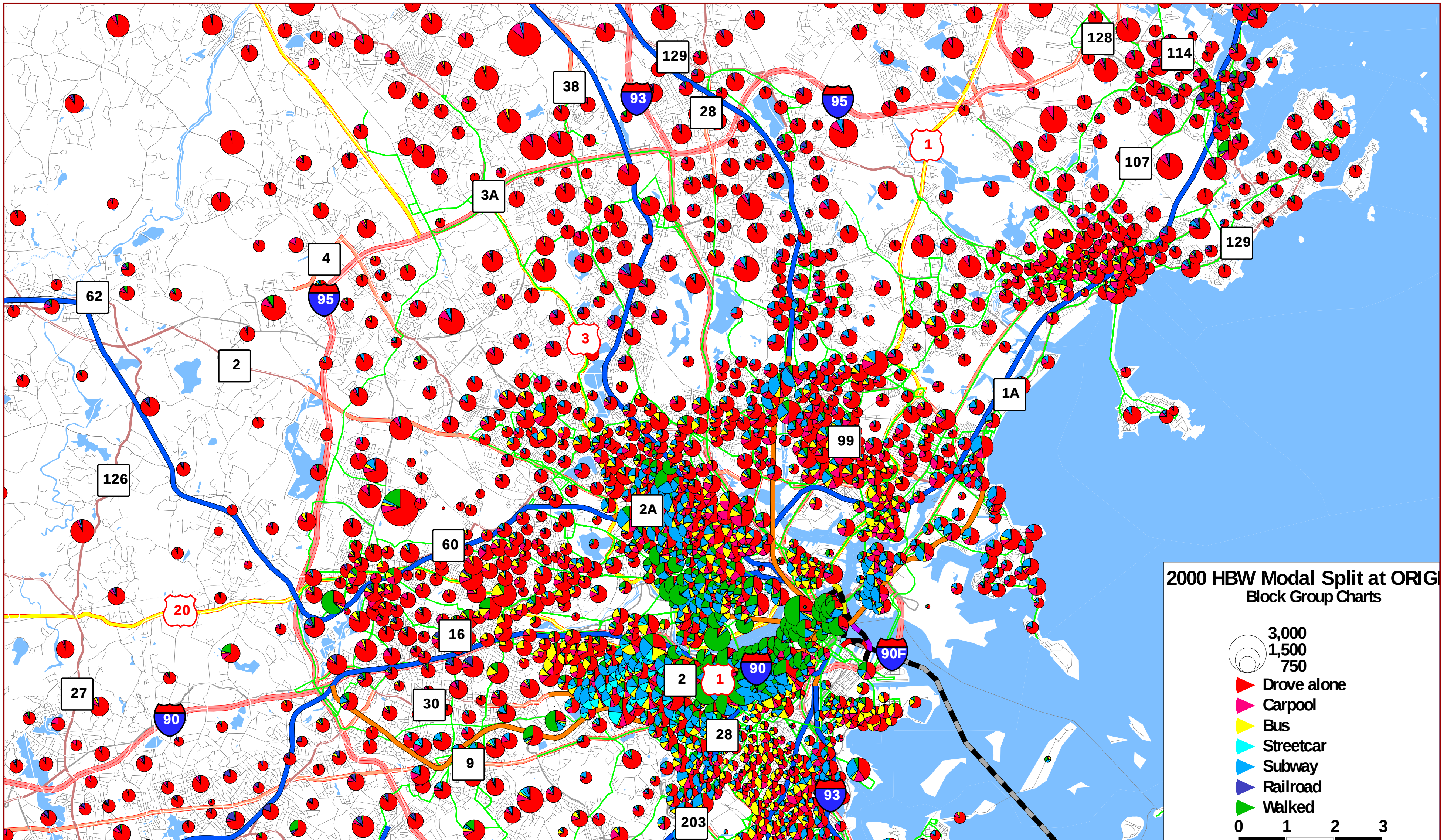
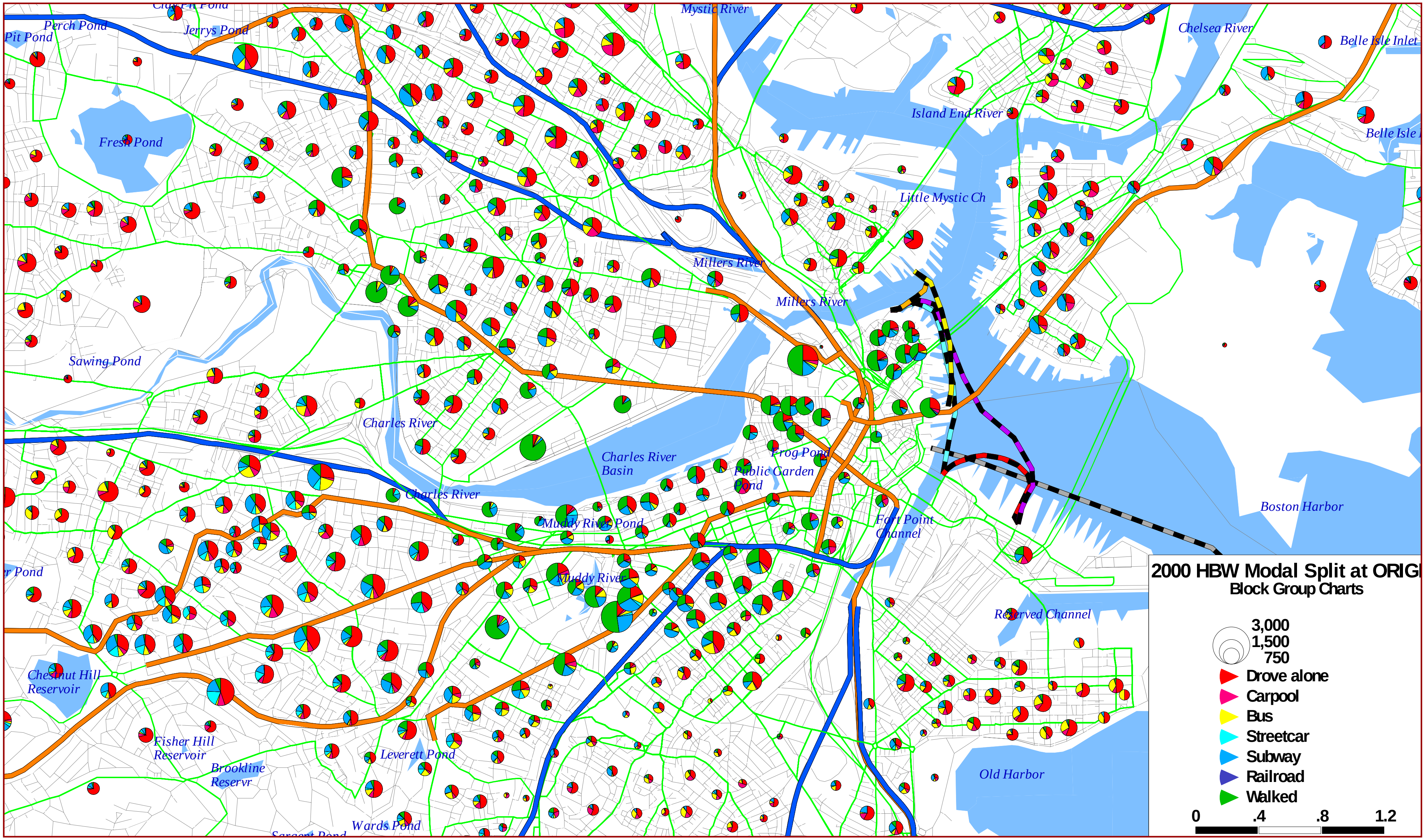
Block 3: *Behavioral Patterns*
Modal Split at the Residential End

Massachusetts Institute of Technology



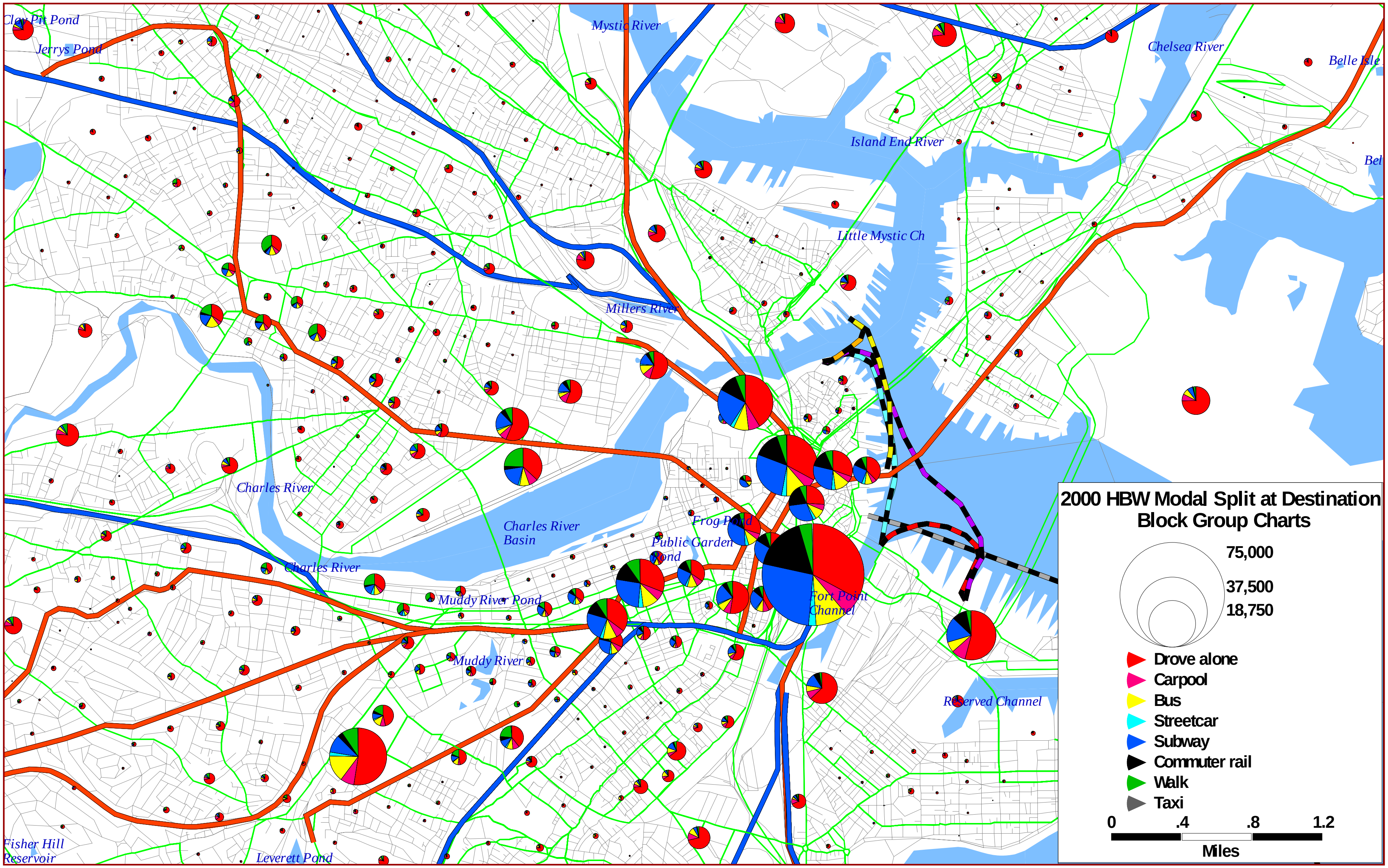
Block 3: *Behavioral Patterns*
Modal Split at the Residential End

