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Urban morphogenesis of Bejaia (1833-1962): A GIS-based framework for architectural heritage planning

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Abstract:
Evidence-informed architectural heritage planning requires a robust understanding of long-term urban morphogenesis. This paper reconstructs the spatial evolution of Bejaia (Bougie), Algeria, from 1833 to 1962 and tests how diachronic Geographic Information System (GIS)-based indicators can substantiate safeguarding priorities in Mediterranean coastal historic centres. A multi-source corpus of alignment plans, topographic and cadastral maps, port documents and administrative reports was critically assessed, georeferenced and vectorised to produce comparable urban-form states. A morphological geodatabase of built-up envelopes, street hierarchy, squares, facilities and boundaries supported measurements of land take, growth rates, block fragmentation and Gravelius compactness, with uncertainty addressed through source cross-checking. Results reveal three growth regimes: limited expansion up to 1890 (+11.4 ha; 0.20 ha/year), structured growth from 1890 to 1958 (+78.2 ha; 1.15 ha/year) and abrupt acceleration from 1958 to 1962 (+52.7 ha; 13.18 ha/year). Across phases, inherited boulevards, former defensive boundaries and the port-city interface emerge as active structures that organise urban continuity and guide phased conservation, regeneration and stitching interventions. The protocol is, in principle, transferable to comparable coastal and heritage cities with sufficient archival and cartographic coverage.

Keywords:
Bejaia; urban geohistory; historical cartography; GIS; urban morphology; architectural heritage; planning decision support

1. Introduction

Urban morphogenesis and spatial expansion have become central questions in contemporary planning, particularly in coastal and heritage-rich cities where rapid urbanisation, infrastructure pressure and environmental vulnerability intersect. International research increasingly emphasises that urban growth should be analysed not only as a quantitative increase in built-up land, but also as a transformation of spatial structures, interfaces, public spaces and ecological performance. This position is especially relevant for historic Mediterranean cities, where inherited fabrics, port functions, defensive limits and modern extensions remain interdependent. This interpretation is grounded in established work on town-plan analysis, urban permanences, the street-block system and the Historic Urban Landscape approach [1-4].

Geographic Information System (GIS)-based historical analysis offers a rigorous means of documenting these long-term transformations. By georeferencing archival maps, vectorising comparable urban-form states and computing morphometric indicators, researchers can identify growth rhythms, spatial discontinuities, permanent structures and areas where planning intervention should be prioritised. Recent studies on urban expansion, local climate zones, heat-island exposure, vegetation dynamics and environmentally sensitive productivity confirm the value of coupling spatial measurement with planning interpretation [5-8]. It also follows a broader historical-GIS and landscape-information logic in which archival maps, georeferenced layers and spatial indicators are combined to make past urban states comparable and analytically interpretable [5-10].

Despite these advances, many Mediterranean and North African cities remain under-represented in international debates on urban morphogenesis and heritage planning. Bejaia, a historic Algerian port city with a complex stratification of pre-colonial, colonial and post-colonial layers, provides a relevant case for addressing this gap. Its coastal location, constrained topography, inherited fortifications, and port-city interface make it an instructive laboratory for examining how historical limits become contemporary planning structures.

Existing research on Bejaia has addressed urban regeneration, heritage practices, social perceptions of historic spaces and the difficulties of listing and governance [11-13]. Other works have reconstructed aspects of long-term change using cartographic and planimetric archives [9]. Broader debates on heritage as a social and spatial construct, the notion of patrimoine in Algeria, colonial patrimonialisation, and safeguarding plans also help situate the local case within wider heritage-planning literature [14-19]. However, two issues remain insufficiently developed for an operational diagnosis: first, a fine-grained reconstruction of the morphogenetic sequences that structured Bejaia between 1833 and 1962; second, a quantitative characterisation of these transformations through comparable spatial measures such as land take, growth rates and compactness indices.

This article therefore connects geohistorical reconstruction, morphometric measurement and planning-oriented interpretation. It asks which ruptures and continuities emerge across the successive phases of urbanisation between 1833 and 1962, and how a diachronic reading can support the delimitation and prioritisation of architectural heritage safeguarding and

enhancement planning. The contribution is both empirical and methodological: it clarifies Bejaia's colonial-period spatial transformation and proposes a transferable GIS-based protocol for heritage cities facing similar issues of growth, fragmentation and conservation.

Accordingly, the originality of the paper does not lie only in reconstructing historical growth, but in translating morphogenetic evidence into operational criteria for heritage planning. The approach is positioned between urban morphology, historical GIS and conservation planning: urban morphology provides concepts for reading blocks, axes, limits and permanences; historical GIS provides the technical framework for comparing heterogeneous cartographic states; and heritage planning translates these findings into safeguarding, regeneration and stitching priorities.

1.1. Study area and urban context

Bejaia is located on Algeria's northern seaboard and occupies a strategic position within the western Mediterranean. Its centrality has long depended on the articulation between the urban core, the bay, port infrastructures and connections to the hinterland. Early descriptions, historical notices and local studies document the pre-colonial, Ottoman and early colonial contexts of the city and help reconstruct the evolution of its historic urban fabric [20-25]. Studies of Bougie as a Maghrebi port show that the port-city interface predates the nineteenth century, which helps explain why this interface remained a persistent operator in later morphogenesis [26]. Longer historical syntheses also underline the importance of pre-colonial urban layers, from Saldae to the Hammadid foundation of al-Nasiriyya, as inherited alignments and polarities onto which nineteenth-century interventions were grafted [27,28].

The city is strongly constrained by the bay, relief and valleys, which define circulation corridors, thresholds and preferred directions of expansion. Classical descriptions emphasise the amphitheatre setting between mountain and sea and the role of the bay in organising access and limiting devices [22]. Studies of military forts and the medieval wall further confirm that defensive structures functioned both as heritage landmarks and as morphological supports, which were later reinterpreted during the colonial period [29,30]. Beyond heritage, contemporary work on sustainability assessment and mobility pressures in Bejaia highlights the need for evidence-based planning instruments capable of linking conservation, mobility and environmental performance [31,32]. The post-independence expansion of the city (1962-present), characterised by diffuse, infrastructure-led sprawl and the loss of agricultural and natural land, has been analysed in a complementary diachronic study [33]; the present paper concentrates on the formative colonial period (1833-1962) that produced the structures this later growth inherited. The study area and the main periodisation are presented in Fig. 1 and Fig. 2.

