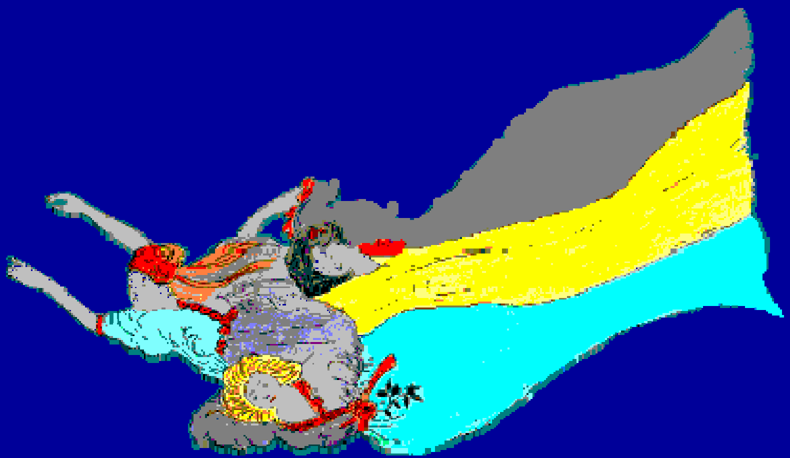
# The MUSSA Land Use Model



Presented by: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University of Chile

# Presentation

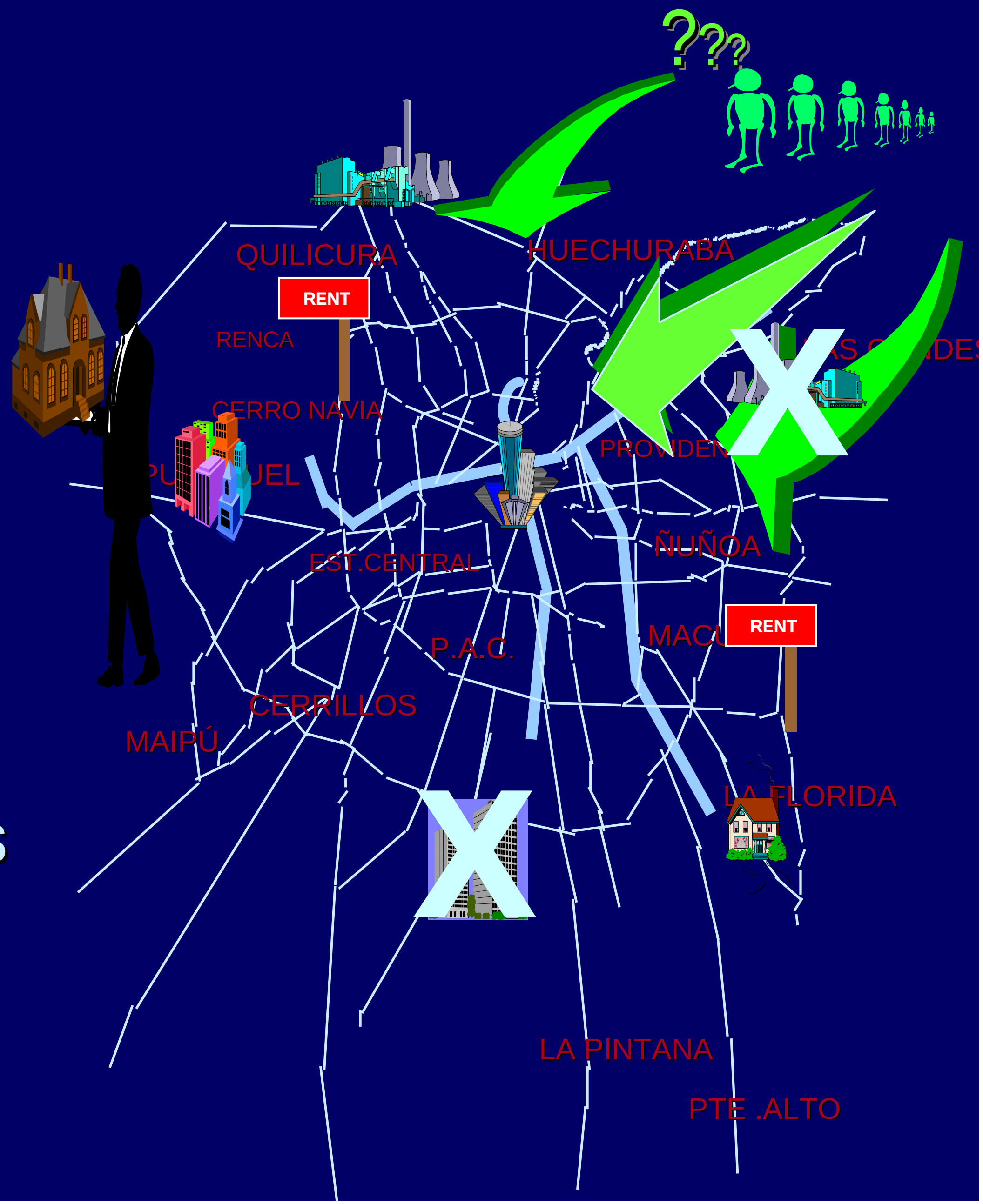
- Components of MUSSA
- The RBM: random bidding model
- The equilibrium problem
- Software
- Other issues

# Presentation

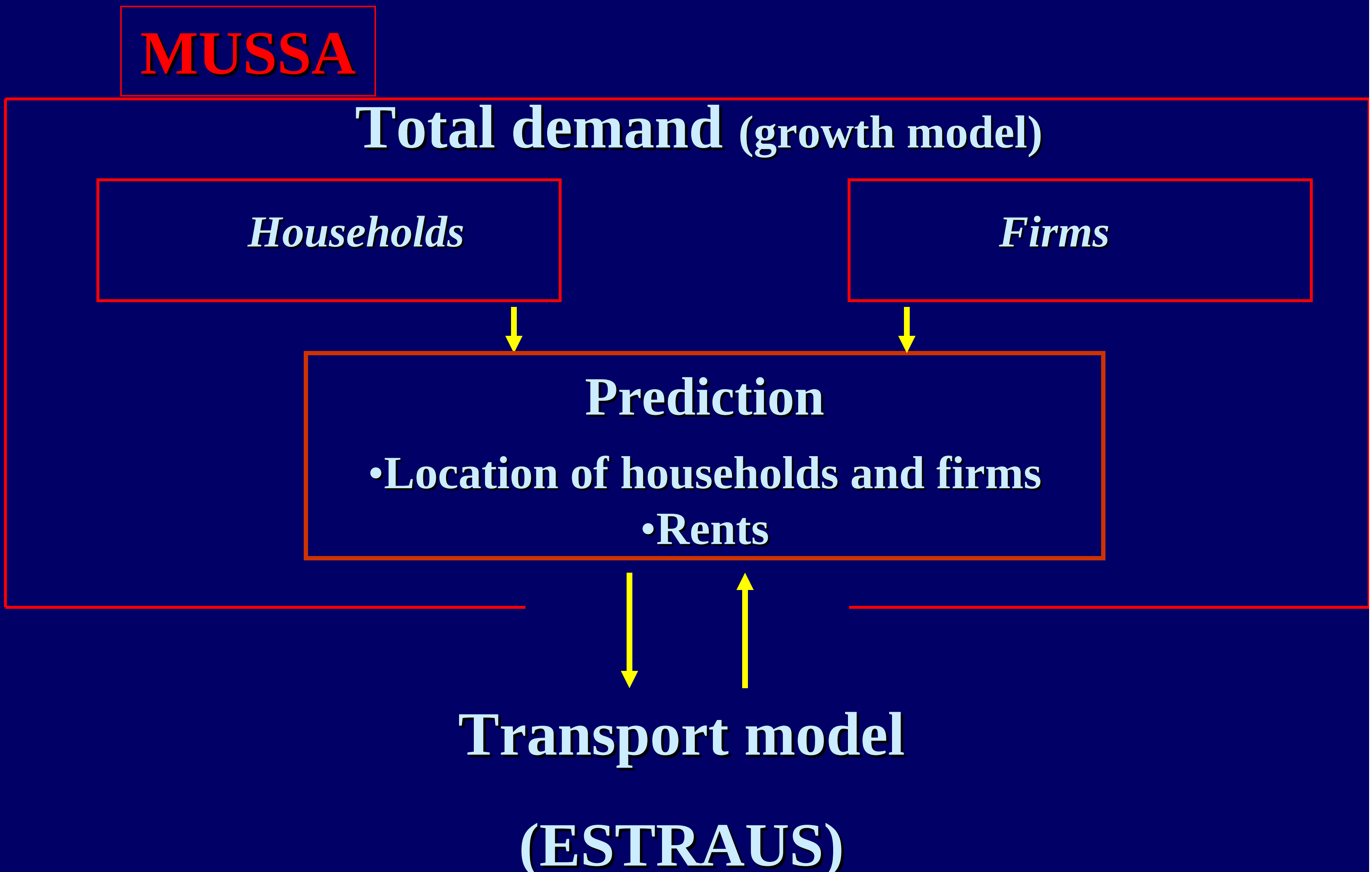
- **Components of MUSSA**
  - The supply model
  - The RBM: random bidding model
  - The equilibrium problem
  - Software
  - Other issues

