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Analysis of Coastal Urban Skyline Development Using Digital Tools: The Case of Świnoujście (Poland)

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Katarzyna Styborska[1]

Abstract:

Purpose: *The aim of the article is to analyse the directions and nature of the transformation of Świnoujście's urban skyline in the context of increasing building density and vertical pressure.*
Design/Methodology/Approach: *The research utilises orthophotomaps from various time periods and point cloud data acquired through geographic information services (GIS). Based on this, a digital model and BIM software were used to analyse urban silhouette development trends and determine the directions of vertical expansion and urban densification in the context of current planning assumptions.*
Findings: *The observed increase in building intensity in Świnoujście is largely concentrated within a single skyline unit, dominated by the Radisson Blu high-rise. This structure redefines the proportions of the panorama, making subsequent lower-rise developments appear visually insignificant. This creates a false sense of compositional stability and highlights the need for localised visual analyses, rather than relying solely on averaged statistical indicators. The study applies a segmentation method that enables a more precise assessment of new developments in their immediate spatial context.*
Practical Implications: *The results may inform local urban policies and spatial planning strategies, particularly regarding the balance between tourism development and protection of the urban landscape. The adopted methodology can be replicated in other coastal cities experiencing rapid spatial and functional transformation.*
Originality/Value: *The originality of the article lies in its combination of 2D (historical orthophotomaps) and 3D (LiDAR/BIM) data within a single analytical model, enabling simultaneous tracking of vertical and spatial densification processes. Working in the ARCHICAD environment, the study creates an interactive BIM platform that supports visual analysis, zoning scenarios (LDPs), and automated generation of quantitative data. The segmentation approach eliminates distortions caused by dominant high-rise structures and simplifies landscape assessment to three spatial categories: sky, built-up area, and greenery. Additionally, the use of original indicators—built-to-sky (BS) and built-to-greenery (BG)—provides an innovative tool to evaluate verticalisation pressure and loss of the natural buffer zone in coastal urban areas.*

Keywords: *Architecture, coastal development, digital planning tools, urban planning.*

JEL Codes: *R52, R14, Z32.*
Paper Type: *Research Article*

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[1]*Zachodniopomorski Uniwersytet Technologiczny w Szczecinie, Poland,*
e-mail: katarzyna.florysiak@zut.edu.pl;

1. Introduction

The coastal urban fringe is defined in scholarly literature as a landscape zone where interactions occur between anthropogenic activities and natural coastal processes, such as abrasion, marine sedimentation, and microclimatic dynamics (Mykhailyk, 2024). This phenomenon presents a range of both risks and opportunities in the context of growing tourism flows and ongoing urban expansion. Simultaneously, coastal developments offer the potential for commercializing a particularly sought-after asset in the real estate market—the scenic quality of the landscape, specifically, visual access to the sea (Garza-Lagler *et al.,* 2018).

As a result, large-scale apartment-hotel complexes have emerged as key agents in shaping the contemporary coastal urban landscape. These complexes, often organized horizontally, respond to the increasing demand for accommodation infrastructure. Studies on Polish seaside resorts indicate that, particularly since 2013, the country's coastline has been undergoing a phase of intensified development with tourism-related facilities, fundamentally altering the visual structure of the coastal skyline.

A particularly notable example is the city of Świnoujście, where the construction of a single high-rise building - Radisson Blu - has transformed entire visual sequences along the promenade and harbor (Bal and Czałczyńska-Podolska, 2020).

Świnoujście is a coastal city with a strong touristic profile and a geographically unique location. The urban area spans across the islands of Uznam, Wolin, and Karsibór, which are separated by river channels and situated directly along the Polish-German border.

The city's dynamic transformatio from a "spa-park resort" to a "recreational metropolis" - can be traced through several distinct developmental phases shaped by geopolitical contexts (e.g., the wartime period), infrastructural advancements (such as the construction of the tunnel beneath the Świna River), and socio-economic shifts (notably, the increased acquisition of private properties during the COVID-19 pandemic) (Table 1).

Table 1. *Phases of functional development in the coastal zone of Świnoujście – chronological model.*

Phase	Timeframe	Dominant Functions	Characteristics
I. Historic Resort	ca. 1850-1914	health treatment, recreation	orthogonal layout of promenades and spa villas
II. Military Period	1914-1989	naval port, shipbuilding industry	low development density, restricted access to beaches
III. Tourist Transformation	1990-2016	guesthouses, 3–4-star hotels	linear promenade development; absence of vertical dominants
IV. Intensification	2017-present	5-star resorts, condo-	high-rise clusters (Radisson

and Verticalisation		hotels	Blu, Hilton) + modernized promenades

Source: *Own study.*

The objective of this study is to capture the dynamics and directional trends of skyline transformations within the coastal strip of Świnoujście during the period 2006–2024, and to assess the spatial implications of the provisions of the current local development plan. The research employs a sequential diachronic strategy, involving successive, temporally comparable cross-sections along a fixed visual axis.

2. Literature Review

Contemporary research into urban silhouettes increasingly employs digital methods, enabling precise and repeatable spatial analyses. The works of Czapliński (Czapliński, 2022), Czyńska, Marzęcki, Rubinowicz (Czyńska, Rubinowicz, and Marzęcki, 2024), and Ozimek (Ozimek, 2019), demonstrate that cityscape analysis can be based on both height cross-sections and advanced 3D models or image analysis.

Czapliński (Czapliński, 2022), introduces an analytical approach for the selected resort town of Międzyzdroje by establishing two orthogonal elevation profiles intersecting the coastal strip (NE–SW and NW–SE), complemented by additional profiles along major urban streets. Each cross-section is interpreted as a horizon line, from which the amplitude and rhythm of urban massing are examined in relation to the distance from the shoreline.

The researcher calculates the average urban height, the proportions of low-, mid-, and high-rise buildings, and interprets the resulting vertical variability as an index of skyline coherence and compactness. The further the profile extends inland, the more uniform the skyline becomes, while sudden height changes within 100-400 meters from the beach are indicative of intensified touristic development.