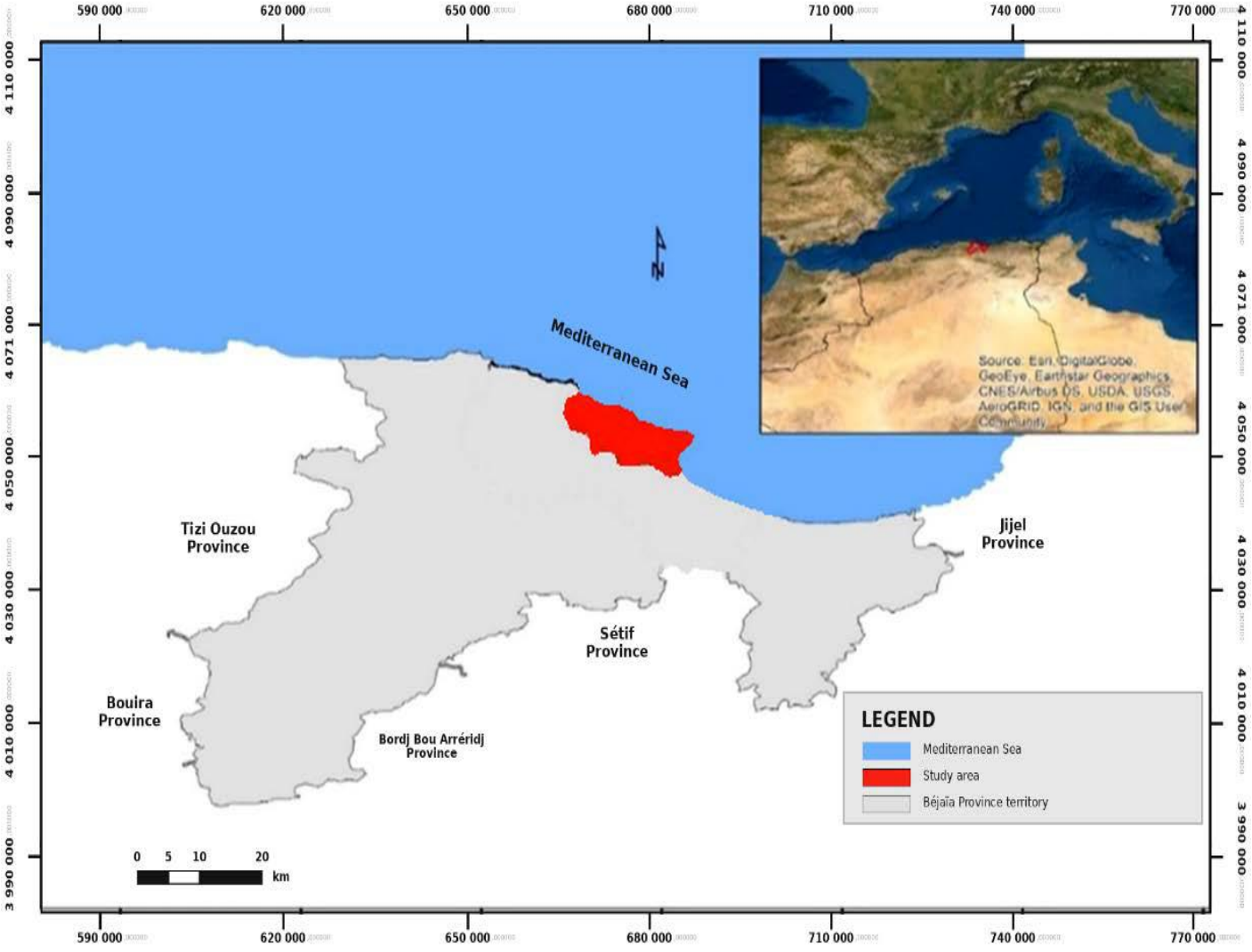

Fig. 1. Location map of Bejaia and the research area. Source: author's elaboration based on GIS data and spatial analysis of the study area

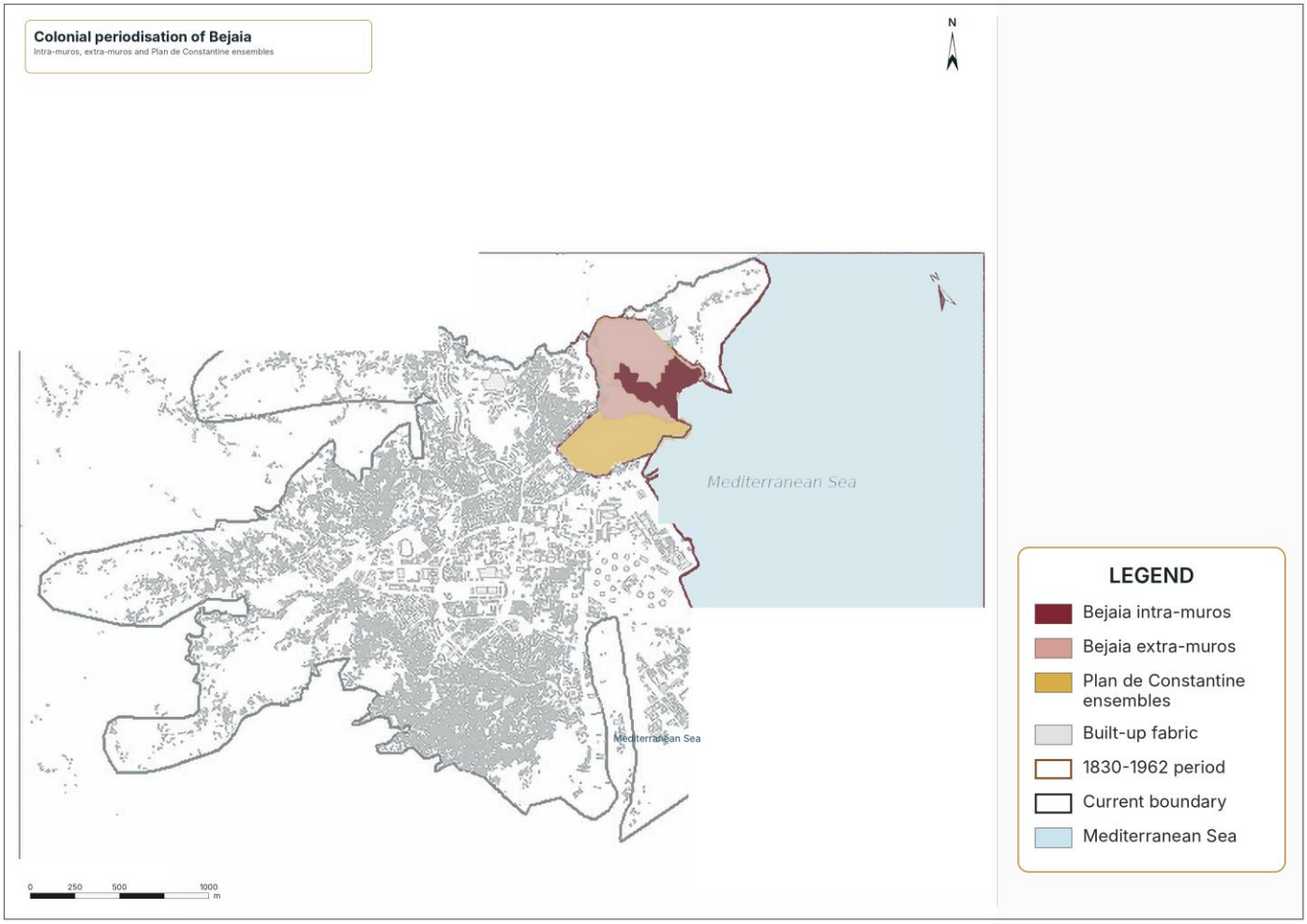

Fig. 2. Periodisation of colonial Bejaia: intra- and extra-muros footprints and ensembles associated with the Plan de Constantine. Source: author's elaboration based on GIS data and spatial analysis of the study area

2. Materials and methods

This research adopts a geohistorical and morpho-spatial approach to reconstruct the urban evolution of Bejaia between 1833 and 1962. The methodological objective is to make heterogeneous archival sources comparable within a transparent GIS workflow and to translate the resulting measurements into criteria useful for heritage planning. The protocol is organised into five sequential phases: corpus compilation and source critique, georeferencing and cartographic harmonisation, diachronic vectorisation, morphometric measurement, and cross-validation through planning-oriented interpretation. The main source families and their analytical uses are summarised in Tab. 1. Comparable geo-historical and morpho-spatial approaches have been used in town-plan analysis, historical urban evolution studies, landscape information modelling, urban morphology studies and heritage-planning frameworks [1,4,9,10,34,35]. The complete workflow is summarised in Fig. 3, while representative archival documents are presented in Fig. 4 and Fig. 5.

Step by step, the procedure begins by identifying and criticising the archival corpus, then georeferencing the selected plans against stable spatial anchors, vectorising comparable urban-form layers, calculating morphometric indicators and finally cross-validating the spatial measurements with historical interpretation. This sequence was designed to avoid a purely illustrative use of maps and to ensure that each cartographic operation contributes to an explicit analytical function.

