

Restructuring of metropolitan systems to polycentric models?: The case of Barcelona Metropolitan Region (RMB)

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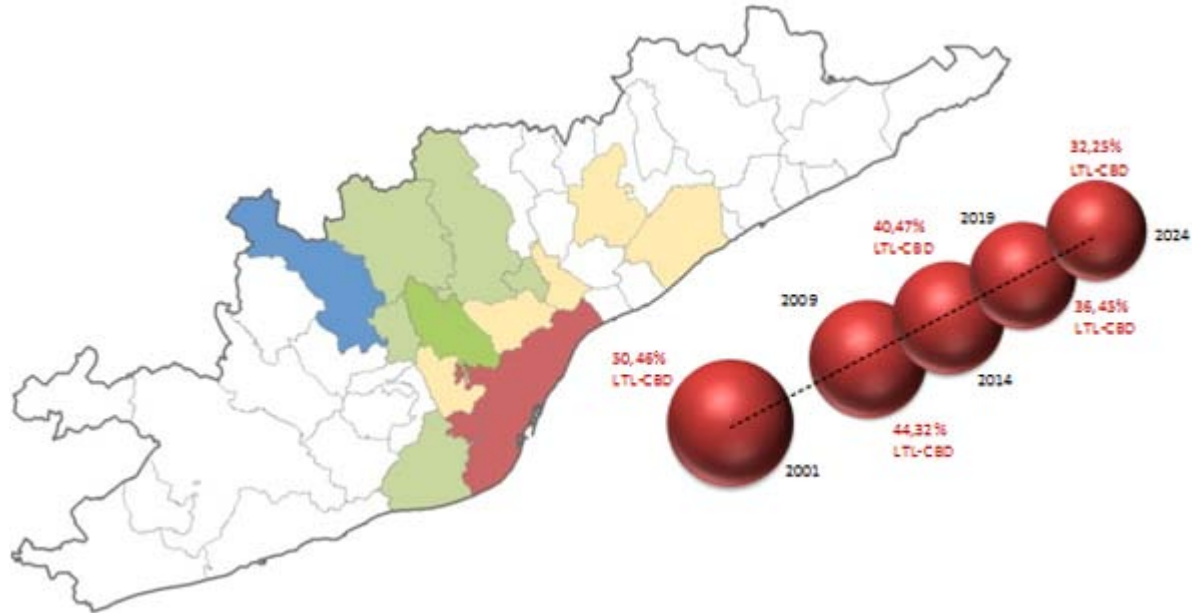
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SUMMARY

1. Introduction
2. Data & Case of study
3. Identification of urban sub-centres (2001)
4. A methodology to classify sub-centres into “emerging” and “consolidated”
5. Spatial interaction model: Emergence of sub-centres
6. Evolution of polycentrism level (2001-2024)
7. Conclusions

1 INTRODUCTION

The **main objective** of the paper is:

- 1) **Analyzing the current (2001) and the prospective (2001-2024) spatial structure of the Barcelona Metropolitan Region**

The **specific objectives** are:

Referring to the current spatial structure (2001)

- 1) **Identifying urban sub-centres (density + mobility)**
- 2) **Classifying the identified sub-centres into “emerging” and “consolidated” by using a proposed methodology in this paper**

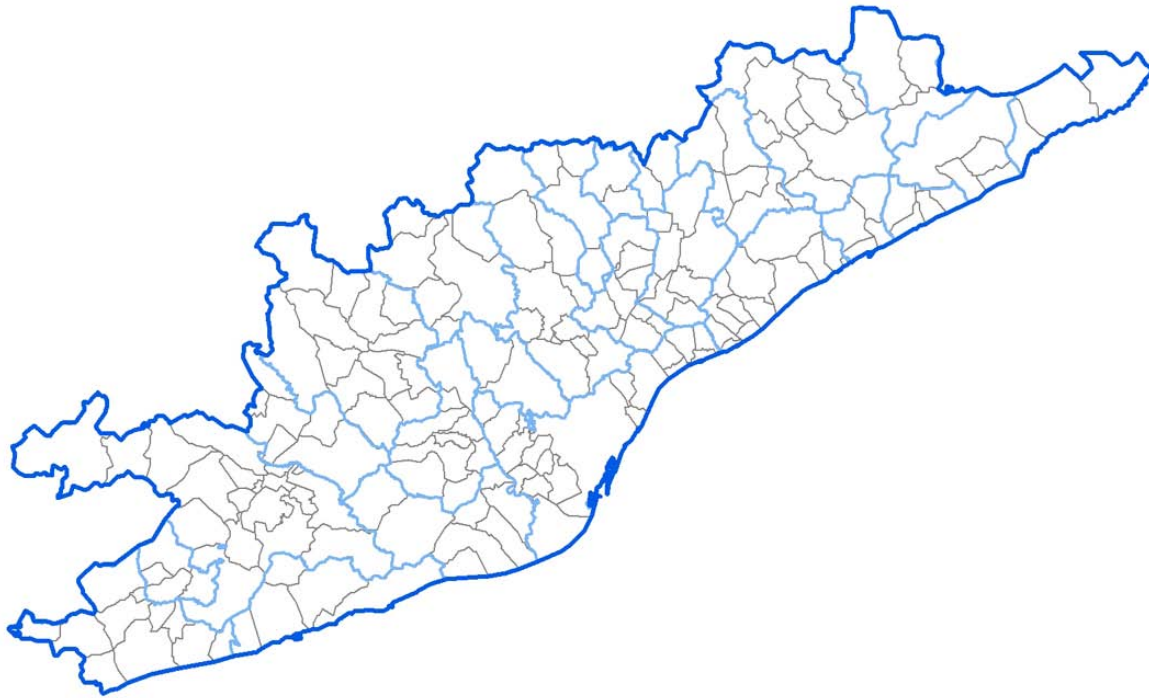
According to the prospective spatial structure (2001-2024)

- 3) **Knowing the evolution of the polycentrism level. Towards a more polynucleated structure of the Barcelona Metropolitan system in 2024?**

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6. Evolution of polycentrism level (2001-2024)
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2 DATA & CASE OF STUDY

Our **case of study** is the **metropolitan area of Barcelona** defined by a **functional approach** to delimit them and following the methodology proposed by Roca (2009, 2011)



- Barcelona Metropolitan System. 184 municipalities, 3760km² and 745km² of artificialised land
- Census of Population and Housing INE 2001
- Corine Land Cover 2000

Artificial land uses:

1. *Not taking into account: the railroad and highway networks, mineral extraction sites and dump sites*
2. *Not completely considering the construction sites (deducting the areas which are roads...)*

	Number of municipalities	Number of consolidated protosystems	Artificialised land	LTL (working places)	Population	Density
			a	b	c	.(=b+c)/a
Barcelona Metropolitan Region	184	24	744,99	1903867	4530164	8636

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3 IDENTIFICATION OF SUB-CENTERS

The vast majority of methodologies have focused on the identification of subcentres: **a) density family:** how dense in employment terms is a site and **b) functional relations:** the influence of a site in organizing the commuting flows in a more complex urban systems

In this paper 4 ways to detect sub-centres has been tested:

1) Using classic approach: it is to say using the classic density (LTL/a) and functional form:

$$\ln D_x = k + BD_{cx} \quad \text{Density is a function of distance to CBD (McDonald \& Prather, 1994)}$$

2) Using the cutoff approach: in the way as has been used by **Garcia-Lopez (2007)**

$$LTL \geq 1\% \sum LTL_{BMR} \quad D_{lfl} \geq D_{Average_BMR} \quad \text{(density and mass of employment-LTL)}$$

