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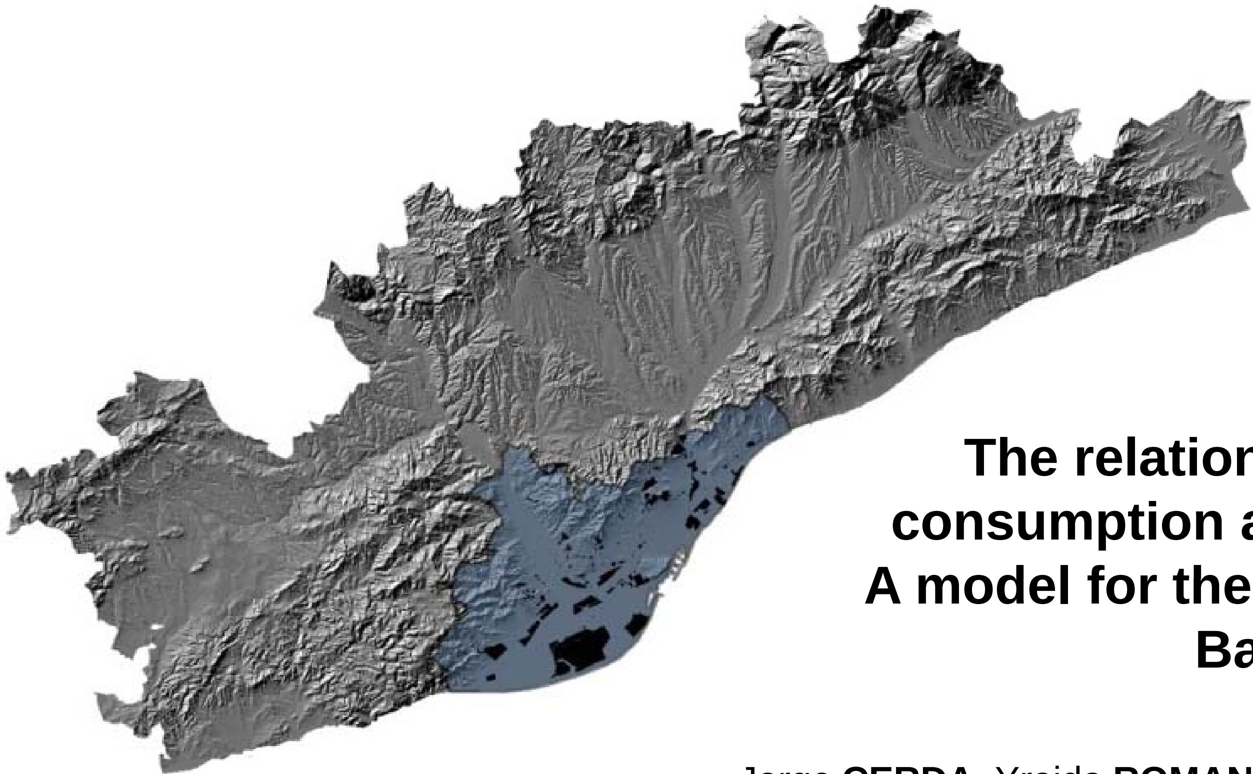

The relation between energy consumption and developed land; A model for the Metropolitan Area of Barcelona

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CONTENT OF THE PRESENTATION

- **RESEARCH PROBLEM**
- **OBJECTIVES**
- **THE MATHEMATICAL MODEL**
- **RESULTS**
- **FINAL REMARKS**

THE RESEARCH PROBLEM

- In recent decades, Southwest Europe metropolises have undergone a process of territorial dispersion.

- In the context of modelling environmental and energy efficiency of the territorial functionality of the metropolitan area of Barcelona, one of the problems is to model the consumption of natural soil, and to model the electric consumption by located activities