Czyńska, Marzęcki, and Rubinowicz (Czyńska, Rubinowicz and Marzęcki, 2024), conduct a fully digital analysis of the skyline of Toruń. Their research begins with a Digital Surface Model (DSM) generated from LiDAR point clouds, upon which they perform a Visual Impact Size (VIS) analysis. The VIS model determines the geometric visibility range of a proposed high-rise building and identifies strategic viewing points from which the structure will be visible.

These points are then verified in situ through photographic documentation with precise geolocation. Subsequently, they generate 3D visualizations of the proposed building in various height and form scenarios. In their simulations, they use a height scale bar to identify the threshold above which the building surpasses the tree canopy of Kępa Bazarowa and test multiple façade colour schemes.

The entire process—from VIS mapping to visual renderings—is executed within custom-developed C++ software, allowing a parametric evaluation of the new building's impact on the UNESCO-listed historic landscape.

Ozimek (Ozimek, 2019), investigates urban silhouettes by treating them as configurations of "landscape dominants," which can be objectively detected in photographs. The researcher manually segments each image frame, converting every visible tree or building into a separate white contour on a black background.

A proprietary MATLAB-based application calculates contour area, maximum height (in pixels above the horizon line), and eleven shape coefficients, ranging from basic circularity metrics (W_1–W_2) to advanced indices of irregularity, fragmentation, and compactness (W_4–W_{11}). RGB components are also averaged to identify colour disharmonies.

All values are normalized to a 0–1 scale and compared against the median of the entire frame. The element that deviates most significantly in terms of size, height, or hue is identified as the skyline dominant. This methodology transforms photographic images into quantifiable metrics, making skyline evaluations less subjective and more replicable.

The approaches compiled in the literature highlight the growing role of digital tools in urban silhouette analysis. The integration of spatial data, 3D visualisations and image-based analysis supports the objectification of conclusions and facilitates the development of urban growth scenarios with a balanced visual character.

3. Research Methodology

The objective of this study is to capture the dynamics and direction of morphological transformations in the coastal skyline of Świnoujście over the period 2006–2024, and to assess the spatial implications of the current local zoning plan.

The research adopts a sequential diachronic approach, based on a series of temporally aligned cross-sections along a consistent visual axis.

The following section of the article provides a detailed overview of the research materials and methodological framework used to construct skyline profiles of the city of Świnoujście.

Chapter three presents the results of the analysis concerning the spatial relationship between built structures and coastal greenery, allowing for the identification of significant changes in the urban silhouette that affect both landscape perception and the quality of coastal public space.

The article concludes with a fourth chapter that synthesizes the findings in relation to the existing literature and outlines recommendations for further research and urban planning practice.

***Table 2**. Compilation of research materials.*

Research Materials	**Data Source**	**Format Resolution Specification**
Orthophotomaps (2006, 2011, 2017, 2019, 2024)	Geoportal.gov.pl, WMTS service “Standard Archival Orthophotomap”	0,25 m/pixel, TIFF
LiDAR point cloud	Świnoujście City Public Information Bulletin (text + plan in PDF format)	~6 pts/m²
Resolution No. LXIX/559/2010 of the Świnoujście City Council of 7 May 2010 on the local zoning plan for the Świnoujście Seaside District	Świnoujście City Public Information Bulletin (text + plan in PDF format)	scale 1: 2000

***Source:** Own study.*

3.1 Selection of the Study Area

The study area was delineated by the Polish-German border to the west, the Świna Strait to the east, the shoreline to the north, and Stefana Żeromskiego Street to the south.

This zone constitutes a coastal strip separated from the main urban fabric by the first vehicular circulation belt adjacent to the sea. It is composed of a linear sequence including the beach zone, the dune zone with tall vegetation, and a built-up strip (Figure 1).

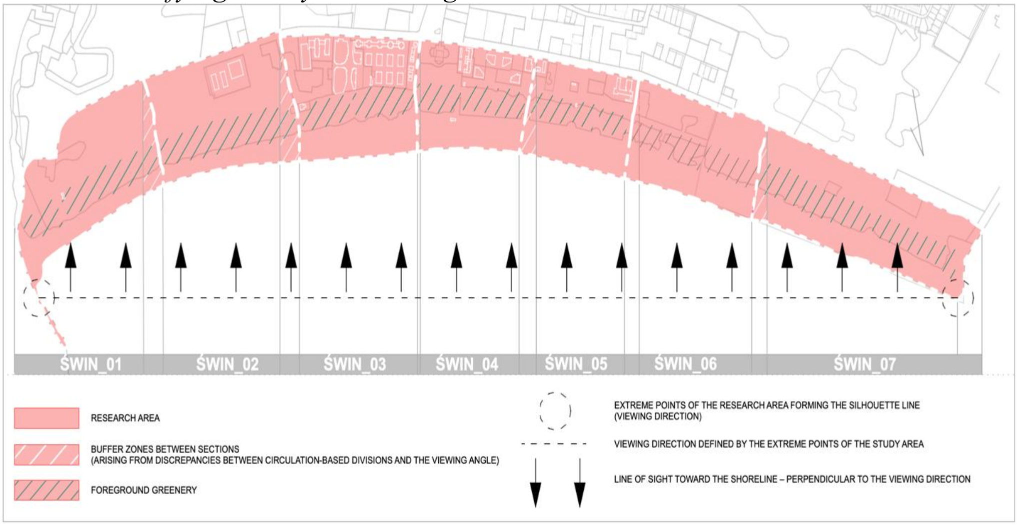
3.2 Selection and Calibration of Orthophotomaps

Eleven orthophotomaps from the years 2003, 2006, 2007, 2011, 2012, 2014, 2017, 2019, 2020, 2022, and 2024 were downloaded using the WMTS[2] service available on geoportal.gov.pl. A preliminary analysis of the individual images revealed that not all years exhibit significant changes relevant to the development of the skyline within the study area.