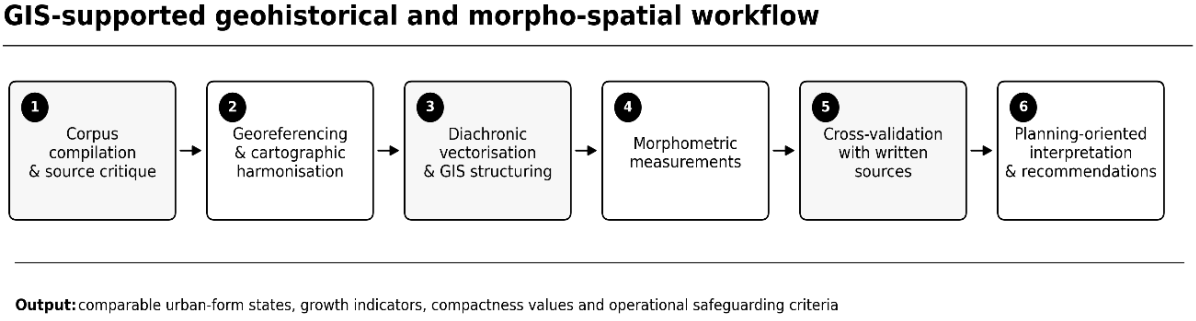

Fig. 3. Methodological workflow linking source critique, GIS processing, morphometric measurement and planning-oriented interpretation. Source: author's elaboration

Table 1. Historical cartographic corpus and analytical use. Source: author's compilation based on archival and cadastral material

Source family	Date / period	Main information extracted	Analytical use
Alignment, military and development plans	1833-1871	Defensive perimeter, gates, initial streets, alignments and control points	Definition of the intra-muros baseline and early rationalisation sequence
French National Archives, Cartes, plans et croquis	1844 and the nineteenth century	Urban development plan, Gulf of Bougie plan and port-city interface	Georeferencing support, source critique and identification of thresholds
Cadastral Service of the Wilaya of Bejaia	1891	Parcels, street pattern and intra-/extra-muros contrast	Validation of extra-muros expansion and fabric differentiation
Port and maritime works documents	1884 and the late nineteenth century	Port works, shoreline relations and infrastructural fronts	Analysis of the port-city interface and its role in morphogenesis
Administrative reports and historical works	Nineteenth-twentieth centuries	Contextual information, place names, project chronology and historical interpretation	Cross-validation of mapped states and distinction between planned and realised forms

Fig. 4. Development plan of Bougie (1844). Source: French National Archives, Cartes, plans et croquis; digitised, enhanced for legibility

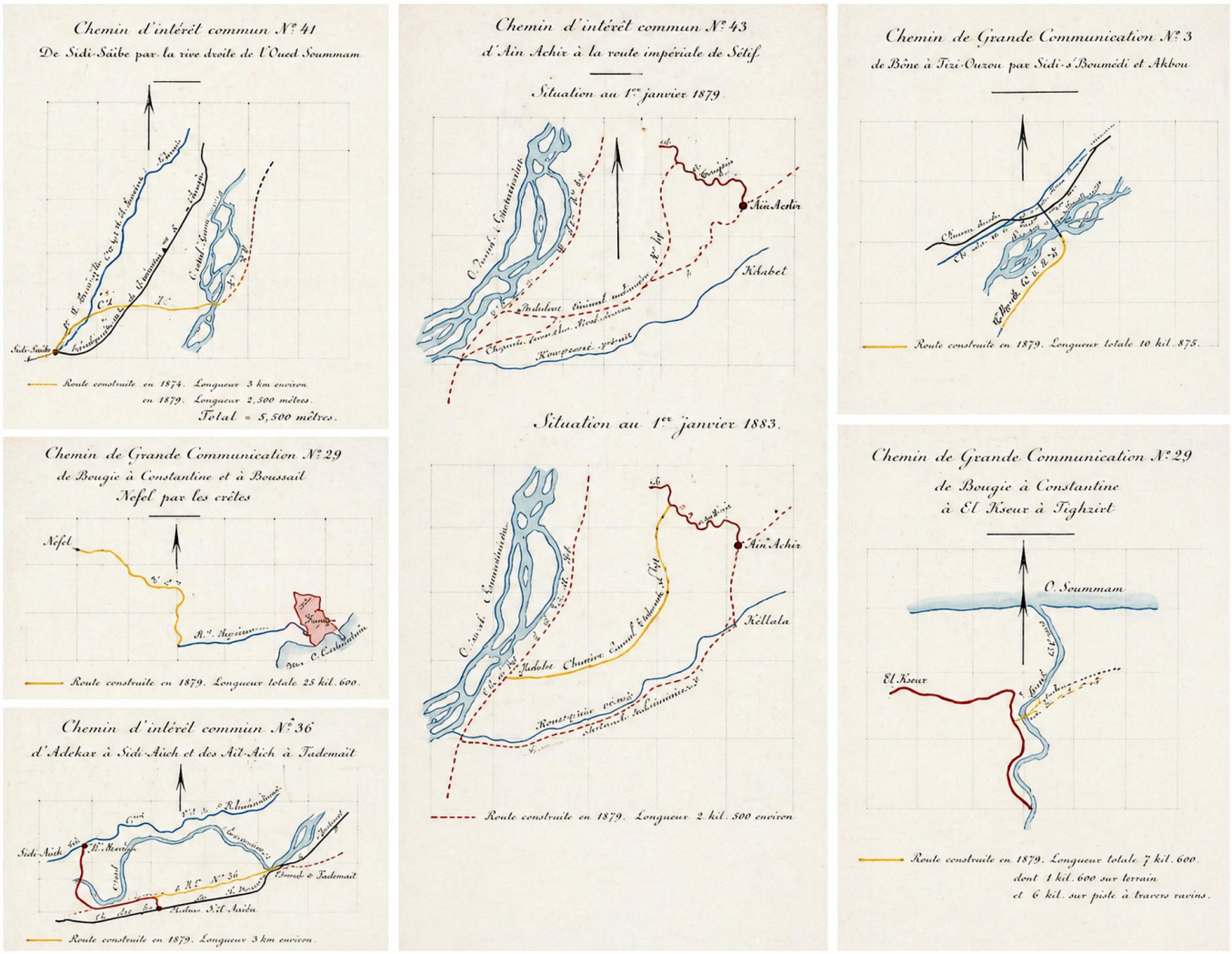

Fig. 5. Plan of the Gulf of Bougie and the port-city interface (nineteenth century, undated). Source: French National Archives, Cartes, plans et croquis; digitised, enhanced for legibility

2.1. Corpus compilation and source critique

The corpus combines alignment plans, military and topographic maps, cadastral plans, port documents, administrative reports and historical works. Each source was assessed according to date, scale, graphic precision, spatial coverage and relevance for identifying built-up envelopes, streets, defensive limits, public spaces and port-city interfaces. Where documents were undated or heterogeneous, their information was cross-checked against dated plans and written sources to avoid treating projected layouts as realised urban form. This stage produced a hierarchy of evidence and grouped the material into diachronic states corresponding to major morphogenetic sequences. In practical terms, each document was entered into a source inventory sheet specifying date, producer, scale or approximate scale, spatial coverage, graphic condition, type of information extracted and reliability level. This made it possible to separate primary cartographic evidence from contextual historical interpretation.

2.2. Georeferencing and cartographic harmonisation

The selected plans were digitised, standardised and georeferenced in a consistent metric coordinate framework suitable for Bejaia's coastal setting. Stable control points were selected from features that persisted across periods, including coastline segments, major route intersections, defensive thresholds, port structures and topographic anchors. Because historical documents vary in scale and deformation, a multi-scale georeferencing strategy was used, and residual errors were recorded in metadata sheets. Root Mean Square Error (RMSE) values and qualitative confidence levels were used to document positional uncertainty rather than conceal it. Control points were selected only when they could be recognised across several temporal states; when uncertainty was too high, the area was used for qualitative interpretation rather than precise measurement.

2.3. Diachronic vectorisation and GIS structuring

Georeferenced maps were vectorised into comparable layers: built-up envelopes, street hierarchy, blocks, squares and nodes, defensive boundaries, facilities and port-related structures. Each object was documented in an attribute table containing date, source, category, reliability level and interpretive notes. This diachronic morphological geodatabase enabled comparison of successive urban-form states without reducing the analysis to a simple overlay of images. Vectorisation followed a conservative rule: only features clearly identifiable on the source were digitised as measured objects, while ambiguous traces were retained as interpretive annotations. This reduced the risk of transforming uncertain archival marks into apparently precise GIS data.

2.4. Morphometric measurements

Urban change was quantified through land take, net growth by period, mean annual growth rates, block fragmentation and the Gravelius compactness index. These indicators were selected because they capture both the rhythm of expansion and the changing geometry of the urban footprint. The Gravelius index ($K_G = P / (2\sqrt{(\pi A)})$, where P is the perimeter and A is the area) was used as a synthetic measure of compactness: values closer to 1 indicate a more compact footprint, while higher values indicate elongation, deformation, or fragmentation. Measurements were interpreted in relation to the mapped sequences rather than as isolated numerical results. The indicators were therefore used comparatively across periods, not as absolute measurements detached from source quality. Their function was to identify changes in rhythm, compactness and spatial logic that could be checked against the cartographic sequence.