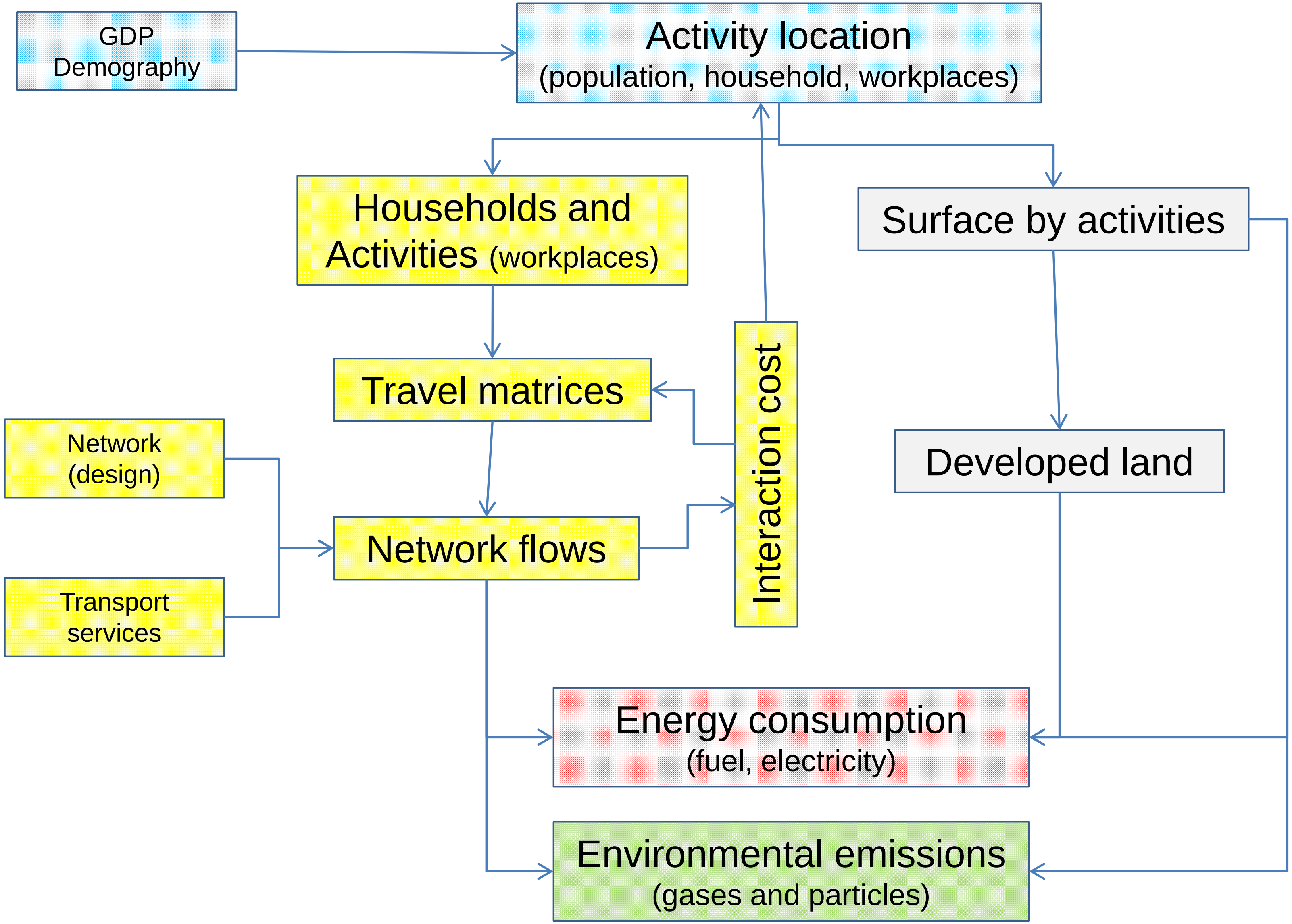
- A simple point of view of the relation between electric consumption, activities, and developed land is a direct relation. But this statement is simple and not very analytical, in the sense that not all activities have the same need of land and electric consumption for its operation.