# Model Elements

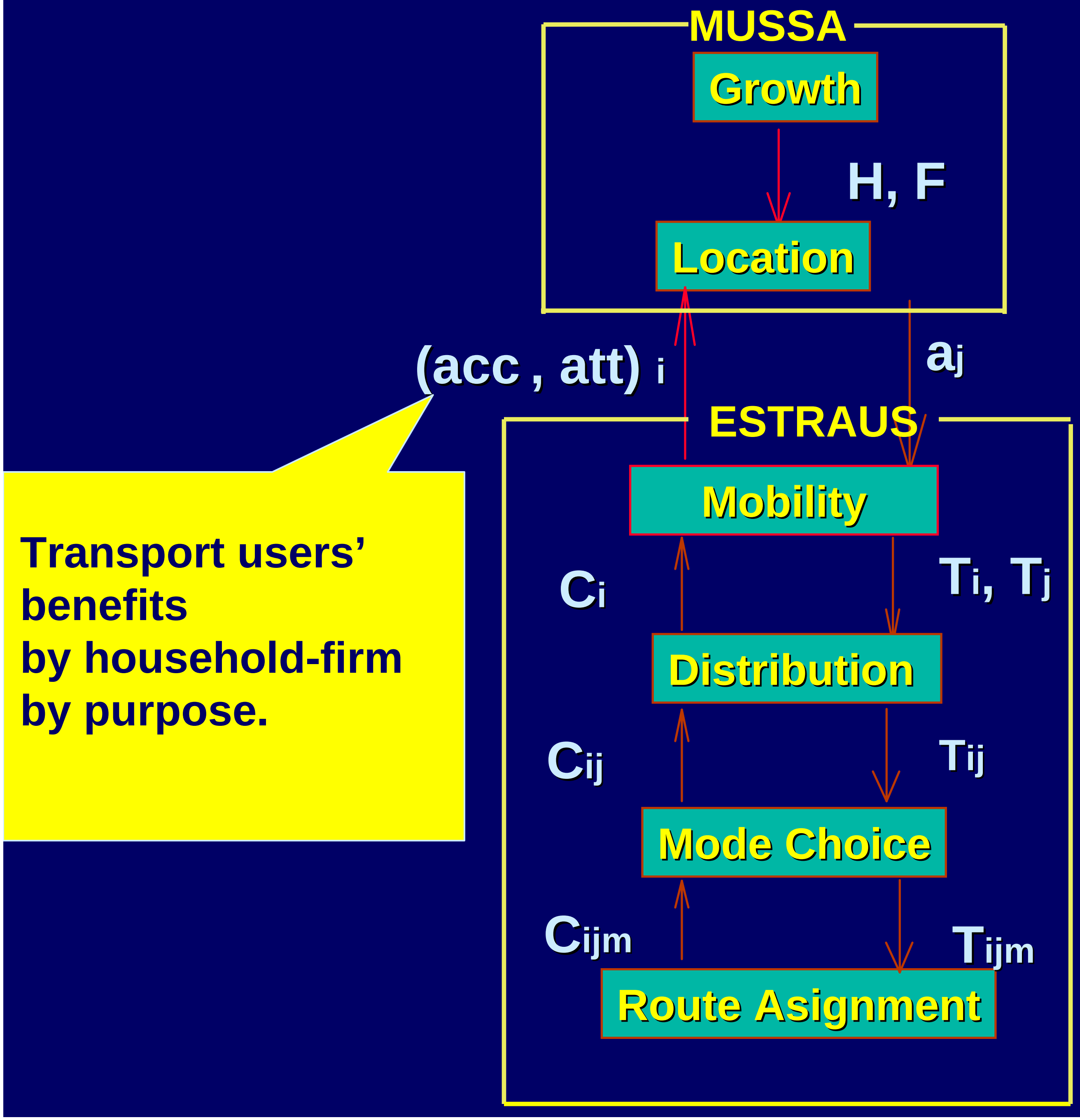
- Consumers
  (household and firms)
- Suppliers
  (developers)
- Land
- Buildings
- Planning Regulations
- Transport system



# Model Components



# LUS & T INTERACTION



# Economic Interaction

$$U_{hi} = U_h(activities_i)$$
$$s.t.\ \text{Income} + \text{Time constraints}$$

Activity framework

$$V_{hi}(z_i, acc_{hi}, att_{hi}, I_h - p_i, \beta_h)$$

***acc*** and ***att*** **are transport users' benefits**

Aggregation issue: use a vector and synthetic measures and test statistically against data

# LU & T interaction

- Can be lagged.
- Assumption on trips affecting location choices: NOT needed.
- Aggregation issue: by hh members and by trip purposes.
- Any transport model  Estraus, EMME2, TRIPS, or activity based model.
- Activity interaction ONLY by trip distribution model (firms incl.)

# MUSSA: agents

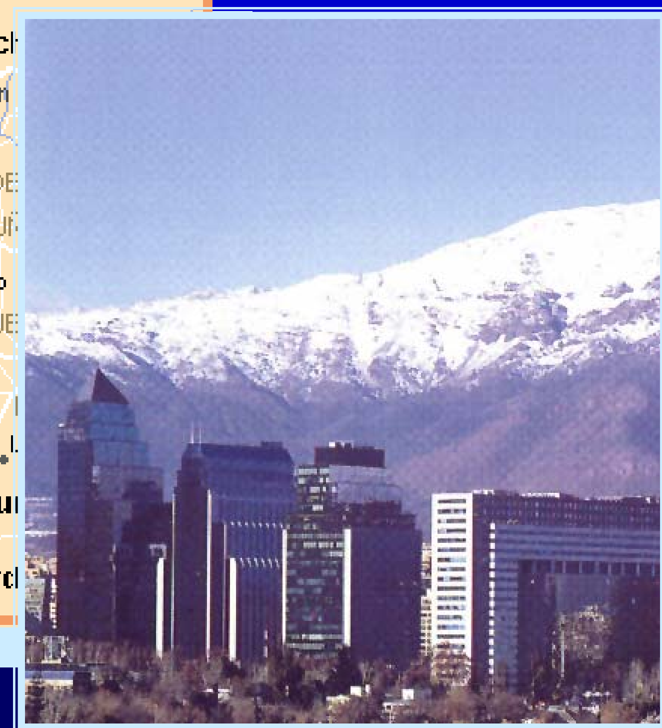
Building supply

Consumers

- MUSSA describes the market by different suppliers and locating agents


Houses (4)

