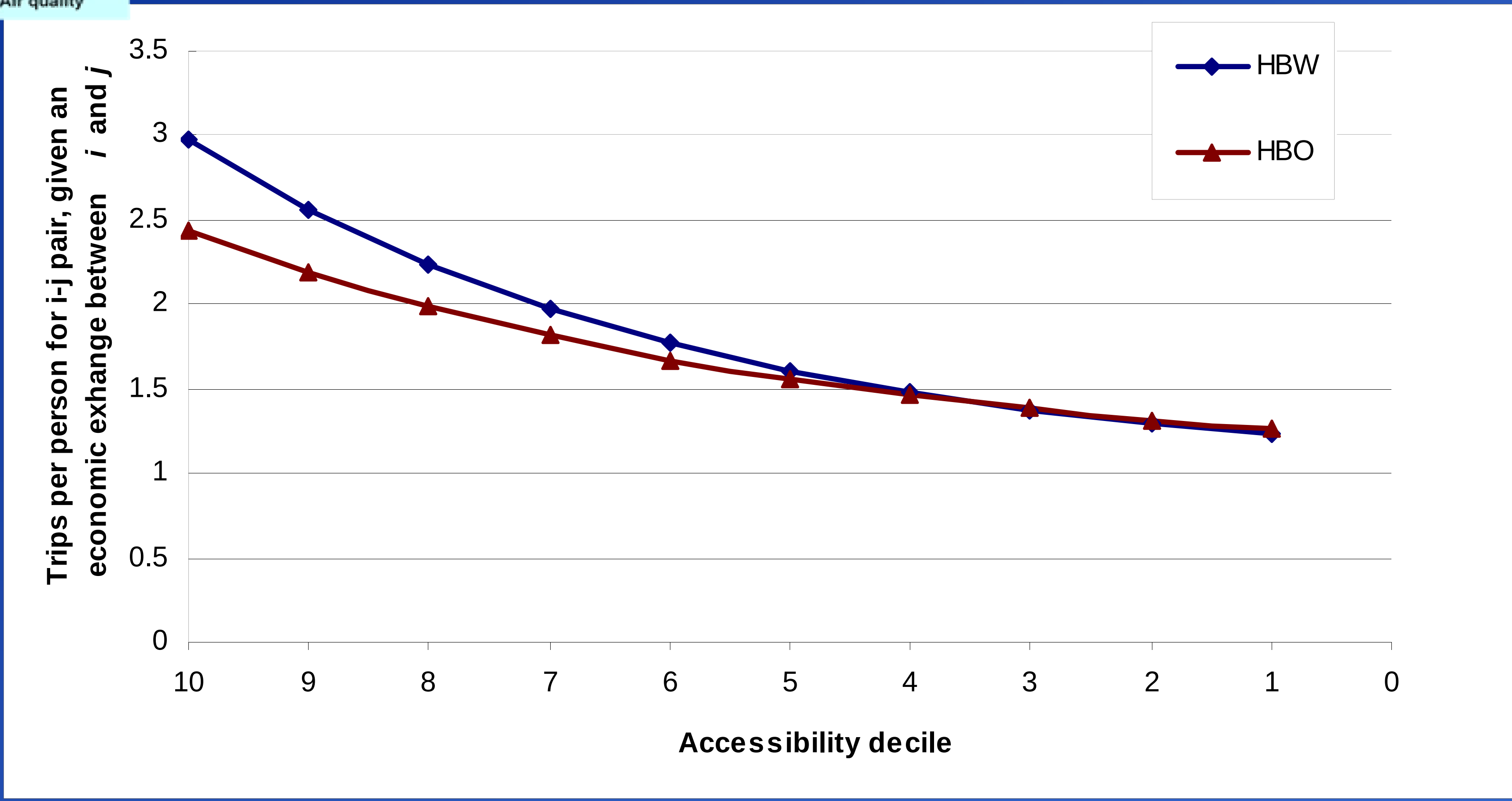


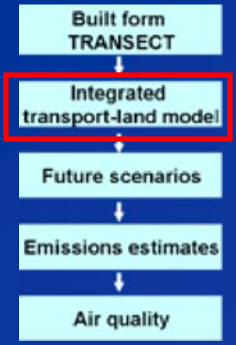
Structure of pax transport model





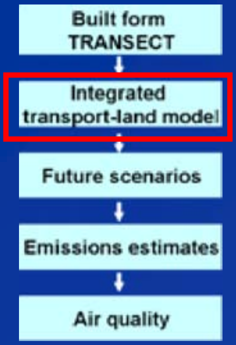
Passenger flows





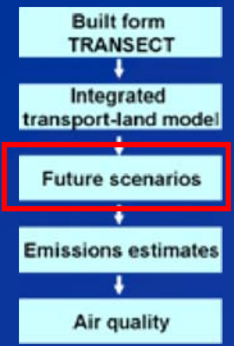
Modal split

- Mode choice *f* (built form)
- 2002 regional travel survey
  - Home-based work travel
    - Transit & walking environments for O and D
      - Trips from walk-friendly to walk-friendly zones 7 times higher odds by walking
        - » Comes from high and middle income groups
    - Little transit effects