Therefore, only the raster sheets that demonstrated clear spatial transformation were selected for further investigation. To ensure consistency across the dataset, each raster was cropped using a uniform method focused on the designated study zone.

[2]WMTS (Web Map Tile Service) – map viewing service in the form of transmitted raster images.

Figure 1. *Diagram of the Świnoujście coastal zone showing the extent of the study area and clarifying the skyline viewing line*



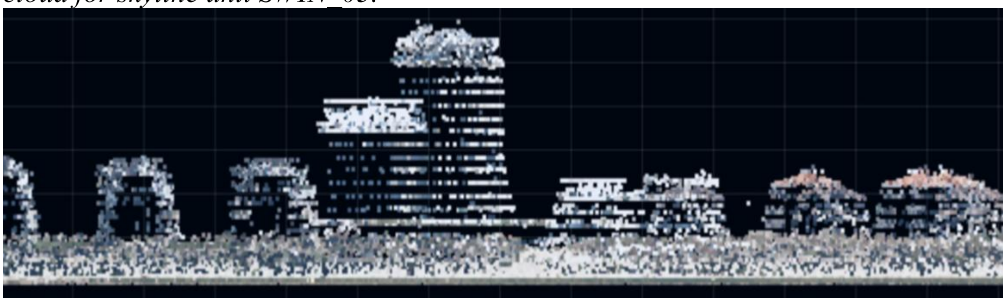
Source: *Own study.*

3.3 3-D Reconstruction Based on LiDAR

For the precise analysis of spatial relationships between terrain, built structures, and vegetation, the profile tool available on the geoportal.gov.pl platform (within the point cloud service) was employed. This method allows for the efficient and accurate generation of cross-sections—of any defined extent—through areas subject to analysis.

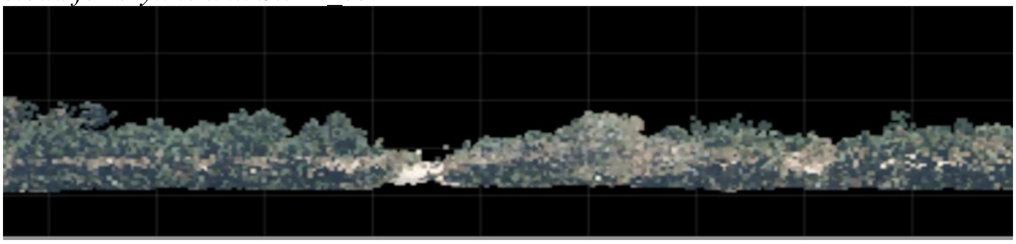
An additional advantage of the tool lies in its ability to toggle individual layers that compose the visual model, including water bodies, terrain, high vegetation, low vegetation, and buildings (Figures 2, 3). The resulting cross-sections document height relations between newly constructed apartment buildings, existing residential structures, and the surrounding natural environment.

Figure 2*. View profile of the buildings + terrain layer generated from the point cloud for skyline unit ŚWIN_03.*



Source: *Geoportal.gov.pl*

Figure 3. *View profile of the greenery + terrain layer generated from the point cloud for skyline unit ŚWIN_03.*



Source: *Geoportal.gov.pl*

The analytical process conducted with the Geoportal profile tool was complemented by transferring point cloud data into the ARCHICAD environment. The BIM platform enabled the conversion of discrete LiDAR points into parametric 3D solids, to which attributes such as year of construction or ridge height could be assigned. The layered structure of the model allowed for the isolation of buildings from specific decades, comparison of local zoning plan (LZP) scenarios, and the generation of sections, elevations, and surface area summaries—without the need for exporting data to external applications.

During the 3D reconstruction process, geometric solids were assigned classifications based on the year in which each object first appeared on the corresponding processed orthophotomap. This approach enabled the allocation of individual buildings to their appropriate skyline units. The analysis of these datasets did not reveal significant changes in the foreground greenbelt; therefore, its visual form was assumed to remain constant throughout the study period.

3.4 Skyline Generation

A unified camera plane was established for all projections (defined along the visual profile between Uzdrowiskowa Street and the beach). Orthogonal views were generated for the years 2006, 2011, 2017, 2019, 2024, as well as for the Local Zoning Plan variant, which simulates the maximum allowed building envelopes in accordance with the provisions of the local zoning plan.

3.5 Landscape Segmentation and Skyline Section Height

The skyline was divided using transportation axes perpendicular to the main promenade, resulting in seven spatial units: ŚWIN_01, ŚWIN_02, ŚWIN_03, ŚWIN_05, ŚWIN_06, and ŚWIN_07. The height of each section was defined by setting the bottom edge at sea level (0 m) and the top edge equal to the height of the tallest building in the silhouette plus one-third of the distance from ground level to the highest point of that dominant structure (in this case, it is the Radisson Blu, which is located in unit ŚWIN_03, the development of which is presented in Figure 11). The author adopted the 1/3 to 2/3 ratio in reference to the golden section, a principle commonly used to create compositional harmony in disciplines such as photography, architecture, and urban design.

3.6 Quantitative Analysis and Comparative Indicators

To conduct a visual analysis of spatial transformations, the skyline units generated in the 3D modelling environment (ARCHICAD) were manually edited using graphic tools. A fill tool was applied to isolate and quantify the three primary landscape components: built-up area, vegetation, and sky, enabling precise measurement of their proportions within the visual profile. This process resulted in 42 synthetic vector drawings (e.g., Figure 13 and Figure 15) at true scale, representing seven skyline units across six selected time intervals (2006, 2011, 2017, 2019, 2024, and the LZP scenario).