Massachusetts Institute of Technology



Block 3: *Behavioral Patterns*
Modal Split at the Work Center End

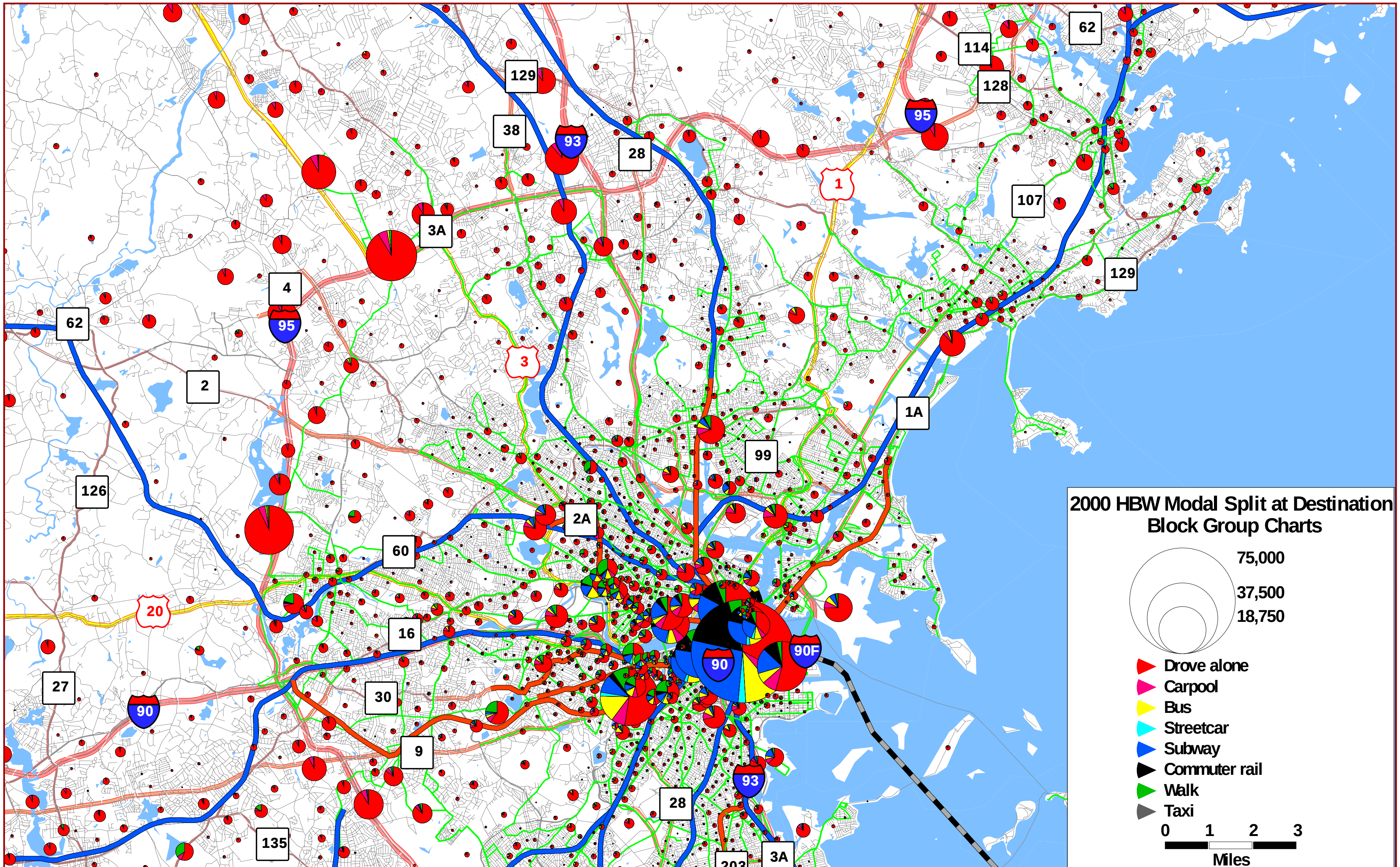
Massachusetts Institute of Technology



Block 3: *Behavioral Patterns*

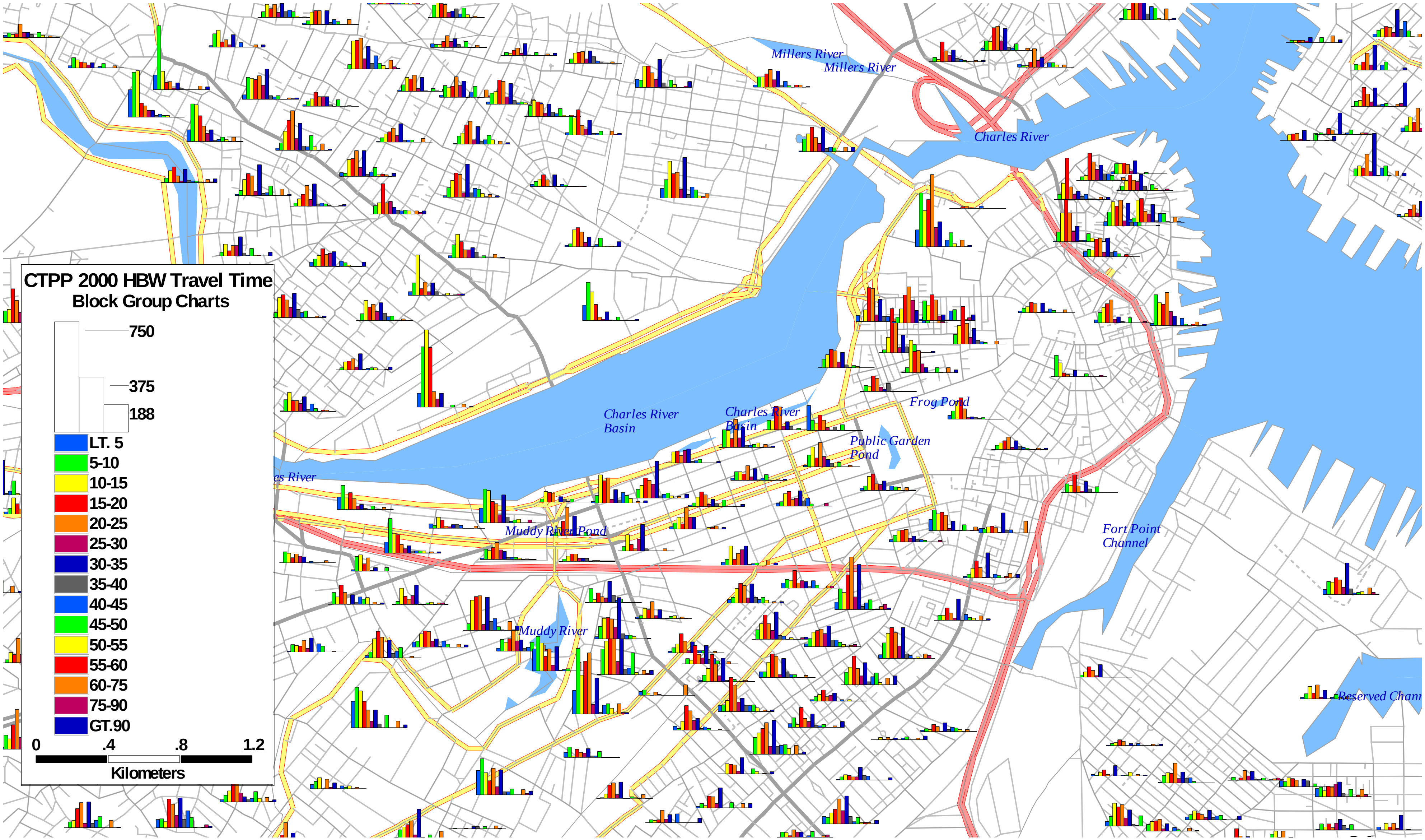
Modal Split at the Work Center End

MIT
Massachusetts Institute of Technology



Block 3: *Behavioral Patterns*
Commuting Time from Residence

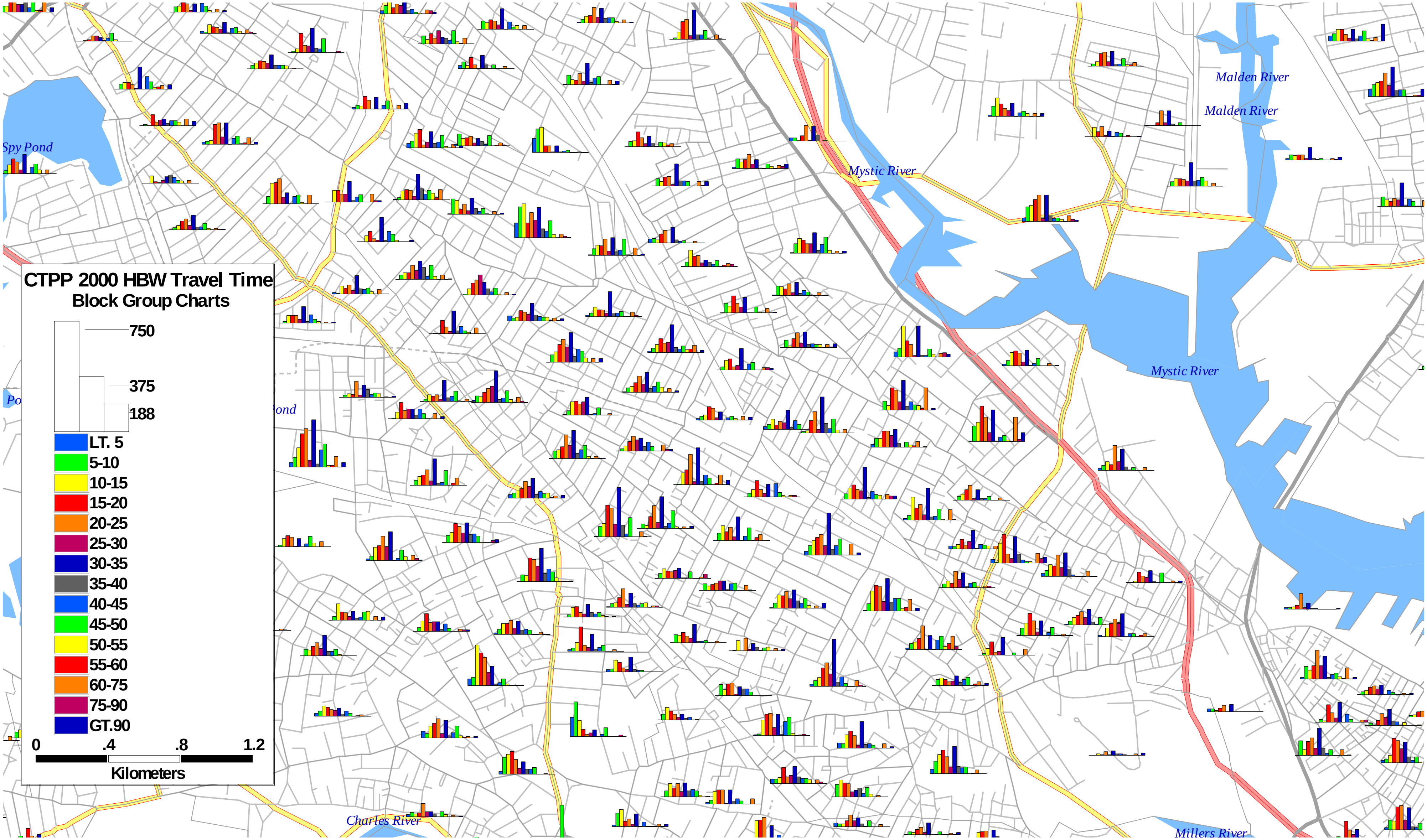
Massachusetts Institute of Technology



Block 3: *Behavioral Patterns*

Commuting Time from Residence

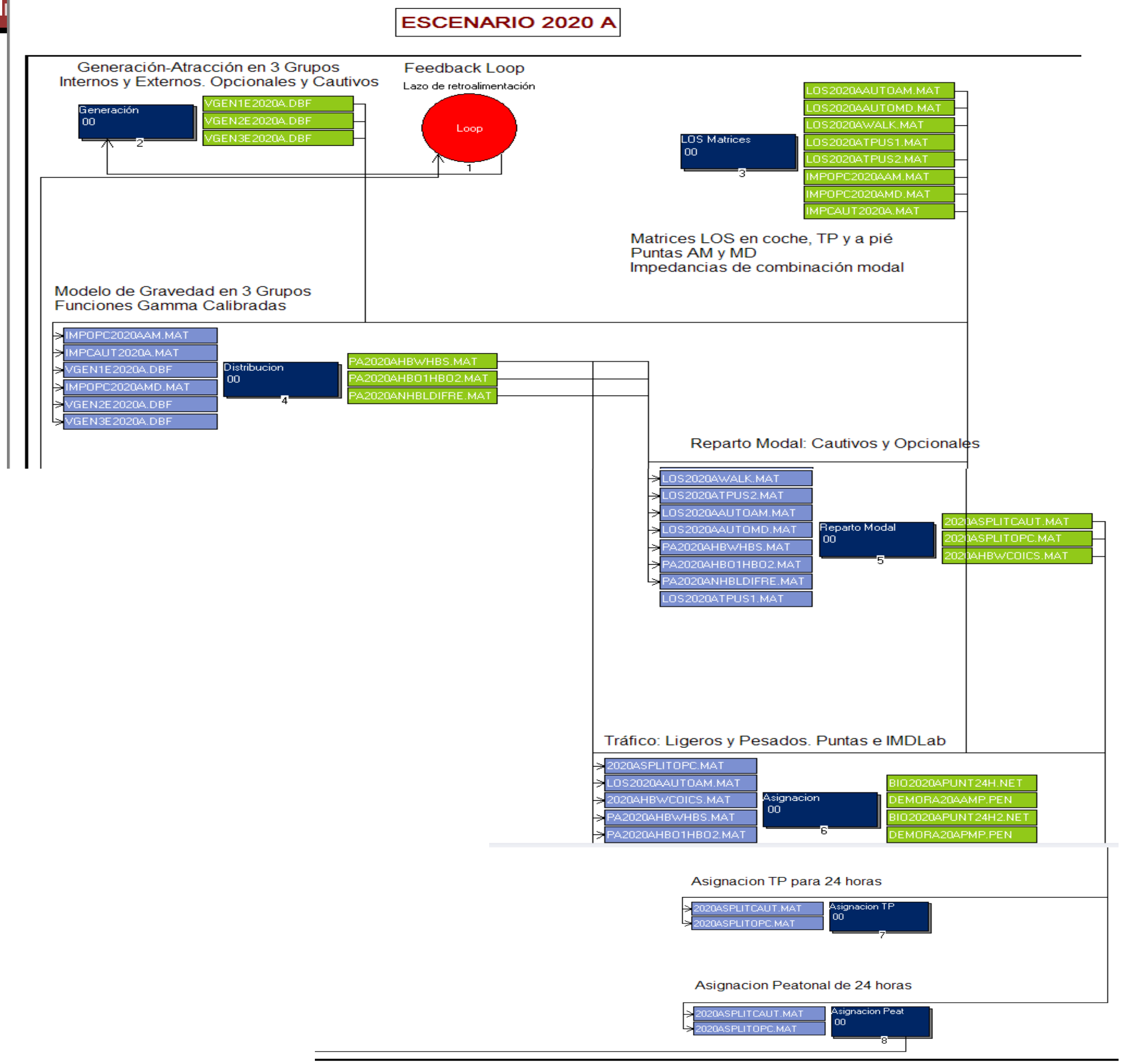
MIT
Massachusetts Institute of Technology



MIT

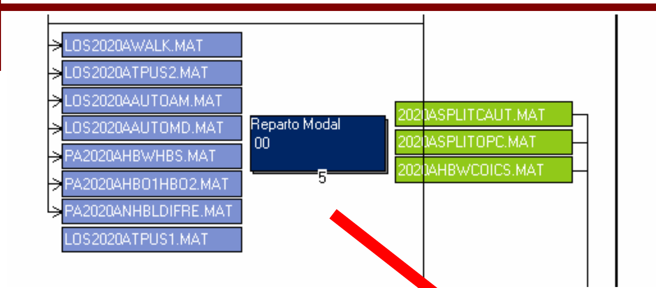
Block 3: Behavioral Patterns turned into a program

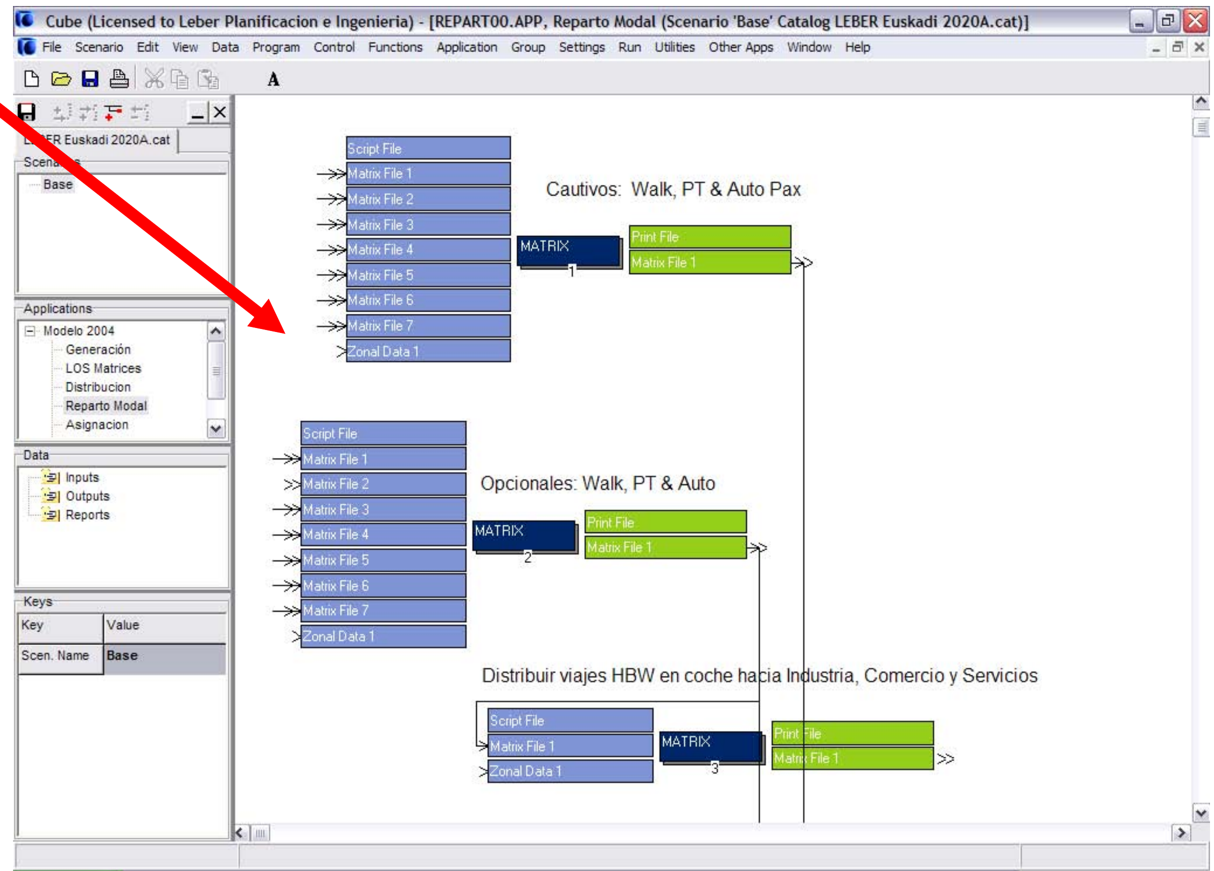
Massachusetts I



MIT

Block 3: Behavioral Patterns turned into a program

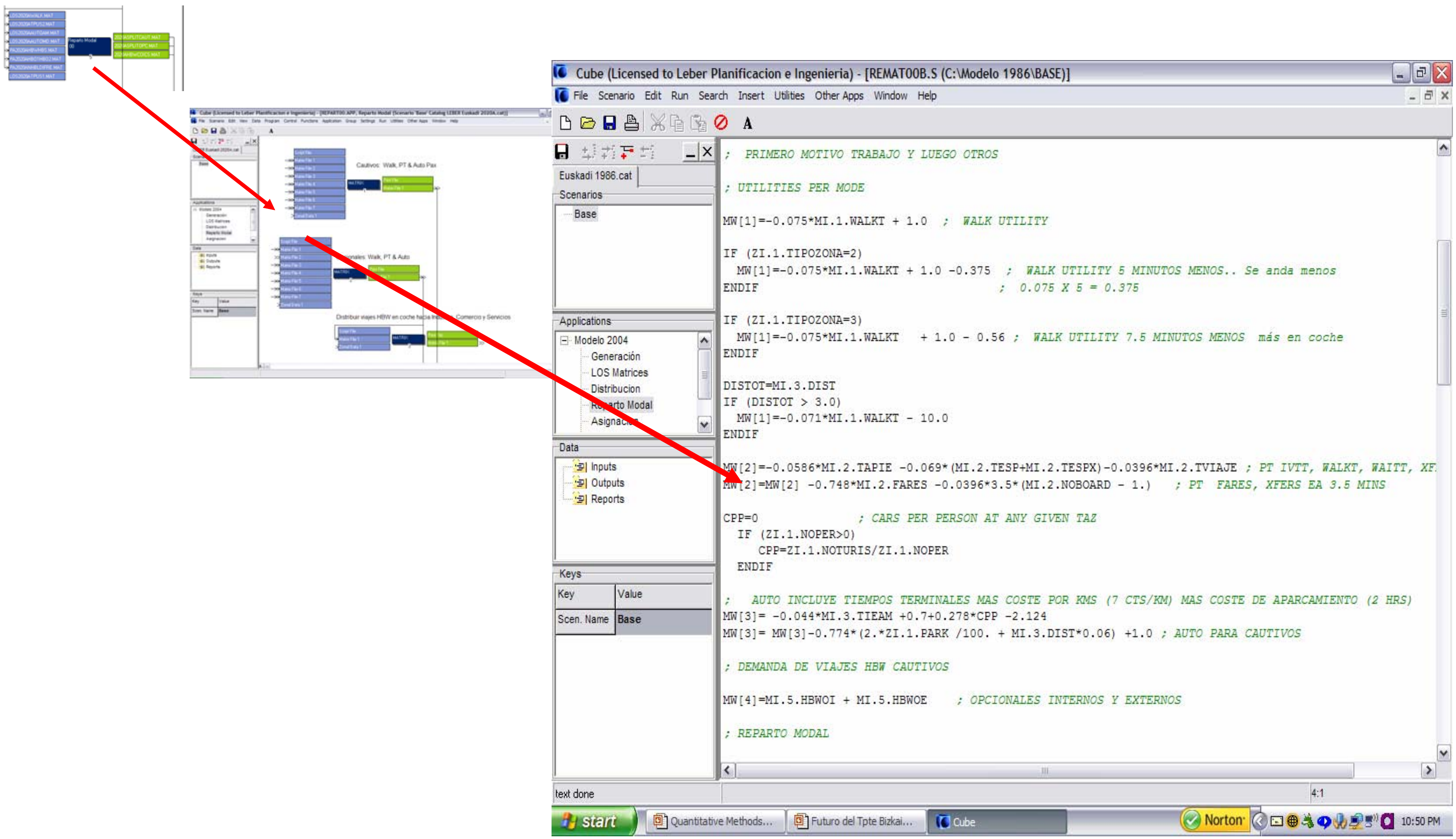




MIT

Massachusetts Institute of Technology

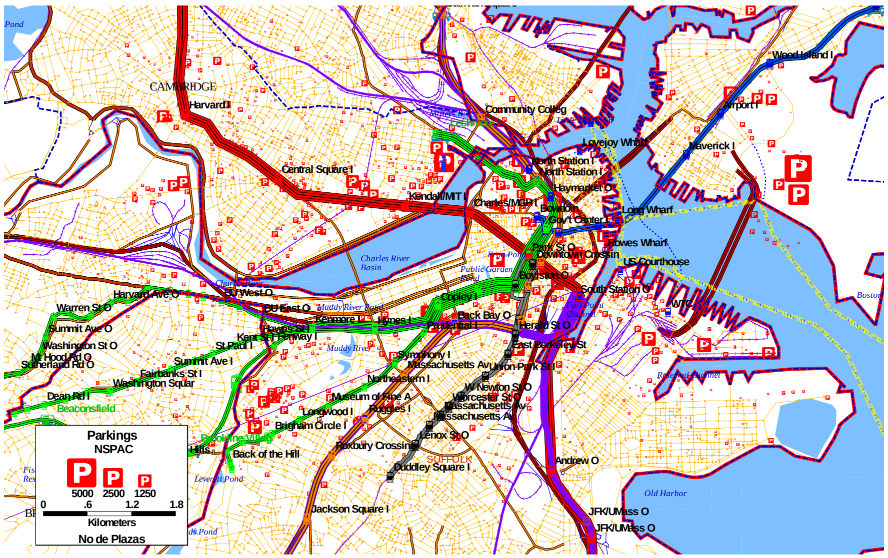
Block 3: Behavioral Patterns turned into a program