OBJECTIVES

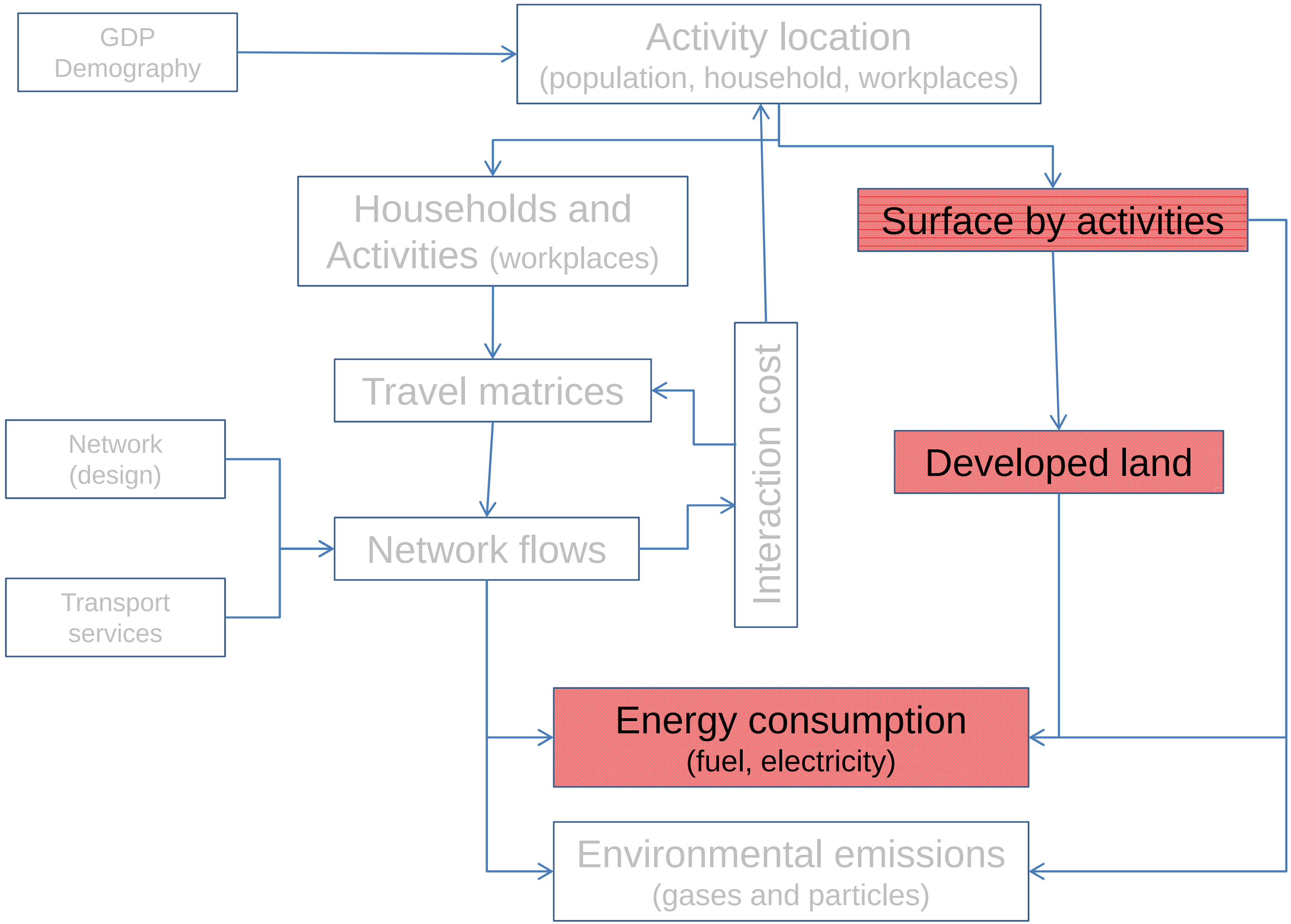
- Understanding the phenomenon of consumption (electrical and land) as a production process, the relation become nonlinear equations (Cobb-Douglas).

- The aim of this study is to quantify the relationship between activity surfaces, developed land, and electric consumption (that they generate), in the municipalities of the Metropolitan Region of Barcelona.

THE MAIN MODEL : ENVIRONMENTAL EFFICIENCY OF THE TERRITORIAL FUNCTIONALITY



THE MATHEMATICAL MODEL



THE MATHEMATICAL MODEL

Surface by activities

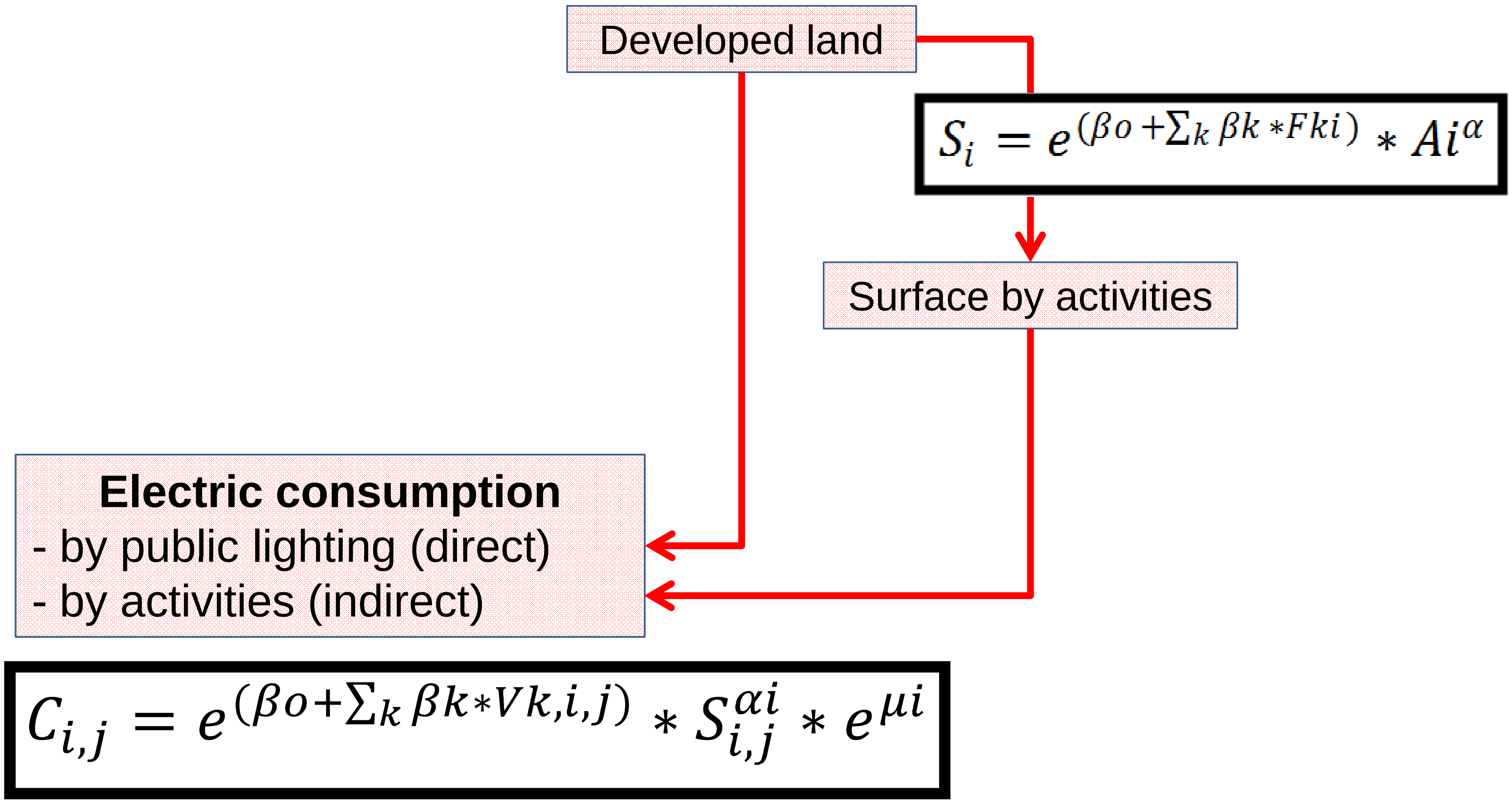
$$A_i = e^{(\beta o + \sum_k \beta k * Fki)} * Si^{\alpha} * e^{\mu i}$$

