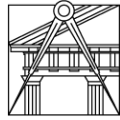




LISBOA

UNIVERSIDADE  
DE LISBOA



**FACULDADE DE ARQUITETURA**  
**LISBON SCHOOL OF ARCHITECTURE**  
UNIVERSIDADE DE LISBOA

**In-Between Spaces**  
**A configurational history of gated enclaves**  
**in the Lisbon Metropolitan Area**

**Vol. II**

Ramo de Doutoramento em Arquitetura  
Especialidade em Teoria e Prática de Projeto

João Bernardo Ponce de Leão Paulouro das Neves

José Nuno Beirão

Victor Mota Ferreira

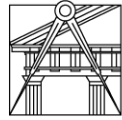
Tese especialmente elaborada para a obtenção do grau de doutor

2024





UNIVERSIDADE  
DE LISBOA



**FACULDADE DE ARQUITETURA**  
**LISBON SCHOOL OF ARCHITECTURE**  
UNIVERSIDADE DE LISBOA

# **In-Between Spaces**

## **A configurational history of gated enclaves in the Lisbon Metropolitan Area**

**Vol. II**

Ramo de Doutoramento em Arquitetura  
Especialidade em Teoria e Prática de Projeto

João Bernardo Ponce de Leão Paulouro das Neves

José Nuno Beirão  
Victor Mota Ferreira

### **Constituição do júri**

#### **Presidente:**

Doutor Paulo Jorge Garcia Pereira  
Professor Associado com Agregação  
Faculdade de Arquitetura da Universidade de Lisboa

#### **Vogais:**

Doctor Jorge Alberto Lopes Gil  
Professor Associado  
Department of Architecture and Civil Engineering of the Chalmers University of Technology

Doutor Francisco Manuel Camarinhas Serdoura  
Professor Associado  
Faculdade de Arquitetura da Universidade de Lisboa

Doutora Cristina Delgado Henriques  
Professora Auxiliar  
Faculdade de Arquitetura da Universidade de Lisboa

Doutor José Nuno Dinis Cabral Beirão  
Professor Auxiliar  
Faculdade de Arquitetura da Universidade de Lisboa, orientador

Doutor Frederico Amado de Moura e Sá  
Professor Auxiliar Convidado  
Departamento de Ciências Sociais, Políticas e do Território da Universidade de Aveiro

Tese especialmente elaborada para a obtenção do grau de doutor  
2024



Esta pesquisa foi parcialmente financiada pela FCT através de bolsa de doutoramento SFRH/BD/118696/2016, e pelo CIAUD através de bolsas de investigação BI\_DCG\_01-UIDB/04008/ 2020 e BI\_StreetAAP/UIDB/04008/2020



# Contents

## Volume I

Acknowledgements	ix
Conventions	xi
Abstract	xiii
Resumo	xv
List of Figures	xxvii
List of Tables	xxxvii
List of Algorithms	xxxix
List of Equations	xli
Acronyms	xliii
1 Introduction	1
1.1 Background . . . . .	2
1.2 The Problem and its Setting . . . . .	4
1.2.1 A Schismogenic Urban Practice . . . . .	5
1.2.2 Statement of the Problem . . . . .	9
1.2.3 Statement of the Subproblems . . . . .	12
1.3 The Hypotheses and Objectives . . . . .	17
1.3.1 Hypothesis . . . . .	17

## Contents

1.3.2	Objectives . . . . .	20
1.4	Relevance of the Study . . . . .	22
1.5	Research Methodology . . . . .	26
1.5.1	Research Design and Outline of the Thesis . . . . .	28
1.5.2	Sources of Evidence and Use of the Data . . . . .	31
1.5.3	Software Stack . . . . .	34
2	State of the Art . . . . .	37
2.1	The Manifold Designations of Self-Segregation . . . . .	37
2.2	An Initial Definition of Self-Segregation . . . . .	39
2.3	A Historical Biography of Gated Enclaves . . . . .	41
2.3.1	The Long History of Intramural Self-Segregation . . . . .	41
2.3.2	Foundations of European Self-Segregation . . . . .	56
2.3.3	The Dawn of Communal Enclosure . . . . .	63
2.3.4	The Zenith of Monasticism in Lisbon . . . . .	73
2.4	The Divided City . . . . .	79
2.5	The Advent of Gated Archipelagos . . . . .	81
2.6	A Characterisation of Gated Enclaves . . . . .	86
2.6.1	The Early Typologies . . . . .	87
2.6.2	The Localised Studies . . . . .	93
2.6.3	The Original Gated Triad . . . . .	96
2.6.4	The Territory of Self-Segregation . . . . .	99
2.6.5	The Operation of Self-Segregation . . . . .	100
2.6.6	The Temporal and Cultural Context of Self-Segregation . . . . .	102
2.7	The European Case . . . . .	104
2.8	The Portuguese Case . . . . .	111
2.9	The Limitations of Existing Research . . . . .	116
2.9.1	Historical-Ontological Priority: The Original Sin . . . . .	116
2.9.2	An Archaic Epistemological Conception of the City . . . . .	124
2.9.3	Innovations in Technology and Instrumentation . . . . .	125
2.9.4	The Development of a Real-Time Model of the City . . . . .	138
3	Data collection: A Survey of Gated Enclaves in the AML . . . . .	157
3.1	Data Collection and Initial Treatment for Fine-Grained Long-Term Analysis of the City . . . . .	157
3.1.1	The Current Data Landscape . . . . .	158
3.1.2	Sources and Initial Treatment of the Data . . . . .	160

3.2	The Late Medieval and Early Modern Period . . . . .	162
3.2.1	Historical Demographic Data . . . . .	162
3.2.2	Collection of Historical Spatial Data . . . . .	178
3.2.3	Treatment of Historical Spatial Data . . . . .	183
3.2.4	The Four Historical Models . . . . .	185
3.3	The Contemporary Period . . . . .	195
3.3.1	Contemporary Demographic Data . . . . .	195
3.3.2	Contemporary Ancillary Data . . . . .	200
3.3.3	Collection of Contemporary Spatial Data . . . . .	204
3.3.4	Treatment of Contemporary Spatial Data . . . . .	209
3.4	Survey Methodology . . . . .	222
3.4.1	Definition of the Object of Study . . . . .	222
3.4.2	A Survey of Medieval Enclaves . . . . .	226
3.4.3	A Survey of Contemporary Enclaves . . . . .	242
4	Methodology: From Modelling a City Without Humans to a Model of Humans Without a City . . . . .	249
4.1	Analytical Workflow . . . . .	249
4.2	Calibration, Validation and Control . . . . .	253
4.3	Longitudinal Urban Morphological Analysis Applied to an Architectural Typology . . . . .	256
4.3.1	Classic Urban Morphology . . . . .	257
4.3.2	The Development of Urban Research in Portugal . . . . .	260
4.3.3	The Limitations of Classic Urban Studies . . . . .	270
4.3.4	Complex Morphological Studies . . . . .	277
4.3.5	The Space Before the City . . . . .	283
4.3.6	The Configurational Void . . . . .	299
4.4	A Model for Informed Urban Network Analysis . . . . .	302
4.4.1	Model Execution . . . . .	304
4.4.2	Measures of Separation . . . . .	396
5	Results: The Re-emergence of Gated Enclaves in Lisbon and their Configuration . . . . .	403
5.1	Overview of the Collected Data and its Quantification . . . . .	403
5.2	The Main Classes of Gated Enclaves . . . . .	405
5.2.1	The Medieval Classes . . . . .	405
5.2.2	The Contemporary Classes . . . . .	417
5.3	Aggregate Evaluation of Gated Enclaves . . . . .	433
5.3.1	The Rise and Fall of Medieval Enclaves . . . . .	433

## *Contents*

5.3.2	Temporal Progression . . . . .	441
5.3.3	Geographic Distribution . . . . .	443
5.3.4	Typological Progression and Distribution . . . . .	448
5.3.5	Demographic Extrapolations of the Enclaves . . . . .	453
5.4	The Partitioned Occupation of Organic Space . . . . .	456
5.4.1	Late Modern Enclave Morphology . . . . .	456
5.4.2	Contemporary Enclave Morphology . . . . .	476
5.4.3	Configurational Observations . . . . .	491
6	Conclusion . . . . .	589
6.1	Synergetic Self-Segregation in the City: A Summary of the Findings . . . . .	590
6.2	The Re-Emergence of a Gated Typology . . . . .	597
6.3	Concluding Statements . . . . .	603
6.4	Recommendations and Further Research . . . . .	610
6.5	Contributions . . . . .	620
6.5.1	Atlas of Gated Enclaves in the AML . . . . .	624
6.5.2	Inventory of Gated Enclaves in the AML (1801) . . . . .	626
6.5.3	Inventory of Gated Enclaves in the AML (2016) . . . . .	629
	References . . . . .	637
	Cartography & Iconography . . . . .	713

## **Volume II**

### Appendices

A	Digital Supplements . . . . .	ii-5
B	The GNA Project: A VGI Platform for Urban Networks . . . . .	ii-7
C	Spatial Data Collection and Validation . . . . .	ii-13
D	Network Validation and Feature Selection . . . . .	ii-19
E	Spatial Analysis of the Late Medieval and Early Modern Models . . . . .	ii-33
F	Spatial Analysis of the Contemporary Model . . . . .	ii-41

G Macro Distribution of Contemporary Gated Enclaves	ii-47
H Macro Network Analysis of Gated Enclaves	ii-69
I Statistical Analysis	ii-79
J Morphological Analysis	ii-93
K Configurational Analysis	ii-109
L Hierarchical Classification	ii-149
M Atlas of Gated Enclaves (1801 and 2016)	iii-1

**Volume III**

N Inventory of Gated Enclaves in the AML, 1801	iv-1
--	------

**Volume IV**

O Inventory of Gated Enclaves in the AML, 2016	iv-57
Index of Gated Enclaves (by code)	ii-331
Index of Gated Enclaves (by name)	ii-346



# List of Figures

1.1	Organisational chart of the research project. . . . .	11
1.2	Statement of the problem and subproblems. . . . .	16
1.3	Publications on gated enclaves . . . . .	25
1.4	Organisation of the research design . . . . .	29
2.1	Chang'an, China . . . . .	46
2.2	Bentham's Panopticon . . . . .	52
2.3	New Harmony, Whitwell . . . . .	57
2.4	Mount Grace Carthusian monastery . . . . .	58
2.5	Monastery of Saint Catherine . . . . .	59
2.6	Saint Daniel the Stylite . . . . .	60
2.7	Thebaid, Fra Angelico . . . . .	65
2.8	Morphological dendrogram of contemporary enclaves . .	71
2.9	Saint Cuthbert and Le Corbusier . . . . .	73
2.10	<i>Olissippo quae nunc Lisboa</i> , Braun, 1598 . . . . .	75
2.11	Gated enclaves in the United States . . . . .	86
3.1	Bicentennial population estimates (AD 700–2000) . . . .	173
3.2	ATLAS platform disparities . . . . .	177
3.3	Geo-reference GCP analysis of Folque's 1858 survey. . . .	187
3.4	XIX century model cartography assembly . . . . .	190
3.5	High-level architecture of the web scraper . . . . .	202
3.6	Active business counts per municipality . . . . .	204
3.7	Quality assessment of Montijo cartography . . . . .	213
3.8	Feature and CGA map assessment . . . . .	214
3.9	Partitioning techniques for quality assessment . . . . .	217
3.10	Feature counts and CGA area in Montijo maps . . . . .	219
3.11	CGA correlations using BGRI tracts . . . . .	220

## List of Figures

3.12	Vectorisation of Seixal cartography . . . . .	221
3.13	Vectorisation of Vila Franca de Xira cartography . . . . .	222
3.14	AML municipalities . . . . .	244
3.15	AML survey grid . . . . .	245
3.16	Cascais survey grid . . . . .	246
4.1	Organisation of the methodology design . . . . .	250
4.2	Disaggregated population and control correlation . . . . .	331
4.3	Cascais dasymetric disaggregation . . . . .	333
4.4	Building count Pearson's population correlation coefficient . . . . .	340
4.5	Building count $R^2$ values . . . . .	341
4.6	AML building count disaggregation estimate test . . . . .	342
4.7	Integrating resident population in network analysis . . . . .	349
4.8	Pearson correlation for pedestrian counts . . . . .	357
4.9	Polynomial regression of vehicle network attributes . . . . .	360
4.10	Vehicle counts model linear dimensionality reduction . . . . .	361
4.11	Spatial buffer and isochrone techniques . . . . .	367
4.12	Multi-spatial demographic metrics . . . . .	387
5.1	Wall of the Convento do S. Jesus da Boa Morte . . . . .	407
5.2	Walls of the <i>Convento da Estrela</i> . . . . .	412
5.3	Distribution of medieval enclave type walled areas . . . . .	417
5.4	Aerial view of enclave in São Francisco . . . . .	418
5.5	Aerial view of <i>Jardins de Bicesse</i> . . . . .	419
5.6	Gated enclave in São Francisco . . . . .	420
5.7	Gated enclave in Estoril e Cascais . . . . .	421
5.8	Monsanto's Palms, Benfica . . . . .	423
5.9	Belém Gardens exterior . . . . .	424
5.10	Belém Gardens entrance . . . . .	425
5.11	<i>Quinta Patino</i> entrance and perimeter . . . . .	426
5.12	<i>Residências Sénior Carnaxide</i> , Oeiras . . . . .	429
5.13	Quinta da Beloura I, Sintra. Warning. . . . .	431
5.14	Quinta da Beloura I, Sintra. Interior. . . . .	432
5.15	AML enclave occupation by bicentenary . . . . .	435
5.16	Lisbon enclaves, XII-XVII . . . . .	437
5.17	Lisbon enclaves in 1801 . . . . .	440
5.18	Evolution of gated enclaves . . . . .	444
5.19	Gated enclaves by year and municipality . . . . .	445
5.20	Choropleth map of enclave municipality counts, 2016 . . . . .	446

5.21	Choropleth map of enclave to municipal area, 2016 . . . .	447
5.22	Choropleth map of enclave population ratio, 2016 . . . .	449
5.23	Choropleth map of average isolation scores, 2016 . . . .	450
5.24	Development of enclaves by year and type . . . . .	450
5.25	Isolation score counts per gated enclave type . . . . .	451
5.26	Choropleth map of C4 type enclave counts . . . . .	452
5.27	Household measurements of enclave population (i) . . . .	455
5.28	Educational and age attributes of gated enclaves . . . .	455
5.29	Morphological dendrogram of medieval enclaves . . . . .	466
5.30	3D plot of medieval morphological classification . . . . .	467
5.31	Medieval enclave class alluvial flow chart . . . . .	469
5.32	Medieval enclaves morphological correlations . . . . .	472
5.33	Morphological dendrogram of contemporary enclaves . . .	482
5.34	3D plot of contemporary morphological classification . . .	484
5.35	Contemporary enclave class alluvial flow chart . . . . .	486
5.36	Contemporary morphological correlation . . . . .	487
5.37	Contemporary qualitative metrics charts . . . . .	492
5.38	Street segment population distributions (1801, 2016) . . .	501
5.39	NACH AML residential distributions . . . . .	503
5.40	NACH AML enclave distributions . . . . .	505
5.41	Occupation dendrogram of contemporary enclaves . . . .	508
5.42	Hierarchical clusters and qualitative classes . . . . .	513
5.43	3D plot of contemporary occupation clusters . . . . .	514
5.44	Manifold dendrogram of contemporary enclaves . . . . .	515
5.45	Aerial photo of gated enclave in Almada . . . . .	518
5.46	Isochronic map of 1801 AML enclaves . . . . .	519
5.47	Isochronic map of 1801 AML enclaves . . . . .	522
5.48	Isochronic map of 1801 AML enclave walls . . . . .	524
5.49	Isochronic map of 1801 Setúbal enclaves . . . . .	529
5.50	Population count distribution for medieval enclaves . . . .	534
5.51	Vehicular and pedestrian networks AML star chart . . . .	542
5.52	Pedestrian star chart of municipalities ( $r=2400$ ) . . . .	546
5.53	Contemporary enclave wall isochrones . . . . .	547
5.54	Syntactic map of the AML with enclave clusters . . . . .	553
5.55	Population dot map and enclave clusters . . . . .	554
5.56	Enclave map of Cascais e Estoril . . . . .	558
5.57	Enclave map of Lumiar, Lisboa . . . . .	559
5.58	Enclave map of Parque das Nações, Lisboa . . . . .	560
5.59	Enclave map of Quinta do Conde, Sesimbra . . . . .	562

*List of Figures*

5.60	Enclave map of Queluz e Belas, Sintra . . . . .	563
5.61	Syntax integration in the AML vehicular network . . . . .	564
5.62	Enclave NAIN, NASS, NASC, and NASP, by class . . . . .	565
5.63	NAIN ( $r=n$ ) KDE of enclaves to AML housing . . . . .	566
5.64	Syntax choice in the AML vehicular network . . . . .	568
5.65	NACH probability distribution of enclave access (i) . . . . .	569
5.66	Enclave walls and street segment 60 m intersection . . . . .	570
5.67	NACH probability distribution of enclave walls (i) . . . . .	574
5.68	NACH_il probability distribution of enclave access (iii) . . . . .	576
5.69	NACH probability distribution of enclave access (ii) . . . . .	578
6.1	Atlas page of Carcavelos e Parede 2016 model . . . . .	627
6.2	Inventory page of M002, M012, and M075 . . . . .	630
6.3	Inventory page of E70, E71, and E687 . . . . .	634
B.1	GNA Platform full stack diagram . . . . .	ii-9
B.2	GNA Project administration interface . . . . .	ii-10
B.3	GNA Project unit interface . . . . .	ii-11
C.1	CGA correlations using BGRI tracts . . . . .	ii-14
C.2	CGA correlation at 1 km hexagonal grid . . . . .	ii-14
C.3	CGA correlation at 500 m hexagonal grid . . . . .	ii-15
C.4	CGA correlation at 250 m hexagonal grid . . . . .	ii-15
C.5	Total count and area of gated enclaves in the AML . . . . .	ii-16
C.6	Total count and area of gated enclaves in the AML . . . . .	ii-17
C.7	Twenty-four hour Uber movement box plot . . . . .	ii-18
D.1	Pedestrian model PCA dimensionality reduction . . . . .	ii-20
D.2	Feature importance for pedestrian counts (RFR) . . . . .	ii-21
D.3	Pedestrian model Pearson's feature correlation . . . . .	ii-22
D.4	Pedestrian model MIC regression feature correlation . . . . .	ii-23
D.5	Pedestrian model MIC feature correlation . . . . .	ii-24
D.6	Pearson correlation coefficient for pedestrian counts . . . . .	ii-24
D.7	Top 10 features for pedestrian model (F-Regression) . . . . .	ii-25
D.8	Top 10 features for pedestrian model (MIC) . . . . .	ii-25
D.9	Vehicle model PCA dimensionality reduction . . . . .	ii-26
D.10	Feature importance for vehicle counts (RFR) . . . . .	ii-27
D.11	Vehicle model Pearson's feature correlation . . . . .	ii-28
D.12	Vehicle model MIC regression feature correlation . . . . .	ii-29

D.13	Vehicle model MIC feature correlation . . . . .	ii-30
D.14	Pearson correlation coefficient for vehicle counts . . . . .	ii-30
D.15	Top 10 features for vehicle model (F-Regression) . . . . .	ii-31
D.16	Top 10 features for vehicle model (MIC) . . . . .	ii-31
E.1	1718, 1758 Lisbon cartography geo-reference analysis . . . . .	ii-34
E.2	Pre-earthquake Lisbon geo-reference analysis . . . . .	ii-34
E.3	1761 Lisbon geo-reference analysis . . . . .	ii-35
E.4	1856-1858 Lisbon geo-reference analysis . . . . .	ii-35
E.5	1856-158 Lisbon atlas geo-reference analysis . . . . .	ii-36
E.6	DDA analysis of historical maps . . . . .	ii-37
E.7	Integrating of demographic attributes in 1801 model . . . . .	ii-38
E.8	Late XVI and early XVII century city gates network . . . . .	ii-39
F.1	Enclaves (2016), 5-20 min. pedestrian isochrones . . . . .	ii-42
F.2	Enclaves (2016), 5 min. pedestrian isochrones . . . . .	ii-43
F.3	Enclaves (2016), population and integration . . . . .	ii-44
F.4	Detail of Cascais and Sintra (2016) analysis . . . . .	ii-45
G.1	Choropleth map of gated enclave area, 1991 . . . . .	ii-48
G.2	Choropleth map of gated enclave area, 2001 . . . . .	ii-48
G.3	Choropleth map of gated enclave area, 2011 . . . . .	ii-49
G.4	Choropleth map of gated enclave surface areas, 2016 . . . . .	ii-49
G.5	Choropleth map of mean gated enclave areas, 1991 . . . . .	ii-50
G.6	Choropleth map of mean gated enclave areas, 2001 . . . . .	ii-50
G.7	Choropleth map of mean gated enclave areas, 2011 . . . . .	ii-51
G.8	Choropleth map of mean gated enclave areas, 2016 . . . . .	ii-51
G.9	Choropleth map of enclave occupation ratio, 1991 . . . . .	ii-52
G.10	Choropleth map of enclave occupation ratio, 2001 . . . . .	ii-52
G.11	Choropleth map of enclave occupation ratio, 2011 . . . . .	ii-53
G.12	Choropleth map of enclave to municipal area, 2016 . . . . .	ii-53
G.13	Choropleth map of enclave municipality counts, 1991 . . . . .	ii-54
G.14	Choropleth map of enclave municipality counts, 2001 . . . . .	ii-54
G.15	Choropleth map of enclave municipality counts, 2011 . . . . .	ii-55
G.16	Choropleth map of enclave municipality counts, 2016 . . . . .	ii-55
G.17	Choropleth map of total enclave population, 1991 . . . . .	ii-56
G.18	Choropleth map of total enclave population, 2001 . . . . .	ii-56
G.19	Choropleth map of total enclave population, 2011 . . . . .	ii-57
G.20	Choropleth map of total enclave population, 2016 . . . . .	ii-57

*List of Figures*

G.21	Choropleth map of enclave population ratio, 1991 . . . . .	ii-58
G.22	Choropleth map of enclave population ratio, 2001 . . . . .	ii-58
G.23	Choropleth map of enclave population ratio, 2011 . . . . .	ii-59
G.24	Choropleth map of enclave population ratio, 2016 . . . . .	ii-59
G.25	Choropleth map of average isolation scores, 1991 . . . . .	ii-60
G.26	Choropleth map of average isolation scores, 2001 . . . . .	ii-60
G.27	Choropleth map of average isolation scores, 2011 . . . . .	ii-61
G.28	Choropleth map of average isolation scores, 2016 . . . . .	ii-61
G.29	Choropleth map of C2 enclave counts, 1991 . . . . .	ii-62
G.30	Choropleth map of C2 enclave counts, 2001 . . . . .	ii-62
G.31	Choropleth map of C2 enclave counts, 2011 . . . . .	ii-63
G.32	Choropleth map of C2 type enclave counts . . . . .	ii-63
G.33	Choropleth map of C3 enclave counts, 1991 . . . . .	ii-64
G.34	Choropleth map of C3 enclave counts, 2001 . . . . .	ii-64
G.35	Choropleth map of C3 enclave counts, 2011 . . . . .	ii-65
G.36	Choropleth map of C3 type enclave counts . . . . .	ii-65
G.37	Choropleth map of C4 enclave counts, 1991 . . . . .	ii-66
G.38	Choropleth map of C4 enclave counts, 2001 . . . . .	ii-66
G.39	Choropleth map of C4 enclave counts, 2011 . . . . .	ii-67
G.40	Choropleth map of C4 type enclave counts . . . . .	ii-67
H.1	Isochronic map of enclaves in XVI century Lisbon . . . . .	ii-70
H.2	Isochronic map of enclaves in XVII century Lisbon . . . . .	ii-70
H.3	Isochronic map of enclaves in XVIII century Lisbon . . . . .	ii-71
H.4	Isochronic map of enclaves in XIX century Lisbon . . . . .	ii-71
H.5	Contemporary SC map with enclave clusters . . . . .	ii-72
H.6	Contemporary SS map with enclave clusters . . . . .	ii-72
H.7	Syntax choice skeleton (AML vehicular network) . . . . .	ii-73
H.8	Main syntax patterns in the late modern AML . . . . .	ii-74
H.9	Main syntax patterns in the AML . . . . .	ii-75
H.10	Public transport stops and gated enclaves . . . . .	ii-76
H.11	Public transport routes and isochrones . . . . .	ii-77
I.1	Distribution of monasteries in Portugal by year . . . . .	ii-80
I.2	Monasteries by foundation year . . . . .	ii-81
I.3	Housing area of contemp. enclaves by municipality . . . . .	ii-82
I.4	Housing area of contemp. enclaves by parish . . . . .	ii-82
I.5	Housing area of contemp. enclaves (disaggregated) . . . . .	ii-83
I.6	Enclave housing and total area, by parish . . . . .	ii-83

I.7	Enclave housing (log) and total area, by parish . . . . .	ii-84
I.8	Housing (log) and total area of contemp. enclaves . . . . .	ii-84
I.9	Commercial establishments and gated enclaves . . . . .	ii-85
I.10	Mean parish and gated enclave NAIN values . . . . .	ii-85
I.11	Distribution of orders in Portugal by foundation year . . . . .	ii-86
I.12	Isolation scores of gated enclave types . . . . .	ii-87
I.13	Gated enclaves by type and isolation . . . . .	ii-87
I.14	Communities by year and type . . . . .	ii-88
I.15	Community evolution by year and type . . . . .	ii-88
I.16	Enclave footprints by year and type . . . . .	ii-89
I.17	Isolation scores by year KDE plot . . . . .	ii-89
I.18	Population attributes AML vs enclaves 2011 . . . . .	ii-90
I.19	Population attributes AML vs enclaves 2016 . . . . .	ii-90
I.20	Household measurements of enclave population (ii) . . . . .	ii-91
I.21	Enclave population education and age . . . . .	ii-91
I.22	Employment measurements of enclave population (ii) . . . . .	ii-92
I.23	Employment measurements of enclave population (i) . . . . .	ii-92
J.1	Layered KDE of morphological measures (1801) . . . . .	ii-94
J.2	Comparative KDE of XXI morphological measures . . . . .	ii-95
J.3	Layered KDE of nPI by XIX enclave type . . . . .	ii-96
J.4	nPI KDE enclave plots (XXI AML) . . . . .	ii-97
J.5	Enclave and 1801 Lisbon morphological measures . . . . .	ii-98
J.6	Probability morphological histogram (XXI AML) . . . . .	ii-99
J.7	Probability morphological histogram (XXI Lisbon) . . . . .	ii-100
J.8	Comparative boxplots of XIX morphological measures . . . . .	ii-101
J.9	nDI, ERI KDE joint plot by type (1801) . . . . .	ii-102
J.10	nPI, ERI KDE joint plot by type (XXI AML) . . . . .	ii-103
J.11	nDI, ERI of four medieval enclave classes . . . . .	ii-104
J.12	nPI and ERI of four medieval enclave classes . . . . .	ii-105
J.13	nPI, ERI by XXI enclave class . . . . .	ii-106
J.14	nDI, ERI plots by XXI enclave class . . . . .	ii-107
K.1	NAIN count distribution for medieval enclaves . . . . .	ii-110
K.2	Count distribution (nain-pop) for medieval enclaves . . . . .	ii-110
K.3	Count distribution (population) for medieval enclaves . . . . .	ii-110
K.4	NACH probability distribution of enclave walls (ii) . . . . .	ii-111
K.5	NACH probability distribution of enclave access (ii) . . . . .	ii-111
K.6	Probability distribution of walls (Pop, Cmc, Svc) . . . . .	ii-111

*List of Figures*

K.7	NACH, NAIN probability at 15 minutes (1801)	ii-112
K.8	NACH, NAIN probability at 15 minutes (2016)	ii-113
K.9	SP, SP_100 m probability at 15 minutes (1801)	ii-114
K.10	SP, SP_100 m probability at 15 minutes (2016)	ii-115
K.11	NAIN (r=800) KDE of enclaves to AML housing	ii-116
K.12	Aggregate CSW, CSA network values of XXI enclaves	ii-117
K.13	Incomplete urbanisation (vehicular network)	ii-118
K.14	Incomplete urbanisation (pedestrian network)	ii-119
K.15	Pedestrian star charts of the XXI AML model	ii-120
K.16	Vehicular star charts of the XXI AML model	ii-120
K.17	Vehicular star charts of the XXI Lisbon model	ii-121
K.18	Pedestrian star charts of XXI Lisbon model	ii-121
K.19	Pedestrian star chart of municipalities (r=n)	ii-122
K.20	Vehicular star chart of municipalities at global radius	ii-122
K.21	Pedestrian star chart of municipalities (r=2400)	ii-123
K.22	Vehicular star chart of municipalities at medium radius	ii-123
K.23	NAIN 2016 enclave walls comparison	ii-124
K.24	NACH 2016 enclave walls comparison	ii-124
K.25	NAIN 2016 enclave access comparison	ii-124
K.26	GE v. AML panels of pop, cmc and svc (gates)	ii-125
K.27	GE v. AML panels of pop, cmc and svc (gates)	ii-126
K.28	GE v. AML panels of pop, cmc and svc (gates)	ii-127
K.29	GE v. AML panels of pop, cmc and svc (gates)	ii-128
K.30	p16 v. pexo16 panels of NACH_il (gates)	ii-129
K.31	p16 v. pexo16 panels of NACH (gates)	ii-130
K.32	v16 v. vexo16 panels of NACH_il (gates)	ii-131
K.33	p16 v. pexo16 panels of NACH_il (walls)	ii-132
K.34	v16 v. vexo16 panels of NACH_il (walls)	ii-133
K.35	Enclave walls v. remaining residential stock (CS)	ii-134
K.37	Enclave walls v. remaining residential stock (60m)	ii-136
K.39	Enclave walls v. remaining residential stock (1200m)	ii-138
K.41	Preliminary taxonomy of confinement structures	ii-141
K.42	Configuration of interior confinement typologies	ii-145
L.1	Morphological dendrogram of gated enclaves (1801)	ii-150
L.2	Spatial dendrogram of gated enclaves (1801)	ii-150
L.3	Occupational dendrogram of gated enclaves (pexo16)	ii-151
L.4	Occupational dendrogram of gated enclaves (vexo16)	ii-151
L.5	Network dendrogram of gated enclaves (pexo16)	ii-152

L.6 Network dendrogram of gated enclaves (vexo16) . . . . . ii-152  
L.7 Distance network dendrogram of enclaves, pexo16 . . . . . ii-153  
L.8 Distance network dendrogram of enclaves, vexo16 . . . . . ii-153  
L.9 Score dendrogram of gated enclaves (pexo16) . . . . . ii-154  
L.10 Score dendrogram of gated enclaves (vexo16) . . . . . ii-154  
L.11 Combined dendrogram of gated enclaves (pexo16) . . . . . ii-155  
L.12 Combined dendrogram of gated enclaves (vexo16) . . . . . ii-155  
L.13 comb 1200m clusters v. classes . . . . . ii-156  
L.14 net 1200m clusters v. classes . . . . . ii-157  
L.15 net-dist 1200m clusters v. classes . . . . . ii-158  
L.16 comb 1200m clusters v. classes . . . . . ii-159  
L.17 score 1200m clusters v. classes . . . . . ii-160



# List of Tables

1.1	Data sources for historical analysis . . . . .	32
1.2	Data sources for contemporary analysis . . . . .	33
1.3	Research software stack . . . . .	35
3.1	XVII–XIX century GIS models . . . . .	191
3.2	Geo-referenced cartography . . . . .	196
3.3	Business listing sources . . . . .	204
3.4	Definition of LPP values . . . . .	209
3.5	AML Cartographic Sources . . . . .	210
4.1	Speed of uber vehicles by hour of day . . . . .	315
4.2	Travel time by distance and mode of transport . . . . .	317
4.3	Population estimate coefficients of determination . . . . .	331
4.5	Network measures . . . . .	351
4.4	Building count $\rho$ values . . . . .	367
4.6	Most important network features . . . . .	368
4.7	Access quantification of enclaves . . . . .	392
4.8	Access classification of enclaves . . . . .	393
4.9	Housing classification of enclaves . . . . .	393
4.10	Perimeter classification of enclaves . . . . .	394
4.11	Social sphere classification of enclaves . . . . .	394
4.12	Tentative classification of enclaves . . . . .	397
4.13	Measures of separation . . . . .	400
5.1	Morphological indices for the 19th century AML . . . . .	461
5.2	Datasets for contemporary configurational analysis . . . . .	499
5.3	Geometric attributes of enclave isochrones . . . . .	550

*List of Tables*

5.4 Geometric attributes of distinct enclave isochrones . . . 551

# List of Algorithms

3.3.1 Business record scraper . . . . .	203
4.4.1 Population Disaggregation . . . . .	326
4.4.2 Remaining population distribution . . . . .	336
4.4.3 Population Generation . . . . .	343
4.4.4 Remaining population distribution . . . . .	377



# List of Equations

1	Urban use to subtract relation . . . . .	329
2	Census subtracts by urban use classes . . . . .	329
3	Population density in $C$ . . . . .	330
4	Urban class population density coefficients . . . . .	330
5	Disaggregated population zones . . . . .	332
6	Disaggregated rural population zones . . . . .	332
7	Pycnophylactic distribution of population . . . . .	335
8	Final disaggregated population of zone . . . . .	335
9	Final disaggregated population zone coefficient . . . . .	337
10	Street network voronoi regions . . . . .	346
11	Disaggregated population per sub-segment voronoi . . . . .	347
11	Street segment population standardisation . . . . .	347
13	Normalisation of street segment population . . . . .	348
14	SP street segment coefficient . . . . .	348
14	Residential building sample size . . . . .	350
15	Disaggregated population estimate of density cluster . . . . .	376
16	Segment length to segment cluster intersection ratio . . . . .	378
17	Relative weight of street segments within cluster . . . . .	378
18	Cluster population sum and standard deviation . . . . .	378
19	Mean segment-cluster intersection syntax . . . . .	378
20	Metacluster population and network attributes . . . . .	379
21	Convexity Index (Basaraner & Centinkaya impl.) . . . . .	383
22	Basaraner & Centikay's Equivalent Rectangular Index . . . . .	383
23	Nagel's Normalised Perimeter Index . . . . .	384
24	Parent, Civco & Angel's Normalised Detour Index . . . . .	385
25	Inverse segment length weight . . . . .	575

*List of Equations*

26 Configurational definition of Gated Enclaves . . . . . 604

# Acronyms

ADL	Alexandria Digital Library Project
AEAULP	<i>Academia de Escolas de Arquitectura e Urbanismo de Língua Portuguesa</i> , Academy of Portuguese Language Schools of Architecture and Urban Planning
AML	<i>Área Metropolitana de Lisboa</i> , Lisbon Metropolitan Area
APA	<i>Agência Portuguesa do Ambiente</i> , Portuguese Environment Agency
API	Application Programming Interface
AWS	Amazon Web Services
Az	Provinces of the Azores islands
BGE	<i>Base Geográfica Espacial</i> , Spatial Geographic Base
BGRE	<i>Base Geográfica de Referenciação Espacial</i> , Geographic Base for Spatial Referencing
BGRI	<i>Base Geográfica de Referenciação da Informação</i> , Geographic Base for Information Referencing
BSA	<i>Base de Segmentos de Arruamentos</i> , Street Segment Base
CAD	Computer Aided Design

## Acronyms

CAE	<i>Código de Actividade Económica</i> , Economic Activity Code
CC-FAUL	Cartographic Centre of the Faculty of Architecture, University of Lisbon
CERN	<i>Conseil Européen pour la Recherche Nucléaire</i> , European Organization for Nuclear Research
CGA	Construction Gross Area
CIAM	<i>Congrès Internationaux d'Architecture Moderne</i> , International Congresses of Modern Architecture
CIC	<i>Codex Iuris Canonici</i> , Code of Canon Law
CIGeoE	<i>Centro de Informação Geoespacial do Exército</i> , Portuguese Army Geospatial Information Centre
CIUL	<i>Centro de Informação Urbana de Lisboa</i> , Lisbon Centre for Urban Information
CLC	CORINE Land Cover
CM	<i>Congregatio Missionis</i> , Congregation of the Mission (Vincentians)
CML	<i>Câmara Municipal de Lisboa</i> , Lisbon Municipal Council and City Hall
CO	<i>Congregatio Oratorii</i> , Congregation of the Oratory of Saint Philip Neri (Oratorians)
COS	<i>Cartografia de Ocupação do Solo</i> , Land Use Cartography
CR	<i>Ordo Clericorum Regularium</i> , Congregation of Clerics Regular of the Divine Providence (Theatines)
CRS	Coordinate Reference System
CRSA	<i>Canonici Regulares Sancti Augustini</i> , Canons Regular of Saint Augustine (Austin Canons)
CSA	Closest segment to access
CSIR	Council for Scientific and Industrial Research
CSW	Closest segment to wall

CTE	Common Table Expression
CTT	<i>Correios de Portugal</i> , Postal Services of Portugal
DARPA	Defense Advanced Research Projects Agency
DBSCAN	Density-based spatial clustering of applications with noise
DCG	Design & Computation Group
DGT	<i>Direcção-Geral do Território</i> , Directorate-General for Spatial Planning
DIE	<i>Direcção de Infra-Estruturas do Exército</i> , Directorate of Army Infrastructures
DLI	Digital Libraries Initiative
EC2	Elastic Compute Cloud
EEA	European Environment Agency
EP	<i>Exército Português</i> , Portuguese Army
EPSG	European Petroleum Survey Group
EUA	European Urban Atlas
EURAU	European Symposium on Research in Architecture and Urban Design
FCT	<i>Fundação para a Ciência e a Tecnologia</i> , Science and Technology Foundation
FUA	Functional Urban Area
GCP	Ground Control Point
GDAL	Geospatial Data Abstraction Library
GEAEM	<i>Gabinete de Estudos Arqueológicos de Engenharia Militar</i> , Military Engineering Archaeological Studies Office
GEO	<i>Gabinete de Estudos Olisiponenses</i> , Olisiponenses Studies Bureau
GIS	Geographic Information System

## Acronyms

GPS	Global Positioning System
GRASS	Geographic Resources Analysis Support System
GTFS	General Transit Feed Specification
HGIS	Historical Geographic Information System
HH	<i>Hillier &amp; Hanson</i> , Syntax measure calculated according to Hillier and Hanson's equation
HOA	Homeowners' Association
HOT	Humanitarian OpenStreetMap Team
HTTP	Hypertext Transfer Protocol
ICNF	<i>Instituto da Conservação da Natureza e das Florestas</i> , Nature and Forestry Conservation Institute
IGeoE	<i>Instituto Geográfico do Exército</i> , Portuguese Army Geographic Institute
IGOT	<i>Instituto de Geografia e Ordenamento do Território da Universidade de Lisboa</i> , Institute of Geography and Spatial Planning of the University of Lisbon
IGP	<i>Instituto Geográfico Português</i> , Portuguese Geographic Institute
IHRU	<i>Instituto da Habitação e Reabilitação Urbana</i> , Urban Housing and Rehabilitation Institute
INE	<i>Instituto Nacional de Estatística</i> , National Statistics Office
INSPIRE	INfrastructure for SPatial InfoRmation in Europe
INT	Angular Integration
IQM	Interquartile Mean
IST	Instituto Superior Técnico
JRC	Joint Research Centre

LPP	Level of Post-Processing
MAE	Mean Absolute Error
MAUP	Modifiable Areal Unit Problem
MC	<i>Congregatio Missionariorum a Caritate</i> , Missionaries of Charity
Md	Provinces of the Madeira islands
MI	<i>Clerici Regulari Ministeri Infirmaribus</i> , Clerics Regular Ministers to the Sick (Camillians)
MIC	<i>Congregatio Clericorum Marianorum ab Immaculata Conceptionis Beatissimae Virginis Mariae</i> , Congregation of Marian Fathers of the Immaculate Conception of the Most Blessed Virgin Mary
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NSF	National Science Foundation
NTNU	Norwegian University of Science and Technology
OAD	<i>Ordo Augustiniensium Discalceatorum</i> , Order of Discalced Augustinians (Augustinians)
OAvi	<i>Ordem Militar de Avis</i> , Military Order of Aviz
OCarm	<i>Ordo Fratrum Beatissimae Mariae Virginis de Monte Carmelo</i> , Order of the Brothers of the Blessed Virgin Mary of Mount Carmel (Carmelites)
OCart	<i>Ordo Cartusienensis</i> , Carthusian Order (Carthusians)

## Acronyms

OCD	<i>Ordo Fratrum Carmelitarum Discalceatorum Beatae Mariae Virginis de Monte Carmelo</i> , Order of the Discalced Carmelites of the Blessed Virgin Mary of Mount Carmel (Carmelites)
OCist	<i>(Sacer) Ordo Cisterciensis</i> , Cistercian Order (Cistercians)
OCrist	<i>Ordem Militar de Cristo</i> , Military Order of Christ
OdeM	<i>Ordo Beatae Mariae de Mercede redemptionis captivorum</i> , Royal, Celestial and Military Order of Our Lady of Mercy and the Redemption of the Captives (Mercedarians)
OESA	<i>Ordo eremitarum sancti Augustini</i> , Order of Hermits of Saint Augustine (Austin Friars)
OFM	<i>Ordo Fratrum Minorum</i> , Order of Friars Minor (Franciscans)
OFMCap	<i>Ordo Fratrum Minorum Capuccinorum</i> , Order of Friars Minor Capuchin (Franciscans)
OFMConv	<i>Ordo Fratrum Minorum Conventualium</i> , Order of Friars Minor Conventual (Franciscans)
OH	<i>Ordo Hospitalarius Sancti Ioannis de Deo</i> , Hospitaller Order of the Brothers of Saint John of God (Brothers Hospitallers)
OIC	<i>Ordo Immaculatae Conceptionis</i> , Order of the Immaculate Conception (Conceptionists)
OM	<i>Ordo Minimorum</i> , Order of Minims (Minims)
OP	<i>Ordo Praedicatorum</i> , Order of Preachers (Dominicans)
ORDBMS	Object-Relational Database Management System
ORM	Object Relational Mapper
ORP	<i>Ordo Religiosus de Penitentia</i> , Penitent order (Scalzette, or Nazareni)

OSant	<i>Ordem Militar de Sant'Iago da Espada</i> , Military Order of Saint James of the Sword
OSB	<i>Ordo Sancti Benedicti</i> , Order of Saint Benedict (Benedictines)
OSBT	<i>Benedictinas Missionárias de Tutzing</i> , Missionary Benedictine Sisters of Tutzing (Benedictines)
OSC	<i>Ordo sanctae Clarae</i> , Order of Saint Clare (Clarisses)
OSCCap	Order of Saint Clare Capuchin (Capuchin Poor Clares)
OSCT	<i>Ordo sanctae Clarae</i> , Order of Saint Clare (Poor Clares)
OSGeo	Open Source Geospatial Foundation
OSH	<i>Ordo Sancti Hieronymi</i> , Order of Saint Jerome (Hieronymites)
OSM	OpenStreetMap
OSM	<i>Ordo Servorum Beatae Mariae Virginis</i> , Order of Friar Servants of Mary (Servites)
OSPPE	<i>Ordo Fratrum Sancti Pauli Primi Eremitæ</i> , Order of Saint Paul the First Hermit (Pauline Fathers)
OSsS	<i>Ordo Sanctissimi Salvatoris</i> , Order of the Most Holy Saviour (Bridgettines)
OSST	<i>Ordo Sanctissimae Trinitatis et Captivorum</i> , Order of the Most Holy Trinity and of the Captives (Trinitarians)
PBH	<i>Congregação dos Cónegos Seculares de São João Evangelista</i> , Secular Canons of St. John the Evangelist (Boni Homines)
PDDM	Sister Disciples of the Divine Master (Society of Saint Paul)

## Acronyms

PL/pgSQL	Procedural Language/PostgreSQL Structured Query Language
QGIS	Quantum GIS
RA	Relative Asymmetry
REGIS	Research Program in Environmental Planning and GIS
RER	<i>Réseau Express Régional</i> , Regional Express Network
RGB	Red, Green, Blue
RRA	Real Relative Asymmetry
SAC	Segment Angular Choice
SC	Segment commerce
SIGMA	<i>Sistema de Informação Geográfica e Modelação de Dados Aplicado à História de Portugal</i> , Data Modelling and Geographic Information System Applied to the History of Portugal
SJ	<i>Societas Iesu</i> , Society of Jesus (Jesuits)
SNIG	<i>Sistema Nacional de Informação Geográfica</i> , National System for Geographic Information
SNSF	Servas de Nossa Senhora de Fátima
SP	Segment population
SPM	Sisters of the Presentation of Mary
SQL	Structured Query Language
SRID	Spatial Reference System Identifier
SRS	Spatial Reference System
SS	Segment services
SSD	Congregação de Santa Doroteia
SVD	<i>Societas Verbi Divini</i> , Society of the Divine Word
Th	Third Orders

TIGER	Topologically Integrated Geographic Encoding and Referencing
TOCarm	Third Order of Our Lady of Mount Carmel (Lay Carmelites)
TOR	<i>Tertius Ordo Regularis Sancti Francisci</i> , Third Order Regular of St. Francis of Penance (Franciscans)
UCL	University College London
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
USA-CERL	U.S. Army Construction Engineering Research Laboratories
USGS	United States Geological Survey
VGA	Visibility Graph Analysis
VGI	Volunteered Geographic Information
VHM	<i>Ordo Visitationis Beatissimae Mariae Virginis</i> , Order of the Visitation of Holy Mary (Visitandines)
WFS	Web Feature Service
WMS	Web Map Service
XML	Extensible Markup Language
ZODUC	<i>Zonas de Desarrollo Urbano Condicionado</i> , Zones of Constrained Urban Development



# Appendices



# A Digital Supplements

A large sample of original source code developed by the author during the research is made available, under the GNU v3 general public license, in a digital repository accessible at:

<https://github.com/joaoponceleao/ibs>

The source code is intended for anyone to use in the reproduction or validation of the research work undertaken herein, aiding further research, and giving back to the the open source data science and software development community. This includes code developed for the spatial disaggregation algorithms and processes, data scraping modules, SP, SC, and SS measure algorithms, as well as code used for geographic spatial analysis and data visualisation, the latter, where possible, in the form of Jupiter notebooks — all contained within folders mimicking the structure of the thesis.

In the majority of cases the source code expects to connect directly to a PostgreSQL + PostGIS database, that the user will have to deploy. We have included some data files (in the form of CSV and SQL data dumps) within the data directory. These have been extracted from the original database used in our research but include only a subset of columns, in order to save storage space and to anonymise data. We expect more complete datasets to be made available in the future, following completion of ongoing research and a more stringent process of data anonymisation, particularly of geographic elements, in the interests of

## *A Digital Supplements*

privacy protection. The source code of the GNA Project VGI platform, summarised in `xpref{app:gna-project}`, resides in a separate repository and is not publicly available at the moment.

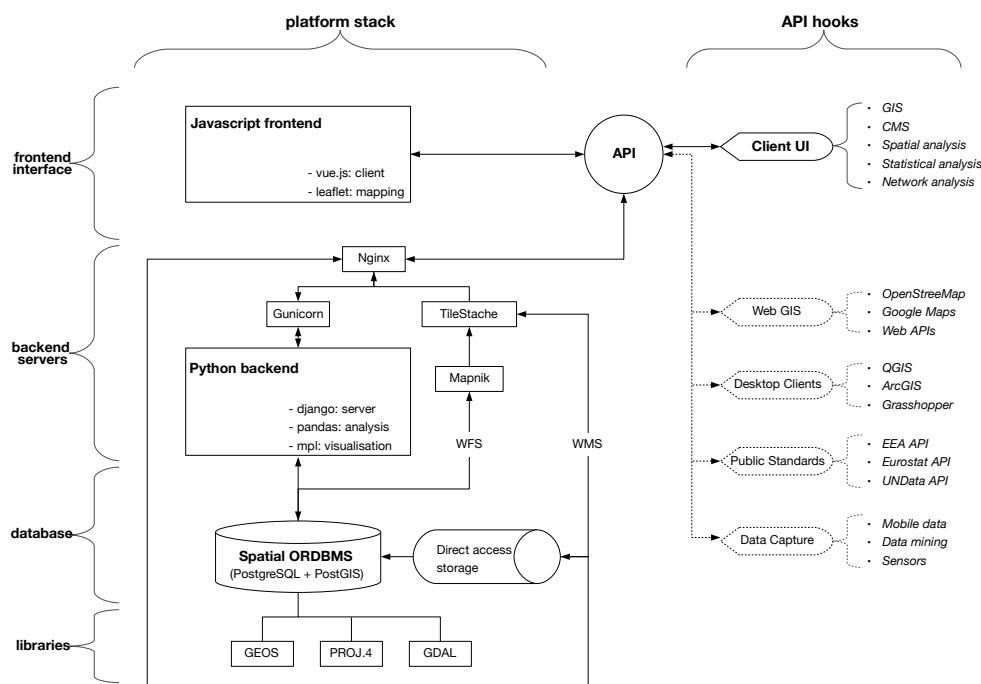
# B The GNA Project: A VGI Platform for Urban Networks

Within our research, statistical and network analysis are encapsulated within a data-driven research methodology, following on recent developments in data science (Cleveland, 2001; Dhar, 2013; Donoho, 2017; Naur, 1966) and laying the foundations for future work through what Gray in 2007 termed *eScience*, which he presented as the “fourth paradigm” of scientific research, following on the *empirical* branch developed millennia ago, the *theoretical* branch of the last few centuries, and the *computational* branch of the last few decades (escience originally defined in J. Gray, 2007; but see also Bell et al., 2009). We began to implement early in the research project a system for the collection and analysis of data that would grow into what is commonly referred to as an HGIS platform, and evolve into the continuing development of a modular open platform for direct participation by researchers in associative geographic mapping and analysis, loosely modelled on the OSM concept. It quickly became apparent however, that the focus by past and current HGIS platforms on data and visualisation was woefully inadequate, and nowhere close to what would be required in Gray’s fourth paradigm.

One of the difficulties with current urban network analysis is that, despite being a relatively mature subject, there exists no central database of findings and measurements. Furthermore, were such findings and source

data by multiple institutes to be collected into a central database, any analysis would be hindered by the fact that different researchers utilise different tools or methodologies, both in the collection of data and in subsequent measurements. It became clear early on that what was required in the research field was not merely a central database of spatial network maps for analysis and comparisons, but a platform that could structure the entire research process, from data collection, through input, measurement and analysis, to comparison and validation. This is the premise of the GNA (Geographic Network Analysis) Project, an original geospatial VGI platform for collaborative mapping and spatial analysis purpose-built for this research project, whereupon results from the survey and subsequent analysis are assembled to construct a multivariate geo-referenced relational database of gated enclaves, constituting not only the main disseminator of data, but equally a future aggregator of data and a platform for socio-spatial analysis to be customised and used by researchers and professionals of all disciplines working on the socio-urban problematic.

In working with quantitative data throughout the research project, measurable indicators of social and spatial exclusion were constructed, and as such, interventionist active investigations can be carried out through virtual simulations that have a direct data-driven relationship with specific sites or case studies. This study therefore intends to provide a practical application to urban design that goes beyond observation, analysis, and dissemination, into constructing a framework for identifying and predicting problematic urban situations for subsequent analysis and viable simulated, and measurable, experiments to take place in resolving socio-spatial exclusion. Currently in alpha stage and consisting of over 40 000 lines of original code, the platform, with a focus on crowd-sourcing of data, citizen-science participation, and spatial analysis, is built upon a PostGIS database with a python backend, a javascript frontend, and a REST API (see full stack diagram of platform in fig. B.1 on page ii-9).



**Figure B.1:** Diagram of the full stack structure of the GNA VGI platform

Current working implementations of the administration interface can be seen in figs. B.2 to B.3 on pages ii-10–ii-11.

The GNA Project application is intended as a platform that will outlive the research project and grow as an independent collaborative research tool, aggregating information and providing a geo-referenced timeline of gated enclave development, with room to expand as a multivariate database with ever-increasing data for analytical research. Such a combination of geographic information systems, network analysis, and crowd-mapping, allows us to constantly refine the system to better measure urban fragmentation, predict problematic spatialities and, eventually, simulate future projections based on new variables input by designers, researchers and policy makers. As such, the initial mixed non-interventionist qualitative and quantitative methodology and toolset is developed in the latter stages of the research project into an interventionist quasi-experimental

## B The GNA Project: A VGI Platform for Urban Networks

investigation through software simulations, allowing urban areas most at risk of social division and fragmentation to be identified early on, whilst simultaneously providing the techniques to propose and test viable measurable solutions, indicating future practical uses for urban planners, architects, researchers, policy makers, and institutes beyond both the lifespan and research topic of this project.

**Change project** History

**Title** 1950-1999 Subtitle

The title of the project. The subtitle of the project.

**Description** Modern to Contemporary confinement. Social housing to lifestyle communities.

Description of the project.

---

**Project details**

**Status** Unfinished, but viewable by all with  Project website  Project email

Publication status of the project. URL link to the project website. Contact email for the project.

---

**Related data**

Related images, documents and other files.

**References**  Documents  Images

Related references. Hold down "Control", or "Command" on a Mac, to select more than one. Related documents. Hold down "Control", or "Command" on a Mac, to select more than one. Related images. Hold down "Control", or "Command" on a Mac, to select more than one.

**Misc files**  Video files  Audio files

Related files. Hold down "Control", or "Command" on a Mac, to select more than one. Related video files. Hold down "Control", or "Command" on a Mac, to select more than one. Related audio files. Hold down "Control", or "Command" on a Mac, to select more than one.

---

**Filters**

Active  Private

Disable object instead of deleting it. Private objects can only be accessed by team or project members.

**Keywords**

List of comma-separated keywords

**Categories**

---

**Metadata**

**Date created** June 30, 2016, 5:16 p.m.

**Date modified** July 6, 2016, 5:04 p.m.

**Owner** Joao Paulouro Neves

---

**Project members**

Member	Role	Mailto	In active	Date created
Joao Paulouro Neves	Moderator <input type="button" value="v"/>	<input type="button" value="send email"/>	<input checked="" type="checkbox"/> <input type="button" value="Disable member instead of deleting"/>	June 30, 2016, 5:16 p.m.

[Add another project member](#)

---

**Invite users**

Email address	Role	Message
<input type="text"/>	<input type="text"/>	<input type="text"/>

[Add another user](#)

---

**Parent teams**

**Team**

**Gated communities**


[Add another parent team](#)

Figure B.2: GNA Project administration interface. Editing research project attributes

### Add unit

Name  Address

Unit name  Address (leave blank for automatic geocoding)

Geom 

**Unit details**

Start date  End date

Description

- Surface area: 347.69 ha
- Estimated population: 1492
- Address: 2820-567 Herdade da Aroeira, Charneca da Caparica, Almada, Setúbal
- Foundation: 1999
- Access: Guarded gates
- Access Points: Dual
- Perimeter: Discontinuous walls, High walls, Landscape buffers
- Sphere: Private space, Shared amenities, Shared road, Shared space
- Housing: Single Family Residences
- Class: Communal amenities

Notes

The enclave association has informed its residents that the compound is not considered a gated enclave, having this status been confirmed by the town hall of Almada, and as such its residents should inform the Autoridade Tributária (being the Portuguese revenue authority) of this fact in order to avoid an increase in their municipal property tax (APRHA, 2013, Circular n. 14). This statement, and the recognition by the town hall, not only contradicts the ground truth we derived from direct observation, but equally contradicts the publicity and informational material published by the developer, where the compound is characterized as being "completely walled in and under permanent surveillance" allowing one to "live in perfect safety" (SILAroeira, 1993, "Aroeira Viva", p. 3).