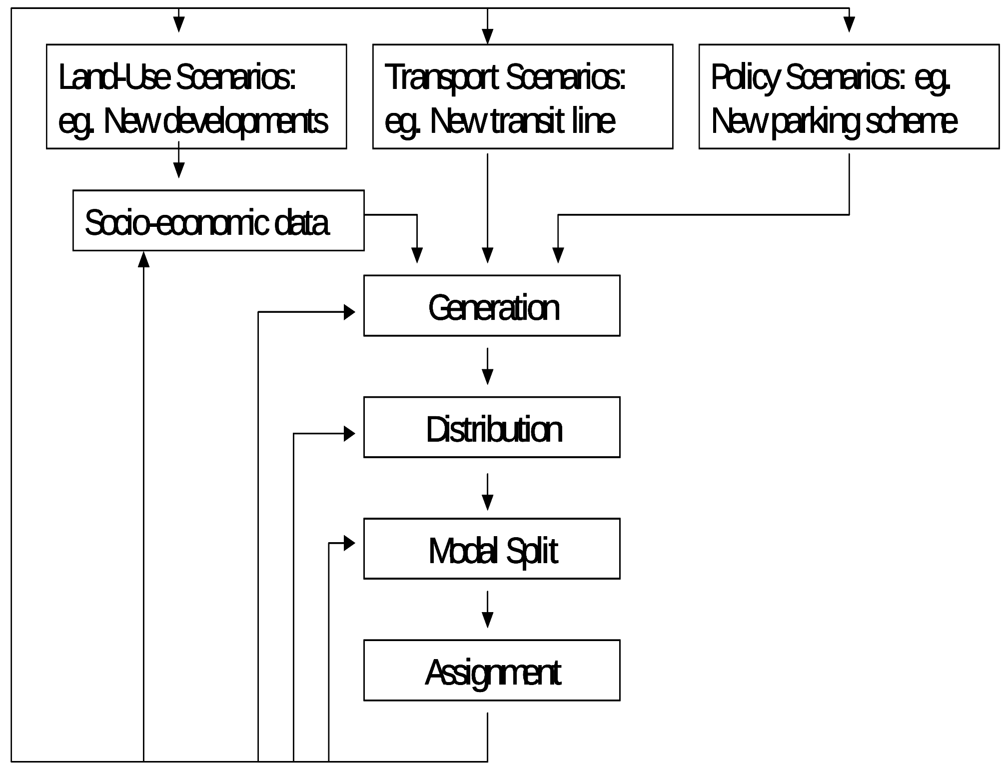


F.Salvucci and M.Murga

MIT
Massachusetts Institute of Technology

Are we ready for the 4 Step Model?





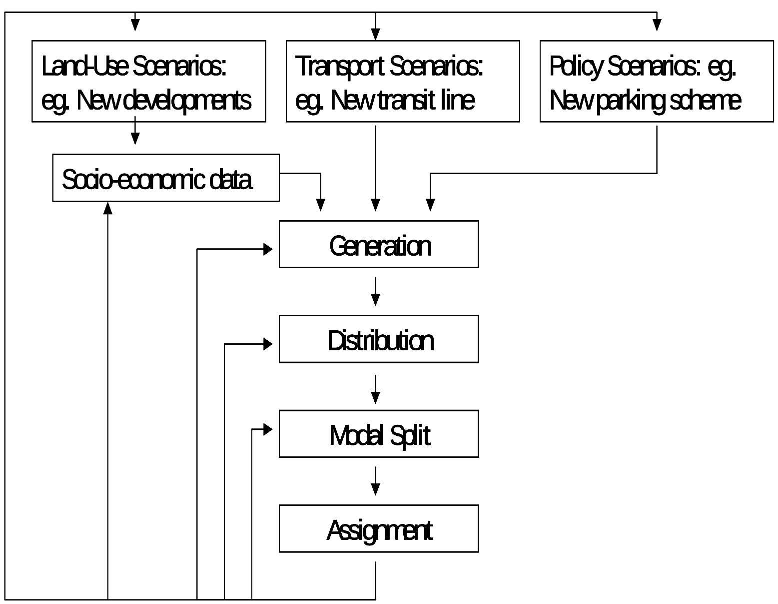
MIT
Massachusetts Institute of Technology

Use of Planning models

- Traditionally:
  - Demand estimates per mode
  - Explore impact of future alternative land use-transport scenarios
- More and more:
  - Short term policies: Detours, parking policies, street closings, modal split ...
  - Environmental impacts
  - Impacts of ITS technologies
  - Operational studies for “non-regular” days
- Adapting to today’s needs: congestion & demand management, plus, air-quality issues

MIT
Massachusetts Institute of Technology

Why planning models are important?



- Forecasts numbers can be easily used to kill a project or to keep it alive, even if it has no real merits
- Models often used as "black boxes"
- They can be manipulated to produce results fitting client's wishes
- As few post-mortems are conducted, many are happy "to predict the future"

The 4-Step Model

Massachusetts Institute of Technology

- ***I don't believe in models!***
- ... but everyone has a model in his mind. Modeling just a mental abstraction. Often a very simple one!
- Don't be afraid to model a particular behavior, even if it is not in the books
- Models (and simulations) may become self-educating tools

MIT
Massachusetts Institute of Technology

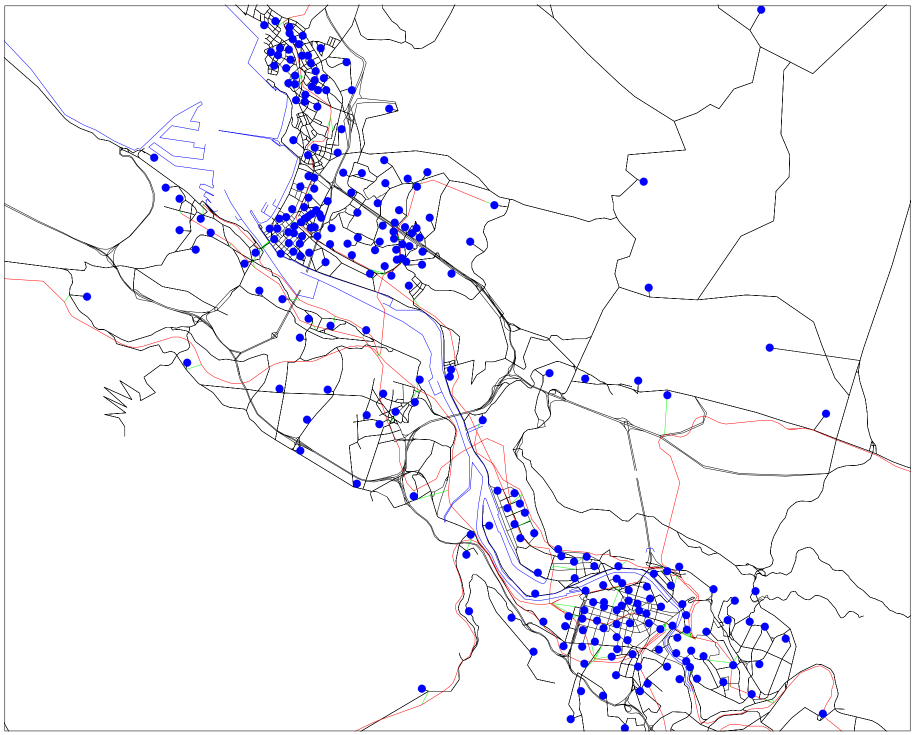
The 4-Step Model Software

- Commercial packages:
  - TransCAD
  - Cube Voyager
  - Emme2
  - Vissum
  - Trips
  - Tranplan
  - MinUTP
  - ....
- From black boxes to script languages with open subroutines
- User-friendliness versus flexibility to model *your own thing*
- Bugs galore -> Direct link with programmers

"When using mathematics in modeling, if one cannot interpret the outcome in good, plain English then the paper should be burnt and one should start again"
Alfred Marshal, 19th century UK economist

MIT Massachusetts Institute of Technology

The 4-Step Model



Initial considerations:

- Modeling objective
- Area to be modeled
- Level of detail
- Availability and quality of data
- Trip purposes to be represented
- Transport modes to include
- Treatment of heavy vehicles
- ……………………………

MIT
Massachusetts Institute of Technology

The 4-Step Model: Generation

- Generated trips:
  - Household as basic unit for home survey analysis
  - Cross-classification of households as a function of number of people, no of workers, no of cars (or income), age groups ...
  - Most important parameter: Number of members per dwelling unit
- Attracted trips: (See ITE Trip Generation)
  - Job centers – number of employees
  - Shopping areas – footage area
  - Airport – passengers
  - ....

The 4-Step Model: 1.Generation

Massachusetts Institute of Technology

- Generation:
  - How many trips per family?[1]
  - Home Surveys to establish:
    - No of trips as a function of number of people per household, income, number of cars, type of dwelling, residential area...
    - Distribution among trip purposes: Usually HBW (Home-Based-Work), HBO (Home-Based-Other) and NHB (Not-Home-Based)
    - Distribution between motorized and non-motorized
    - Distribution between chained and un-chained trips
    - Number of captive public transport users: e.g.: f (*No of people per household vs no of automobiles in household)*

[1] Number of trips per person a quasi-constant

MIT Massachusetts Institute of Technology

The 4-Step Model: Generation

Some basic questions:

- Is trip generation sensitive to policy changes?:
  - If we improve the transport system, will we experience more trips per family?
  - Just the total number of trips or only those at a given time?
  - Or perhaps, just the trips made on a given mode?
  - What is the influence of land use?

MIT The 4-Step Model: 2.Distribution

Massachusetts Institute of Technology

- Probably the most important of the 4 steps
- An analytical description of where people choose to locate their residence and where do they choose to work, to shop, to socialize ...

The 4-Step Model: 2.Distribution

MIT Massachusetts Institute of Technology

- What is it needed?
  - Trips generated at household level
  - Attractions points (shops, job centers, other residences, special generators: airports, hospitals..) defined in quantitative terms
  - Balance between trips generated and trips attracted
  - Time (and cost) matrices by car and by transit to travel from generation points to attraction points
  - Measured people's aversion against traveling longer distances, times..

MIT

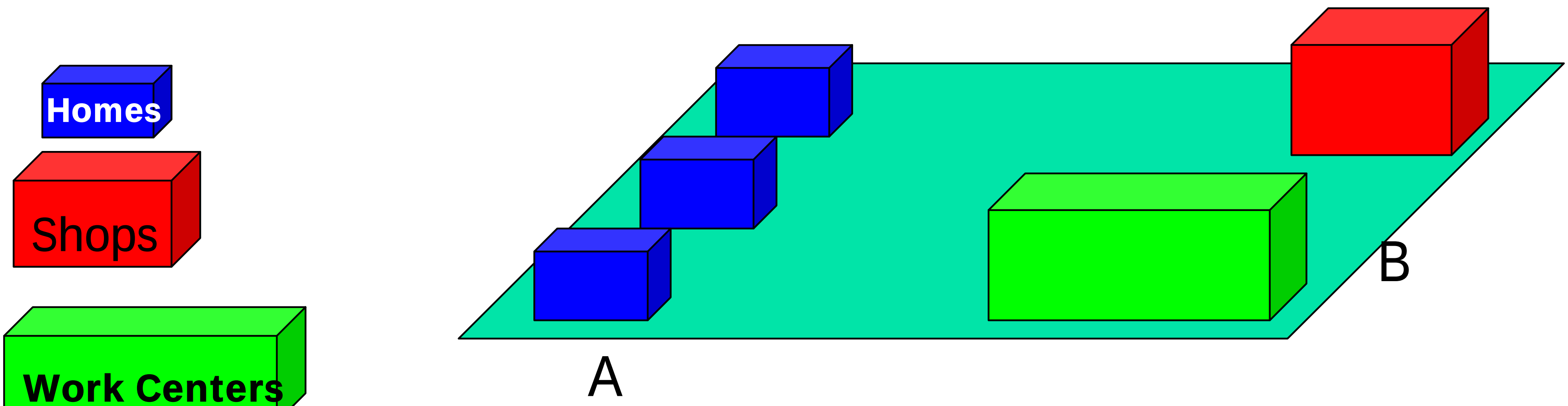
Massachusetts Institute of Technology

The 4-Step Model: Distribution

- Where will the generated trips go to? Generation ←→Attraction (jobs, shops, schools, residences...)
- Travel impedance as a restraint:
  - Travel impedance elements: time, distance, tolls, ramps, scenic value...
  - Friction curves or people´s aversion to travel, expressed as f (time, distance, tolls...)
  - Times during peak hour??

MIT
Massachusetts Institute of Technology

The 4-Step Model: Distribution

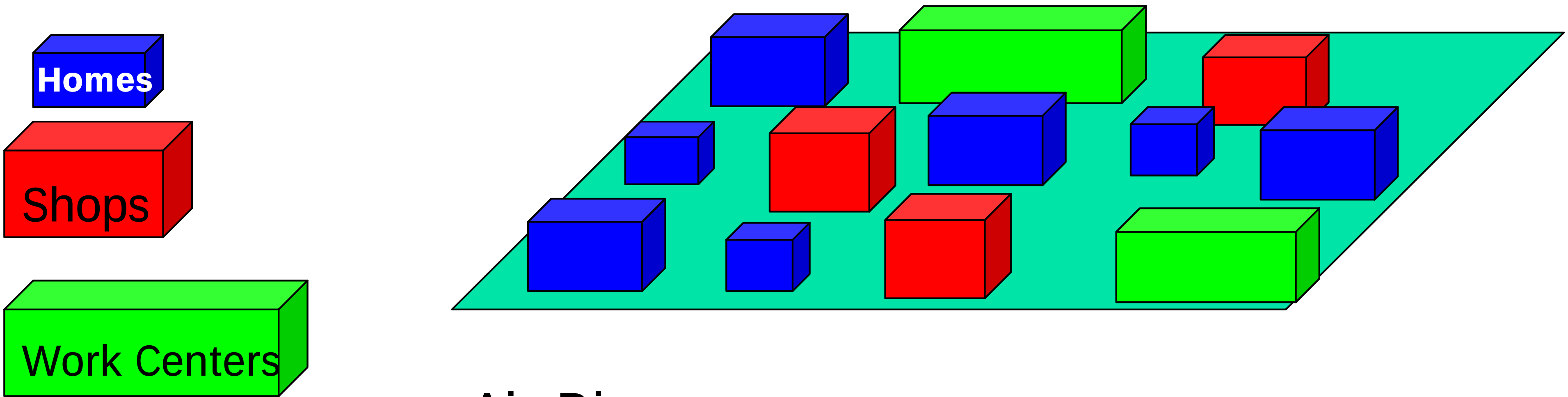


- We have obtained "skimmed matrices" (time&cost to go from A to B)
- We know how reluctant people are to travel far (friction curves)

For above situation, how critical is it going to be the postulated friction function for the estimation of the Trip Distribution?