Developed land

Electric consumption
- by public lighting
- by activities

$$C_{i,j} = e^{(\beta o + \sum_k \beta k * Vk,i,j)} * S_{i,j}^{\alpha i} * e^{\mu i}$$

<u>THE MATHEMATICAL MODEL</u> : With a planning approach



$$S_i = e^{(\beta o + \sum_k \beta k * Fki)} * Ai^{\alpha}$$

$$C_{i,j} = e^{(\beta o + \sum_k \beta k * Vk,i,j)} * S_{i,j}^{\alpha i} * e^{\mu i}$$

RESULTS

Activity	Annual electric consuption (Kwh 2005)	%	Built surface (m2 2005)	%
Industry	7.030.724.574	**38,0**	57.126.766	14,2
Residence	5.792.747.971	31,3	257.597.812	**64,2**
Shops	2.159.251.967	11,7	23.469.345	5,9
Transport and comunication	764.144.468	4,1	21.190.966	5,3
Health	666.538.743	3,6	3.500.726	0,9
Hotels	426.138.862	2,3	4.843.349	1,2
Personal services	415.165.810	2,2	22.553.418	5,6
Public administration	218.896.512	1,2	1.399.358	0,3
Financial services	217.414.542	1,2	1.504.748	0,4
Education	101.702.346	0,5	7.909.588	2,0
Public lighting system	705.920.396	3,8		
Total	**18.498.646.190**	**100,0**	**401.096.076**	**100,0**

RESULTS

$$C_{i,j} = e^{(\beta o+\sum_k \beta k * Vk,i,j)} * S_{i,j}^{\alpha i} * e^{\mu i}$$

Variables	Electric consumption models										
	Residence	Public administration	Shops	Education	Financial services	Hotels	Industry	Health	Personal services	Transport and comunication	Public lighting system
Constant	1,207	-7,763	2,718	4,489	6,221	3,335	-5,965	7,722	-7,698	-8,388	10,496
Ln (residence surface)	**1,001**										
Ln (Public administration surface)		**,764**									
Ln (Shops surface)			**,921**								
Ln (Education surface)				**,847**							
Ln (Financial services surface)					**,868**						
Ln (Hotels surface)						**,377**					
Ln (Industry surface)							**1,138**				
Ln (Health surface)								**,793**			
Ln (Personal services surface)									**1,200**		
Ln (Transport and comunication surface)										**,514**	
Summer minimum temperature	**,106**		**,161**			**,477**			**,427**		
Summer average temperature		**,686**					**,346**			**,814**	
Average working time							**,158**				
Average time of personal engagement					**,164**						
Ln(Total developed land)											**1,326**
% developed land between cadastral areas											**10,454**
Adjust R square	**,909**	**,531**	**,725**	**,696**	**,773**	**,448**	**,638**	**,705**	**,543**	**,511**	**,546**