Households (65)



Firms (5)

Buildings (2)

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# Housing Supply Model

## How many properties are available ?

↑ Demand ( $H_h$ ) → ↑ Rent ( $r_v$ ) → ↑ Supply ( $f_v$ )

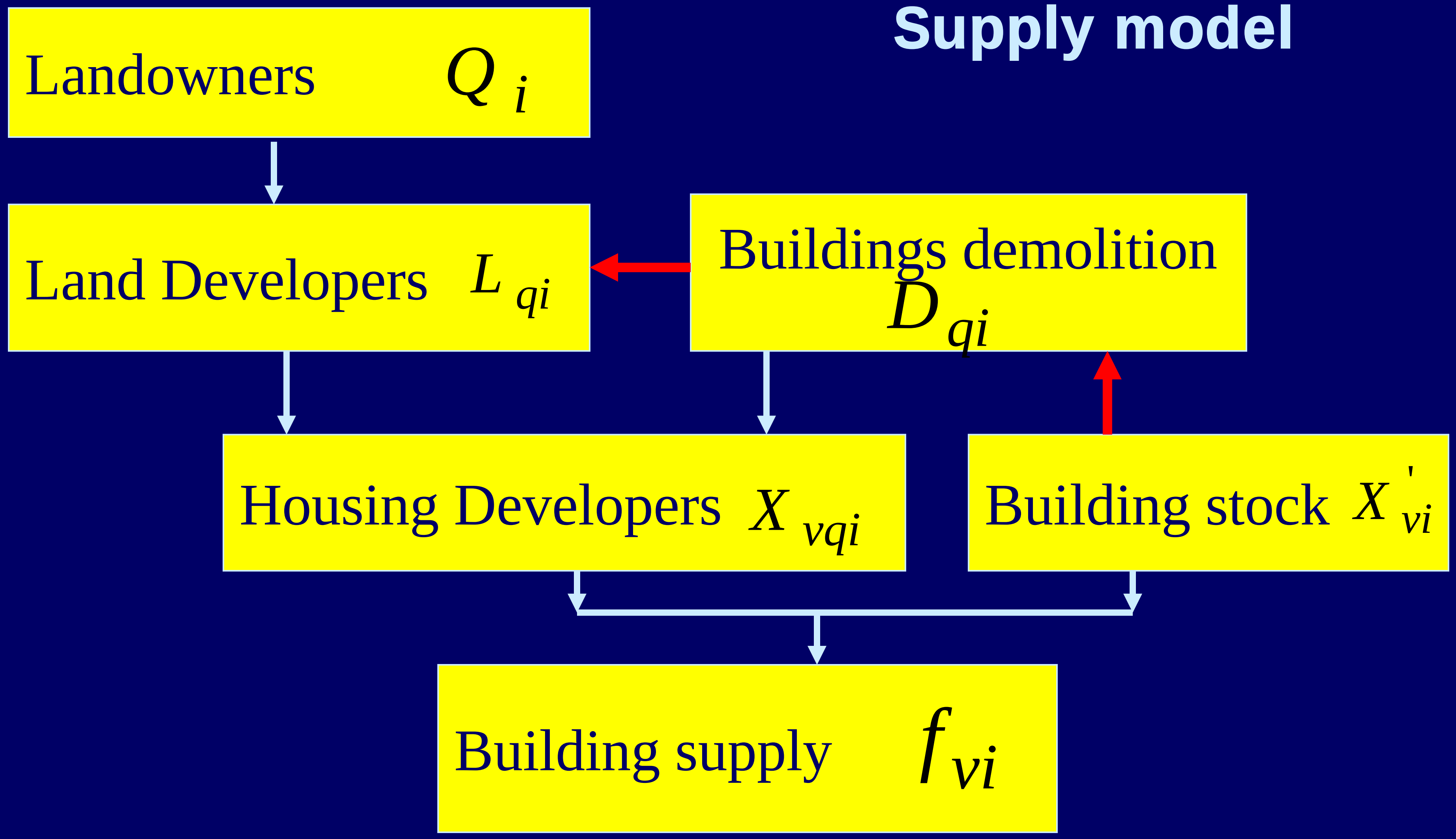
↑ Cost ( $c_v$ ) → ↓ Supply ( $f_v$ )

$$f_v^t = \Theta\left(r_v^t, f_v^{t-R}; c_v^t\right) \quad \Rightarrow \quad f_c^t = \Theta\left(\overline{r_c^t}, f_c^0, z_c^0\right)$$

Time series model

**In MUSSA**

# Supply model




**Imperfect competition: suppliers capture location advantages**

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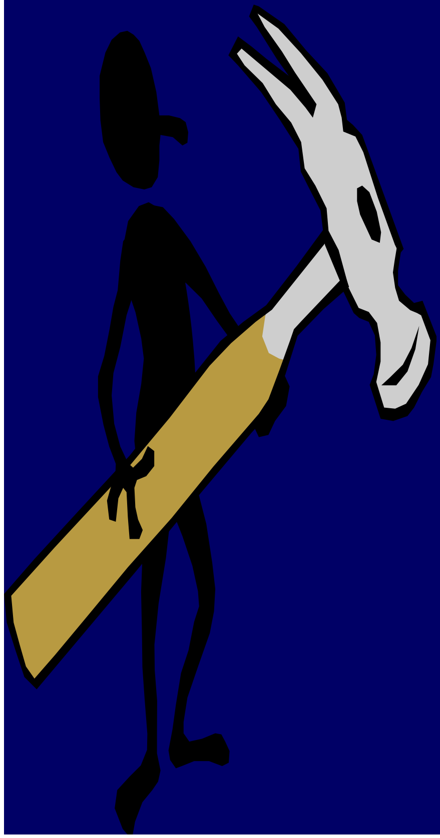
# The Random Bidding Model

**Basic Principle:**

Land is a quasi-unique good.

Then …



**Auction**

**Best bidder rule**

# Behavioral Bid Functions

$$U_{hvi} = U_h(activities_i)$$
$$s.t.\ \text{Income} + \text{Time constraints}$$

$$V_{hvi}(z_{vi}, acc_{hi}, att_{hi}, I_h - p_{vi}, \beta_h)$$

Inverting in *p*

$$WP_{hvi} = I_h - V^{-1}(\bar{z}_{vi}, acc_{hi}, att_{hi}, \beta_h, U^*)$$

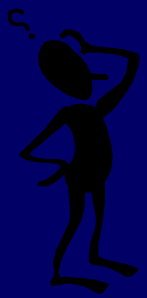
expenditure function

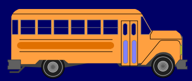
*WP:* value for option (*v*,*i*), described by attributes vector **(z)** and access vector (acc, att) obtaining a utility level (U*)

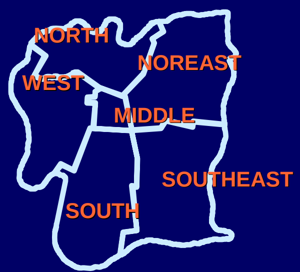
z : Attributes vector describes built environment

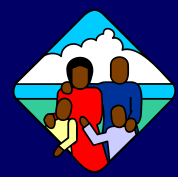
NO FIXED ZONAL ATTRACTION FACTORS

# The BID function







- Consumer clustering variables

- Property attributes (*D*)
  (land lot and building)