2.5. Cross-validation and planning-oriented interpretation

The quantitative results were validated through triangulation between GIS measurements, morphological reading and written historical sources. This final stage identified persistent axes, former boundaries converted into boulevards, port-city interfaces, nodal public spaces and hinge sectors where continuity is weakened. These elements were interpreted as active structures: inherited spatial supports that continue to organise mobility, centrality and legibility, and that can therefore inform safeguarding boundaries, regeneration priorities and urban stitching strategies. This validation stage was essential for distinguishing three situations: persistent structures that continued to organise urban form, ruptures that modified the inherited grammar, and hinge areas where conservation and regeneration priorities overlap.

3. Results

The results combine diachronic reconstruction, quantitative indicators and planning-oriented interpretation. They show that Bejaia's colonial-period transformation was not a linear replacement of the inherited town, but a sequence of reconfigurations in which defensive limits, port interfaces and circulation axes remained structurally active.

3.1. Diachronic reconstruction of transformation sequences (1833-1962)

3.1.1. 1833-1848: intra-muros appropriation and establishment of a control perimeter

The first sequence unfolded within the walls. It combined access control, reactivation of fortified points and spatial organisation, establishing an initial morphological baseline. The wall-limit functioned as both an organising matrix and a reading device for understanding the old town. Archival military plans clarify the defensive perimeter effectively held at the beginning of the occupation and locate the main thresholds and fortified points. This phase is mapped in Fig. 6.

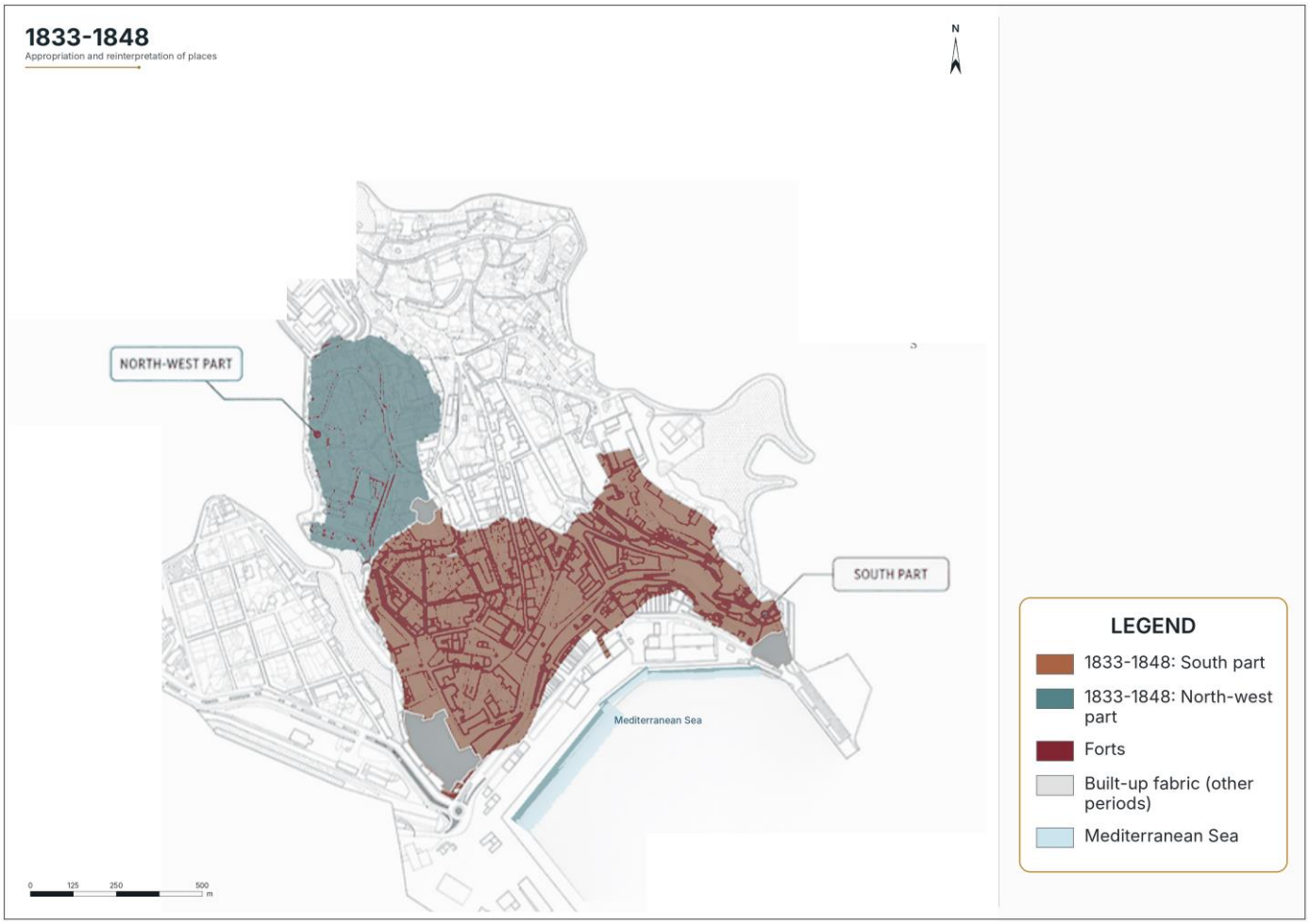

Fig. 6. Historical evolution of Bejaia (1833-1848): intra-muros appropriation and spatial structuring. Source: author's elaboration based on historical cartography, French National Archives, cadastral data of Bejaia and GIS processing

3.1.2. 1848-1871: morphological rationalisation, alignments and nodal centralities

The second sequence corresponds to interventions associated with the engineering corps. Widenings, street cut-throughs and alignments re-hierarchised the street network while partly relying on inherited routes. Intersections stabilised as squares and junctions, and facilities reinforced new polarities. The result was a framework of public spaces, axes and nodes whose heritage value lies not only in built objects but also in the continuities they organise. This phase is mapped in Fig. 7.