Miscellaneous notes

Taxon

Unit taxon

Categories

Available categories

- Communal Street (C2)
- Communal Space (C3)
- Communal Amenities (C4)
- Lifestyle Community (C5)
- Non-town (C6)
- CHC 1
- CHC 2
- CHC 3
- CHC 4
- CHC 5
- CHC 6
- CHC 7
- CHC 8
- CHC 9
- CHC 10

Chosen categories

- Communal Amenities (C4)
- CHC 3
- CHC 1
- CHC 1
- SCHC 9

Projects

Available projects

Project title: Project 2, Owner: Joao Paulouro Neves, Private: False

Chosen projects

Project title: 1950-1999, Owner: Joao Paulouro Neves, Private: False

Teams

Available teams

- Team 3
- Team 4
- Team 5

Chosen teams

- Galici communities
- Laboia

**Related data**

Filters

Active  Private

Disable object instead of deleting it. Private objects can only be accessed by team or project members.

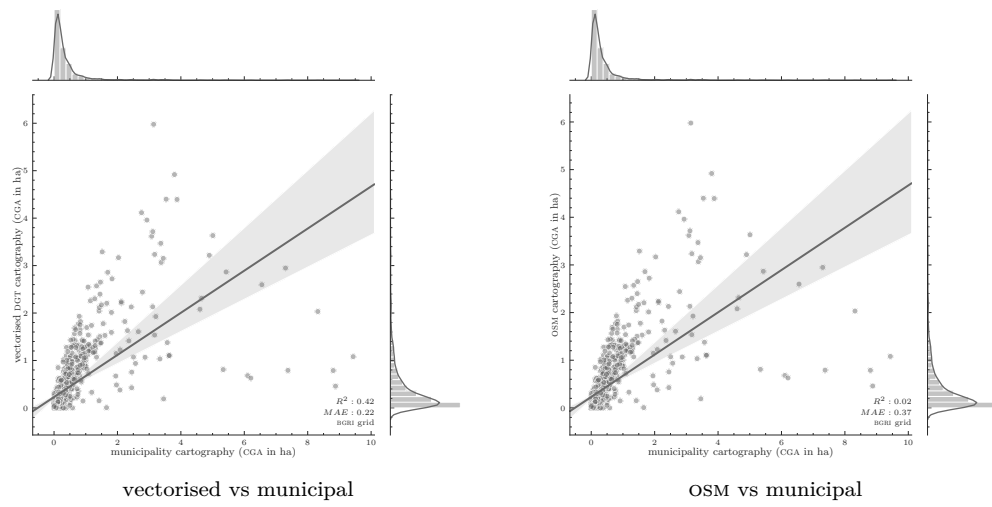
**Metadata**

Date created July 6, 2016, 5:09 p.m. Data modified Owner

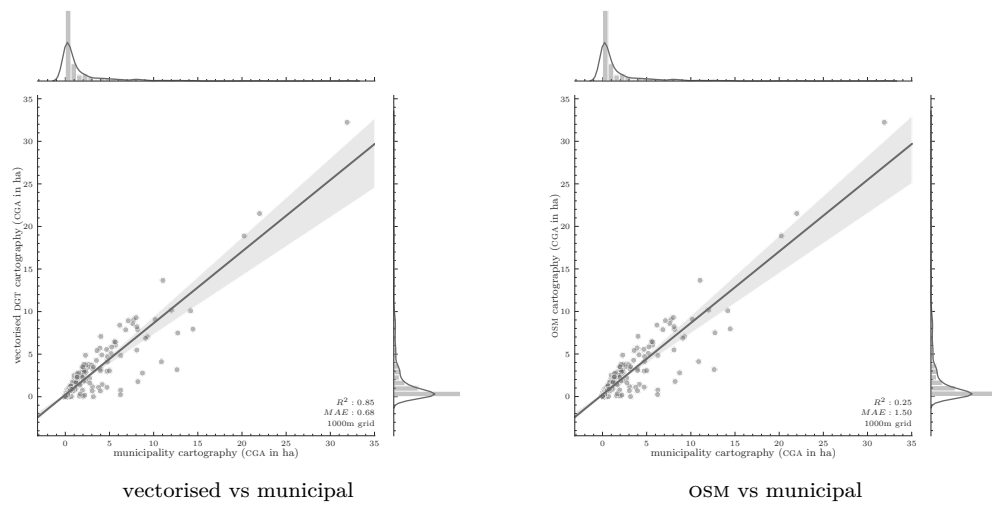
Figure B.3: GNA Project administration interface. Adding geographic unit



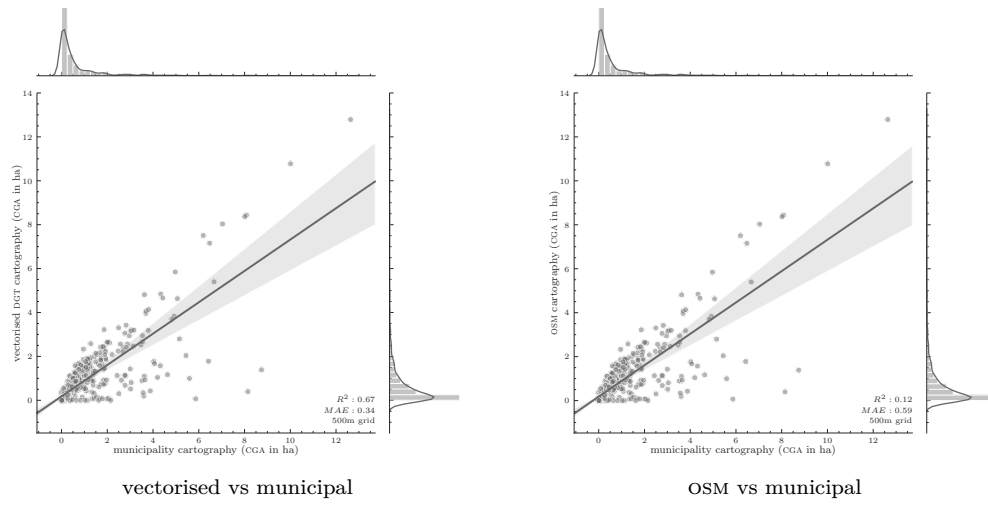
# C Spatial Data Collection and Validation



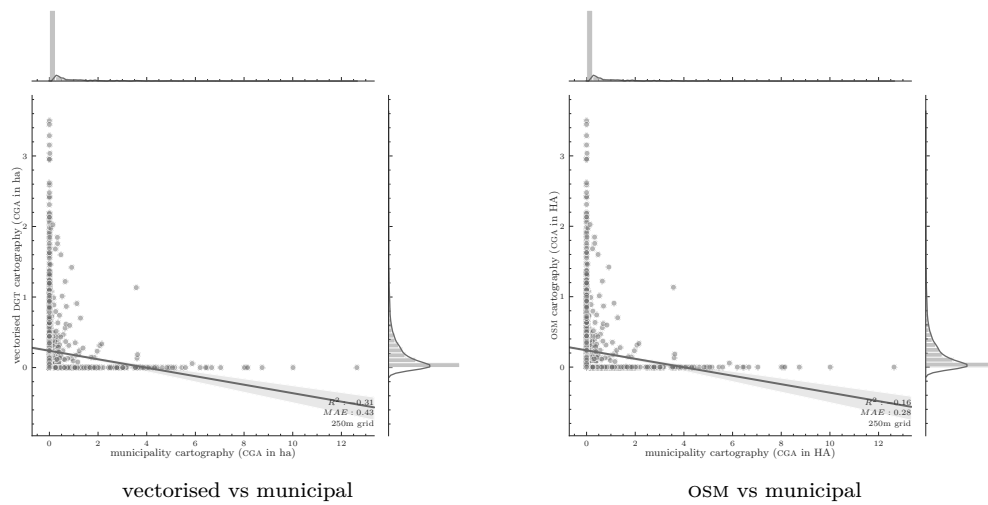
**Figure C.1:** Joint plot showing scatter plot, linear regression fit line, and respective univariate histograms on the margins of CGA values in vectorised, OSM and official cartography through a BGRI census tract spatial sampling.



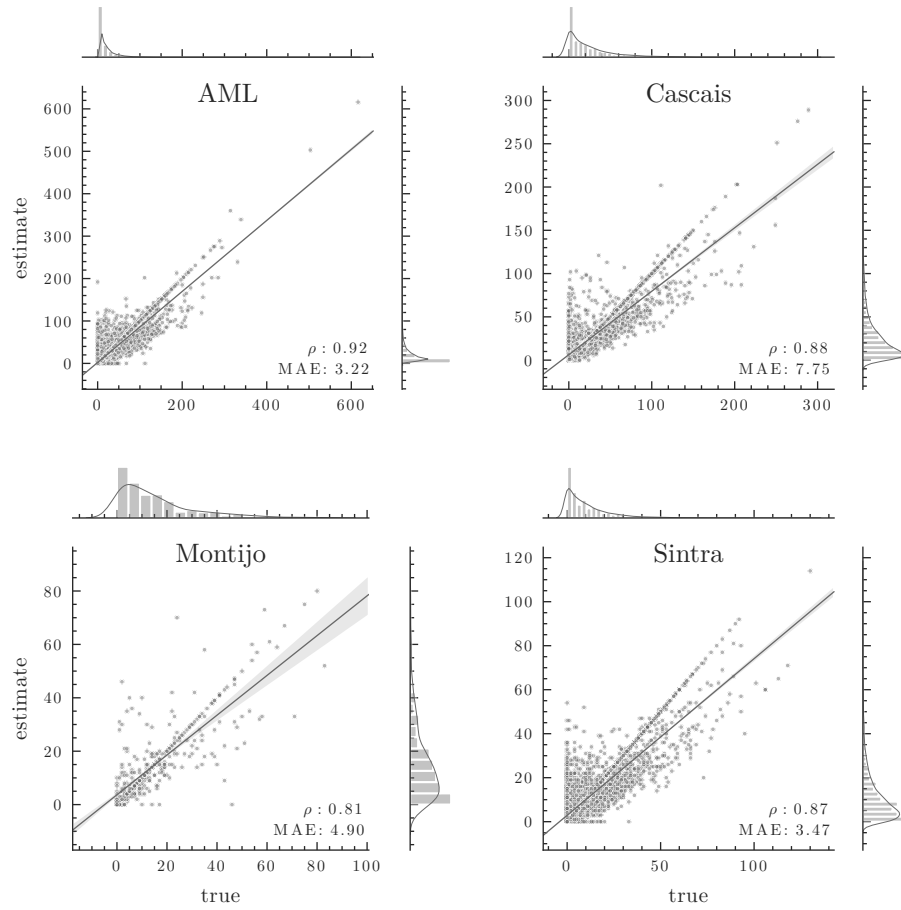
**Figure C.2:** Joint plot showing scatter plot, linear regression fit line, and respective univariate histograms on the margins of CGA values in vectorised, OSM, and official cartography through 1 km hexagonal grid sampling.



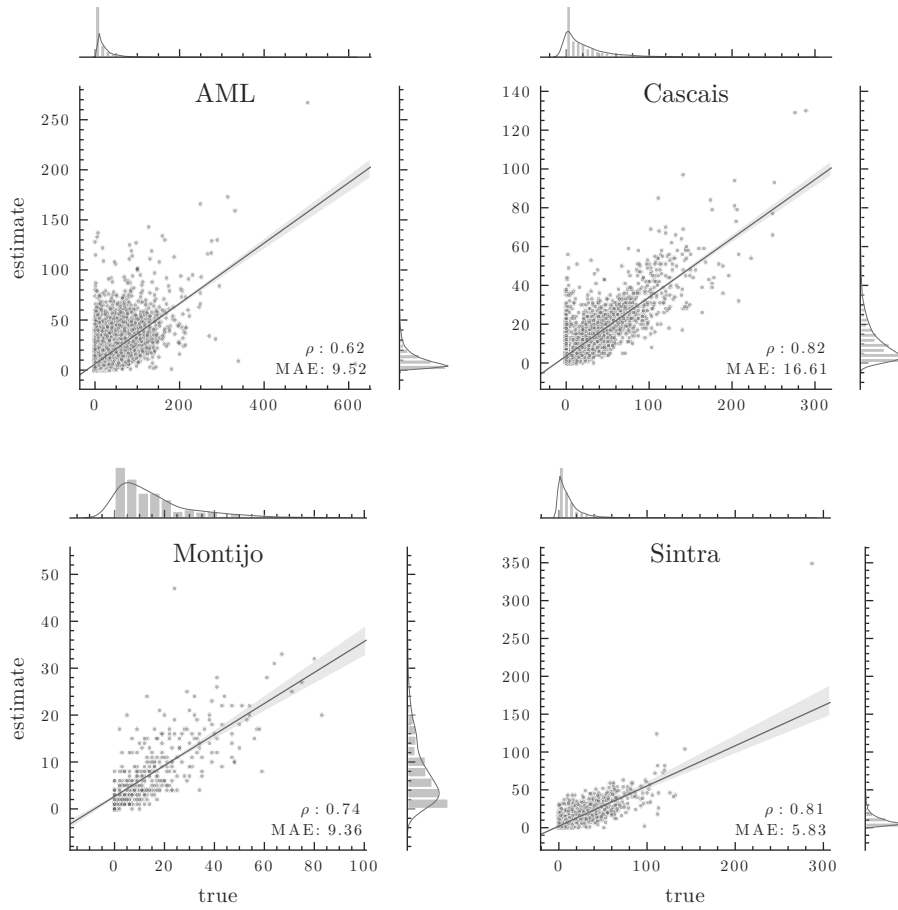
**Figure C.3:** Joint plot showing scatter plot, linear regression fit line, and respective univariate histograms on the margins of CGA values in vectorised, OSM and official cartography through 500 m hexagonal grid sampling



**Figure C.4:** Joint plot showing scatter plot, linear regression fit line, and respective univariate histograms on the margins of CGA values in vectorised, OSM and official cartography through 250 m hexagonal grid sampling.

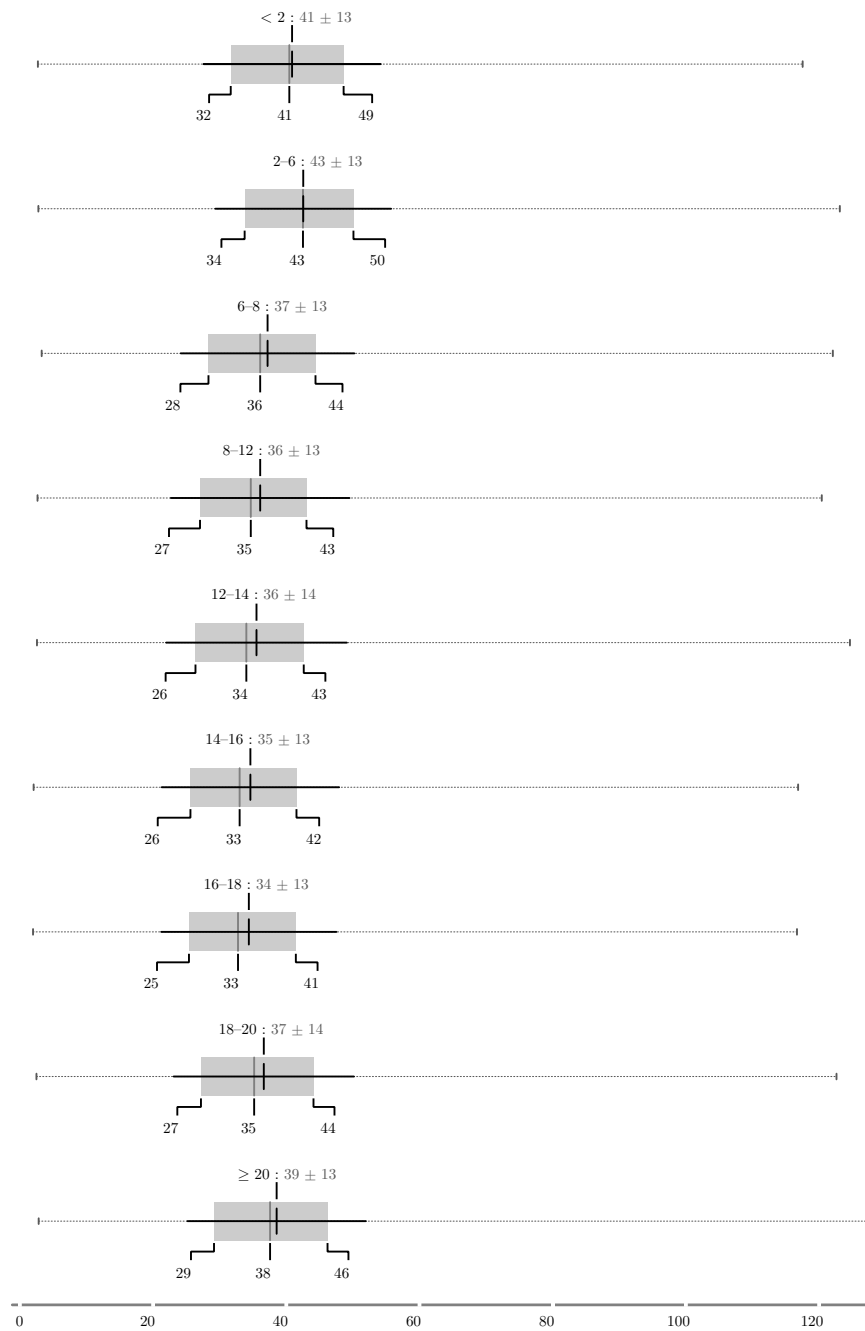


**Figure C.5:** Sum of total number of gated enclaves and total occupied area (km<sup>2</sup>, 2016 estimate) in the AML region by year.



**Figure C.6:** Sum of total number of gated enclaves and total occupied area (km<sup>2</sup>, 2016 estimate) in the AML region by year.

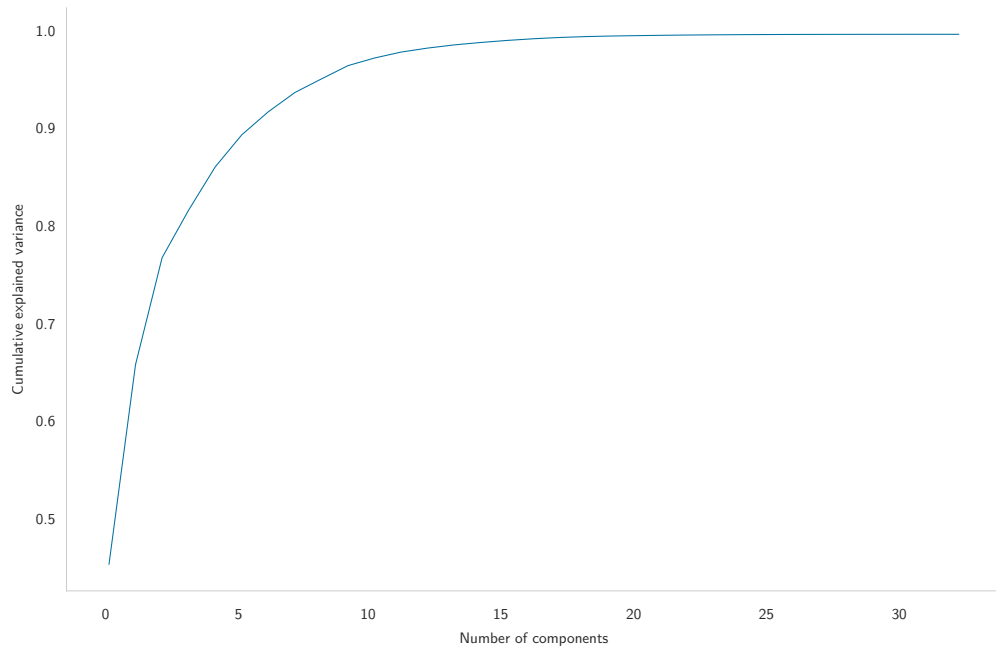
## C Spatial Data Collection and Validation



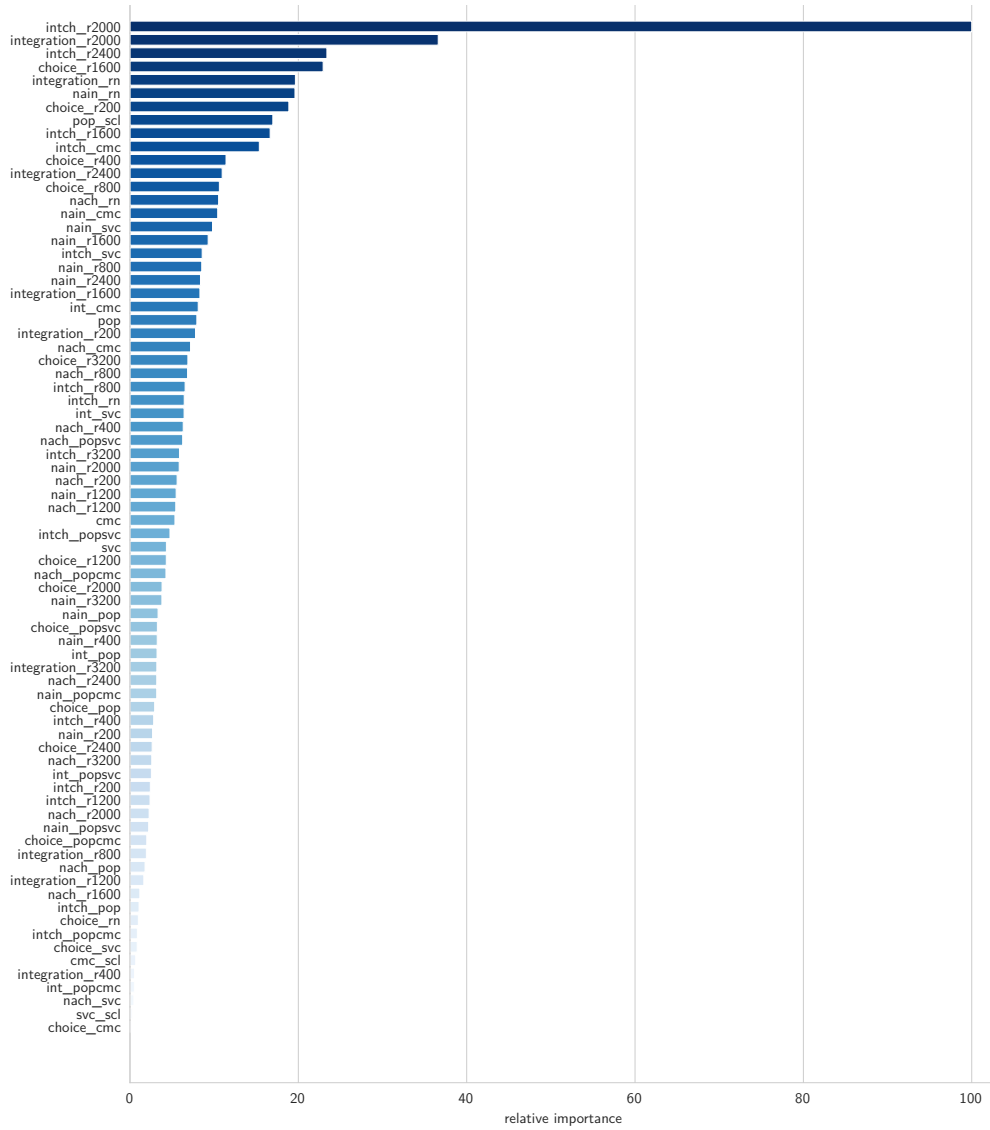
**Figure C.7:** Box plot of recorded mean speeds by uber vehicles for 2018 in London(km/h). Data retrieved from Quarterly Speeds Statistics by Hour of Day for London, Uber Movement dataset, and processed in Orange3 (Demsar et al., 2013).

## D Network Validation and Feature Selection

## D Network Validation and Feature Selection

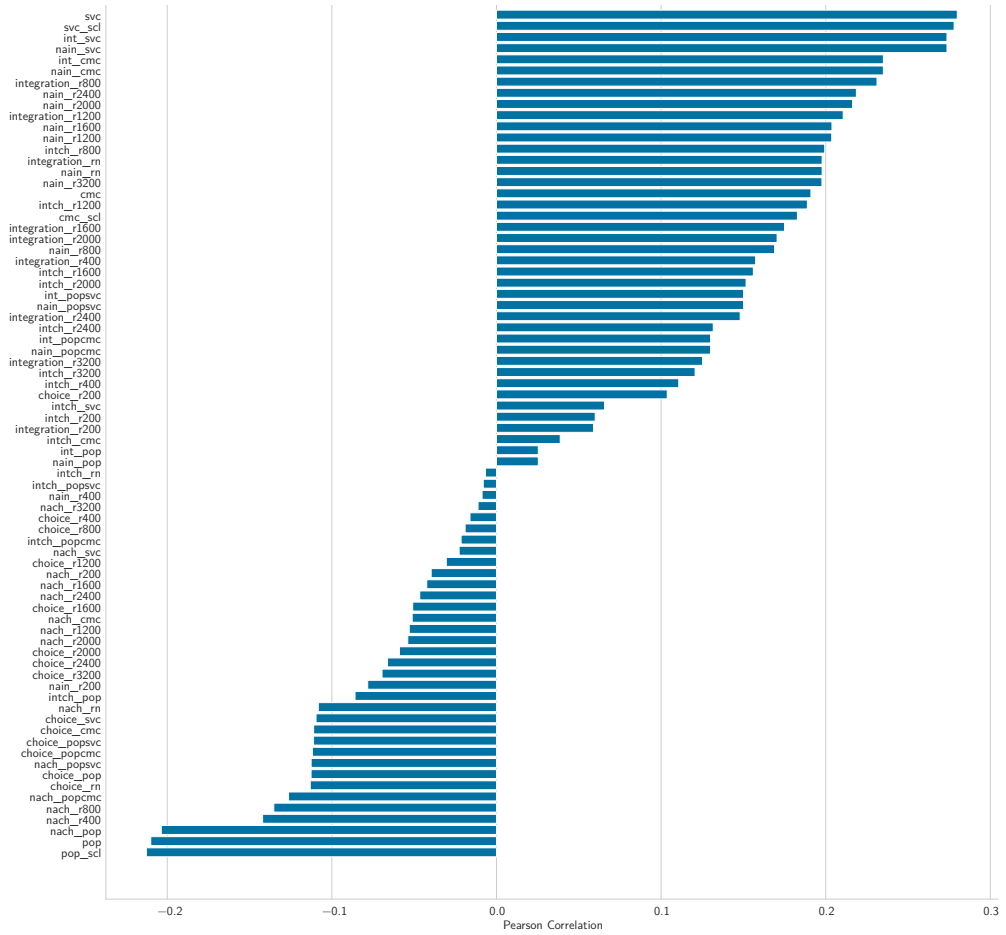


**Figure D.1:** Linear dimensionality reduction using (PCA) Randomized Singular Value Decomposition for pedestrian counts target

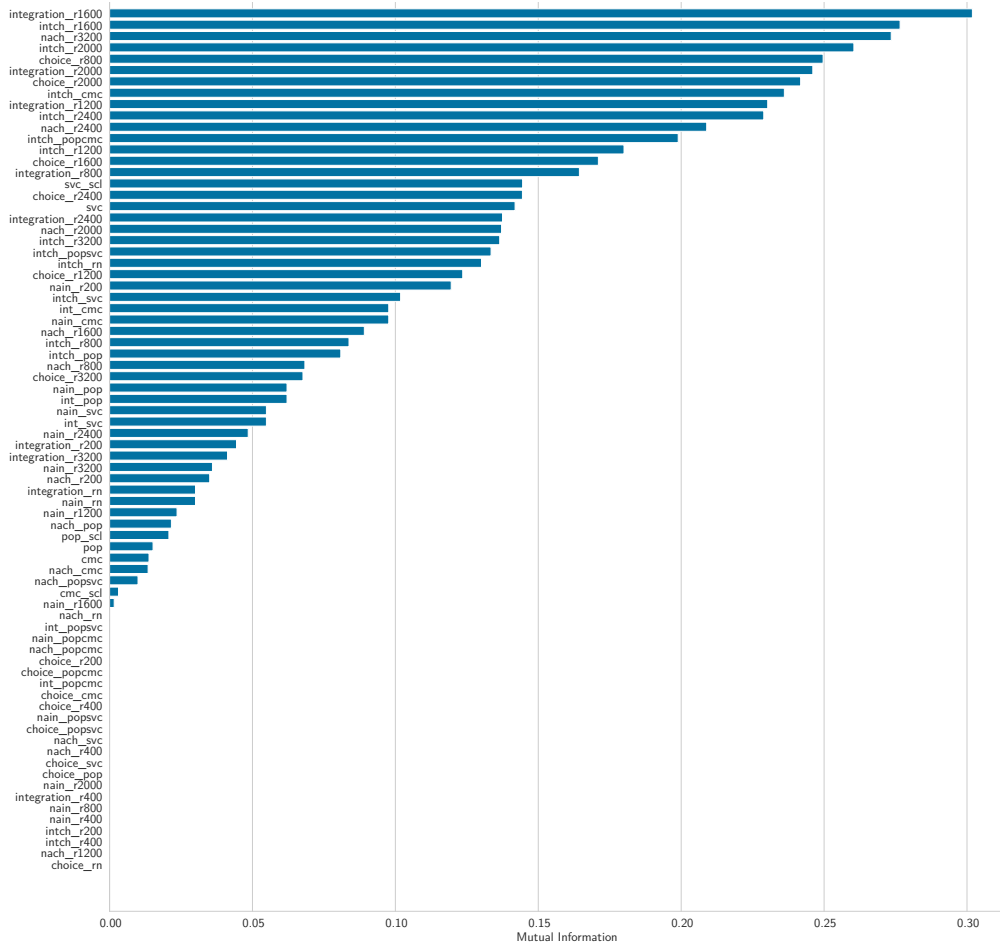


**Figure D.2:** Feature importances of 76 features with pedestrian counts using Random Forest Regressor.

## D Network Validation and Feature Selection

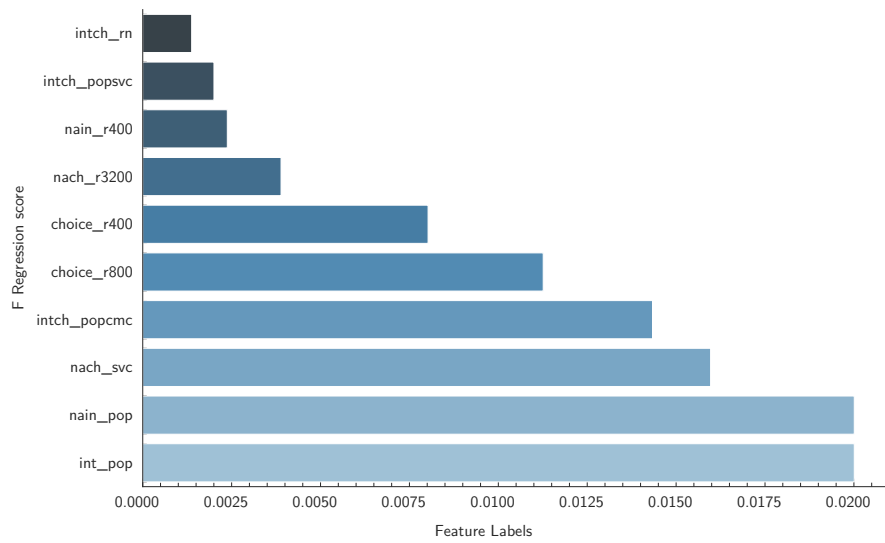


**Figure D.3:** Feature correlation of 76 features with pedestrian counts using Pearson's  $r$

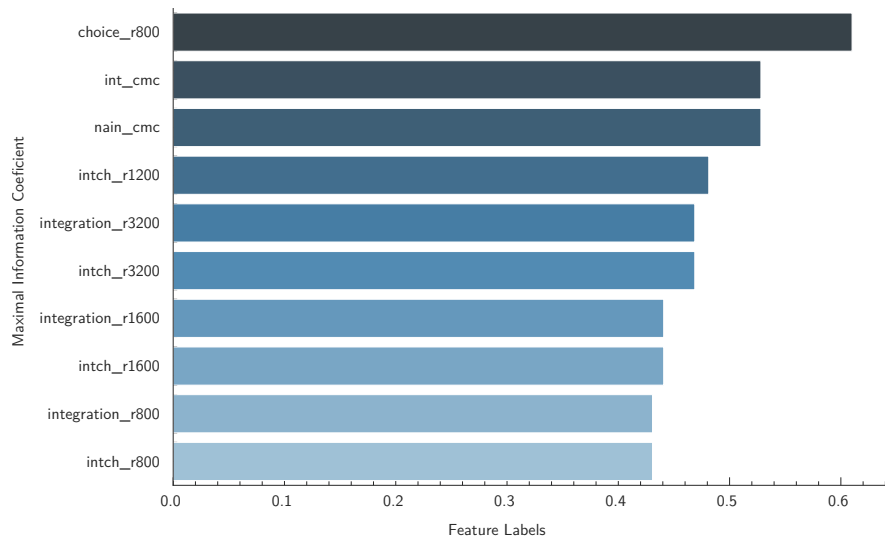


**Figure D.4:** Feature correlation of 76 features with pedestrian counts using Mutual Information Regression



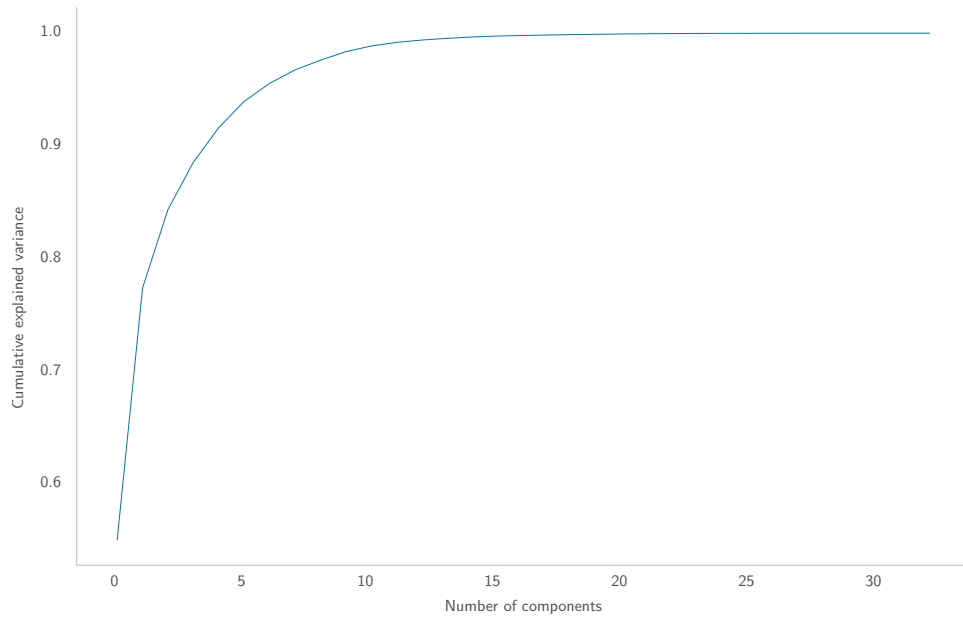


**Figure D.7:** Top 10 features for pedestrian count target based on F-Regression score

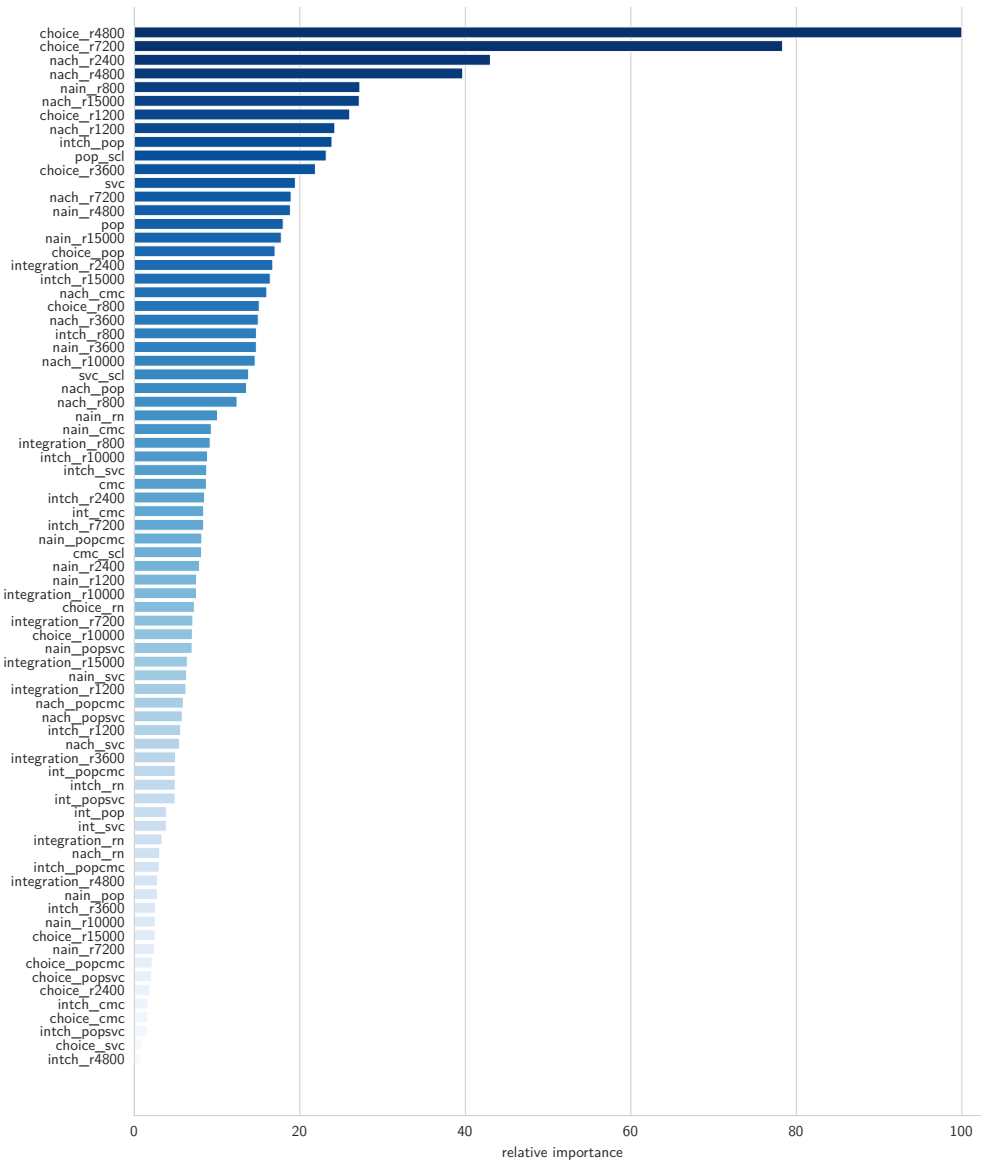


**Figure D.8:** Top 10 features for pedestrian count target based on Maximal Information Coefficient

*D Network Validation and Feature Selection*



**Figure D.9:** Linear dimensionality reduction using (PCA) Randomized Singular Value Decomposition for vehicle counts target



**Figure D.10:** Feature importances of 76 features with vehicle counts using Random Forest Regressor.

## D Network Validation and Feature Selection

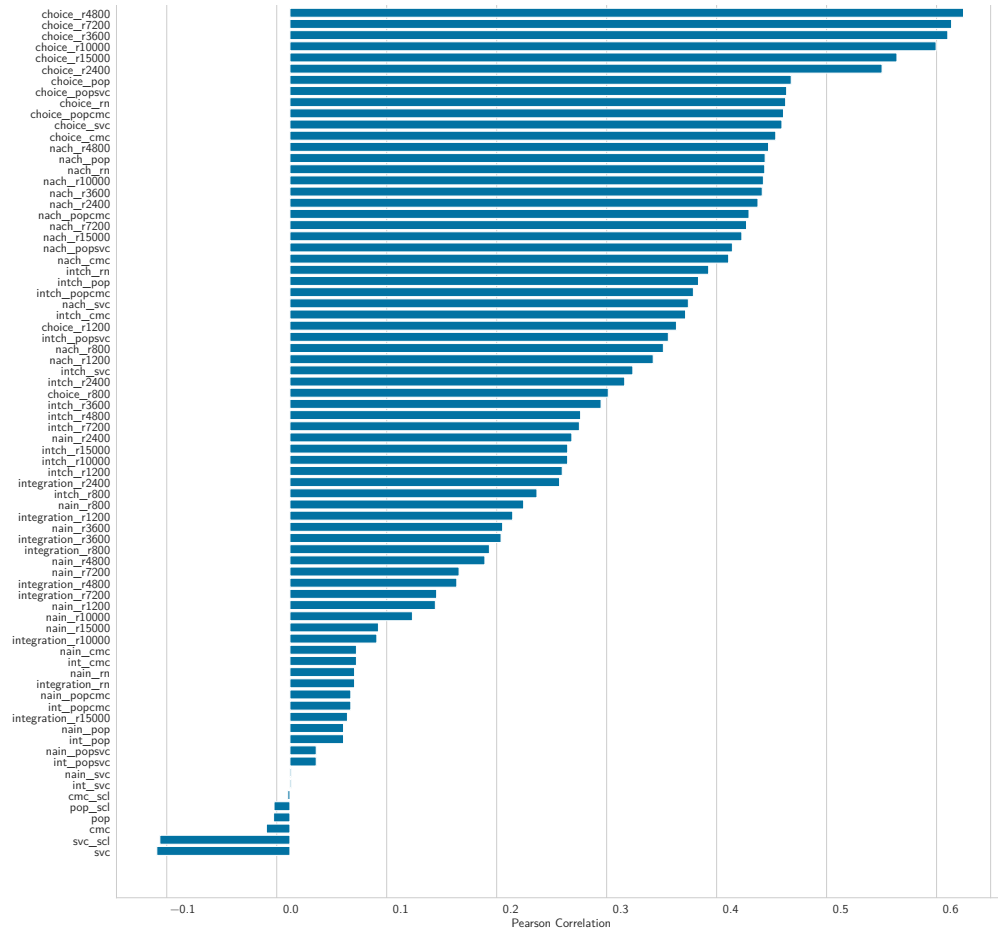
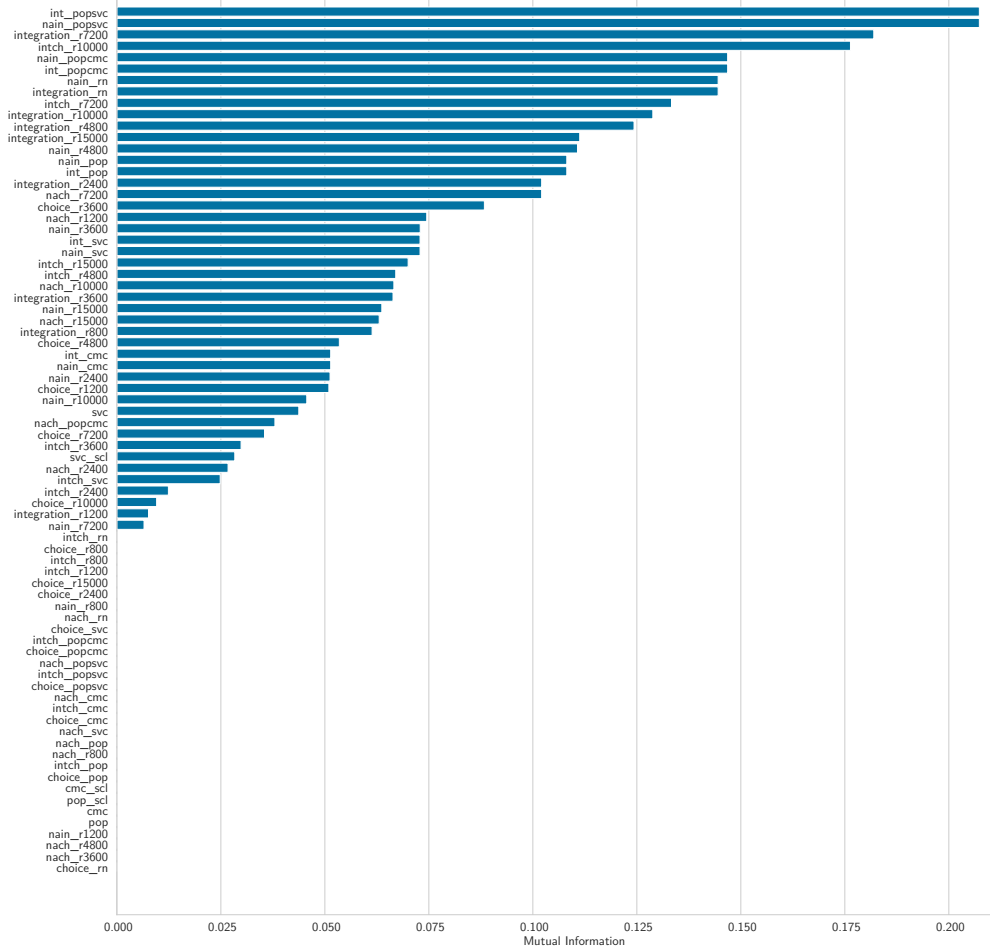
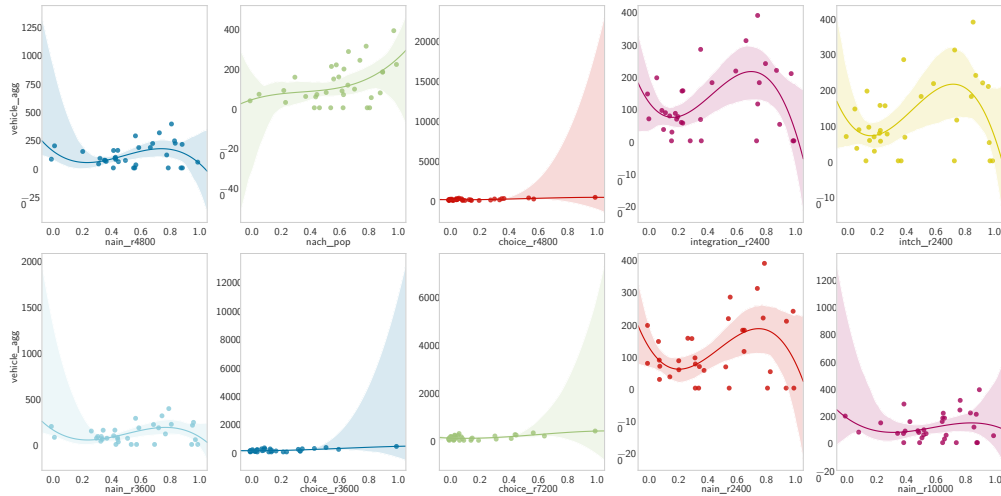


Figure D.11: Feature correlation of 76 features with vehicle counts using Pearson's  $r$

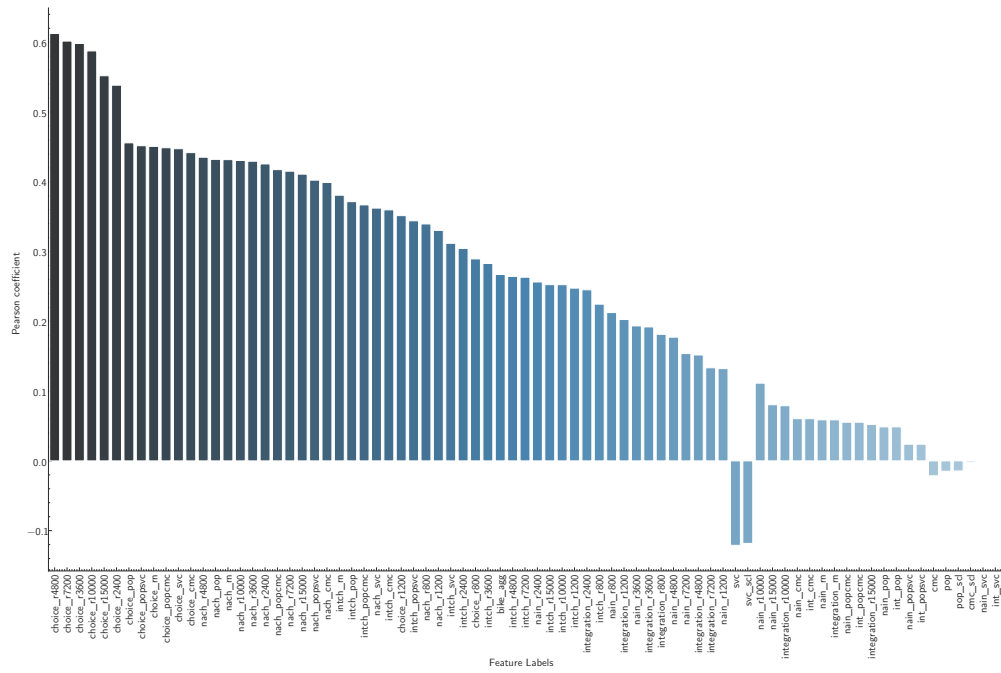


**Figure D.12:** Feature correlation of 76 features with vehicle counts using Mutual Information Regression

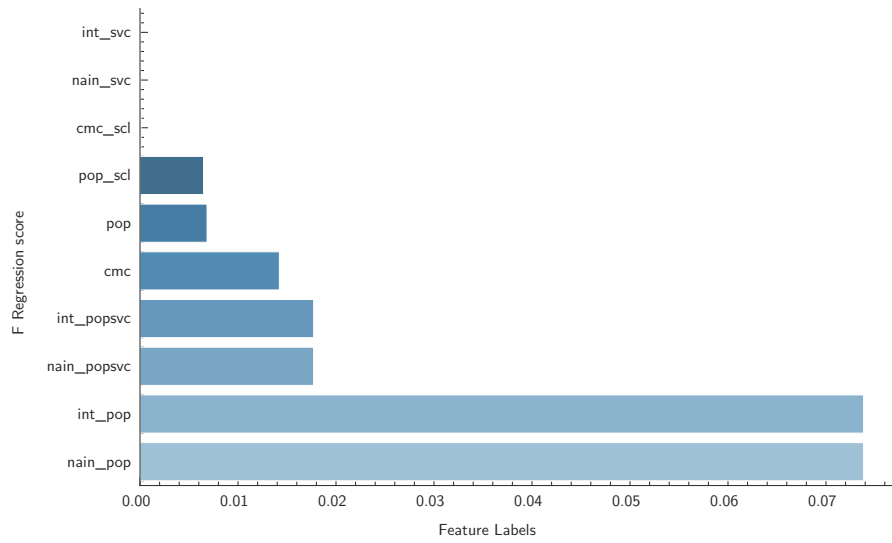
## D Network Validation and Feature Selection



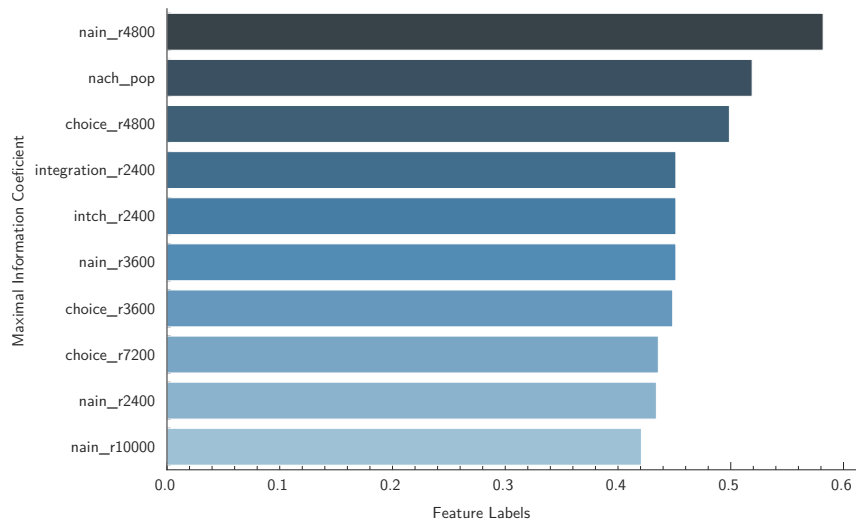
**Figure D.13:** Third degree polynomial regression between vehicle counts and top 10 features as determined by MIC



**Figure D.14:** Pearson correlation coefficient, ordered by two-tailed p-value, between 78 features and vehicle counts.



**Figure D.15:** Top 10 features for vehicle count target based on F-Regression score



**Figure D.16:** Top 10 features for vehicle count target based on Maximal Information Coefficient



E Spatial Analysis of the Late  
Medieval and Early Modern  
Models

*E Spatial Analysis of the Late Medieval and Early Modern Models*



**Figure E.1:** 1718, 1758 Lisbon cartography geo-reference analysis, calculated on (Anon, 1758)



**Figure E.2:** Pre-earthquake Lisbon survey geo-reference analysis, calculated on (Freitas, 1850)



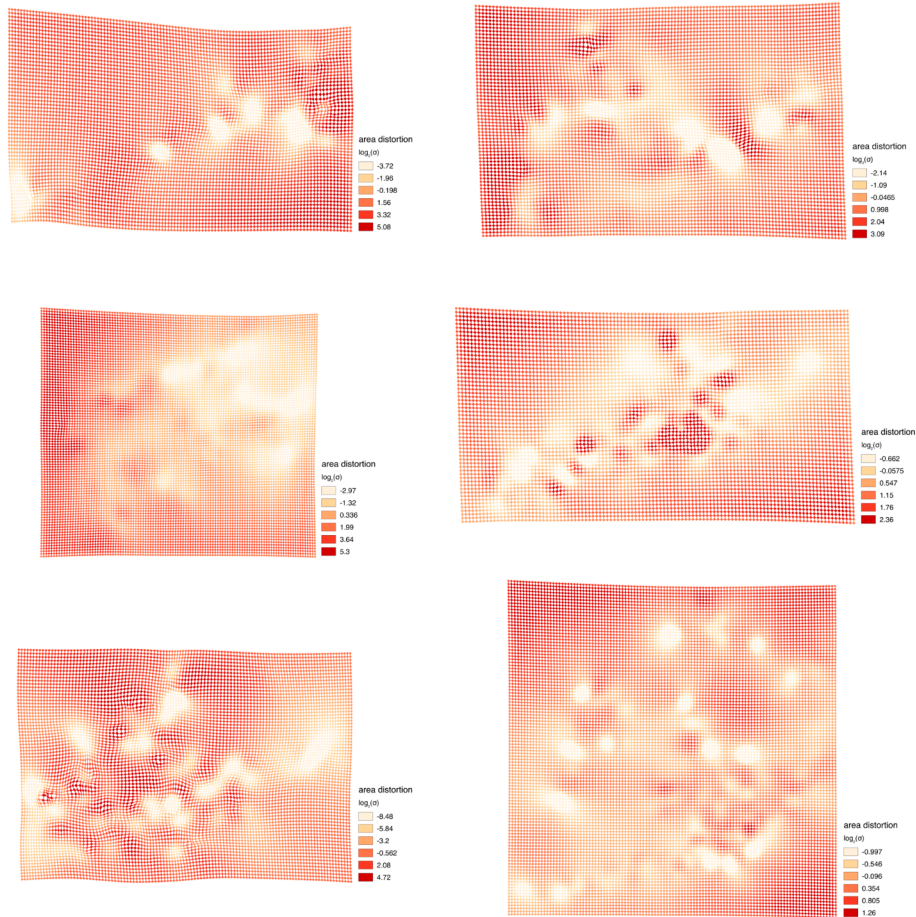
**Figure E.3:** 1761 Lisbon geo-reference analysis, calculated on (Anon, 1761)