- Zone attributes (*X*)
  (build & natural environment)

- Transport attributes (*T*)
  (access)

Bid (*D*,*X*,*T*)

***Location externalities***

# The bidding-auction process

- Given a supply option (*v,i*)
- Consumers assess their willingness to pay *WP*, or actual value
- Bids are *WP* minus speculation *w*
- Speculation depends on a number of factors in the market
- Suppliers accept the highest bid…their choice set is made out of agents

# Conceptual Approach

**A Consumer "*l*" located at property *v* in zone *i***

$$bid_{lvi} \geq \underset{g}{Max}(bid_{gvi})$$

$B = WP$ + speculative term

**at maximun utility level**

**Rent at location v in zone *i***

$$r_{vi} = \underset{g}{Max}\left(bid_{gvi}\right)$$

# Probabilistic viewpoint

**Consumer "*l*" located at property *v* in zone *i***

$$P_{l/vi} = P\left[ bid_{lvi} \geq \underset{g}{Max}(bid_{gvi}) \right]$$

**Rent at location v in zone *i***

$$r_{vi} = E\left[ \underset{g}{Max}\left(bid_{gvi}\right) \right]$$

$$bid_{lvi} = B_{lvi} + random\ \ error$$

?

# Logit model

$$Bid_{lvi} = B_{lvi} + Gumbel\ random\ term\ (0,\mu)$$

Total demand

Probability of being bidder

**A Consumer "*l*" located at property *v* in zone *i***

$$P_{l/vi} = \frac{\overline{H}_l \phi_{lvi} \exp(\mu B_{lvi})}{\sum_{g \in H} \overline{H}_g \phi_{gvi} \exp(\mu B_{gvi})}$$

Bidders

Bid determines location and rent

**Rent at location v in zone *i***

$$r_{vi} = \frac{1}{\mu} \ln \left[ \sum_{g \in H} \overline{H}_g \phi_{gvi} \exp(\mu B_{gvi}) \right] + \frac{\gamma}{\mu}$$

# Specification of bids and rents

$$B_{hvi} = WP_{hvi} - \omega_h = b_h + b_{vi} + b_{hvi}$$

## Household

## Firms

$$= f(b_{hvi})$$

$$g(b_{hvi}, b_{vi})$$

$$B_{vi}(\beta_1) = \beta_{10} + \sum_p \beta_{1p} x_{vip}$$

UFC
Arco
EdadC

$$B_{hvi}(\beta_2) = c_h y_h + \beta_{2h0} + \sum_j \beta_{2hj} x_{hvij}^{\theta_{nj}}$$

CaDep
Acc
Arte
Arco
ZIng
ZSup

$$\beta_{2hj} = \sum_l b_{njl} x_{hl}^{\lambda_{njl}} \quad \forall j \quad \forall h \in n$$

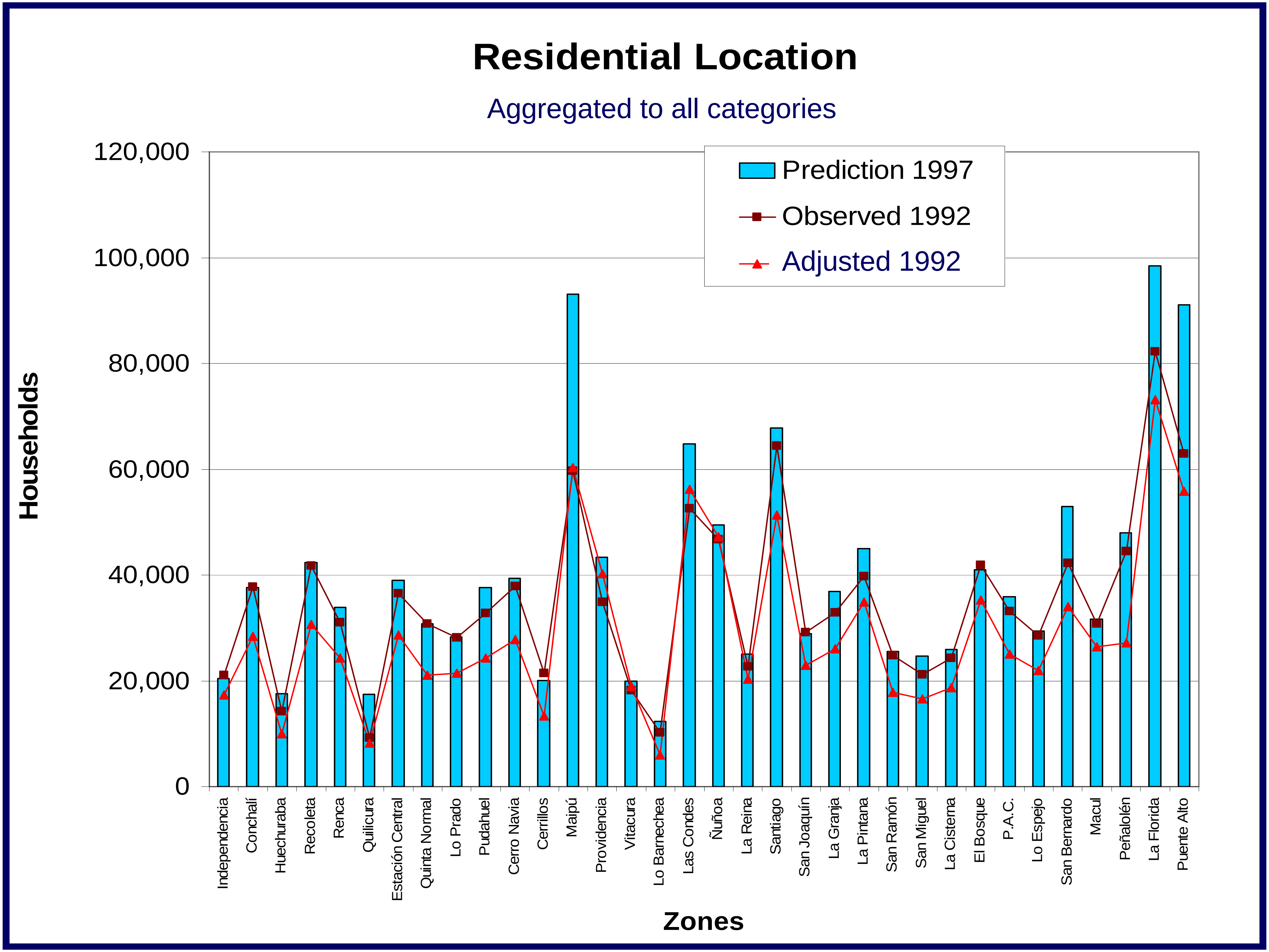
NPer
CaDep

tt, Zing, Arco, Arte

$$\ldots_{mvi0} + \sum_j \alpha_{2mvij} z_{vij}^{\theta_{mj}}$$

$$\ldots_{2mvij} \ldots \sum_l d_{mjl} z_{vil}^{\lambda_{mjl}} \quad \forall j$$

$$r_{vi} = \frac{1}{\mu} ln \sum_{g \in H} \overline{H}_g \phi_{gvi} exp(\mu B_{gvi}(\beta_2)) + B_{vi}(\beta_1) + \frac{\gamma}{\mu}$$


Residential Location
Aggregated to all categories
Households
Zones
Prediction 1997
Observed 1992
Adjusted 1992
120,000
100,000
80,000
60,000
40,000
20,000
0
Independencia
Conchalí
Huechuraba
Recoleta
Renca
Quilicura
Estación Central
Quinta Normal
Lo Prado
Pudahuel
Cerro Navia
Cerrillos
Maipú
Providencia
Vitacura
Lo Barnechea
Las Condes
Ñuñoa
La Reina
Santiago
San Joaquín
La Granja
La Pintana
San Ramón
San Miguel
La Cisterna
El Bosque
P.A.C.
Lo Espejo
San Bernardo
Macul
Peñalolén
La Florida
Puente Alto