MIT
Massachusetts Institute of Technology

The 4-Step Model: Distribution

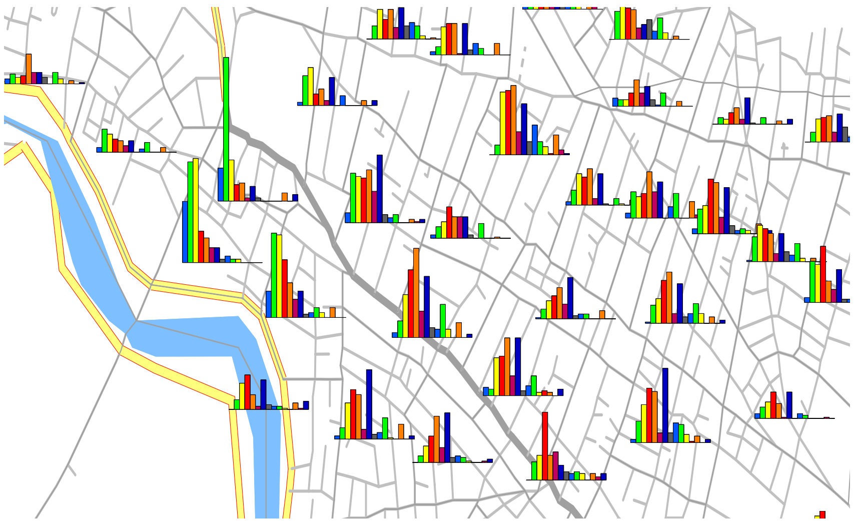


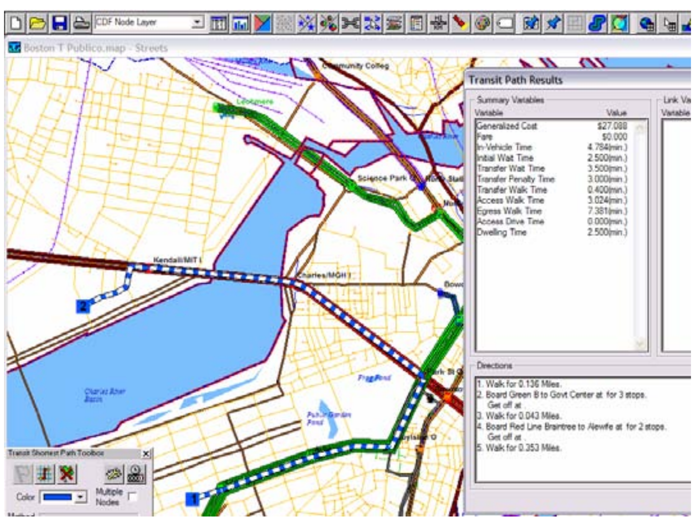
Ai Bj

What about now..., how critical is now the postulated friction function for the estimation of the Trip Distribution?

The 4-Step Model: Distribution
We start with...

MIT
Massachusetts Institute of Technology





- A time (or impedance) matrix between each i-j zone pair
- A time distribution for each zone (ie Census or survey data) on their aversion to travel
- The estimated trips generated and/or attracted at each zone

- OUR GOAL is to estimate **a P-A matrix** (easily turned into an O-D matrix) for each trip purpose

The 4-Step Model: Distribution
We proceed by...

MIT
Massachusetts Institute of Technology

- Adopting a gravity model algorithm (or other similar approach), so that we estimate the trips between any two pairs by:
  - $T_{ij} = P_i * (A_j F_{ij} / Sum (A_k F_{ik}))$ with k=1 to all zones and F_{ij} being the friction function corresponding to the time (or impedance) between zones i and j

- Note that this is an iterative process, where we change the friction factors and at the same time we have to guarantee that the sum of production trips is equal to the total number of attracted trips

MIT

Friction functions for distribution

Massachusetts Institute of Technology

- Postulate a friction function (or look up table) for each trip purpose. You can choose for example between: Exponential
  - $f(tij) = \exp -c(tij)$
  - Inverse power $f(tij) = tij^{-b}$
  - Or, Gamma $f(tij) = a\ tij^{-b} \exp -c(tij)$

    tij being the time (or impedance) between zones i and j

- Visualize NCHRP 365's gamma functions:
  - HBW a= 28,507 b=-0.02 c= -0.123
  - HBO 139,173 -1.285 -0.94
  - NHB 219,113 -1.332 -0.100

The 4-Step Model: Distribution
We continue by...

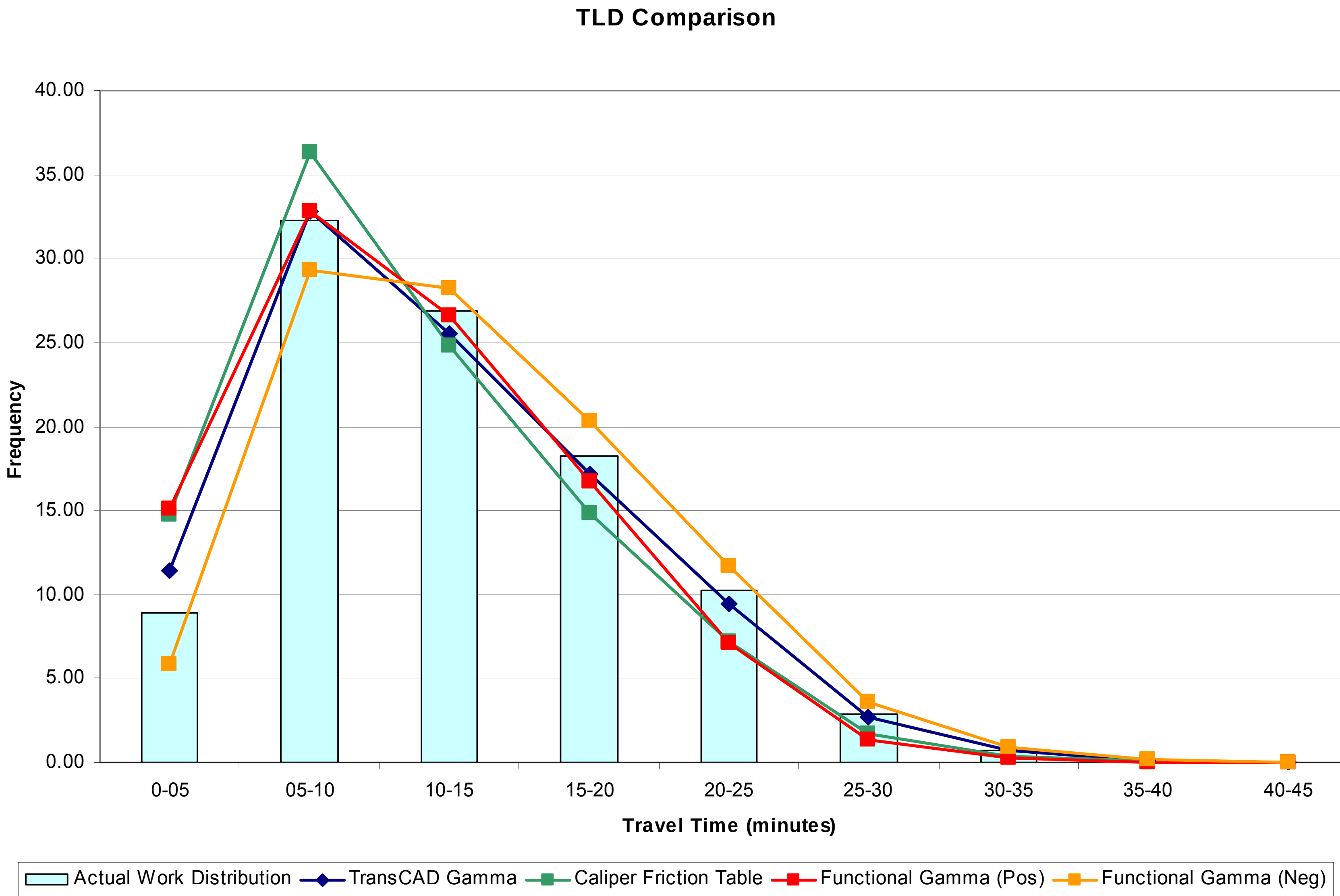
Massachusetts Institute of Technology

- Estimating the P-A (Production-Attraction) matrix and then calculating the trip time distribution for all zones (or just some zones)
- Comparing those distributions with the observed distributions
- Iterating and modifying the friction functions until we converge

- Finally, we validate the model by comparing the full estimated P-A matrix with the census or survey P-A (or O-D matrix)

You compare the trip time distributions which result from the generated P-A matrix with the observed distributions

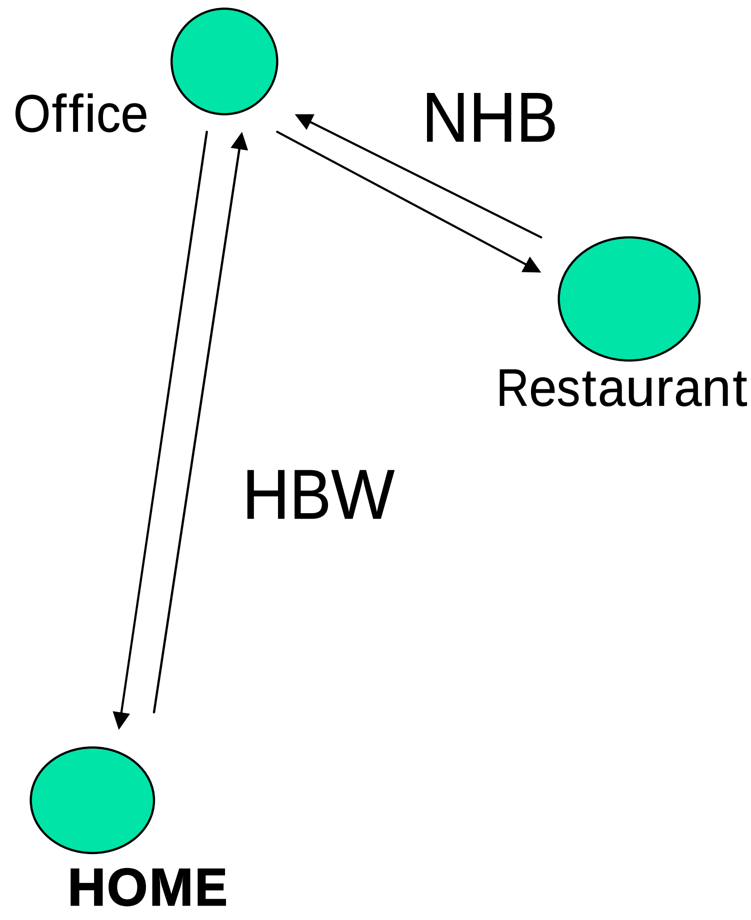
Massachusetts Institute of Technology



You need to generate P-A matrices for each trip purpose: HBW, HBO and NHB trips

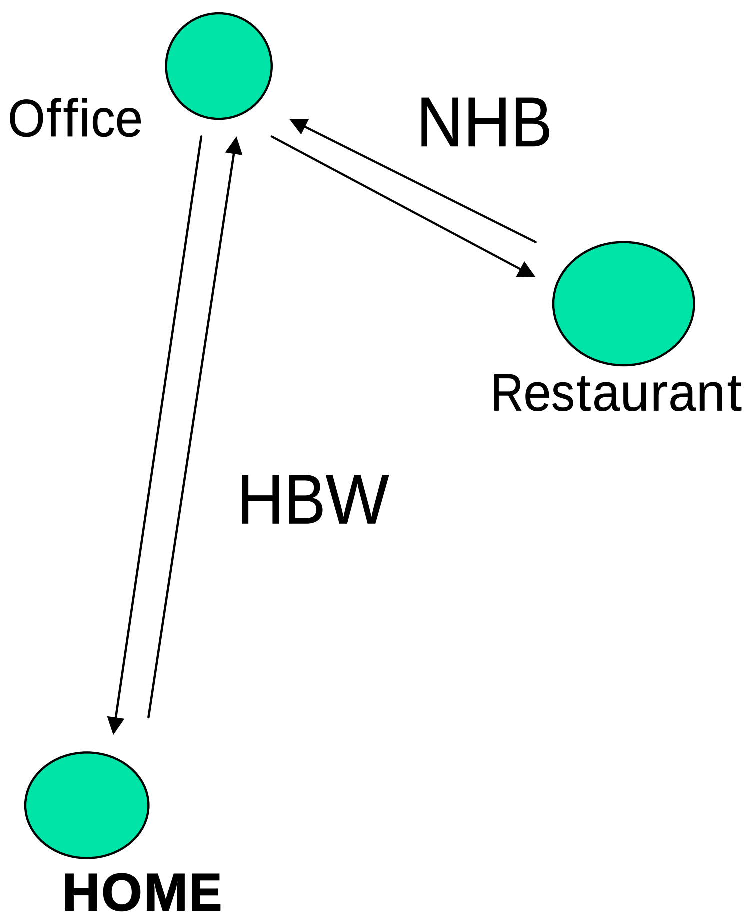
MIT Massachusetts Institute of Technology

- HBW: Home-based work trips
- HBO: schools, leisure, medical, social, shopping, etc.
- NHB: those which do not begin nor end at home (a crude attempt to chained trips)
- Many others depending on requirements, plus special generators: hospitals, airports..
- Plus taxis, freight movement, etc.
- See the National Home Travel Survey



MIT Massachusetts Institute of Technology

NHB balanced holding attractions constant



- For NHB trips, attractions are taken as the reference (square feet of GLA) See ITE Trip Generation
- The same can be said for special generators:
  - Hospitals
  - Airports

  (These latter ones may require a very different friction function as they may be regional in nature)

The 4-Step Model: 3. Modal Split

Massachusetts Institute of Technology

- Modal Split:➔ Which transport mode will they choose? How do we divide the total o-d matrix?
  - Motorized vs Non-motorized trips
  - Motorized:
    - Automobile vs Transit
    - Automobile: auto drivers vs auto passengers
    - Transit: bus vs rail
  - Exceptions from the idealized analytical flow:
    - Captive riders case:
      - They are inelastic versus transit improvements
      - Their distribution stage is not necessarily the same as car drivers
        - Some destinations may become off-limits
    - Non-motorized trips: walk and bike trips

MIT Massachusetts Institute of Technology

The 4-Step Model: Modal Split

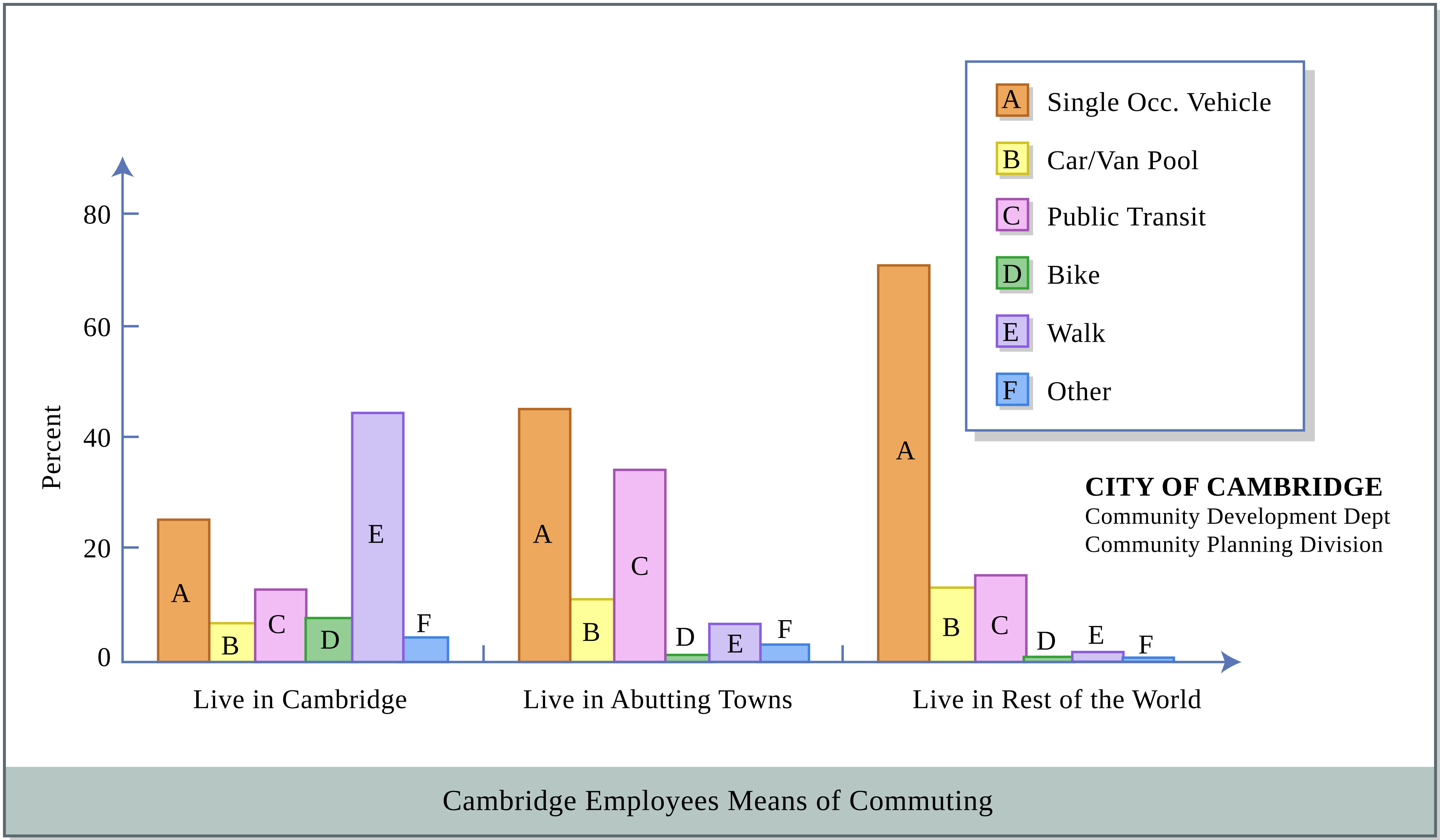


Figure by MIT OCW.