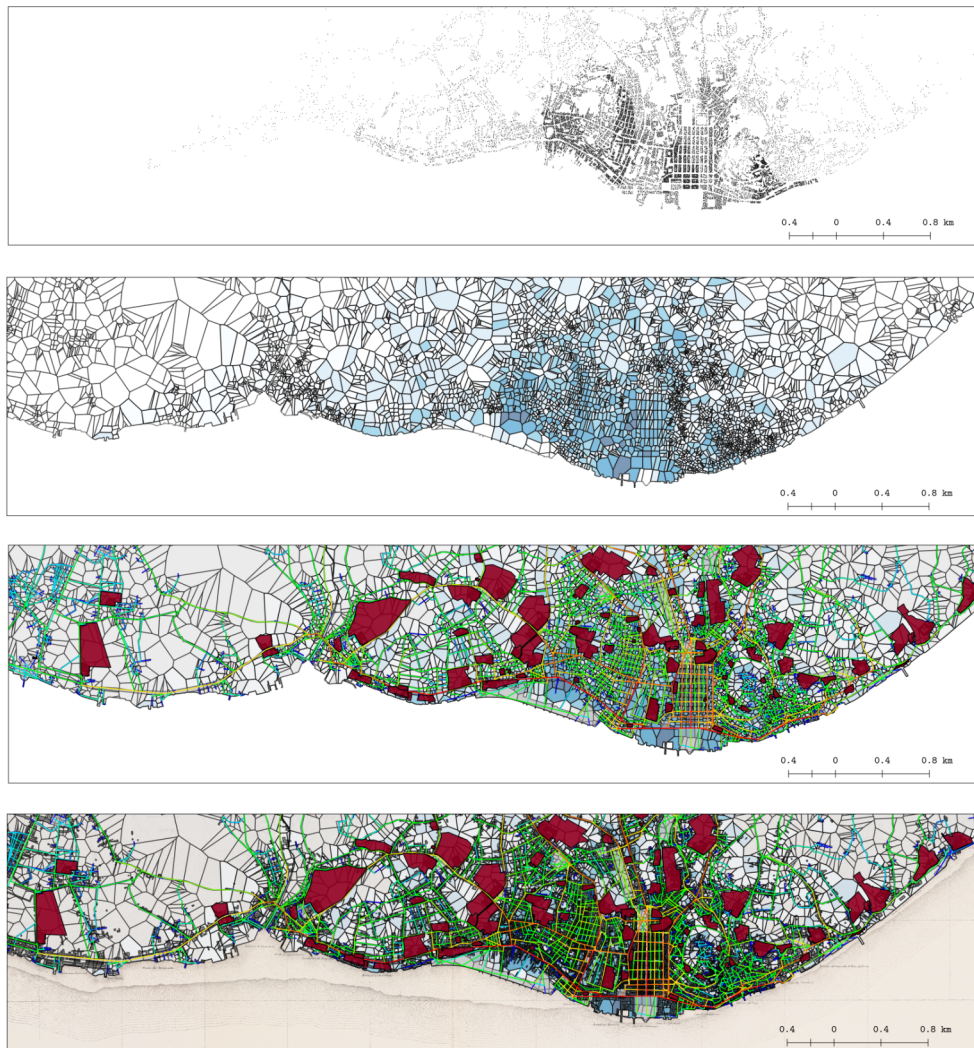
**Figure E.4:** 1856-1858 Lisbon geo-reference GCP analysis of Folque's 1858 survey, calculated on (Folque, 1871)



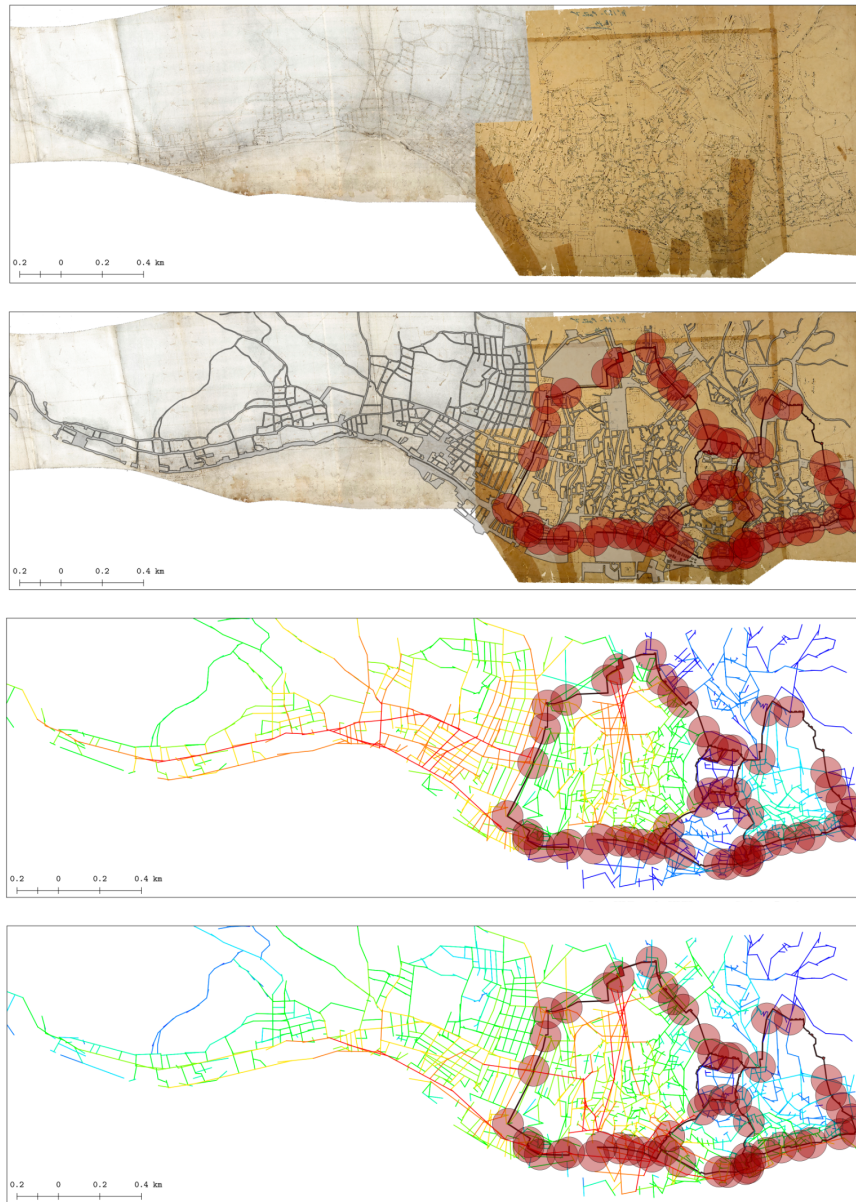
**Figure E.5:** 1856-158 Folque topographic Lisbon atlas geo-reference analysis, calculated on (Folque, 1858/2000)



**Figure E.6:** DDA analysis for geo-referenced cartography of Lisbon (from left to right, top to bottom): 1581, 1718-1758, pre-earthquake, 1761, 1856-1858 Lisbon, 1856-1858 atlas. Calculated on cartography from, respectively, Anon (1581), Anon (1758), Folque (1871), and Folque (1858/2000)



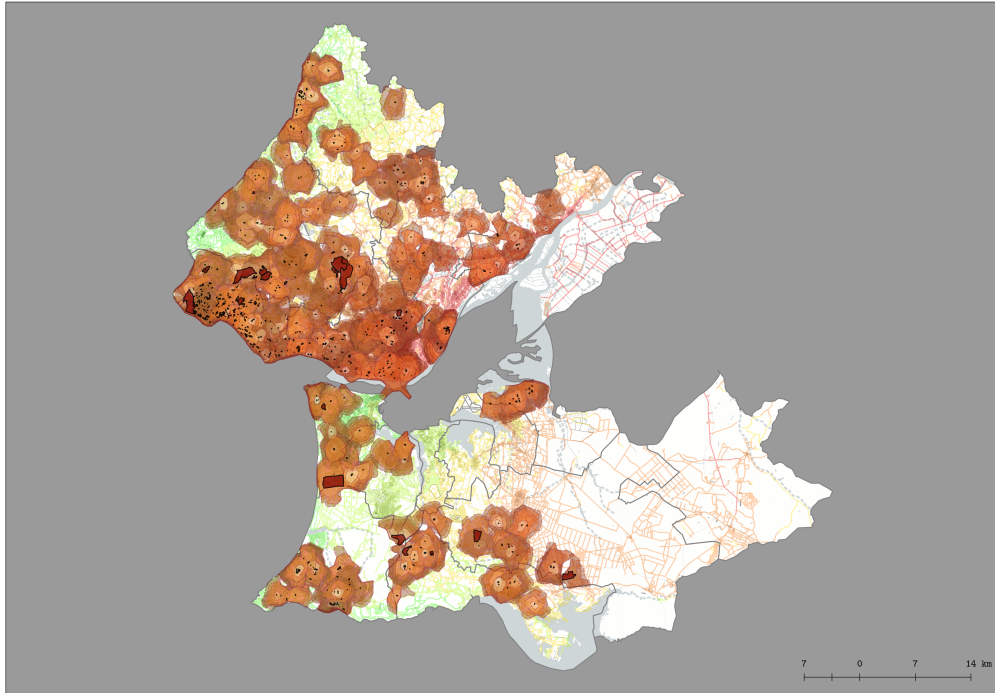
**Figure E.7:** Process of integration of demographic features in space. Lisbon 1801 model example. From top to bottom: disaggregated population dot map according to the 1801 *Recenseamento* (population count); Voronoi cells of the urban network street segments, graduated by colour according to disaggregated population; space syntax integration network, weighed according to street segment resident population; combination of previous three layers on top of original geo-referenced base cartography



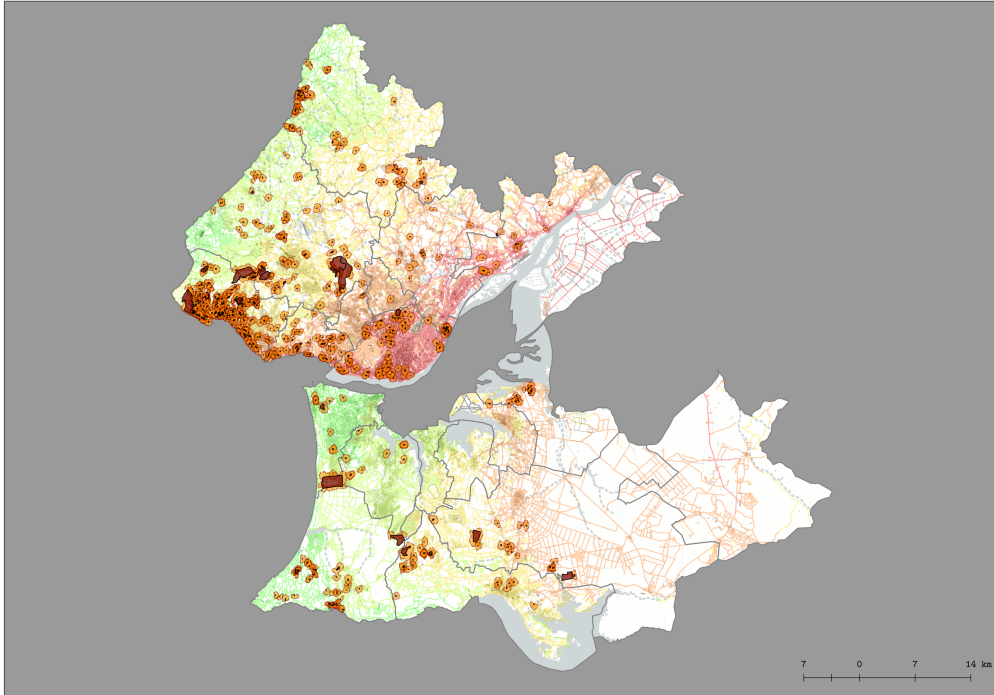
**Figure E.8:** Late sixteenth and early seventeenth century Lisbon city gates network. From top to bottom: Geo-referencing and combining closest period maps for street network construction; drafting of urban network, unfenced space, city walls, and identification of the 53 city gates; space syntax network analysis showing global integration (HH) assuming all gates are closed; space syntax network analysis showing global integration (HH) assuming all gates are open



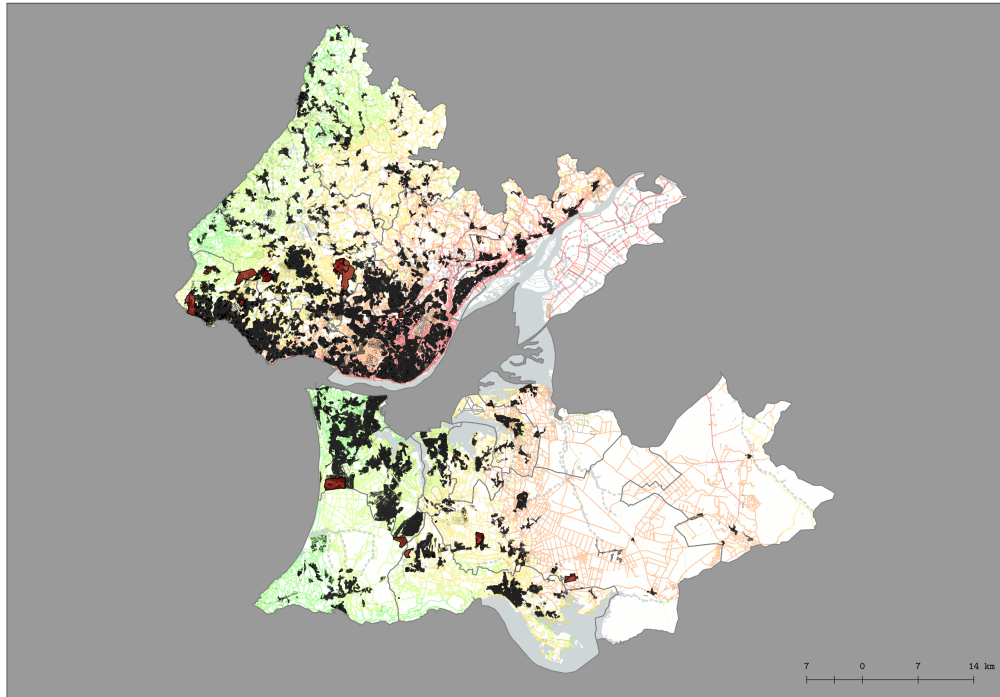
# F Spatial Analysis of the Contemporary Model



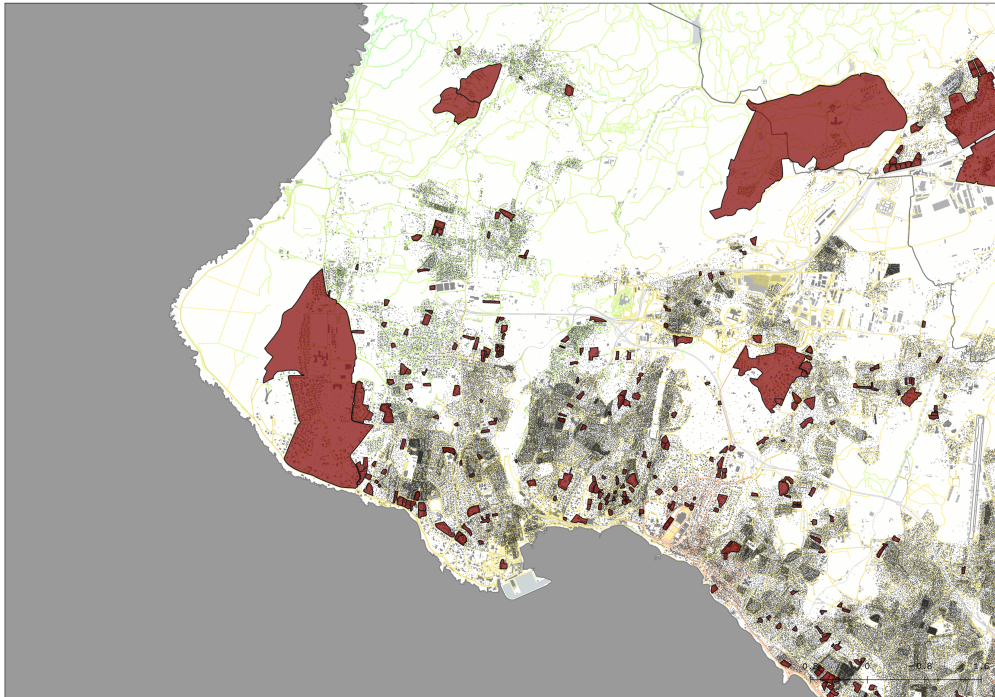
**Figure F.1:** Map depicting the 765 identified inhabited gated enclaves (in red) in the AML in 2016, along with respective isochrones with a graduated range of between 5 and 20 minutes walking distance. Background shows the integration (HH) values following angular segment analysis of the pedestrian road network



**Figure F.2:** Map depicting the 765 identified inhabited gated enclaves (in red) in the AML in 2016, along with respective 5 minute walking distance isochrones (in orange). Background shows the integration (HH) values following angular segment analysis of the pedestrian road network



**Figure F.3:** Map depicting the 765 identified inhabited gated enclaves in the AML in 2016 (in red), along with the disaggregated dot population points (one dot equals one person) used to calculate the additional network measures and weighed space syntax values. Background shows the calculated integration (HH) values following angular segment analysis of the pedestrian network

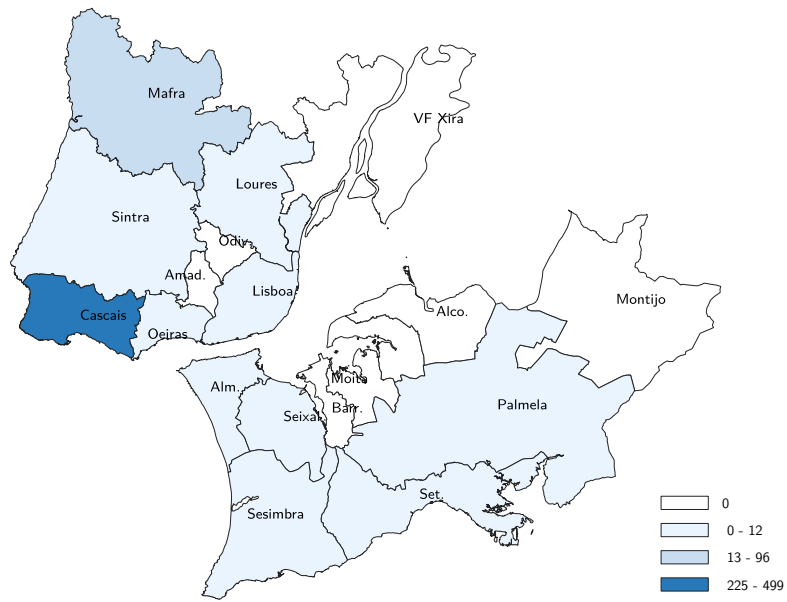


**Figure F.4:** Detail of a section of Cascais and Sintra municipalities in 2016, showing the gated enclaves (in red) and disaggregated dot population points (one dot equals one person) used to calculate the additional network measures and weighed space syntax values. Background shows the calculated integration (HH) values following angular segment analysis of the pedestrian network

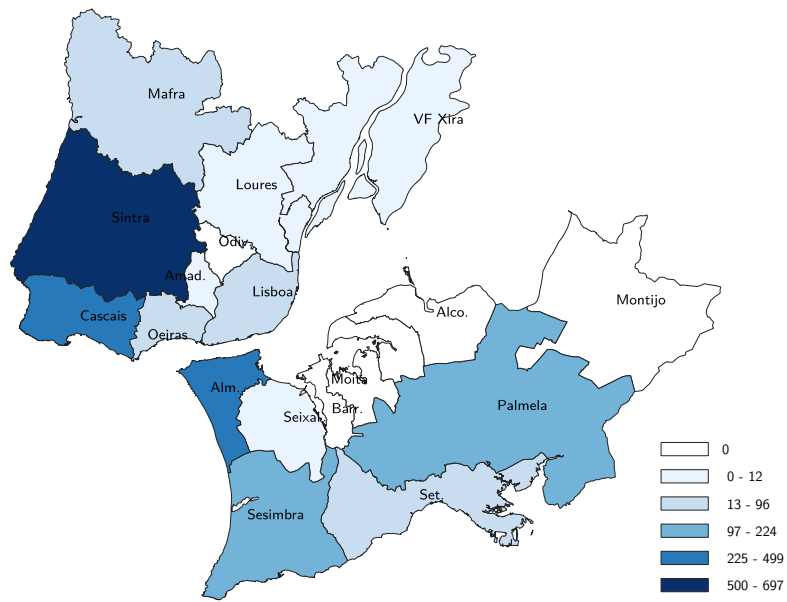


# G Macro Distribution of Contemporary Gated Enclaves

*G Macro Distribution of Contemporary Gated Enclaves*



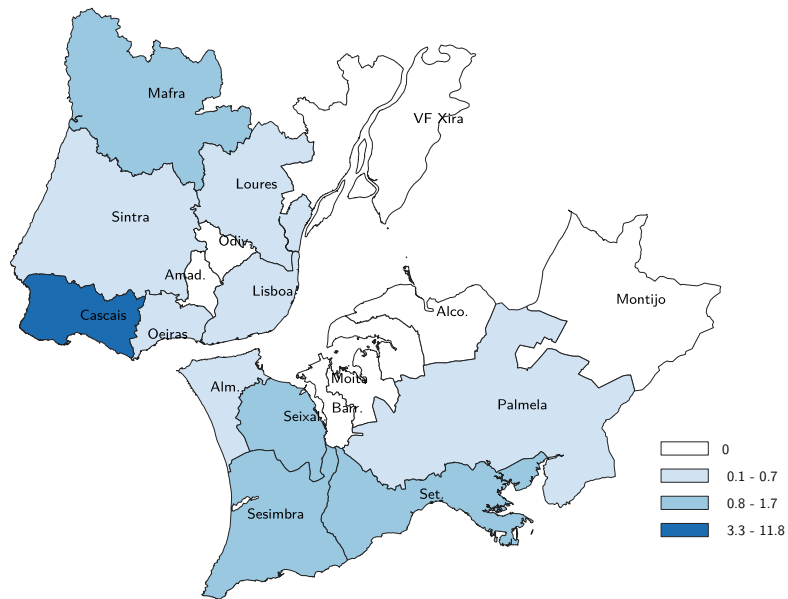
**Figure G.1:** Choropleth map of gated enclave surface areas, 1991. Area (ha) figures aggregated by municipality.



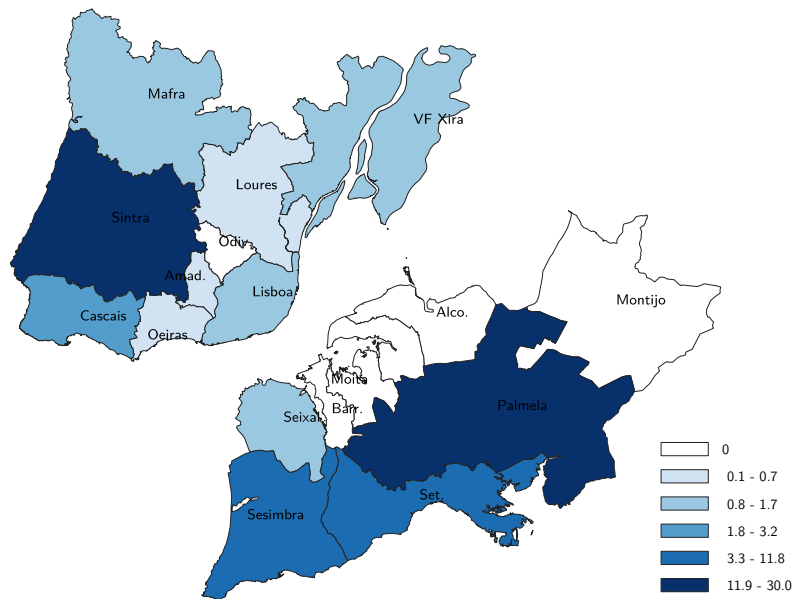
**Figure G.2:** Choropleth map of gated enclave surface areas, 2001. Area (ha) figures aggregated by municipality.



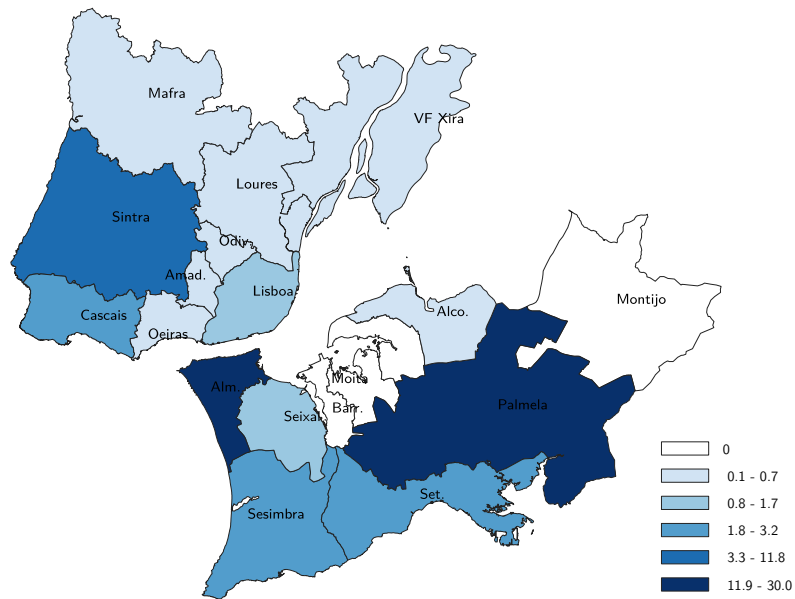
*G Macro Distribution of Contemporary Gated Enclaves*



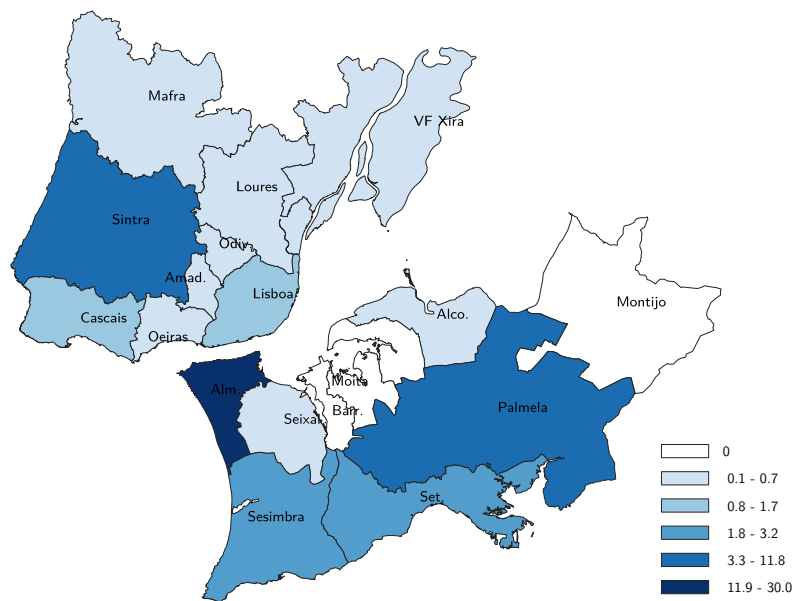
**Figure G.5:** Choropleth map of mean gated enclave surface areas, 1991. Area (ha) figures correspond to the arithmetic mean of all gated enclaves in each municipality.



**Figure G.6:** Choropleth map of mean gated enclave surface areas, 2001. Area (ha) figures correspond to the arithmetic mean of all gated enclaves in each municipality.

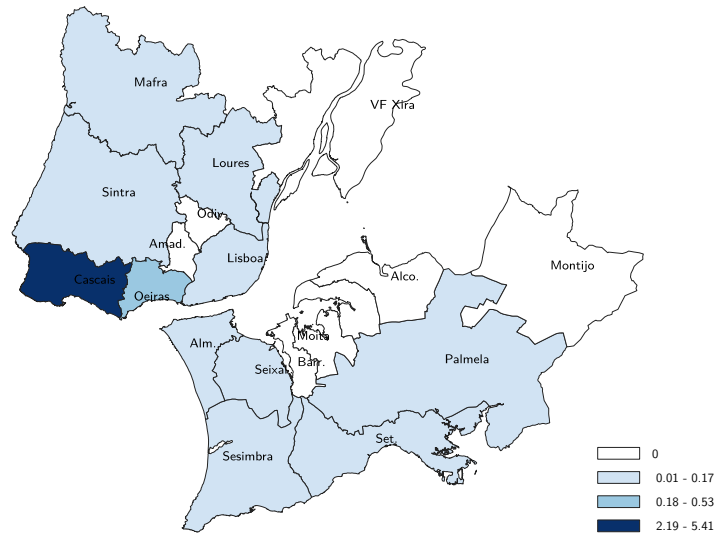


**Figure G.7:** Choropleth map of mean gated enclave surface areas, 2011. Area (ha) figures correspond to the arithmetic mean of all gated enclaves in each municipality.

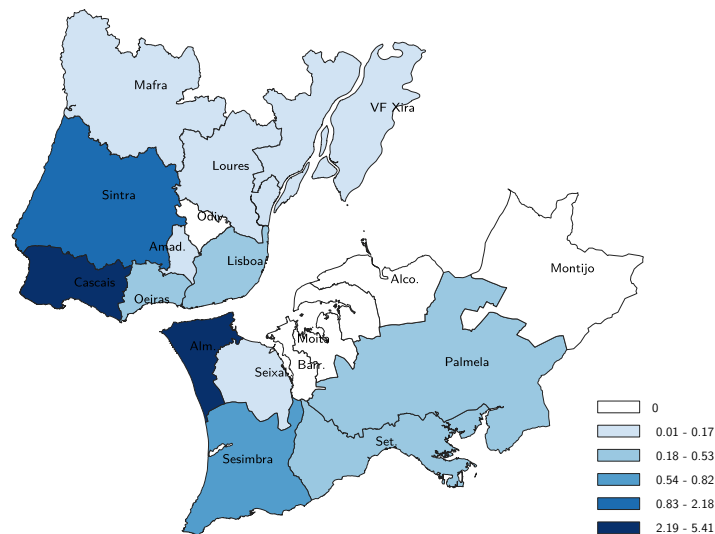


**Figure G.8:** Choropleth map of mean gated enclave surface areas, 2016. Area (ha) figures correspond to the arithmetic mean of all gated enclaves in each municipality.

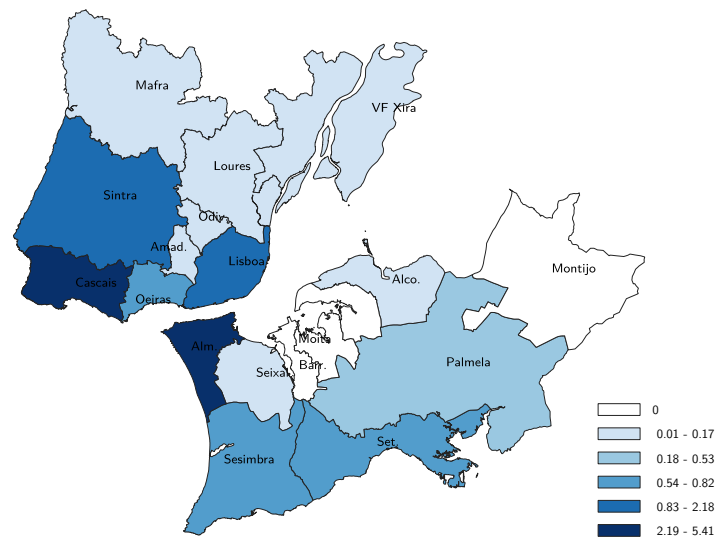
*G Macro Distribution of Contemporary Gated Enclaves*



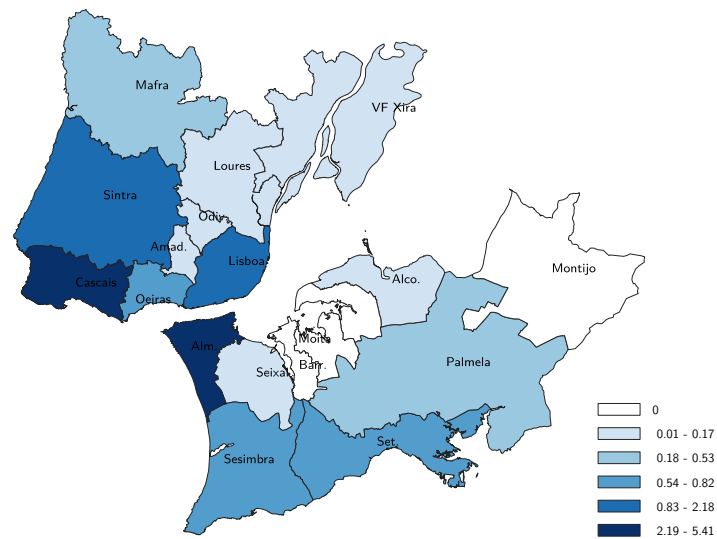
**Figure G.9:** Choropleth map of gated enclave occupation to total land surface area ratio, 1991. Ratio (given as a percentage) corresponds to the total gated enclave surface area divided by the total surface area of a municipality (including land not suitable or authorised for residential construction, but excluding major water areas).



**Figure G.10:** Choropleth map of gated enclave occupation to total land surface area ratio, 2001. Ratio (given as a percentage) corresponds to the total gated enclave surface area divided by the total surface area of a municipality (including land not suitable or authorised for residential construction, but excluding major water areas).

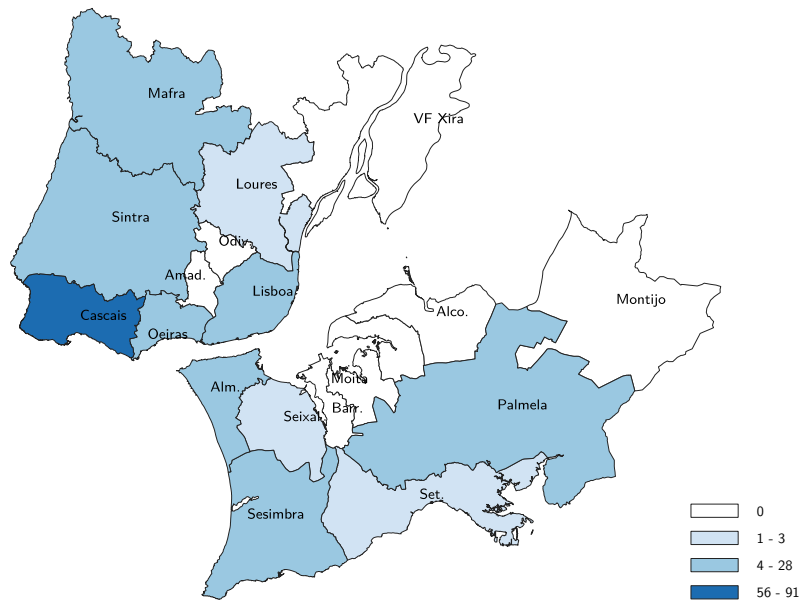


**Figure G.11:** Choropleth map of gated enclave occupation to total land surface area ratio, 2011. Ratio (given as a percentage) corresponds to the total gated enclave surface area divided by the total surface area of a municipality (including land not suitable or authorised for residential construction, but excluding major water areas).

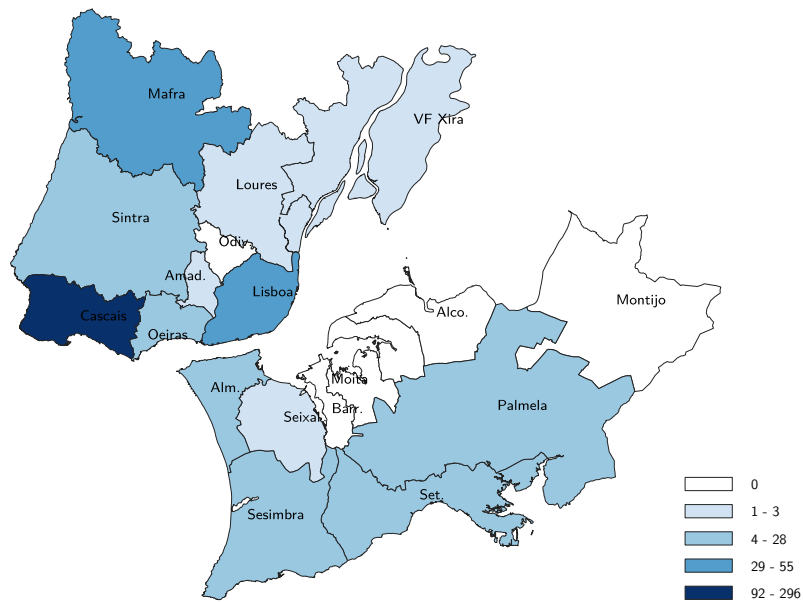


**Figure G.12:** Choropleth map of gated enclave occupation to total land surface area ratio, 2016. Ratio (given as a percentage) corresponds to the total gated enclave surface area divided by the total surface area of a municipality (including land not suitable or authorised for residential construction, but excluding major water areas).

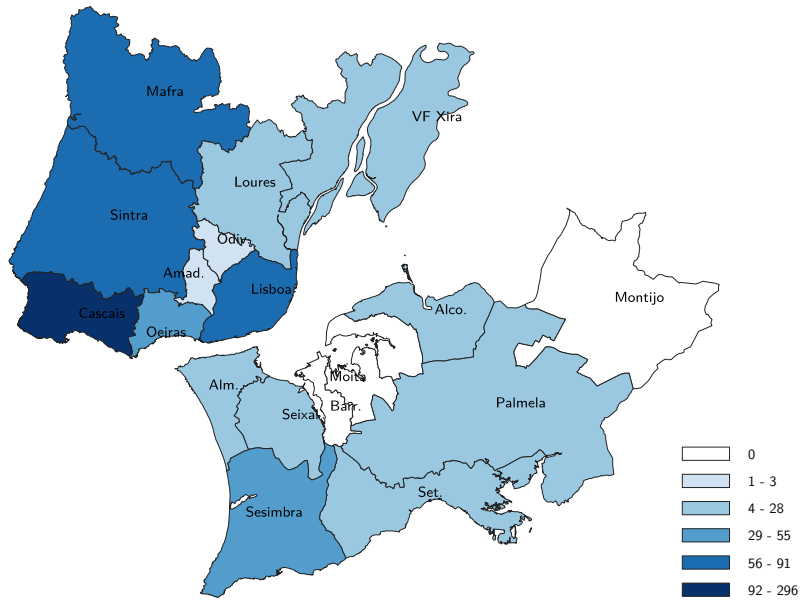
*G Macro Distribution of Contemporary Gated Enclaves*



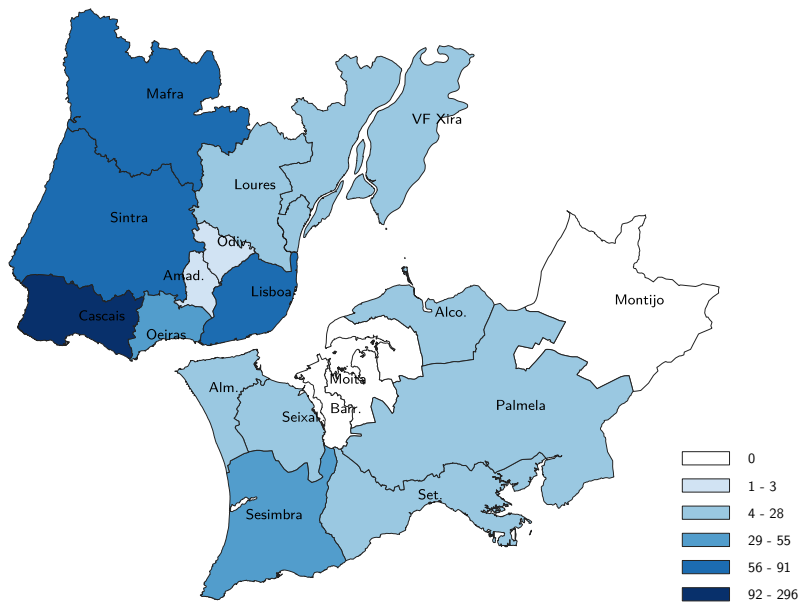
**Figure G.13:** Choropleth map of total gated enclave counts aggregated by municipality, 1991.



**Figure G.14:** Choropleth map of total gated enclave counts aggregated by municipality, 2001.

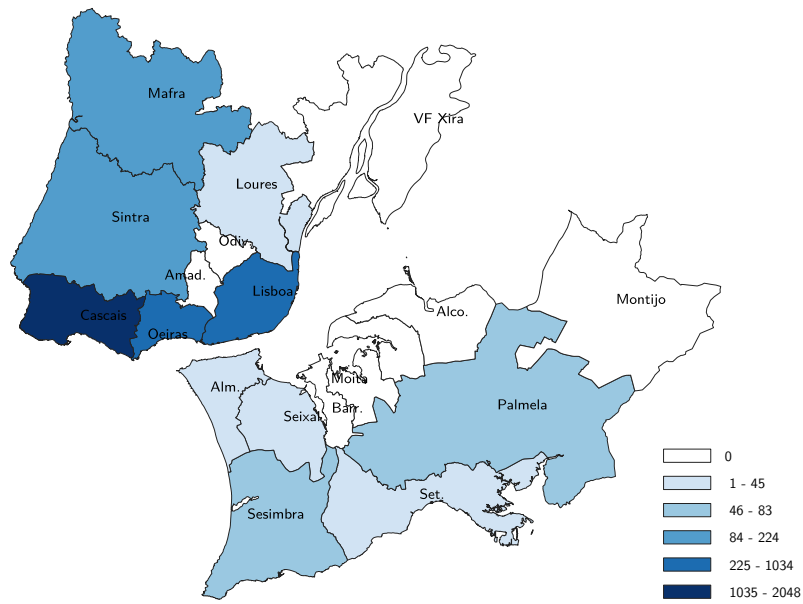


**Figure G.15:** Choropleth map of total gated enclave counts aggregated by municipality, 2011.

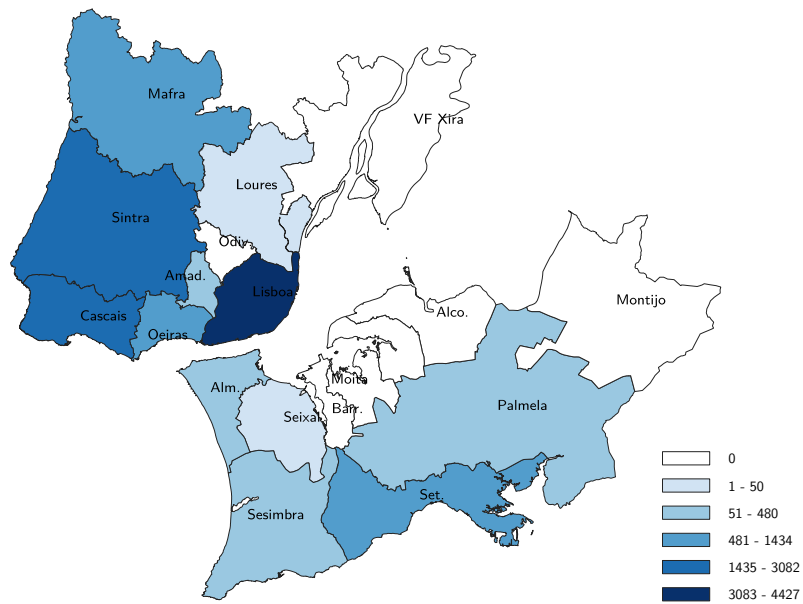


**Figure G.16:** Choropleth map of total gated enclave counts aggregated by municipality, 2016.

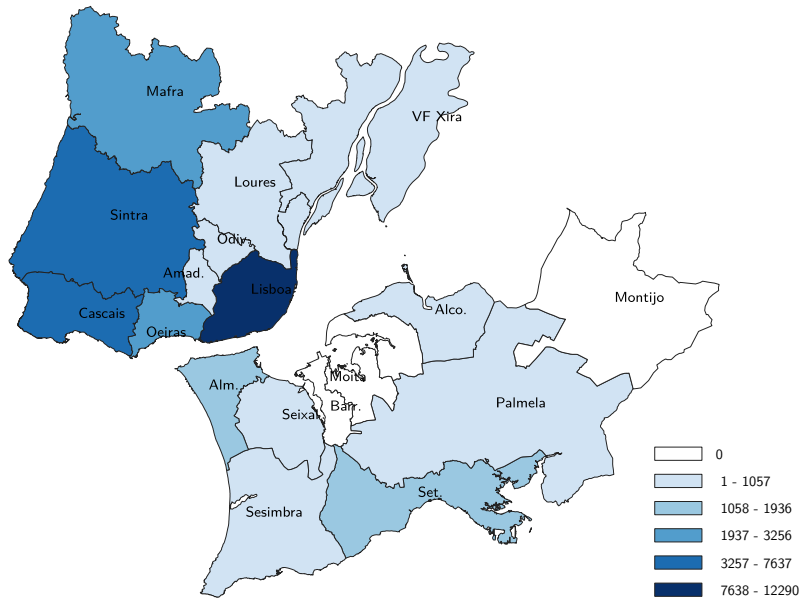
*G Macro Distribution of Contemporary Gated Enclaves*



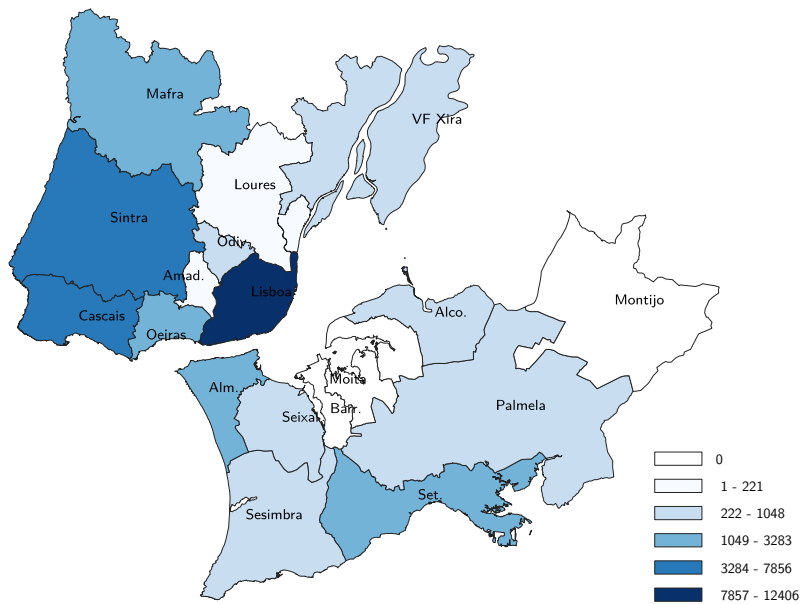
**Figure G.17:** Choropleth map depicting the total gated enclave population aggregated by municipality, 1991.



**Figure G.18:** Choropleth map depicting the total gated enclave population aggregated by municipality, 2001.

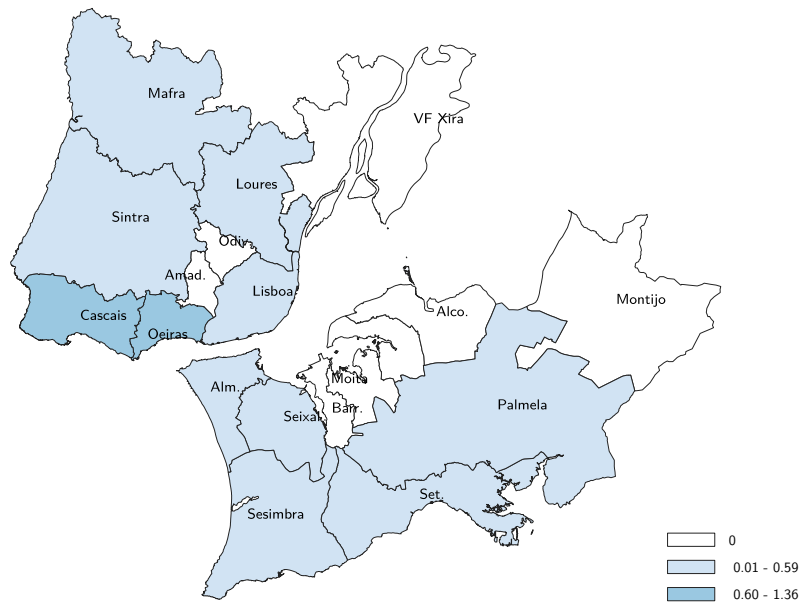


**Figure G.19:** Choropleth map depicting the total gated enclave population aggregated by municipality, 2011.

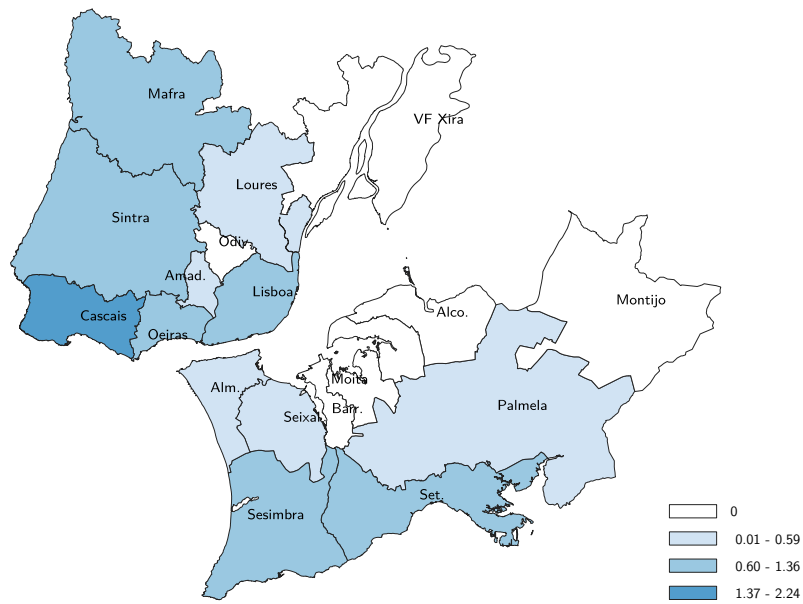


**Figure G.20:** Choropleth map depicting the total gated enclave population aggregated by municipality, 2016.

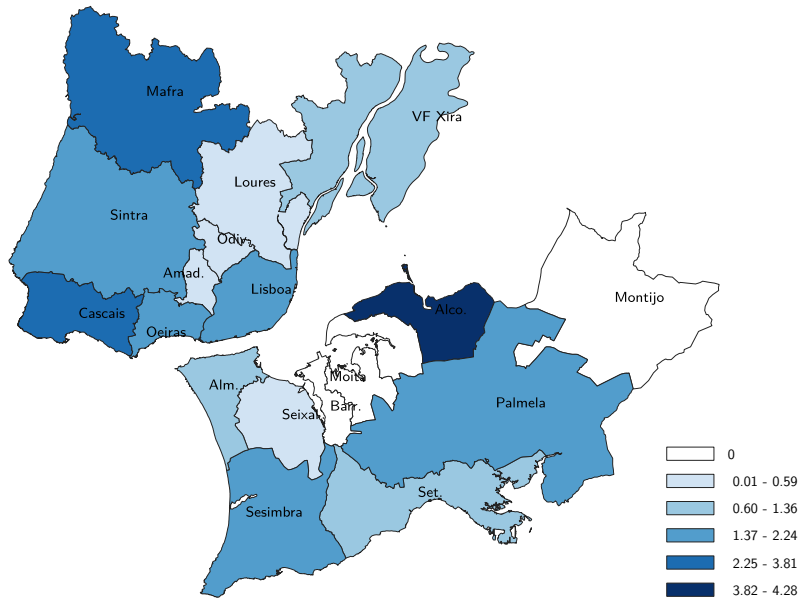
*G Macro Distribution of Contemporary Gated Enclaves*



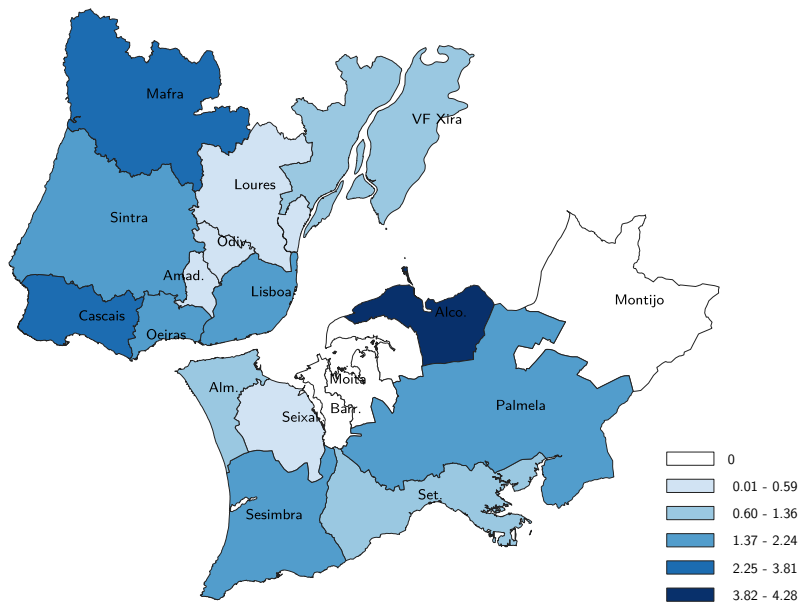
**Figure G.21:** Choropleth map depicting the ratio of the gated enclave population to the municipality population, displayed as percentages, 1991.



**Figure G.22:** Choropleth map depicting the ratio of the gated enclave population to the municipality population, displayed as percentages, 2001.

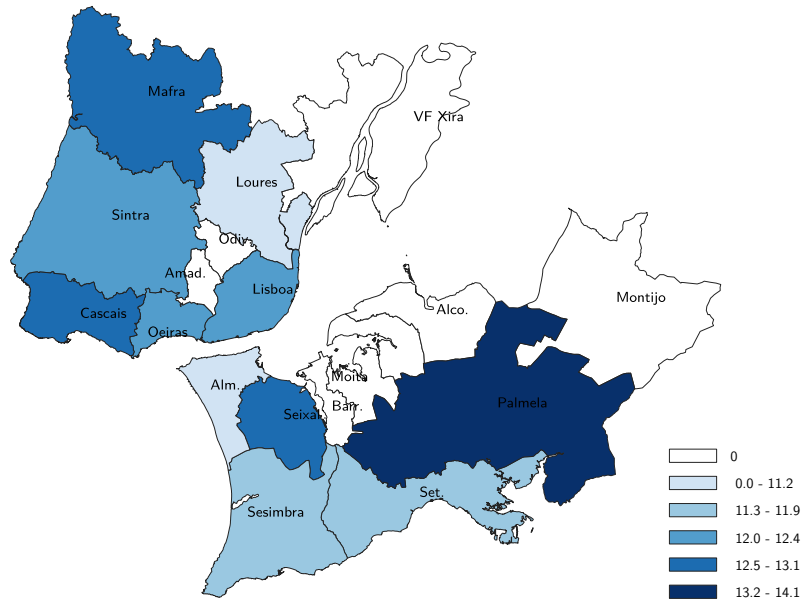


**Figure G.23:** Choropleth map depicting the ratio of the gated enclave population to the municipality population, displayed as percentages, 2011.

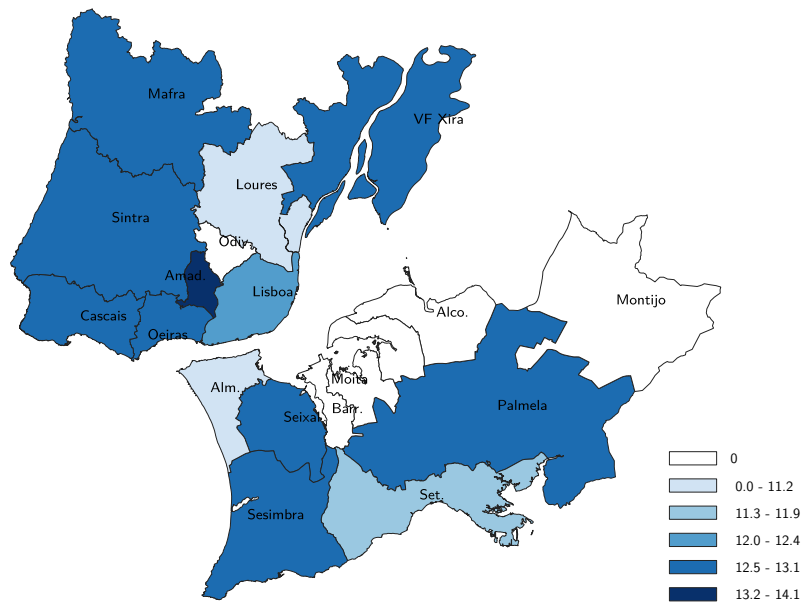


**Figure G.24:** Choropleth map depicting the ratio of the gated enclave population to the municipality population, displayed as percentages, 2016.