# Presentation

- Components of MUSSA
- The supply model
- The RBM: random bidding model
- **The equilibrium problem**
- Software
- Other issues

# Equilibrium model

**Input data**

- Growth of total demand
- Transport attributes: access benefits
- Regulations and subsidies
- Supply information

# Equilibrium Problem

**All consumers located**

$$\sum_{v,i} P_{l/vi} f_{vi} = \overline{H}_l \quad \forall l$$

**Consumers' behaviour**

$$P_{l/vi} = \frac{\overline{H}_l \phi_{lvi} \exp\left(\mu B_{lvi}(P)\right)}{\sum_g \overline{H}_g \phi_{gvi} \exp\left(\mu B_{gvi}(P)\right)}$$

**Supply model**

$$f_c = \Theta\left(\overline{r}_c\right) \quad \forall c$$

**Land capacity**

$$\sum_v f_{vi} q_v \leq Q_i \quad \forall i$$

**Planning regulations**

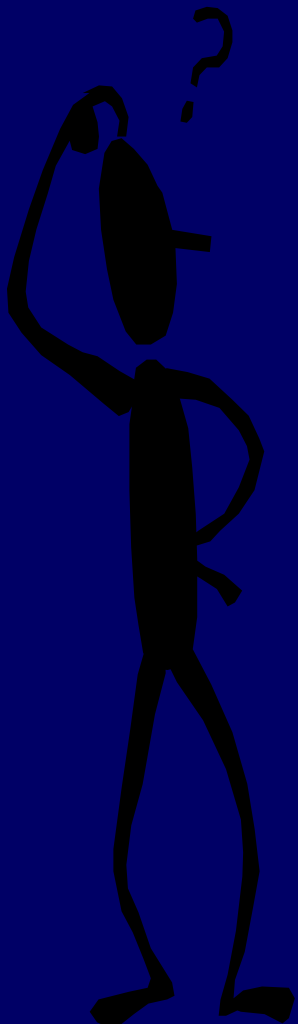
$$R(f, B, P) \leq 0$$

# Changes in the land use system

**Regulation of land use**

**Transport system**

**Distribution of consumers**



accessibility

$$\underset{f_{vi},\ B_l}{Min} \sum_{l} \left( \sum_{v,i} P_{l/vi} f_{vi} - \bar{H}_l \right)^2$$

$f_{vi}$ $B_l$

Road infrastructure, parking

$$s.a. \quad \sum_{v} f_{vi} q_v \le Q_i \quad \forall i$$

$$\sum_{v,i \in c} f_{vi} \approx \Theta(\bar{r}_c) \quad \forall c$$

accessibility

accessibility

$$P_{l/vi} = \frac{\bar{H}_l \phi_{lvi} \exp(\mu B_{lvi}(P))}{\sum_{g} \bar{H}_g \phi_{gvi} \exp(\mu B_{gvi}(P))}$$

$$f_{vi} \ge K_{vi} \quad \forall v, i$$

$+ f_{vi} \le U_{vi}$

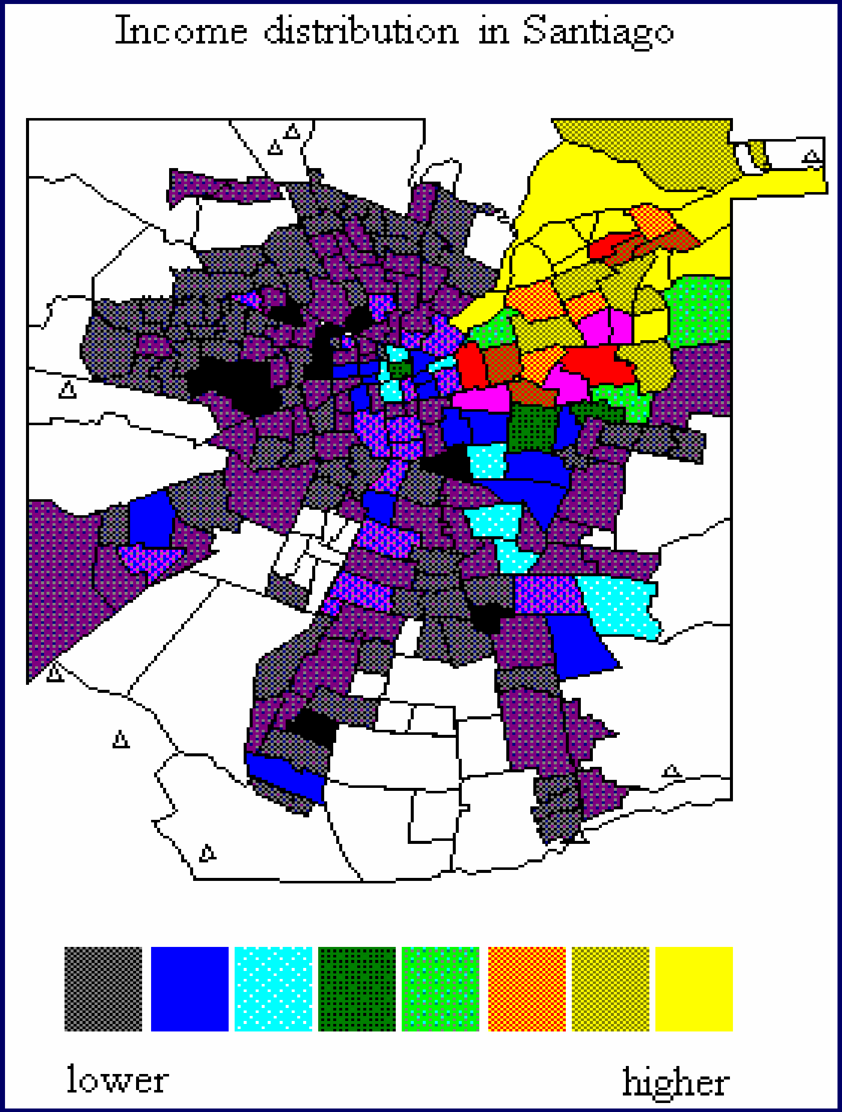
# Algorithm description

- Location externalities fixed point in *P* : adjust, all land use/neighborhood variables, both residential and commercial attractiveness
- Utility level fixed point in $b_h$ : Bids depends on utility level independently on location attributes; adjust to equilibrium conditions
- Supply adjust to prices/rents: fixed points define adjusted bids, hence rents, then supply optimise profit subject to regulations

# Equilibrium characteristics

- Imperfect competitive auction market
- Suppliers anticipate rents/prices
- Non-linear mathematical problem
- Non-economic optimization problem

# Problem dimension of MUSSA




- Types of consumers : 70
  - Households : 65
  - Firms : 5
- Types of Supply : 4908
  - Dwellings : 6
  - Non-residential properties : 6

**X** 409 zones

# Constraints of the Equilibrium Problem

- Supply Model

An aggregated time-series model of residential supply for 34 macrozones. Next: detailed model

- Land Use Regulations

Existing local and global regulations, plus subsidies

- Supply Bounds

# Land Use Regulations

**Control of supply**

- Dwelling density
- Land use capacity
- Building height
- Size of a property in terms of land and structure