The 4-Step Model: Modal Split

Massachusetts Institute of Technology

- A Utility Function per mode:
  - $U_i = a_i + b_i * IVTT_i + c_{i*} OVTT_i + d_{i*} COST_i$
  - a_i = modal constant
  - b_i = In-Vehicle-Travel Time coefficient
  - c_i = Out-Vehicle-Travel Time coefficient
  - d_i = Cost (or ticket) coefficient

    relationships among coefficients??
- For each modal option and for every o-d pair, there will be a utility function

The 4-Step Model: Modal Split

Massachusetts Institute of Technology

- Modal Split:
  - Revealed and Stated-Preferences
  - Calibrated utility functions with weight factors: value of time[1], penalty for waiting time...
  - *The modal constant*
  - Logit curves (or "S" curves):
    - $P(k) = e^{Uk} / sum(e^{Ux})$
    - Sequential split or nested logit

Value of time – Analysis and... Evaluation?

The 4-Step Model: 4. Assignment

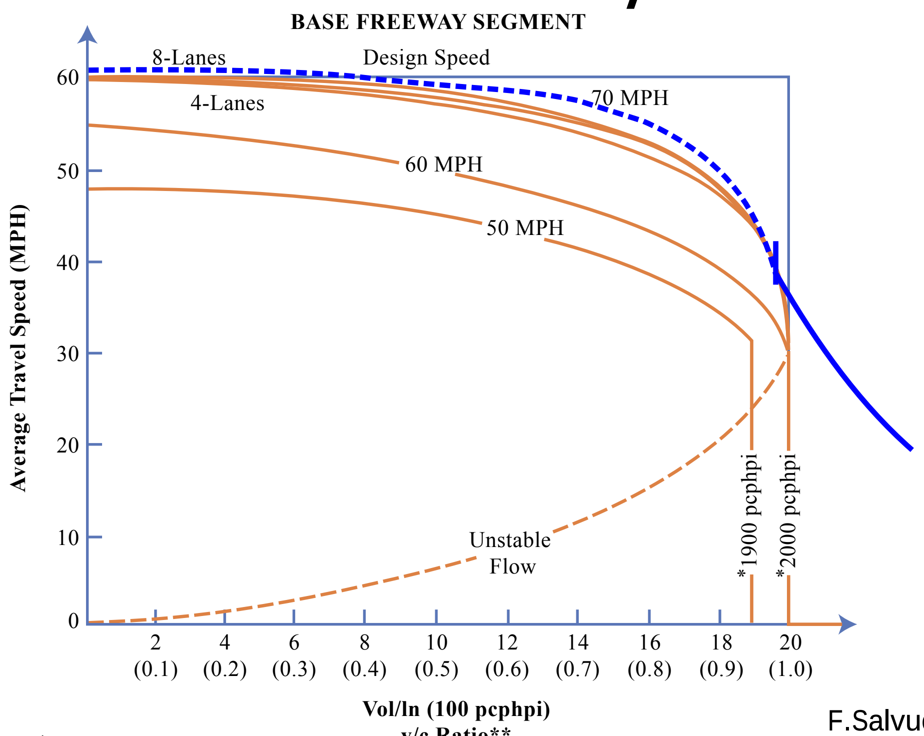
Massachusetts Institute of Technology

- *Assignment* ➔ Which route will they take?
  - The shortest? The fastest? The least costly route? The more scenic route?
  - As more cars choose a route, what happens?
  - How do we represent mounting congestion?
  - Analytical options:
    - All or Nothing (AOL) *Winner gets it all*
    - Capacity restraint *How to incorporate mounting congestion*
    - Equilibrium *A very rational universe out there*
    - Stochastic User Equilibrium*: Different folks, different tunes*

MIT Massachusetts Institute of Technology

The 4-Step Model: Assignment

- Volume-Delay curves – or how to represent growing congestion:
  - The BPR story: *Nothing like a good and simple formula to explain it all*



*capacity
**v/c ratio based on 2000 pcphpi valid only for 60- and 70-MPH design speeds

$$T_c = T_{ff}\,(1 + \text{alpha}\,(i/C))^{\text{beta}}$$

Even for intersection delay?

F.Salvucci and M.Murga

Figure by MIT OCW.

MIT
Massachusetts Institute of Technology

The 4-Step Model: Assignment

- Assignment:
  - Critical pathing:
    - Capacity restraint
    - User Equilibrium, etc.
  - ... *but we´re dealing with human nature: Stochastic User Equilibrium, plus...*
    - Volume-delay curves
    - V/C versus peak spreading
    - Tolls
    - Time segment of the O-D matrix to assign

MIT
Massachusetts Institute of Technology

The 4-Step Model: Assignment

- Assignment period:
  - 24 hour assignment as ADT (Average Daily Traffic)
  - Morning and evening rush-hour, off-peak...
  - Time variations associated to each trip purpose

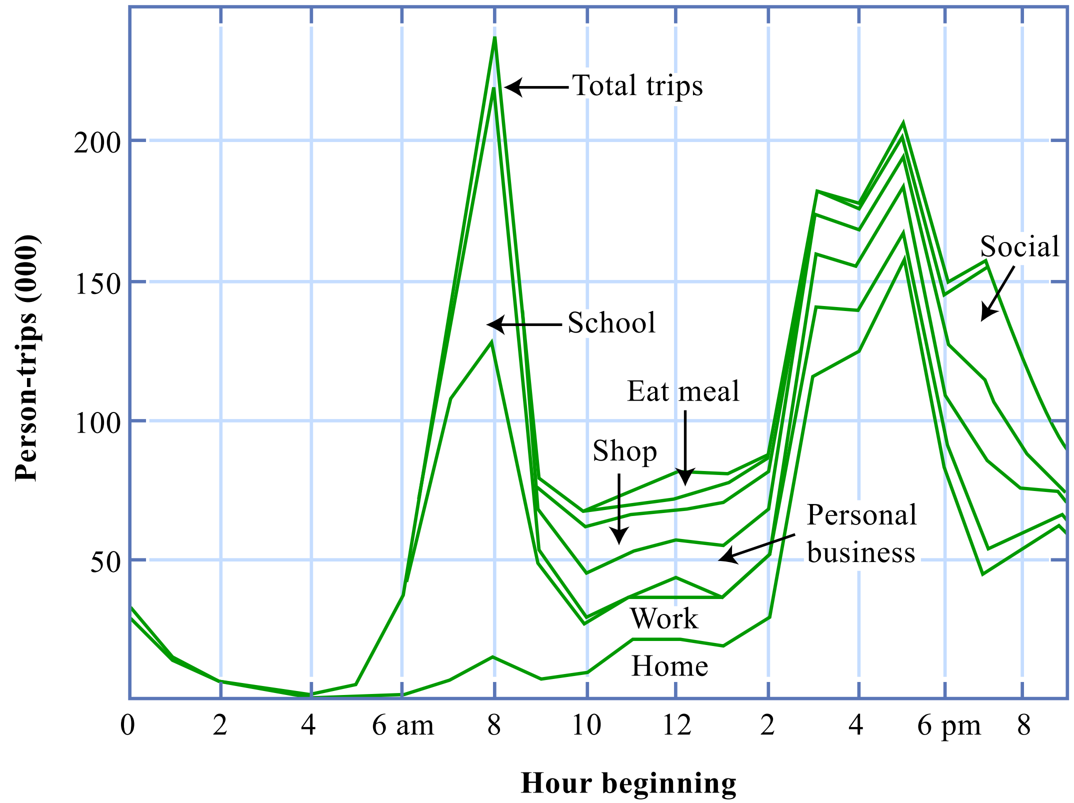


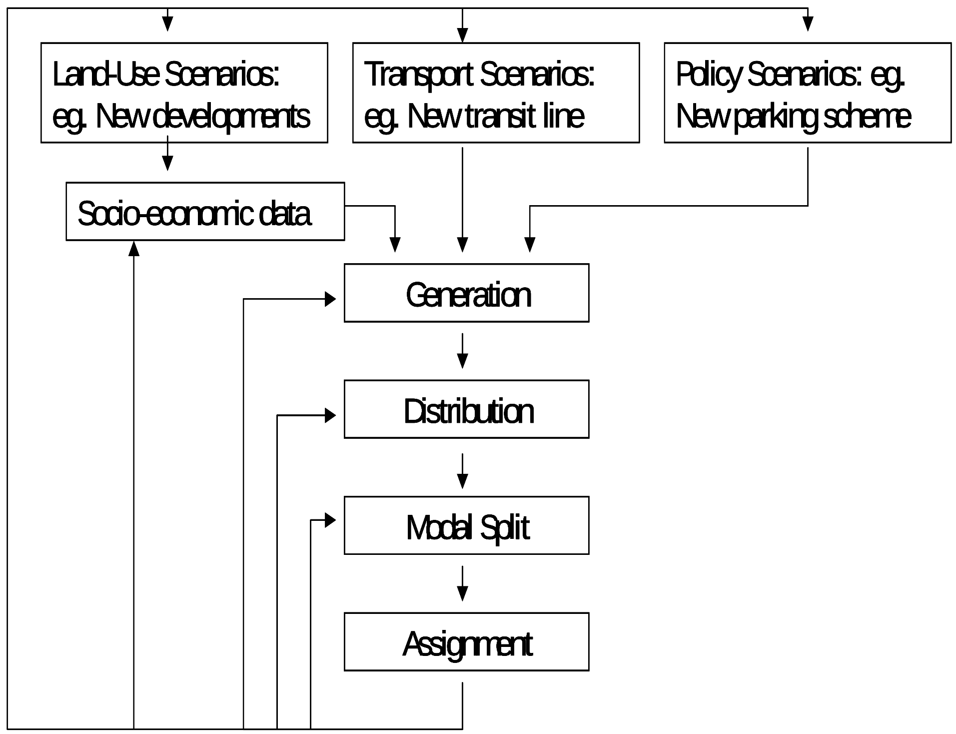
Figure by MIT OCW.

MIT

Massachusetts Institute of Technology

The 4-Step Model: *The Fifth Step*

- Feedback Loops:
  - Speed vs Volumes
  - Transit vs Road
  - How far or how long?
  - Trip generation sensitive to ease of travel?
- Convergence criteria
- Coherence with basic land use- transport scenarios?



MIT Massachusetts Institute of Technology

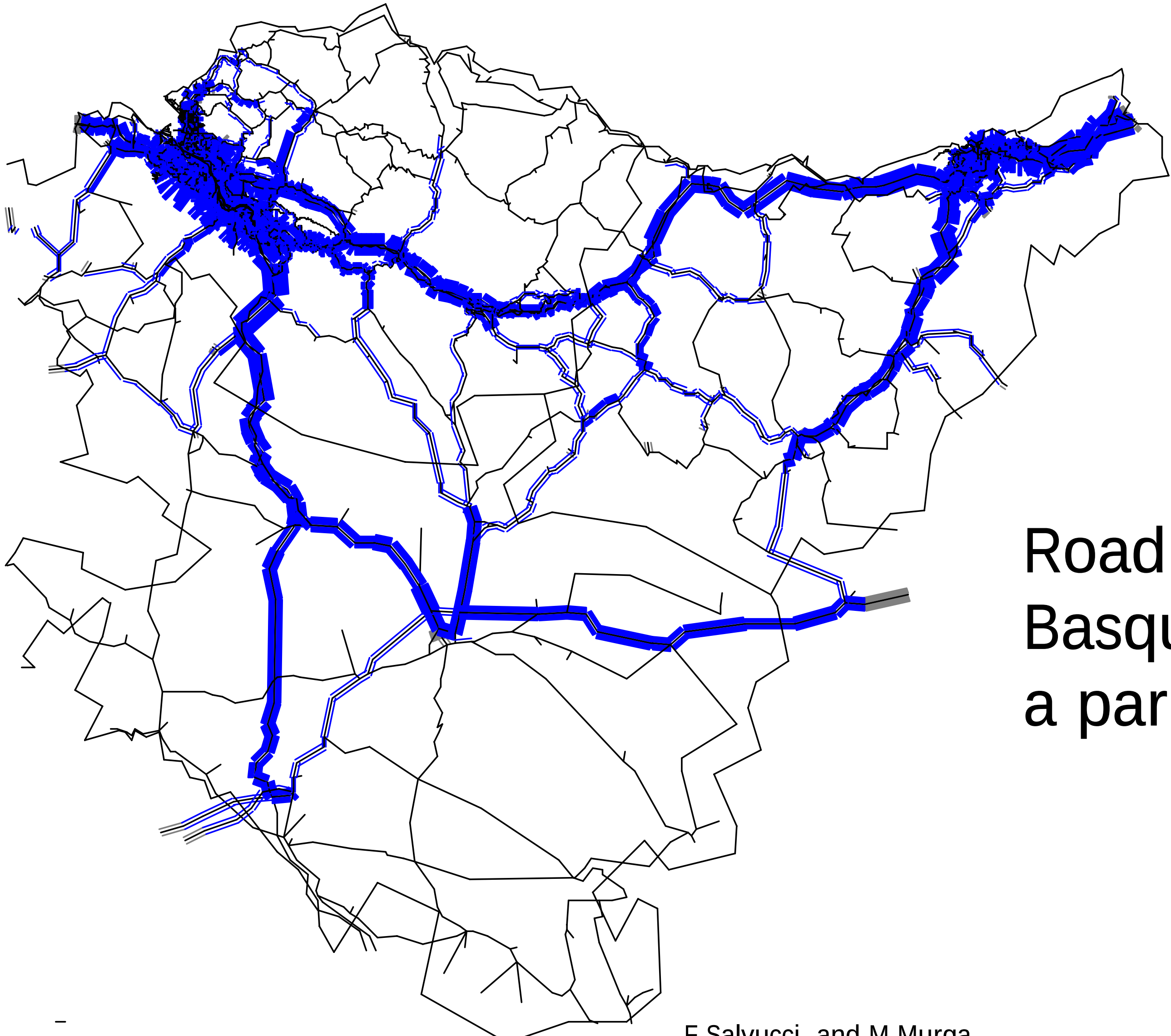
The 4-Step Model

- To know more about the analytical process:
  - "Modelling Transport" by Ortuzar, J. de D. and Willumsen, L.G., John Wiley, NY, 3rd Edition,2001
  - "Travel Estimation Techniques for Urban Planning" NCHRP Report 365, 1998
  - User manuals of most commercial packages