RESULTS

$$A_i = e^{(-13{,}473 - 0{,}527 * DFi)} * Si^{1{,}058}$$

Where

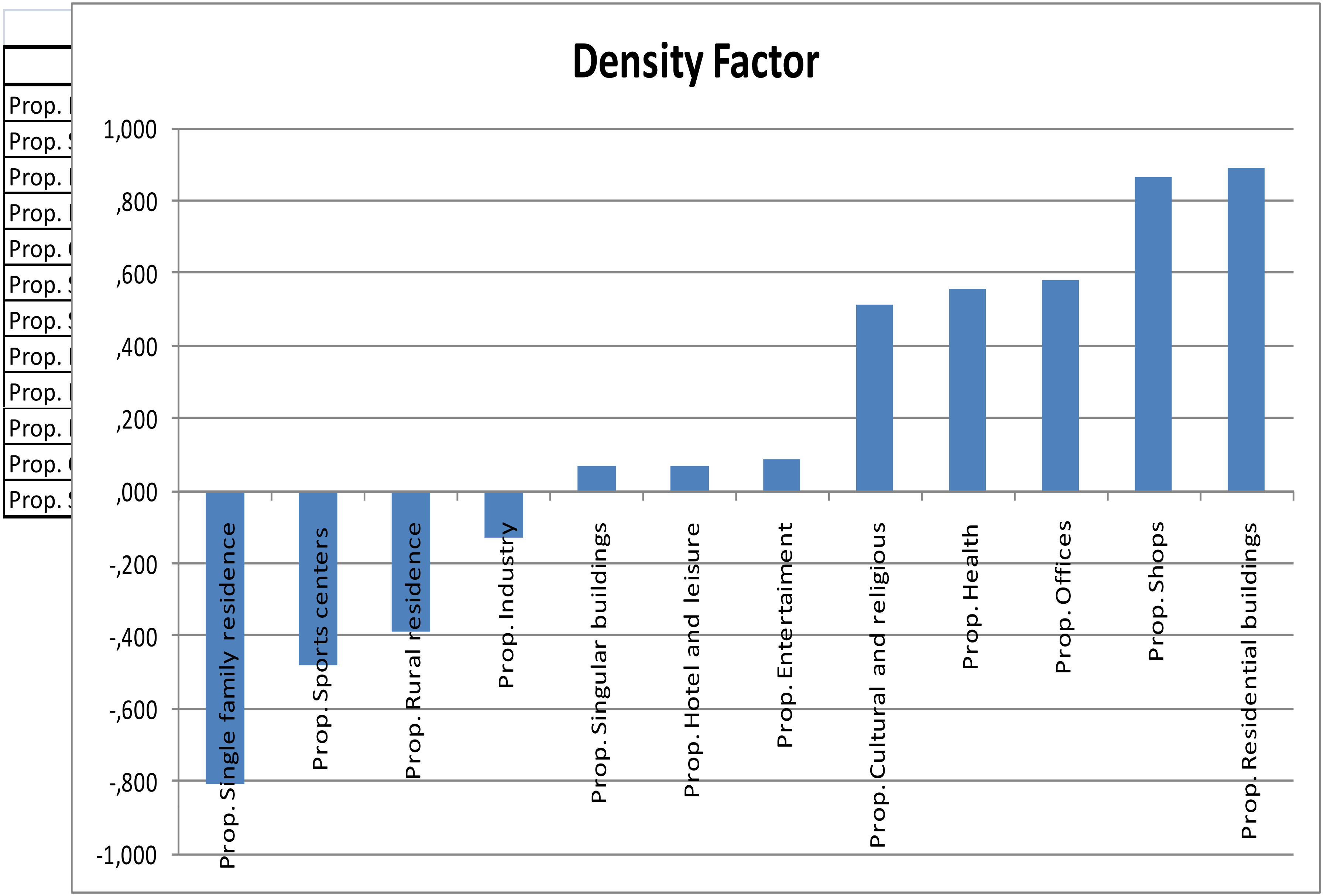
Ai : developed land produced in the municipality i

Si : total activity surface in the municipality i

DFi : density factor of municipality i

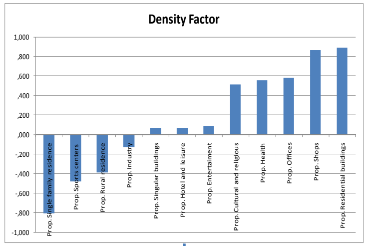
$$S_i = e^{(12{,}734 + 0{,}498 * DFi)} * Ai^{0{,}945}$$

RESULTS



Prop. I
Prop. S
Prop. I
Prop. I
Prop. C
Prop. S
Prop. S
Prop. I
Prop. I
Prop. I
Prop. C
Prop. S
Density Factor
1,000
,800
,600
,400
,200
,000
-,200
-,400
-,600
-,800
-1,000
Prop. Single family residence
Prop. Sports centers
Prop. Rural residence
Prop. Industry
Prop. Singular buildings
Prop. Hotel and leisure
Prop. Entertaiment
Prop. Cultural and religious
Prop. Health
Prop. Offices
Prop. Shops
Prop. Residential buildings