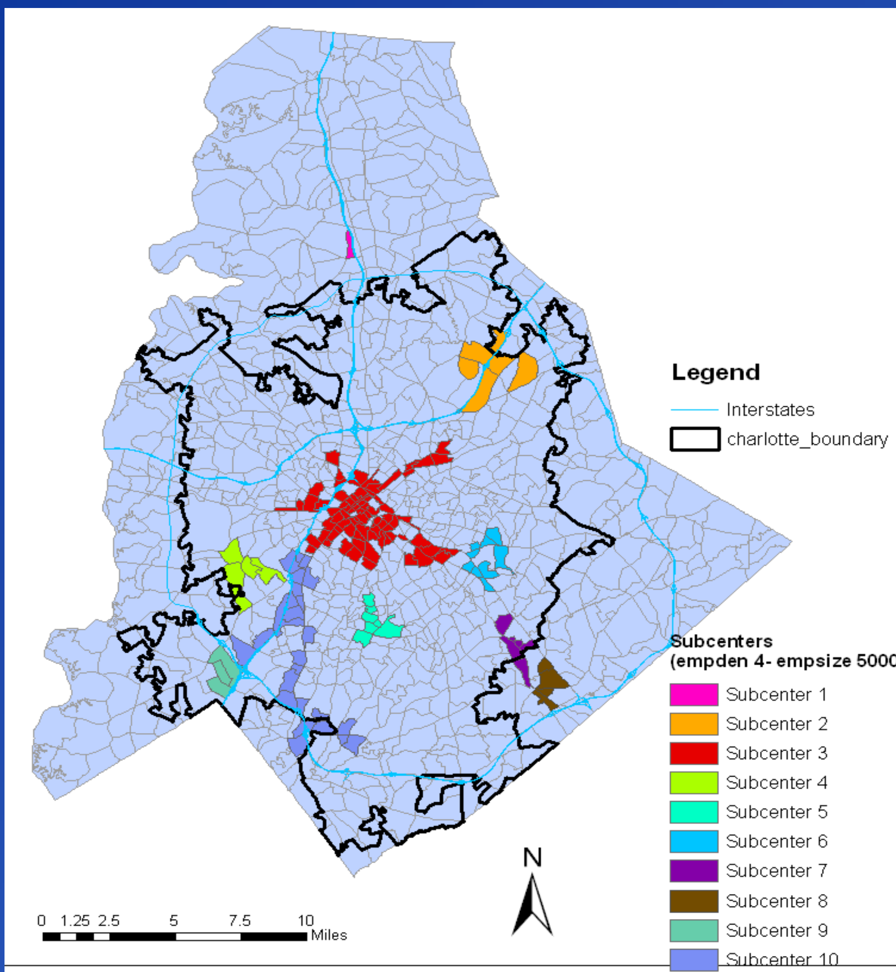
Modal split

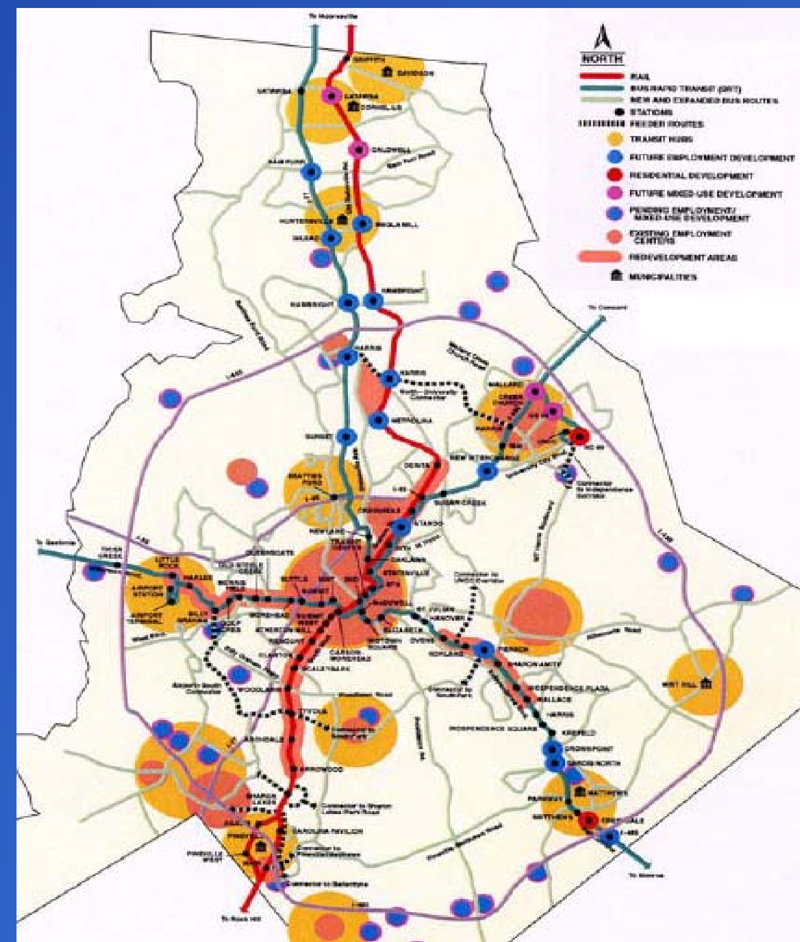
- 2002 regional travel survey
  - Other home based trips
    - Trips from walk-friendly to walk-friendly zones1.5 times higher odds of choosing walking
    - Trips from transit-friendly to transit-friendly zones 3.12 higher odds of choosing transit
  - Non-home based trips
    - Trips from walk-friendly to walk-friendly zones have 7 times higher odds of choosing walking