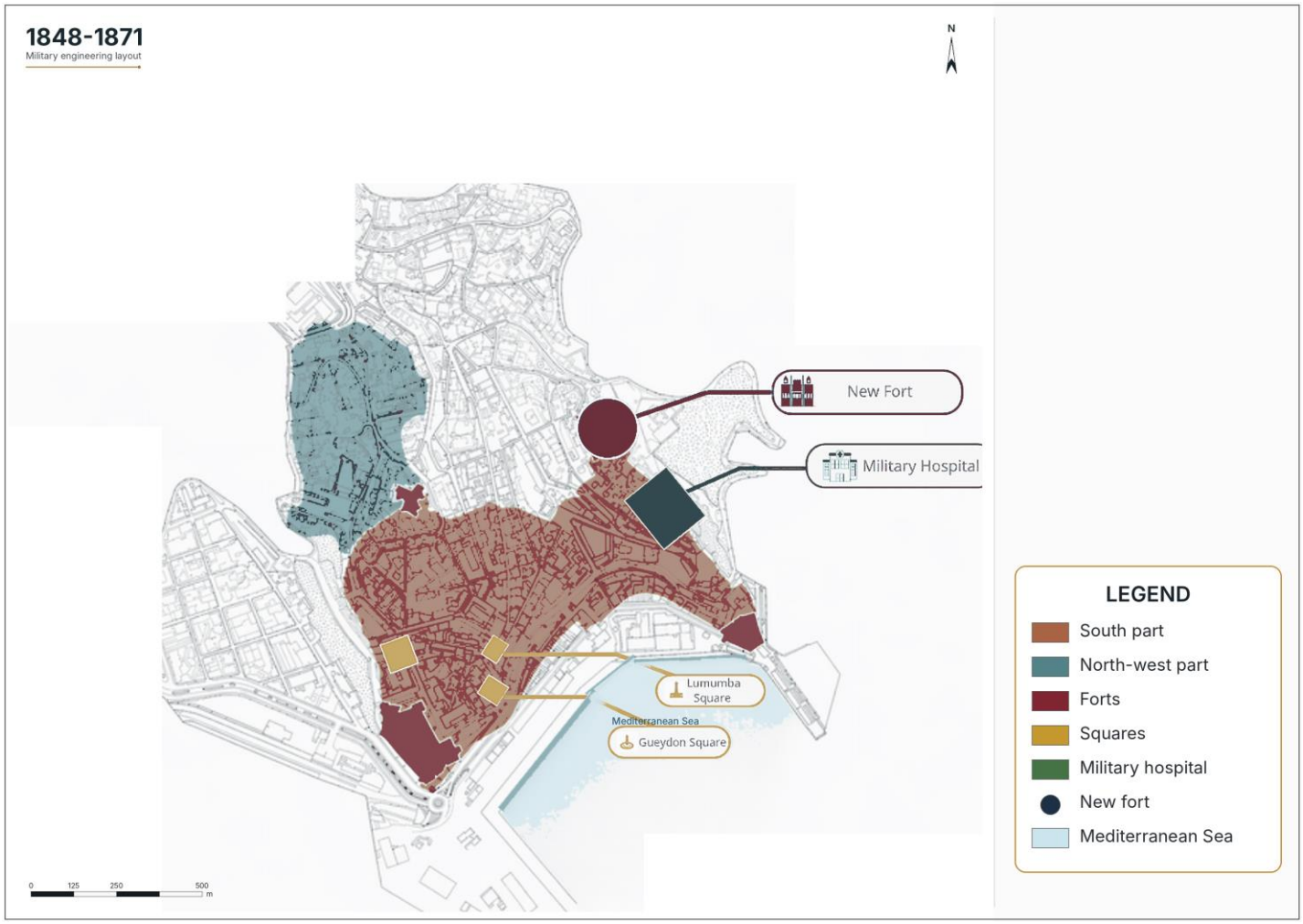

Fig. 7. Historical evolution of Bejaia (1848-1871): military engineering layout and consolidation of squares. Source: author's elaboration based on historical cartography, French National Archives, cadastral data of Bejaia and GIS processing

3.1.3. 1871-1890: crossing boundaries and converting the wall into a boulevard

Extra-muros expansion marked a turning point. The demolition of enclosure segments and their replacement with roads established an articulation belt between the old core and the extensions. The limit ceased to be purely defensive and became a support for growth and urban continuity. This wall-to-boulevard logic is fundamental for understanding the transition between the historic centre and later fabrics. The phase is mapped in Fig. 8, and the 1891 cadastral reference state is shown in Fig. 9.

3.1.4. 1890-1958: densification, expansion and consolidation of stitching areas

This sequence combined densification within existing perimeters with the stabilisation of extra-muros extensions. Growth was organised through stitching axes linking the core, the plain and the port interface. The port and railway acted as catalysts, reconfiguring urban frontages and intensifying movement corridors. Boulevards derived from former boundaries, structuring axes and consolidated nodes constitute active permanences that can be mobilised to prioritise safeguarding and enhancement interventions. This phase is mapped in Fig. 10.

3.1.5. 1958-1962: modernist rupture, slab blocks and a shift in interfaces

Late colonial operations associated with the Plan de Constantine introduced open layouts and slab-block housing estates that altered the traditional relationship between blocks, streets and squares. The reuse of some former limit traces as organisational support points to a paradoxical continuity: inherited structures remained legible, but their spatial register changed. For a safeguarding boundary, these areas should be treated as transition and stitching spaces rather than as undifferentiated peripheries. This phase is mapped in Fig. 11; complementary archival materials on the port-city interface and urban layout are presented in Fig. 12 and Fig. 13.

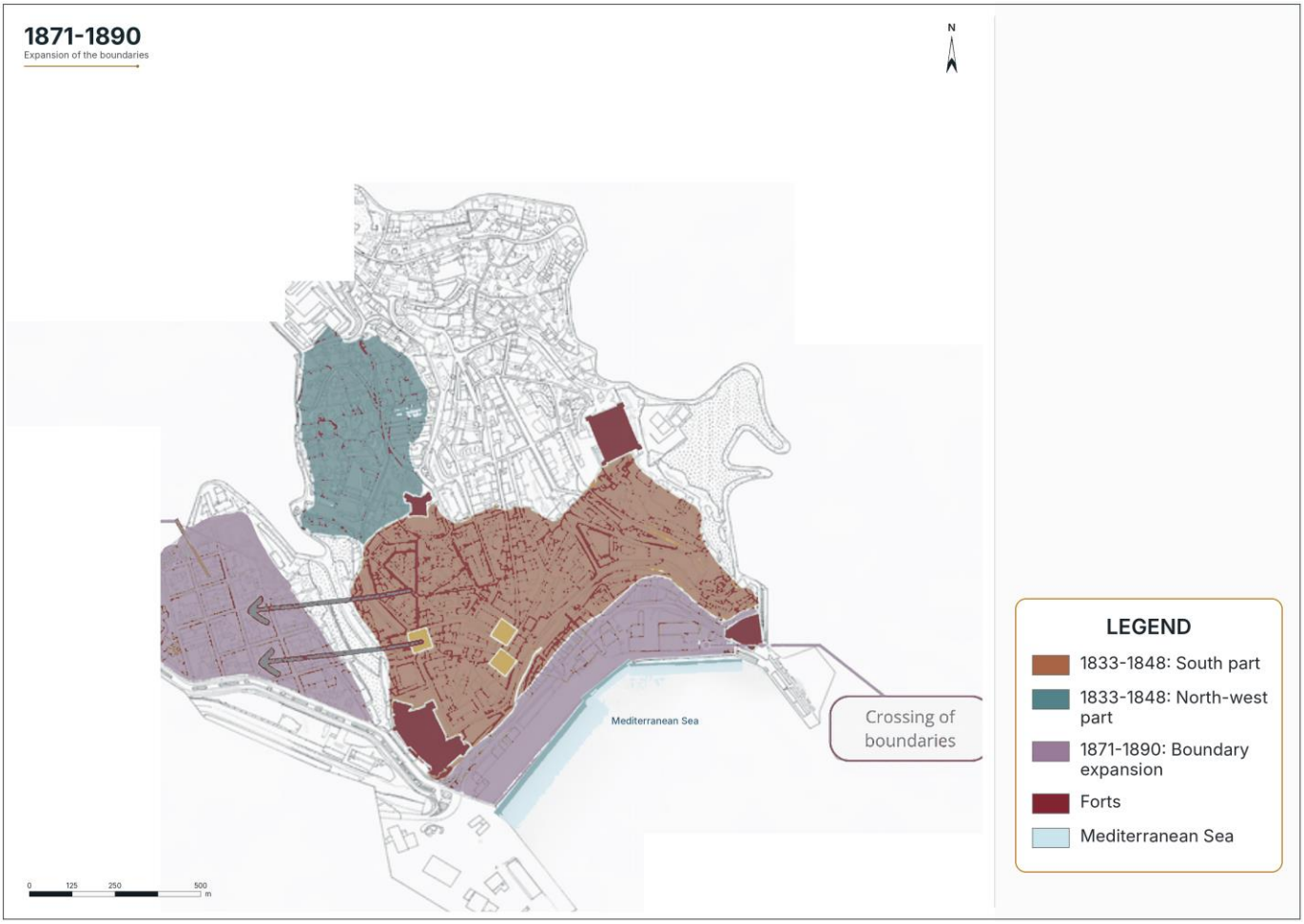

Fig. 8. Historical evolution of Bejaia (1871-1890): crossing boundaries and transforming the wall into a boulevard. Source: author's elaboration based on historical cartography, French National Archives, cadastral data of Bejaia and GIS processing

Fig. 9. Cadastral plan of Bejaia (1891) after extra-muros expansion: contrast between intra-muros fabric and grid extension towards the plain. Source: Cadastral Service of the Wilaya of Bejaia