Giuliano&Small (1991); Garcia-Lopez (2007); Song (1994); Cervero&Wu (1997); Bogart&Ferry (1999); Shearmur&Coffey (2002); Giuliano&Readfearn (2007)

3 IDENTIFICATION OF SUB-CENTERS

3) **Using functional approach:** considering as candidate to subcentre to those municipalities leading each subsystem (the municipality with most density and critic mass) as suggested by **Roca et al. (2009, 2011)**

$$IV_{ij} = \frac{f_{ij}^2}{RWP_i LTL_j} + \frac{f_{ji}^2}{RWP_j LTL_i}$$

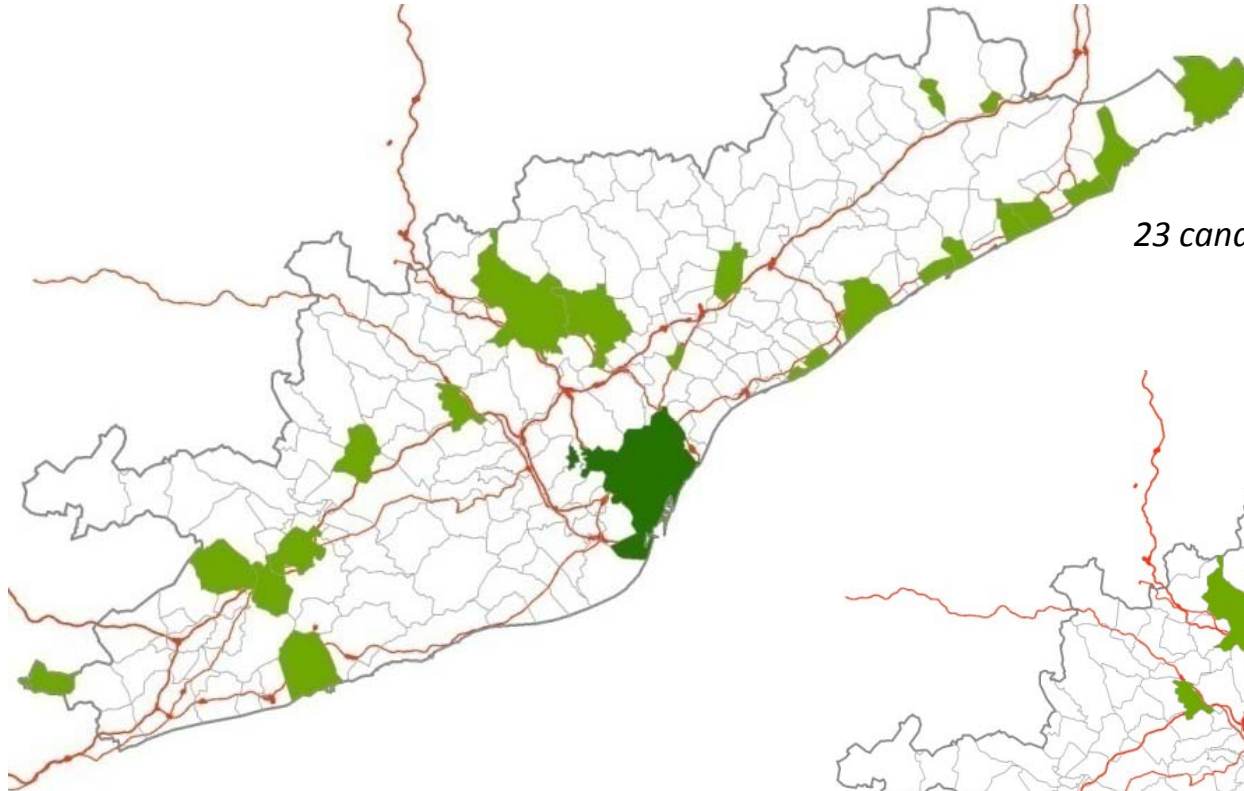
Bourne (1989); Gordon & Richardson (1996); Roca et al., (2009); Roca et al. (2011)

4) **Using an approach based on functional relations and density analysis:** considering as a candidate to sub-centre the **protosystems -44 in 2001-** (way 3) that satisfy the criteria of using cut-off approach (way 2). In that sense, this “new approach” could identify centres in a network of cities function as nodes that at the same time they also are dense spots.

$$IV_{ij} = \frac{f_{ij}^2}{RWP_i LTL_j} + \frac{f_{ji}^2}{RWP_j LTL_i} \quad + \quad \left\{ \begin{array}{l} LTL \geq 1\% \sum LTL_{BMR} \\ D_{ltl} \geq D_{Average_BMR} \end{array} \right.$$

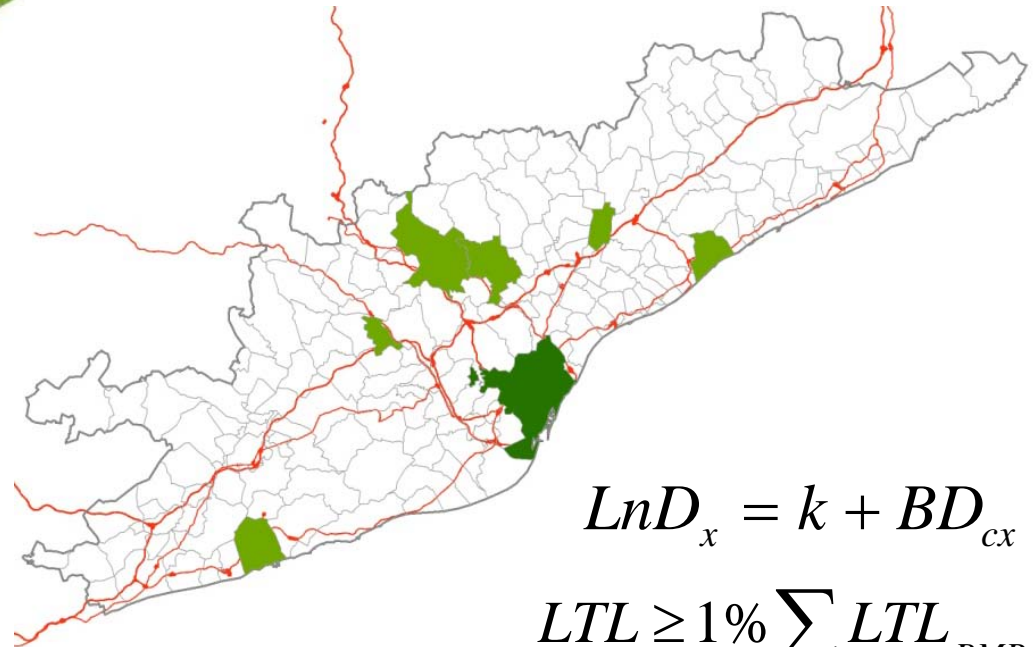
3 IDENTIFICATION OF SUB-CENTERS

1. Candidates to sub-centre. Using classic approach (CL)



$$\ln D_x = k + BD_{cx}$$

23 candidates to sub-centres + CBD (Barcelona)



