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TRANSIT-ORIENTED DEVELOPMENT (TOD) AS A TOOL FOR SHAPING SPATIAL ORDER

STRATEGIA ROZWOJU ZORIENTOWANEGO NA TRANSPORT (TOD) JAKO NARZĘDZIE KSZTAŁTOWANIA ŁADU PRZESTRZENNEGO

ABSTRACT

This paper aims to identify the theoretical assumptions of the Transit-Oriented Development (TOD) strategy and its impact on spatial planning. It presents an overview of the TOD's factors and indicators from the perspective of a Polish researcher who describes and analyses a best-practices example of TOD implementation, selected by the authors together with an American proponent of Transit-Oriented Development. The paper also presents the results of preliminary analyses of the link between the TOD Index potential assessment method and the author's own method for assessing physiognomic order. The method for assessing spatial order presented in this paper can be used to analyse the connection between a public transport hub and the centre of an urban settlement. The visual and functional quality of public spaces that constitutea pedestrian route that connectsa train station with a main public space is one of the most important elements that determines TOD's success.

Keywords: Transit Oriented Development (TOD), physiognomic order, sustainable development of cities and housing estates

STRESZCZENIE

Celem niniejszego artykułu jest identyfikacja założeń teoretycznych strategii Rozwoju Zorientowanego na Transport (TOD) oraz jej wpływu na planowanie przestrzenne. Artykuł przedstawia przegląd czynników i wskaźników strategii TOD z perspektywy polskiego badacza, a także analizę przykładu najlepszych praktyk wybranego przez amerykańskiego propagatora strategii TOD. W artykule przedstawiono również wyniki wstępnych analiz powiązania między metodą oceny potencjału Wskaźnika TOD a autorską metodą oceny porządku fizjonomicznego. Metoda oceny ładu przestrzennego przedstawiona w niniejszym artykule może być wykorzystana do analizy powiązania węzła komunikacji publicznej z centrum jednostki osadniczej. Jakość wizualna i funkcjonalna przestrzeni publicznych stanowiących ciąg pieszy, łączący dworzec kolejowy z główną przestrzenią publiczną, jest jednym z istotnych elementów decydujących o sukcesie TOD.

Słowa kluczowe: Rozwój Zorientowany na Transport (TOD), porządek fizjonomiczny, zrównoważony rozwój miast i osiedli mieszkaniowych

1. INTRODUCTION

Transit-Oriented Development (TOD) is an instrument that facilitates urban development sustainability and is a strategy that assumes increasing transport efficiency through improving the accessibility of urbanized areas. TOD is close to the assumptions of New Urbanism, understood as a method of development planning and compact city design (Domińczak, 2020) with clear and hierarchized layouts that ensure a proper availability of services, workplaces and leisure spots within comfortable walking distance. TOD supplements those assumptions by adding a postulate of convenient and competitive public transport, understood as a system of intermodal transfer nodes and public transport lines. TOD may be a tool for the implementation of short-distance cities, balancing the development of urbanized areas with the protection of green areas and ensuring appropriate spacing and spatial arrangement of planned buildings. TOD implementation can contribute to ensuring physiognomic order and serve to limit negative phenomena such as anthropopressure or urban sprawl.[1]

The Transit-Oriented Development strategy was formulated as a toolfor counterbalancing urban growth by increasing public transport efficiency through improved accessibility (Calthorpe, 1993). The main idea is based on creating a system of public transport networks and nodes/hubs around which mixed-use built-up areas with high population density are located along with pedestrian-friendly public spaces that support reducing excessive car dependency in road traffic. TOD is an attempt to saturate the suburbs with elements characteristic of city centres to make them less congested and chaotic but still vibrant and functional places with high quality public spaces and green areas. InTOD, the central area (*centrality)* is defined as an area where services and retail accompany residential use, with much importance attached to its role as a transport node/hub and the emphasized significance of transport infrastructure in creating friendly living environments (Ibraeva et al., 2020).

TOD can be characterized as a concept of planning the development of settlement units located within a walking distance of no more than 800–1000 m from public transport nodes/hubs (Ill. 1), with mixed-use, compact development of higher or moderate density which creates compositions with legible spatial interiors and encourages walking and cycling thanks to the availability of services and appropriate amenities.

Spatial development of settlement units under TOD is characterized by a settlement pattern with a clear core with services and retail surrounded by an area of up to 70 ha of development with housing and service uses, a well-developed road network that offers pedestrians the sense of safety and comfort thanks to the right street cross-section distinct for a neighbourhood within a particular settlement unit (Parker et al., 2002; Hale and Charles, 2006; Dorsey and Mulder, 2013). Thanks to these solutions, the area will be reminiscent of a traditional city-centre built form with unique spatial organization characteristics where the railway station and its closest environs is the central point.