**Control of location**

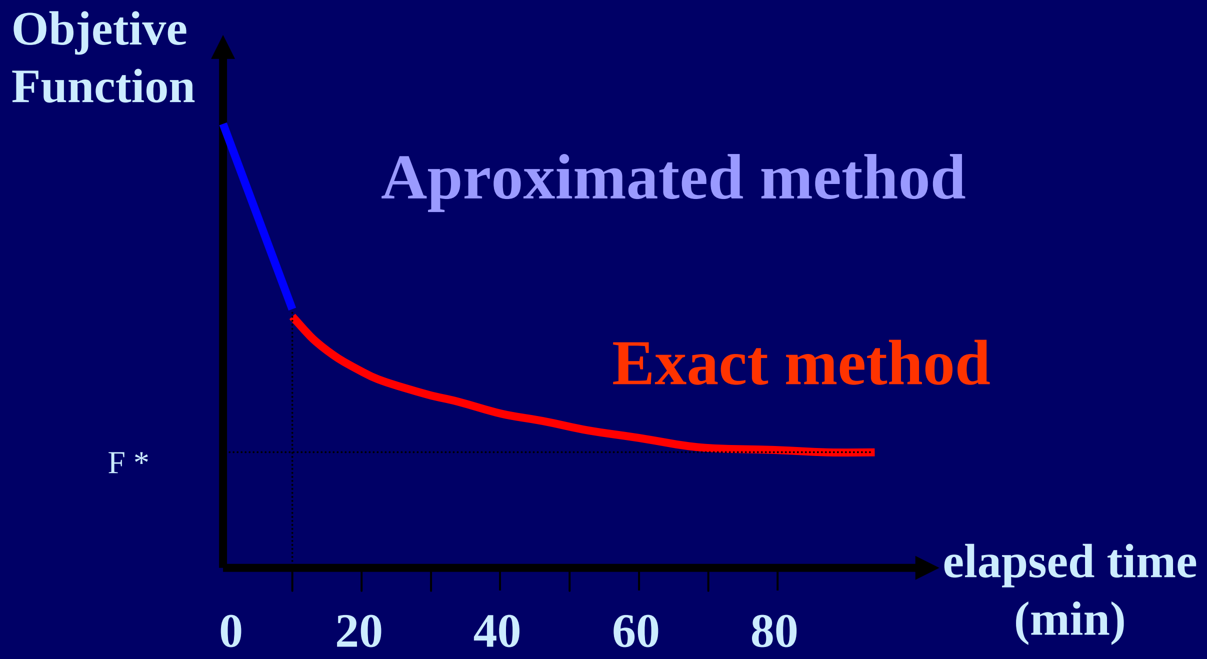
- Not allowed activities at some types of supply
- Subsidies in the city center for urban development

# Typical Macro Equilibrium Problem : XXL size

- Number of Optimization Variables : 478

  “f” variables : 12 * 34 = 408 “b” variables : 70

- Number of Constraints : 700



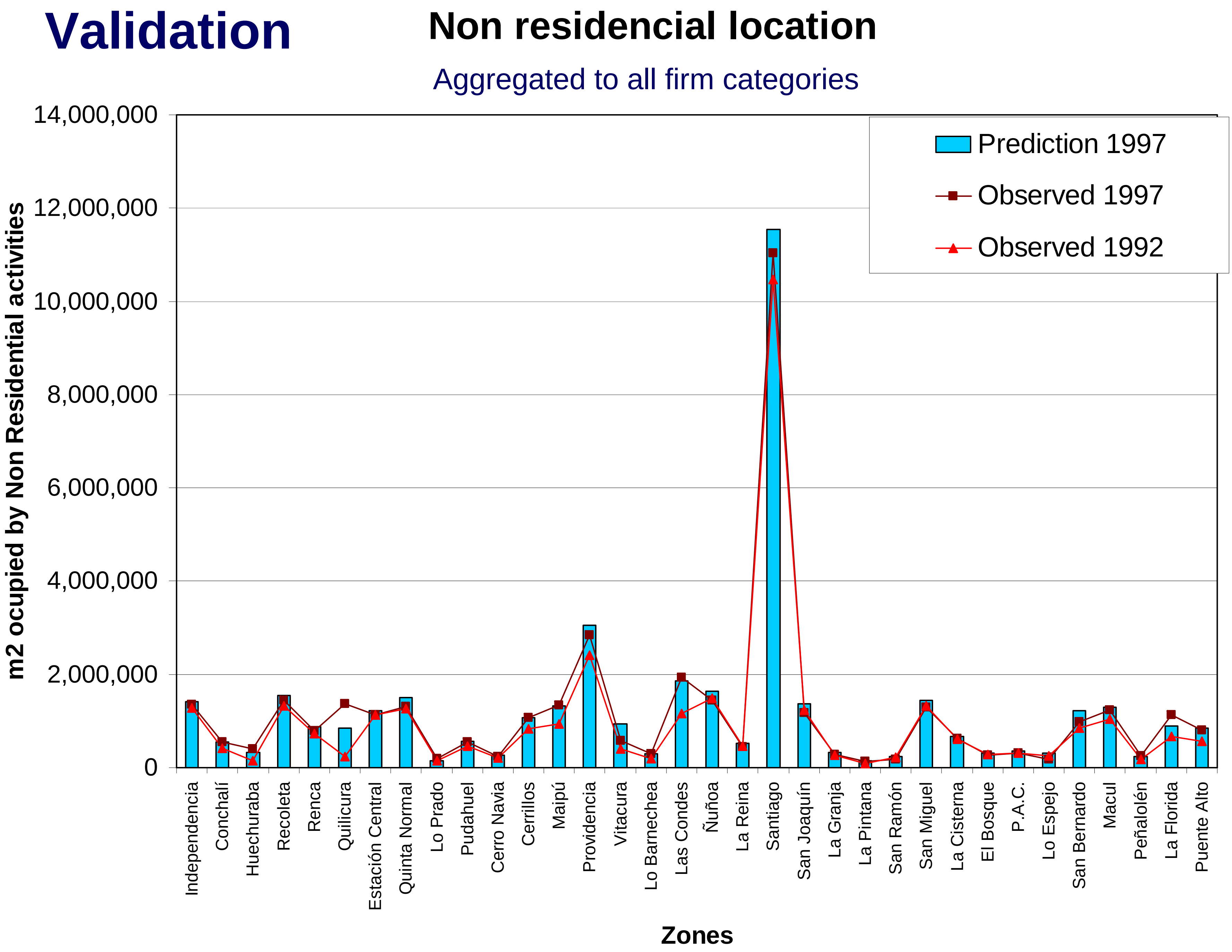

PC Pentium 166

80 Mb RAM

# Prediction Results

- Supply (*vi*) : $f_{vi}$
- Location (*hvi*) : $f_{vi} P_{h/vi}$
- Rents (*vi*) : $r_{vi}$
- LU Benefits (*hvi*) : $\boldsymbol{F}(B_{hvi})$
- Sensitivity of the equilibrium to supply, regulation constraints and subsidy/tax policies