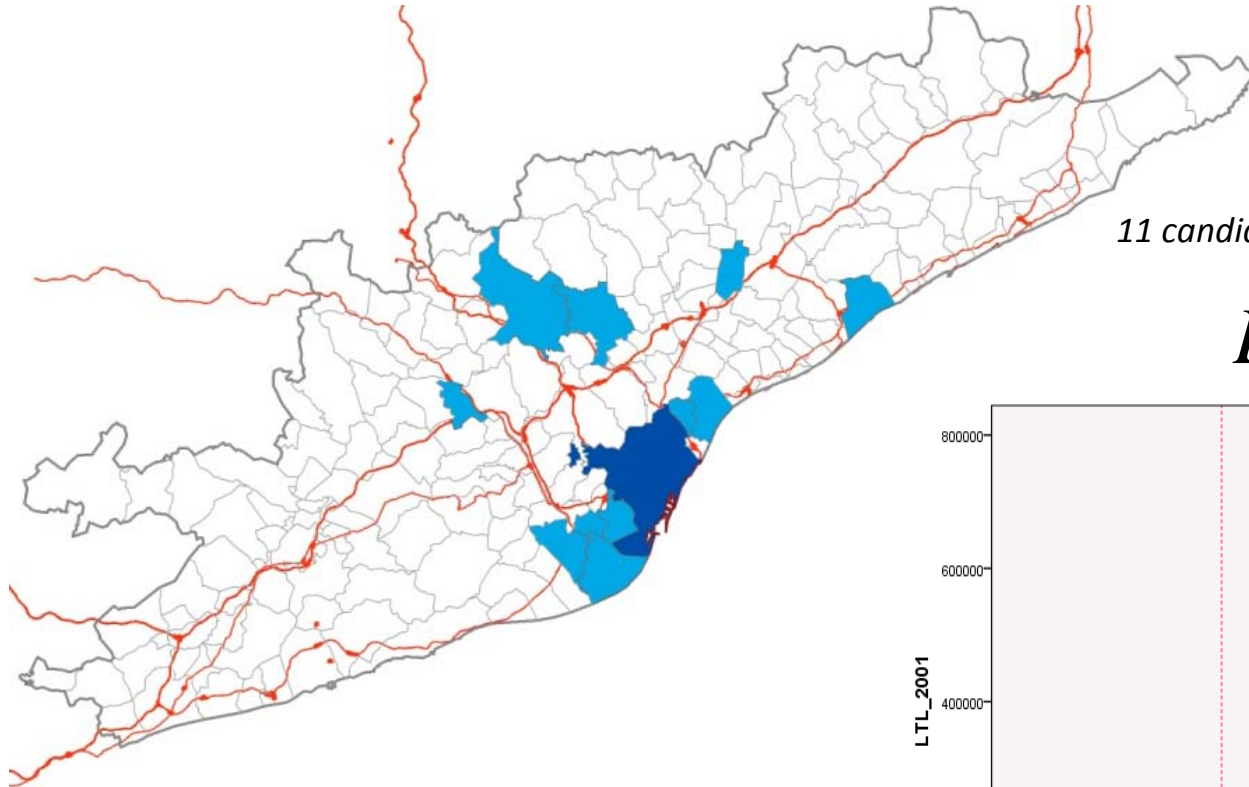
$$\ln D_x = k + BD_{cx}$$

$$LTL \geq 1\% \sum LTL_{BMR}$$

6 candidates to sub-centres + CBD (without taking into account the municipalities with less 1% of the LTL of the metropolitan system)

3 IDENTIFICATION OF SUB-CENTERS

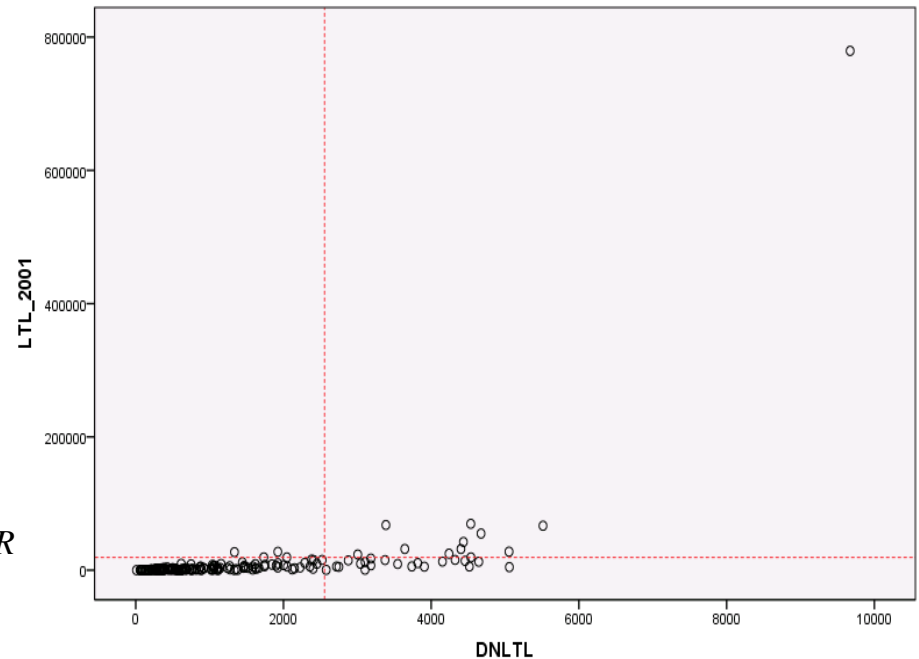
2. Candidates to sub-centre. Using the cutoff approach (GL)



11 candidates to sub-centres + CBD (Barcelona)