RESULTS : Relation procedure



$$S_i = e^{(12{,}734+0{,}498 * DFi)} * Ai^{0{,}945}$$

	Electric consumption models										
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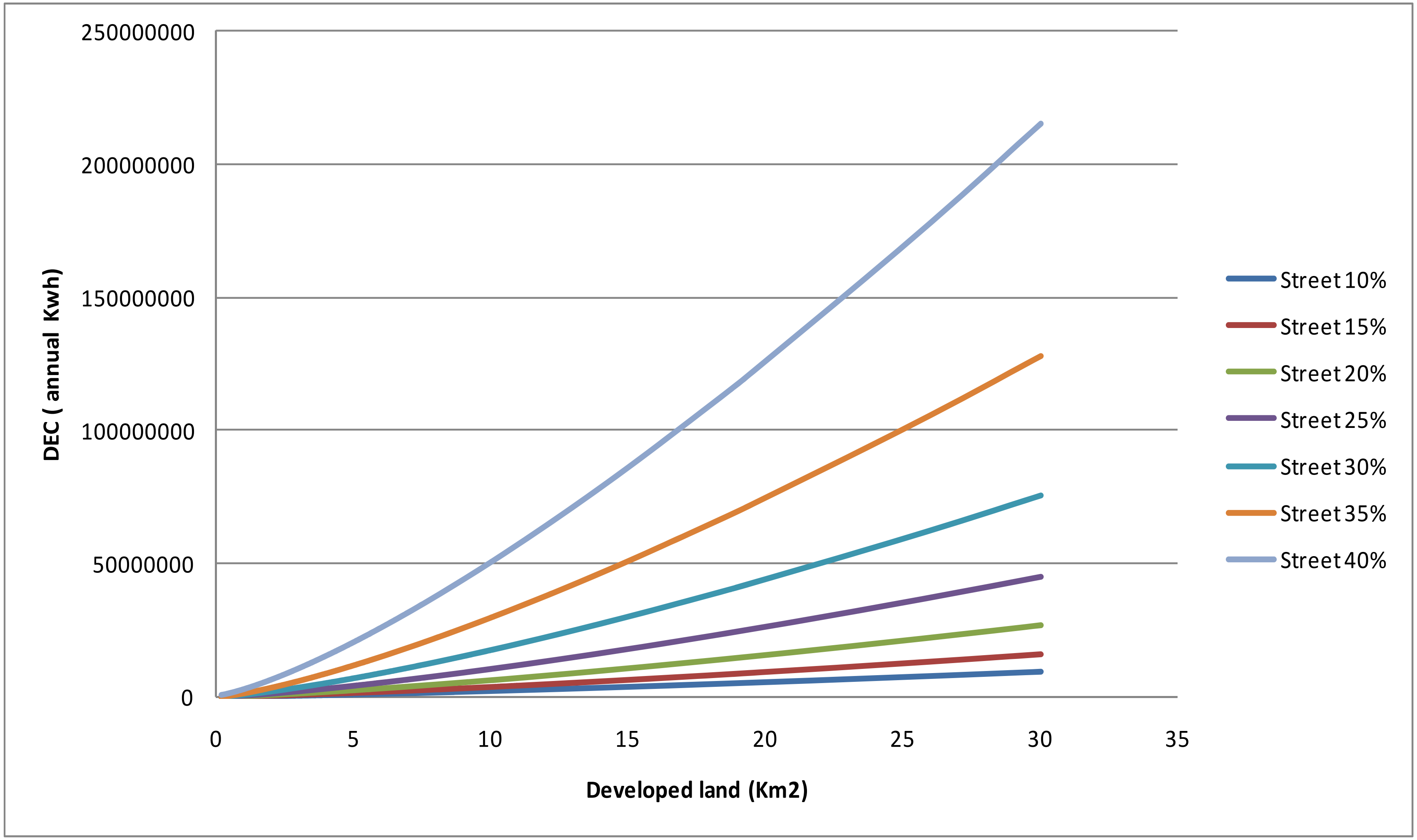
TOTAL INDIRECT CONSUMPTION + TOTAL DIRECT CONSUMPTION = TOTAL CONSUMPTION