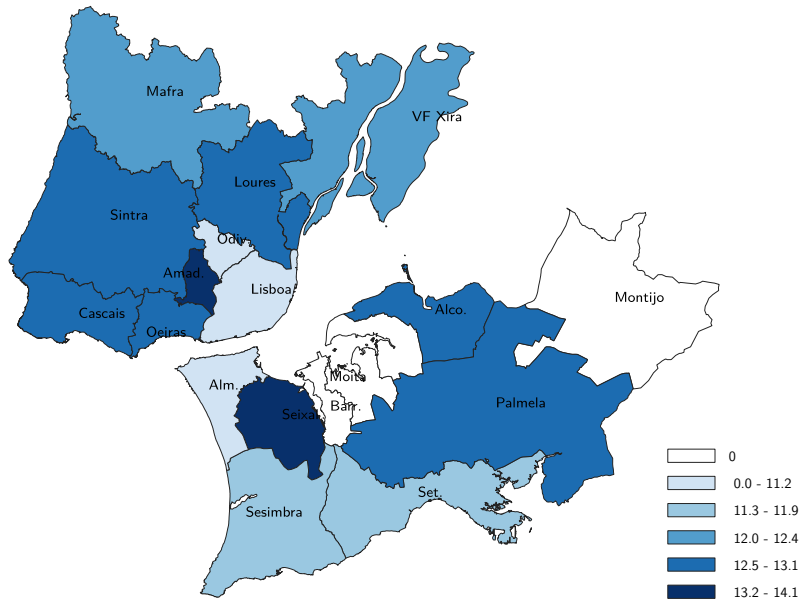
*G Macro Distribution of Contemporary Gated Enclaves*



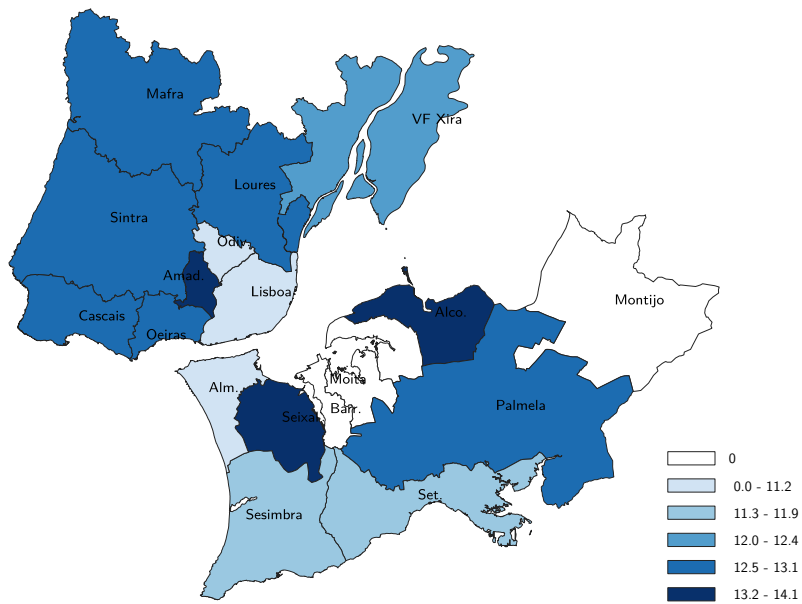
**Figure G.25:** Choropleth map depicting the mean gated enclave isolation-score by municipality, 1991.



**Figure G.26:** Choropleth map depicting the mean gated enclave isolation-score by municipality, 2001.

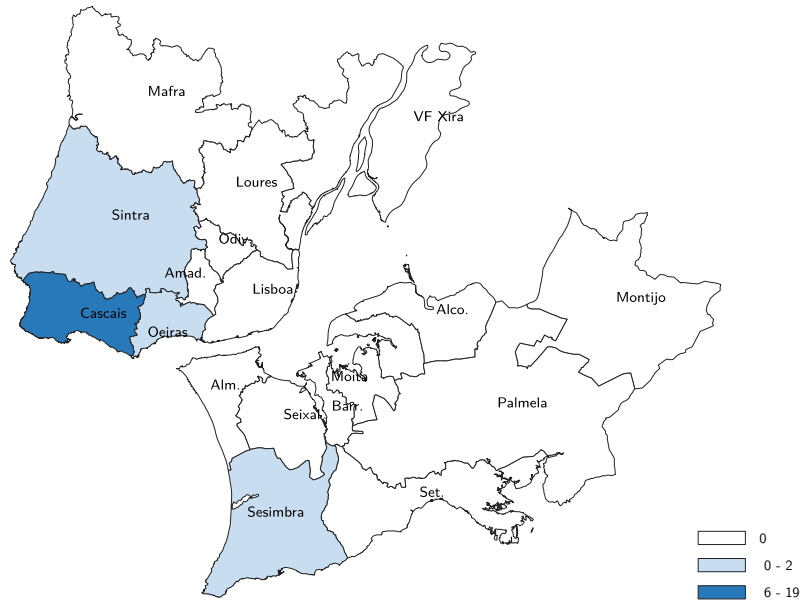


**Figure G.27:** Choropleth map depicting the mean gated enclave isolation-score by municipality, 2011.

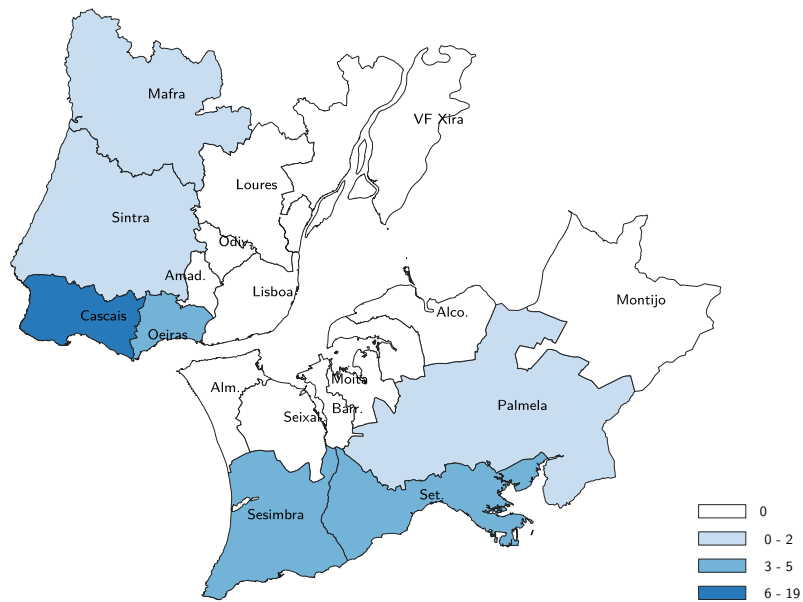


**Figure G.28:** Choropleth map depicting the mean gated enclave isolation-score by municipality, 2016.

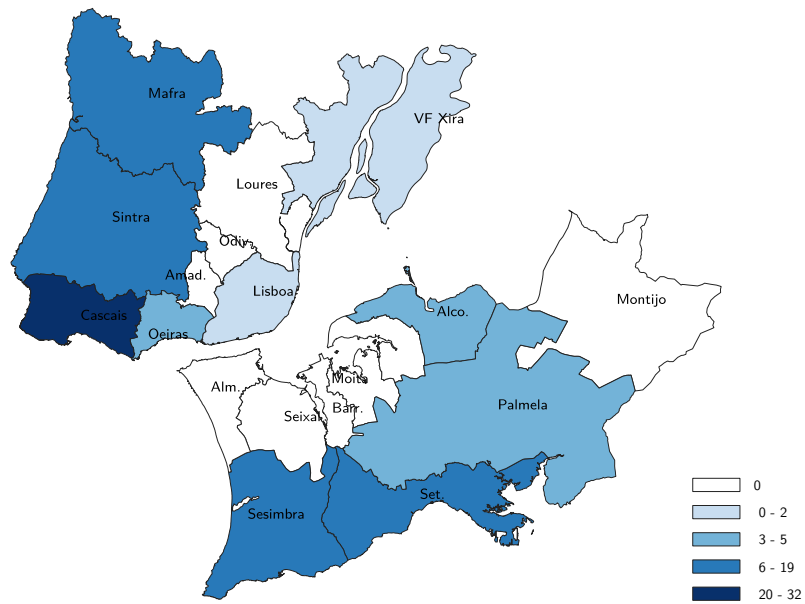
*G Macro Distribution of Contemporary Gated Enclaves*



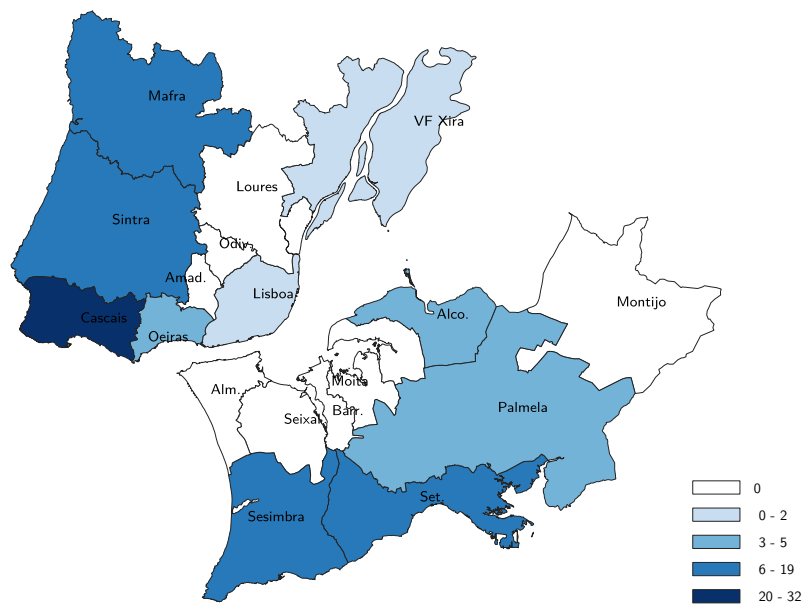
**Figure G.29:** Choropleth map of total C2 type (communal street) gated enclave counts aggregated by municipality, 1991.



**Figure G.30:** Choropleth map of total C2 type (communal street) gated enclave counts aggregated by municipality, 2001.

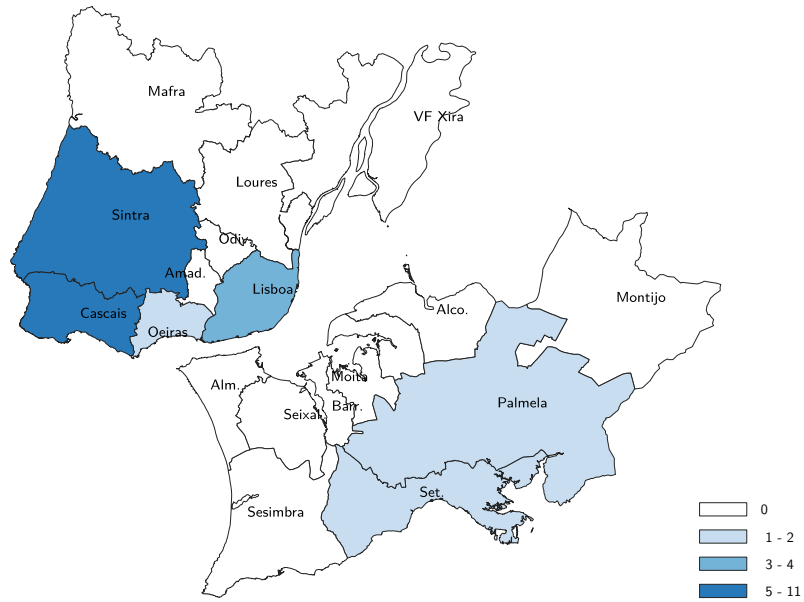


**Figure G.31:** Choropleth map of total C2 type (communal street) gated enclave counts aggregated by municipality, 2011.

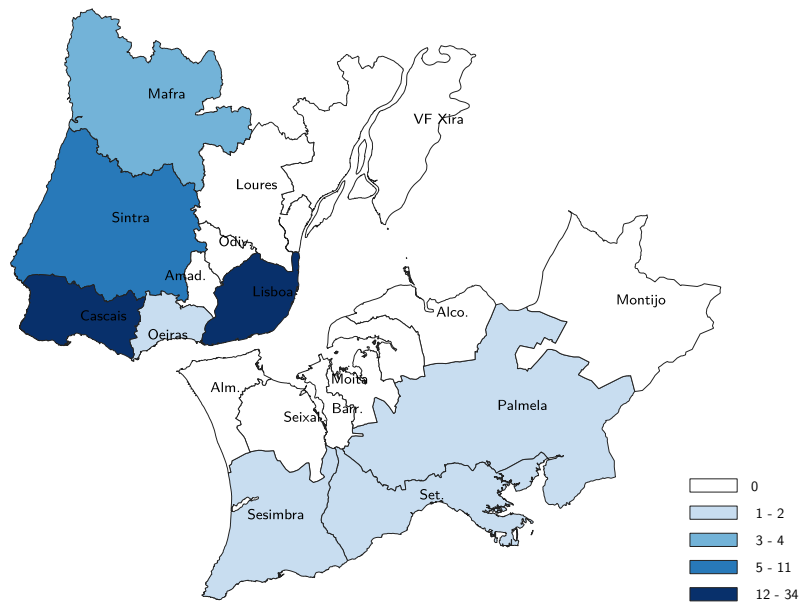


**Figure G.32:** Choropleth map of total C2 type (communal street) gated enclave counts aggregated by municipality, 2016.

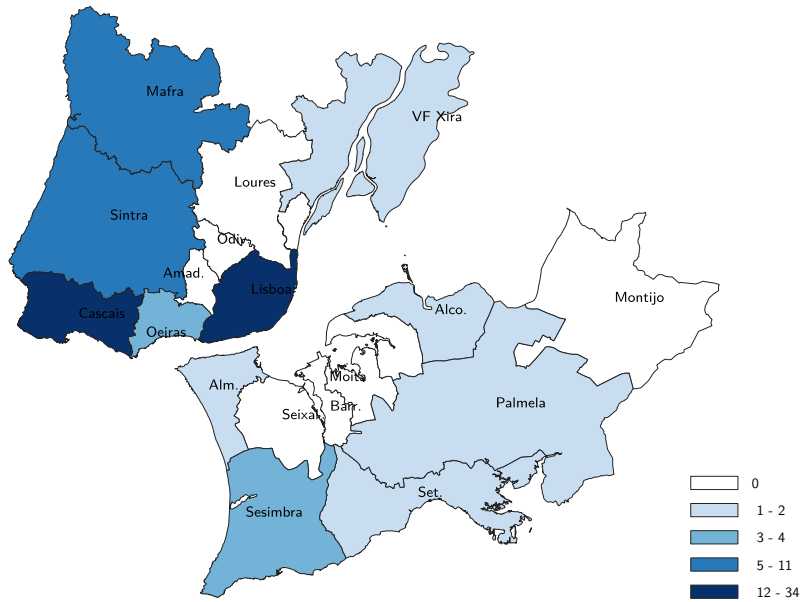
*G Macro Distribution of Contemporary Gated Enclaves*



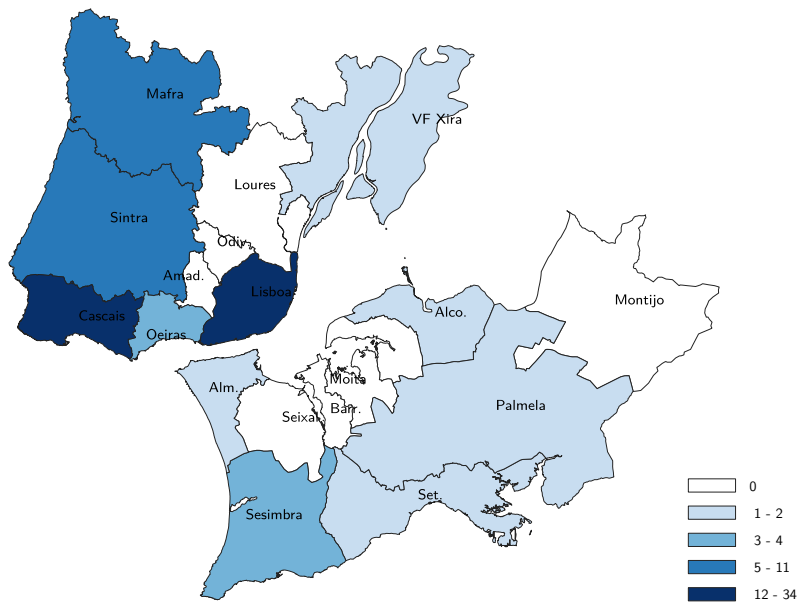
**Figure G.33:** Choropleth map of total C3 type (communal space) gated enclave counts aggregated by municipality, 1991.



**Figure G.34:** Choropleth map of total C3 type (communal space) gated enclave counts aggregated by municipality, 2001.

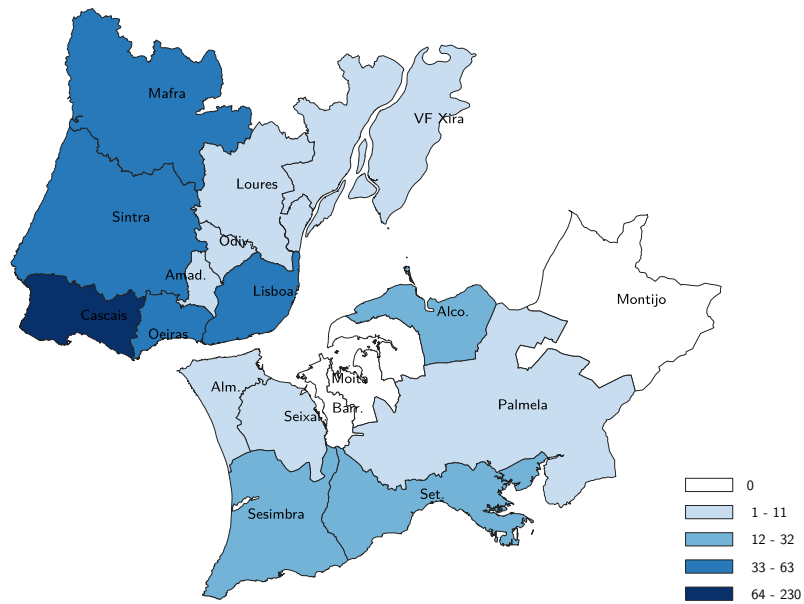


**Figure G.35:** Choropleth map of total C3 type (communal space) gated enclave counts aggregated by municipality, 2011.

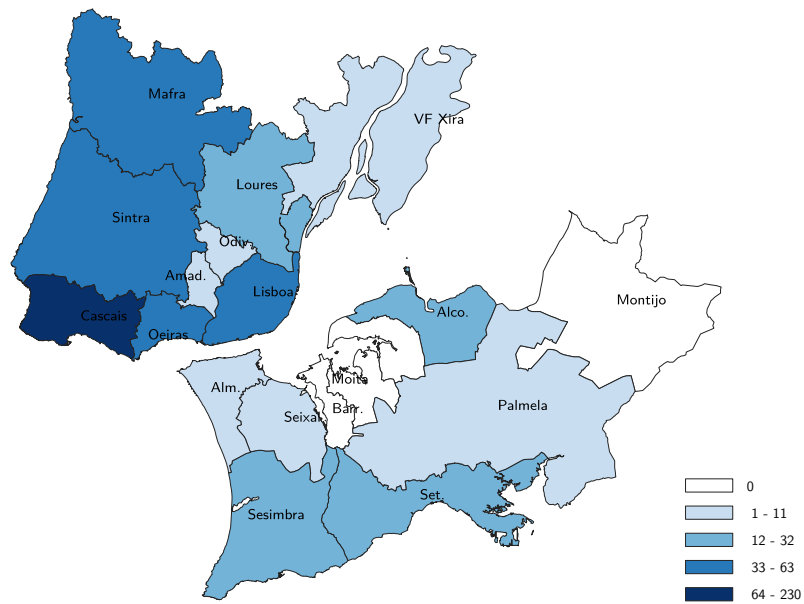


**Figure G.36:** Choropleth map of total C3 type (communal space) gated enclave counts aggregated by municipality, 2016.





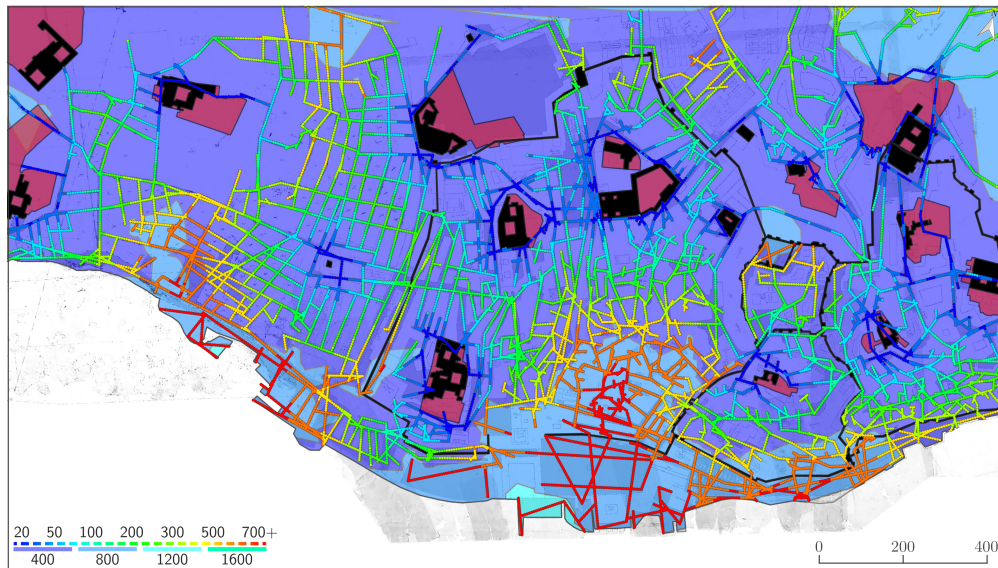
**Figure G.39:** Choropleth map of total C4 type (communal amenities) gated enclave counts aggregated by municipality, 2011.



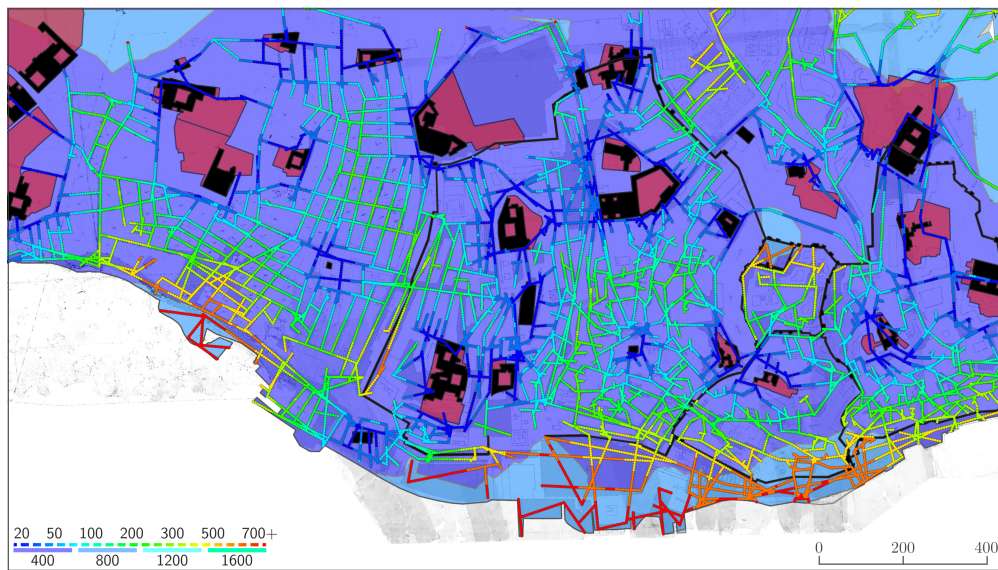
**Figure G.40:** Choropleth map of total C4 type (communal amenities) gated enclave counts aggregated by municipality, 2016.



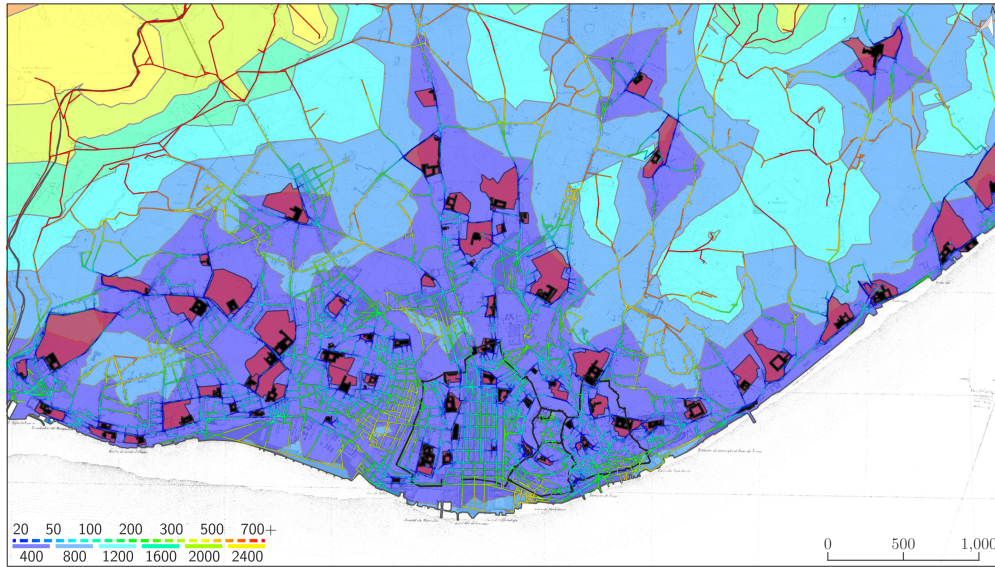
# H Macro Network Analysis of Gated Enclaves



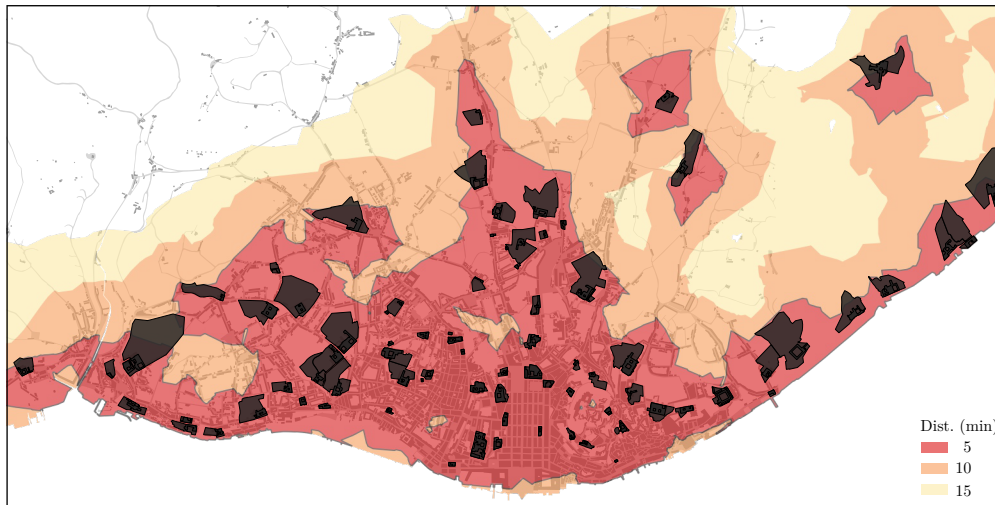
**Figure H.1:** Isochronic map of Lisbon with walled enclaves (in red) of monastic houses (in black) active during the sixteenth century and corresponding pedestrian distance isochrones, in metres, calculated according to main entry points of monasteries (graduated shaded areas, 400–2 400 m), and according to enclave walls (graduated street lines, 20–700 m+).



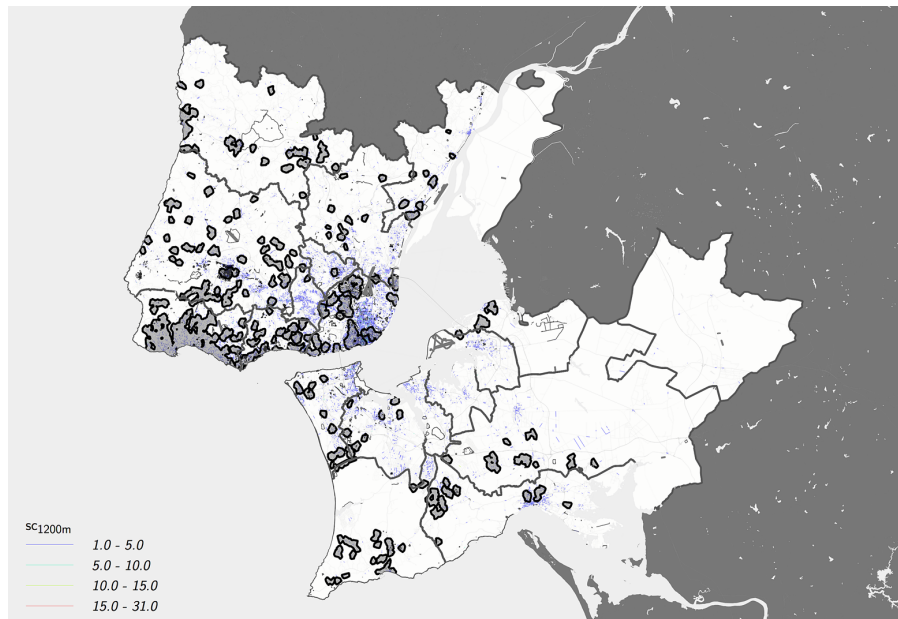
**Figure H.2:** Isochronic map of Lisbon with walled enclaves (in red) of monastic houses (in black) active during the seventeenth century and corresponding pedestrian distance isochrones, in metres, calculated according to main entry points of monasteries (graduated shaded areas, 400–2 400 m), and according to enclave walls (graduated street lines, 20–700 m+).



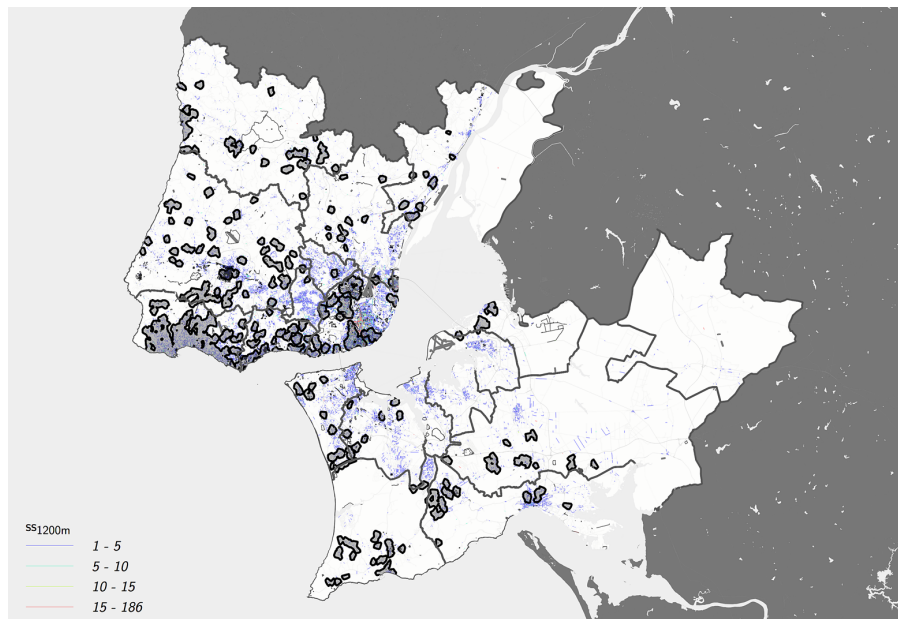
**Figure H.3:** Isochronic map of Lisbon with walled enclaves (in red) of monastic houses (in black) active during the eighteenth century and corresponding pedestrian distance isochrones, in metres, calculated according to main entry points of monasteries (graduated shaded areas, 400–2 400 m), and according to enclave walls (graduated street lines, 20–700 m+).



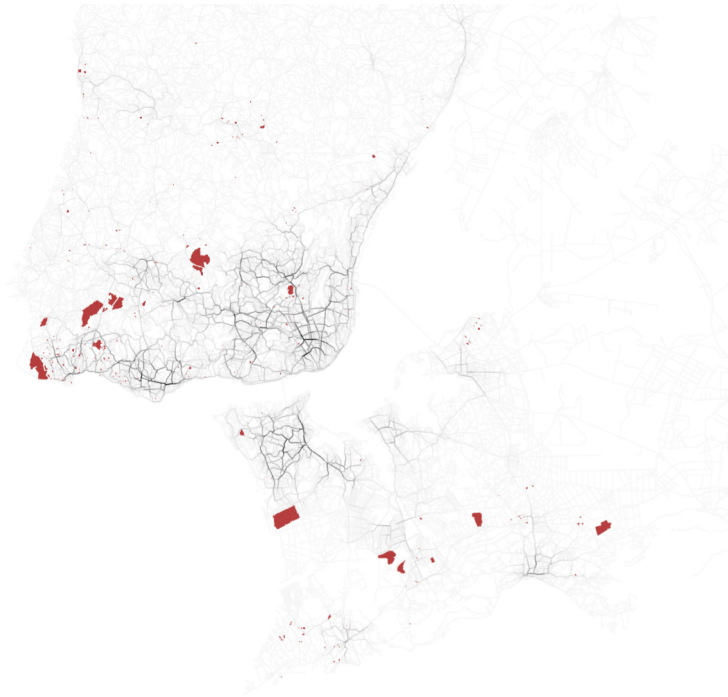
**Figure H.4:** Isochronic map of Lisbon with walled enclaves (in red) of monastic houses (in black) active during the early nineteenth century and corresponding pedestrian distance isochrones, in minutes, calculated according to main entry points of monasteries (graduated shaded areas, 400–2 400 m), and according to enclave walls (graduated street lines, 20–700 m+).



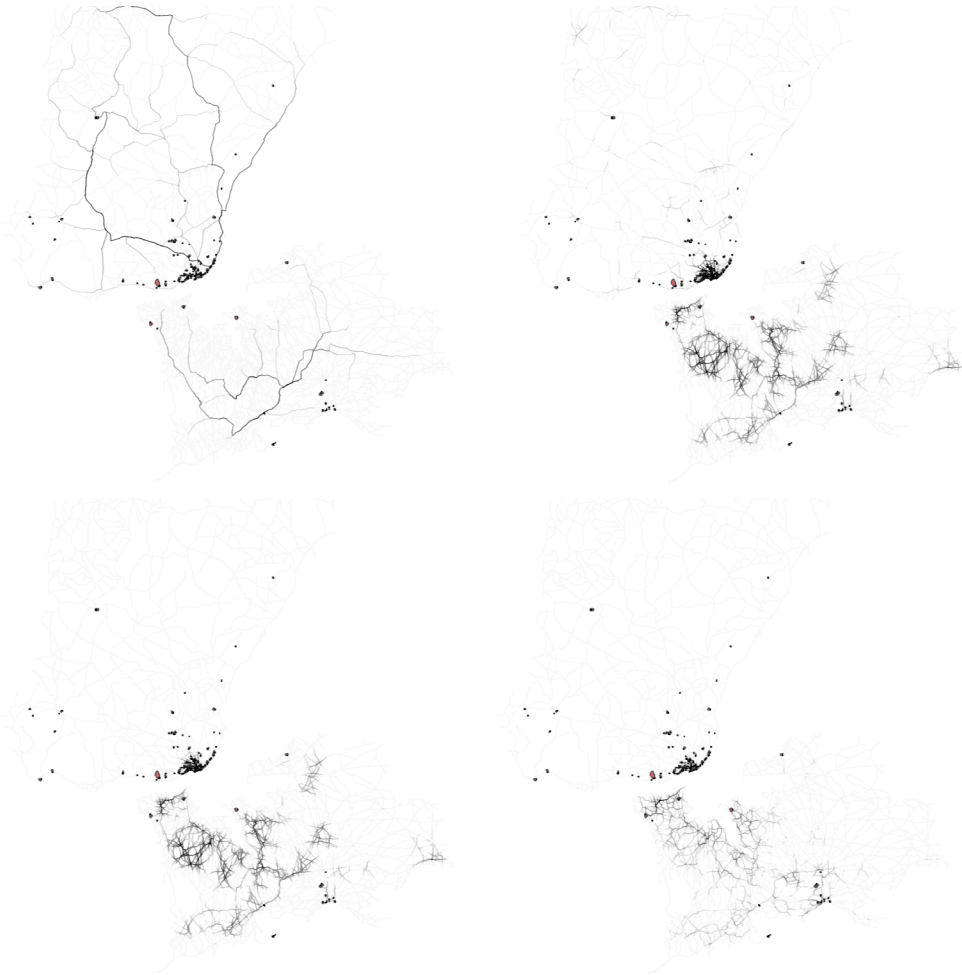
**Figure H.5:** Segment commerce map of the AML, showing the calculated SC (representing commerce count per street segment), and the gated enclave five minute isochrone clusters.



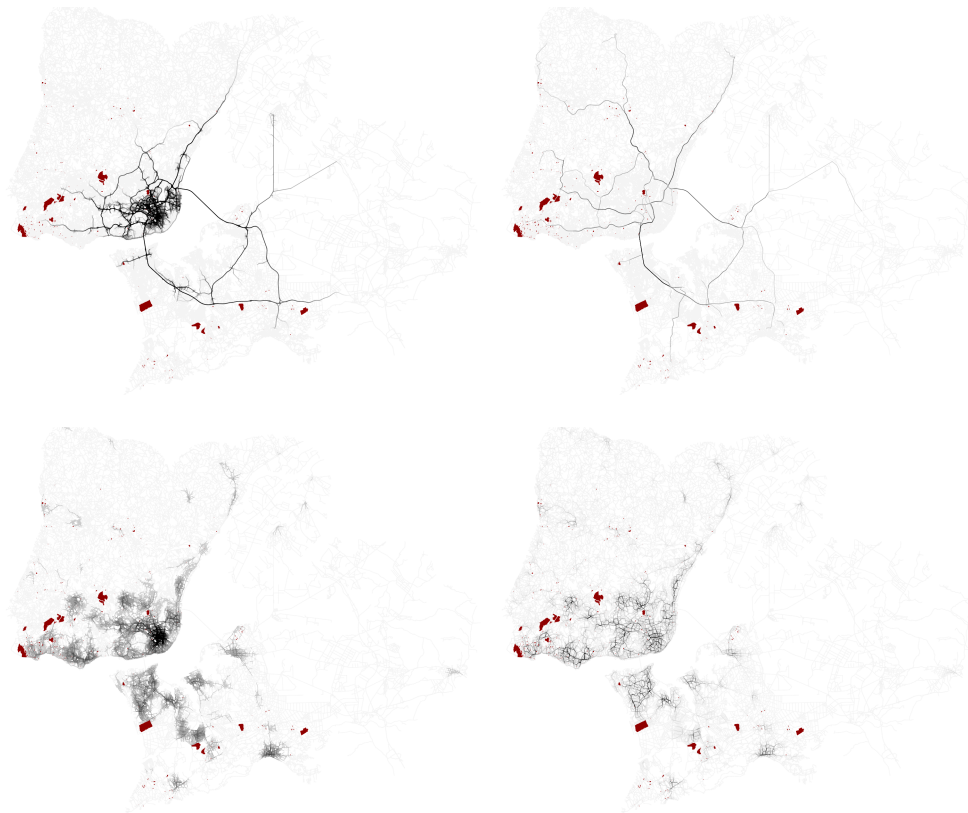
**Figure H.6:** Segment service map of the AML, showing the calculated SS (representing service sector count per street segment), and the gated enclave five minute isochrone clusters.



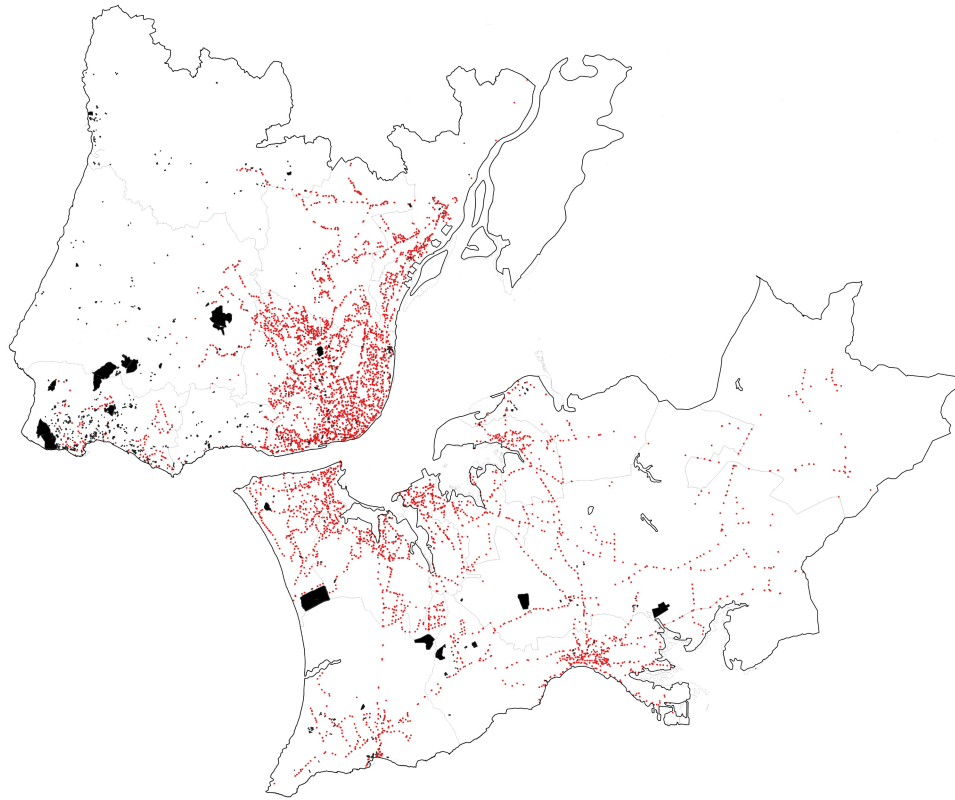
**Figure H.7:** Syntax choice skeleton at  $r = 4800$  in the AML vehicular network and its enclaves, in red.



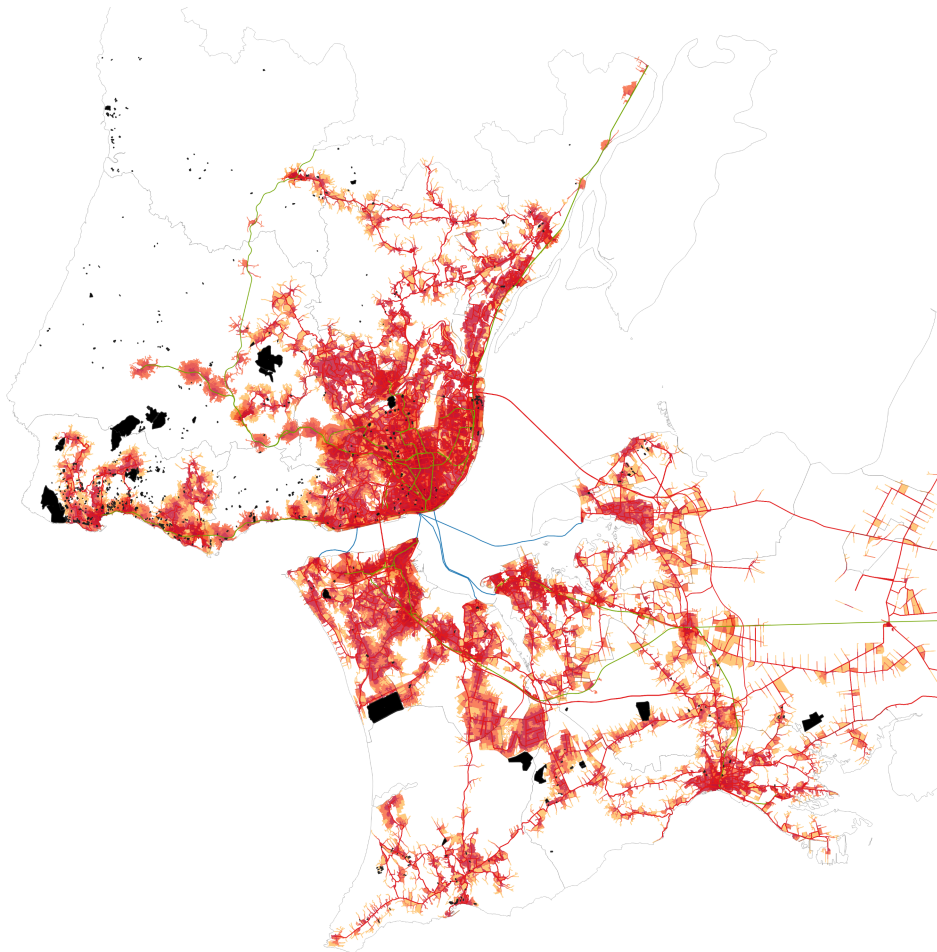
**Figure H.8:** Main syntax patterns in the late modern AML



**Figure H.9:** Main syntax patterns in the AML



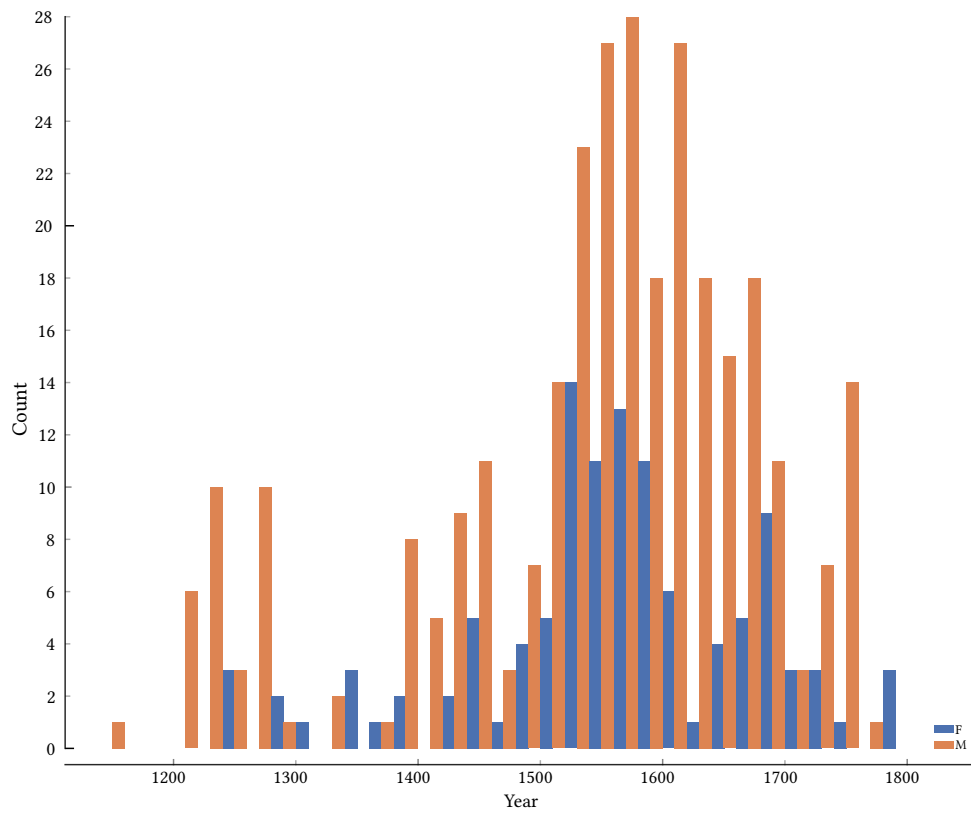
**Figure H.10:** Public transport stops in the Lisbon Metropolitan Area, including bus, subway, railway, and ferry systems, in red. Gated enclaves depicted according to their walled footprints in black.



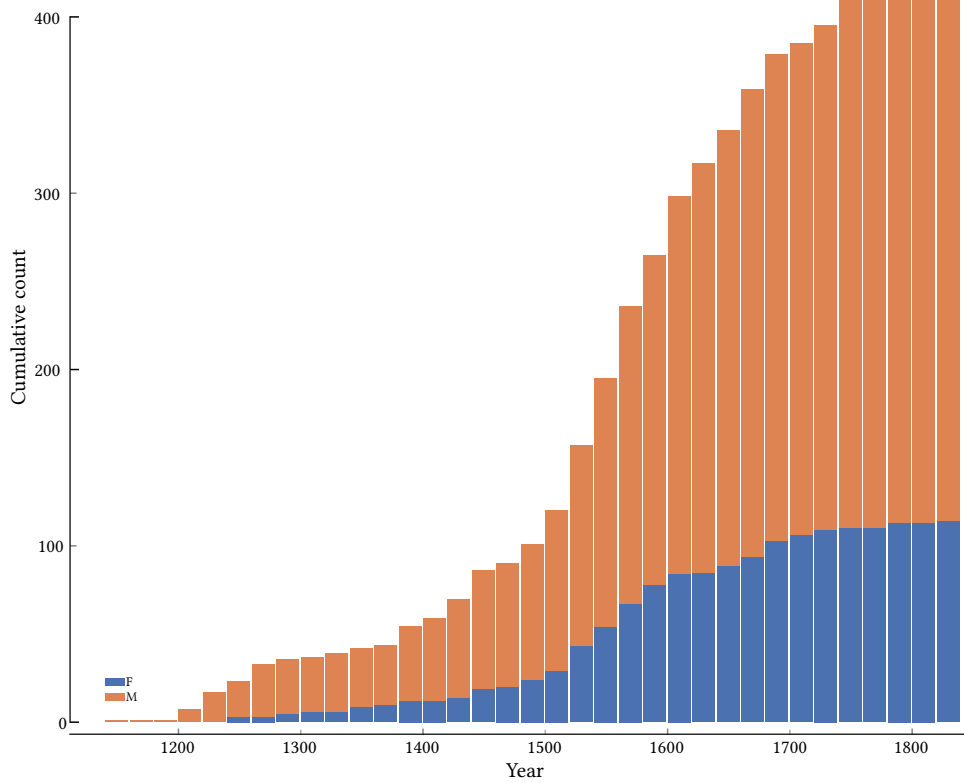
**Figure H.11:** Public transport routes in the Lisbon Metropolitan Area with respective pedestrian isochrones calculated according to a 5, 10, and 15 minute walk from each stop. North and south subway and railway systems in green; local, municipal, and metropolitan bus systems in red; ferry systems in blue. Gated enclaves depicted according to their walled footprints in black.



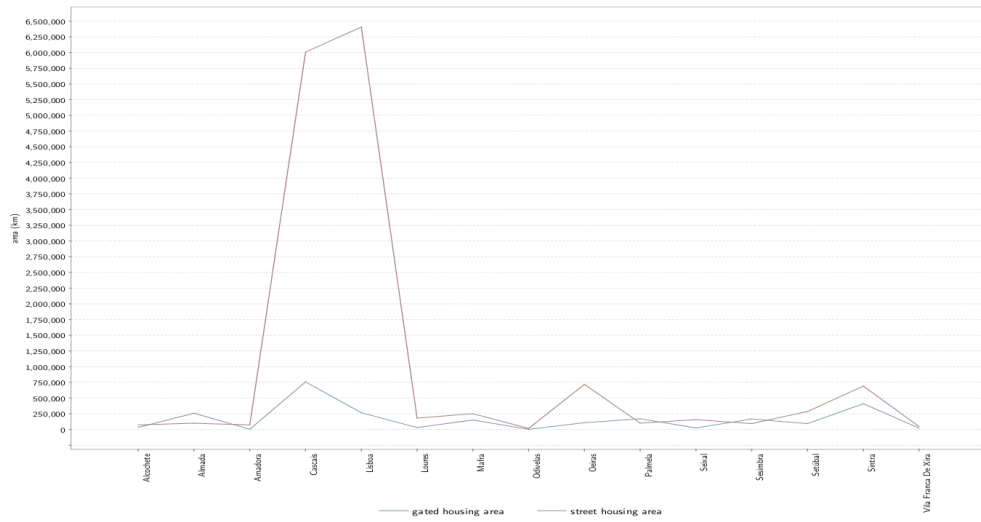
# I Statistical Analysis



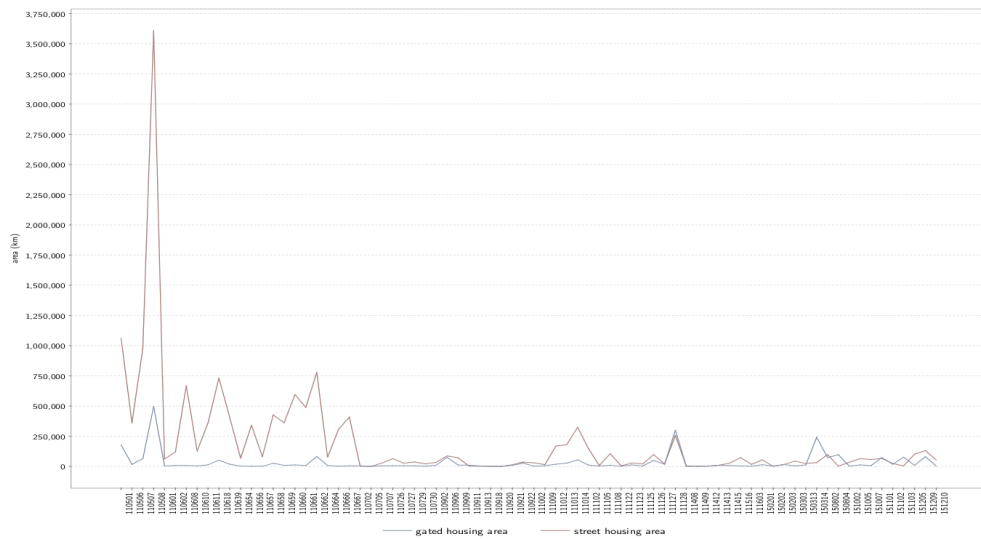
**Figure I.1:** Distribution of total count of monasteries in Portugal, from 1100 to 1900, binned at twenty year intervals, and grouped by type. Male: blue, female: orange. Based on data in (Azevedo, 2000b).



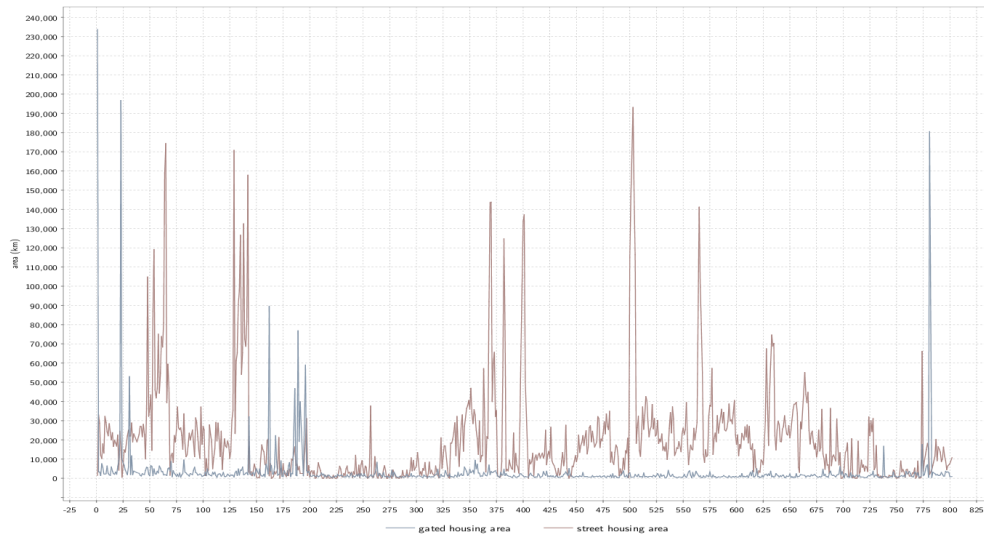
**Figure I.2:** Cumulative distribution of total count of monasteries in Portugal, from 1100 to 1900, binned at twenty year intervals, and grouped by type. Male: blue, female: orange. Based on data in (Azevedo, 2000b).