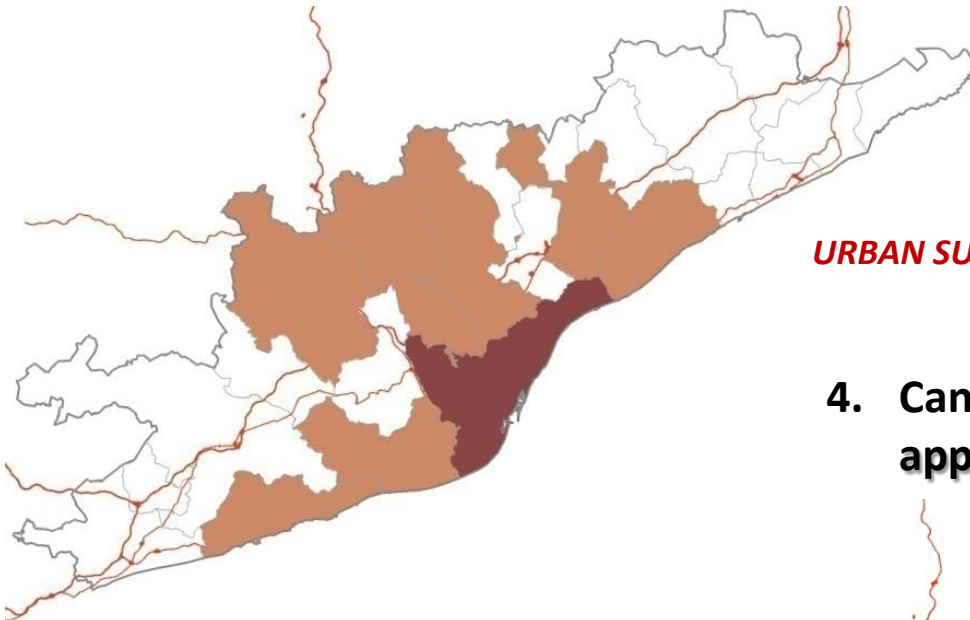
$$D_{ltl} \geq D_{Average_BMR}$$

$$LTL \geq 1\% \sum LTL_{BMR}$$



3 IDENTIFICATION OF SUB-CENTERS

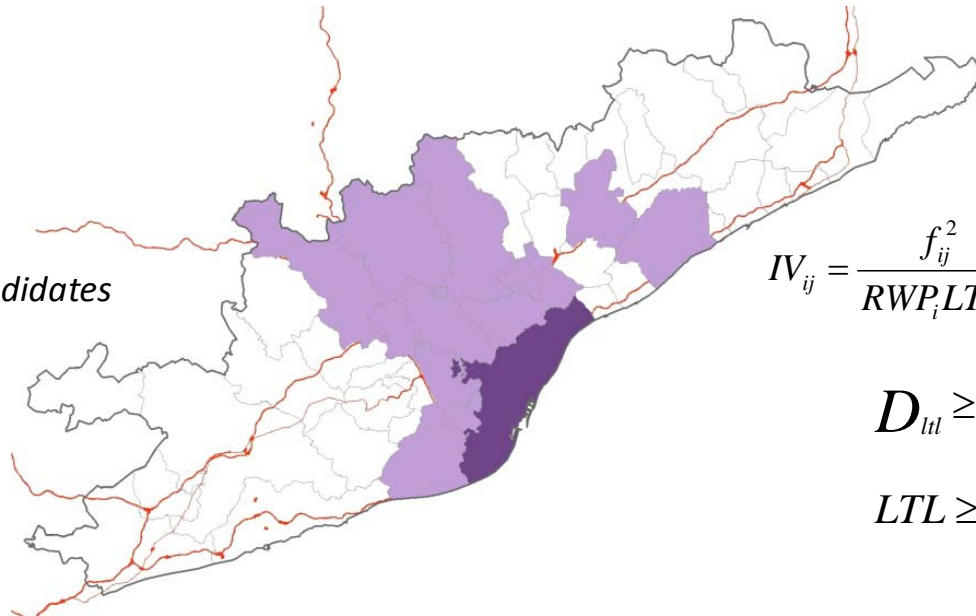
3. Candidates to sub-centre. Using the functional approach (JR)



$$IV_{ij} = \frac{f_{ij}^2}{RWP_i LTL_j} + \frac{f_{ji}^2}{RWP_j LTL_i} \quad LTL \geq 1\% \sum LTL_{BMR}$$

URBAN SUBSYSTEM SCALE: 8 candidates to sub-centres + CBD

4. Candidates to sub-centre. Using the functional approach and density approach (JR + GL)



PROTOSYSTEM SCALE: 13 candidates to sub-centres + CBD

$$IV_{ij} = \frac{f_{ij}^2}{RWP_i LTL_j} + \frac{f_{ji}^2}{RWP_j LTL_i}$$

$$D_{lit} \geq D_{Average_BMR}$$

$$LTL \geq 1\% \sum LTL_{BMR}$$

3 IDENTIFICATION OF SUB-CENTERS

Sub-centre candidates according to different methods to identify sub-centres

Municipality	Parametric method	Cut-off	Mobility (subsystems)	Mobility (protosystem)+ Cut-off
	CL	GL	JR	JR+GL
Badalona	0	1	0	0
Barcelona (CBD)	1	1	1	1
Cerdanyola del Vallès	0	0	0	1
Cornellà de Llobregat	0	1	0	1
Granollers	1	1	1	1
Hospitalet de Llobregat (L')	0	1	0	0
Martorell	1	1	1	1
Mataró	1	1	1	1
Mollet del Vallès	0	0	0	1
Prat de Llobregat (L')	0	1	0	0
Rubí	0	0	1	1
Sabadell	1	1	1	1
Sant Andreu de la Barca	0	0	0	1
Sant Boi de Llobregat	0	1	1	1
Sant Feliu de Llobregat	0	0	0	1
Santa Coloma de Gramanet	0	1	0	0
Santa Perpètua de Mogoda	0	0	0	1
Terrassa	1	1	1	1
Vilanova i la Geltrú	1	0	1	0
Total nuclei	7	12	9	14

Note: without taking into account the subcentre candidates with less 1% LTL

Source: Own Elaboration

Most of municipalities succeed in both methods as candidates to sub-centre like Sabadell, Terrassa, Granollers, Martorell and Mataró. As seen, Barcelona is undoubtedly a polycentric urban system since both methodologies agree in consider most of the candidate to sub-centres.

In the next section (4) these sub-centres are classify into “emerging” and “consolidated” according to its RW & IF Entropy Information

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4 METHODOLOGY TO CLASSIFY SUB-CENTRES INTO “EMERGING” AND “CONSOLIDATED”

If sub-centres are expected to offer a real alternative to the CBD they have to be diverse, not only to increase the probability to retain their working population but also increasing the probability to interact with other sub-centres, its hinterland and being an attractive pole for the whole of the metropolitan area (large-consolidate, sub-centres).

“EMERGING SUB-CENTRE”

Its IF Entropy Information is only above of standard deviation

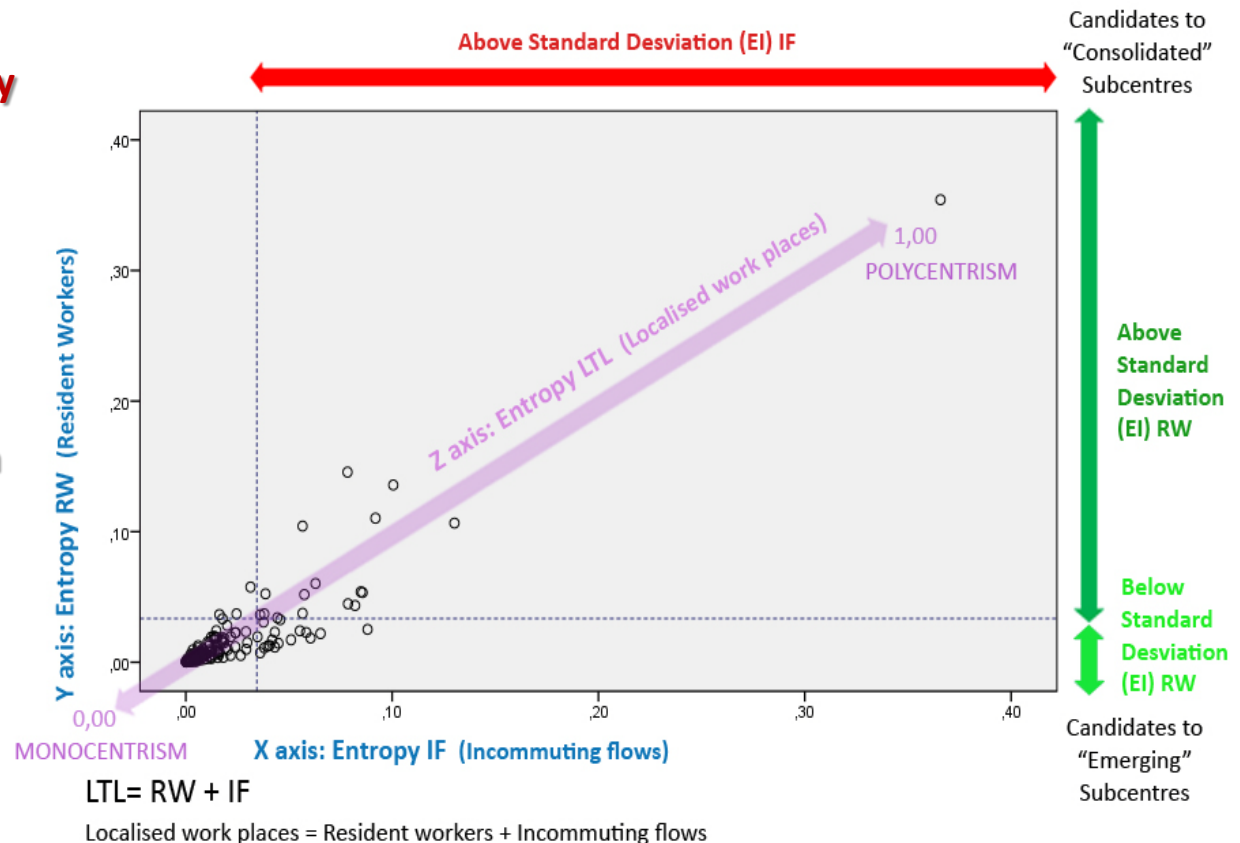
$$EI_{IF} = - \sum_{i=1}^n (IF_i \cdot [\ln (IF_i)])$$