MIT

4-Step Planning Model: Examples

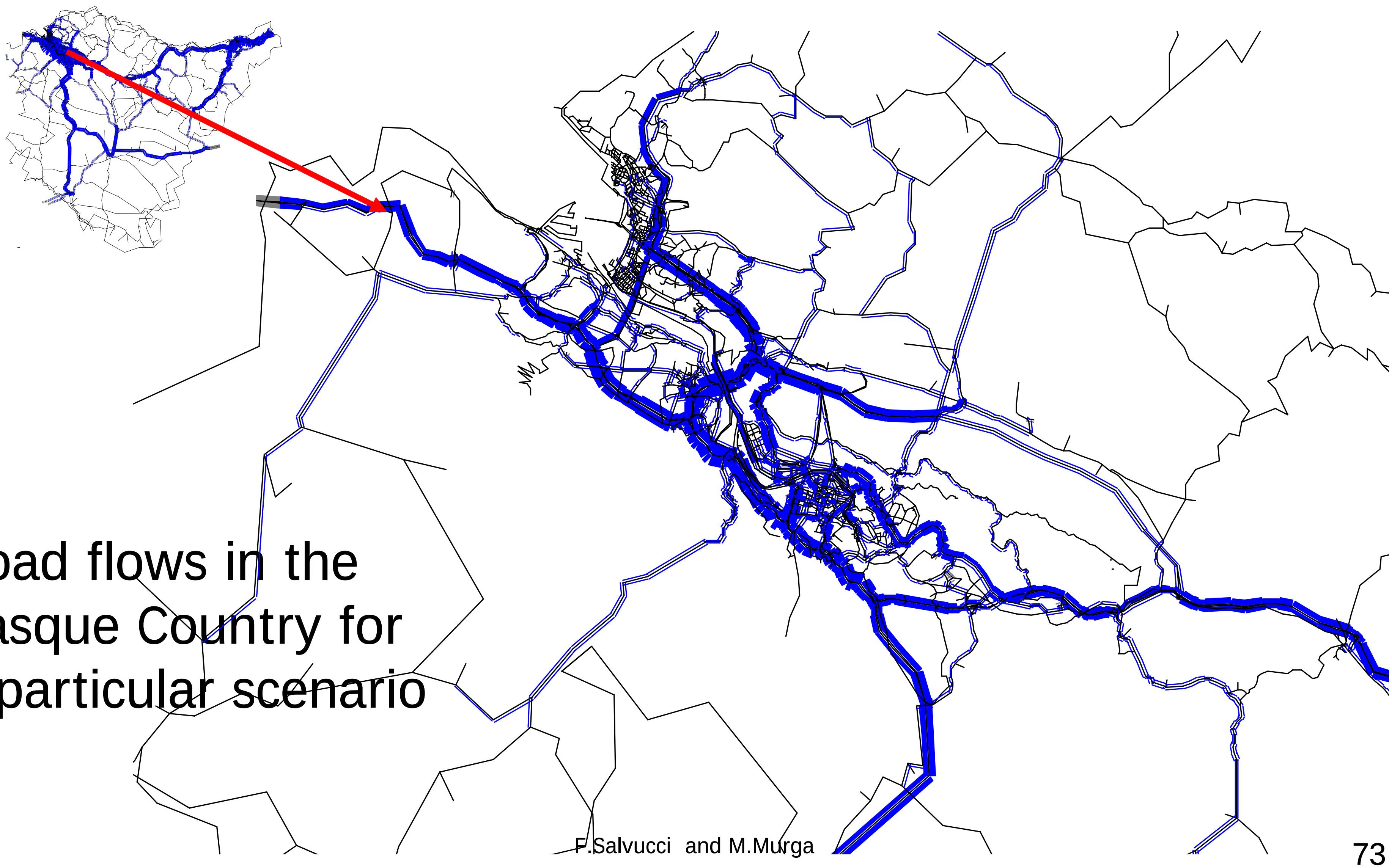
Massachusetts Institute of Technology



Road flows in the Basque Country for a particular scenario

MIT Massachusetts Institute of Technology

4-Step Planning Model

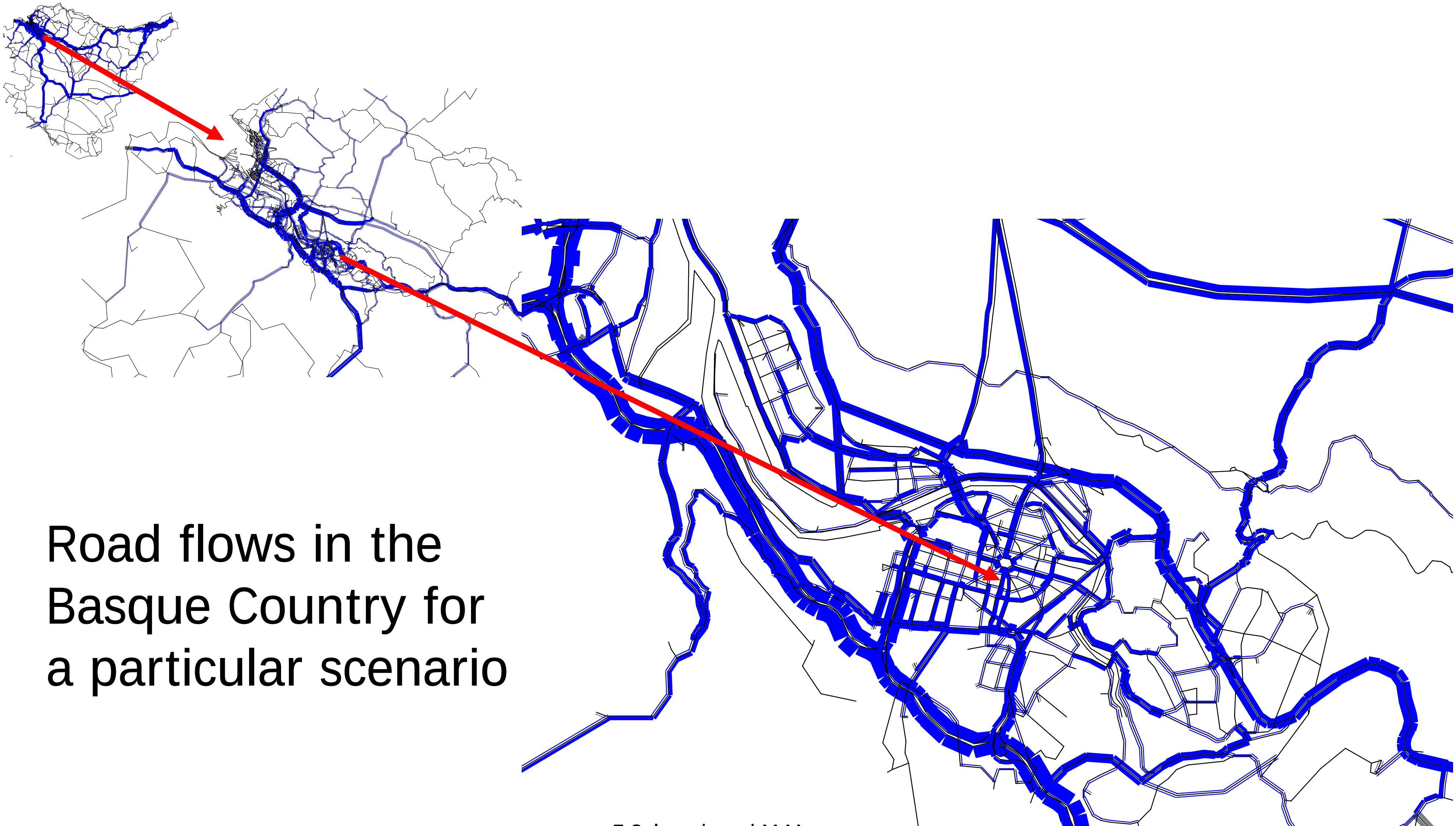


Road flows in the Basque Country for a particular scenario

MIT

4-Step Planning Model

Massachusetts Institute of Technology

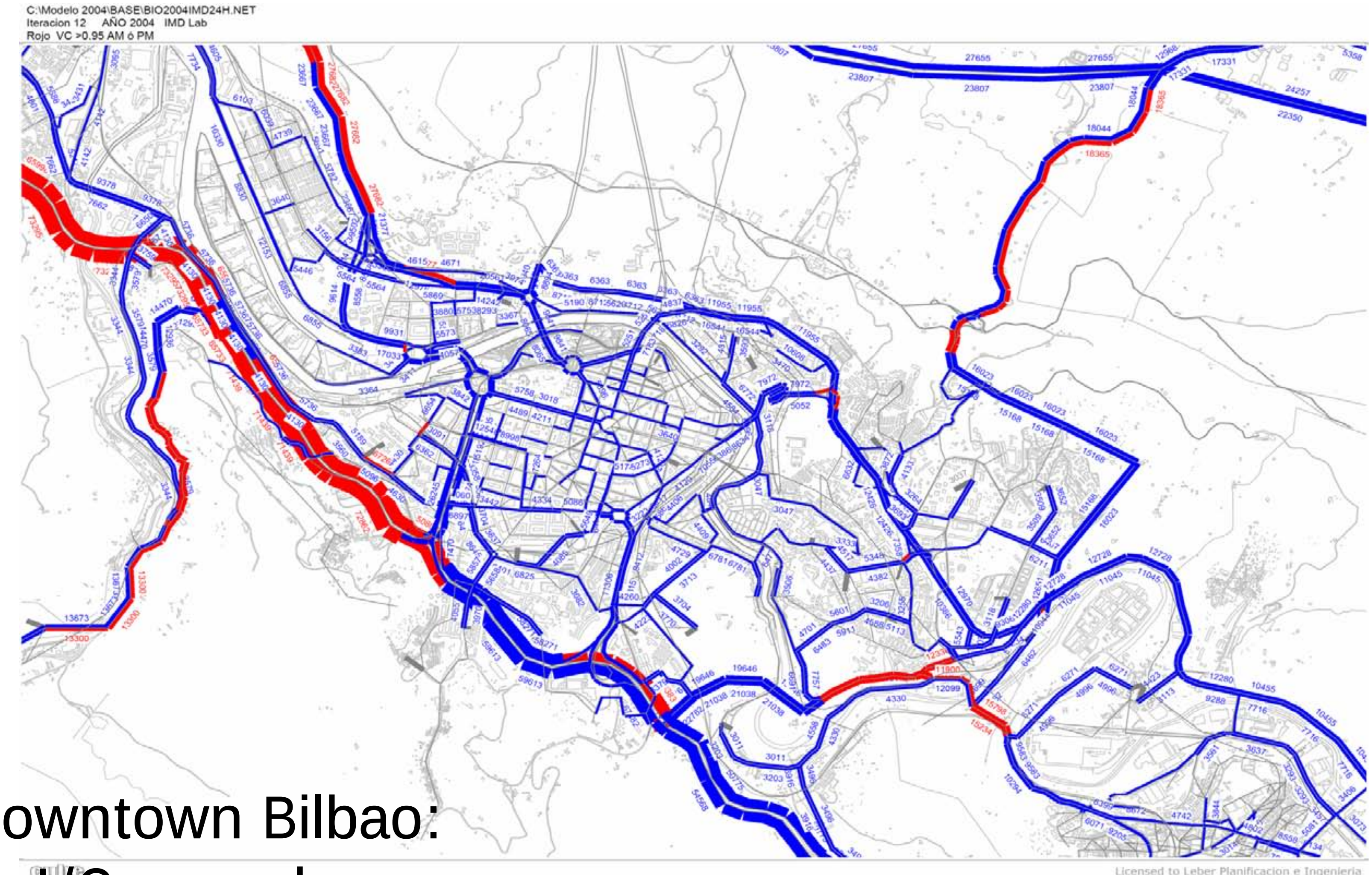


Road flows in the Basque Country for a particular scenario

MIT

4-Step Planning Model

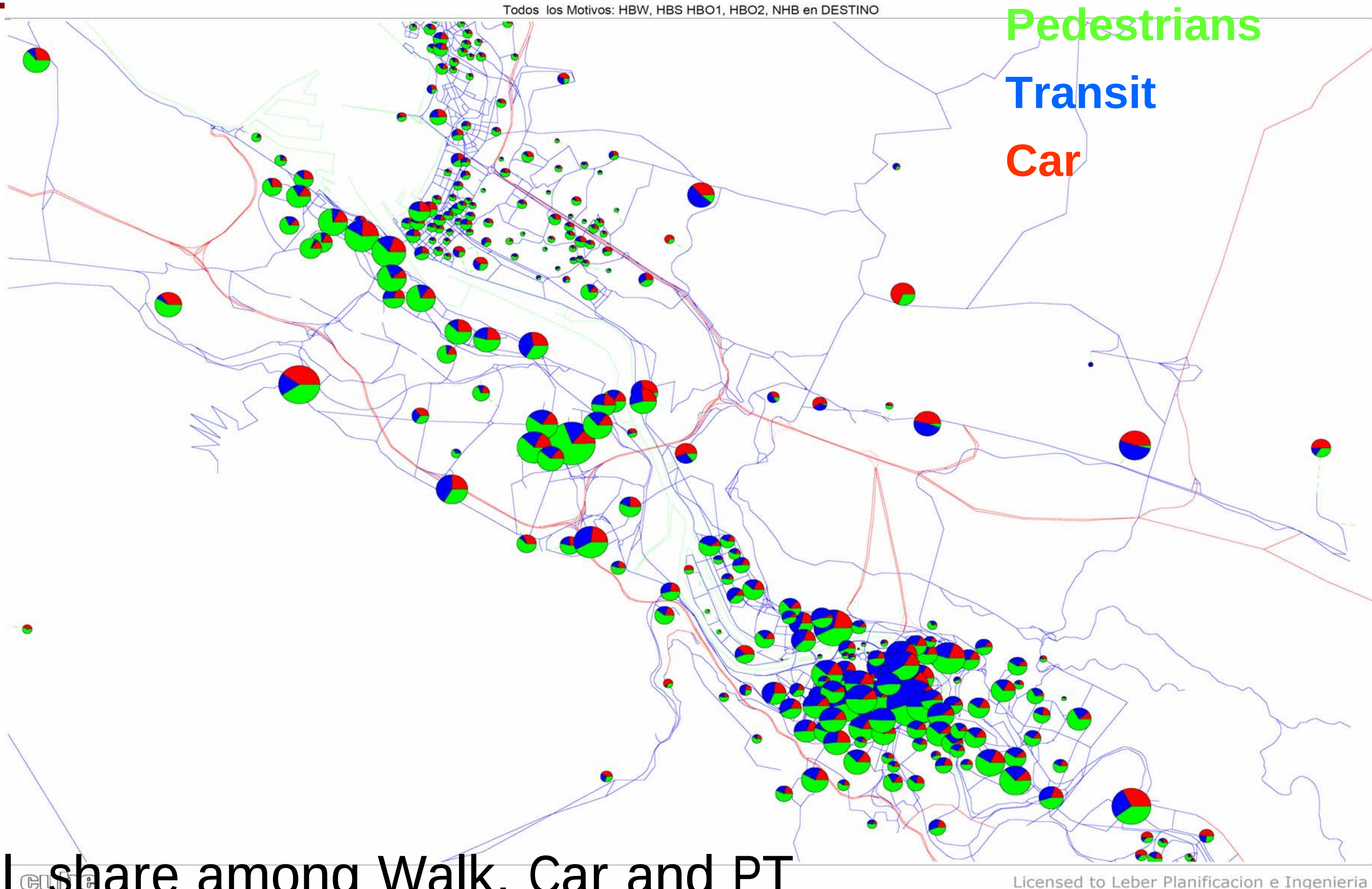
Massachusetts Institute of Technology



View in downtown Bilbao: volumes, I/C, speeds...