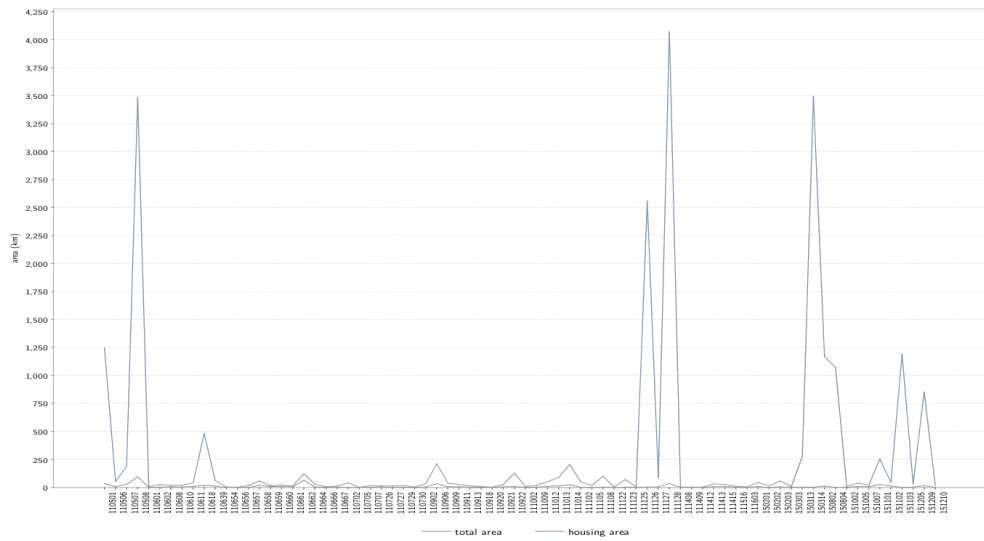
**Figure I.3:** Footprint area (km<sup>2</sup>) occupied by housing buildings (exterior space subtracted) for housing within gated enclaves versus street housing within a 1.2 km buffer of each gated enclave, aggregated by municipality.



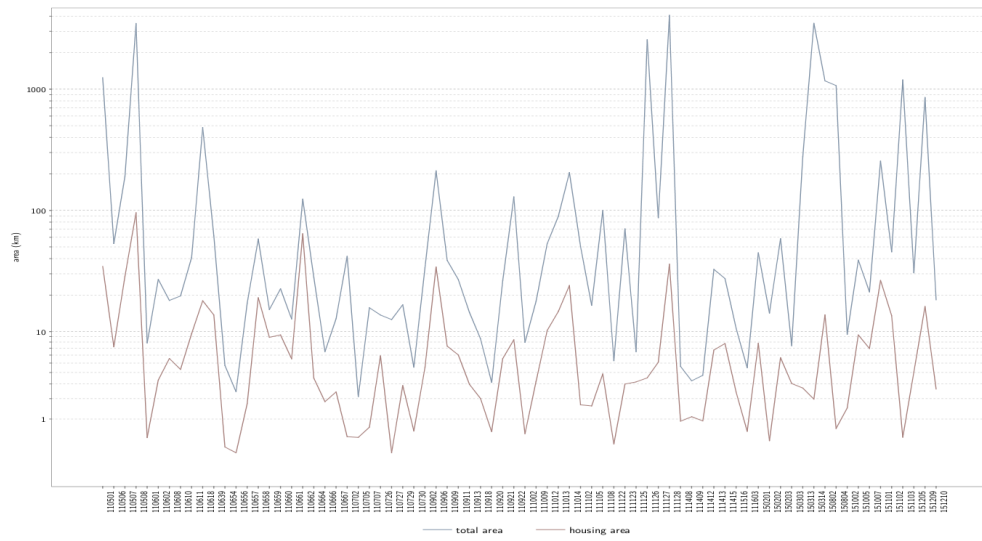
**Figure I.4:** Footprint area (km<sup>2</sup>) occupied by housing buildings (exterior space subtracted) for housing within gated enclaves versus street housing within a 1.2 km buffer of each gated enclave, aggregated by civil parish.



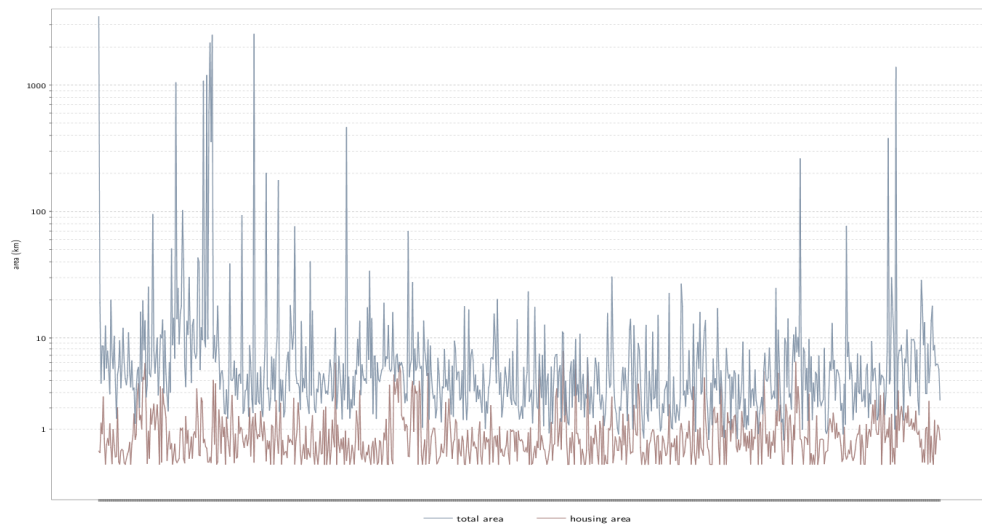
**Figure I.5:** Footprint area (km<sup>2</sup>) occupied by housing buildings (exterior space subtracted) for housing within each gated enclave versus street housing within a 1.2 km buffer of each gated enclave. Figures are per gated enclave.



**Figure I.6:** Footprint area (km<sup>2</sup>) occupied by housing buildings within the gated enclave versus total area occupied by the gated enclave, aggregated by civil parish.

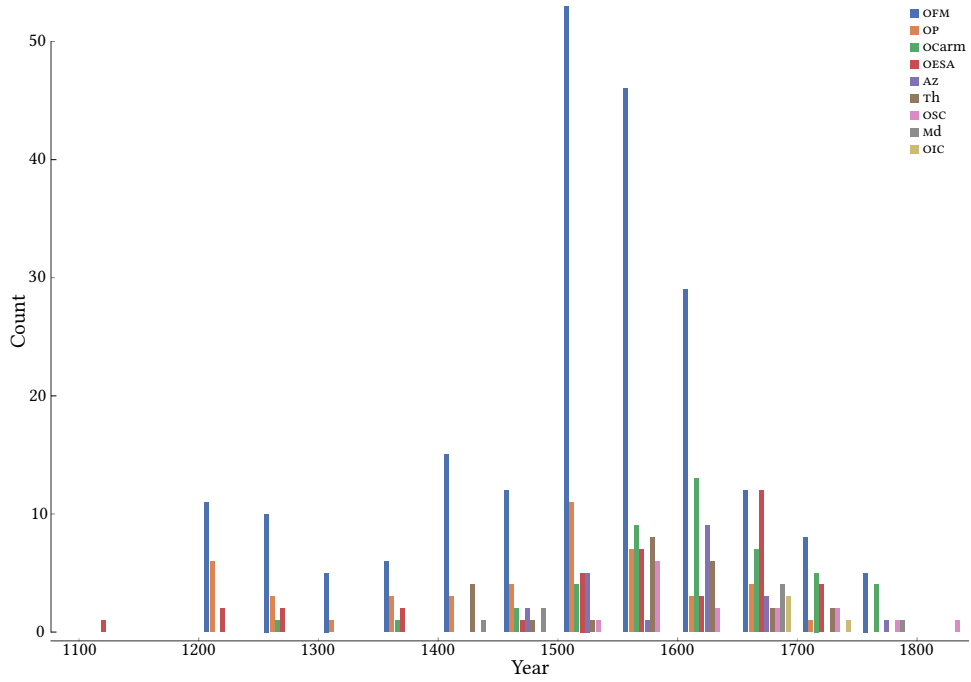


**Figure I.7:** Footprint area (km<sup>2</sup>, in a logarithmic scale) occupied by housing buildings within the gated enclave versus total area occupied by the gated enclave, aggregated by civil parish

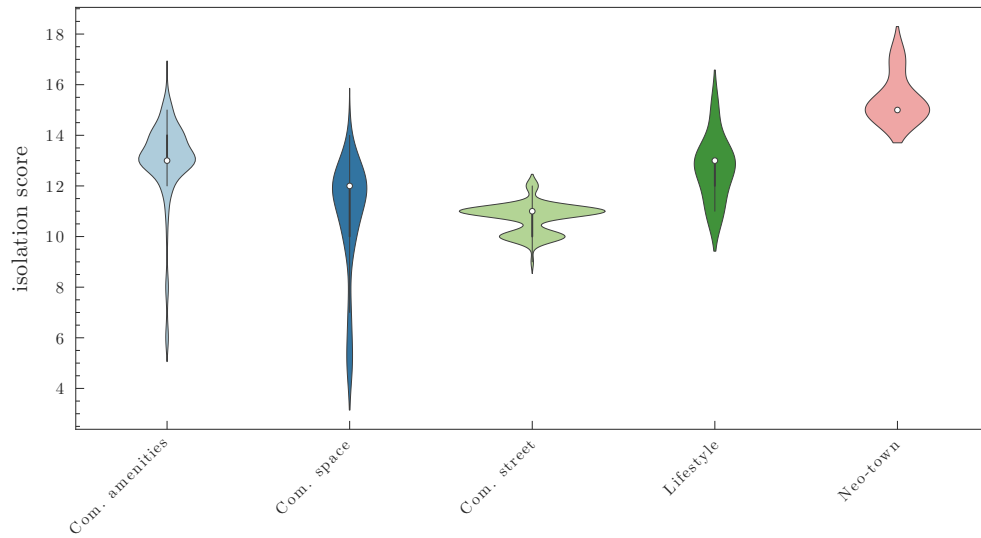


**Figure I.8:** Footprint area (km<sup>2</sup>, in a logarithmic scale) occupied by housing buildings within the gated enclave versus total area occupied by the gated enclave. Figures are per gated enclave.

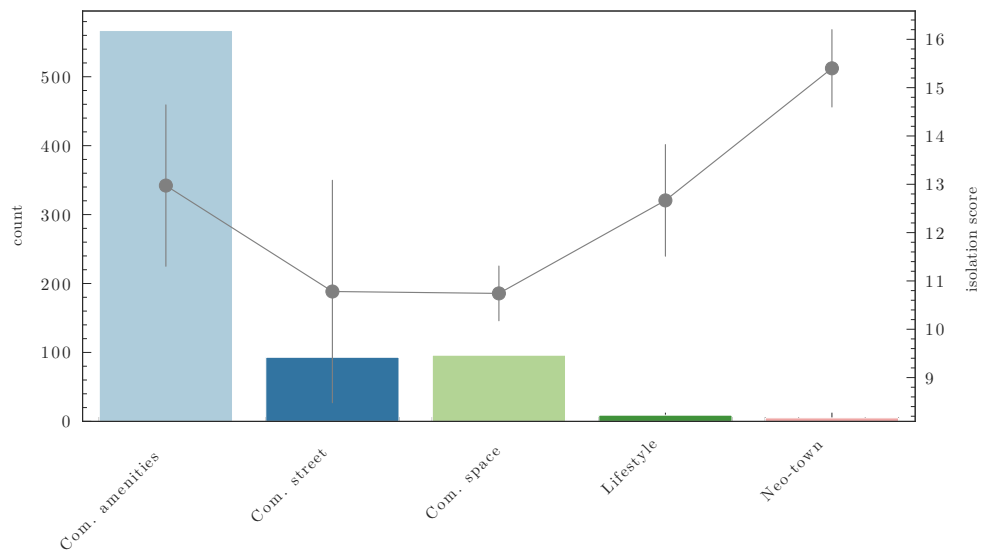




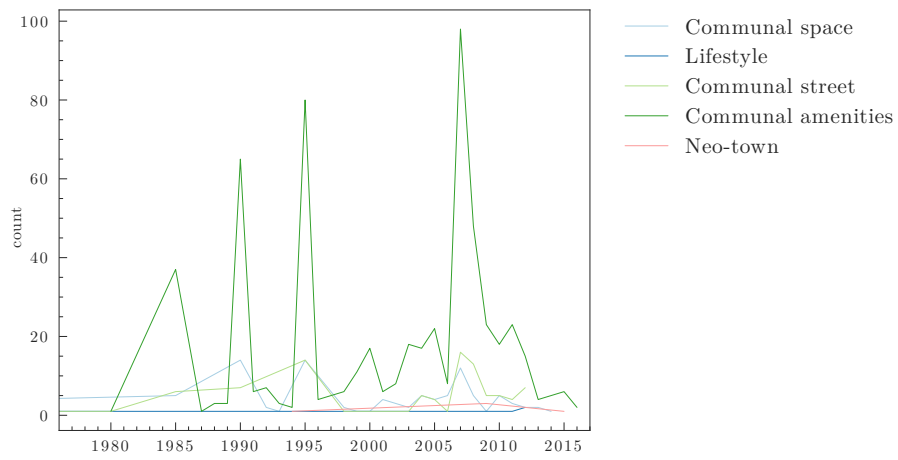
**Figure I.11:** Distribution of total count of monasteries in Portugal, from 1100 to 1900, binned at fifty year intervals, and grouped by main religious order. Standard acronyms used (see List of Acronyms) with the exception of Th, denoting Third orders, AZ, denoting monasteries located in the Azores islands, and Md, denoting monasteries located in the Madeira islands. Based on data in (Azevedo, 2000b).



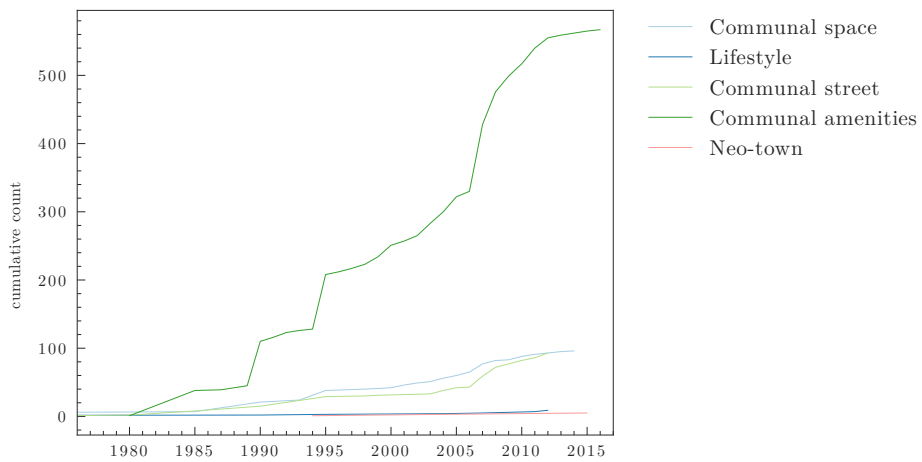
**Figure I.12:** Isolation scores of gated enclave types depicted as a violin plot with IS isolation-score on the left y-axis, and kernel density estimation of the underlying distribution on each categorical x-axis.



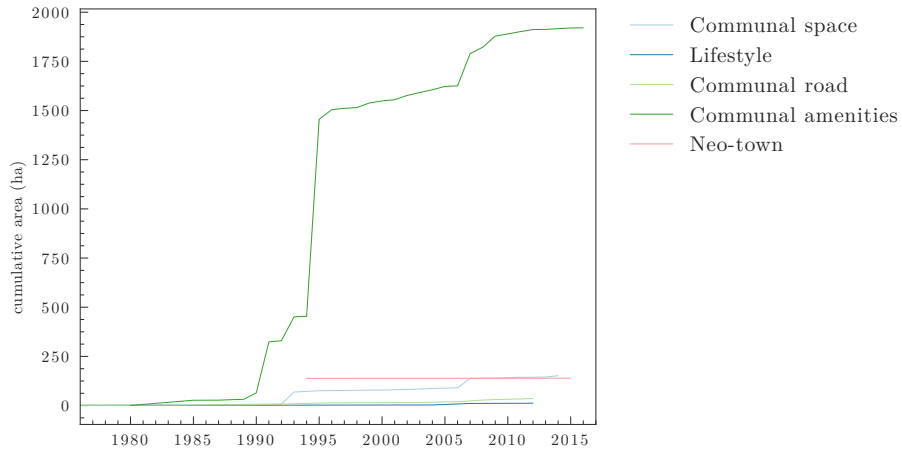
**Figure I.13:** Gated enclaves by type and isolation in the AML. Total count of gated enclaves depicted as bar plots on left y-axis, IS isolation-score depicted as point plots with standard deviation bars on right y-axis.



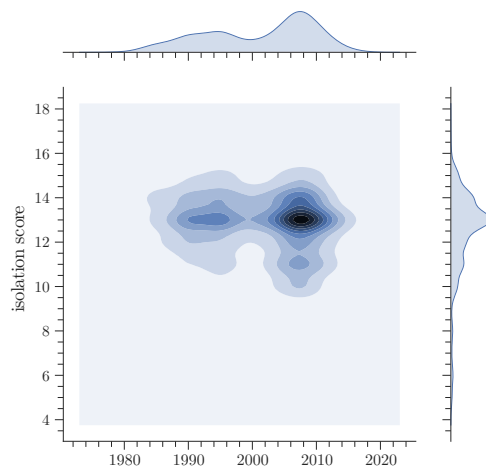
**Figure I.14:** Types of gated enclaves in the AML. Gated enclaves count, by year and type (horizontal axis is in the 1976-2016 range limit).



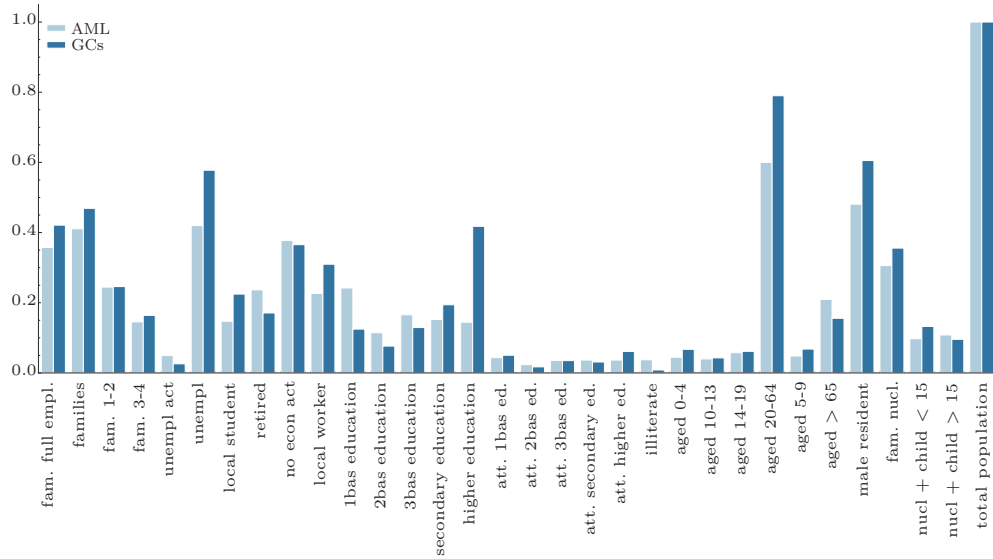
**Figure I.15:** Evolution of types of gated enclaves in the AML. Gated enclaves cumulative count, by year and type (horizontal axis is in the 1976-2016 range limit).



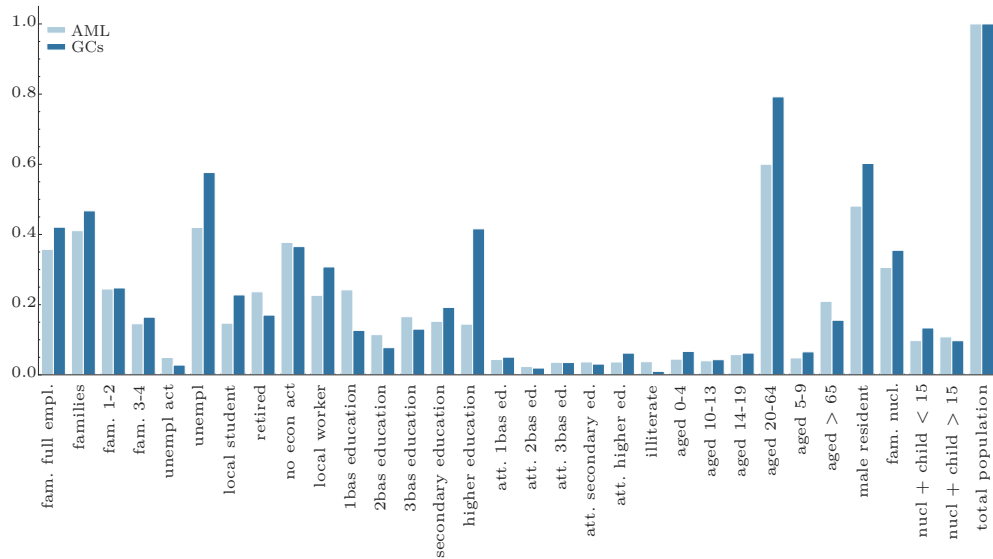
**Figure I.16:** Evolution of area footprint of gated enclaves in the AML. Gated enclaves cumulative area (ha), by year and type (horizontal axis is in the 1976-2016 range limit).



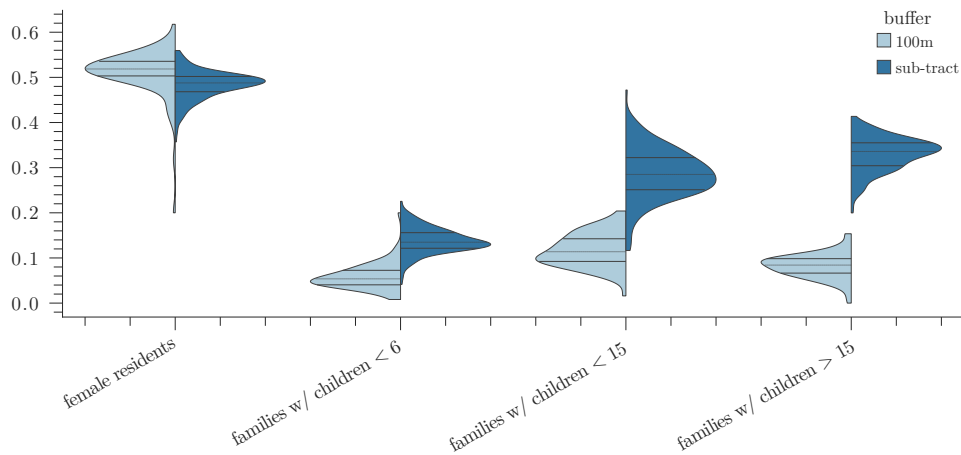
**Figure I.17:** Univariate and bivariate kernel density estimates joint plot of isolation-score vs foundation year of gated enclave.



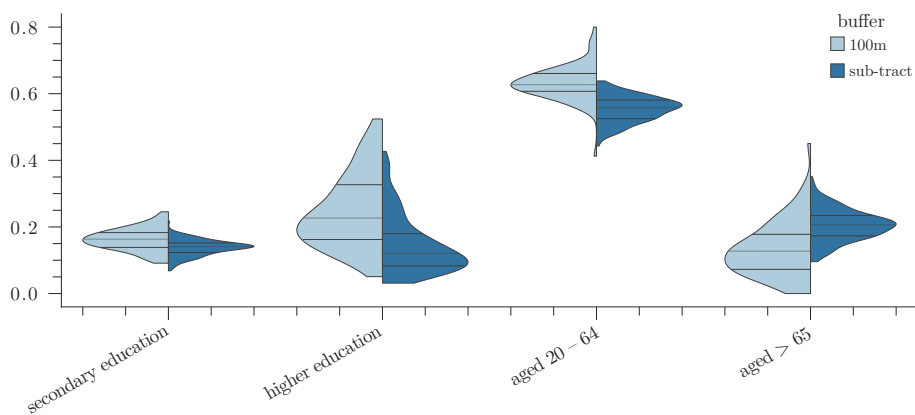
**Figure I.18:** Population attributes AML vs enclaves 2011. Bar plot depicting the arithmetic mean ratio (to the total population) for the AML of 31 2011 census attributes, and the equivalent mean ratio (to the total gated enclave population) for all gated enclaves in the AML in 2011 (using disaggregated data to the building level).



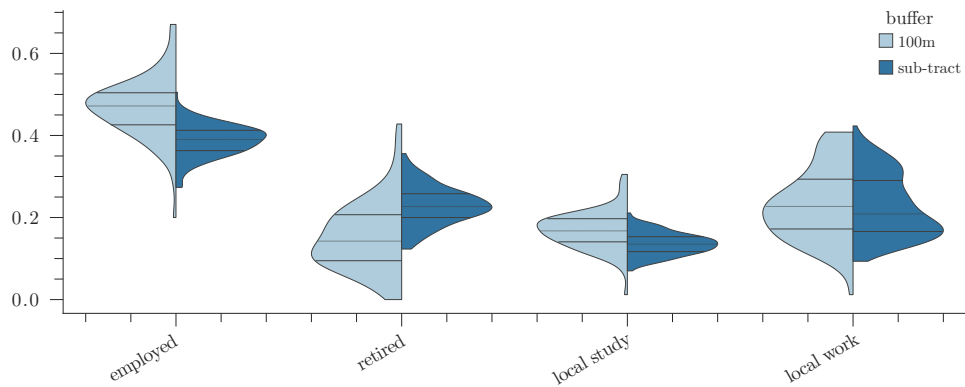
**Figure I.19:** Population attributes AML vs enclaves 2016. Bar plot depicting the arithmetic mean ratio (to the total population) for the AML of 31 2011 census attributes, and the equivalent mean ratio (to the total gated enclave population) for all gated enclaves in the AML in 2016 (using disaggregated data to the building level).



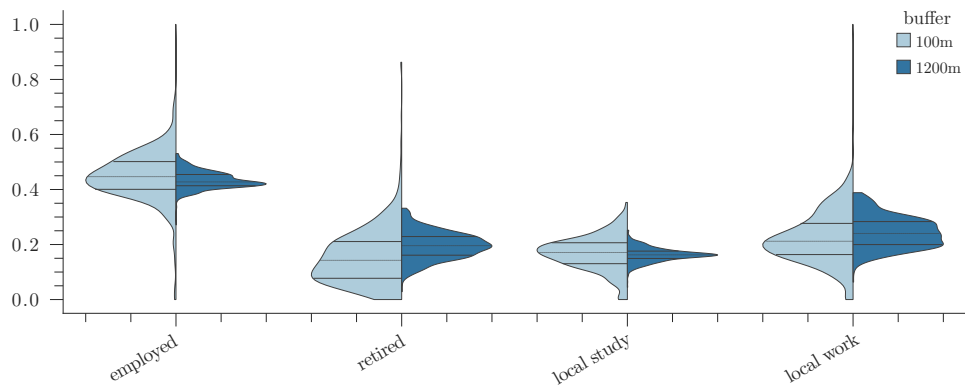
**Figure I.20:** Household attributes of gated enclave population versus wider census sub-tract. Violin plot depicting the arithmetic mean ratio (to the total population) for the population of the total area of the 2011 census sub-tracts of all gated enclaves in the AML in 2016, and the equivalent mean ratio for the population of the total area of a 100 m buffer of all gated enclaves (using disaggregated data to the building level).



**Figure I.21:** Educational and age attributes of gated enclave population versus wider census sub-tract. Violin plot depicting the arithmetic mean ratio (to the total population) for the population of the total area of the 2011 census sub-tracts of all gated enclaves in the AML in 2016, and the equivalent mean ratio for the population of the total area of a 100 m buffer of all gated enclaves (using disaggregated data to the building level).

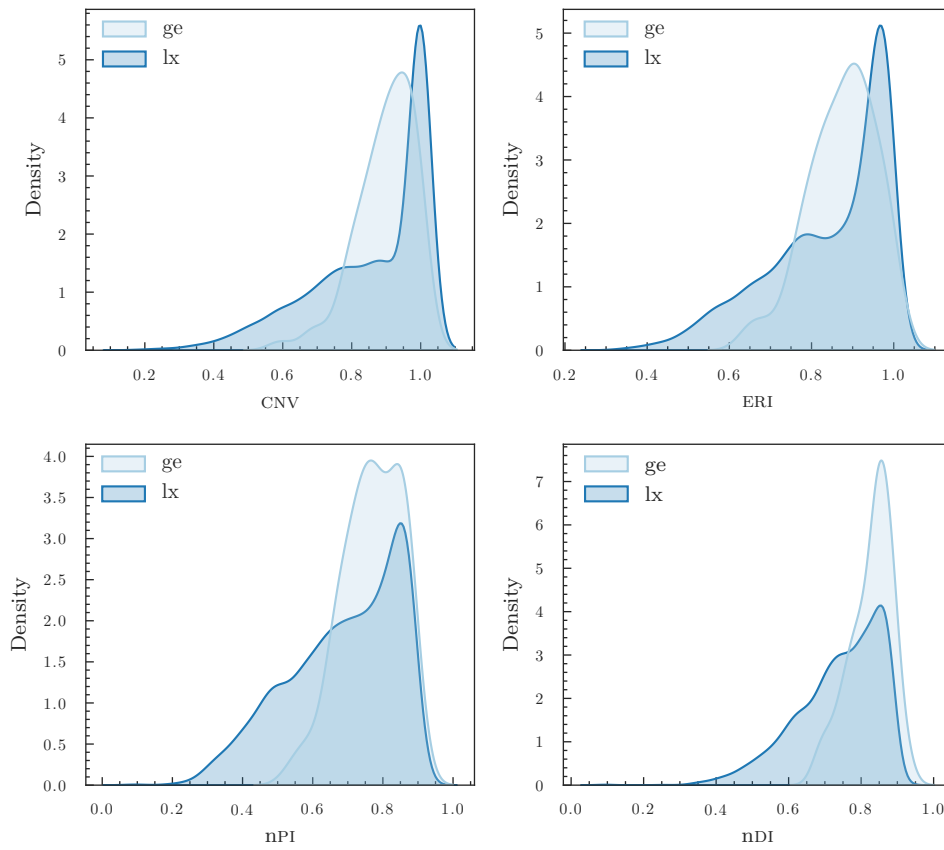


**Figure I.22:** Employment attributes of gated enclave population versus wider census sub-tract. Violin plot depicting the arithmetic mean ratio (to the total population) for the population of the total area of the 2011 census sub-tracts of all gated enclaves in the AML in 2016, and the equivalent mean ratio for the population of the total area of a 100 m buffer of all gated enclaves (using disaggregated data to the building level).

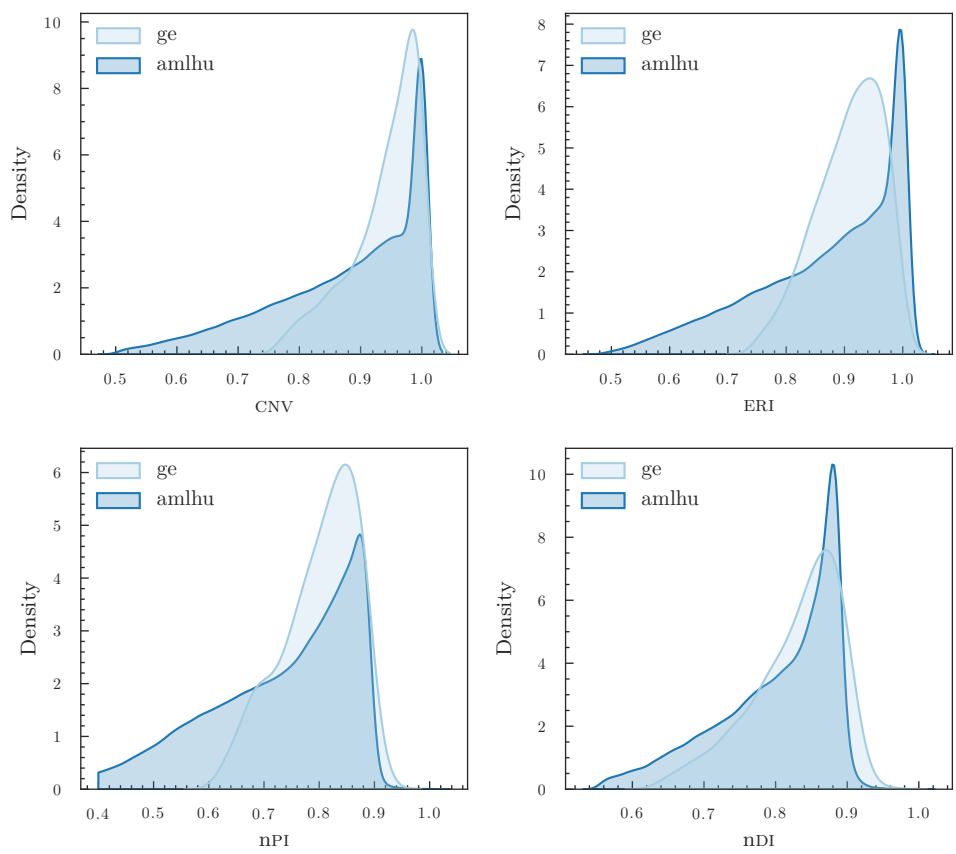


**Figure I.23:** Employment attributes of gated enclave population versus immediate surrounding area. Violin plot depicting the arithmetic mean ratio (to the total population) for the population of the total area of a 1200 m buffer of all gated enclaves in the AML in 2016, and the equivalent mean ratio for the population of the total area of a 100 m buffer of all gated enclaves (using disaggregated data to the building level).

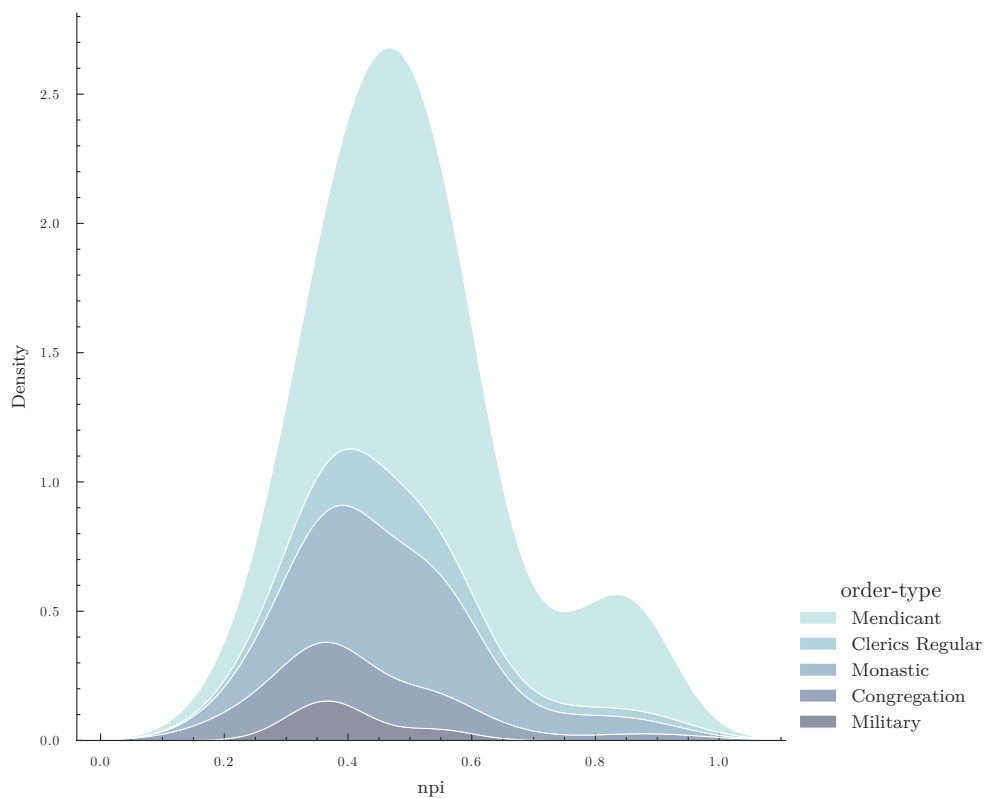
# J Morphological Analysis



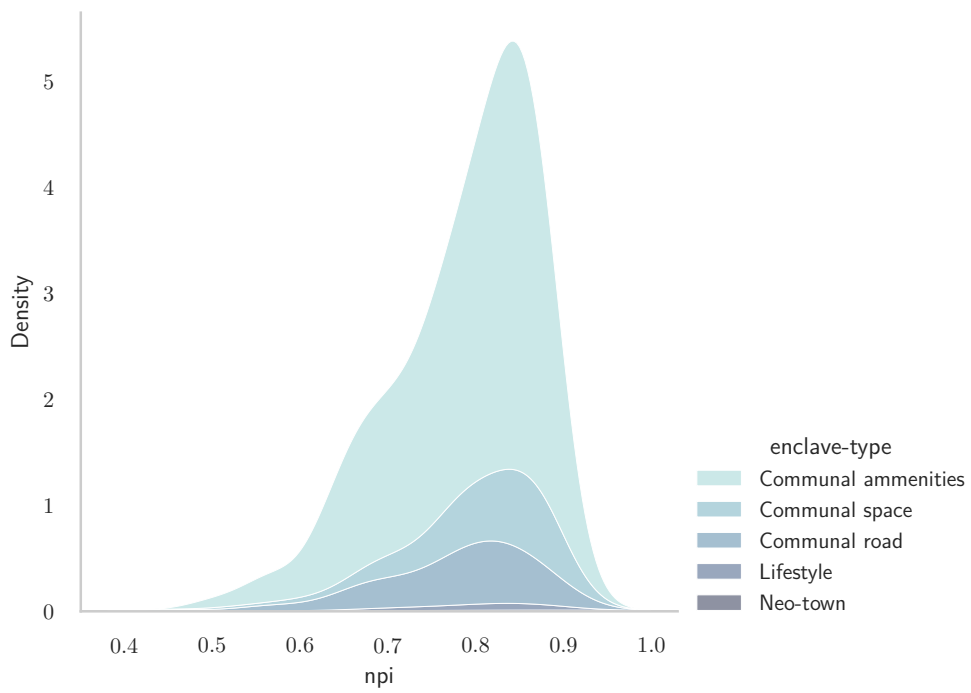
**Figure J.1:** Layered Kernel Density Estimate plot of main morphological measures for gated enclaves and all other built structures in the Lisbon municipality, c.1801.



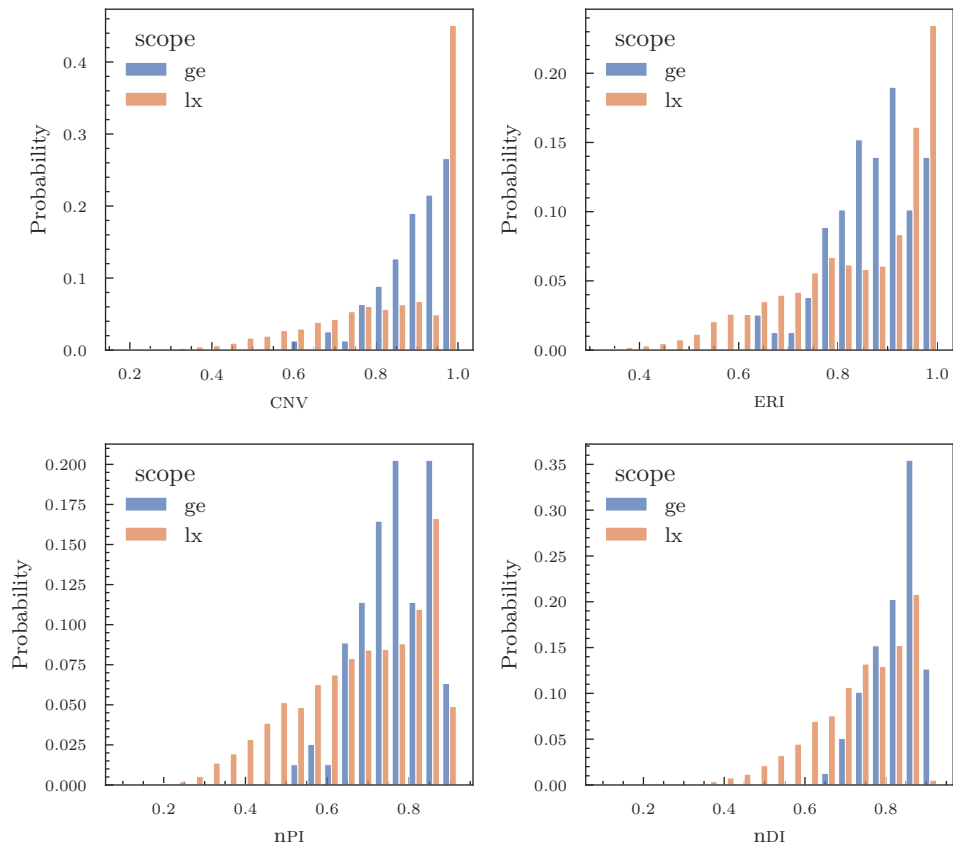
**Figure J.2:** Kernel Density Estimate KDE plot of the main morphological measures (IQR trimmed) for gated enclaves (light blue), and all other residential spatially continuous typologies (dark blue) in the AML, 2016.



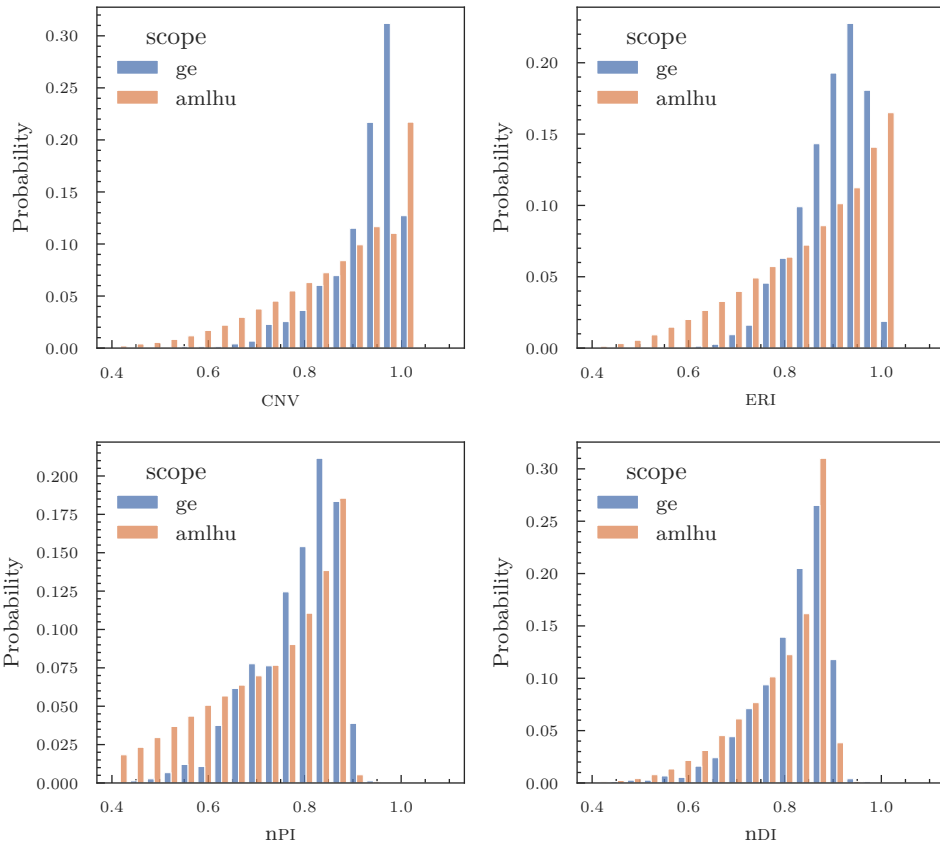
**Figure J.3:** Layered KDE plot of npi values for the various medieval gated enclave classes in the early nineteenth century AML model.



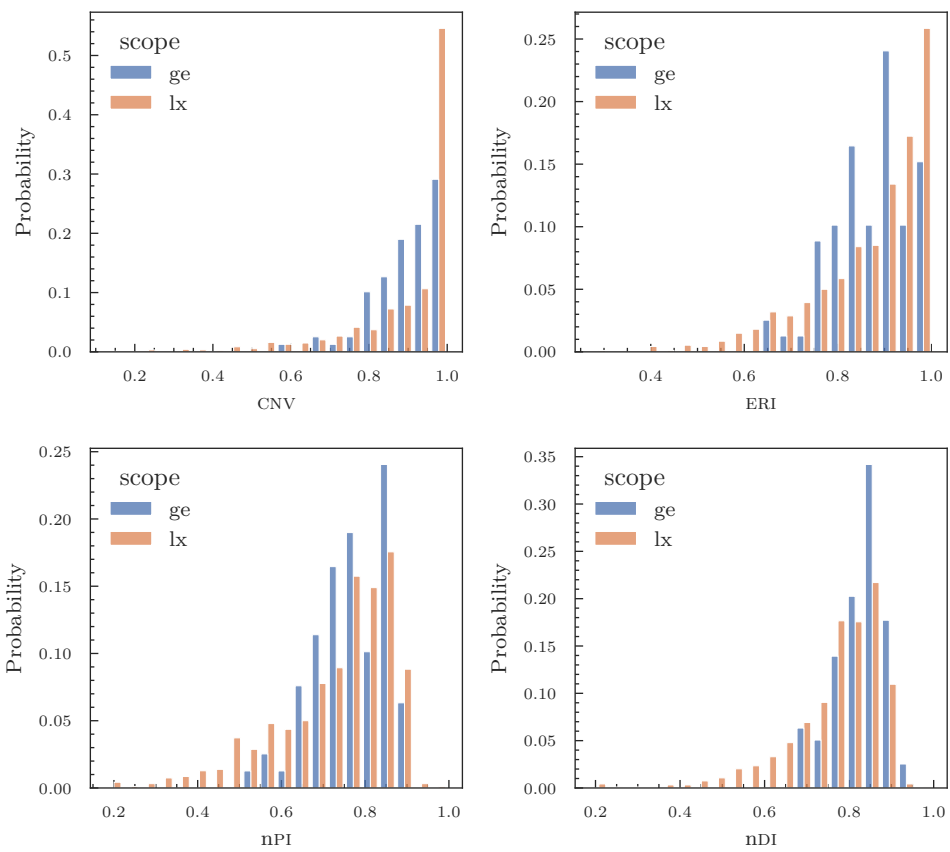
**Figure J.4:** Layered Kernel Density Estimate plot of nPI (normalised Perimeter Index) for gated enclave classes in the AML, 2016.



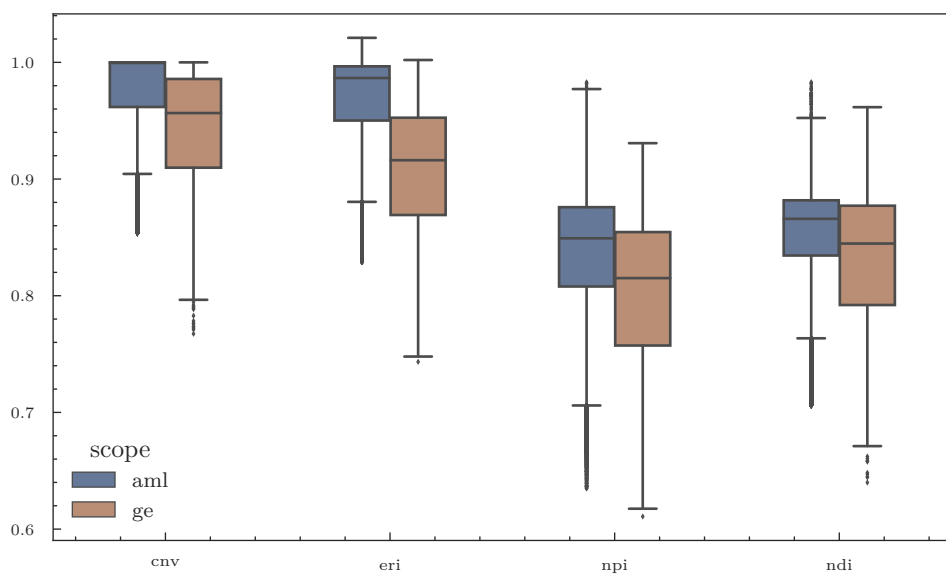
**Figure J.5:** Probability dodged histogram plot of the main morphological measures for gated enclaves (blue), and all other spatially continuous built structures (orange) in the Lisbon municipality, c.1801.



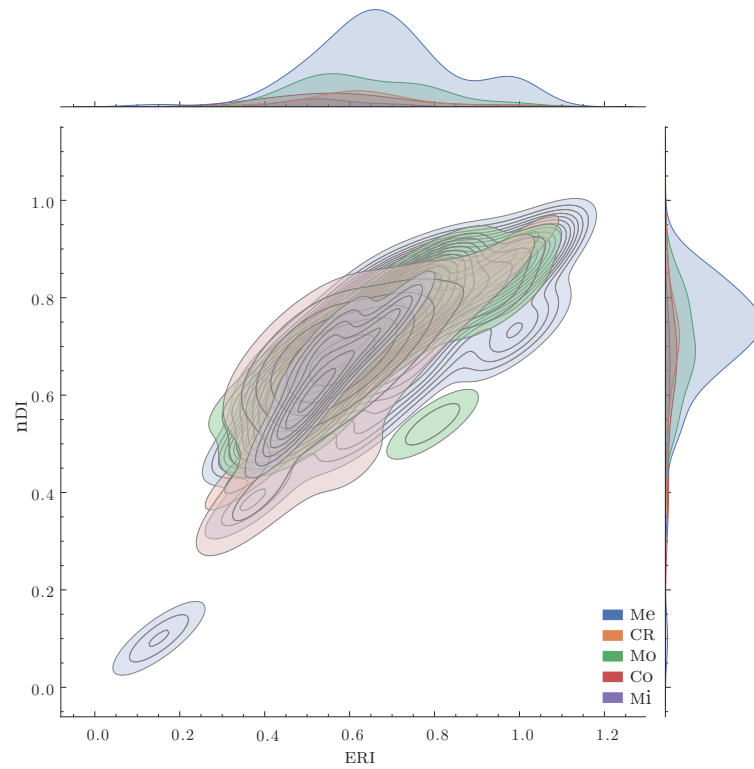
**Figure J.6:** Probability dodged histogram plot of the main morphological measures for gated enclaves (blue), and all other residential spatially continuous typologies (orange) in the AML, 2016.



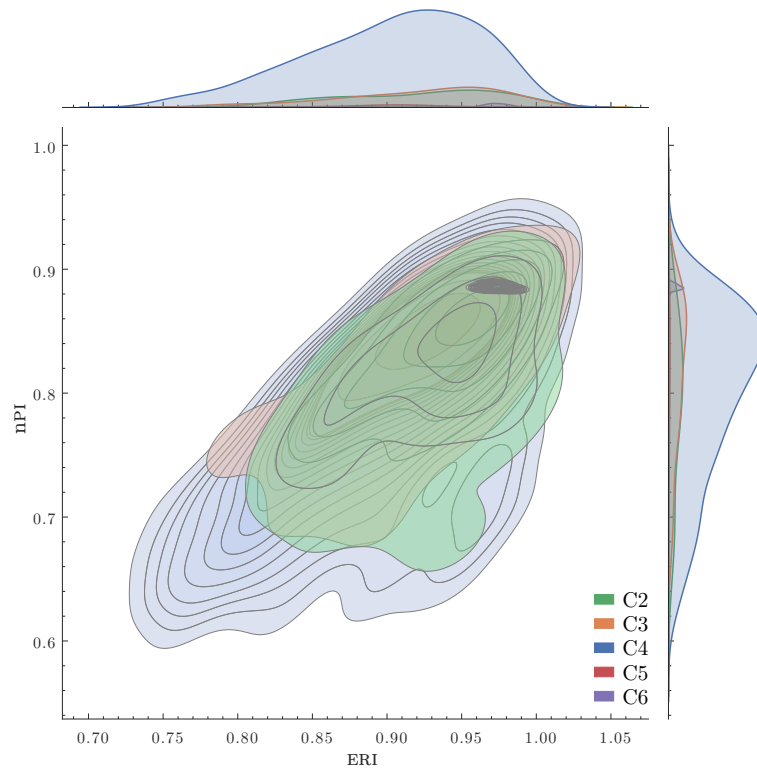
**Figure J.7:** Probability dodged histogram plot of the main morphological measures for gated enclaves (blue), and all other residential spatially continuous typologies (orange) in the Lisbon municipality, 2016.



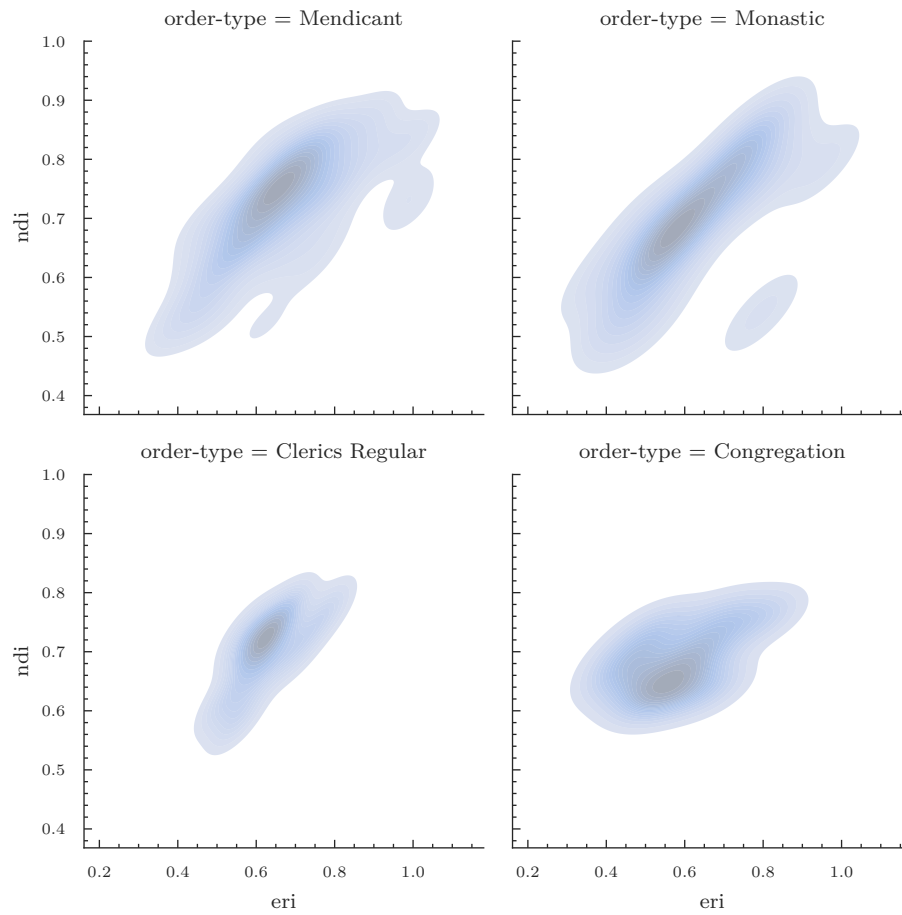
**Figure J.8:** Boxplot of main morphological measures (IQR trimmed) for gated enclaves (orange), and all other built structures (blue) in the AML, c.1801.