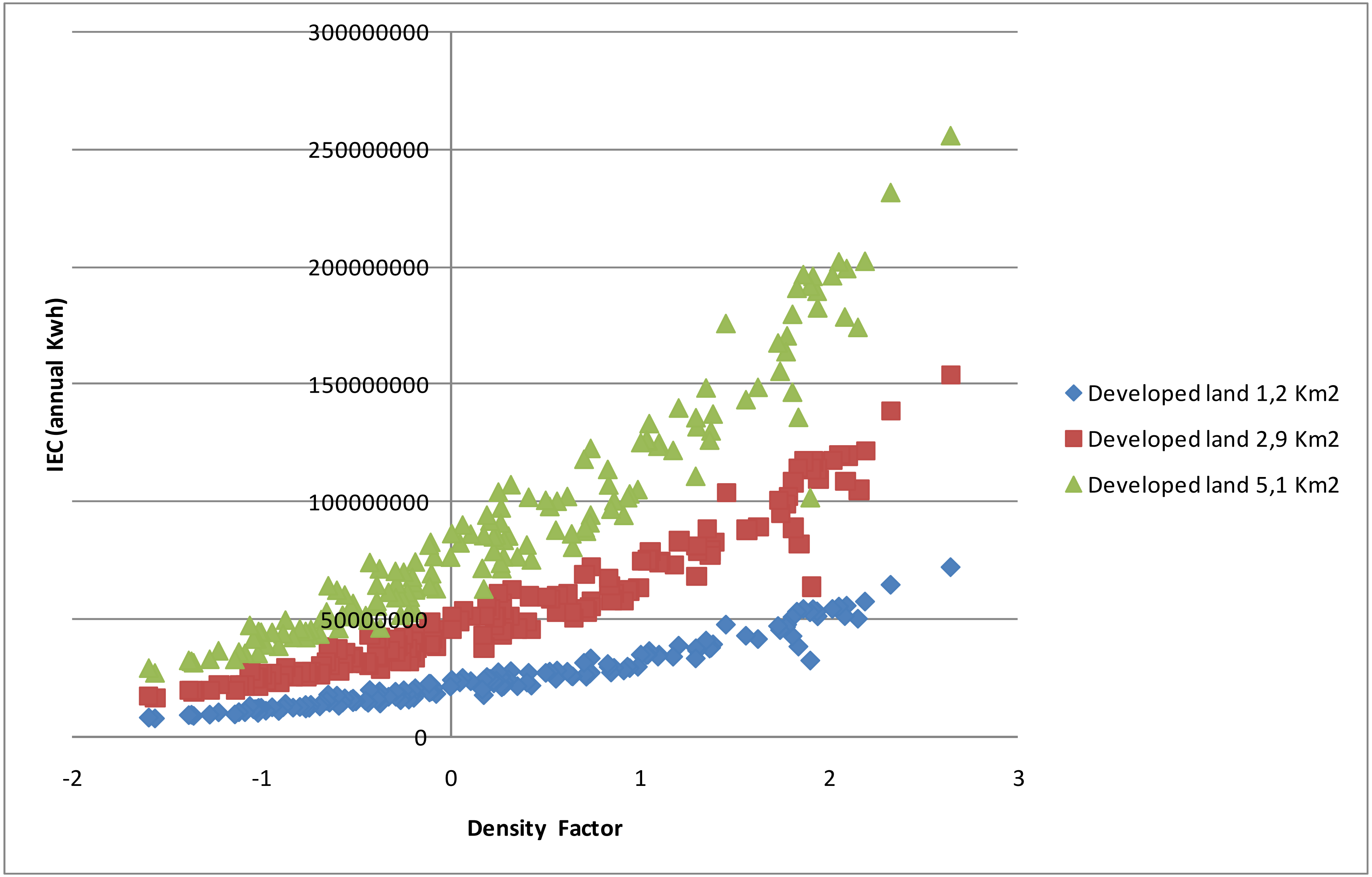
RESULTS

Relation between Direct Electric Consumption and Developed Area



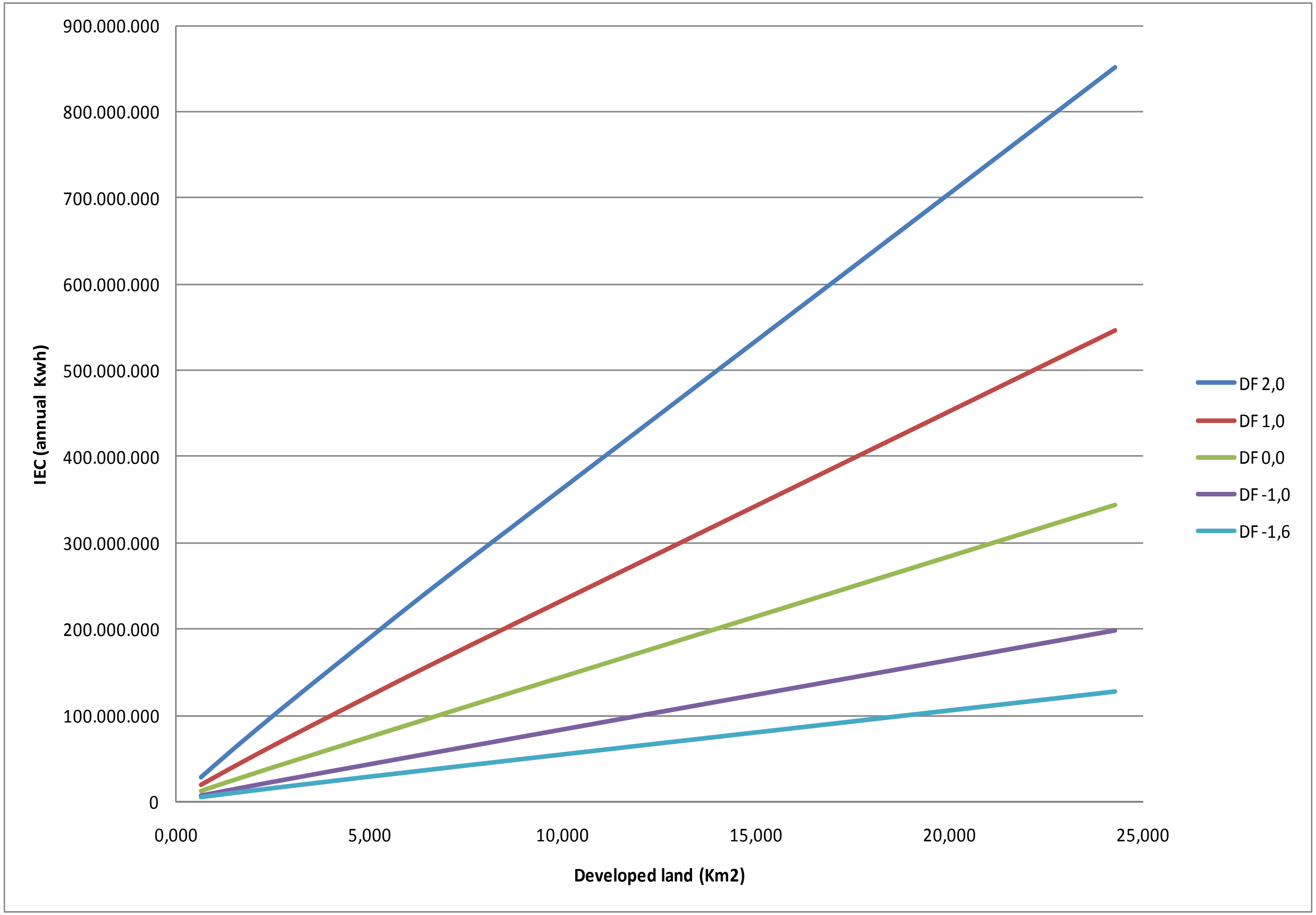
RESULTS

Relation between Indirect Electric Consumption and Density Factor (type of city)



RESULTS

Relation between Indirect Electric Consumption and Developed Area



RESULTS

Sensibility analysis for parameters in the procedure

	Value		Direct electric consumption		Indirect electric consumption		Total electric consumption	
Parámeters	Base	Variation (+/-10%)	Annual Kwh	% variation	Annual Kwh	% variation	Annual Kwh	% variation
Base			**1.455.523**		**85.560.758**		**87.016.281**	
Developed land (Km2)	**2,93**	3,23	1.651.603	**13,5**	92.964.536	**8,7**	94.616.139	**8,7**
		2,64	1.265.740	**-13,0**	78.090.417	**-8,7**	79.356.157	**-8,8**
Density factor	**1,50**	1,65	1.455.523	0,0	90.031.187	**5,2**	91.486.710	**5,1**
		1,35	1.455.523	0,0	82.895.277	**-3,1**	84.350.800	**-3,1**
% Street	**0,22**	0,24	1.826.007	**25,5**	85.560.758	0,0	87.386.765	**0,4**
		0,20	1.160.207	**-20,3**	85.560.758	0,0	86.720.966	**-0,3**
Summer minimun temperature	**16,5**	18,1	1.455.523	0,0	100.308.083	**17,2**	101.763.606	**16,9**
		14,82	1.455.523	0,0	77.063.169	**-9,9**	78.518.692	**-9,8**
Summer average temperature	**21,6**	23,8	1.455.523	0,0	128.346.329	**50,0**	129.801.851	**49,2**
		19,44	1.455.523	0,0	67.984.422	**-20,5**	69.439.944	**-20,2**
Average time of personal engagement	**1,6**	1,8	1.455.523	0,0	85.570.592	0,0	87.026.115	0,0
		1,46	1.455.523	0,0	85.551.182	0,0	87.006.705	0,0
Average working time	**7,0**	7,7	1.455.523	0,0	86.857.599	**1,5**	88.313.122	**1,5**
		6,32	1.455.523	0,0	84.400.145	**-1,4**	85.855.667	**-1,3**

FINAL REMARKS

• The management dimension (variables) of the size of the developed land, and the proportion of built activity surfaces (who affect the DF value), produced a differentiated effect in the annual electric consumption, be greater the effects by the size in relation of the effects by the built activity structure. High level of electric consumption is associated with high density activities (residence in buildings, shops, services, etc) and larger size of developed areas. Low level of electric consumption is associated with low density activities and small developed areas.

• The no management dimension of the weather conditions produced the larger effects in the annual electric consumption. In this sense, the present work has not evaluate the synergic effects produced inside the high density developed areas, called the urban heat island (UHI), but is clear that this effects will be increased the effects of this city structure in the electric consumption.

• Finally, the results shows that the relation between developed land and electric consumption, reveals an advantage of low dense compact structures over dense and compact structures. This arise two conceptual questions; 1) what is the optimal size of the compact city, and 2) the energy cost to be paid by the city to keep one of its genetic factors, the agglomeration economies.

THANKS FOR YOUR ATTENTION