Future scenarios

- Business as usual and smart growth

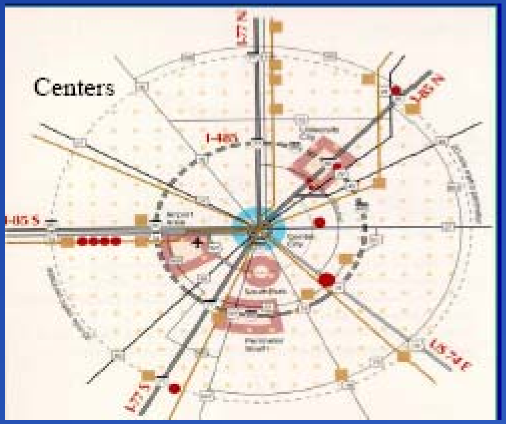


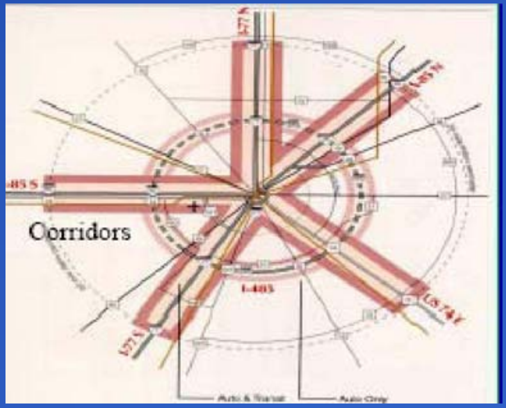


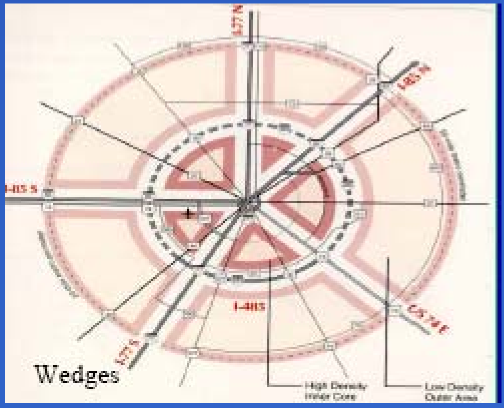
Source: Metrolina COG

Future scenarios and land use

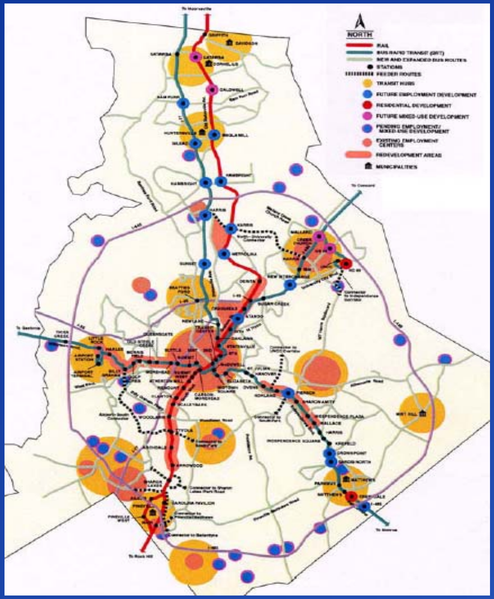
- New zoning around rail stations
  – Density bonuses
  – Incentives for dense development (reflected in land price)
- Down-zoning and land conservation in wedges