“CONSOLIDATE SUB-CENTRE”

Its IF & RW Entropy Information are above of standard deviation

$$EI_{IF} = - \sum_{i=1}^n (IF_i \cdot [\ln (IF_i)])$$

$$EI_{RW} = - \sum_{i=1}^n (RW_i \cdot [\ln (RW_i)])$$



4 METHODOLOGY TO CLASSIFY SUB-CENTRES INTO “EMERGING” AND “CONSOLIDATED”

Municipalities & candidate to sub-centre which its “RW Entropy information” is above of the standard deviation

Municipality	Entropy Shannon (STD.DEV.=0,0334)	Entropy Shannon (normalized) (STD.DEV=0,00642)	More 1 % LTL of the metropolitan system	Candidate Subcentre CL	Candidate Subcentre GL	Candidate Subcentre JR (subsystem)	Candidate Subcentre JR + GL (protosystem+ cut-off)
Barcelona	0,354185898	0,067988644	1	1	1	1	1
Terrassa	0,145593644	0,027947794	1	1	1	1	1
Sabadell	0,135699284	0,026048497	1	1	1	1	1
Badalona	0,110281276	0,021169319	1	0	1 0*	0**	
Hospitalet de Llobregat (L')	0,106557732	0,020454557	1	0	1 0*	0**	
Mataró	0,104250934	0,02001175	1	1	1	1	1
Rubí	0,060301971	0,011575416	1	0	0	1	1
Vilanova i la Geltrú	0,057567842	0,01105058	1	1	0	1 0**	
Granollers	0,053861284	0,010339078	1	1	1	1	1
Prat de Llobregat (El)	0,053331211	0,010237327	1	0	1 0*	0**	
Santa Coloma de Gramenet	0,052346091	0,010048225	1	0	1 0*	0**	
Sant Boi de Llobregat	0,051842783	0,009951612	1	0	1	1	1
Sant Cugat del Vallès	0,044760889	0,008592189	1	0	0 0*	0**	
Cornellà de Llobregat	0,043426339	0,008336012	1	0	1 0*		1
Cerdanyola del Vallès	0,037451597	0,007189115	1	0	0 0*		1
Viladecans	0,036995302	0,007101526	0	0	0 0*	0**	
Castelldefels	0,036991644	0,007100824	0	0	0 0*	0**	
Blanes	0,036533504	0,007012881	0	1	0	1 0**	
Vilafranca del Penedès	0,036327656	0,006973367	0	1	0	1 0**	
Mollet del Vallès	0,034026643	0,00653167	0	0	0	1	1
Lloret de Mar	0,033287854	0,006389854	0	0	0 0*	0**	
Gavà	0,032566779	0,006251438	0	0	0 0*	0**	
Sant Feliu de Llobregat	0,030714942	0,005895964	0	0	0 0*		1
Vendrell (El)	0,028126911	0,005399172	0	0	0	1 0**	
Martorell	0,025134829	0,004824819	1	1	1	1	1

4 METHODOLOGY TO CLASSIFY SUB-CENTRES INTO “EMERGING” AND “CONSOLIDATED”

Municipalities & candidates to sub-centre which its “IF Entropy information” is above of the standard deviation

Municipality	Entropy Shannon (STD.DEV.=0,0344)	Entropy Shannon (normalized) (STD.DEV.=0,0066)	More 1 % LTL of the metropolitan system	Candidate Subcentre CL	Candidate Subcentre GL	Candidate Subcentre JR (subsystem)	Candidate Subcentre JR + GL (protosystem+ cut-off)
Barcelona	0,36579597	0,070217284	1	1	1	1	1
Hospitalet de Llobregat (L')	0,130198621	0,024992603	1	0	1 0*	0**	
Sabadell	0,100528433	0,019297188	1	1	1	1	1
Badalona	0,091938543	0,017648294	1	0	1 0*	0**	
Martorell	0,088073491	0,016906368	1	1	1	1	1
Prat de Llobregat (El)	0,085675805	0,016446114	1	0	1 0*	0**	
Granollers	0,084839334	0,016285547	1	1	1	1	1
Cornellà de Llobregat	0,082042102	0,015748598	1	0	1 0*		1
Sant Cugat del Vallès	0,07859968	0,015087799	1	0	0 0*	0**	
Terrassa	0,078382208	0,015046054	1	1	1	1	1
Barberà del Vallès	0,065283378	0,012531635	0	0	0 0*	0**	
Rubí	0,062873081	0,01206896	1	0	0	1	1
Santa Perpètua de Mogoda	0,06044362	0,011602607	0	0	0 0*		1
Montcada i Reixac	0,058366497	0,011203888	0	0	0 0*	0**	
Sant Boi de Llobregat	0,057454931	0,011028906	1	0	1	1	1
Cerdanyola del Vallès	0,05660507	0,010865768	1	0	0 0*		1
Mataró	0,056585247	0,010861963	1	1	1	1	1
Esplugues de Llobregat	0,055302884	0,010615804	0	0	0 0*	0**	
Sant Joan Despí	0,050993758	0,009788635	0	0	0 0*	0**	
Gavà	0,045766819	0,008785285	0	0	0 0*	0**	
Parets del Vallès	0,044880182	0,008615088	0	0	0 0*	0**	
Mollet del Vallès	0,044365192	0,008516232	0	0	0	1	1
Sant Just Desvern	0,043158273	0,008284555	0	0	0 0*	0**	
Sant Andreu de la Barca	0,043123244	0,008277831	0	0	0	1	1
Sant Adrià de Besòs	0,0418423	0,008031944	0	0	0 0*	0**	
Castellbisbal	0,040605991	0,007794625	0	0	0 0*	0**	
Palau-solità i Plegamans	0,039767212	0,007633615	0	0	0	1 0**	
Santa Coloma de Gramenet	0,03861382	0,007412213	1	0	1 0*	0**	
Abrera	0,038007726	0,007295869	0	0	0 0*	0**	
Viladecans	0,037980309	0,007290606	0	0	0 0*	0**	
Sant Feliu de Llobregat	0,037692038	0,00723527	0	0	0 0*		1
Polinyà	0,036030722	0,006916368	0	0	0 0*	0**	
Vilafranca del Penedès	0,036012125	0,006912798	0	1	0	1 0**	
Molins de Rei	0,034749644	0,006670455	0	0	0 0*	0**	
Vilanova i la Geltrú	0,031353052	0,006018454	1	1	0	1 0**	

4 METHODOLOGY TO CLASSIFY SUB-CENTRES INTO “EMERGING” AND “CONSOLIDATED”

Candidates to sub-centre at least one identified used method:

Barcelona, CBD

Badalona (1), “Consolidated”

Cerdanyola del Vallès (1), “Consolidated”

Cornellà de Llobregat (2), “Consolidated”

Granollers (4), “Consolidated”

Hospitalet de Llobregat (1), “Consolidated”

Martorell (4), “Emerging”

Mataró (4), “Consolidated”

Mollet del Vallès (1), “Emerging”

Prat de Llobregat (1), “Consolidated”

Rubí (2), “Consolidated”

Sabadell (4), “Consolidated”

Sant Andreu de la Barca (1), “Emerging”

Sant Boi de Llobregat (3), “Consolidated”