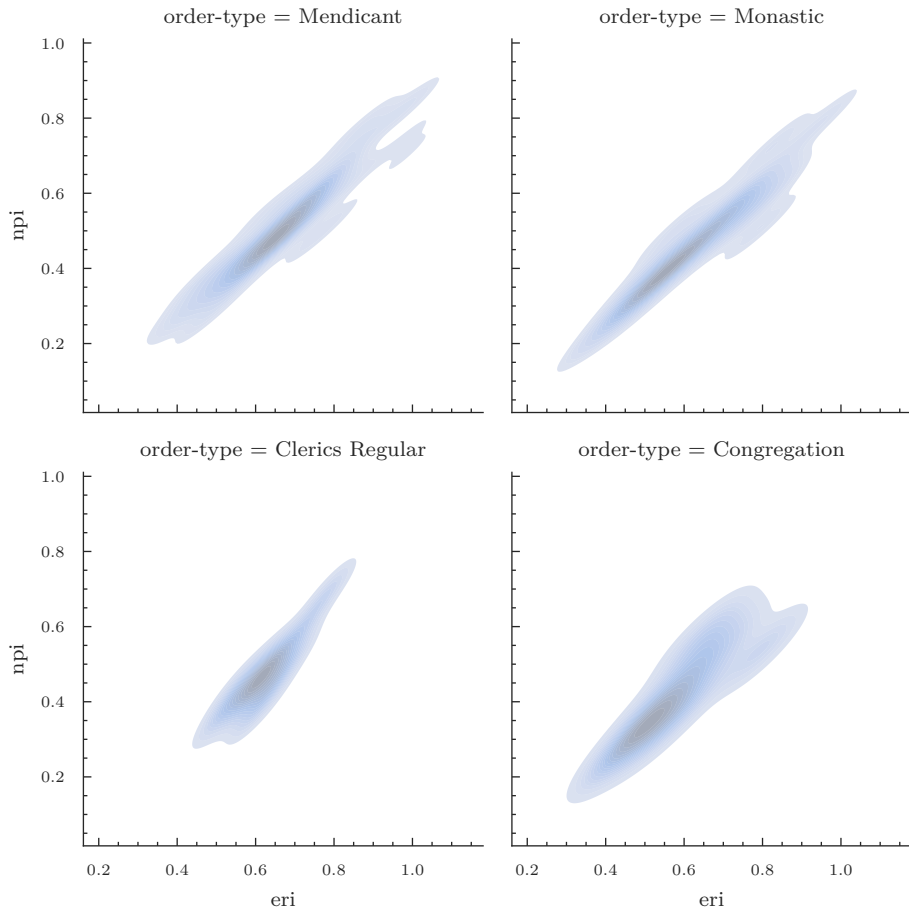
**Figure J.9:** Joint plot showing bivariate Kernel Density Estimate (KDE) for nDI and ERI indices and respective univariate KDE plots on the margins, for the main medieval gated enclave classes in the AML c.1801.



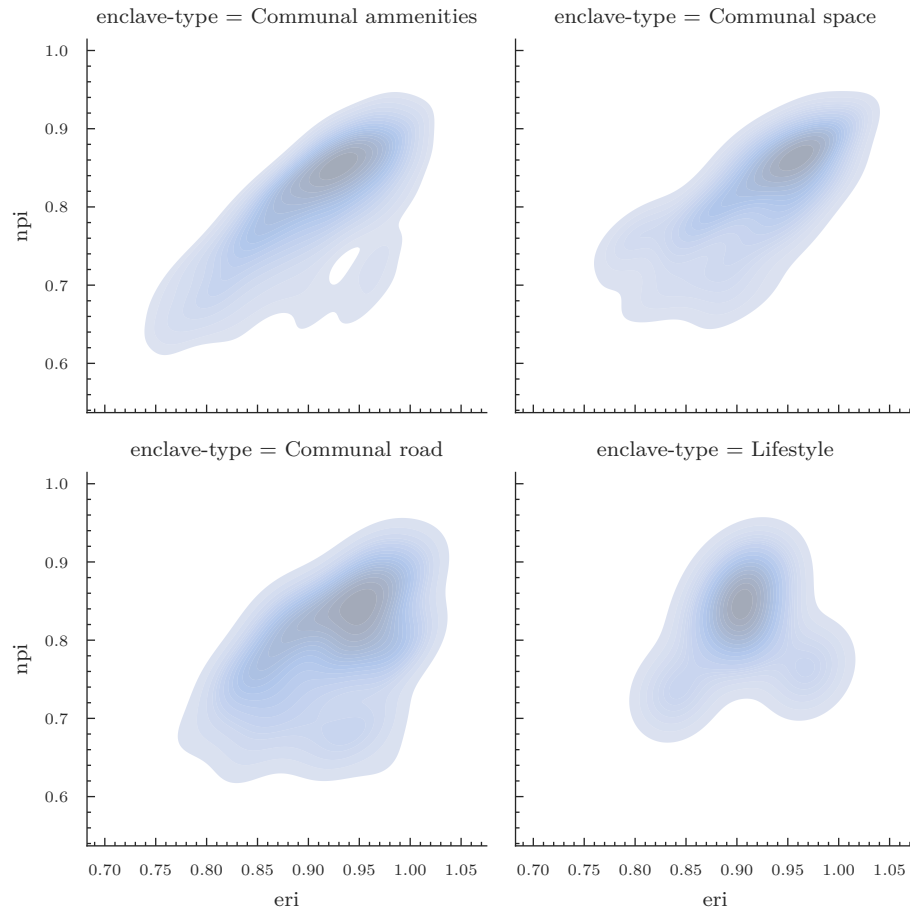
**Figure J.10:** Joint plot showing bivariate Kernel Density Estimate (KDE) for nPI and ERI indices (IQR trimmed) and respective univariate KDE plots on the margins, for the main gated enclave classes (see table 4.12 on page 397) in the AML in 2016.



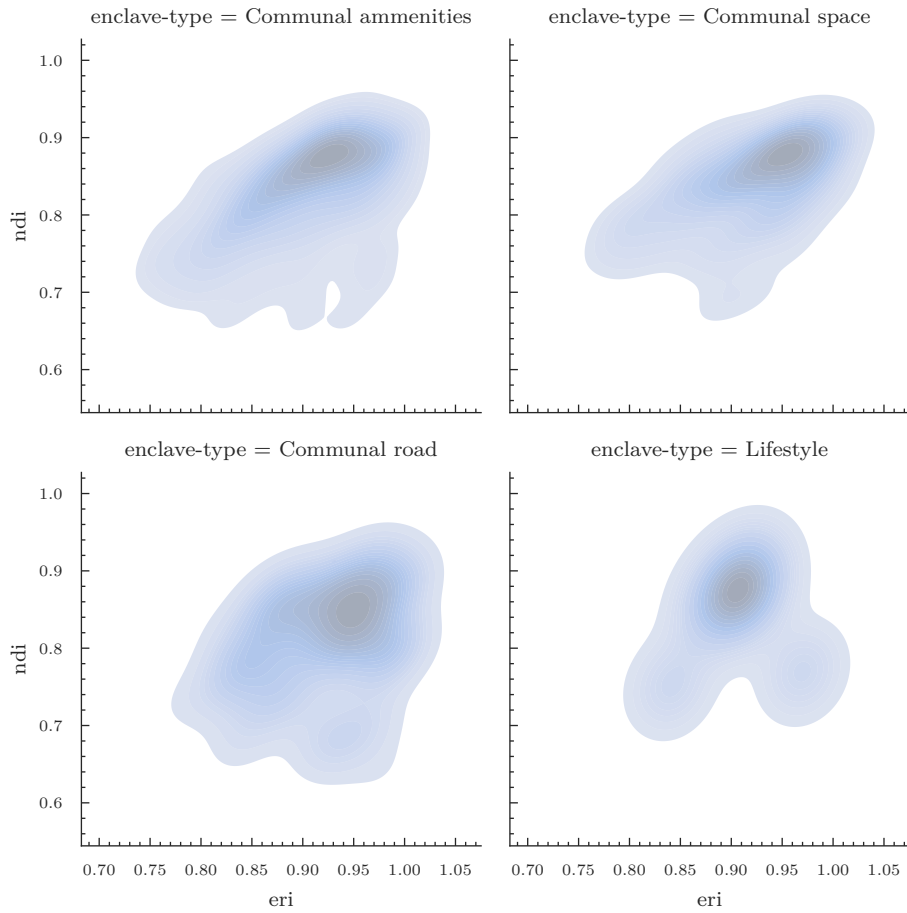
**Figure J.11:** Bivariate plots for nDI and ERI (IQR trimmed) of four main medieval gated enclave classes in the early nineteenth century AML model.



**Figure J.12:** Bivariate plots for nPI and ERI (IQR trimmed) of four main medieval gated enclave classes in the early nineteenth century AML model.



**Figure J.13:** Bivariate plots for nPI and ERI (IQR trimmed) of four main gated enclave classes in the contemporary AML model.

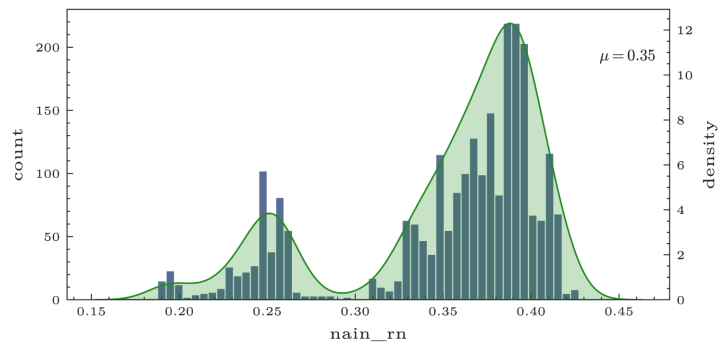


**Figure J.14:** Bivariate plots for nDI and ERI (IQR trimmed) of four main gated enclave classes in the contemporary AML model.

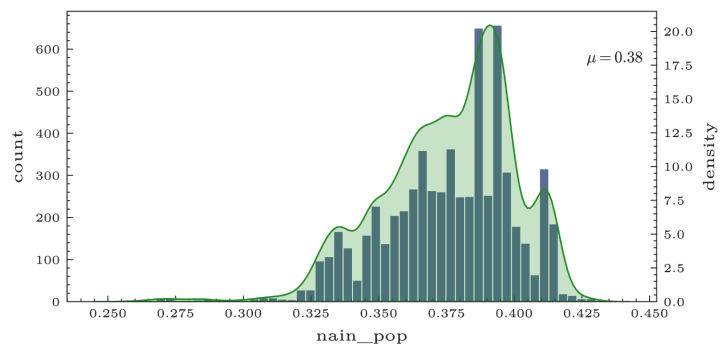


# K Configurational Analysis

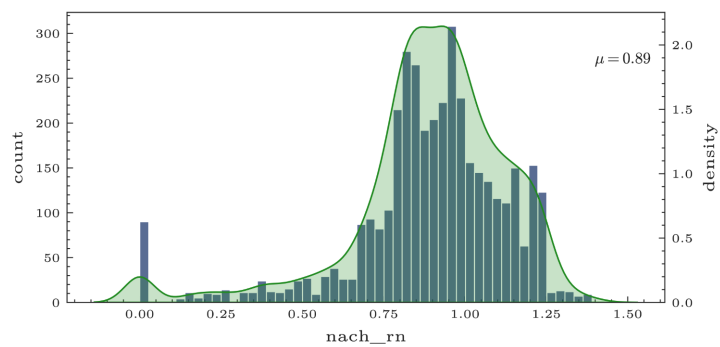
## K Configurational Analysis



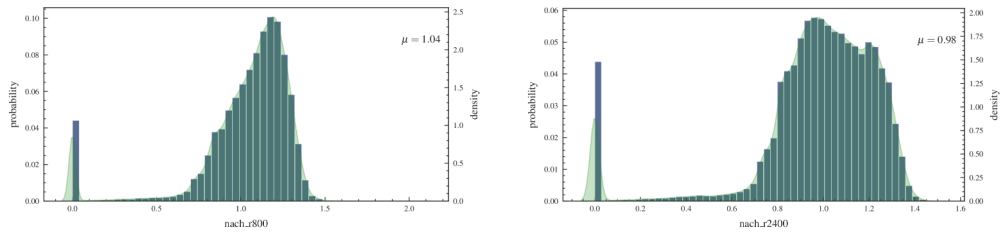
**Figure K.1:** Count distribution plot of NAIN at  $r = n$  for the 5 minute enclave entry isochrones of the early nineteenth century AML network, and corresponding kernel density estimate curve.



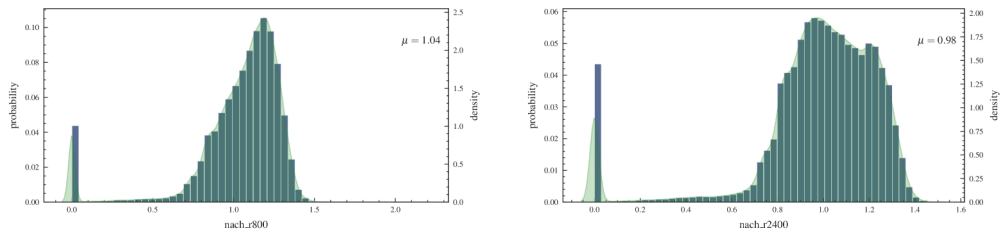
**Figure K.2:** Count distribution plot of segment NAIN\_pop (resident population weighted nain) for the 10 minute enclave entry isochrones of the early nineteenth century AML network, and corresponding kernel density estimate curve.



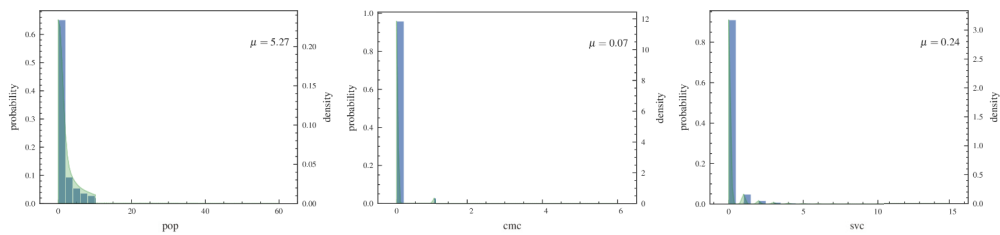
**Figure K.3:** Count distribution plot of NACH at  $r = n$  for the 5 minute enclave wall isochrones of the early nineteenth century AML network, and corresponding kernel density estimate curve.



**Figure K.4:** Probability distribution plots of NACH at  $r = 800$  (left) and  $r = 2400$  (right) for the 10 minute enclave *wall* isochrones of the AML pedestrian network, and corresponding kernel density estimate curves.

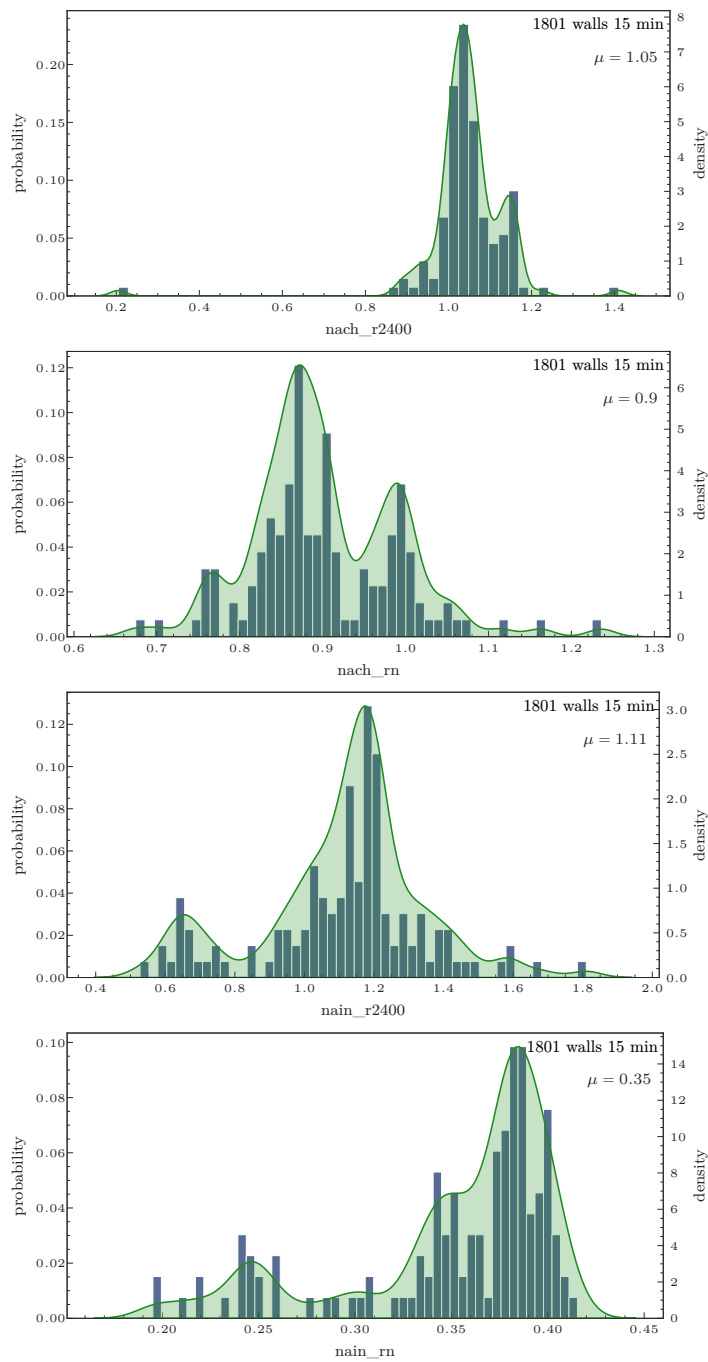


**Figure K.5:** Probability distribution plots of NACH at  $r = 800$  (left) and  $r = 2400$  (right) for the 10 minute enclave *access* isochrones of the AML pedestrian network, and corresponding kernel density estimate curves.

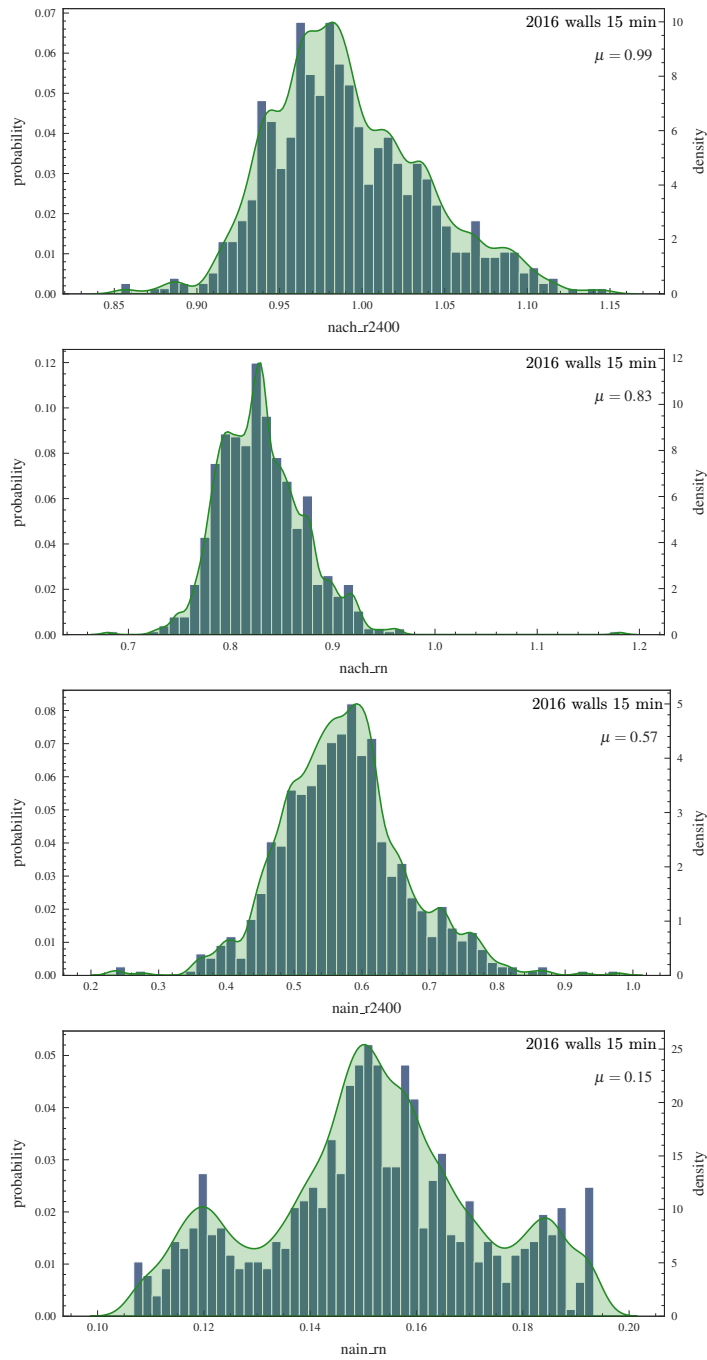


**Figure K.6:** Probability distribution plots of the Pop, CMC, and Svc metrics, corresponding to street segment resident population, commerce, and service, at  $r = n$  for the 10 minute enclave *wall* isochrones of the AML pedestrian network, and corresponding kernel density estimate curves.

## K Configurational Analysis

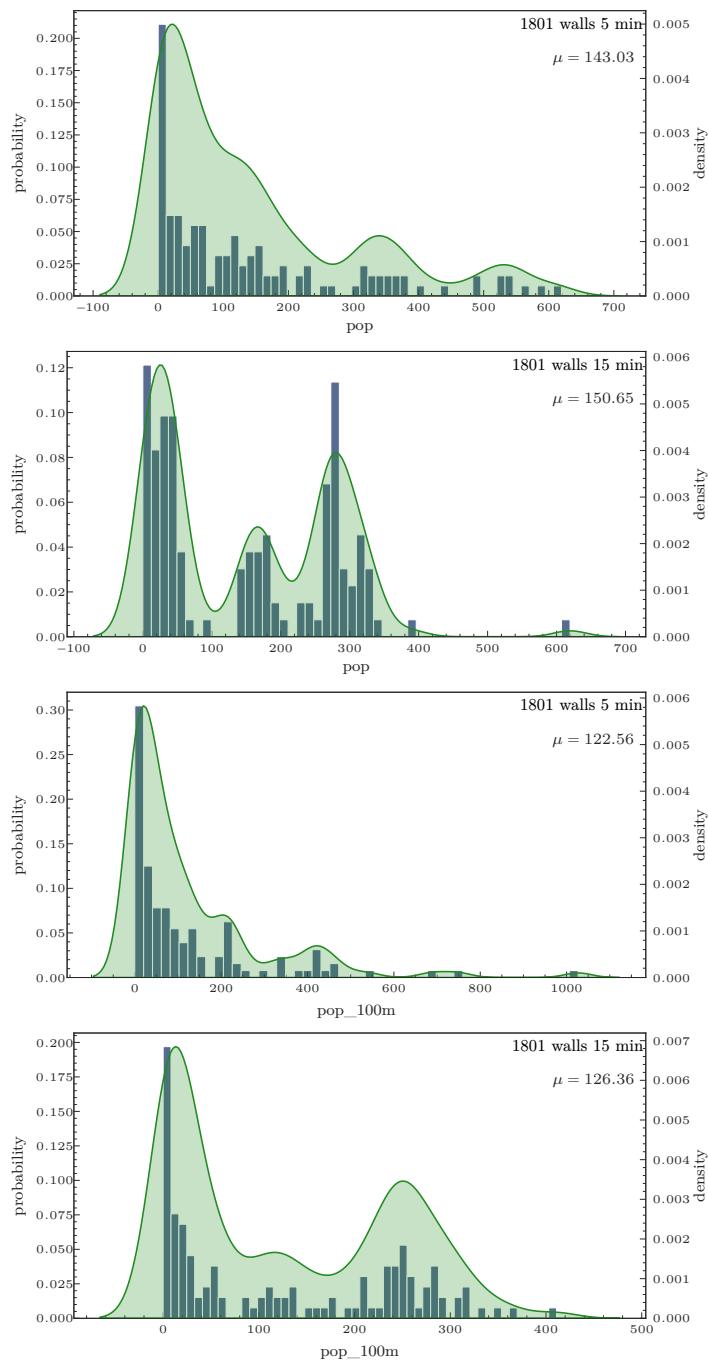


**Figure K.7:** Probability histogram and corresponding kernel density estimate of street segments intersecting 15 minute walk isochrones of enclave walls in the 1801 AML model for: NACH and NAIN at  $r = n$  and  $r = 2400$  m

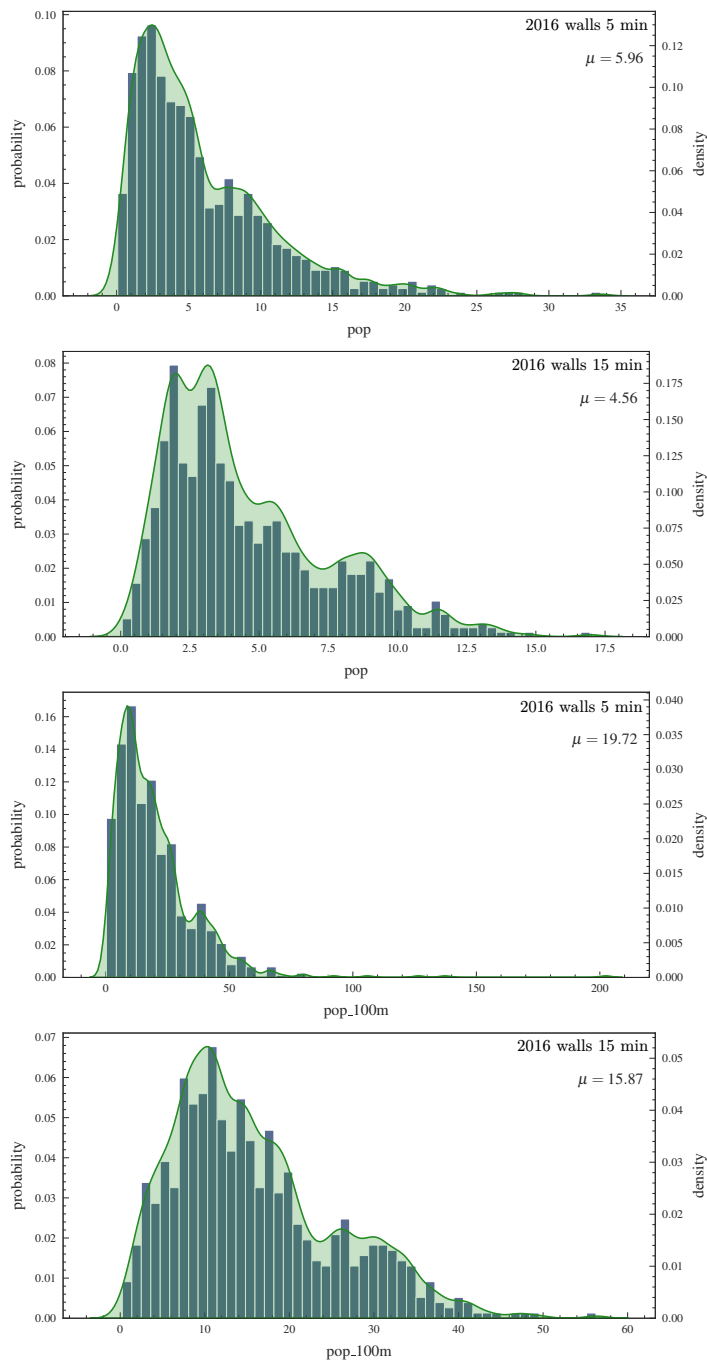


**Figure K.8:** Probability histogram and corresponding kernel density estimate of street segments intersecting 15 minute walk isochrones of enclave walls in the 2016 AML model for: NACH and NAIN at  $r = n$  and  $r = 2400$  m

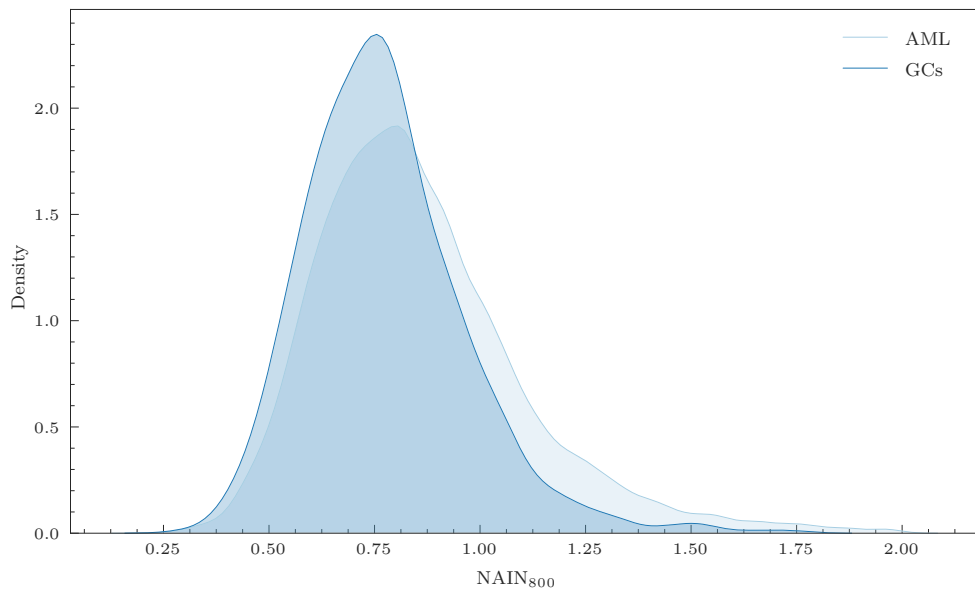
## K Configurational Analysis



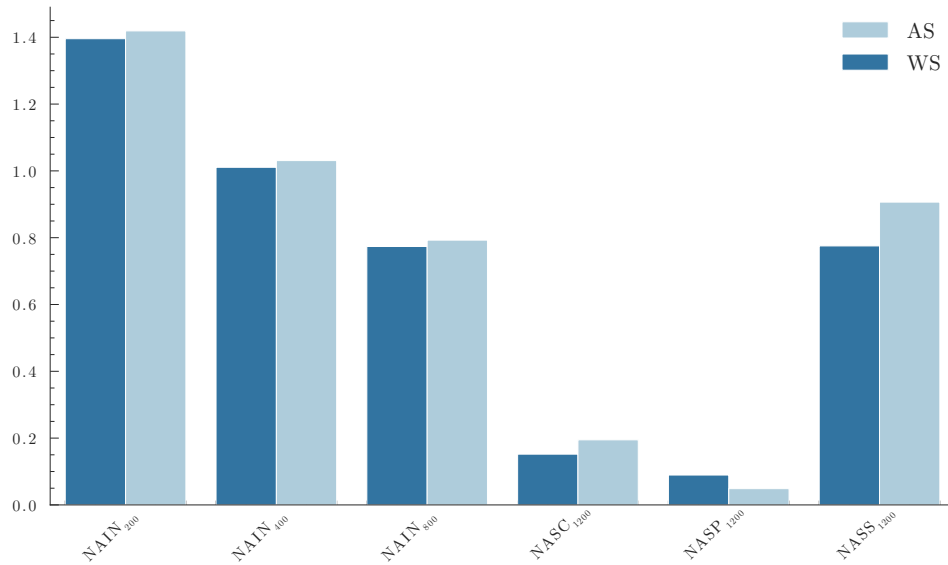
**Figure K.9:** Probability histogram and corresponding kernel density estimate of street segments intersecting 15 minute walk isochrones of enclave walls in the 1801 AML model for: absolute SP (pop) and absolute SP within a 100 m street segment buffer (pop\_100m)



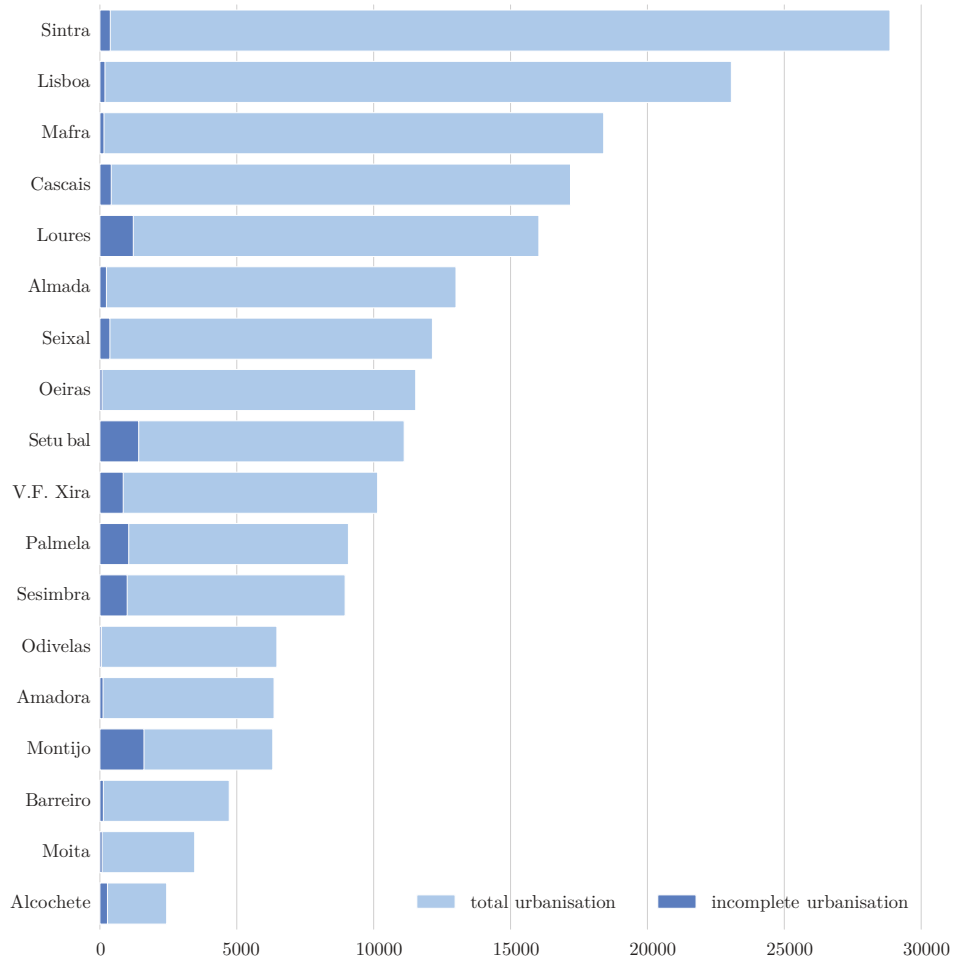
**Figure K.10:** Probability histogram and corresponding kernel density estimate of street segments intersecting 15 minute walk isochrones of enclave walls in the 2016 AML model for: absolute SP (pop) and absolute SP within a 100 m street segment buffer (pop\_100m)



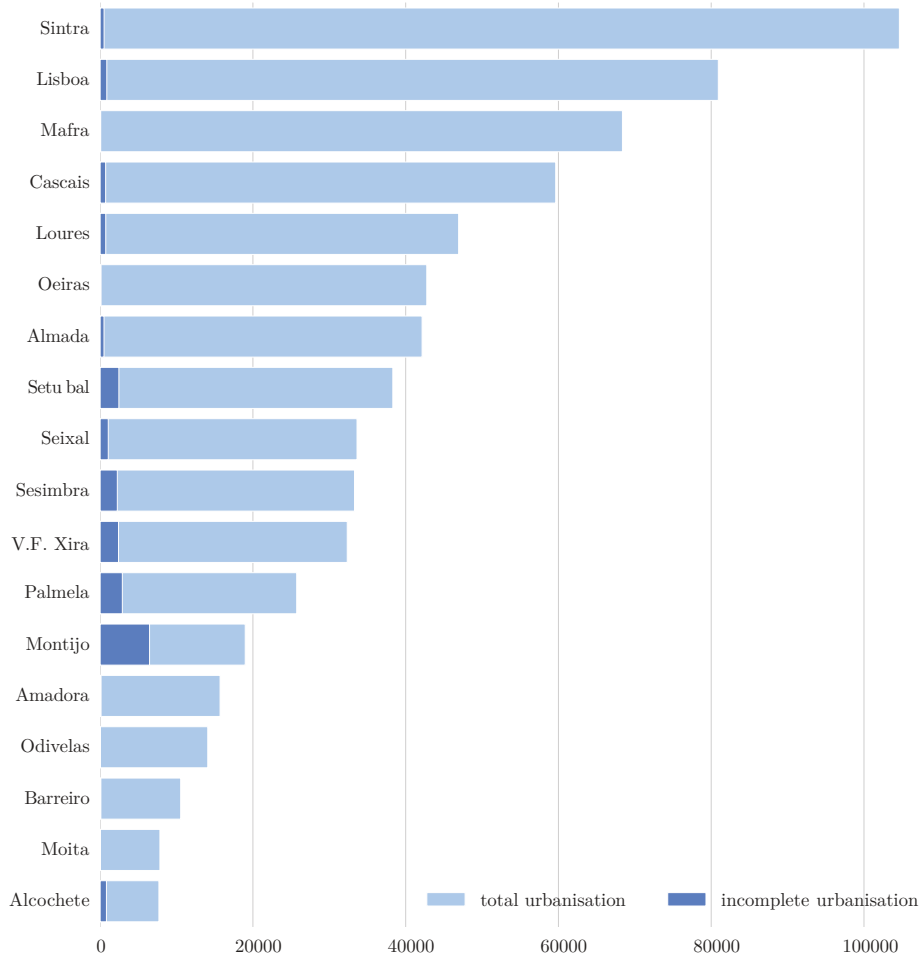
**Figure K.11:**  $NAIN_{800}$  densities of enclaves vs residential buildings. Univariate kernel density plot of  $NAIN_{800}$  values for the closest street segment to gated enclave walls vs the closest street segment to all predominantly residential buildings in the AML.



**Figure K.12:** Mean network measures of gated enclaves by closest street segment to perimeter wall and main entry access point. AS (access segment): closest street segment to entry access point. WS (wall segment): closest street segment to perimeter wall. From left to right, measures are:  $NAIN_r$  Normalised angular integration at metric radius of  $r$ .  $NASC_{1200}$  Normalised angular commerce sector count for the closest street segment within a 1 200 m buffer area of the gated enclave.  $NASP_{1200}$  Normalised angular resident population count for the closest street segment within a 1 200 m buffer area of the gated enclave.  $NASS_{1200}$  Normalised angular service sector count for the closest street segment within a 1 200 m buffer area of the gated enclave.

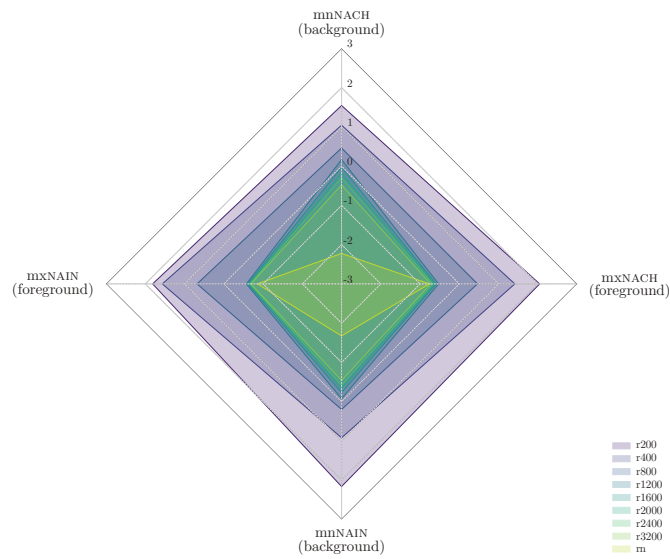


**Figure K.13:** Incomplete urbanisation in the contemporary AML vehicular network

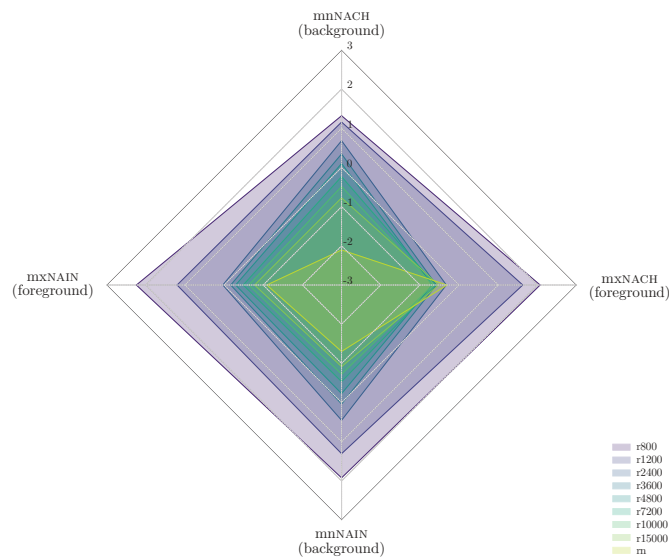


**Figure K.14:** Incomplete urbanisation in the contemporary AML pedestrian network

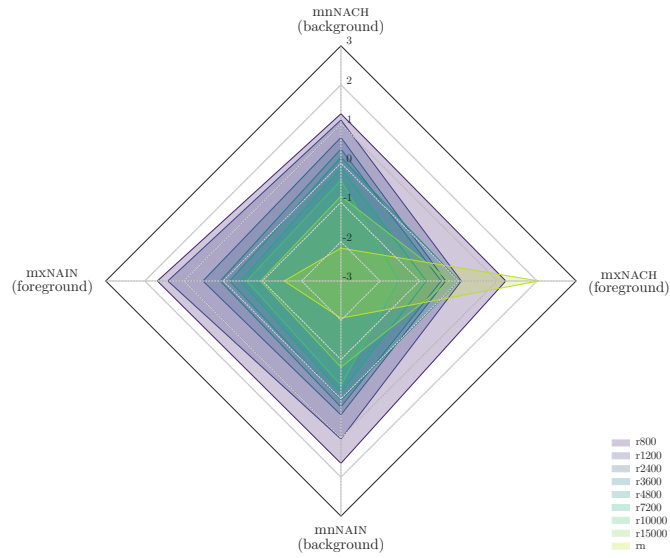
*K Configurational Analysis*



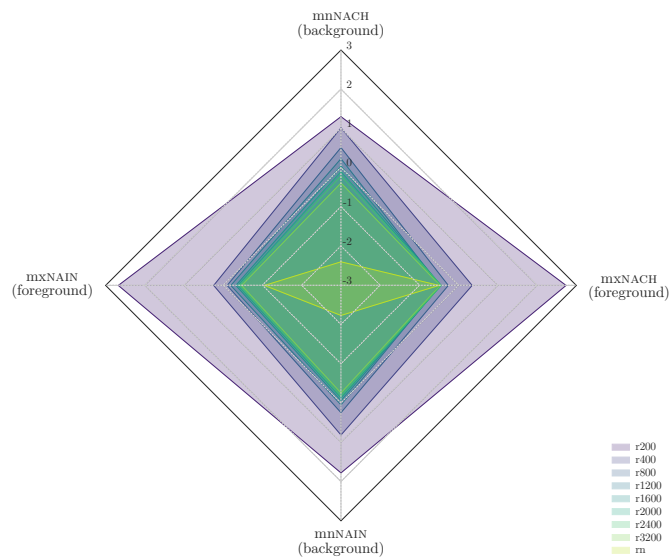
**Figure K.15:** Pedestrian star chart of the contemporary AML model at multiple radii. Standardised by zscore, plotted on -3 to 3 axes, sorted by mean nach.



**Figure K.16:** Vehicular star chart of the contemporary AML model at multiple radii. Standardised by zscore, plotted on -3 to 3 axes, sorted by mean nach.

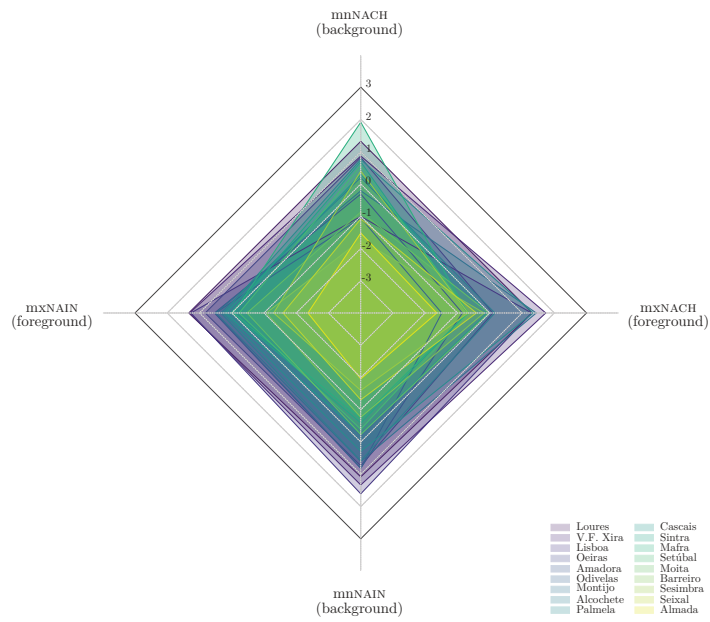


**Figure K.17:** Layered vehicular star chart of the contemporary Lisbon municipality model at various radii. Standardised by zscore, plotted on -3 to 3 axes, sorted by mean NACH.

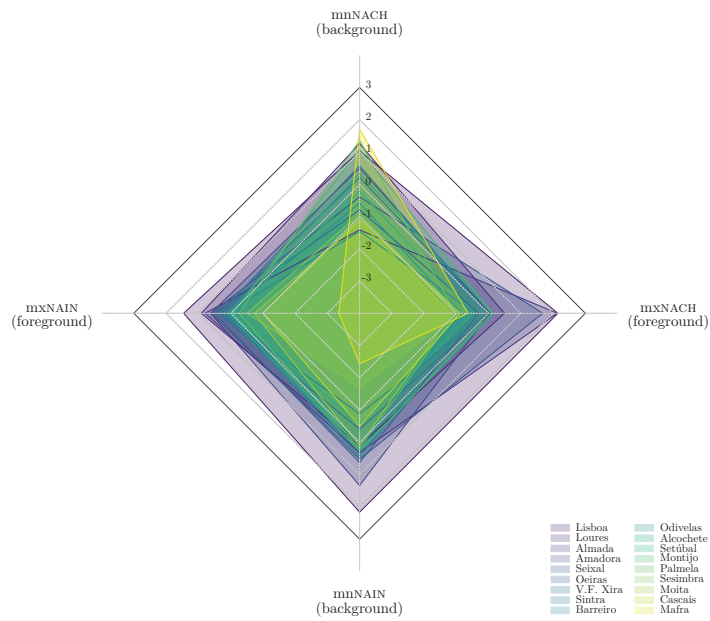


**Figure K.18:** Layered pedestrian star chart of the contemporary Lisbon municipality model at various radii. Standardised by zscore, plotted on -3 to 3 axes, sorted by mean NACH.

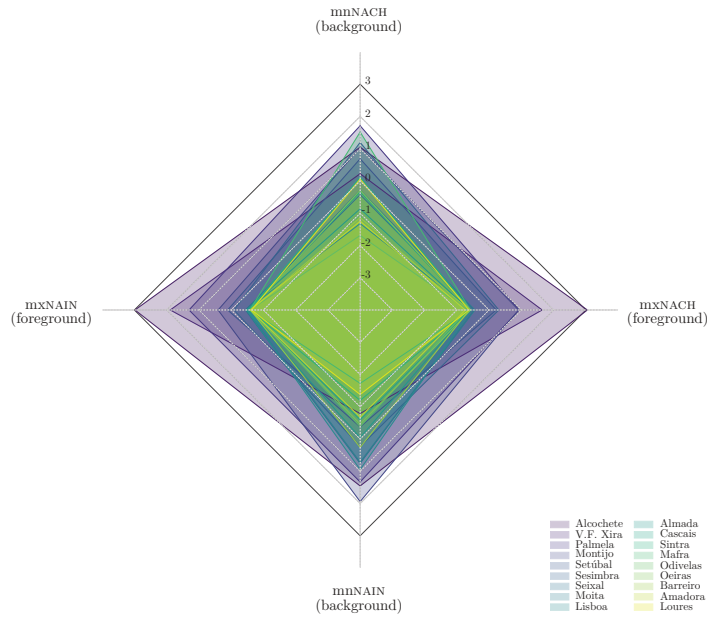
*K Configurational Analysis*



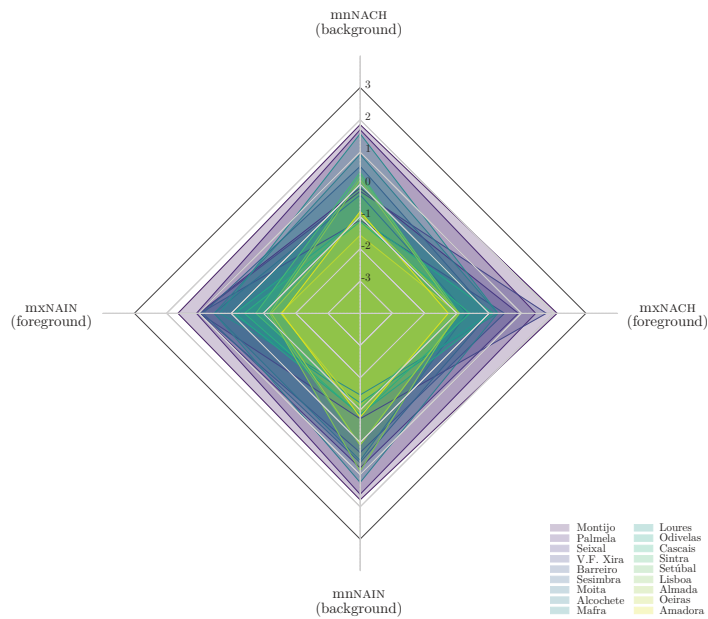
**Figure K.19:** Pedestrian star chart of municipalities at global radius ( $r=n$ ). Standardised by zscore, plotted on -4 to 4 axes, sorted by mean NACH.



**Figure K.20:** Vehicular star chart of municipalities at global radius ( $r=n$ ). Standardised by zscore, plotted on -4 to 4 axes, sorted by mean nach.

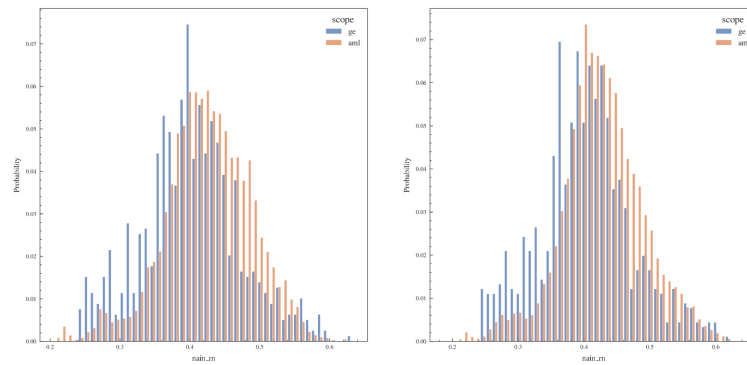


**Figure K.21:** Pedestrian star chart of municipalities at medium radius ( $r=2400$ ). Standardised by zscore, plotted on -4 to 4 axes, sorted by mean nach.

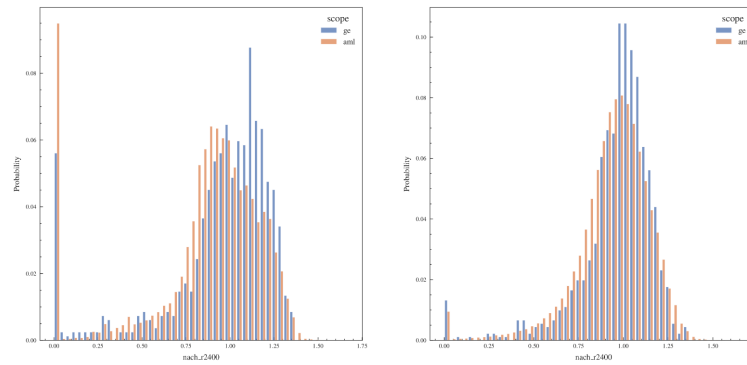


**Figure K.22:** Vehicular star chart of municipalities at medium radius ( $r=2400$ ). Standardised by zscore, plotted on -4 to 4 axes, sorted by mean nach.

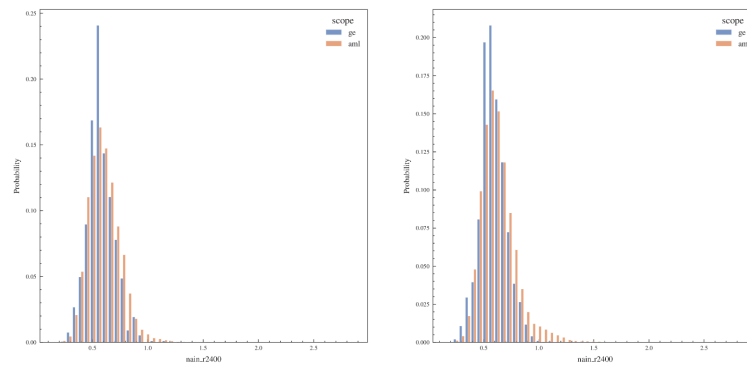
## K Configurational Analysis



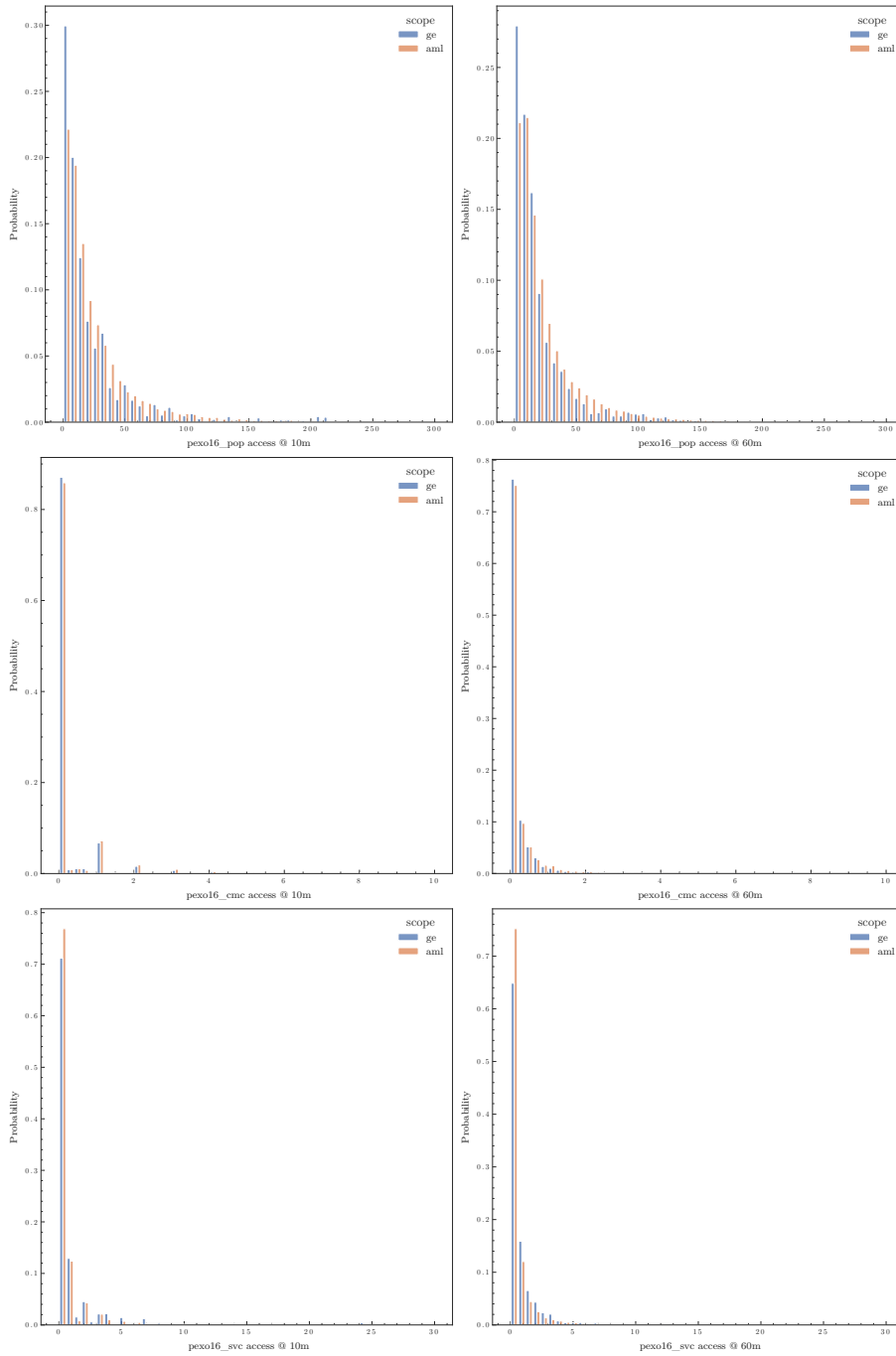
**Figure K.23:** Probability distribution dodged plots of the 2016 vehicular network NAIN at  $r = n$  for a 10 m (left) and 60 m (right) wall-segment buffer intersection. Gated enclaves in blue, remaining AML residential typologies in orange.