Subsequently, a quantitative analysis was carried out in which the surface areas of the three identified landscape classes were tabulated for each silhouette. This yielded a matrix of 126 surface values, which were then transferred into a spreadsheet for further comparative analysis and visualization of spatial trends. To deepen the interpretation and assess the trajectory of urban skyline transformation in Świnoujście, two comparative indices were introduced:

- the built-to-sky ratio $BS=A_{sky}/A_{built,}$ where A_{built} denotes the projected surface area of all buildings visible within the analysed frame, and A_{built} – refers to the projected surface area of the unobstructed skyline;
- the built-to-greenery ratio $BG= A_{sky} /A_{green,}$ where A_{green} represents the cumulative projected area of tree and shrub canopies within the foreground zone.

The first index compares the projected area of built structures to the visible sky portion and serves as a measure of the degree of skyline verticalisation. The second index relates built-up areas to the projected canopy cover of foreground vegetation, enabling an assessment of the loss of natural landscape features. When analysed together, these indicators provide a comprehensive framework for evaluating changes in landscape composition and their impact on the perception of coastal space.

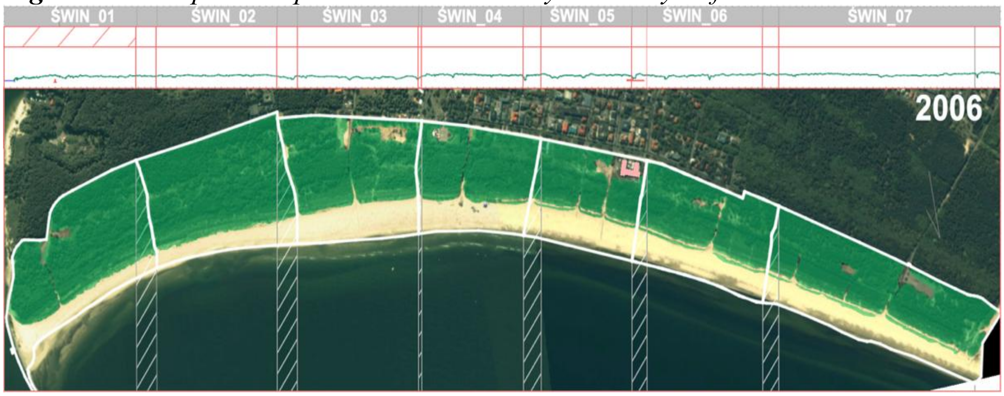
4. Results

4.1 Development Trends of the Świnoujście Skyline

This section presents both the quantitative and visual assessment of the transformation of the coastal skyline of Świnoujście between 2006 and 2024, along with a simulation based on the provisions of the current local zoning plan. In order to identify structural changes within the coastal strip, a series of orthophotomaps were analysed, with the results illustrated in schematic form in Figures 6-11.

Additionally, a preliminary analysis - based on the legend in Figure 12 - indicates the intensity of visible development within the study area.