F.Salvucci and M.Murga

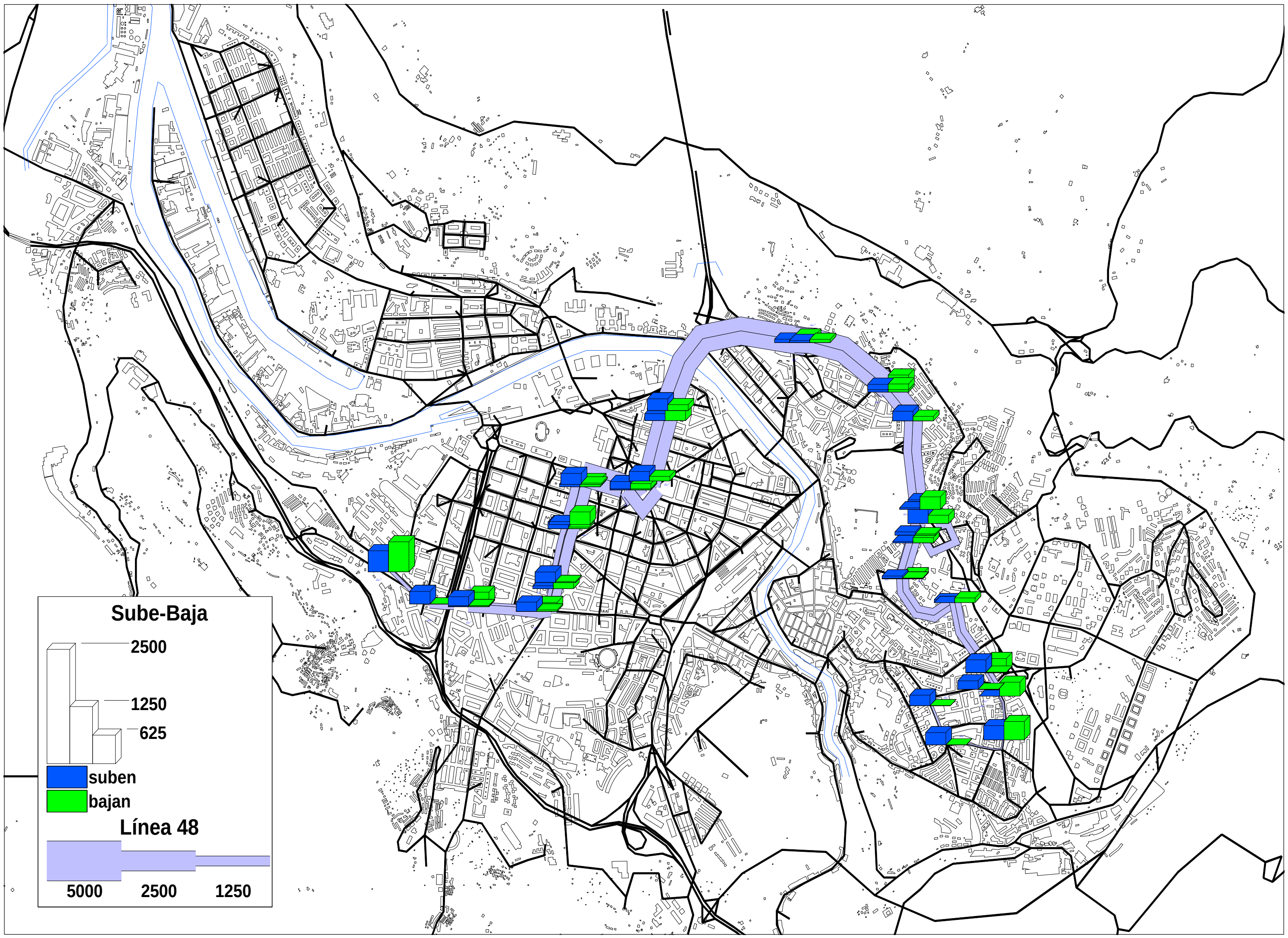
4-Step Planning Model



Modal share among Walk, Car and PT

4-Step Planning Model

Massachusetts Institute of Technology

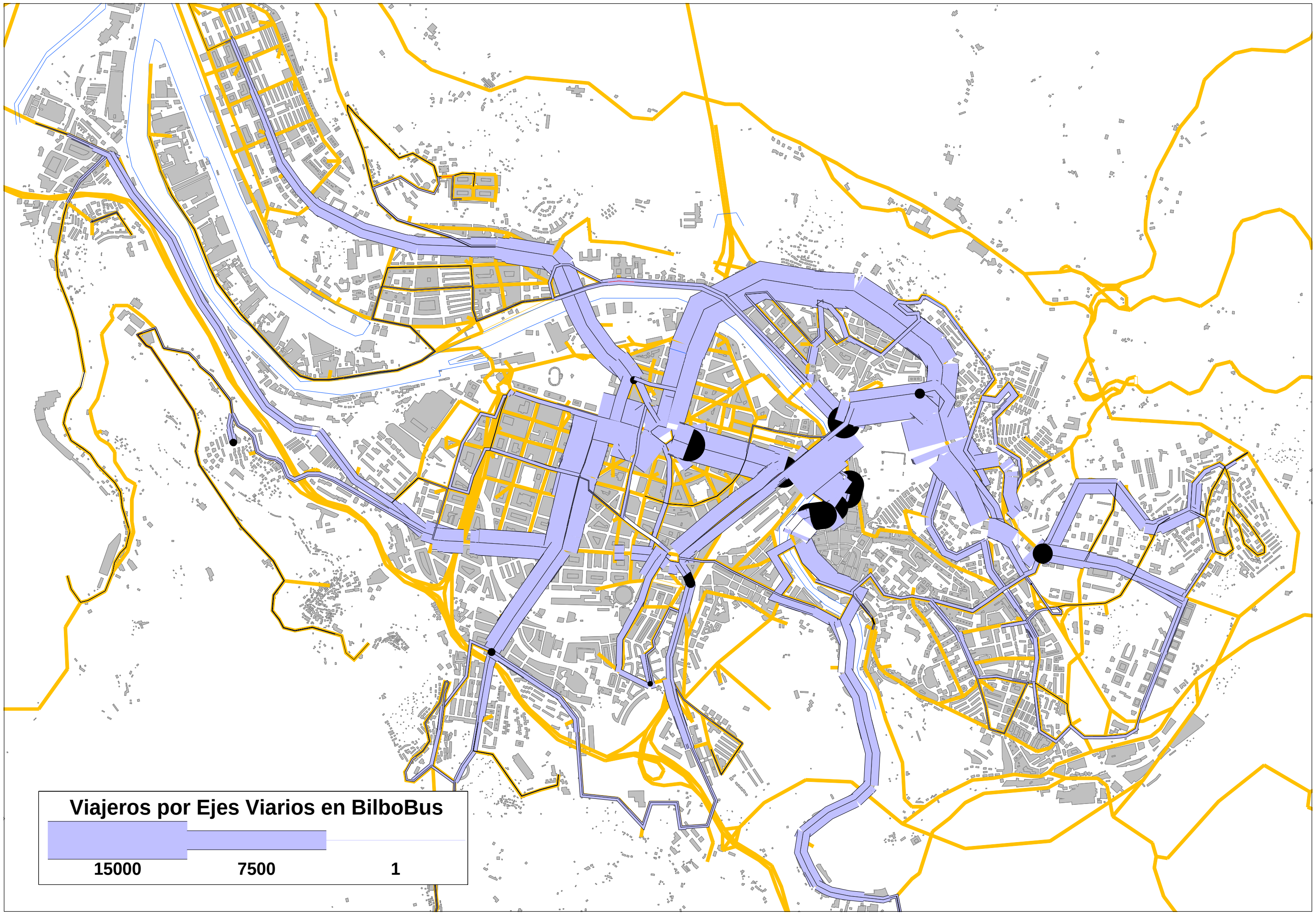


On-off counts per bus stop for all routes

MIT

4-Step Planning Model

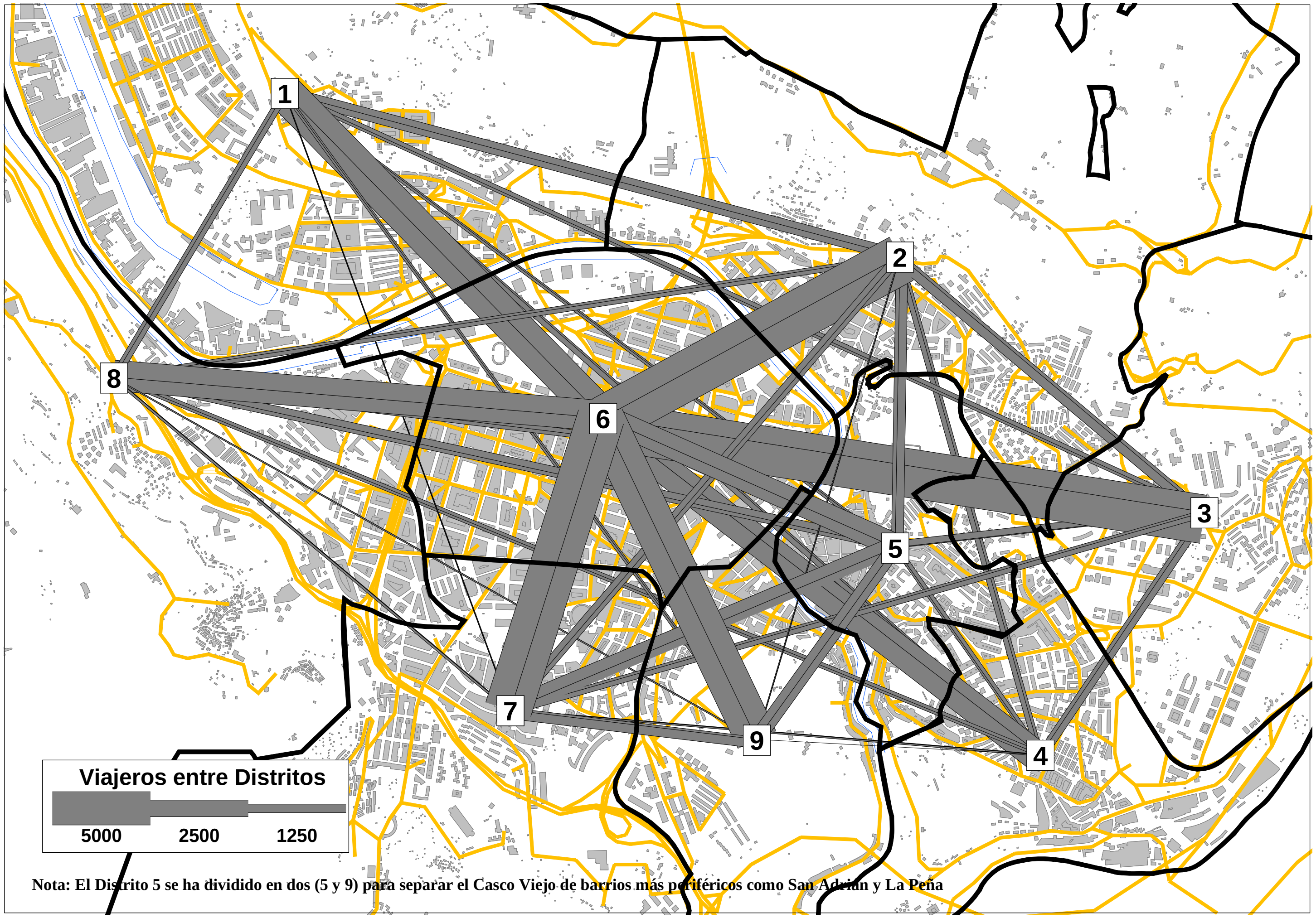
Massachusetts Institute of Technology



Aggregated bus flows along corridors

4-Step Planning Model

Massachusetts Institute of Technology

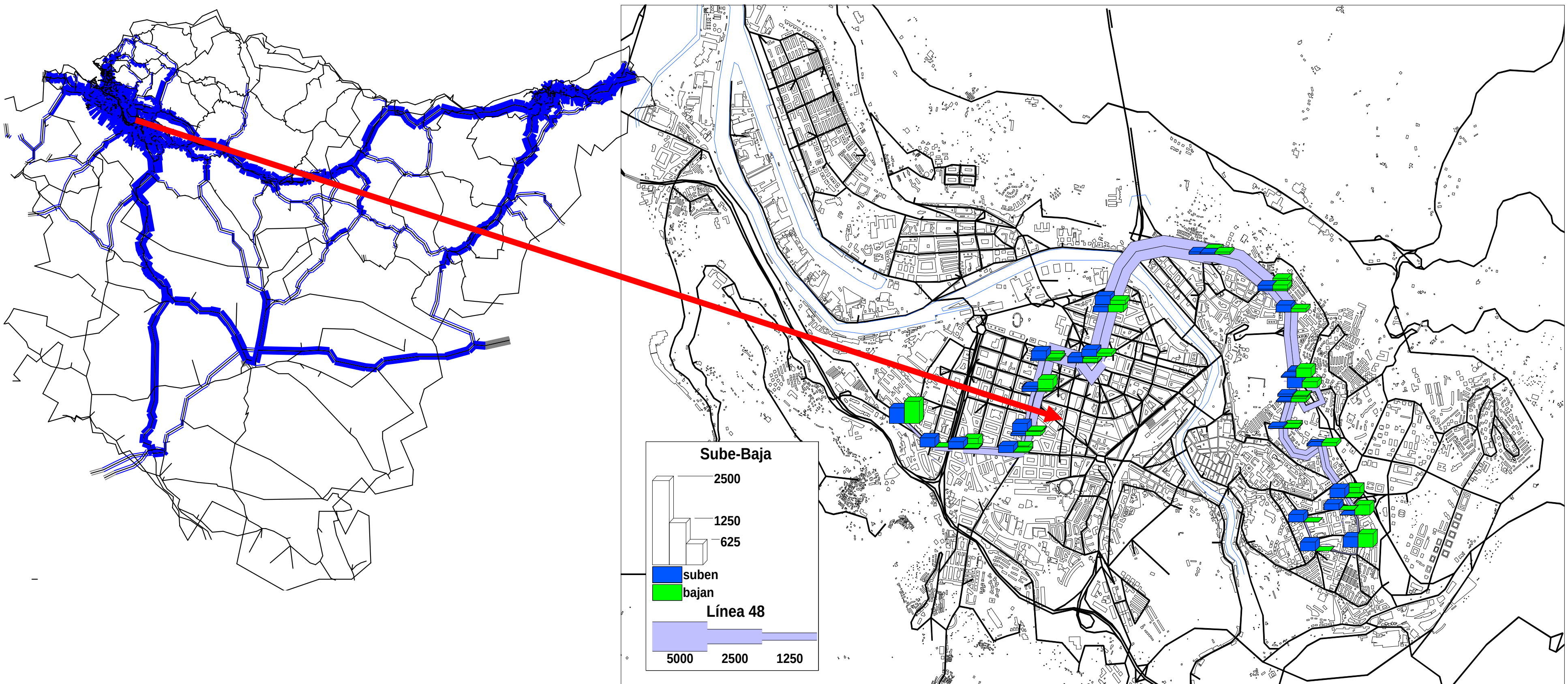


The Overall View: A simplified O-D matrix

MIT | Massachusetts Institute of Technology

4-Step Planning Model

In a nutshell: every settlement, every dwelling, job center, road, no of lanes, posted speeds, signals, transit lines, stops, headways, commercial speeds...



F.Salvucci and M.Murga

MIT Massachusetts Institute of Technology

Critique of the 4-step Method

- A tool created for a different goal: a new road infrastructure. Today, focus on system management
- New issues such as peak spreading, induced demand...
- Trip substitution? Impact of Information technologies?
- Description of “average, ideal conditions”
- Forecasting: Will basic parameters remain constant in the future? Should we use back-casting?
- Underlying theme: Individual choices of the user

MIT
Massachusetts Institute of Technology

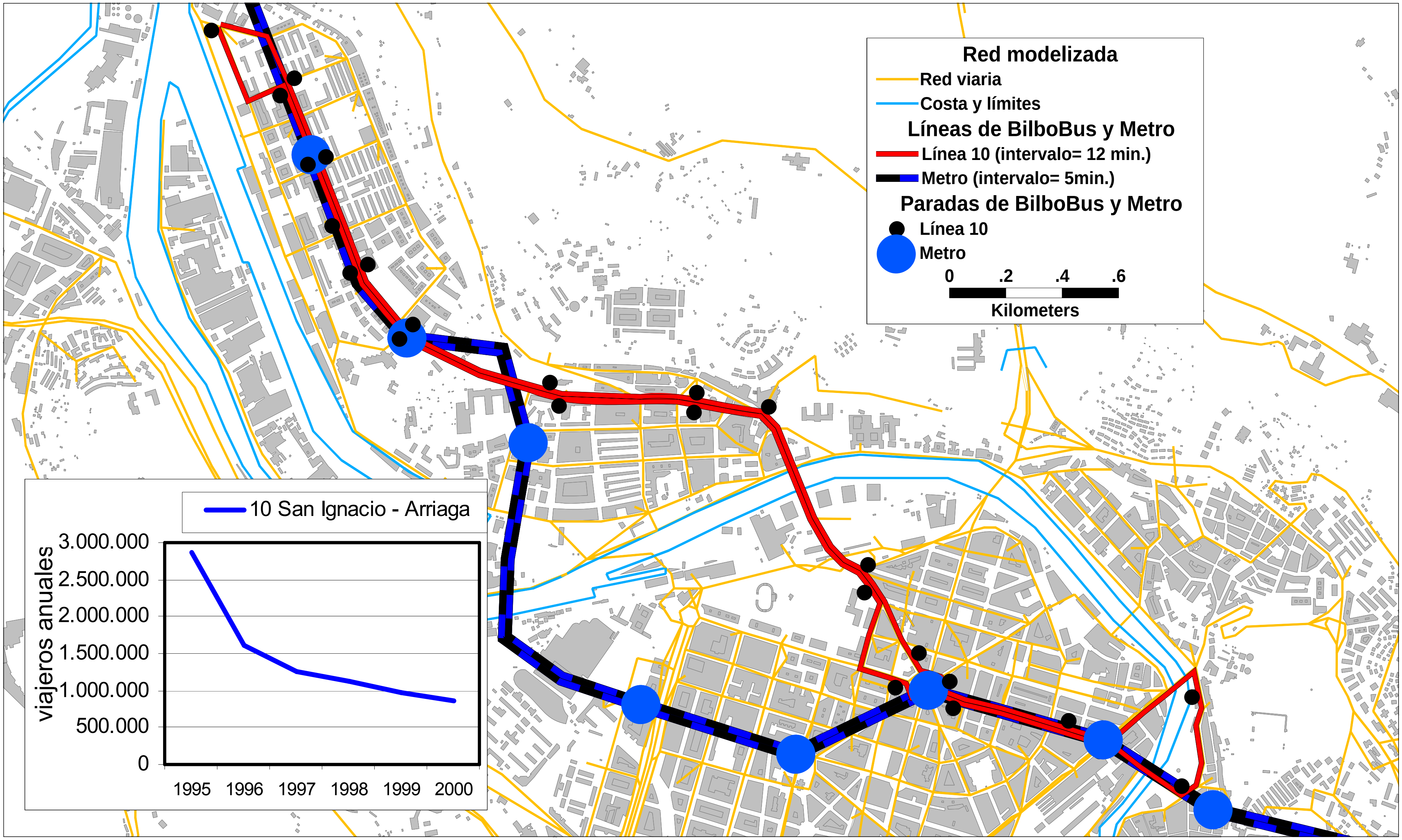
Questions to ask

As a user of 4-step models results, you may want to raise questions such as:

- Right scale? Discretized enough?
- Calibration? For every step??
- Validation? *Backcasting before forecasting*
- Sensitivity analyses of results?
- Modes considered?
- Is it sensitive to policies being discussed?

Do not forget that the 4-step model describes final equilibrium... and new habits!