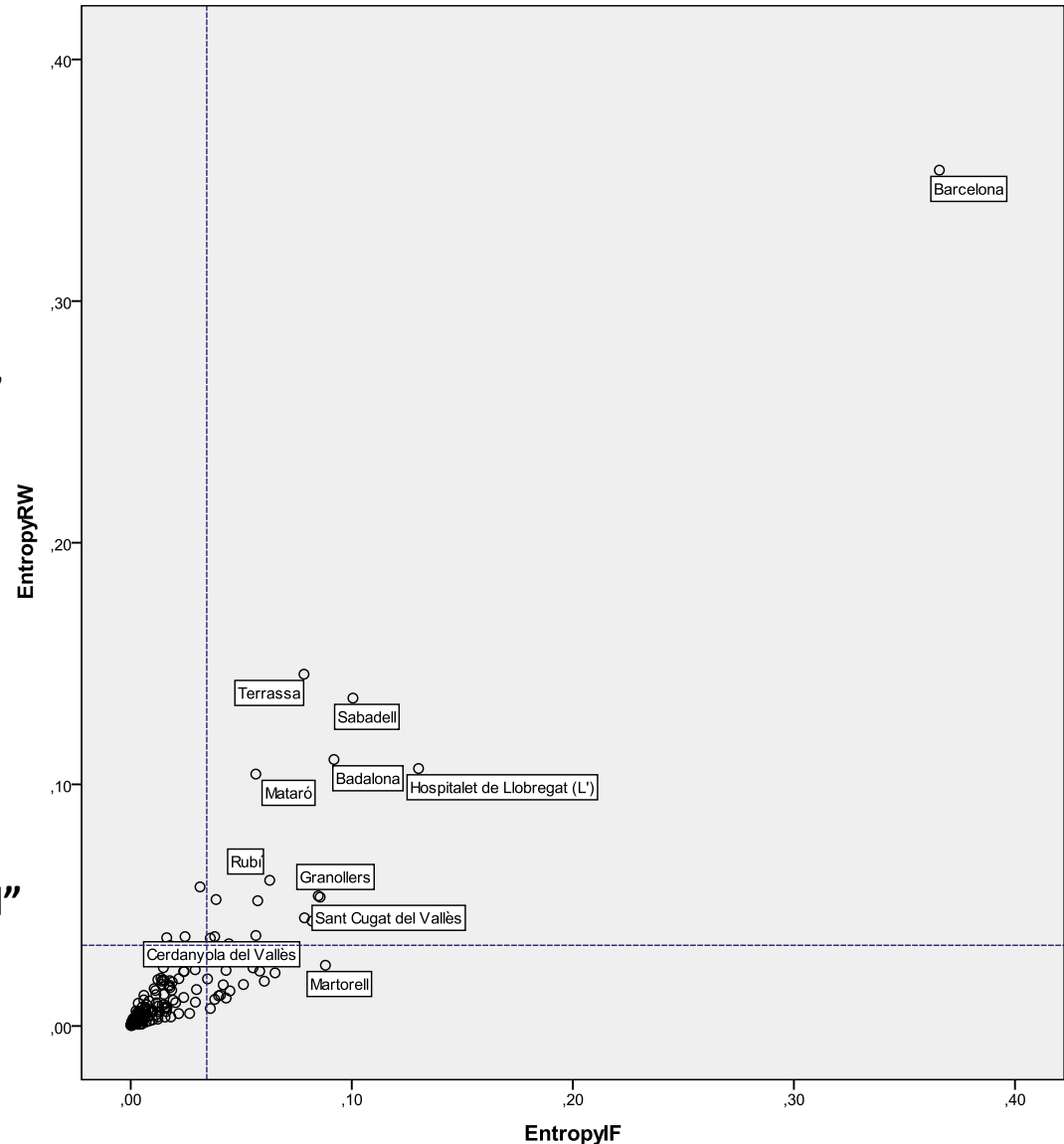
Sant Feliu de Llobregat (1), “Emerging”

Santa Coloma Gramanet (1), “Consolidated”

Santa Perpètua Mogoda (1), “Emerging”

Terrassa (4), “Consolidated”

Vilanova i la Geltrú (2), “Emerging”



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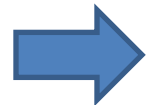
5 SPATIAL INTERACTION MODEL

To know **the prospective workplaces (2001-2024) at protosystem scale** it is used...

A model –centralization and decentralization forces- proposed by **Krugman (1996)** and used as a fully gravitational algorithm in **Roca & Marmolejo (2006)**

$$AT_i = \underbrace{\int_j A \cdot M_i^{k1} \cdot M_j^{k2} / d_{ij}^{r1}}_{\text{Gravitational attractive forces}} - \underbrace{\int_j B \cdot M_i^{k1} \cdot M_j^{k2} / d_{ij}^{r2}}_{\text{Centrifugal or anti-gravity forces}}$$

The attractive potential
of each location:



$$ATP_i = AT_i - ATM$$



$$ATM = \underbrace{\int_j AT_i \cdot M_i \cdot di}_{\text{Average attractive (metropolitan)}}$$

Given a **workplace evolution** (projection of workplaces by GDP) from 2001 to 2024, the **future LTL** for each **location (protosystem)** it is estimated by using:

$$\frac{dM_i}{dt} = G \cdot (AT_i - ATM) / ATM \cdot M_i$$

The results...

5 SPATIAL INTERACTION MODEL

Protosystem	Barcelona Distance	% LTL1991 (model origen) (a)	% LTL 2001	% LTL 2009	% LTL 2014	% LTL 2019	LTL 2024	% LTL 2024 (b)	% LTL 2024-1991 (b-a)
Barcelona (CBD)	0,00	57,34%	50,46%	44,32%	40,47%	36,45%	862572	32,25%	-25,08%
Cornellà de Llobregat	10,50	3,02%	2,96%	2,77%	2,44%	2,11%	46916	1,75%	-1,26%
Sant Feliu de Llobregat	11,52	1,64%	1,82%	2,02%	2,12%	2,22%	62135	2,32%	0,68%
Sant Boi de Llobregat	14,43	3,09%	3,58%	4,08%	4,41%	4,75%	136578	5,11%	2,02%
Rubí	16,54	2,07%	2,90%	3,29%	3,55%	3,82%	109787	4,10%	2,03%
Sant Vicenç dels Horts	16,79	0,52%	0,61%	0,68%	0,73%	0,77%	21980	0,82%	0,30%
Masnou (el)	17,29	0,38%	0,46%	0,51%	0,55%	0,58%	16443	0,61%	0,24%
Cerdanyola del Vallès	18,66	2,26%	2,34%	2,64%	2,83%	3,02%	86218	3,22%	0,96%
Santa Perpètua de Mogoda	18,86	0,79%	1,06%	1,17%	1,22%	1,27%	35450	1,33%	0,53%
Mollet del Vallès	20,67	1,04%	1,14%	1,28%	1,35%	1,42%	40125	1,50%	0,46%
Premià de Mar	21,29	0,76%	0,93%	1,04%	1,10%	1,17%	33044	1,24%	0,47%
Sabadell	22,30	5,79%	5,97%	6,95%	7,76%	8,61%	253771	9,49%	3,70%
Parets del Vallès	22,49	0,91%	1,01%	1,13%	1,20%	1,28%	36341	1,36%	0,45%
Sant Andreu de la Barca	22,79	0,84%	1,14%	1,28%	1,36%	1,44%	40613	1,52%	0,67%
Corbera de Llobregat	23,77	0,07%	0,12%	0,19%	0,20%	0,22%	6175	0,23%	0,16%
Montornès del Vallès	24,74	0,61%	0,65%	0,74%	0,79%	0,84%	23924	0,89%	0,29%
Palau-solità i Plegamans	25,81	0,64%	0,83%	0,94%	1,01%	1,08%	30747	1,15%	0,51%
Martorell	26,75	1,34%	2,58%	2,93%	3,17%	3,43%	98711	3,69%	2,35%
Terrassa	28,01	3,41%	3,93%	4,52%	4,96%	5,42%	157886	5,90%	2,49%
Begues	28,31	0,04%	0,07%	0,07%	0,08%	0,08%	2381	0,09%	0,05%
Mataró	29,91	2,69%	2,76%	3,13%	3,65%	4,08%	105118	3,93%	1,24%
Vallirana	30,00	0,19%	0,24%	0,27%	0,29%	0,31%	8880	0,33%	0,14%
Granollers	30,04	2,16%	2,41%	2,73%	2,94%	3,16%	90545	3,39%	1,23%
Gelida	34,14	0,11%	0,15%	0,17%	0,18%	0,19%	5382	0,20%	0,10%