***Figure 4**. Orthophotomap with a schematic skyline analysis for 2006.*

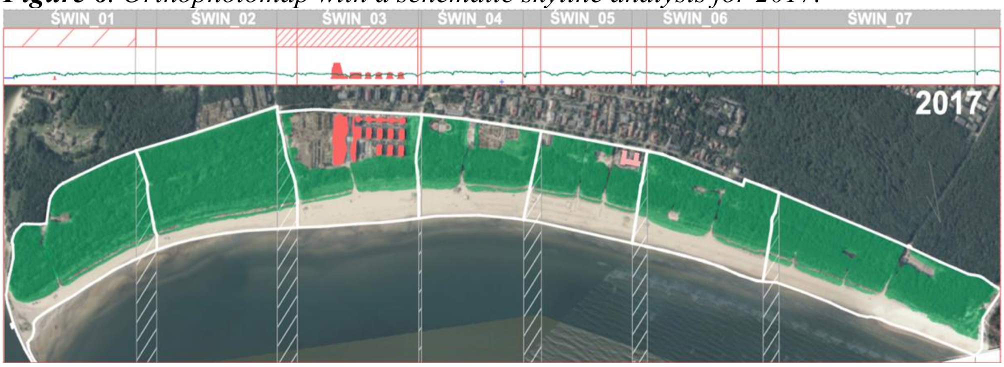


***Source:** Own study.*

***Figure 5**. Orthophotomap with a schematic skyline analysis for 2011.*

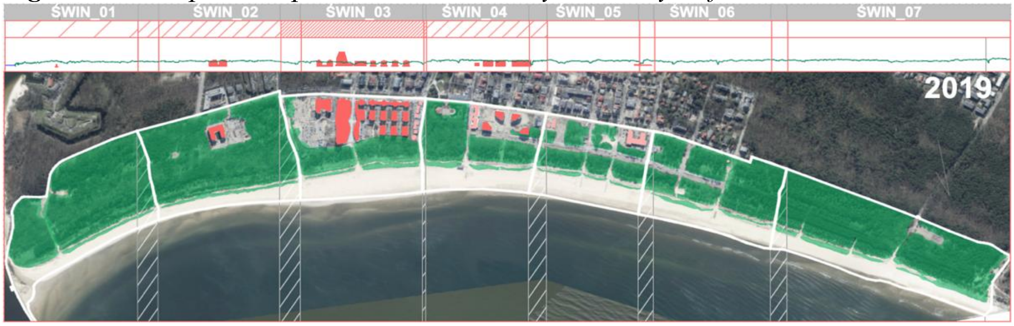
***Source:** Own study.*

***Figure 6**. Orthophotomap with a schematic skyline analysis for 2017.*



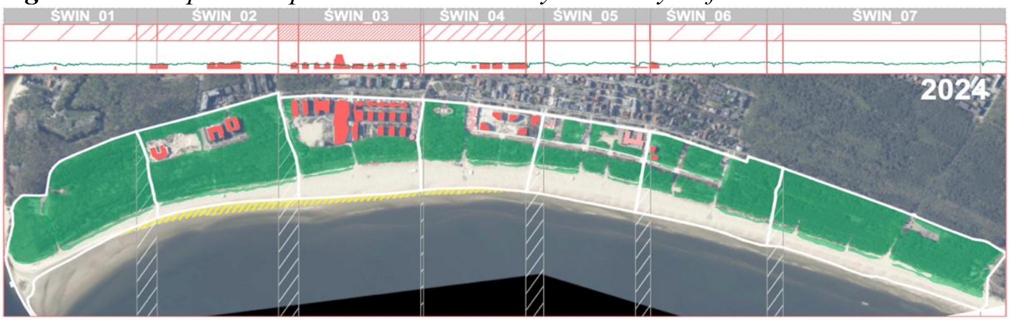
***Source:** Own study.*

Figure 7. *Orthophotomap with a schematic skyline analysis for 2019.*



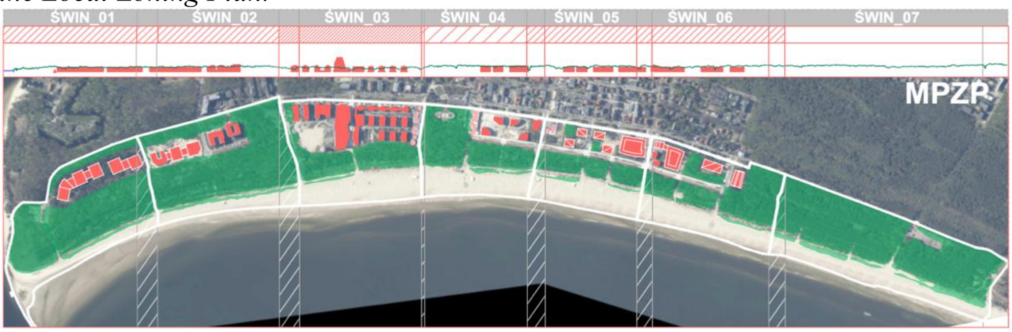
Source: *Own study.*

Figure 8. *Orthophotomap with a schematic skyline analysis for 2024.*



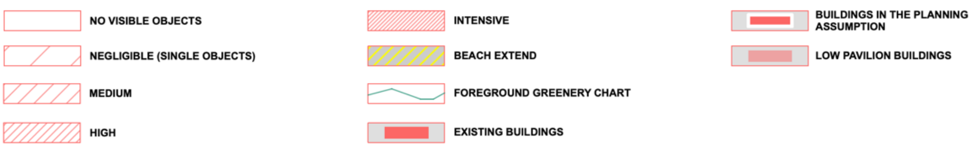
Source: *Own study.*

Figure 9. *Orthophotomap with a schematic skyline analysis for the assumptions of the Local Zoning Plan.*



Source: *Own study.*

Figure 10. *Intensity of skyline transformation – legend of symbols for figs. 5–9.*



Source: *Own study.*

In 2006 (Figure 4), the coastal zone of Świnoujście was characterized by the dominant presence of vegetation. Within the analysed area, only the low-rise municipal swimming pool—constructed in the 1980s—is distinguishable.

However, this structure is not visible in the skyline view due to the dense foreground vegetation. The only discernible built element is the Stawa Młyny[3] navigational structure, located in front of the dune vegetation belt.

In the orthophotomap from 2011 (Figure 5), the first apartment buildings appear within the ŚWIN_03 skyline section. In the imagery corresponding to the period from November 2017 to May 2019 (Figure 6), the third section of the skyline is visibly transformed by the emergence of large hotel developments such as Radisson Blu and Hilton.

The 2019 layer (Figure 7) confirms the continued intensification of development processes, particularly in skyline units ŚWIN_02 and ŚWIN_04, which previously exhibited no significant building volume. By 2024 (Figure 8), the extent of built-up area has further increased, especially through infill development in units ŚWIN_02 and ŚWIN_03, as well as the appearance of the first taller structure in unit ŚWIN_06.

Additionally, a comparison of orthophotomaps reveals the phenomenon of beach expansion in Świnoujście, resulting from water dynamics in the Baltic Sea and the accumulation of sand along the Uznam Island coastline. The schematic in Figure 8 delineates the zone of this beach expansion relative to the baseline year 2006.

The simulation based on the provisions of the local zoning plan (LZP), visualized in Figure 9, indicates further vertical growth of built-up forms exceeding the foreground vegetation line, thus predicting additional transformation of the Świnoujście skyline. Notably, the dune greenbelt has remained unchanged throughout the analysed period.

Detailed studies of individual units are presented in schematic diagrams for ŚWIN_03 (Fig. 11) and ŚWIN_06 (Figure 13), where green indicates foreground vegetation, red represents built structures, and blue denotes visible sky.

The respective changes are also illustrated in linear graphs (Figures 14 and 16). Due to the broad scope of the study, the article illustrates skyline evolution using two selected examples.