**Figure K.24:** Probability distribution dodged plots of the 2016 vehicular network NACH at  $r = n$  for a 10 m (left) and 60 m (right) wall-segment buffer intersection. Gated enclaves in blue, remaining AML residential typologies in orange.

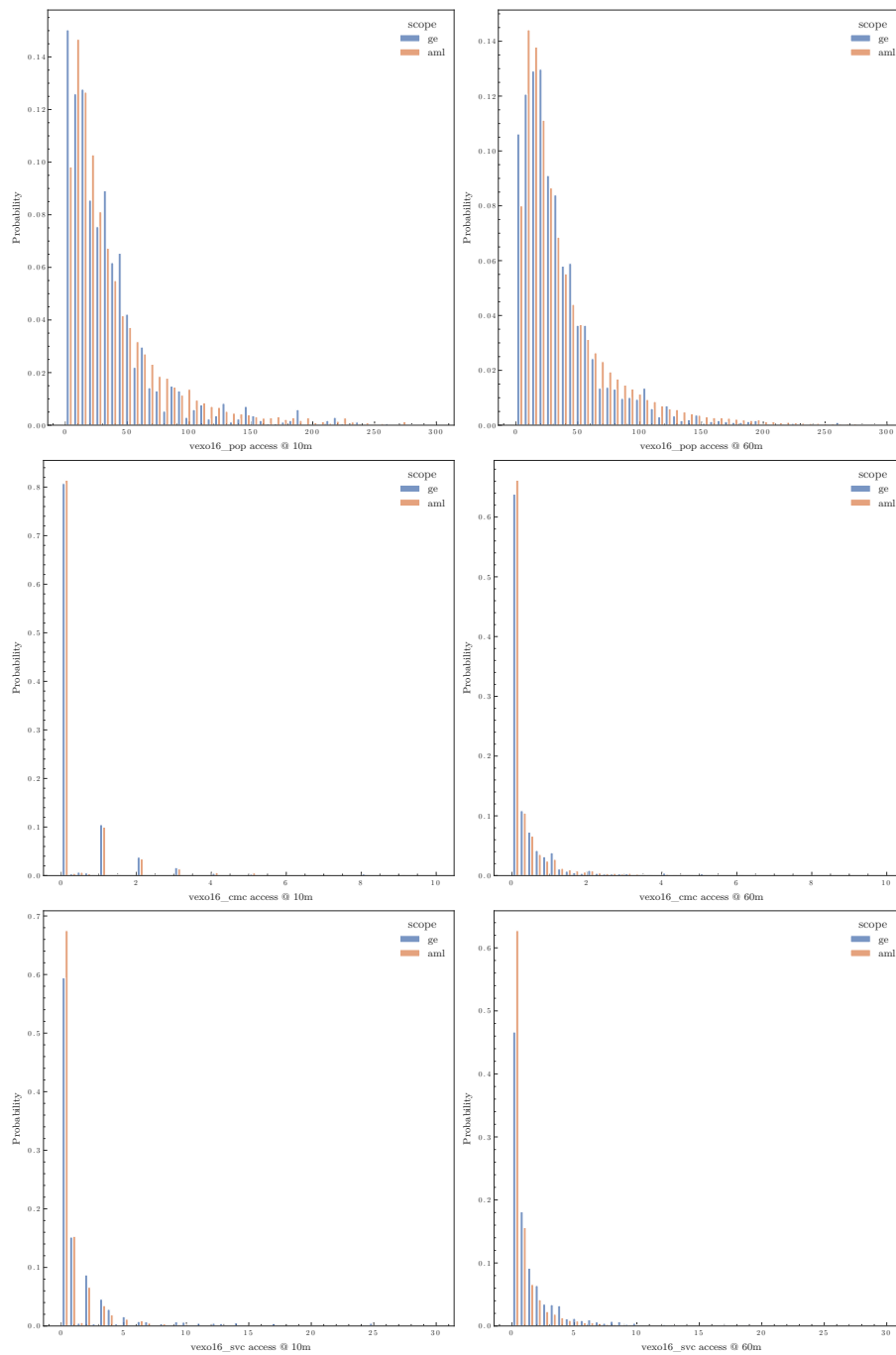


**Figure K.25:** Probability distribution dodged plots of the 2016 pedestrian network NAIN at  $r = 2400$  for a 10 m (left) and 60 m (right) access-segment buffer intersection. Gated enclaves in blue, remaining AML residential typologies in orange.

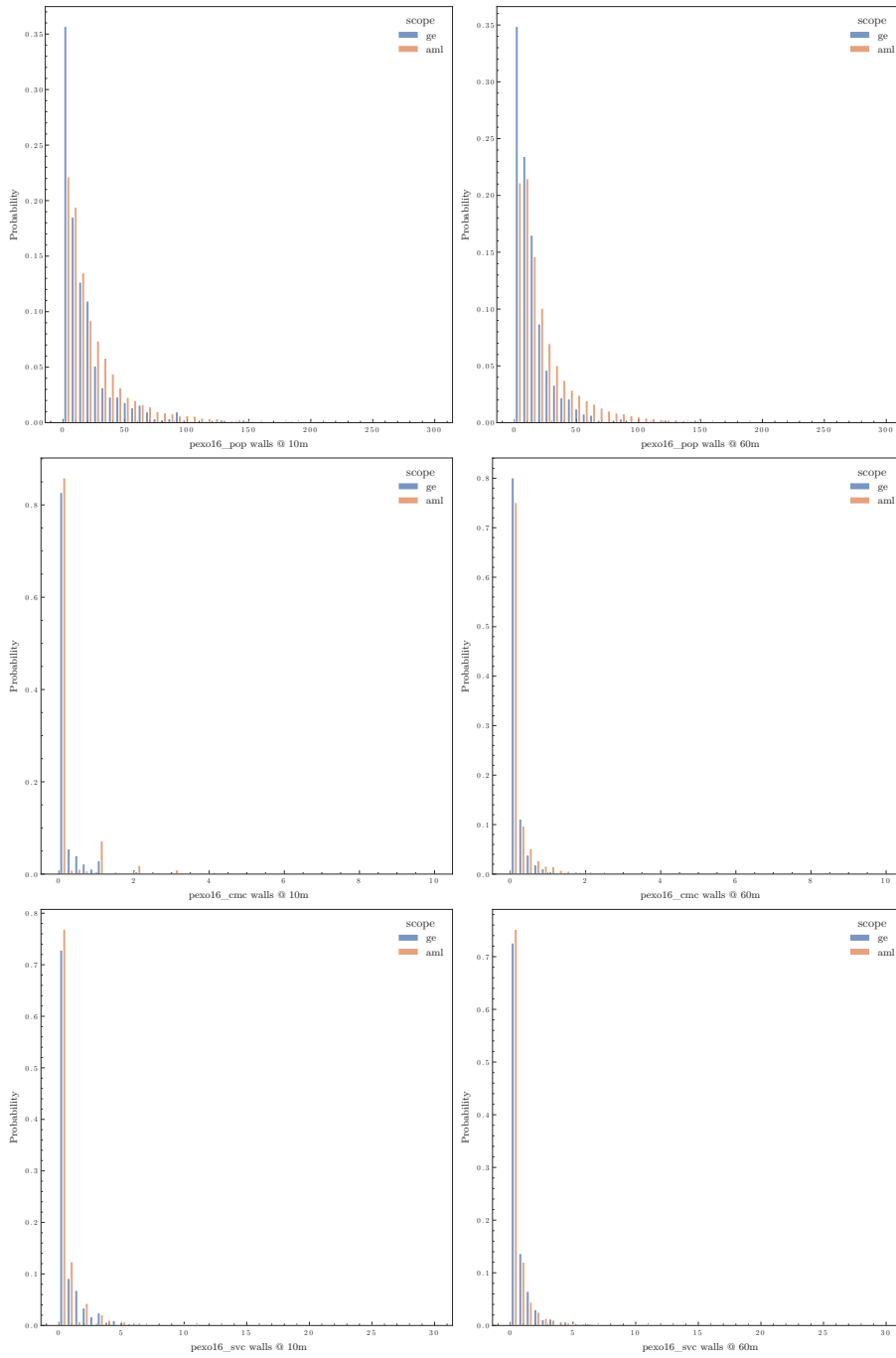


**Figure K.26:** Probability distribution of, from top to bottom, pop, cmc, and svc pedestrian street segments at 10 (left) and 60 m (right) buffers of enclave (ge, in blue) and other residential (aml, in orange) access points. Range used is of the entire AML network.

## K Configurational Analysis

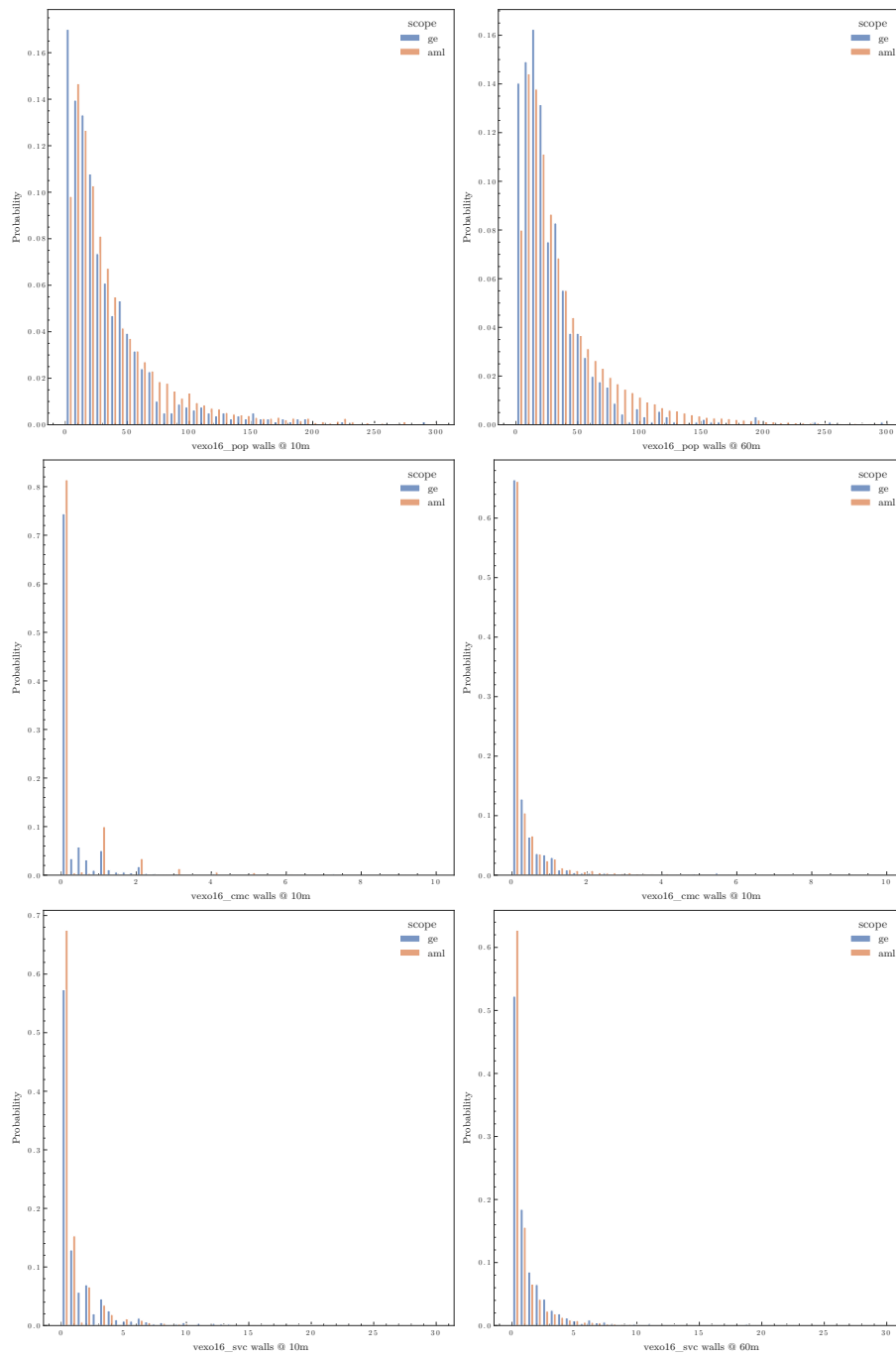


**Figure K.27:** Probability distribution of, from top to bottom, pop, cmc, and svc vehicular street segments at 10 (left) and 60 m (right) buffers of enclave (ge, in blue) and other residential (aml, in orange) access points. Range used is of the entire AML network.

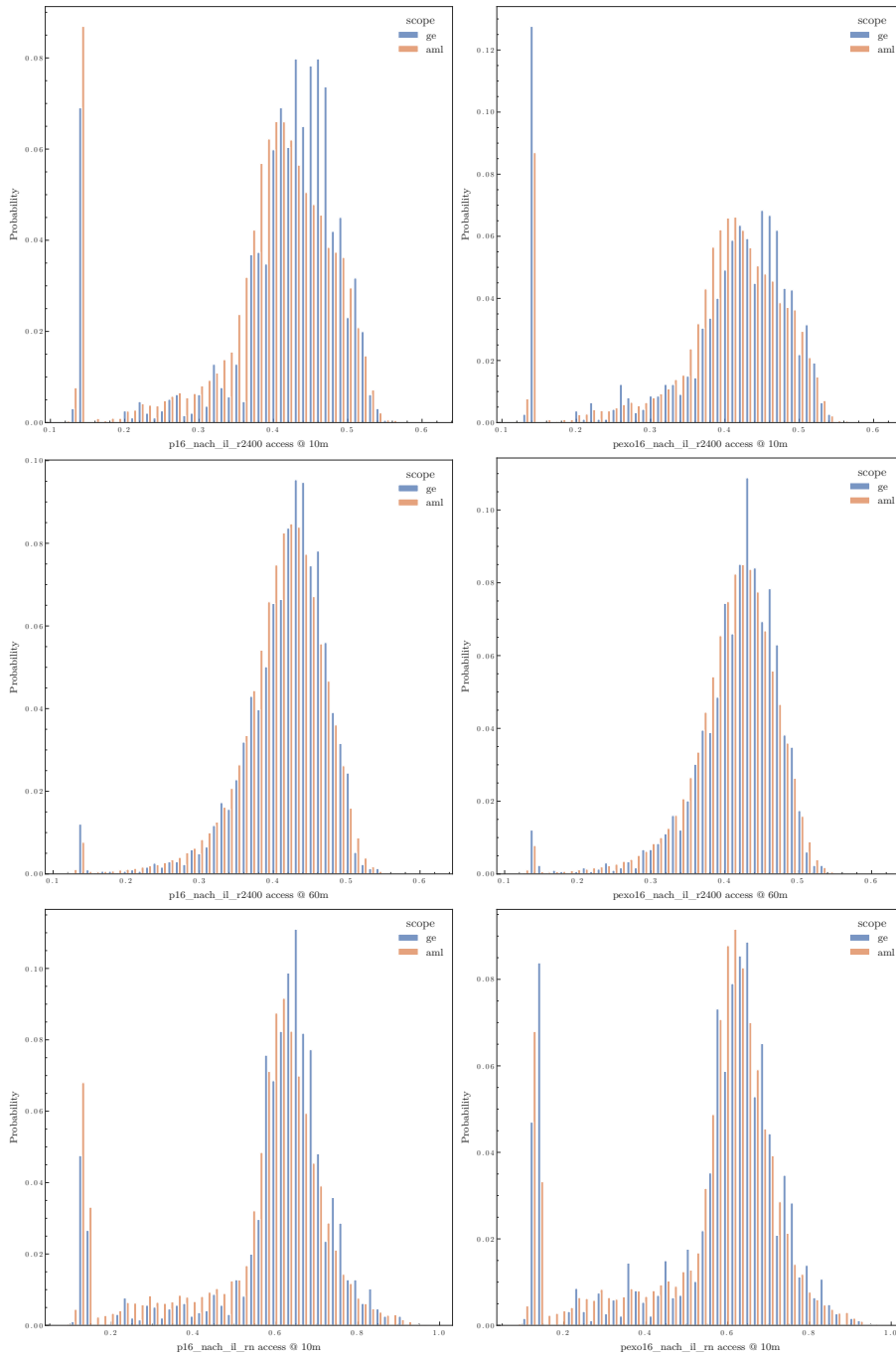


**Figure K.28:** Probability distribution of, from top to bottom, pop, cmc, and svc pedestrian street segments at 10 (left) and 60 m (right) buffers of enclave (ge, in blue) and other residential (aml, in orange) walls. Range used is of the entire AML network.

## K Configurational Analysis

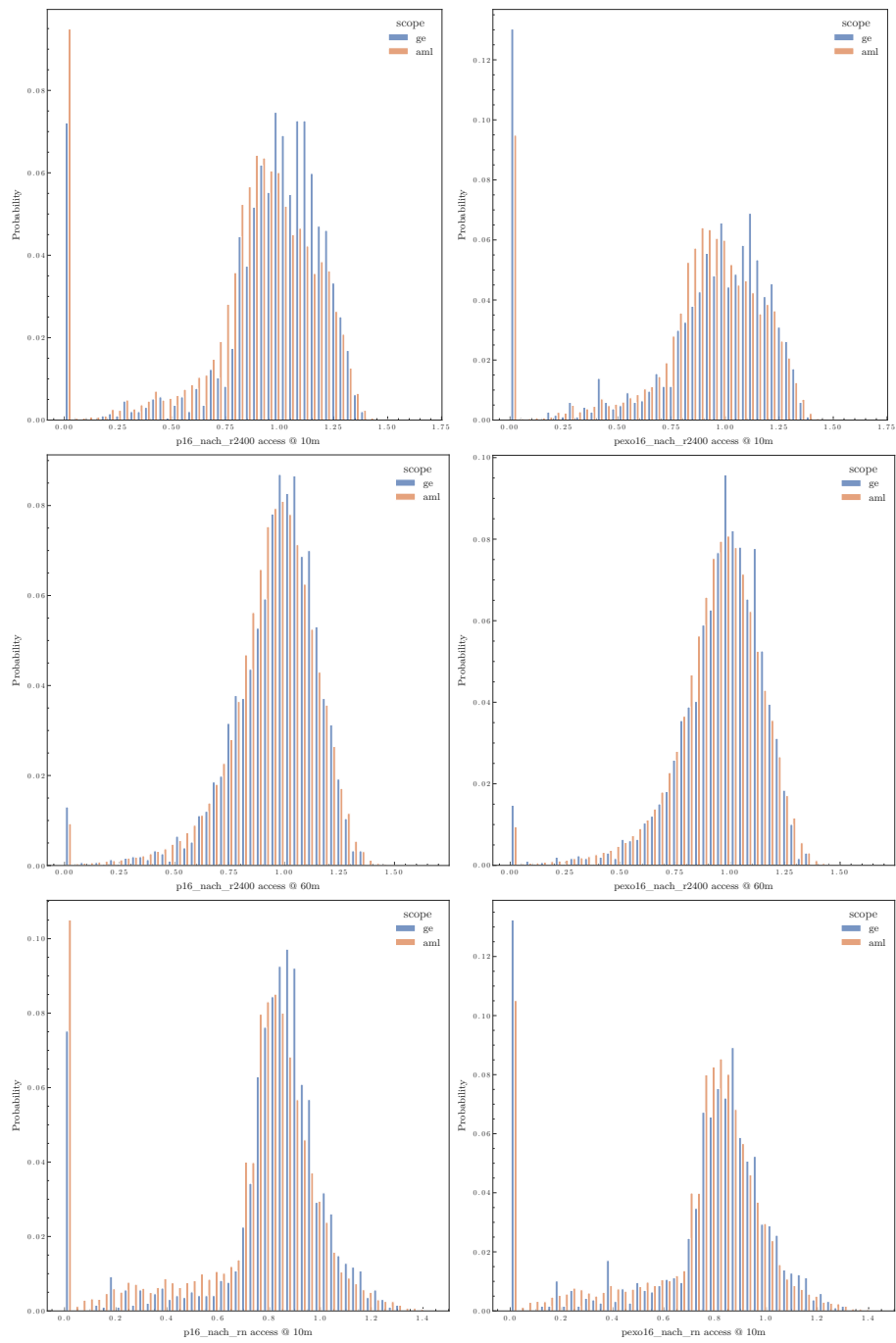


**Figure K.29:** Probability distribution of, from top to bottom, pop, cmc, and svc vehicular street segments at 10 (left) and 60 m (right) buffers of enclave (ge, in blue) and other residential (aml, in orange) walls. Range used is of the entire AML network.

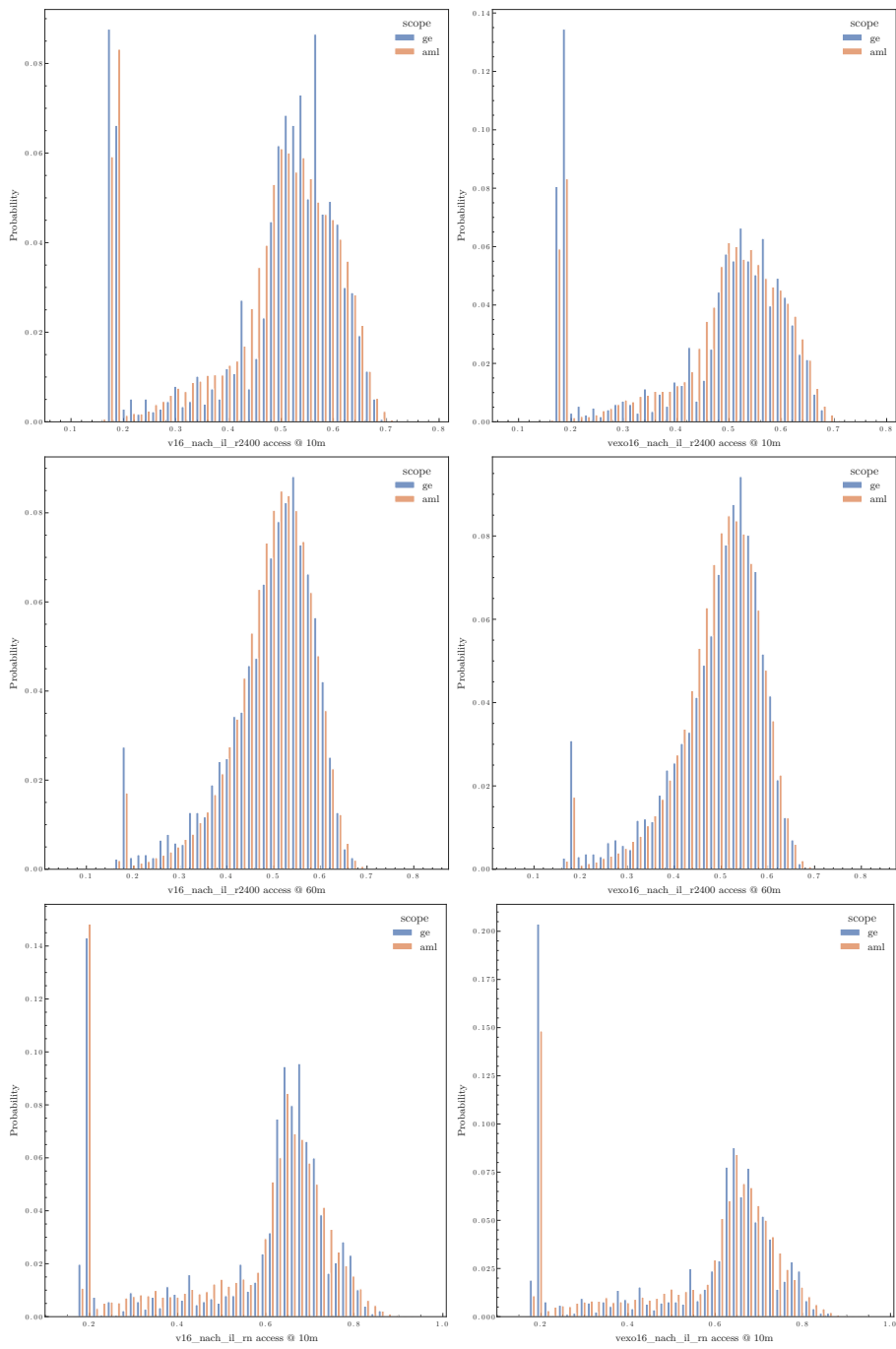


**Figure K.30:** Probability distribution of NACH\_il within open gate (left) versus closed gate (right) pedestrian network buffers of enclave (ge, in blue) and other residential (aml, in orange) access points.

## K Configurational Analysis

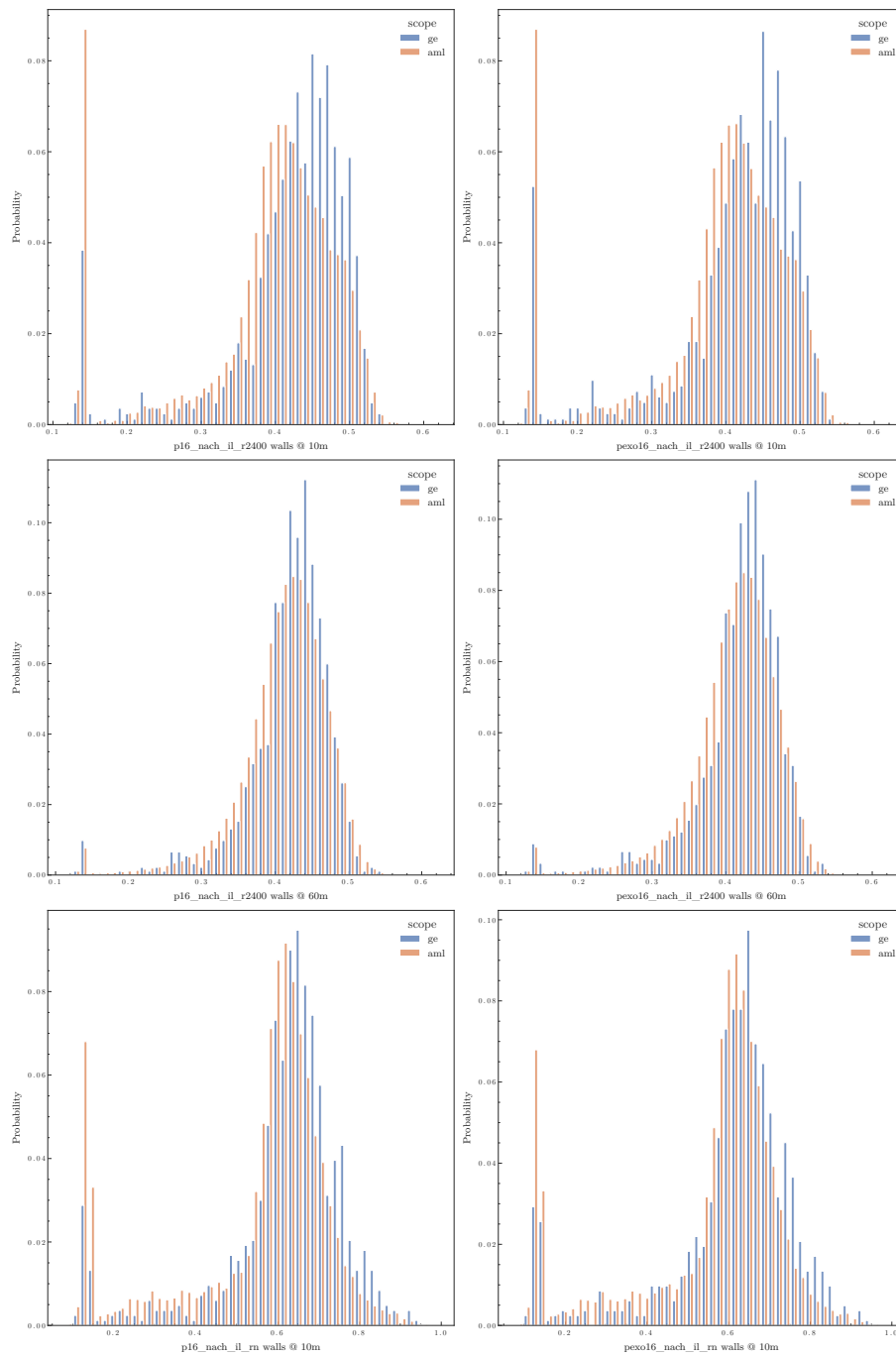


**Figure K.31:** Probability distribution of classic NACH within open gate (left) versus closed gate (right) pedestrian network buffers of enclave (ge, in blue) and other residential (aml, in orange) access points.

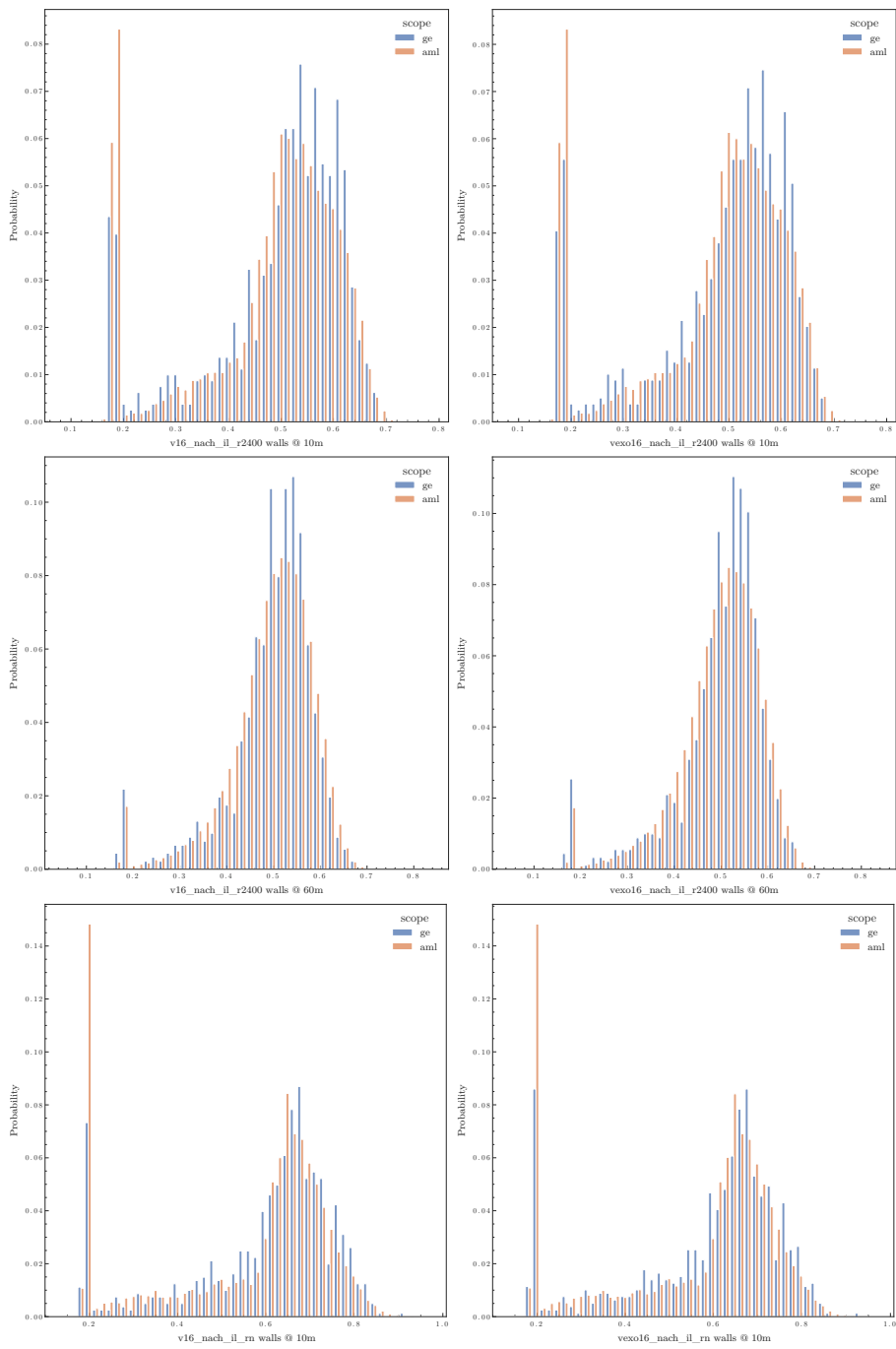


**Figure K.32:** Probability distribution of NACH\_il within open gate (left) versus closed gate (right) vehicular network buffers of enclave (ge, in blue) and other residential (aml, in orange) access points.

## K Configurational Analysis

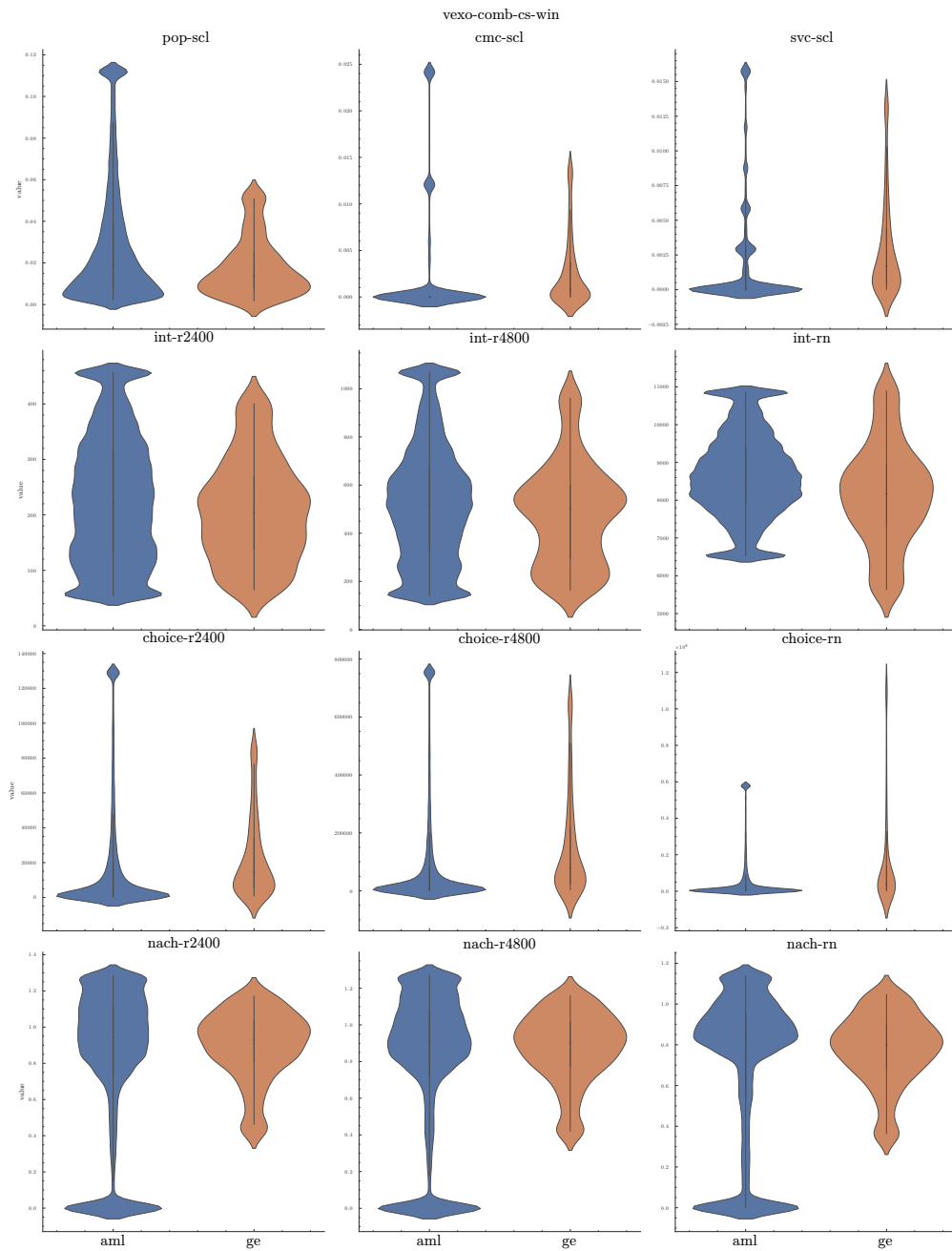


**Figure K.33:** Probability distribution of NACH\_il within open gate (left) versus closed gate (right) pedestrian network buffers of enclave (ge, in blue) and other residential (aml, in orange) walls.

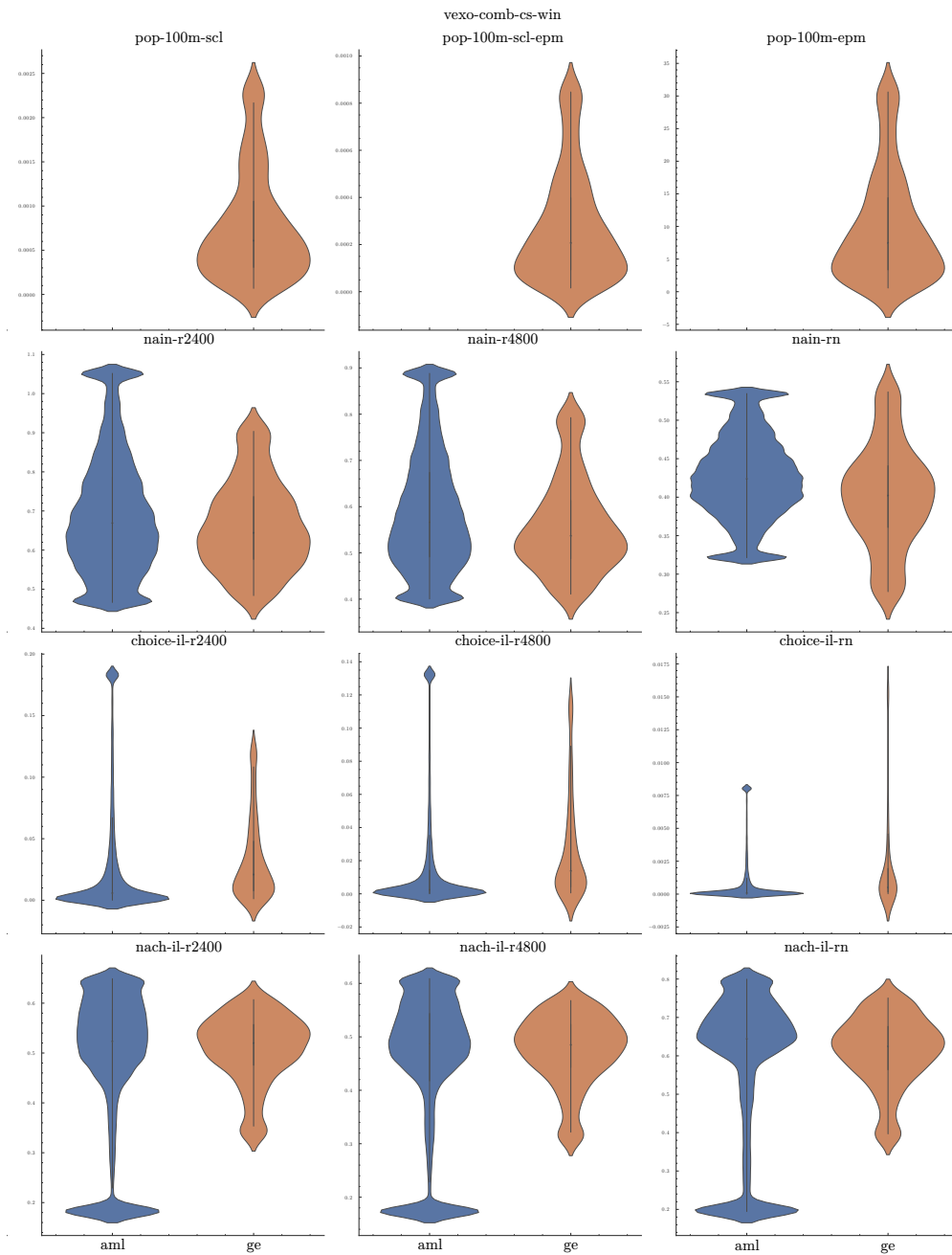


**Figure K.34:** Probability distribution of NACH\_il within open gate (left) versus closed gate (right) vehicular network buffers of enclave (ge, in blue) and other residential (aml, in orange) walls.

## K Configurational Analysis

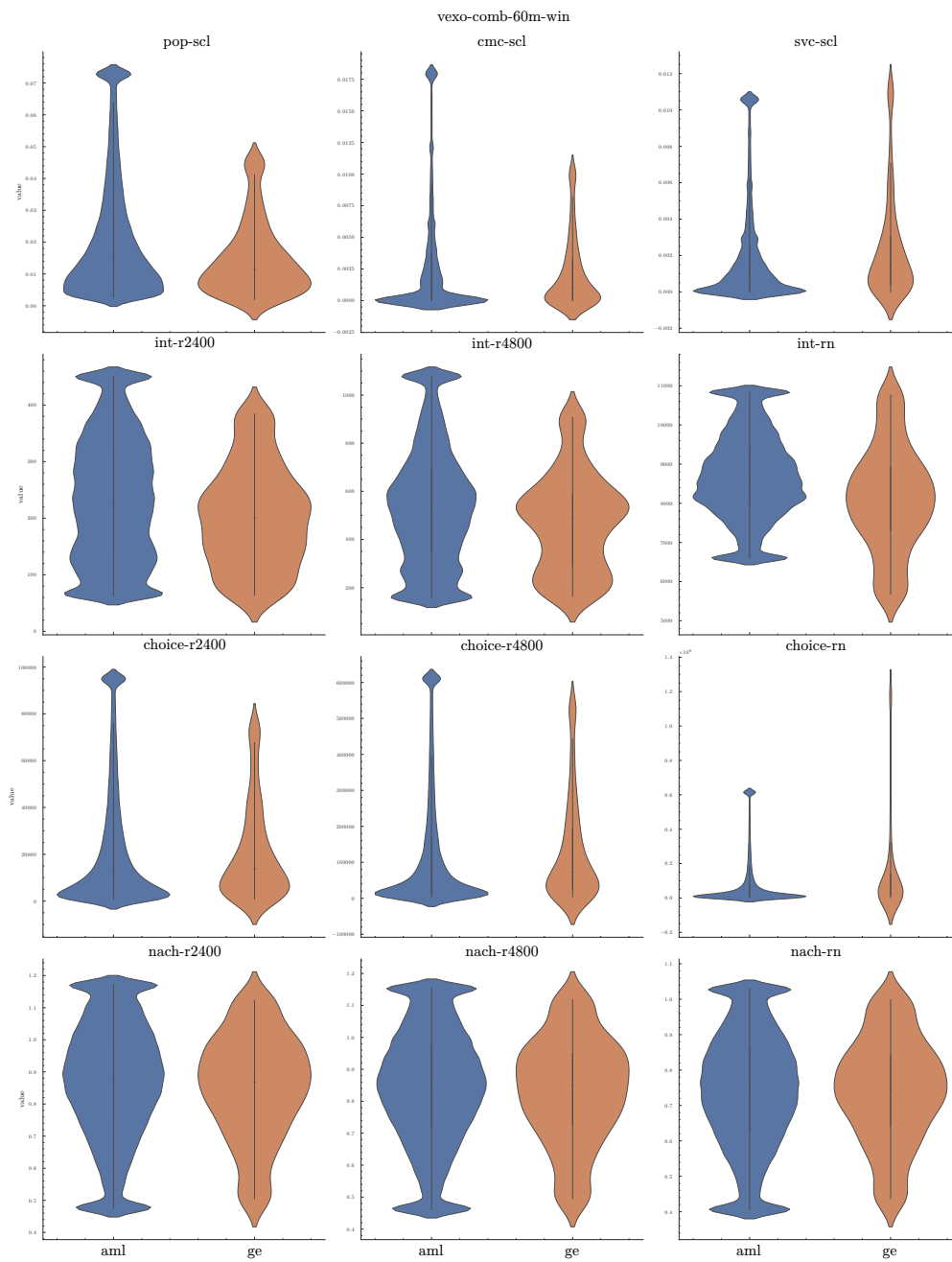


**Figure K.35:** Violin plots of (winsorised) configurational attribute values for the closest street segment (CS) to enclave walls (orange) and the building centroid of the remaining residential stock of the AML (blue). From left to right, top to bottom: SSP, SSC, SSS, integration, choice, and NACH at, respectively,  $r = 2400$  m,  $r = 4800$  m, and  $r = n$  ...

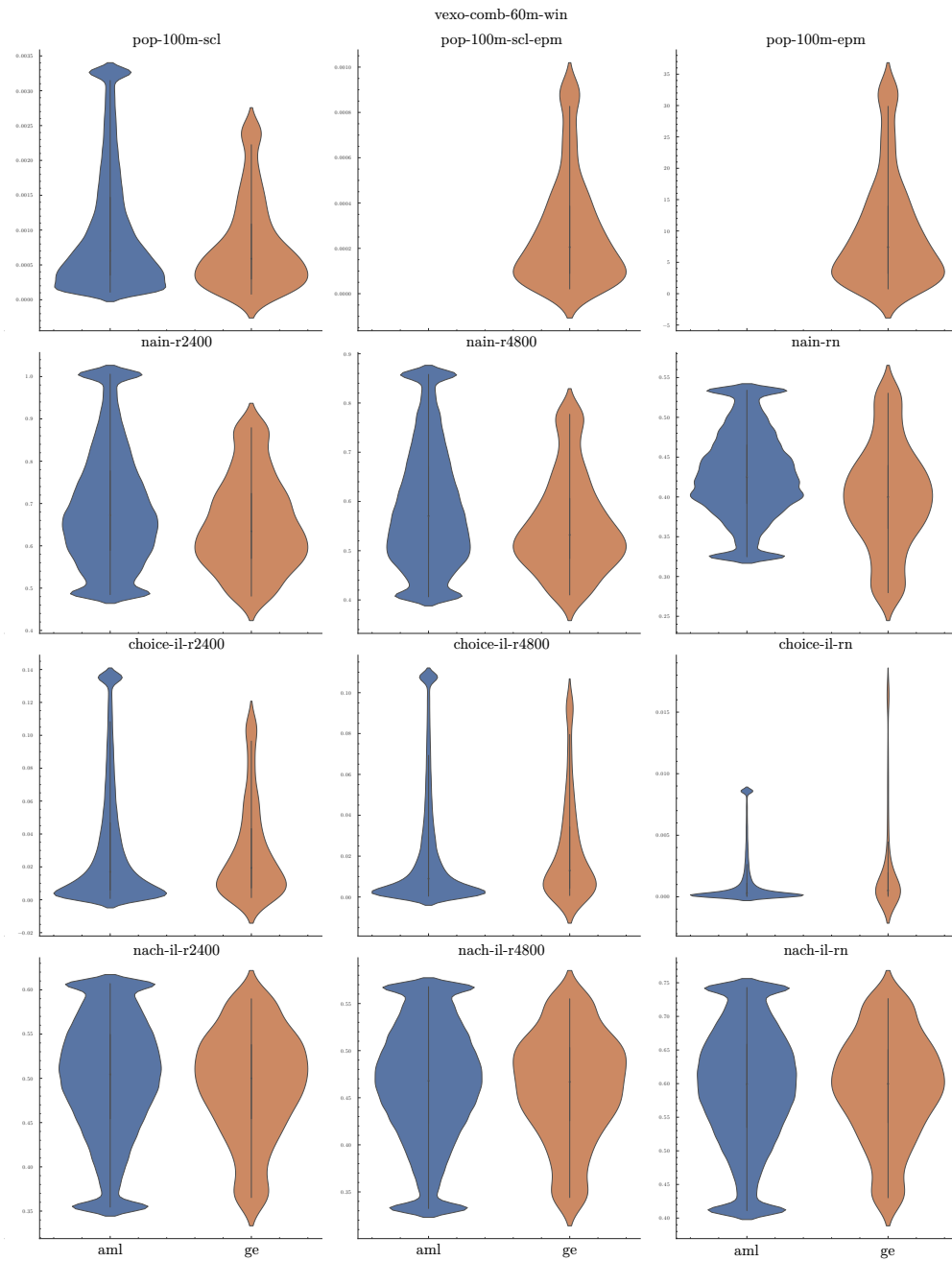


**Figure K.36:** ... SSP (100m SS buffer), SSP (100m SS buffer weighed by wall perimeter), SP (100m SS buffer weighed by wall perimeter), NAIN, SS-length weighed choice, and SS-length weighed NACH at, respectively,  $r = 2\,2400$  m,  $r = 4\,4800$  m, and  $r = n$

## K Configurational Analysis

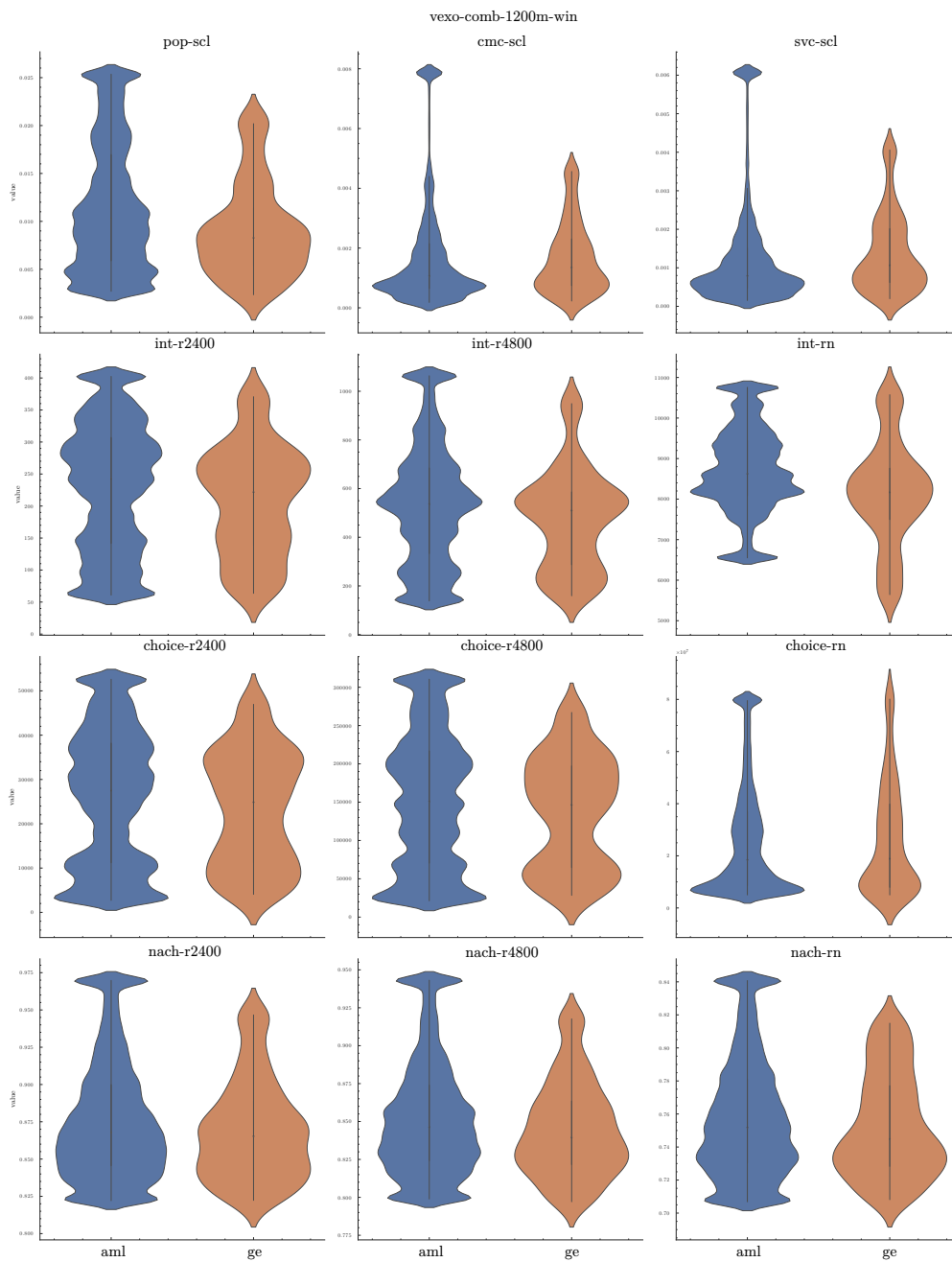


**Figure K.37:** Violin plots of mean (winsorised) configurational attribute values for a 60 m buffer of enclave walls (orange) and building centroid of the remaining residential stock of the AML (blue). From left to right, top to bottom: SSP, SSC, SSS, integration, choice, and NACH at, respectively,  $r = 2\,2400$  m,  $r = 4\,4800$  m, and  $r = n$  ...