Massachusetts Institute of Technology



MIT
Massachusetts Institute of Technology

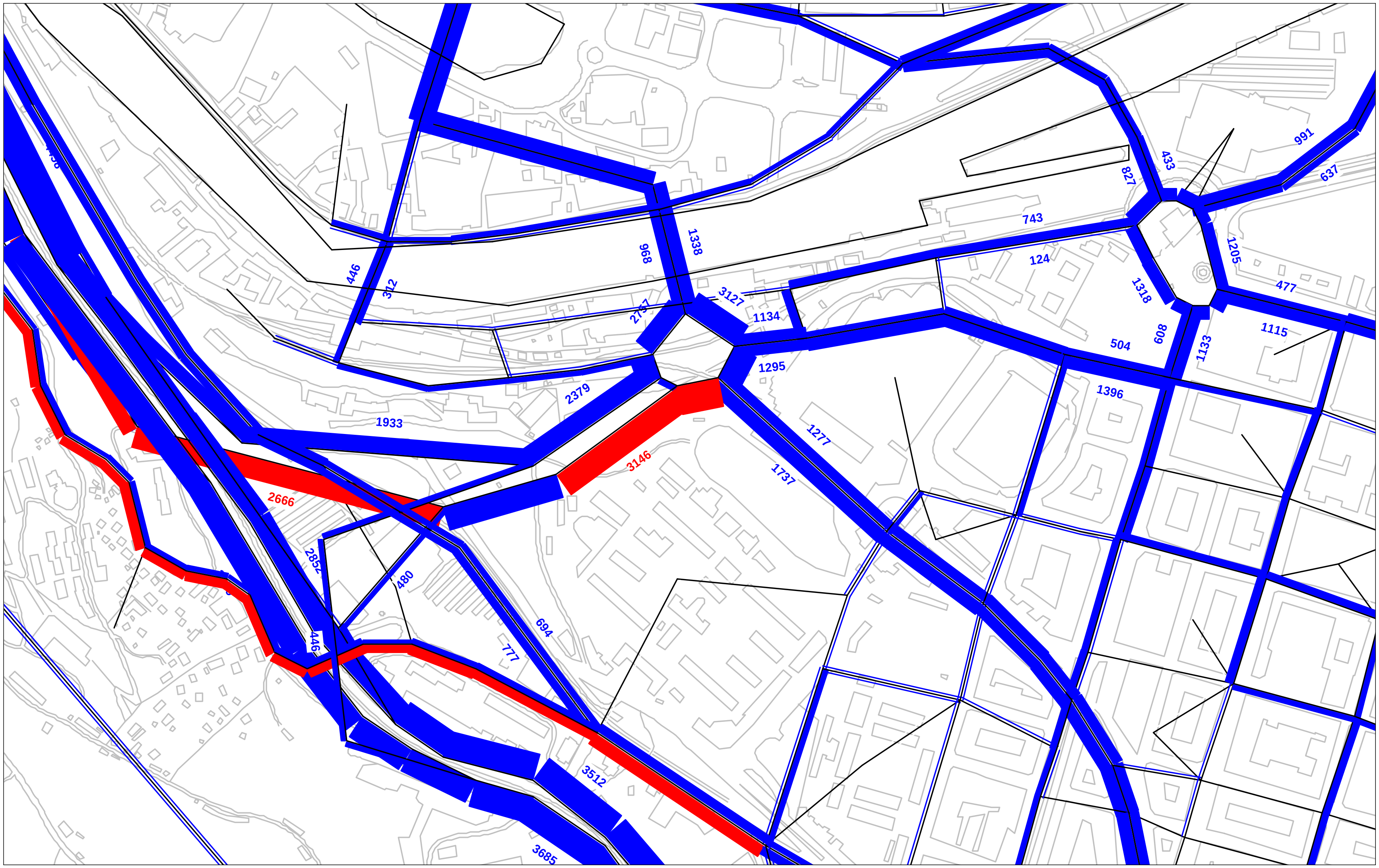
From the 4-step back to traffic models

- Verify and incorporate (and even feedback) the output from the 4-step planning model into traffic models
- Often the 4-Step model entails a rather crude approximation of
  - road or urban streets capacity
  - Interaction, such as queues blocking an intersection
  - Traffic speed (and resulting impacts)

Example: AM peak at a roundabout with V/C greater than 1.0

MIT

Massachusetts Institute of Technology



bilbamu1.dat

MIT

Massachusetts Institute of Technology

Integration of the Analytical Chain

- An automatic chain of events
- Sequence:
  - GIS → Planning Model → Traffic Models → GIS → Postprocessors (environmental studies)
  - Or any combination of the above
- Critical analysis and judgment at every stage of the process

MIT Massachusetts Institute of Technology

Back-Casting and Forecasting

- To calibrate a model is different than to validate a model
- If you want to forecast, you have to remember Soren Kierkegaard!
- To back-cast is to embark into a learning adventure. And probably the best way to validate the dynamics of the model

MIT Massachusetts Institute of Technology

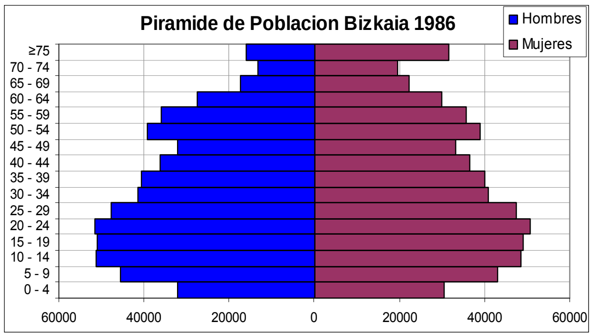
Back-Casting and Forecasting

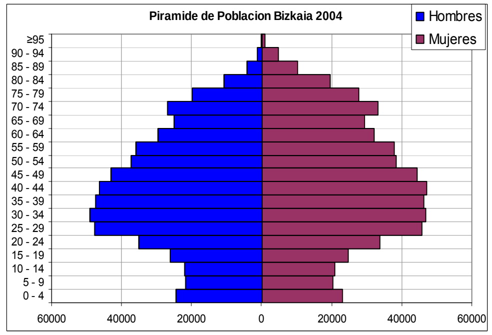
- Forecasting needs other models, such as:
  - Why families buy cars? What are the main drivers of that decision?
  - What is the influence of demographics?
  - What is the mobility of senior citizens?

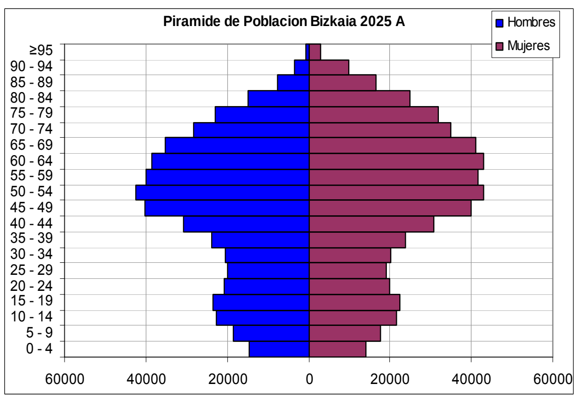
MIT

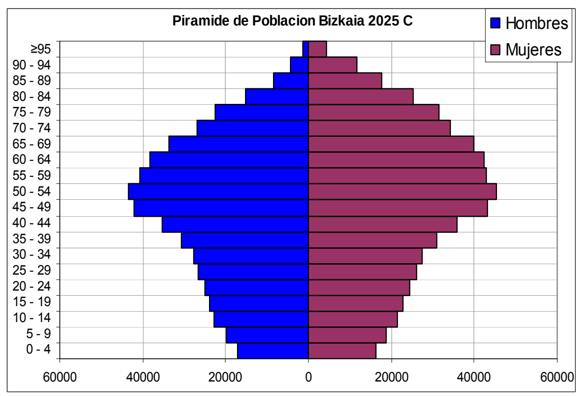
Back-Casting and Forecasting

Massachusetts Institute of Technology









Miles	Escenarios A			Escenarios C		
	Total	Hombres	Mujeres	Total	Hombres	Mujeres
Total	**999**	**475**	**524**	**1076**	**510**	**566**
0 - 4	29	15	14	34	17	16
5 - 9	37	19	18	39	20	19
10 - 14	45	23	22	45	23	22
15 - 19	47	24	23	47	24	23
20 - 24	41	21	20	50	25	25
25 - 29	39	20	19	53	27	26
30 - 34	41	21	20	56	28	28
35 - 39	48	24	24	62	31	31
40 - 44	62	31	31	72	36	36
45 - 49	81	40	40	86	42	43
50 - 54	86	43	43	89	44	45
55 - 59	82	40	42	84	41	43
60 - 64	82	39	43	81	38	43
65 - 69	77	36	41	74	34	40
70 - 74	64	28	35	62	27	34
75 - 79	55	23	32	54	23	32
80 - 84	40	15	25	41	15	25
85 - 89	25	8	17	26	9	18
90 - 94	14	4	10	16	5	12
≥95	4	1	3	6	1	5

- Scenario Planning a must
- See example of two alternative age pyramids for 2025 in Bilbao

MIT

New Trends

Massachusetts Institute of Technology

- Operational Studies: *Life under congestion*
  - From real-time vehicle counts to refined o-d matrices for incident management – The TRANSCOM example
  - Drivers with better information: Does the system behave differently?
  - What role for Intelligent Transport Systems? Tactical tools or strategic approaches?

MIT

Massachusetts Institute of Technology

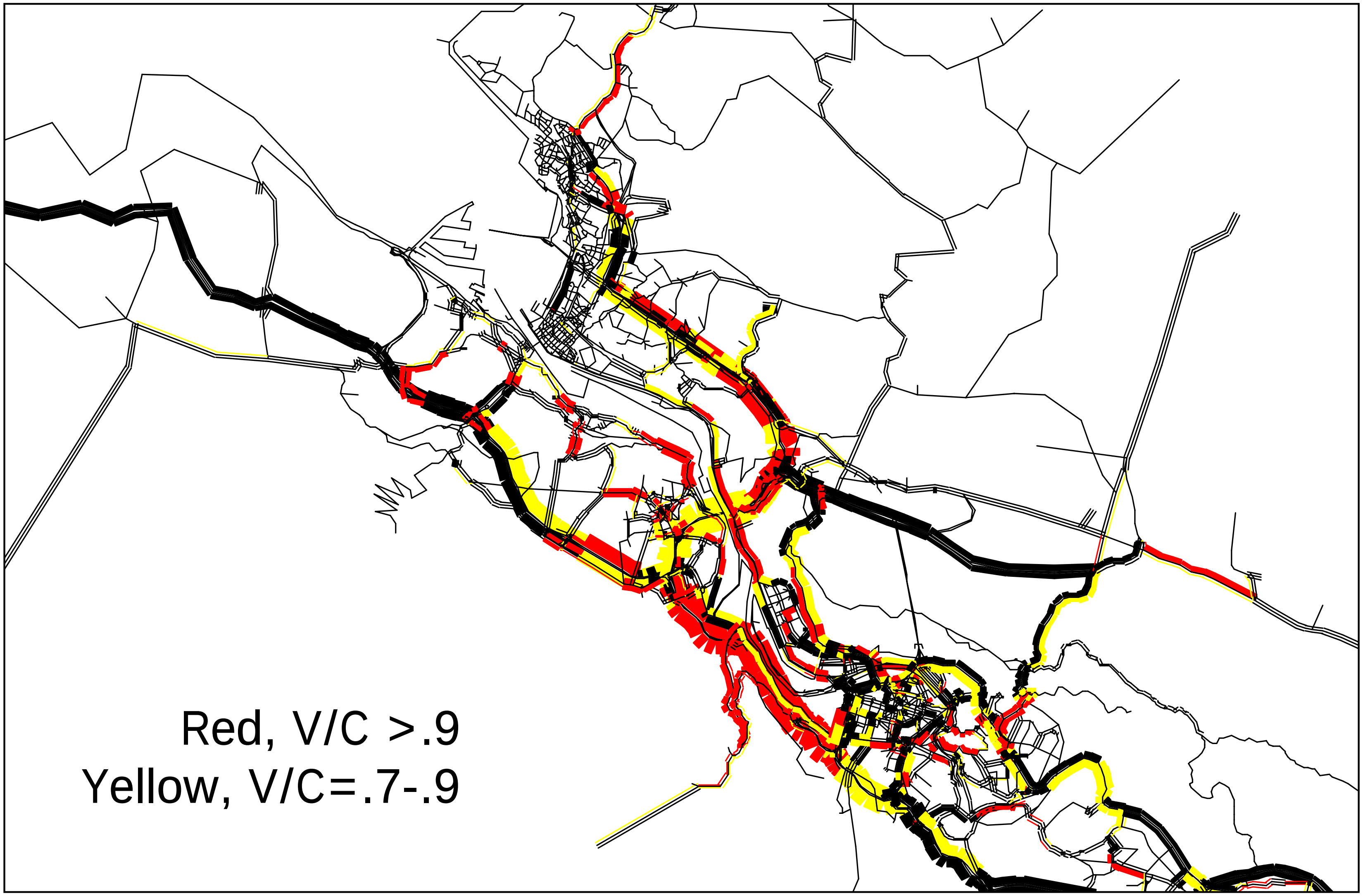
New Trends

- Operational Studies: *Life under congestion*
  - The higher the saturation, the higher the probability of an incident
  - The higher the saturation, the longer it will take to bring the system back to normal conditions, after an incident
  - But the 4-step planning model describes average un-eventful days out there!

MIT

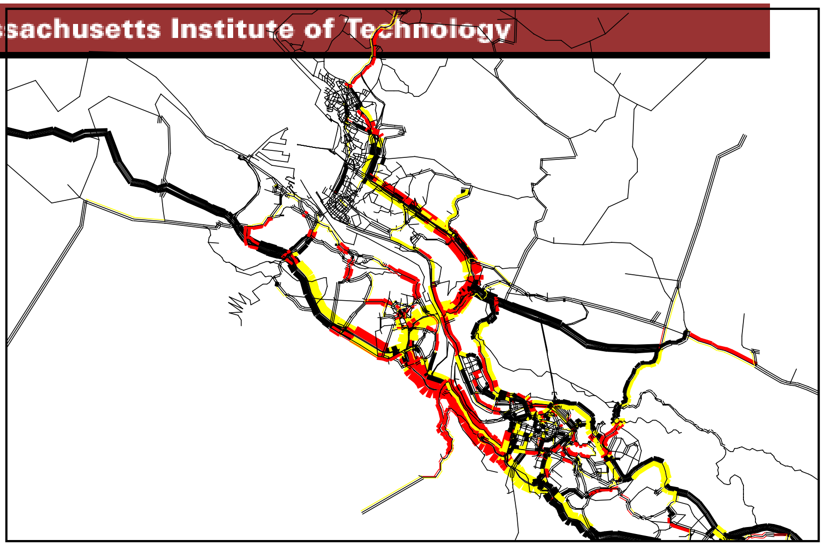
The 4-step planning model results

Massachusetts Institute of Technology



MIT Massachusetts Institute of Technology

Planning vs Operational Studies



- *Not all red colors are created equal*
- The planning red: proximity to capacity
- The field red: actual operational instabilities
- The challenge is how to predict their relationship and take them into account for planning purposes

MIT Massachusetts Institute of Technology

New Trends

Operational Studies: *Life under congestion*

- The IDAS approach
  - How do we measure ITS costs and benefits?
  - Should we incorporate ITS into standard planning procedures?
  - Or, should we resign ourselves to see ITS tools as a last minute tactical solution to be implemented by *practical men*, not planners?

MIT Massachusetts Institute of Technology

IDAS: A new analytical approach

- It starts from the results of traditional 4-step planning packages
- It attempts to reproduce some of the algorithms contained in conventional planning packages
- Its essence is an evolving database on ITS costs and benefits

- It focuses on "problem days" not on the idyllic "average" days depicted by regular planning packages

MIT
Massachusetts Institute of Technology

IDAS approach

- IDAS as a new approach:
  - A must to analyze future scenarios which show growing saturation, as:
    - Operational improvements become critical
    - Integrated planning AND operational policies become compulsory
    - Global indicators become essential
  - A unique approach to deal with the main threat:
    - Road incidents – a harsh everyday reality far away from the ideal “average” planning day

MIT

Massachusetts Institute of Technology

Traffic Models and Real-Time Data

- Real time traffic data is useful not only for travelers, but to calibrate microscopic models under road incident scenarios
- See for instance www.bizkaimove.com (requiring Flash 7) which provides:
  - Speed maps, running times, live cameras...
  - Short Messaging Systems (SMS) sent free to those who have registered

MIT
Massachusetts Institute of Technology

New Trends

- From trip-based modeling towards an activity-based approach:
  - Travel decisions are activity based
  - Understanding activity behavior is fundamental, rather than travel behavior
  - Focus on household dynamics, spatial and temporal interrelationships between trips

MIT
Massachusetts Institute of Technology

New Trends

- Activity-based approach:
  - Travel is derived from the demand for activity participation
  - Sequences of patterns of behavior
  - Scheduling of household activities in time and space
- TRANSIMS (Los Alamos National Lab):
  - The goal is to replace current transport paradigm
  - Already applied in Portland, Or (See Bowman and Ben-Akiva 1997 paper on “Activity-based forecasting”)

MIT
Massachusetts Institute of Technology

A Closing Thought

The McNamara fallacy[1]:

- The first step is to measure whatever can be easily measured. This is **OK** as far as it goes
- The second step is to disregard that which can't be easily measured or to give it an arbitrary quantitative value. This is **artificial and misleading**
- The third step is to presume that what can't be measured easily really isn't important. This is **blindness**
- The fourth step is to say that what can't be easily measured really doesn't exist. This is **suicide**

1 by Charles Handy “The Empty Raincoat”