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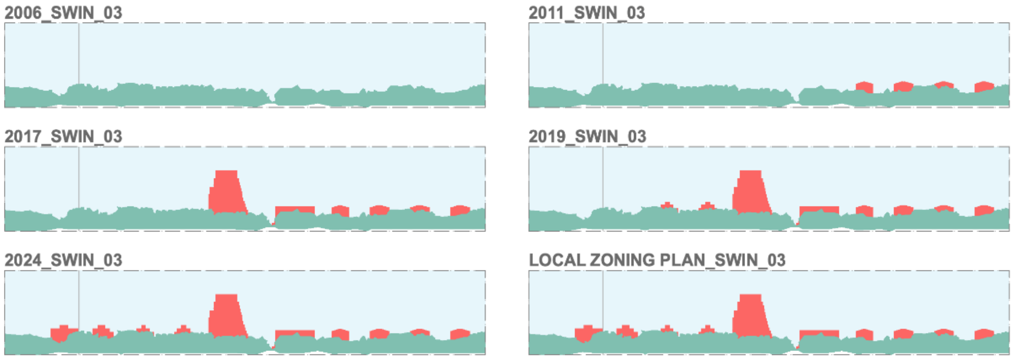
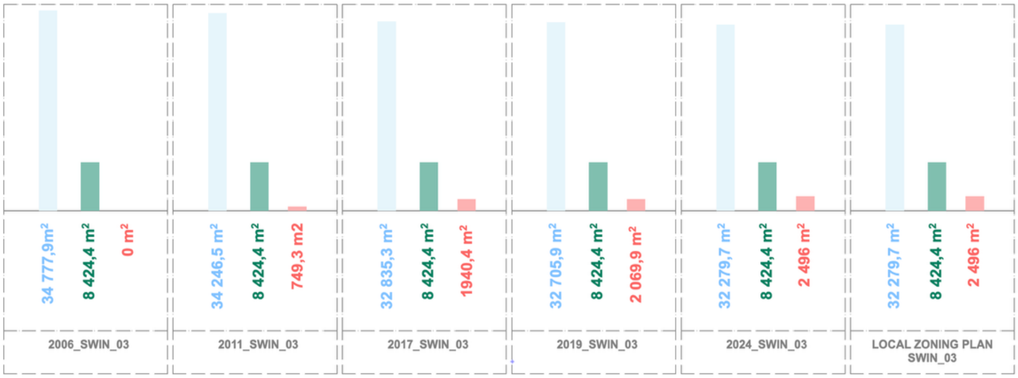
[3]*Stawa Młyny – windmill-shaped structure located at the end of the Western Breakwater, functioning as an element of Świnoujście's official logo.*

Figure 11. *Development of skyline unit ŚWIN_03.*



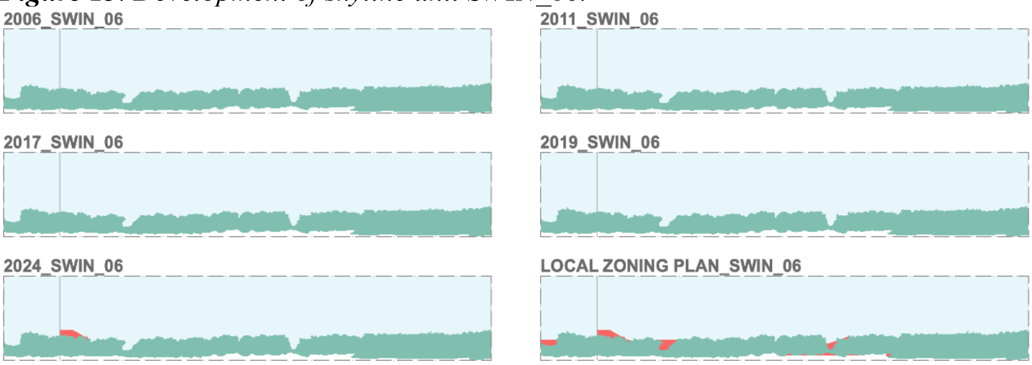
Source: *Own study.*

Figure 12. *Charts illustrating changes in built-up area, greenery and sky for skyline unit ŚWIN_03.*



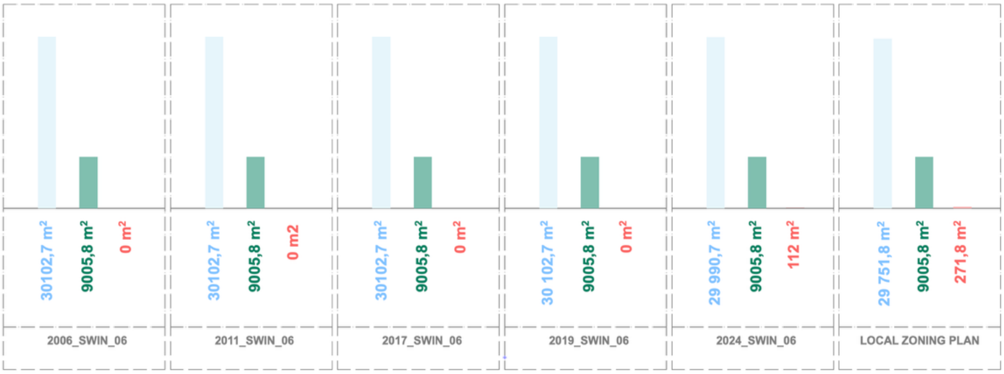
Source: *Own study.*

Figure 13. *Development of skyline unit ŚWIN_06.*



Source: *Own study.*

Figure 14. *Charts illustrating changes in built-up area, greenery and sky for skyline unit ŚWIN_06.*



Source: *Own study.*

The above examples demonstrate that the development of individual landscape units is non-uniform. The formation of the skyline, expressed through numerical values indicating the increase in built-up area and the reduction in visible sky area across all analysed frames, is presented in Tables 3 and 4. For the studied period, no significant changes were observed in the extent of foreground vegetation; therefore, the corresponding surface area of greenery for each skyline section is detailed in Table 5.

Table 3. *Summary of sky surface area changes in individual skyline units within the studied area in Świnoujście.*

SKY	**2006**	**2011**	**2017**	**2019**	**2024**	**LZP**
ŚWIN_01	32047,6	32047,6	32047,6	32047,6	32047,6	31675,9
ŚWIN_02	32084,3	32084,3	32084,3	31923,3	31759,7	31725,4
ŚWIN_03	34777,9	34246,5	32835,3	32705,9	32279,7	32279,7
ŚWIN_04	23496,2	23496,2	23496,2	23187,6	23187,6	23187,6
ŚWIN_05	24943,9	24943,9	24943,9	24908,1	24908,1	24793,9
ŚWIN_06	30102,7	30102,7	30102,7	30102,7	29990,7	29751,8
ŚWIN_07	51916,7	51916,7	51916,7	51916,7	51916,7	51916,7

Source: *Own study.*

Table 4. *Summary of building surface area changes in individual skyline units within the studied area in Świnoujście.*