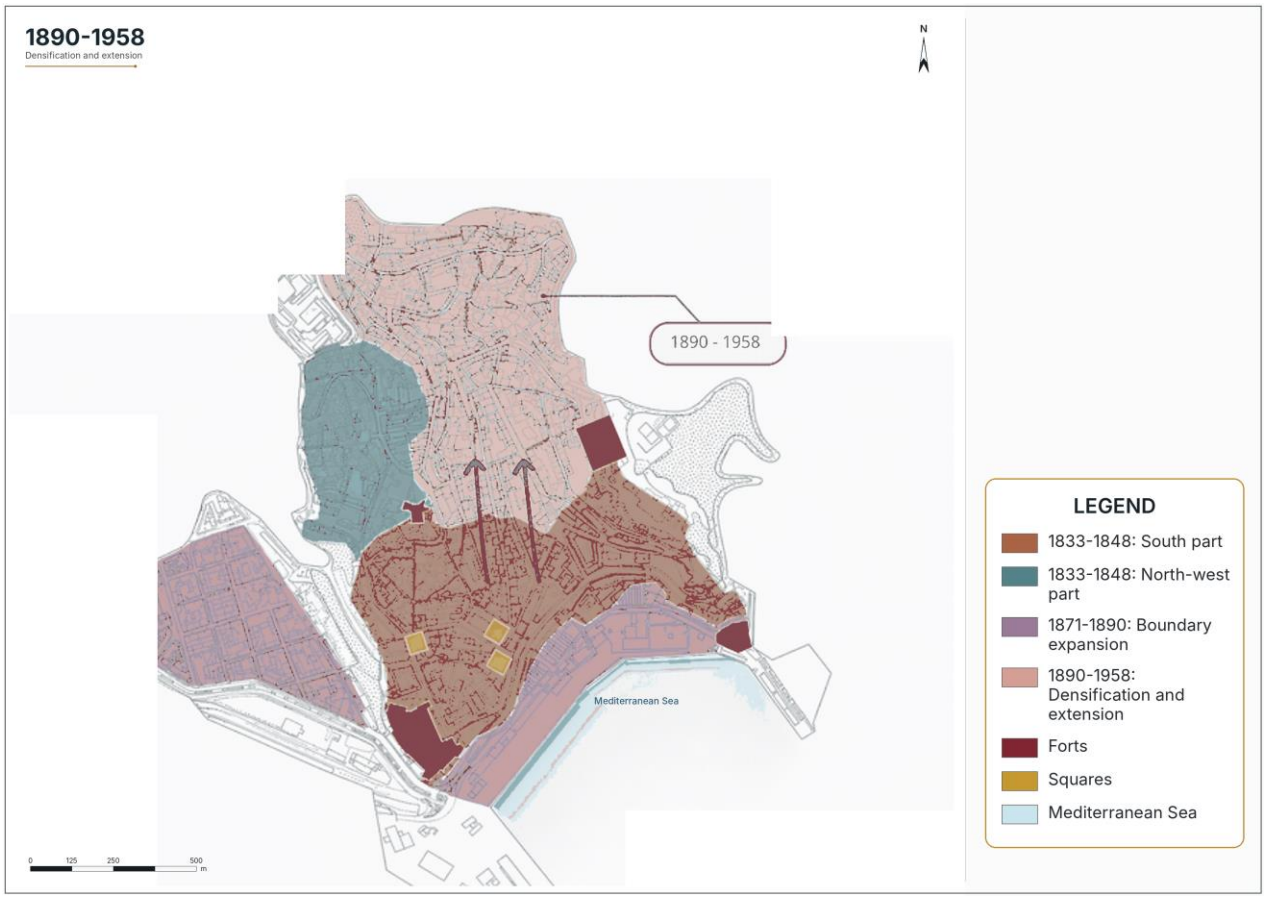

Fig. 10. Historical evolution of Bejaia (1890-1958): densification and expansion. Source: author's elaboration based on historical cartography, French National Archives, cadastral data of Bejaia and GIS processing

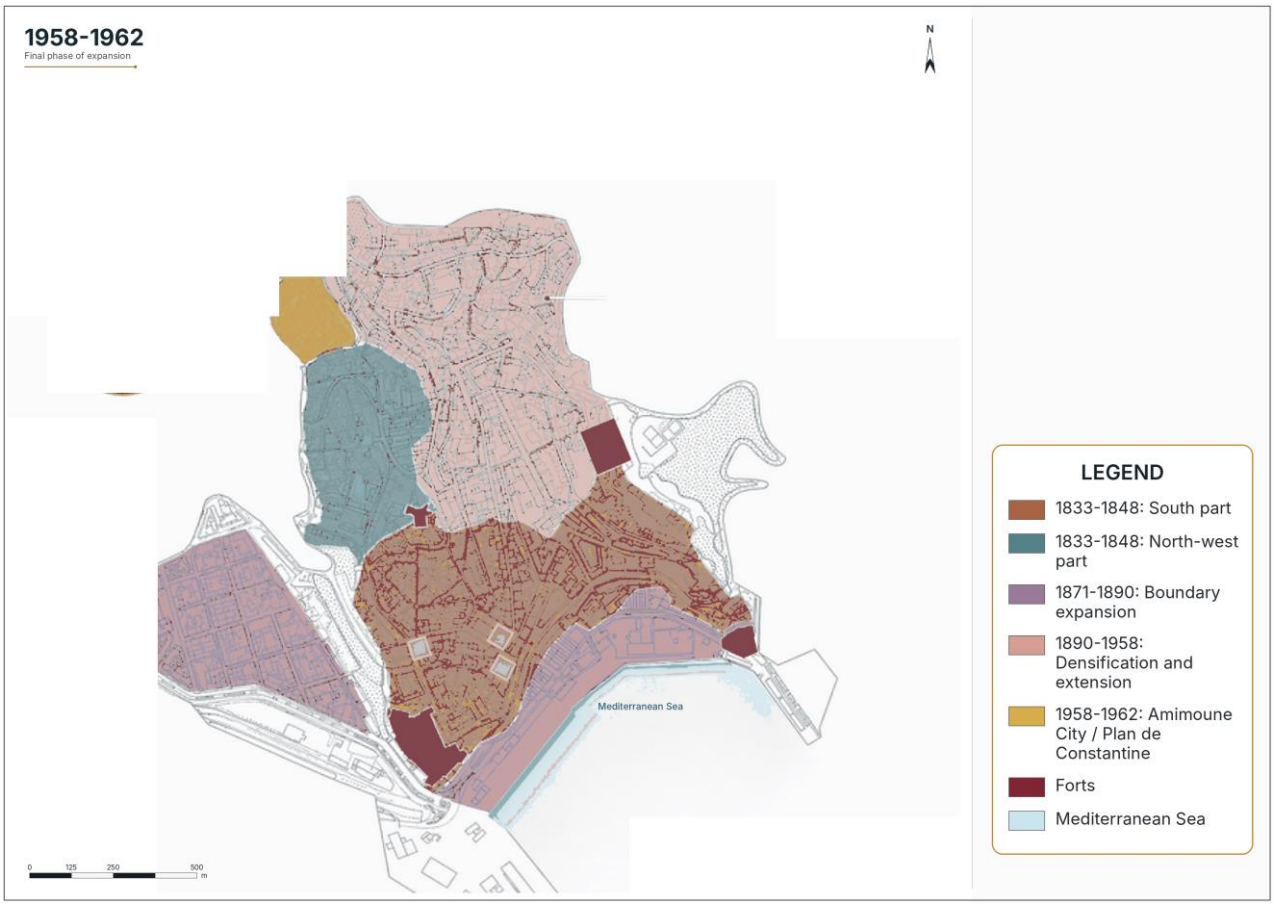

Fig. 11. Historical evolution of Bejaia (1958-1962): Plan de Constantine and slab-block ensembles. Source: author's elaboration based on historical cartography, French National Archives, cadastral data of Bejaia and GIS processing