The table follows until 44 protosystems. The protosystems are ordered by distance from Barcelona (CBD)

Total LTL Barcelona Metropolitan Region	1621451	2014738	2495534	2473496	2542025	2674554
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Candidate Subcentres JR+GL

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6 EVOLUTION OF THE POLYCENTRISM LEVEL (2001-2024) AT PROTOSYSTEM SCALE

URBAN DYNAMIC:

A more polynucleated urban structure of the Barcelona Metropolitan System in 2024: less monocentricity and less urban sprawl

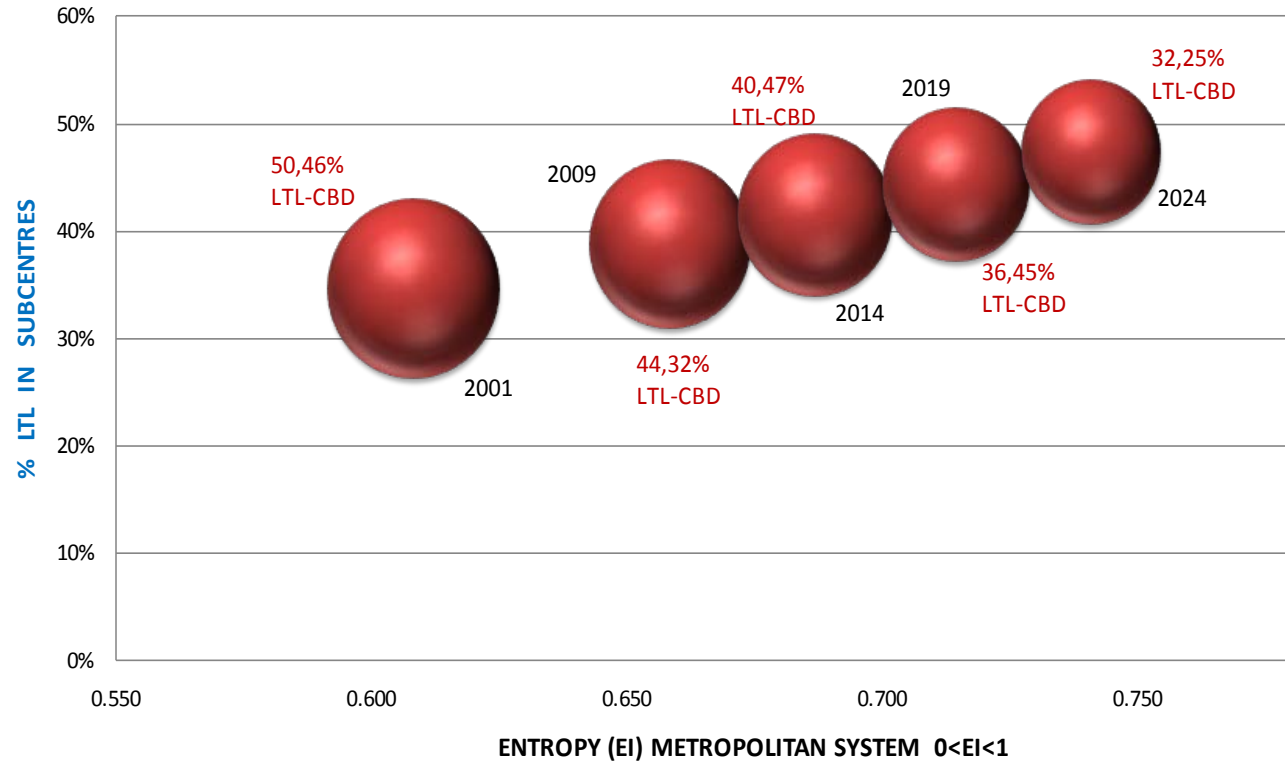
SHANNON FORM

$$EI_{LTL} = - \sum_{i=1}^n (LTL_i \cdot [Ln(LTL_i)])$$

NORMALIZED FORM

$$EI_{LTL} = - \sum_{i=1}^n \frac{(LTL_i) \cdot Ln(LTL_i)}{Ln(n)}$$

Evolution of the Polycentrism Level (2001-2024)



	LTL in subcentres	LTL in CBD	% LTL in subcentres	% LTL in CBD	Entropy (EI) in subcentres	Entropy (EI) in CBD	Entropy (EI) Metropolitan System
2001	696676	1016736	34,58%	50,46%	0,321	0,091	0,608
2009	967912	1106086	38,79%	44,32%	0,348	0,095	0,658
2014	1026194	1001060	41,49%	40,47%	0,363	0,097	0,687
2019	1126318	926603	44,31%	36,45%	0,379	0,097	0,714
2024	1263852	862572	47,25%	32,25%	0,394	0,096	0,741

6 EVOLUTION OF THE POLYCENTRISM LEVEL (2001-2024) AT PROTOSYSTEM SCALE

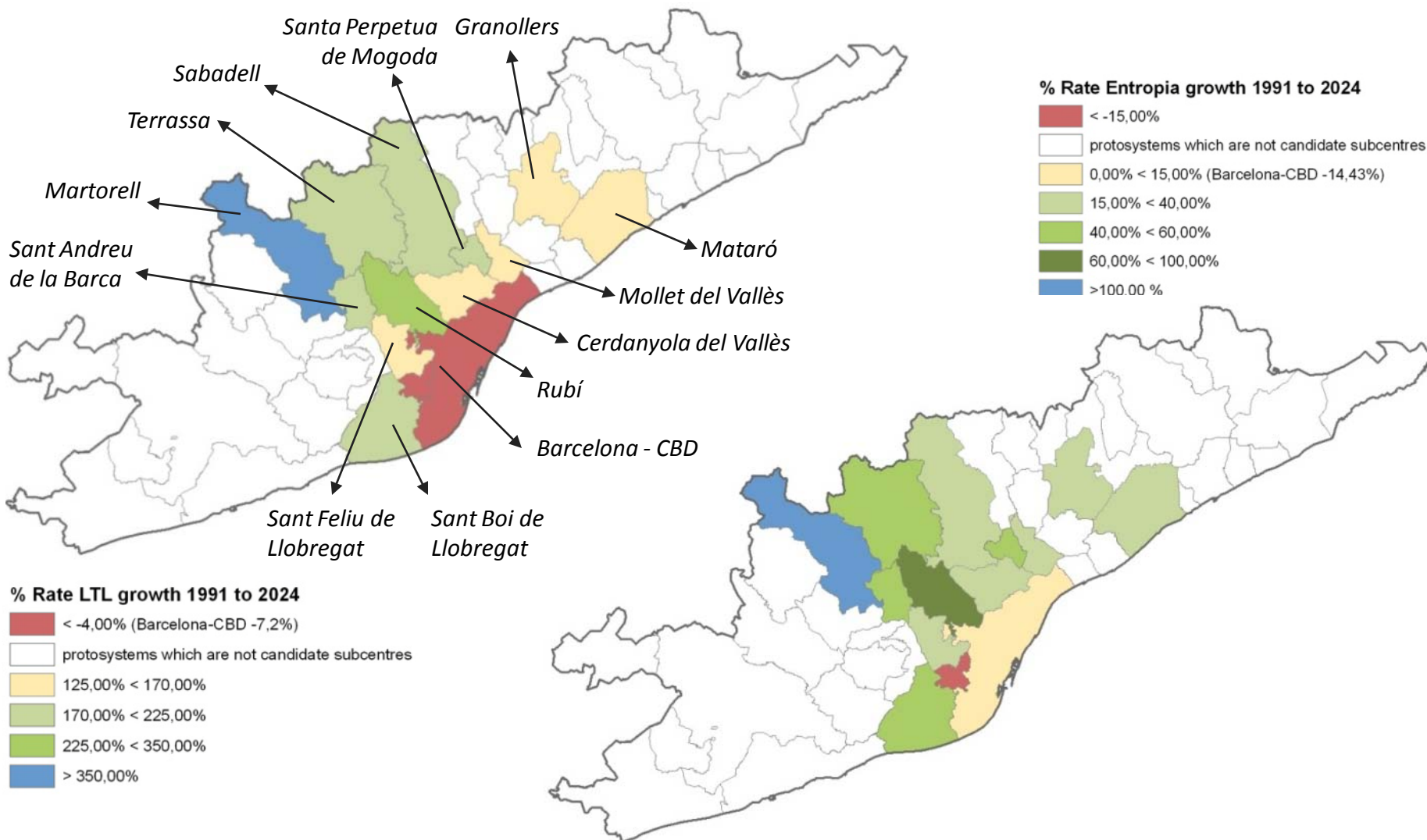
This process towards a **higher polycentricity** in 2024 it will **focus on...**