BULIT	**2006**	**2011**	**2017**	**2019**	**2024**	**LZP**
ŚWIN_01	53,9	53,9	53,9	53,9	53,9	465
ŚWIN_02	0	0	0	161,6	325,2	362,7
ŚWIN_03	0	794,3	1940,4	2069,9	2496	2496
ŚWIN_04	0	0	0	160,6	160,6	160,6
ŚWIN_05	0	0	0	34,3	34,3	271,8
ŚWIN_06	0	0	0	0	112	348,7
ŚWIN_07	0	0	0	0	0	0

Source: *Own study.*

Table 5. *Summary of greenery surface area for individual skyline units within the studied area in Świnoujście.*

	ŚWIN_01	**ŚWIN_02**	**ŚWIN_03**	**ŚWIN_04**	**ŚWIN_05**	**ŚWIN_06**	**ŚWIN_07**
GREENERY	7161,1	10997,9	8424,4	8535,9	8123,1	9005,8	18351,5

Source: *Own study.*

Based on the above Tables, it is possible to identify sections exhibiting highly intensive urban development with nearly exhausted growth potential—such as unit ŚWIN_03, which contains a vertical dominant, and unit ŚWIN_07, located at the Polish-German border, which shows no current or anticipated development trends. In contrast, other units such as ŚWIN_01, ŚWIN_02, ŚWIN_05, and ŚWIN_06 are currently in active phases of transformation.

4.2 Development Assessment of the Entire Skyline

In order to identify broader development trends across the entire study area, data from individual units were aggregated and are presented in Table 6.

Table 6. *Summary of changes in building surface area in individual skyline units within the studied area in Świnoujście.*

Year	**Sky area (m²)**	**Bulit area (m²)**	**Green area (m²)**
2006	229 369	54	70 600
2011	228 838	848	70 600
2017	227 427	1 994	70 600
2019	226 792	2 480	70 600
2024	226 090	3 182	70 600
Local Zoning Plan	225 331	4 105	70 600

Source: *Own study.*

The results indicate a significant increase in built-up area: from 54 m² in 2006 to 3,182 m² in 2024 (an almost 59-fold increase), and a potential 4,105 m² under the planning scenario (a 76-fold increase). Consequently, the visible sky area is reduced by 4% (–4,038 m²) across the entire frame. Vegetation within the view profile remains stable—the tree canopies obscuring the building line have not been removed.

Table 6 allows for the identification of three distinct phases in the development of Świnoujście's skyline:

Phase 2006–2011 – symbolic development; changes in the skyline are barely noticeable.
Phase 2011–2017 – emergence of high-rise hotels and the onset of vertical concentration in unit ŚWIN_03.
Phase 2017–2024 – densification of adjacent parcels (ŚWIN_02, _04, _06); noticeable reduction in sky visibility.

Local Zoning Plan Scenario – an additional reduction of approximately 760 m² in visible sky and a 29% increase in building volume compared to the 2024 state.

4.3 Built-to-Sky and Built-to-Greenery Ratios for Individual Skyline Sections

The previous section described absolute changes in sky area, greenery, and building volume within Świnoujście's skyline. To better understand how these changes affect landscape perception, two ratios were calculated for each skyline unit: the built-to-sky ratio (Table 7) and the built-to-greenery ratio (Table 8). These tables present the spatial relationships for the years 2006–2024 and for the planning scenario.

Table 7. *Built-to-greenery ratio (BS) in individual skyline units within the studied area in Świnoujście.*

BS	2006	2011	2017	2019	2024	LZP
ŚWIN_01	0,002	0,002	0,002	0,002	0,002	0,015
ŚWIN_02	0,000	0,000	0,000	0,005	0,010	0,011
ŚWIN_03	0,000	0,023	0,059	0,063	0,077	0,077
ŚWIN_04	0,000	0,000	0,000	0,007	0,007	0,007
ŚWIN_05	0,000	0,000	0,000	0,001	0,001	0,011
ŚWIN_06	0,000	0,000	0,000	0,000	0,004	0,012
ŚWIN_07	0,000	0,000	0,000	0,000	0,000	0,000

Source: *Own study.*

As in previous analyses, Table 7 indicates the highest degree of transformation in unit ŚWIN_03, where the built-to-sky index ranges from 0.00 to 0.077. For units ŚWIN_01, ŚWIN_02, ŚWIN_05, and ŚWIN_06, the values range from 0.00 up to a maximum of 0.015, which represents only 19.5% of the index value observed in unit ŚWIN_03. Although these figures suggest minimal changes, the interpretation must consider the compression effect caused by the dominant height of the Radisson Blu building, which defines the skyline frame for unit ŚWIN_03.

Due to the substantial sky proportion present in the remaining units, structures with heights of 15–18 meters exert comparatively limited visual impact, a condition that is also reflected in the linear nature of the sky surface change graph (Figure 17). A multiple increase in the ZN index is a clear indicator of the emergence of vertical dominants within the analysed skyline.

Table 8. *Built-to-greenery ratio (BG) in individual skyline units within the studied area in Świnoujście. Source: by author*

BG	2006	2011	2017	2019	2024	LZP
ŚWIN_01	0,008	0,008	0,008	0,008	0,008ana	0,065
ŚWIN_02	0,000	0,000	0,000	0,015	0,030	0,033
ŚWIN_03	0,000	0,094	0,230	0,246	0,296	0,296
ŚWIN_04	0,000	0,000	0,000	0,019	0,019	0,019
ŚWIN_05	0,000	0,000	0,000	0,004	0,004	0,033

ŚWIN_06	0,000	0,000	0,000	0,000	0,012	0,039
ŚWIN_07	0,000	0,000	0,000	0,000	0,000	0,000

Source: *Own study.*

Compared to Table 7, Table 8 indicates substantially higher transformation values. The ZZ index (built-to-greenery ratio) is independent of the height of the skyline section. For example, in the case of unit ŚWIN_06, the ZZ index (0.039) is 225% greater than the ZN index (0.012). In ŚWIN_03, the ZZ index reaches 0.296, which constitutes approximately 13% of the value recorded for ŚWIN_06. This reflects a very intense transformation of the skyline due to new development; however, the indication of local verticalisation is not as apparent as in the case of the ZN index.