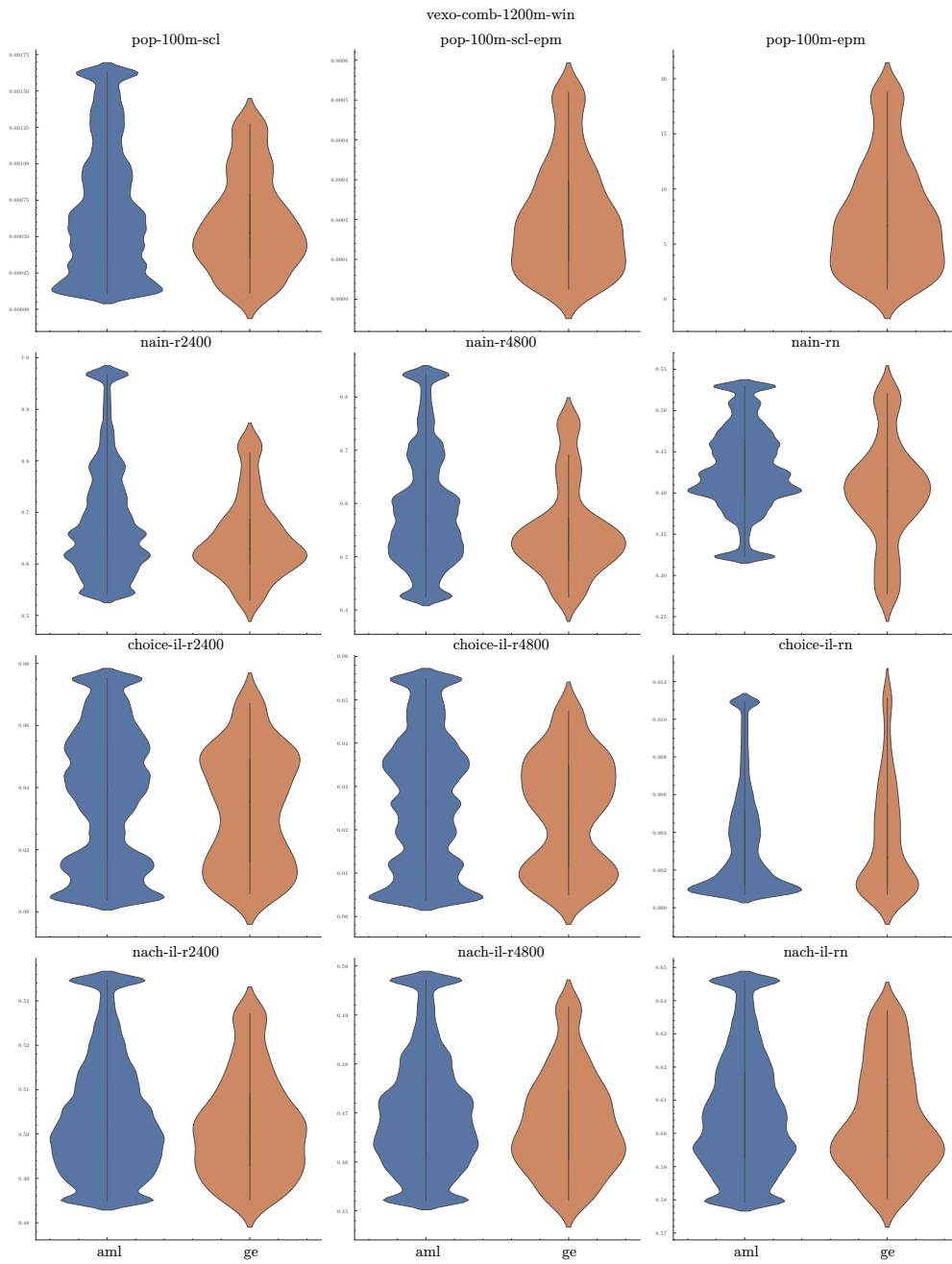


**Figure K.38:** ... SSP (100m SS buffer), SSP (100m SS buffer weighed by wall perimeter), SP (100m SS buffer weighed by wall perimeter), NAIN, SS-length weighed choice, and SS-length weighed NACH at, respectively,  $r = 2\,2400$  m,  $r = 4\,4800$  m, and  $r = n$

## K Configurational Analysis



**Figure K.39:** Violin plots of mean (winsorised) configurational attribute values for a 1200 m buffer of enclave walls (orange) and building centroid of the remaining residential stock of the AML (blue). From left to right, top to bottom: SSP, SSC, SSS, integration, choice, and NACH at, respectively,  $r = 2\,240\text{ m}$ ,  $r = 4\,480\text{ m}$ , and  $r = n \dots$



**Figure K.40:** ... SSP (100m SS buffer), SSP (100m SS buffer weighed by wall perimeter), SP (100m SS buffer weighed by wall perimeter), NAIN, SS-length weighed choice, and SS-length weighed NACH at, respectively,  $r = 2\,240$  m,  $r = 4\,480$  m, and  $r = n$

*K Configurational Analysis*

**Figure K.41 (on next page):** Preliminary taxonomy design of confinement structures



MinimumElements	Differentiation	Subject	Ecology	Process	Context	Integration
Gates,fence or wall,natural features,security guards,cctv, weapons		Prisoners,captives,POWs,or political detainees Subjects with psychiatric disorders, moral or cultural abnormalities, abnormal physical conditions,or pooreconomic conditions	Suburbsand innercity areas	State built and maintained. Increasingly state-sponsored private enterprise	Temporary confinement since ancient times. Permanent confinement mostly since 17th century	8.65
Gates,fence or wall,natural features,security guards,cctv		Refugees,statelesspersons, internally displaced persons,illegal migrants,asylumseekers	Suburbsand innercity areas	State built and maintained.Some private enterprise	Mostly since 17th century	8.65
Gates,fence or wall,natural features,security guards,cctv, weapons		Refugees,statelesspersons, internally displaced persons,illegal migrants,asylumseekers	Rural regionsnear national borders, suburbs,inner city areas.	International cooperations,NGOs, local state-sponsorship		
Natural features,security guards,cctv		Studentsand staff (especially of military institutions) Abandoned children,children under security risk	Mostly rural regions Mostly innercity areas or suburbs	Private enterprise,state sponsorship State built and maintained,state-sponsored private enterprise		4.07
Gates,fence or wall		Workers(adult or children). Normally low working class.	Suburbs,rural areas,and innercity areas	Private enterprises	Mostly since early 19th century	3.17
Natural features,security guards,cctv		Workers.Normally middle class.	Suburbs,rural areas,and innercity areas	Private enterprises,state-sponsored private enterprises	Mostly since mid 20th century	
Gates,fence or wall,natural features,security guards,cctv		Patientsand staff	Suburbsand innercity areas	State built and maintained,private enterprises,state-sponsored private enterprises	Mostly since 18th century	7.77
Fence or wall,natural features, security guards,cctv,weapons	Staff identification.Passenger identification (tickets).Several layersof spatial enclosures. Racial profiling.	Local and international staff. International temporary communities,particularly in meeting loungesand hotels.	Suburbs	State built and maintained,private enterprises,state-sponsored private enterprises	Since mid 20th century	
Gates,fence or wall,natural features,security guards,cctv, weapons		Local staff.Security staff.	Suburbsand city coastlines	State built and maintained,private enterprises,state-sponsored private enterprises	In variousformssince ancient times	
Gates,natural features,cctv		Ambassadorsand respective families,Embassy staff and respective families,military, supporting staff.Majority foreign. Diplomatic immunity for some staff. Diplomatic asylumnormally granted to those within the compounds. Foreign staff and families.Minority of local supporting staff.May enjoy unique regulationswithin the compound.	Wealthy suburbs,top city districts	Host country state built and guest country state-sponsored and maintained	In variousformssince ancient times	
Gates,fence or wall,natural features		Foreign staff and families.Minority of local supporting staff.May enjoy unique regulationswithin the compound.	Wealthy suburbs,top city districts	Private enterprises.May be state-sponsored by host country	In variousformssince ancient times	
Gates,fence or wall,natural features,security guards,cctv		Upper classdwellers	Wealthy suburbs,top city districts	Private enterprises	In variousformssince ancient times	
Gates,fence or wall,natural features,security guards,cctv, weapons		International staff.Most local staff are either excluded fromthe compound orreside with limited rights.	Inner city areasof crisis-hit countries,isolated rural areasnear airfields	International cooperations,NGOs, local state-sponsorship,private enterprises		
Gates,fence or wall,natural features,security guards,cctv, weapons		Military	Innercity areas, suburbs,rural areas	State built and maintained,some private enterprises	Since ancient times	
Gates,fence or wall,natural features,security guards,cctv		Lifestyle dwellers:can include age-related,sports-related,or religious communities.Normally middle or upper class.	Suburbsand rural regions	Private enterprises,some state built and maintained or state-sponsored private enterprises	Mostly since late 1960s	
Gates,fence or wall,natural features,security guards,cctv, weapons		Upper classdwellers.	Top city districts, wealthy suburbs Inner city areas,old suburbs.Areaswith recent migration influx.	Private enterprises	In variousformssince ancient times	
Gates,fence or wall,road barriers,community policing		Upper classor lower classdwellers	Upper classor lower classdwellers	Private enterprises,some may be state-sponsored	In variousformssince ancient times	
Gates,fence or wall,natural features,security guards,cctv, weapons		Upper classdwellers	Top city districts, wealthy suburbs Inner city areas,old suburbs.Areaswith recent migration influx.	Private enterprises	In variousformssince ancient times	
Gates,fence or wall,road barriers,community policing		Upper classor lower classdwellers	Upper classor lower classdwellers	Private enterprises,some may be state-sponsored	In variousformssince ancient times	
Gates,fence or wall,natural features,security guards,cctv, weapons	Staff identification.Foreign vs national staff differentiation. Racial profiling.ID cards.	Refugees,statelesspersons, internally displaced persons	Isolated rural regions near borders	International cooperations,NGOs, local state-sponsorship		
Gates,fence or wall,natural features,security guards,cctv, weapons		Upper classdwellers	Top city districts, wealthy suburbs	Private enterprises	In variousformssince ancient times	
Natural features,cctv		Lifestyle dwellers:can include age-related,sports-related,or religious communities.Normally middle or upper class.	Suburbsand rural regions	Private enterprises,some state built and maintained or state-sponsored private enterprises	Mostly since late 1960s	
Natural features,cctv	Staff identification	Lifestyle dwellers:can include age-related,sports-related,or religious communities.Normally middle or upper class.	Suburbsand rural regions	Private enterprises,state-sponsored private enterprises	At least since early 19th century. Dramatic development since beginning of 21st century	
Gates,fence or wall,natural features,security guards,cctv	Staff identification	Upper classdwellers	Suburbsand rural regions	Private enterprises,state-sponsored private enterprises	Since beginning of 21st century	
Natural features,security guards,weapons	Racial profiling.ID cards.	Refugees,statelesspersons, internally displaced persons	Isolated rural regions nearnational borders	International cooperations,NGOs, local state-sponsorship	N/A	

*K Configurational Analysis*

**Figure K.42 (on next page):** Network configuration graphs of interior confinement typologies based on studies by Markus (1993). Hierarchical layout strategy based on the Sugiyama algorithm, for visualising flows within directed networks, showing respective distances to the root node and the betweenness centrality of each space.

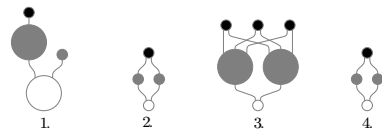
# Interior Network Graphs

Network graphs based on spatial maps produced by Markus (1993).

*Node Shade* = distance from root node (root node in white, furthest nodes in black)

*Node Scale* = Betweenness Centrality (larger nodes are more central)

*Exchange*



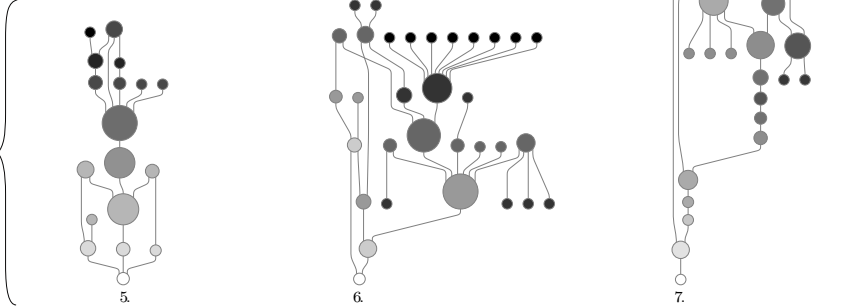
*Exchange:*

1. Spatially independent shop.
2. House dependent shop.
3. Independent rented (bazaar) unit.
4. Proto-department store trading area.

*Recreation:*

5. Bath's New or Upper assembly room (1769-71)
6. Frederick Street baths and wash-house, Liverpool (1842)
7. United Service Club, Robert Smirke's club-house, Charles Street, London (1817-19)

*Recreation*



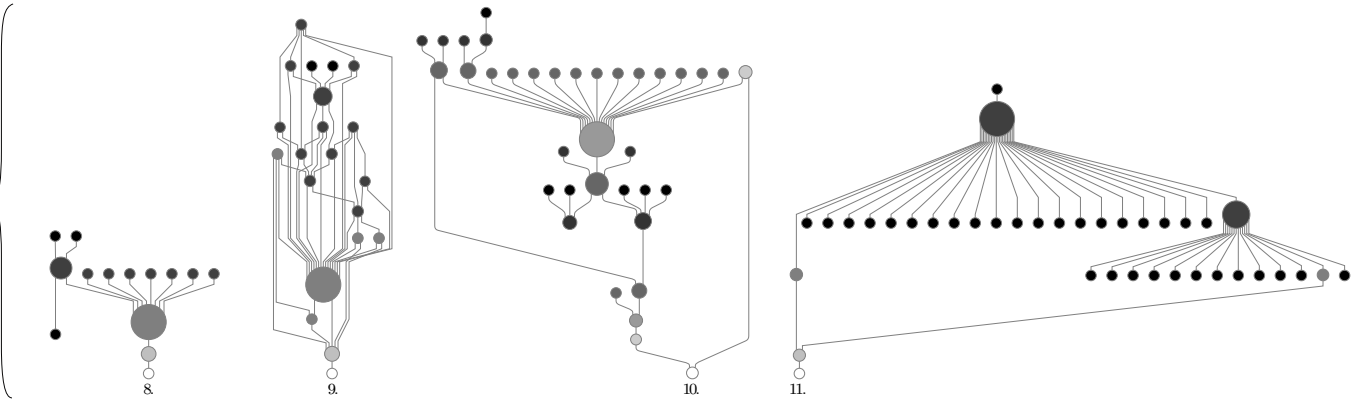
*Health:*

8. The London Hospital (1752)
9. Edinburgh Infirmary (1738)
10. Health Centre
11. Manchester Infirmary with extensions (1797)

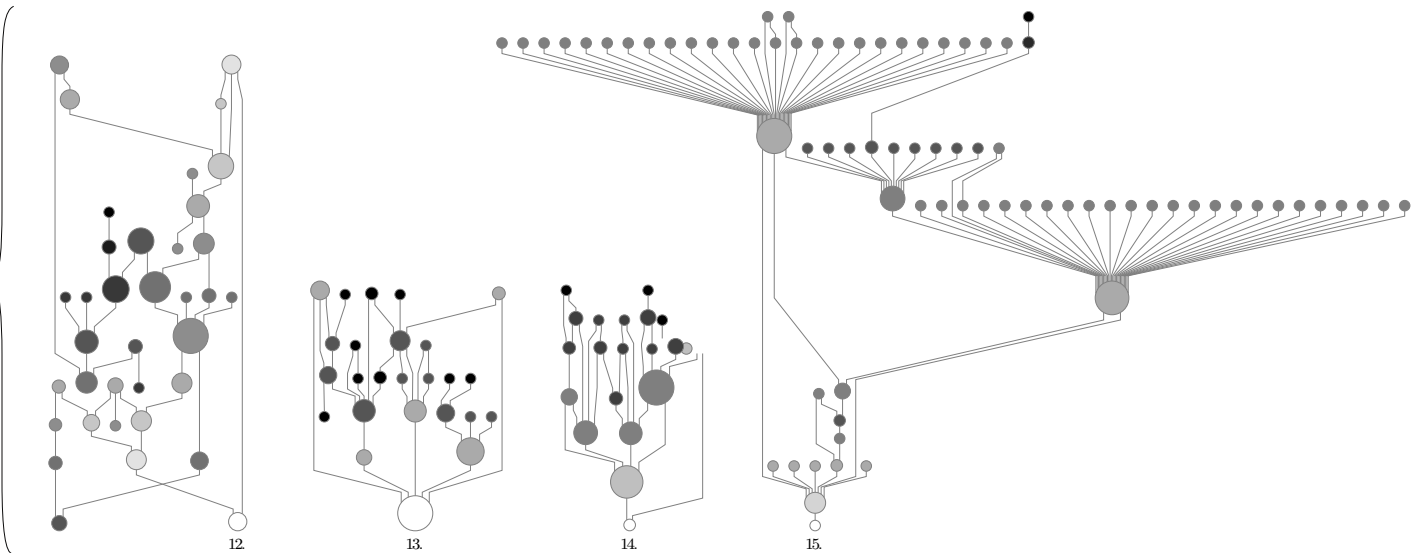
*Knowledge:*

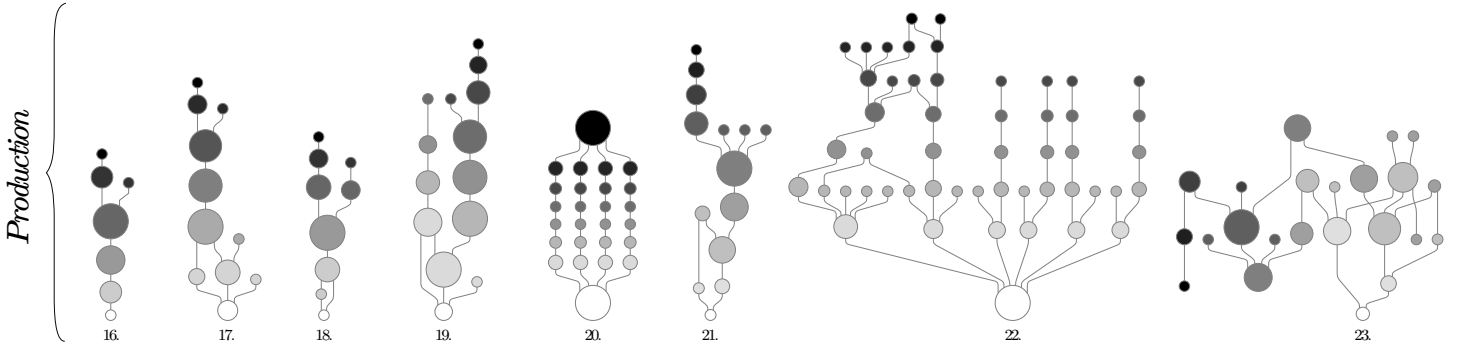
12. Hunterian Museum, Glasgow. William Stark (1803)
13. Great Windmill Street school of anatomy, library, museum and house. William Hunter (1768)
14. Hunterian Museum, Glasgow. Robert Mylne (1799?)
15. Universal Public Library. Leopoldo della Santa (1816)

*Health*



*Knowledge*





*Production:*

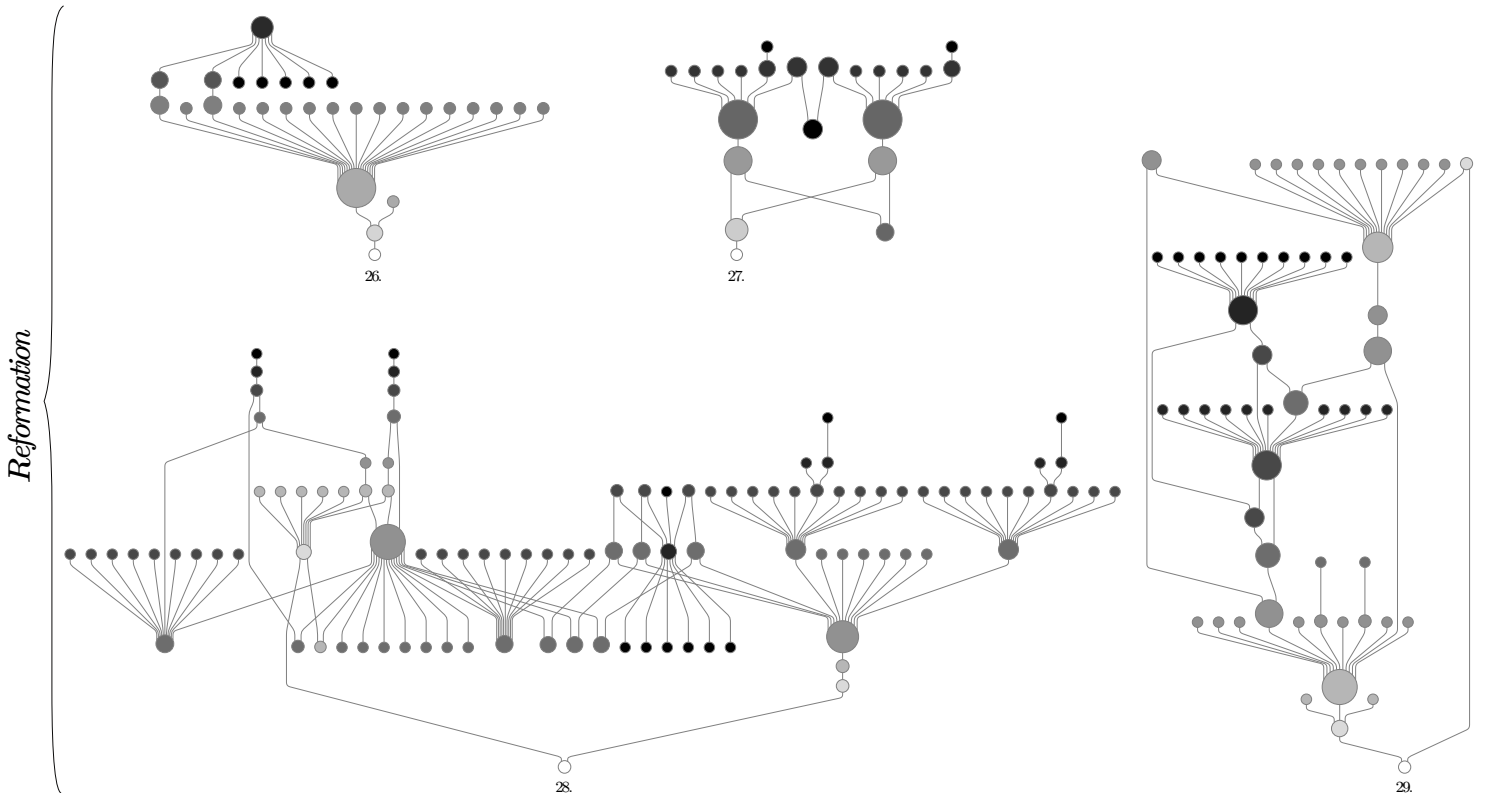
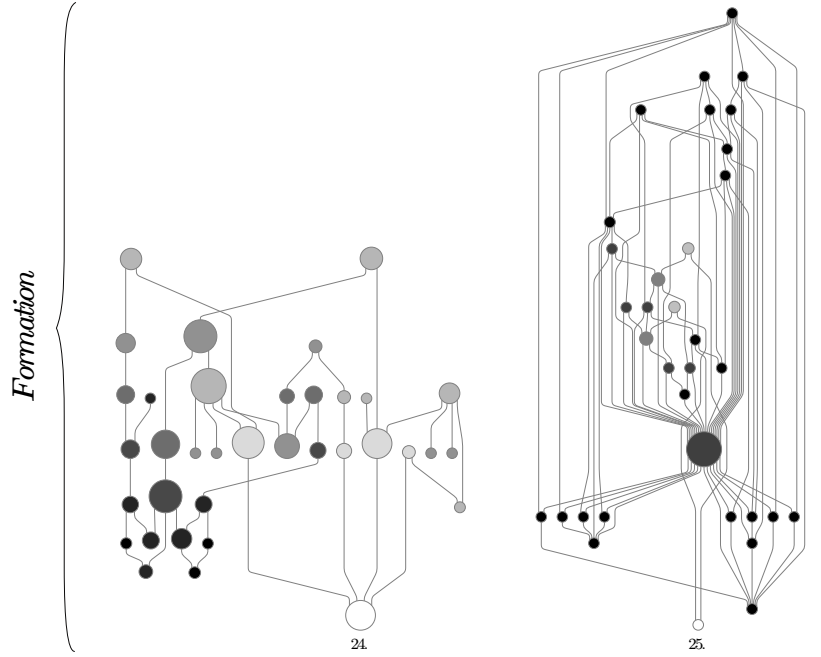
- 16. Hosiery framework knitters' house, Nottingham
- 17. Coventry ribbon loom weaver's house
- 18. Middleton loomhouse
- 19. Company house, North Street Terrace, Cromford. Arkwright (1770)
- 20. Loom shop, Wales
- 21. Silk Weaver Houses, Hope Street, Macclesfield
- 22. Master House, Chapel Street, Macclesfield.
- 23. Ribbon weavers' house, Coventry

*Formation:*

- 24. School Street School, Dublin (1798)
- 25. New North Street (board) school (1874)

*Reformation:*

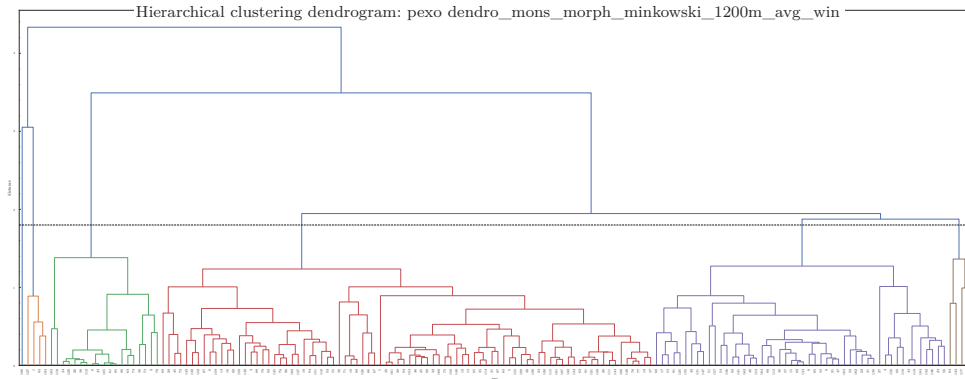
- 26. Edinburgh Bridewell. Robert Adam, 4th design, (1791). (based on Bentham's panopticon)
- 27. Parish workhouse, St. George's Hannover Square, London (1725)
- 28. St Patrick's Hospital, Dublin. George Semple (1749)
- 29. Gloucester infirmary (1760)



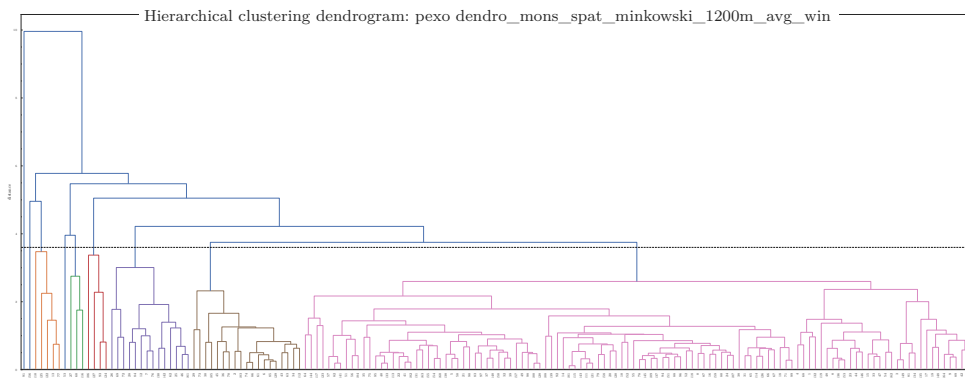


# L Hierarchical Classification

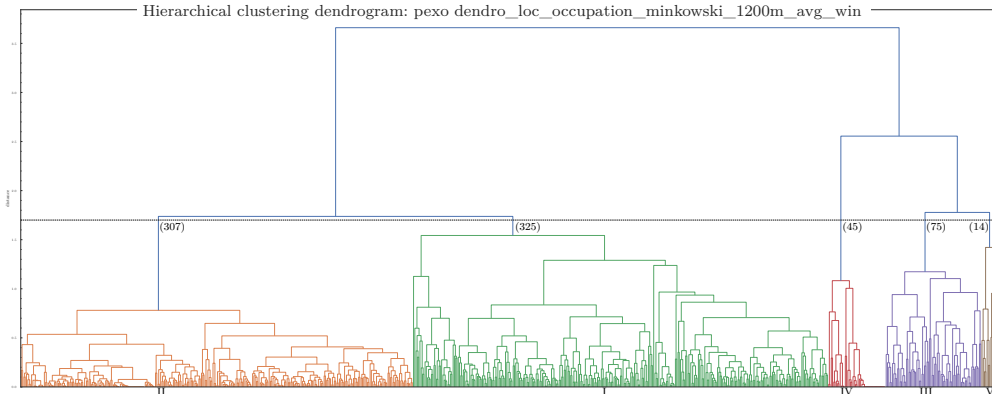
*L Hierarchical Classification*



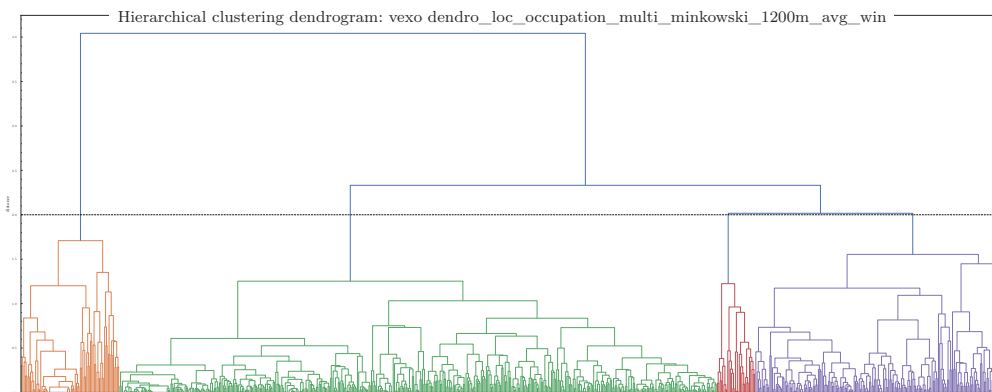
**Figure L.1:** Hierarchical clustering dendrogram of medieval gated enclaves based on morphological attributes and calculated according to Minkowski distance



**Figure L.2:** Hierarchical clustering dendrogram of medieval gated enclaves based on spatial attributes and calculated according to Minkowski distance

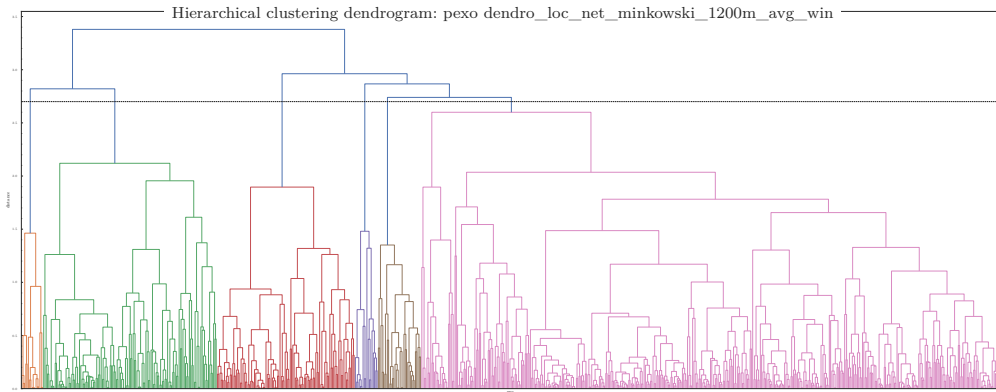


**Figure L.3:** Hierarchical clustering dendrogram of contemporary gated enclaves based on socio-economic attributes of the pedestrian network and calculated according to Minkowski distance

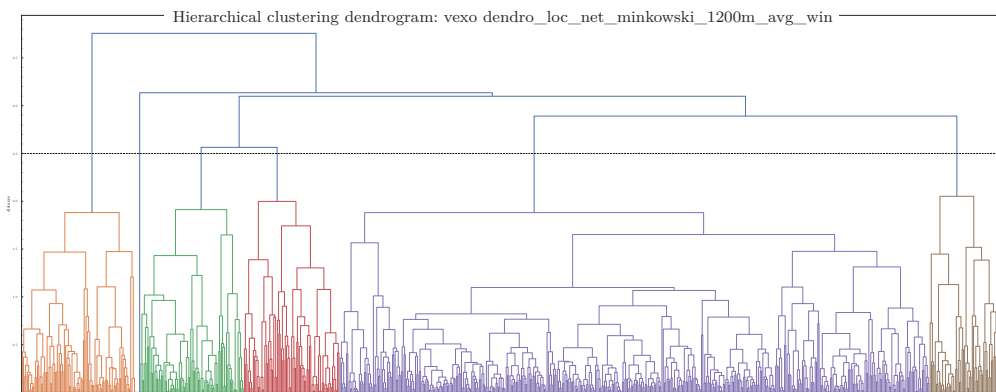


**Figure L.4:** Hierarchical clustering dendrogram of contemporary gated enclaves based on socio-economic attributes of the vehicle network and calculated according to Minkowski distance

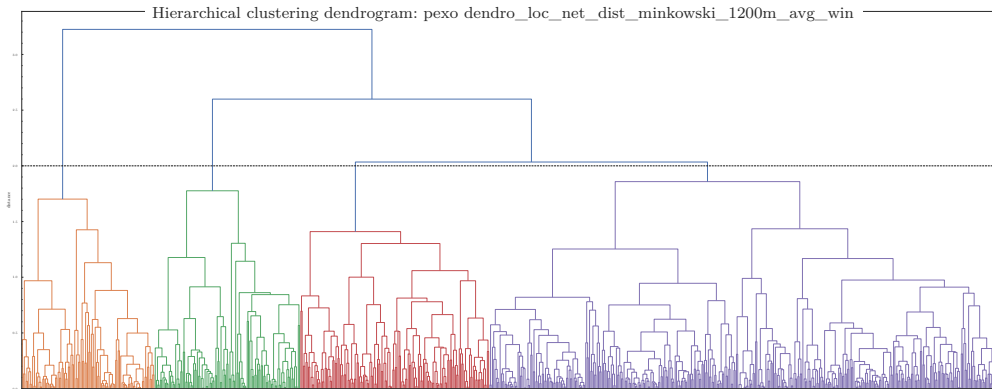
## L Hierarchical Classification



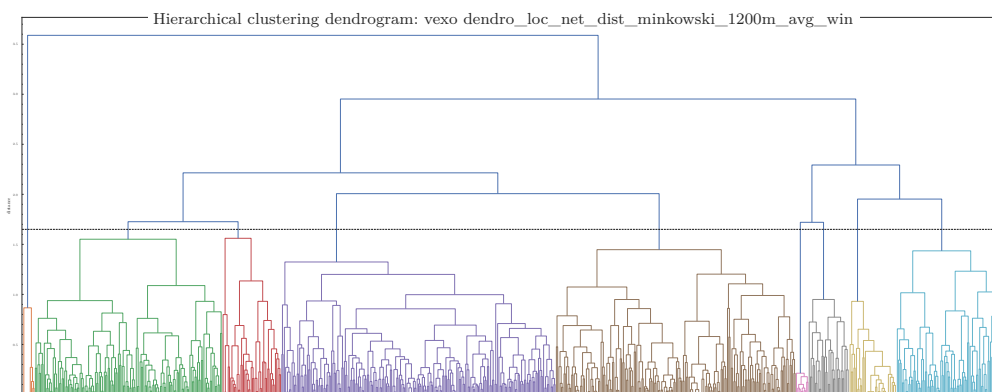
**Figure L.5:** Hierarchical clustering dendrogram of contemporary gated enclaves based on network attributes of the pedestrian network and calculated according to Minkowski distance



**Figure L.6:** Hierarchical clustering dendrogram of contemporary gated enclaves based on network attributes of the vehicle network and calculated according to Minkowski distance

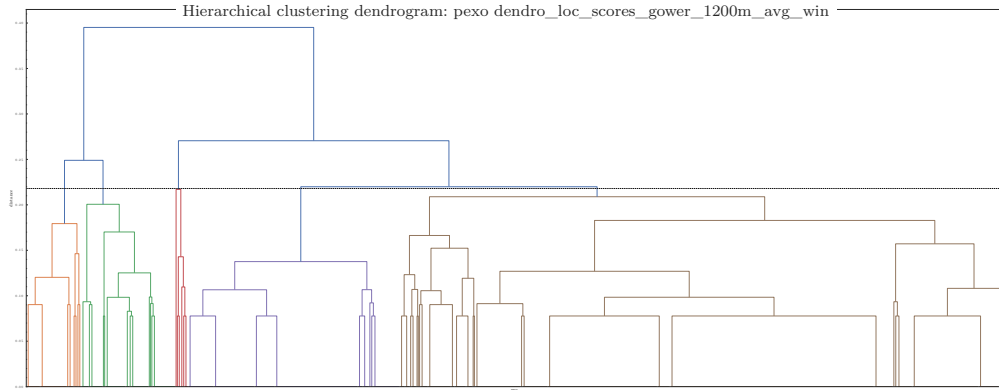


**Figure L.7:** Hierarchical clustering dendrogram of contemporary gated enclaves based on street segment length-weighted network attributes of the pedestrian network and calculated according to Minkowski distance

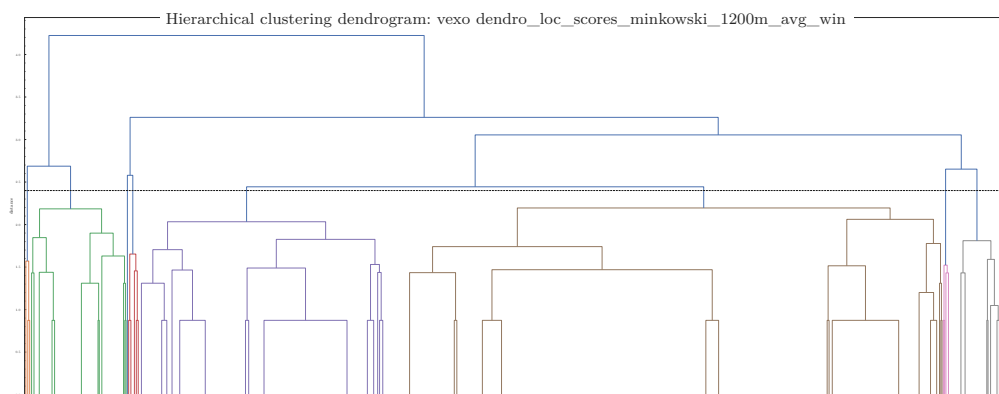


**Figure L.8:** Hierarchical clustering dendrogram of contemporary gated enclaves based on street segment length-weighted network attributes of the vehicle network and calculated according to Minkowski distance

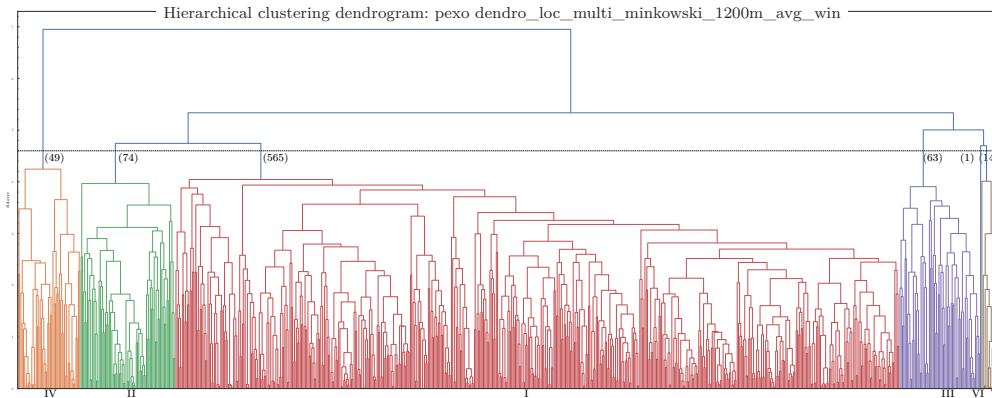
## L Hierarchical Classification



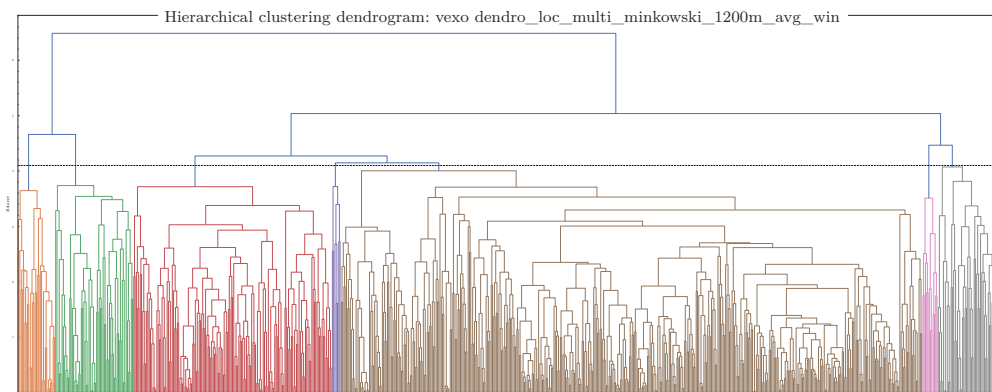
**Figure L.9:** Hierarchical clustering dendrogram of contemporary gated enclaves based on qualitative score attributes of the pedestrian network and calculated according to Minkowski distance



**Figure L.10:** Hierarchical clustering dendrogram of contemporary gated enclaves based on qualitative score attributes of the vehicle network and calculated according to Minkowski distance

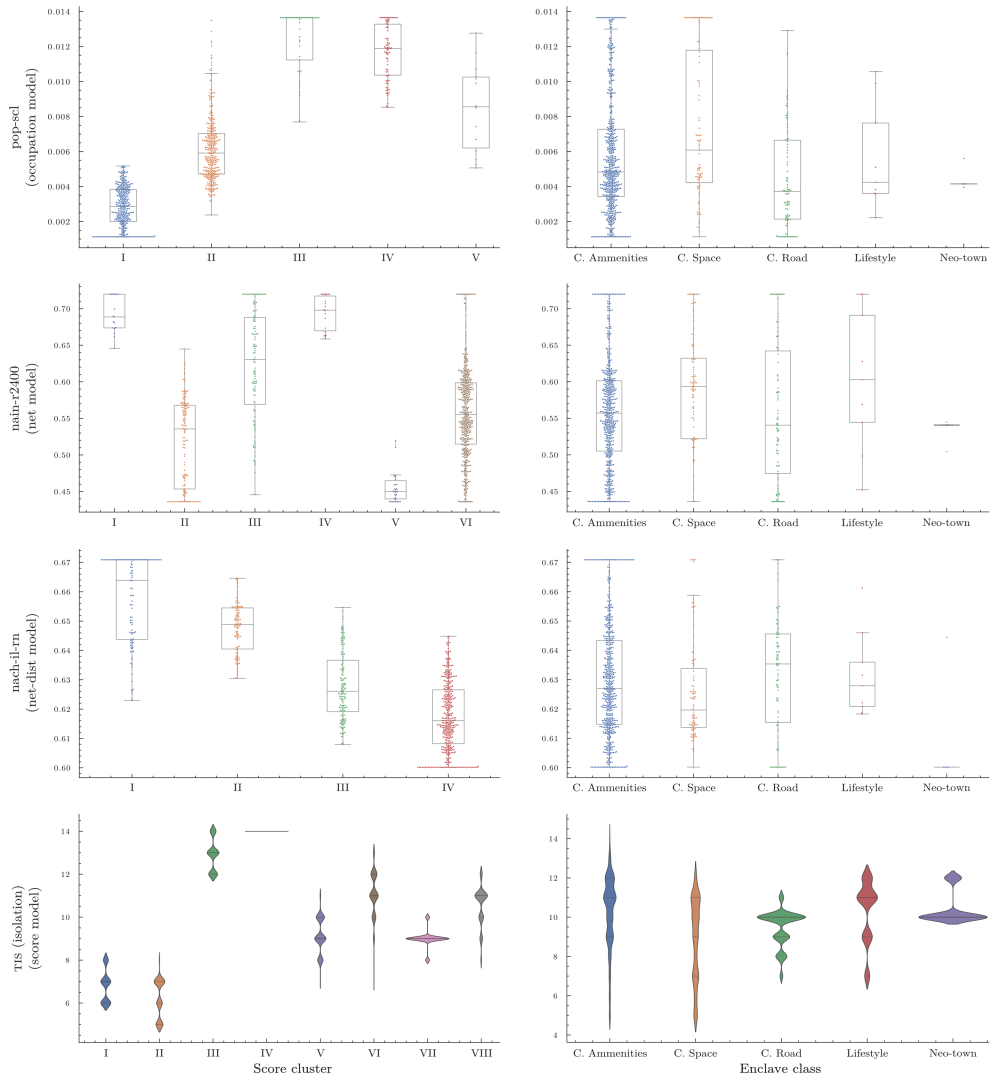


**Figure L.11:** Hierarchical clustering dendrogram of contemporary gated enclaves based on multifarious attributes of the pedestrian network and calculated according to Minkowski distance

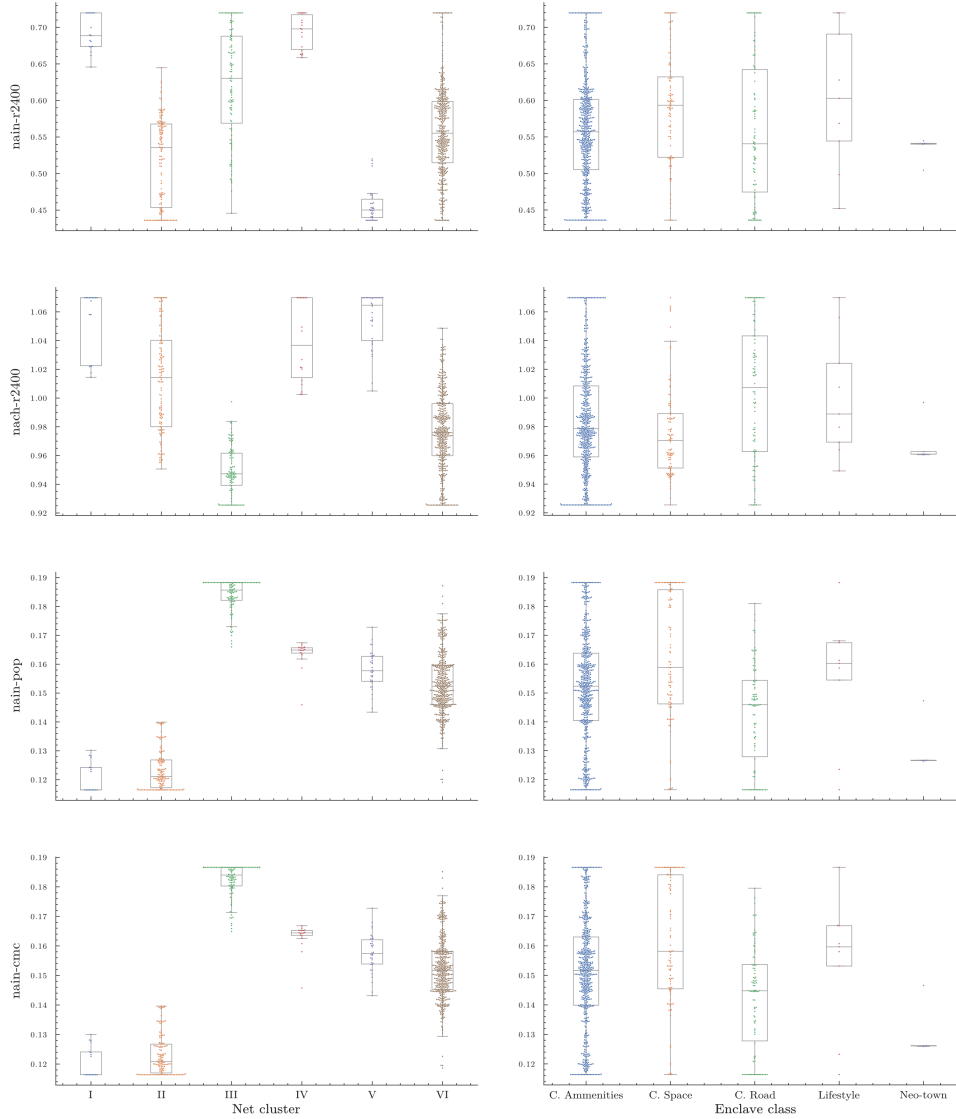


**Figure L.12:** Hierarchical clustering dendrogram of contemporary gated enclaves based on multifarious attributes of the vehicle network and calculated according to Minkowski distance

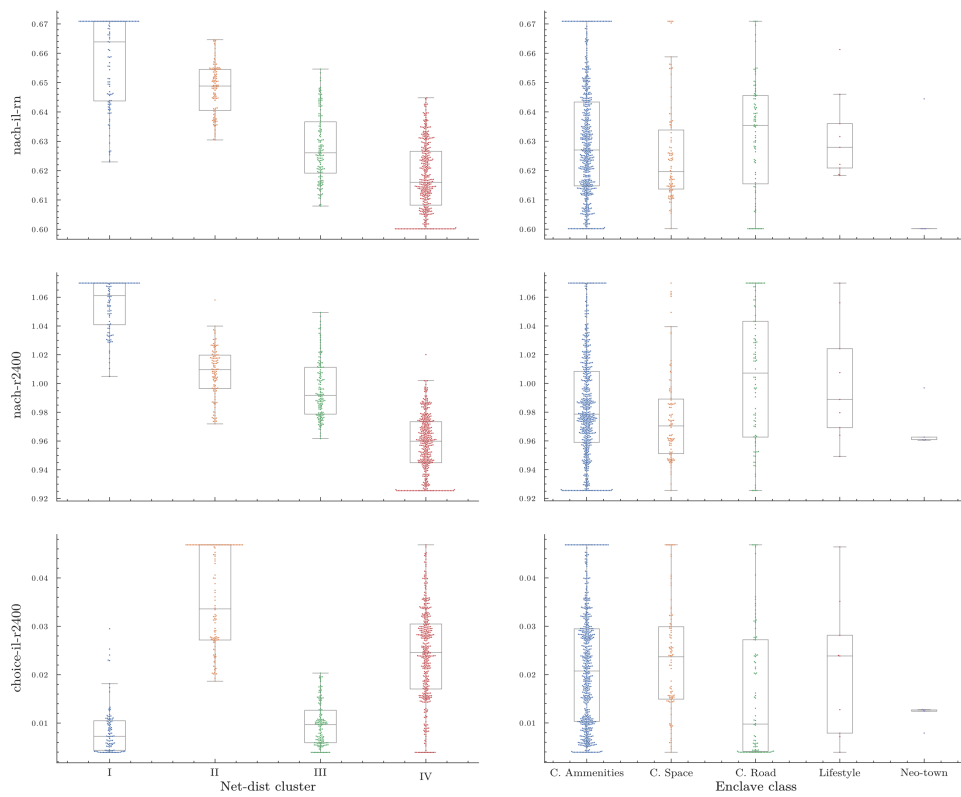
## L Hierarchical Classification



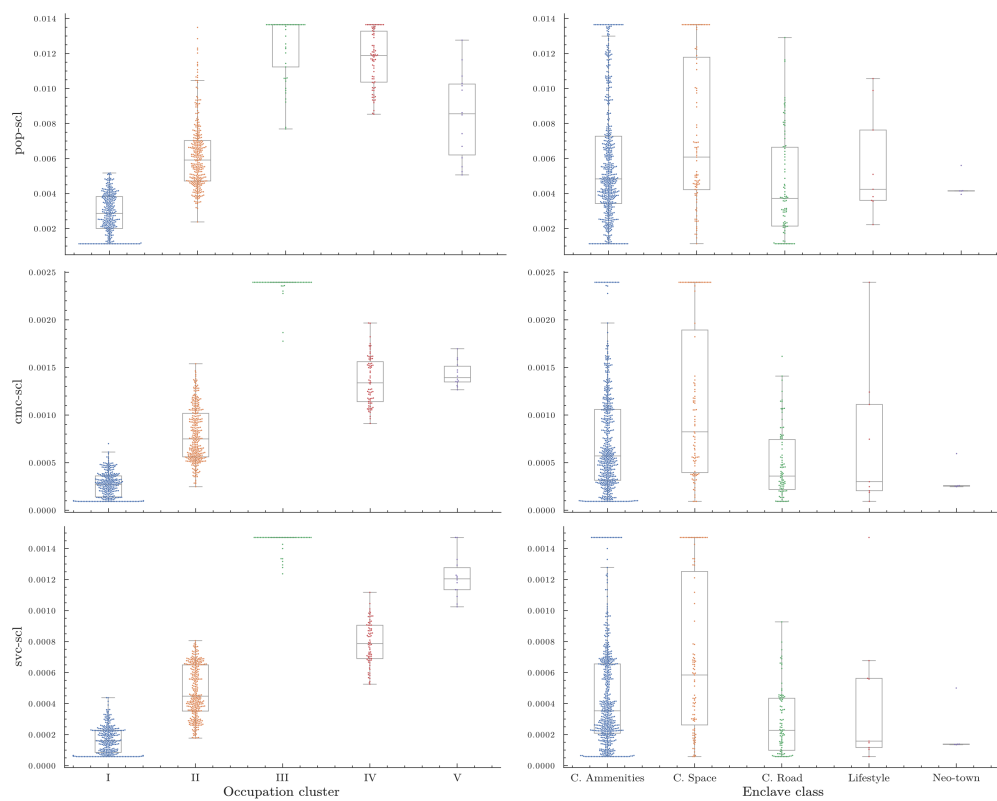
**Figure L.13:** Probability density in hierarchical clusters and qualitative classes. Displayed as combined swarm and box plots of *pop-scl*, *NAIN* at  $r = 2400$  m, *NACH-il* at  $r = n$ , and *TIS*, from the occupational, net, net-dist, and score models. Categorized by comb 1200m hierarchical cluster on left column and initial qualitative classification on the right.



**Figure L.14:** Probability density in hierarchical clusters and qualitative classes. Displayed as combined swarm and box plots of NAIN at  $r = 2400$  m, NACH at  $r = 2400$  m, nain-pop, and nain-cmc. Categorized by net 1200m hierarchical cluster on left column and initial qualitative classification on the right.

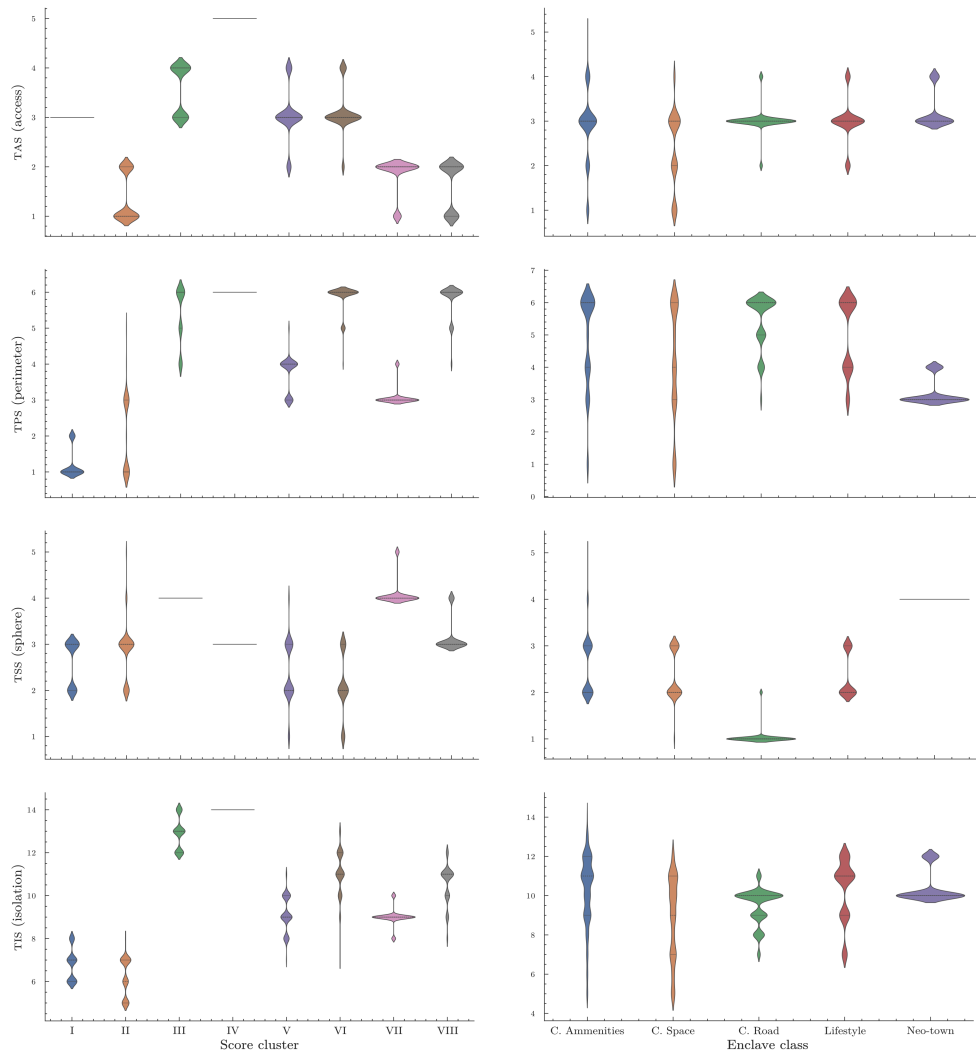


**Figure L.15:** Probability density in hierarchical clusters and qualitative classes. Displayed as combined swarm and box plots of NACH-il at  $r = n$ , NACH at  $r = 2400$  m, and choice-il at  $r = 2400$  m. Categorized by net-dist 1200m hierarchical cluster on left column and initial qualitative classification on the right.



**Figure L.16:** Probability density in hierarchical clusters and qualitative classes. Displayed as combined swarm and box plots of SSP (pop-scl), SSC (cmc-scl), and SSS (svc-scl), from the occupational model. Categorized by occupation 1200m hierarchical cluster on left column and initial qualitative classification on the right.

## L Hierarchical Classification



**Figure L.17:** Probability density in hierarchical clusters and qualitative classes. Displayed as violin plots of TAS, TPS, TSS, and TIS. Categorized by score 1200m hierarchical cluster on left column and initial qualitative classification on the right.