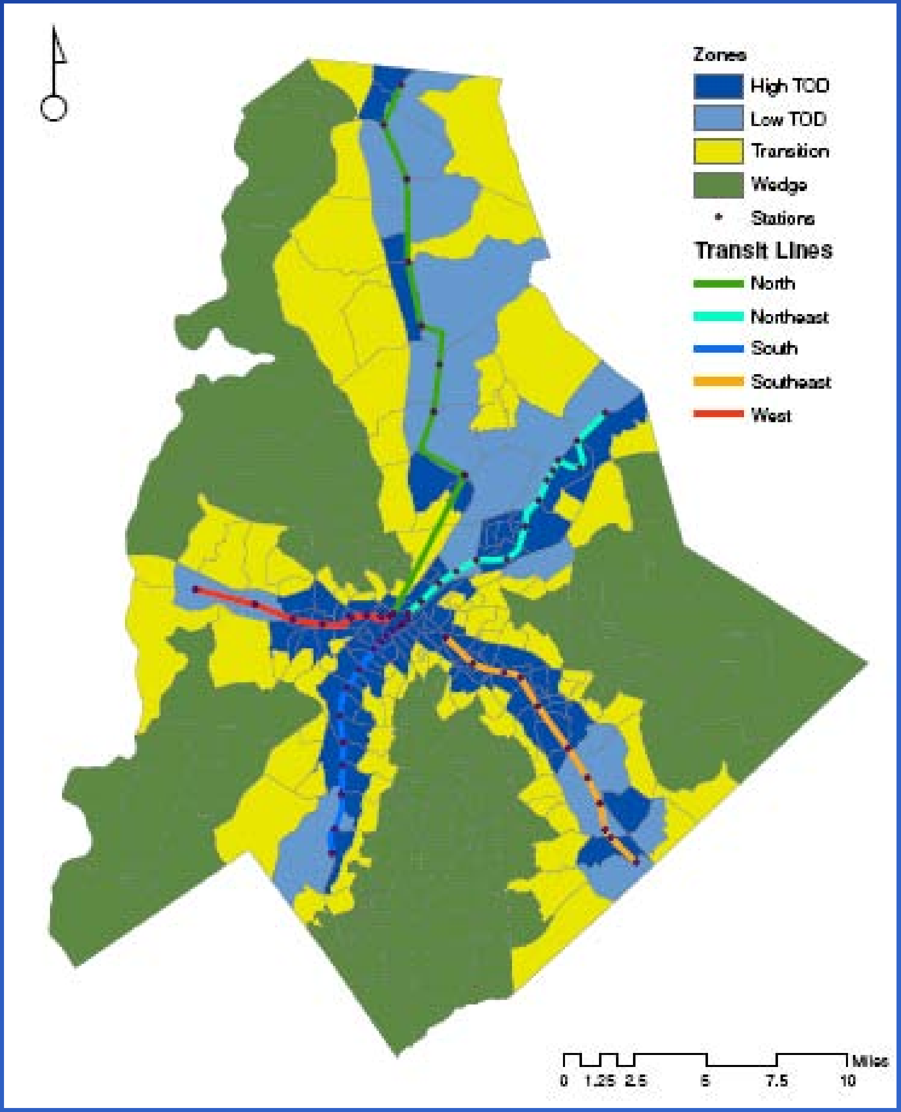






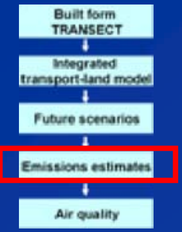
Smart growth scenario





Current status

- TRANUS calibrated to baseline (Y2000)
- Second baseline implemented and run
    - Transit improvements baseline (light rail, BRT, CRT)
    - No population, technology, employment changes
- Scenarios (Y2050) being implemented
- Emissions calculated
  - Baseline
  - For Triangle case (2005 vs 2030) to assess technology/fuel contributions to emissions changes