4.4 Discussion

The coastal frontage of Świnoujście reveals a distinct, three-layered spatial sequence composed of a broad beach zone, a vegetated buffer zone with a dune of approximately 2 meters in height that enhances the perceived verticality of the greenery, and a zone of anthropogenic transformation where contemporary interventions primarily tourist infrastructure are concentrated. Hotel and apartment buildings emerge from behind the foreground vegetation and influence the perception of the skyline from both the beach and the open sea.

In the analysed case, the observed intensification of built-up development is concentrated almost exclusively in a single landscape unit. This trend is evident in the skyline schematic derived from the local zoning plan (Figure 11) and is further substantiated by tabular analyses and the building surface area change graph (Figure 18). The introduction of the Radisson Blu building into Świnoujście's panorama has redefined the scale of the entire visual frame its height now serves as the dominant point of reference for evaluating other structures.

As a result, every subsequent development with lower height parameters is perceived as negligible in terms of its visual impact on the overall skyline composition. The substantial portion of sky remaining in the frame suggests an illusory visual equilibrium. This phenomenon may lead to the erroneous conclusion that additional vertical developments in adjacent units will not significantly affect the perception of the urban skyline, particularly when sky surface indicators change only marginally (Figure 16).

However, decisions regarding the allowance of high-rise development in further sectors should be preceded by detailed visual impact assessments that account for localized spatial conditions, rather than being based solely on aggregate statistical indicators for the entire visual frame. This justifies the methodological approach adopted in this study, in which the skyline is divided into distinct analytical units, thereby allowing for the evaluation of new investments in the context of their immediate surroundings.

Analyses employing the built-to-greenery ratio (BG) allow for the assessment of skyline transformation intensity - the greater the proportion of tree canopies relative to built volume, the more landscape-like the skyline appears.

This metric is particularly sensitive to infill development of low- and mid-rise buildings situated just behind the tree belt. In the present case, foreground vegetation remains unchanged; however, it is anticipated that as the study expands to other areas, this indicator may vary over time.

The built-to-sky ratio (BS) quantifies the extent of vertical space already occupied by dominant structures and indicates the rate at which sky visibility is being altered by new development. Its primary advantage lies in its capacity to clearly signal height increase.

A notable limitation, however, is its low sensitivity to infill development below the tallest dominant structure - when the frame is scaled to a single, very tall building, additional storeys in mid-rise buildings become statistically negligible, despite altering the perceptual experience from the beach level.

The findings presented in this study confirm and expand upon the spatial patterns previously identified in the works of Czapliński, Rubinowicz, and Ozimek. Czapliński's concept, which involves the analysis of skyline rhythm and vertical variability using orthogonal elevation profiles, is reflected in the three-layered composition of Świnoujście's coastal zone. The vertical articulation – particularly the dune and vegetation buffer – corresponds to the modulated building rhythm that Czapliński associates with intensified touristic functions within 100–400 metres of the shoreline.

The dominance of the Radisson Blu building and its impact on the perceived hierarchy of the skyline likewise supports Rubinowicz's findings on the disproportionate visual influence of high-rise forms on cultural heritage panoramas.

As in VIS-based simulations, the present study observes that the introduction of a single, distinct vertical dominant results in subsequent lower-rise developments having minimal influence on the overall visual composition – despite altering the rhythm and density of buildings at eye level.

It is also worth noting that the BS (built-to-sky) ratio for Świnoujście confirms Ozimek's observations: dominant structures distort perceptual scale – supplementary mid-rise buildings become statistically insignificant, even though they affect spatial perception from beach level.

This reinforces the present study's recommendation that skyline assessments should be conducted within smaller analytical units, as global indicators may obscure localised disruptions in the visual landscape.

5. Conclusion and Recommendation

5.1 Urban Skyline – Significance and Research Directions

The author of the present study integrates both 2D data (historical orthophotos) and 3D data (LiDAR/BIM) within a single model, enabling the simultaneous tracking of vertical growth and urban densification. By working within the ARCHICAD environment, a real-scale, interactive BIM platform is created, which supports view-shed analyses, zoning plan scenarios, and automatic generation of precise quantitative outputs.

This framework may significantly expedite future planning dialogues between designers, investors, and regulatory authorities. The researcher segments the skyline into analytical units, thereby eliminating distortions caused by single, disproportionately tall buildings. The synthetic skyline is reduced to three basic landscape components: sky, buildings, and greenery. Surface values for each category are assigned to their respective skyline offer insight into the visual and spatial consequences of vegetation loss in coastal skyline perception.

5.2 Perspectives for Future Research Development

A well-designed skyline should be "legible, varied, yet not chaotic"—in other words, it should present a sequence of buildings with gradually shifting heights, clearly articulated vertical dominants, and receding background elements. This composition allows for an intuitive reading of the city's spatial structure in a single glance. At a macro scale, "the entire urban mass contracts into a horizon line," with tall buildings acting as visual landmarks (Lynch, 1960).

What should the skyline of a coastal tourist town look like? Within the framework of refining urban profile analysis methods, it is crucial to propose an extended research model that evaluates the visibility of structures rising above the foreground tree canopy from the beach zone.

Furthermore, expanding the study to encompass a broader range of case studies may facilitate the establishment of baseline indicators for the automated assessment of skyline transformation levels.

Świnoujście, as examined in this study, represents a model where the foreground greenery remains largely intact and continues to function as a visual screen that conceals much of the recent development. Future analyses involving the Built-to-Greenery (BG) index should include cases in which the foreground tree cover has been significantly altered or was never present, as these would offer insight into the visual and spatial consequences of vegetation loss in coastal skyline perception.

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