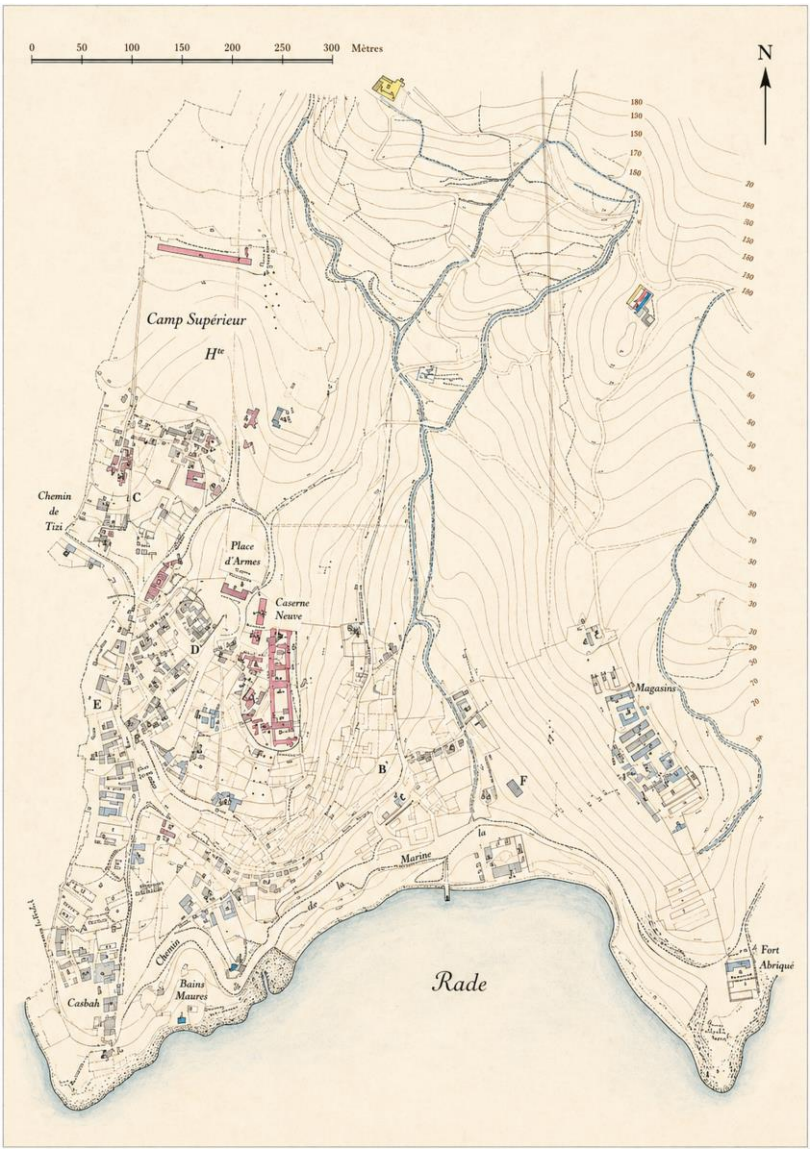

Fig. 12. Plan of the city of Bougie (undated). Source: French National Archives, Paris; digitised archival document, enhanced for legibility

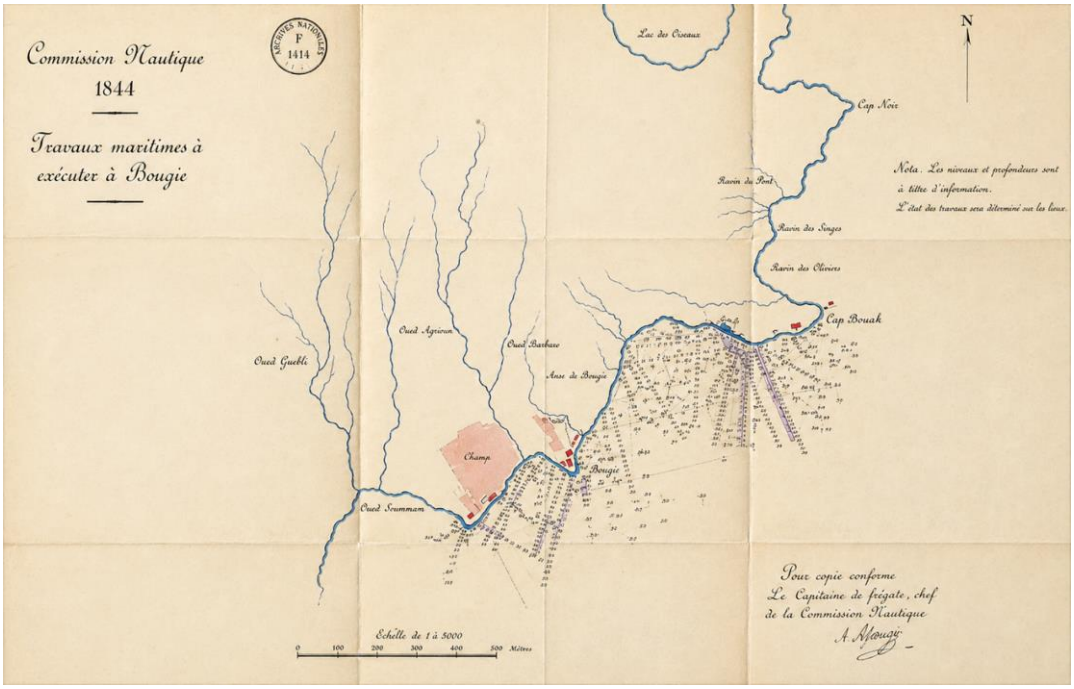

Fig. 13. Nautical Commission (1884): maritime works to be carried out in Bougie and the port-city interface. Source: French National Archives, Paris; digitised archival document, enhanced for legibility

3.2. Urbanised land take and growth rates

Quantification confirms three distinct growth regimes. Up to 1890, urbanisation remained contained around the core. Between 1890 and 1958, growth became moderate and structured. Between 1958 and 1962, the acceleration was abrupt, corresponding to emergency-driven late-colonial planning. These contrasts make the late-period rupture measurable and justify a differentiated reading of fabrics when defining safeguarding and enhancement priorities (Tab. 2). Given the variable scale and deformation of the source plans (Section 2.2), the absolute land-take and rate values are best read as robust orders of magnitude; the documented positional uncertainty affects absolute areas more than the relative contrasts between periods, on which the interpretation primarily rests.

The values show that the last four years of the study period generated about two-thirds as much net gain as the preceding sixty-eight years. This does not simply indicate a larger footprint; it indicates a change in the planning logic, from relatively continuous extension to more discontinuous operations based on open layouts and large housing ensembles.

3.3. Urban form evolution and compactness

The Gravelius index captures the changing geometry of the urban footprint across the study period. The corrected value for 1833 is 1.50, followed by a temporary increase to 1.90 in 1890, which reflects the irregularity of early extra-muros extension. The decrease to 1.23 in 1958 indicates progressive consolidation and infill, while the rise to 1.42 in 1962 reveals renewed elongation and less homogeneous late-period expansion (Tab. 3).

This evolution confirms that compactness should be interpreted alongside morphological evidence. A compact urban envelope may still contain discontinuities, while a less compact envelope can reveal the emergence of interface sectors. In Bejaia, the late increase in the index is consistent with the spatial logic of slab blocks, large voids and weakened street-block-square continuity.

Table 2. Spatial growth of the urban footprint for the 1833-1962 analysis. Source: author's GIS measurements

Interval	Initial area (km²/ha)	Final area (km²/ha)	Net gain (ha)	Duration (years)	Mean rate (ha/year)
1833-1890	0.175 / 17.5	0.289 / 28.9	+11.4	57	0.20
1890-1958	0.289 / 28.9	1.071 / 107.1	+78.2	68	1.15
1958-1962	1.071 / 107.1	1.598 / 159.8	+52.7	4	13.18

Table 3. Compactness index (Gravelius): selected values for 1833-1962. Source: author's GIS measurements

Year	Area (km²)	Perimeter (km)	Compactness index
1833	0.175	2.22	1.50
1890	0.289	3.68	1.90
1958	1.071	4.54	1.23
1962	1.598	6.43	1.42

3.4. Permanences and active structures: operational morphological criteria

Based on the diachronic cartographic series (Figs 6-11), the analysis identifies permanences that durably structure the historic centre and its interfaces. These include linkage trajectories between the core, gates and port; stabilised squares and nodal public spaces; the conversion of former defensive boundaries into boulevards; the reconfiguration of the port-city interface; and hinge areas where urban stitching is required. Together, these active structures provide an objectifiable basis for discussing the coherence of safeguarding boundaries and for prioritising protection, regeneration and transition-zone interventions.