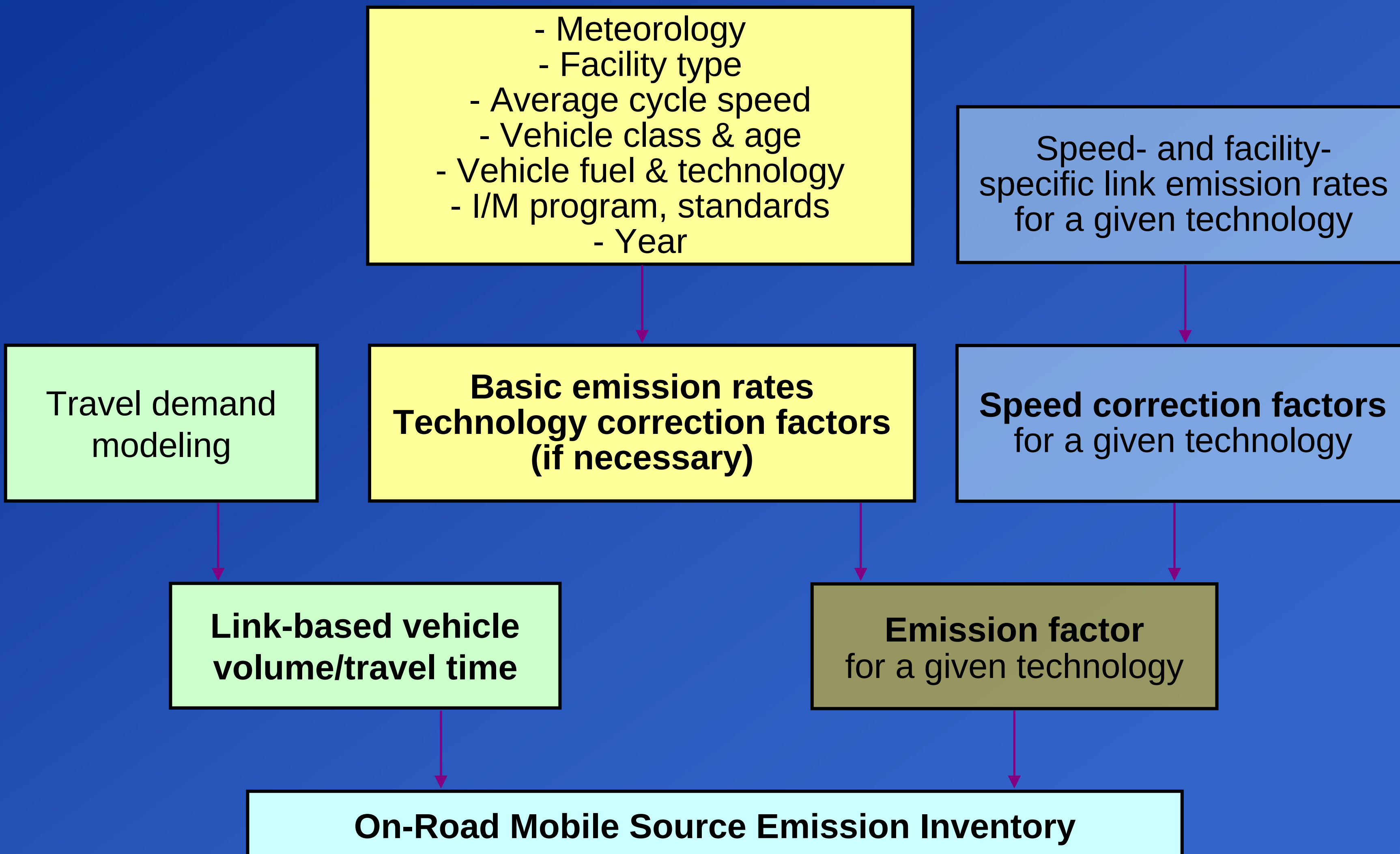


Link-based emissions model

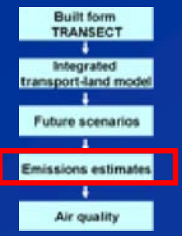
- Vehicle fuel and technology
- Facility type
- Ambient conditions
- Vehicle mean speed for link
- Vehicle class and age
- Vehicle fleet distribution
- Emission control standards and programs

Source: Frey et al 2008

Conceptual approach for emission factors & inventory estimation



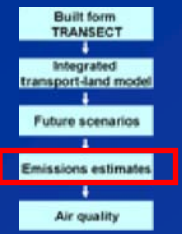
Source: Frey et al 2008



Link-based emissions model

- For each
  - Average link-based speed
  - Facility type
    - Freeway, arterial, ramp, local & collector
  - Technology class
    - Gasoline, diesel, E85, HEV, CNG cars etc