# Validation


Non residencial location
Aggregated to all firm categories
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
m2 ocupied by Non Residential activities
Prediction 1997
Observed 1997
Observed 1992
Independencia
Conchalí
Huechuraba
Recoleta
Renca
Quilicura
Estación Central
Quinta Normal
Lo Prado
Pudahuel
Cerro Navia
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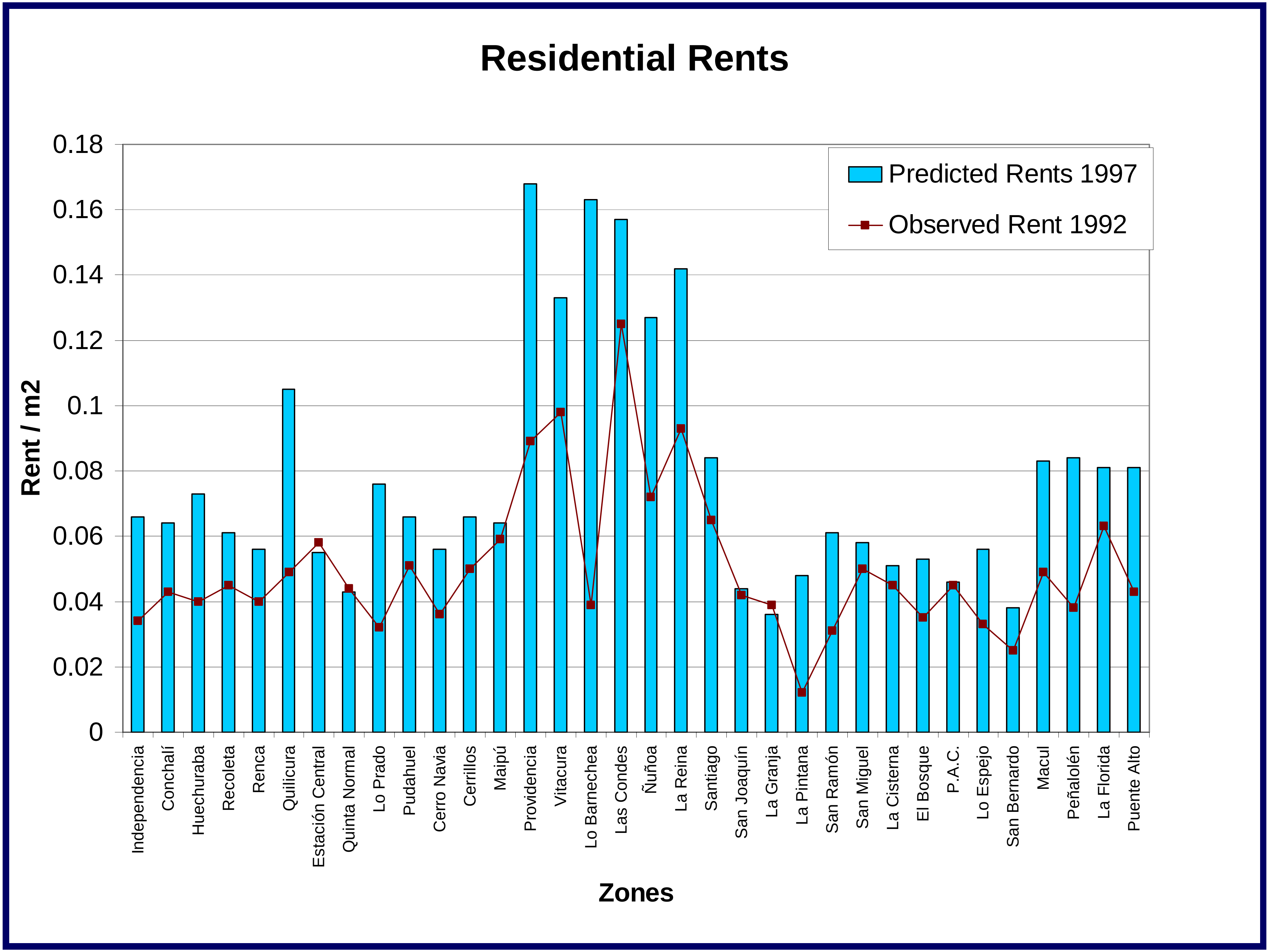
San Ramón
San Miguel
La Cisterna
El Bosque
P.A.C.
Lo Espejo
San Bernardo
Macul
Peñalolén
La Florida
Puente Alto
Zones


Residential Rents
Predicted Rents 1997
Observed Rent 1992
Rent / m2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Independencia
Conchalí
Huechuraba
Recoleta
Renca
Quilicura
Estación Central
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La Florida
Puente Alto
Zones

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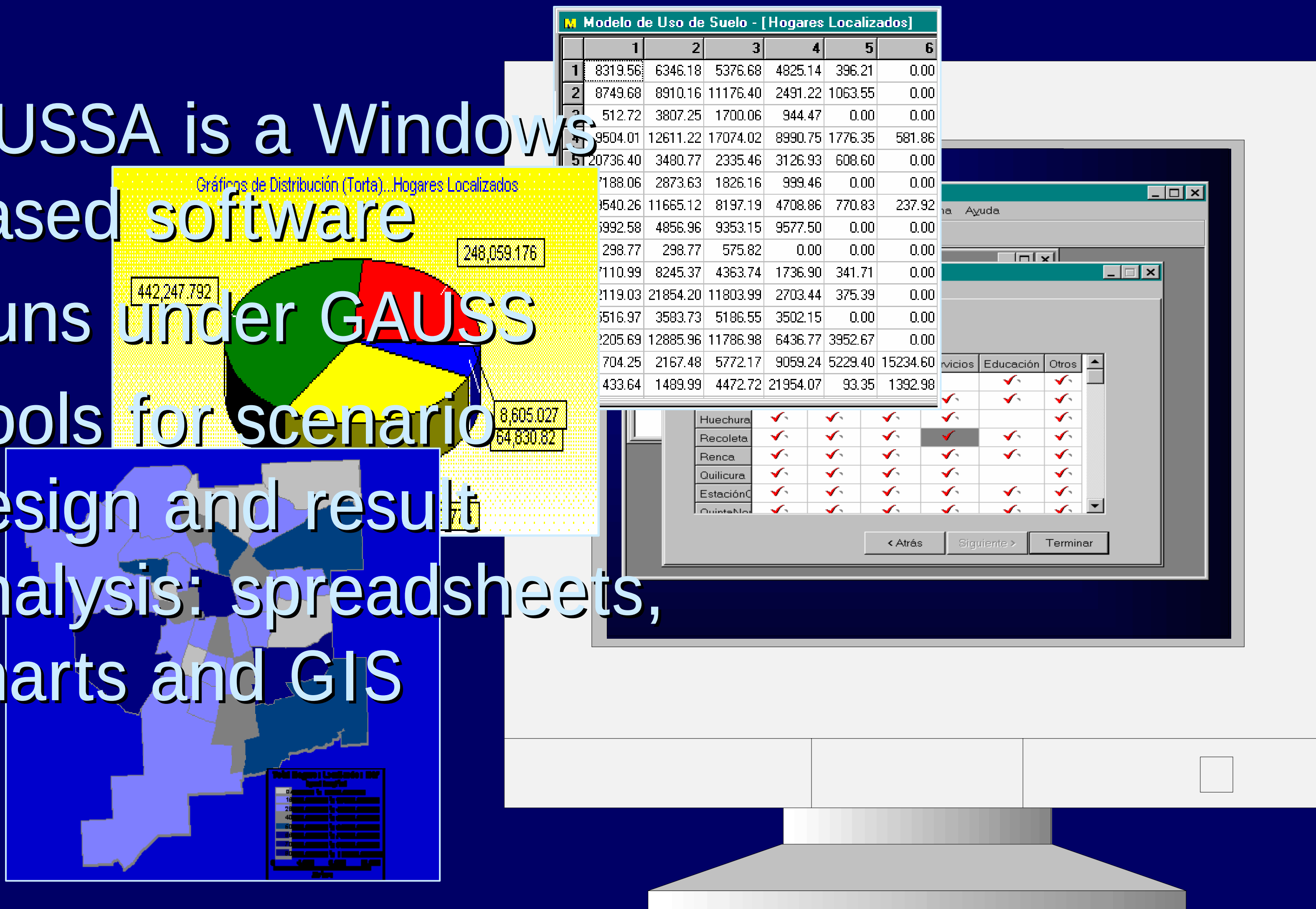
- The equilibrium problem
- **Software**
- Other issues