3.5. Archival contributions, series consolidation and plausibility checks

Archival documents strengthen the GIS series by providing dated reference states, projects and technical evidence on limiting devices, port works and site constraints. They support the wall-to-boulevard interpretation and help distinguish between realised transformations, projected layouts and later reinterpretations. This cross-checking is essential because historical cartography is not neutral evidence: it combines measurement, design intention and administrative representation.

4. Discussion

The findings position Bejaia within broader international debates on urban morphogenesis, spatial expansion and heritage planning. Studies of urban heat exposure, vegetation dynamics and environmental productivity show that urban expansion must be analysed through its spatial form and environmental consequences, not only through population or land-consumption figures [5-8]. The Bejaia case adds a heritage-planning dimension to this discussion by showing how inherited limits and interfaces can remain active after their original defensive or infrastructural functions have changed.

Between 1833 and 1962, Bejaia changed less through total substitution than through the reconfiguration of a pre-existing urban system. Colonial interventions reinterpreted inherited alignments, thresholds and polarities – including the pre-1833 medieval and Ottoman fabric – while introducing rationalisation devices such as alignments, street cut-throughs and nodal squares; these transformations also need to be read through the asymmetric power relations of colonial urbanism [36]. This articulation between inherited frameworks and planning intent explains the persistence of active structures – axes, squares, boulevards derived from former enclosures and the port-city interface – that continue to organise mobility and the legibility of

the historic centre; these persistent elements are what Rossi termed urban permanences [2].

The limit functions as a central morphological operator. The progressive conversion of walls into boulevards and then into articulation lines is not a simple change of state, but a transfer of urban functions: from defensive barrier to infrastructure of continuity, in line with the fixation-line and fringe-belt concepts of town-plan analysis [1]. This wall-to-boulevard process produced belts and thresholds that structure intra- and extra-muros transitions, make phases of extension legible and identify sectors where present-day tensions concentrate. Accordingly, heritage value should not be restricted to isolated buildings; it also resides in the spatial grammar of boundaries, routes, public spaces and interfaces, an understanding consistent with the Historic Urban Landscape approach [4].

The measurements reinforce this interpretation by objectifying the late-period rupture. Moderate growth up to the mid-twentieth century corresponds to urbanisation still largely structured by site constraints and fabric continuity. By contrast, the 1958-1962 sequence associated with the Plan de Constantine introduced open forms, slab blocks and large voids that weakened the traditional block-street-square relationship, the dissolution of the urban block analysed in the morphological literature [3]. This rupture did not erase inherited structures; it placed them under tension and shifted the centre's interfaces towards hinge sectors that require careful regeneration rather than simple protection.

These findings have direct implications for the safeguarding of architectural heritage. The coherence of a safeguarding boundary should depend less on an administrative envelope than on the management of active structures and interfaces: inherited boulevards, thresholds, linkage axes towards the port and plain, nodal public spaces and transition zones where continuity loss and use conflicts occur. A perimeter focused solely on the intra-muros core risks freezing the nucleus while neglecting the articulations that enable it to function. Conversely, an overly extensive perimeter without hierarchy would dilute priorities.

The proposed approach, therefore, supports a graduated planning strategy. High-permanence fabrics should be strongly protected at the level of parcels, volumes, street frontages and public-space alignments. Interface belts should be regulated through rules centred on continuity, permeability and transition quality. Rupture sectors should be treated through stitching actions, including pedestrian reconnection, frontage repair, upgrading of voids and reinforcement of neighbourhood polarities. In this sense, safeguarding becomes an urban project rather than a purely patrimonial inventory.

Methodologically, the GIS-supported geohistorical protocol is, in principle, transferable to other coastal and heritage cities, particularly in North Africa and the Mediterranean, where heterogeneous archives, port-city relations and defensive traces are common, provided that comparable source coverage is available. Its value lies in making historical states comparable while preserving the interpretive depth required by urban history. Its limitations concern the variable precision of historical documents, possible distortions in archival plans, and the conventions used to delineate urban footprints. These limits were addressed by documenting uncertainty, triangulating sources and interpreting numerical indicators together with morphological evidence.

The broader contribution is to connect heritage planning with measurable urban form. By identifying active structures and growth regimes, the study provides decision-support evidence for sector prioritisation, risk reading and stitching strategies. Future applications could extend the series beyond 1962, refine block- and building-scale indicators, and test intervention scenarios for port frontages, inherited boulevards and transition sectors.

5. Conclusions and recommendations

The geohistorical and morphological analysis of Bejaia between 1833 and 1962 shows that the colonial period produced more than a succession of built objects. It installed durable urban structures that still organise the functioning and legibility of the historic centre. The reconstructed sequences – intra-muros appropriation, rationalisation through alignments and cut-throughs, crossing of boundaries, extra-muros expansion, densification and late modernist rupture – reveal a city shaped by a constrained coastal site and by planning decisions that transformed walls and thresholds into growth lines.

The quantified results complement this reading. Land take and growth rates identify a long period of gradual growth followed by a sharp acceleration in 1958-1962. The compactness index and morphological observations converge on the same conclusion: while structuring axes, squares, thresholds, former boundaries and port interfaces persisted, some late operations produced discontinuities and less articulated forms, especially through slab-block housing and the weakening of the street-block-square system.

The main contribution of the paper is to show how safeguarding can be grounded in verifiable urban criteria rather than in the mere selection of remarkable objects. Morphological permanences operate as active structures because they continue to orient mobility, centralities, interfaces and continuity. They therefore provide an argued basis for discussing safeguarding boundaries and for ranking protection, regeneration and stitching interventions.

Safeguarding should thus be understood as an urban project. It must protect fabrics and facades, but also preserve and regenerate public-space continuities, core-extension interfaces, port frontages and inherited boulevards. The proposed GIS-based protocol – combining source critique, georeferencing, diachronic vectorisation, morphometric indicators and cross-validation – is reproducible and transferable to comparable coastal and heritage cities. It offers a decision-support framework for sustainable urban planning while acknowledging uncertainties inherent to historical sources.

Future research should extend the diachronic series beyond 1962 (whose diffuse, post-independence sprawl is documented in a companion study [33]), develop finer indicators at block and building scale, and produce action-oriented maps for intervention prioritisation. Beyond Bejaia, the framework can support heritage cities facing similar challenges of urban growth, spatial fragmentation and conservation, helping to move from isolated protection towards coherent, graduated and sustainable urban enhancement.

From an operational perspective, these findings lead to the following recommendations:

1) Use active structures as criteria for safeguarding boundaries. The delimitation of the heritage area should not be based solely on administrative boundaries or isolated monuments, but on persistent axes, former defensive traces, port-city interfaces, nodal squares, and continuity lines.
2) Protect high-permanence fabrics with differentiated rules. Parcels, street alignments, frontages, volumes and public-space sequences that preserve the historical grammar of

the centre should be subject to stronger conservation and design-control measures.

3) Treat former boundaries as transition belts. Boulevards and streets derived from former walls should be managed as stitching devices between intra-muros and extra-muros fabrics, with attention to pedestrian continuity, frontage quality and public-space legibility.
4) Reconnect the port-city interface. Since the port has acted as a long-term morphological operator, future projects should improve visual, functional, and pedestrian relations among the historic core, waterfront, and port frontages without weakening heritage values.
5) Regenerate rupture sectors through urban stitching. Late modernist ensembles and open-layout areas should not be treated as residual peripheries; they require targeted actions such as repairing voids, improving permeability, reinforcing neighbourhood polarities and reconnecting them to the historic street network.
6) Institutionalise GIS-based monitoring. The diachronic geodatabase developed in this study should be extended beyond 1962 and updated with block- and building-scale indicators to support evidence-based prioritisation, monitoring, and evaluation of safeguarding actions.
7) Transfer the protocol cautiously to other cities. The method can be applied to comparable Mediterranean and North African heritage cities, but only after assessing archival availability, map precision, georeferencing uncertainty and the local meaning of inherited spatial structures.

These recommendations translate the historical diagnosis into planning action. They show that the value of diachronic GIS analysis lies not only in documenting past change, but also in guiding coherent, graduated and sustainable heritage enhancement.

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Conflicts of interest

The author declares no conflict of interest.

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