$$EF = \left(BER \times \alpha\right) \times TCF \times SCF$$



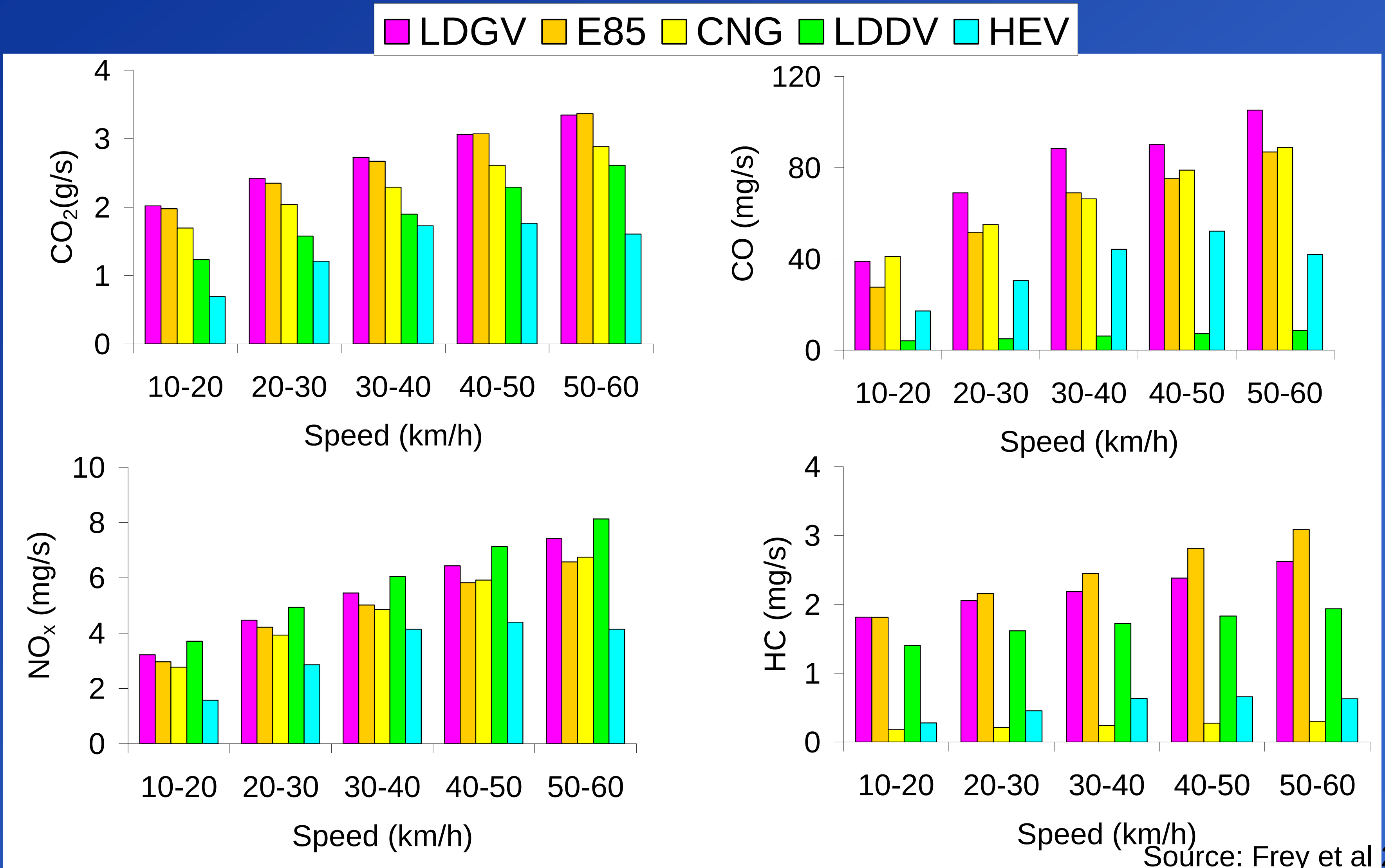
Database

Parameter	Vehicle Fuel & Technology	Source
Basic Emission Rates	LDGV, LDDV, HDDT, HDDB	MOBILE6
Speed Correction Factors	LDGV, HDDT	NCSU PEMS
	HDDB	EPA PEMS
	LDDV	Portugal PEMS
Fuel Economy	LDGV	EPA
	LDDV, HEV, CNG Cars	Fuel Economy Guide by EPA & DOE
Technology Correction Factors	E85, HEV, CNG Cars	EPA Certification Tests
	B20 trucks, CNG Buses	Literature*
Travel Patterns	TRANUS for Charlotte/Triangle Region Model	ITRE, NCSU

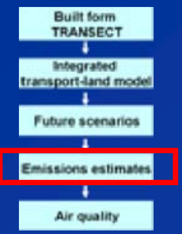
* There were no data available for alternative heavy-duty vehicle technologies. Their TCFs are based on literature estimates for B20 versus diesel heavy-duty trucks, and NG versus diesel buses

Source: Frey et al 2008

Example of link-based tailpipe emission factors: Arterials, CY 2005



Source: Frey et al 2008



Emissions inventory

$$TE = \sum_{ct}^{CT} \left(EF_{ct} \cdot t_{ct} \cdot vol_{ct} \right)$$

Where:

ct = combination of vehicle class and technology;

EF_{ct} = link-based emission factor for vehicle class (*ct*) (g/sec);

t_{ct} = average link travel time of vehicle class (*ct*) (second);

$vol_{i,ct}$ = travel volume of vehicle on link for vehicle class (*ct*) (vehicles/hr);