# Software PC: Running model

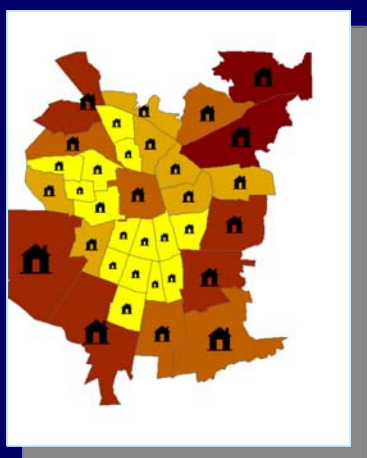
- MUSSA is a Windows based software
- Runs under GAUSS
- Tools for scenario design and result analysis: spreadsheets, charts and GIS



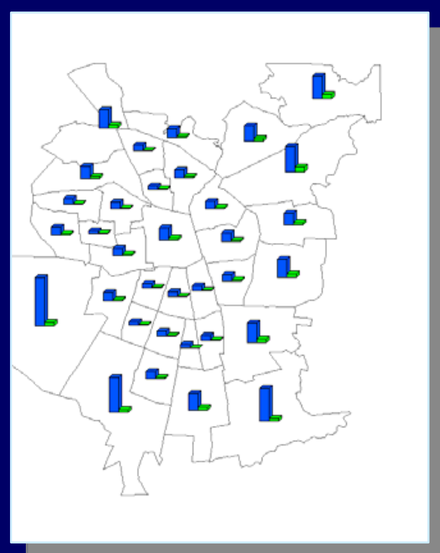

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | 8319.56 | 6346.18 | 5376.68 | 4825.14 | 396.21 | 0.00 |
| 2 | 8749.68 | 8910.16 | 11176.40 | 2491.22 | 1063.55 | 0.00 |
| 3 | 512.72 | 3807.25 | 1700.06 | 944.47 | 0.00 | 0.00 |
| 4 | 9504.01 | 12611.22 | 17074.02 | 8990.75 | 1776.35 | 581.86 |
| 5 | 20736.40 | 3480.77 | 2335.46 | 3126.93 | 608.60 | 0.00 |
| | 7188.06 | 2873.63 | 1826.16 | 999.46 | 0.00 | 0.00 |
| | 9540.26 | 11665.12 | 8197.19 | 4708.86 | 770.83 | 237.92 |
| | 5992.58 | 4856.96 | 9353.15 | 9577.50 | 0.00 | 0.00 |
| | 298.77 | 298.77 | 575.82 | 0.00 | 0.00 | 0.00 |
| | 7110.99 | 8245.37 | 4363.74 | 1736.90 | 341.71 | 0.00 |
| | 2119.03 | 21854.20 | 11803.99 | 2703.44 | 375.39 | 0.00 |
| | 5516.97 | 3583.73 | 5186.55 | 3502.15 | 0.00 | 0.00 |
| | 2205.69 | 12885.96 | 11786.98 | 6436.77 | 3952.67 | 0.00 |
| | 704.25 | 2167.48 | 5772.17 | 9059.24 | 5229.40 | 15234.60 |
| | 433.64 | 1489.99 | 4472.72 | 21954.07 | 93.35 | 1392.98 |

# Software PC: Results

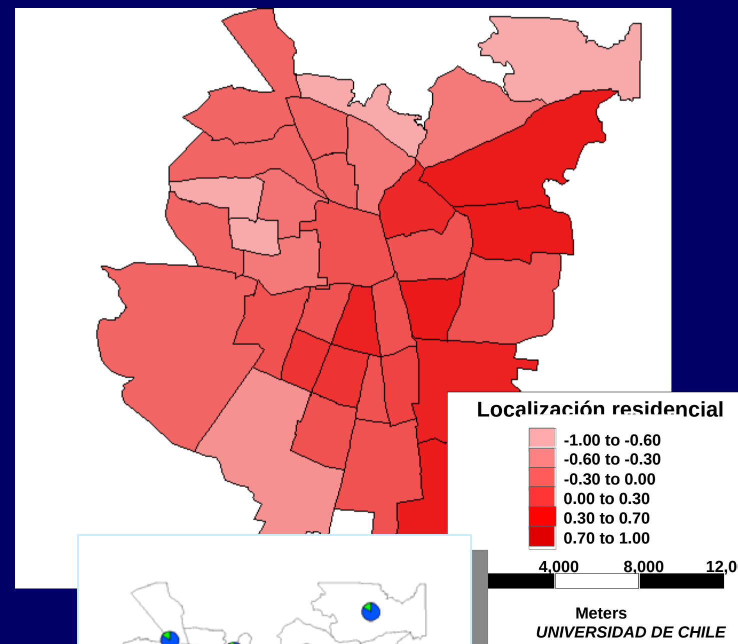
- Produces different displays of results

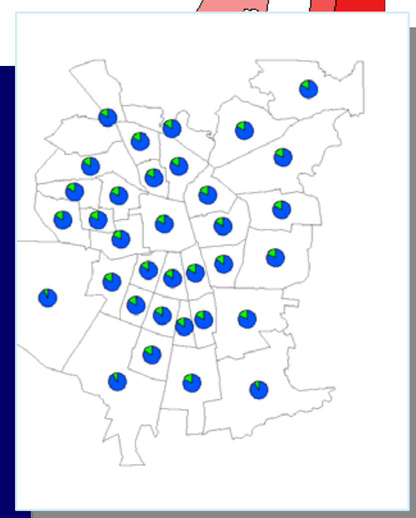


Location of residential (65) and comercial (5) activities



Building supply by 10 types



Land use and prices

# Summary

- Sequential land use-transport interaction
- Simultaneous location and rent formation, unique set of parameters
- Fully Behavioral:locator agents and suppliers
- Non linear location problem due to land use attributes: location externalities
- Equilibrium demand-supply under imperfect market competition
- Operational software

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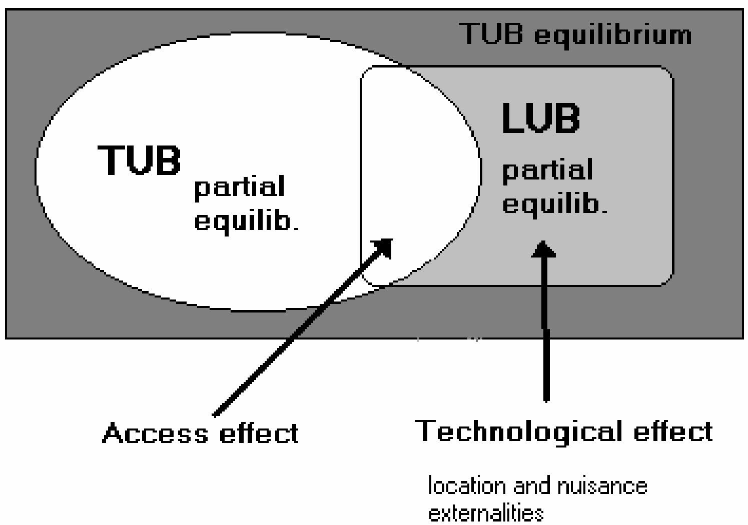
# OTHER ECONOMIC ISSUES

- Transport and Land Use Benefits
- Optimal Planning

# Percolation of Transport Benefits

Figure 1: Composition of transport project benefits




TUB < total
LUB < total
Overlapping

Total benefits needs
LU&T equilibrium

# Optimal Planning

- Define a social function based on land use benefits
- Model land use regulation and subsidies
- Find optimal expropriation prices
- Find optimal land use prices
- Find optimal regulation scenarios


SECTRA

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