- 1.- **Martorell** (characterized as an “emerging sub-centre) is the sub-centre which has the higher % Rate LTL Growth and the higher % Rate Growth LTL Entropy
- 2.-**Rubí** which in comparison with **Terrassa** and **Sabadell** (“consolidated” sub-centres) will have increased more its LTL and its LTL Entropy Information by 2024

Protosystem	LTL 1991 (model origen) (a)	LTL 2024 (b)	% Rate LTL Growth 2024-1991 [(b-a)/(a)]	Entropy 1991 (model origen) (c)	Entropy 2024 (d)	% Rate Growth Entopia 2024-1991 [(c-d)/(c)]
Barcelona (CBD)	929672	862572	-7,2%	0,084278937	0,096443160	14,43%
Cornellà de Llobregat	48930	46916	-4,1%	0,027915901	0,018742018	-32,86%
Sant Feliu de Llobregat	26668	62135	133,0%	0,017852670	0,023097045	29,38%
Sant Boi de Llobregat	50117	136578	172,5%	0,028397337	0,040141221	41,36%
Rubí	33566	109787	227,1%	0,021212006	0,034635852	63,28%
Cerdanyola del Vallès	36708	86218	134,9%	0,022662268	0,029258804	29,11%
Santa Perpètua de Mogoda	12856	35450	175,7%	0,010135125	0,015143239	49,41%
Mollet del Vallès	16900	40125	137,4%	0,012569936	0,016649317	32,45%
Sabadell	93859	253771	170,4%	0,043584774	0,059051105	35,49%
Sant Andreu de la Barca	13688	40613	196,7%	0,010651147	0,016803200	57,76%
Martorell	21664	98711	355,6%	0,015236509	0,032178694	111,19%
Terrassa	55366	157886	185,2%	0,030472758	0,044142234	44,86%
Mataró	43558	105118	141,3%	0,025676612	0,033614112	30,91%
Granollers	35028	90545	158,5%	0,021892530	0,030289125	38,35%

6 EVOLUTION OF THE POLYCENTRISM LEVEL (2001-2024) AT PROTOSYSTEM SCALE

The previous results have the following **spatial distribution**:



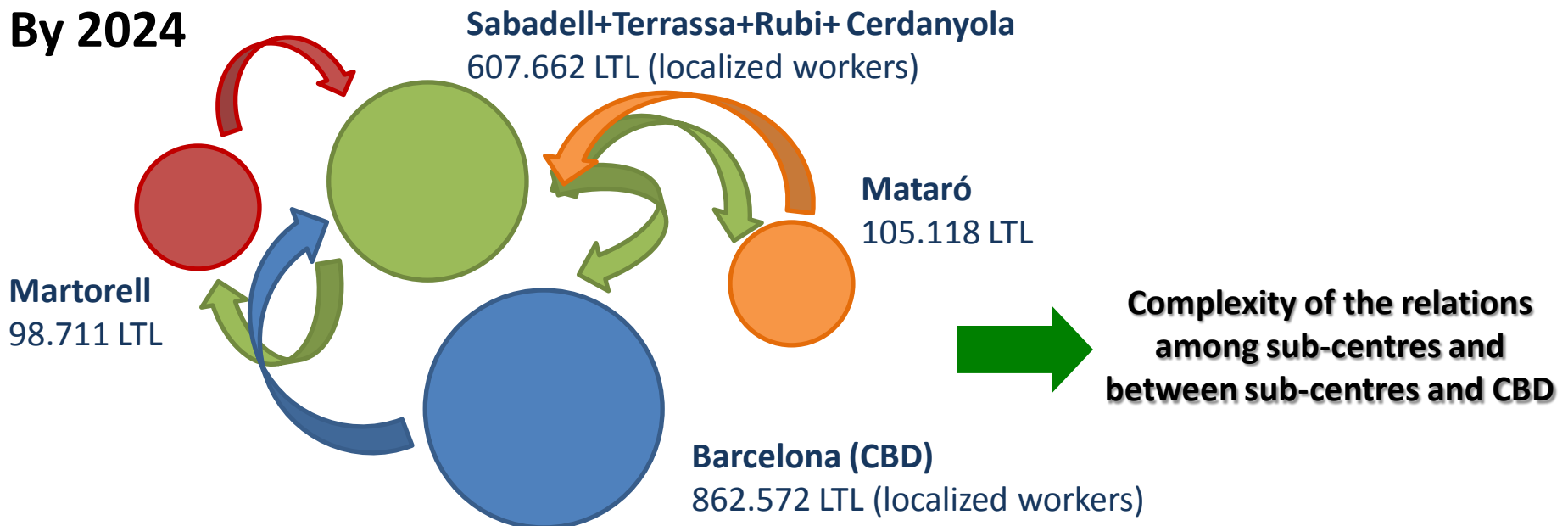
1. Introduction
2. Data & Case of study
3. Identification of urban sub-centres (2001)
4. A methodology to classify sub-centres into “emerging” and “consolidated”
5. Spatial interaction model: Emergence of sub-centres
6. Evolution of polycentrism level (2001-2024)
- 7. Conclusions**

7 CONCLUSIONS

By 2024, Barcelona Metropolitan System will have had a **more polynucleated urban structure**. In such urban dynamic, the sub-centres which will have an important role are:

- 1.-The sub-centres localised in Vallès: Sabadell, Terrassa, Rubí and Cerdanyola (characterized all as “consolidated”) will have together 607.662 LTL what it could lead to a polycentric bipolarity Vallès (607.662LTL) vs. Barcelona-CBD (862.572LTL)
- 2.-Martorell (characterized as “emerging”) with 98.711 LTL
- 3.-Mataró (characterized as “consolidated”) with 105.118 LTL

By 2024



Thank for your patience!

Comments are also welcome at:

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