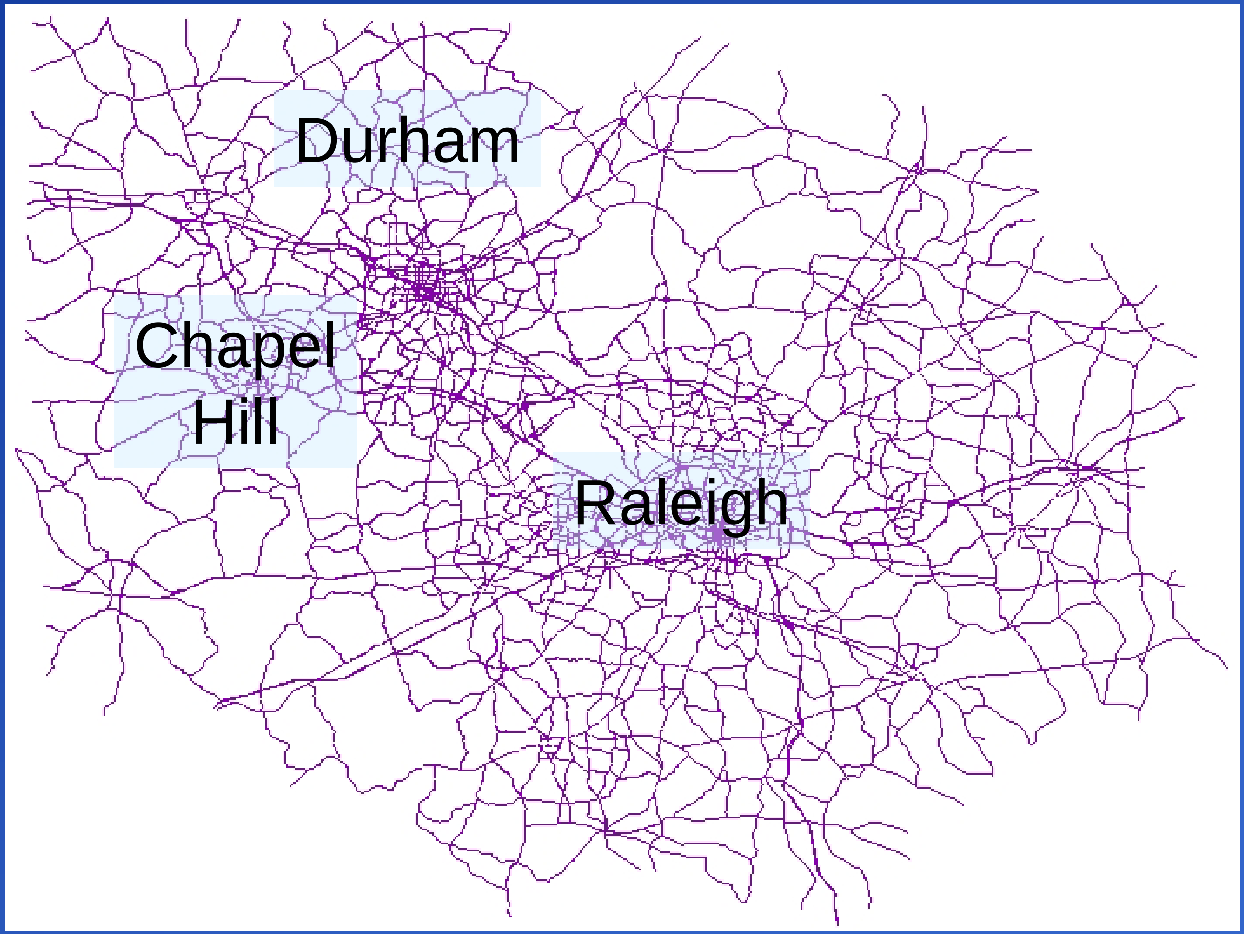
TE = total emissions for a single link (g/hr).

Source: Frey et al 2008

Emissions implementation to Research Triangle

- Baseline scenario (2005)
  - With and without alternative technologies-fuels
- Future scenario (2030)
  - With and without alternative technologies-fuels
  - With and without VMT growth (33%) and speeds decrease (28%)
  - Fleet renewal (to Tier 2 vehicles)

Triangle region transportation network



Source: Frey et al 2008

Emission inventory scenarios & fleet characterization

Vehicle Class	Fuel & Tech.	Fleet Penetration of Each Vehicle Class (%)			
		Present Scenario (2005)		Future Scenario (2030)	
		Baseline	Alternative	Baseline	Alternative
Car	LDGV	100	73	100	73
	E85	0	9.9	0	9.9
	HEV	0	9.9	0	9.9
	LDDV	0	5.9	0	5.9
	CNG	0	1.2	0	1.2
	EV & Fuel Cell	0	0.1	0	0.1
Truck	HDDT	100	73	100	73
	B20 Trucks	0	27	0	27
Bus	HDDB	100	73	100	73
	CNG Bus	0	27	0	27

Source: Frey et al 2008

Regional emissions during weekday morning peak hour

Total Transportation Network Emissions (tons)

Scenario	HC	CO	NO_x	CO_2
Present: Baseline	0.854	34.50	4.63	1376
Present: Alternative	0.788	29.75	4.48	1326
Future, No Growth: Baseline	0.153	9.69	0.39	1200
Future, No Growth: Alternative	0.148	8.36	0.37	1166

Source: Frey et al 2008

Next steps

- Complete similar estimation for Meck County scenarios
  - Incorporate fuel/technology, VMT changes, and URBAN FORM
- Air quality modeling, given emissions

Conclusions

- Calibrated integrated transport & land use model
  - Sensitive to environment --unique
  - Insight into behavior, technology and air pollution
- Neighborhood typology in accordance with theory

Conclusions

- Confirmed empirically relevance of environment
  - Travel mode choice
  - Residential location decisions
  - Implemented relevance in TRANUS framework

Conclusions

- Small market penetration of advanced vehicles and fuels do not appear to alter fleet emissions substantially
- Fleet turnover to Tier 2 vehicles substantially reduces emissions of HC, CO and NO_x
- Modest improvements in fuel economy could be offset by VMT growth/average speed reductions

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