2. EXAMINATION OF THE ROLE OF TOD IN SPATIAL PLANNING

Initial implementations of TOD were limited in scale to a neighbourhood or small city fragments. However, from the very beginning it was postulated to extend the strategy to the scale of regional development planning, which would encompass complex structures such as metropolises and their functional areas (Cervero and Sullivan, 2011; Belzer, 2011). A special term even appears in relevant literature referring to action at this scale: TOM, or Transit Oriented Metropolis (Sung and Choi, 2017) or Transit Metropolis (Cervero, 2020; Xue et al., 2020). Most researchers suggest that TOD is best applied to direct the development of areas located close to high-capacity rail networks, e.g., commuter rail, but some studies (Hendricks et al., 2005) indicate that TOD-compliant solutions are compatible with the new generation of road networks that include bus lines served by low-emission, low-floor buses with the road layout providing buses with a speed advantage over the less efficient private car traffic. Under this approach, the bus station can play a role similar to that of a railway station — create a centre in the urban structure (Hale and Charles, 2006). Some researchers (Belzer and Autler, 2002a, 2000b; Cervero and Duncan, 2002; Dittmar and Ohland, 2004; Renne, 2009) introduce the concept of Transit-Adjacent Development (TAD) in order to differentiate areas that are located close to transport nodes but do not take advantage of this proximity

[1] These ideas are also promoted by Global Urban Development (GUD), an international non-profit organization represented by M.A. Weiss as CEO and B. Kaźmierczak as Senior Member. Global Urban Development is engaged in spatial and economic development policy, conducting educational, research, and implementation activities to promote model solutions and exchange experiences that foster sustainable, economically desirable, and socially inclusive urban development worldwide (https://www.globalurban.net/).

(Ill. 2) from those that are functionally linked to the node in line with TOD.

Both concepts refer to an area located within a 10-minute isochrone of pedestrian accessibility or a 1 km radius from the main transport node. According to TOD, the area surrounding a station should be developed in order to be compact, mixed-use and have good accessibility. Meanwhile, TAD does not formulate such recommendations and only emphasizes the physical proximity of the transport network (Cervero and Duncan, 2002, p. 6; Hale, 2014) (Tab. 1).

Tab. 1. Comparison of the characteristics of a place in the proximity of a public transport node under the TAD and TOD models.

TAD - Transit-Adjacent Development	TOD - Transit-Oriented Development
– amorphic urban grain – low development density – single-family dwellings predominate – employment as part of industrial uses – segregation of uses (uses segregated horizontally) – extensive surface-level car parks – limited accessibility for pedestrians and cyclists	– regular urban grain – high development density – multi-family dwellings predominate – employment as part of commercial uses – mixed-use development (often vertical mixed-use) – concentrated multi-storey car parks – facilitated walking and cycling

Source: Prepared by the author based on:Renne, 2009, p.3.

In turn, Washington, DC, is a successful case of TOD implementation, where an underutilized railyards area experienced an extraordinary economic resurgence through development of a new Metro transit station. In 1997, Washington was suffering from slow job growth, insufficient new development, a declining population, and social challenges in low-income neighbourhoods. Thanks to the federal government's efforts, a committee was established to develop a strategy to overcome the crisis. This strategy was geared towards private sector growth and focused on three categories: strategic industries (investing in six key industry networks/clusters; growing businesses and jobs across the private sector), strategic populations (workforce development; attracting and retaining residents) and strategic areas (downtown; key neighborhoods). The main element of the plan was 40 detailed actions, two of which were crucial: Action 26 — 'develop NoMa (North of Massachusetts Avenue) as a technology, media, housing, and arts district'; and Action 29 — 'build a Metro station at New York Avenue to spur development' (Ill. 3). The basis of the NoMa strategy was to build a new elevated Metrorail station along an existing transit line at the longest distance gap between stations (2 mi) in the central urban part of the Metrorail system (Weiss, 2008).

One negative impact that discourages potential new development in the NoMa area was the requirement by the General Services Administration (GSA) of the US government that all government buildings, as well as any federal government offices or facilities leased from private sector building owners, must be located within 750 m of a Metrorail station. This assumption was intended to promote public transport and discourage workers from driving cars to commute to federal offices. Therefore, to stimulate NoMa\s development, it was necessary to increase its transport accessibility through rail connections and, in particular, to meet the GSA location criteria for federal facilities, which meant that the top priority for the economic development of NoMa was to finance the construction of the New York Avenue Metro station (Washington DC).

This was a strategic move, as the location of important centre-forming uses attracts private investors to invest their capital in the developing zone (Ill. 4). When assessing the results of this decade-long initiative, it is worth mentioning the annual increase in the value of private property of over 30%.[2] Furthermore, since 1998, the number of Metrorail passengers at stations adjacent to New York Avenue has increased by 35% on average (Weiss, 2008). Currently, NoMa is the city district with the best transport connections, with the Walk Score[3] result of 92, excellent cycling infrastructure and railway connections, two metro

[2] An increase from 535 million dollars in 2001 to almost 2.3 billion dollars in 2007 was recorded. [Weiss, 2008].

[3] The Walk Score is a counter that was developed in 2007 to measure *walkability*. By entering an address anywhere in the United States, you can get a score from 0 to 100 points. Walk Score was initiated as a small-scale project with the aim of promoting areas and neighborhoods that are convenient for walking. In 2014, Walk Score was bought by the national real estate agency Redfin and lost its public mission, but in the same year a second counter was launched: the National Walkability Index (NWI). Source: https://www.cnu.org/publicsquare/2019/01/10/walkability-indexes-are-flawed-lets-find-better-method1

stations and access to main motorway (Washington DC). By linking spatial development with public transportation in NoMa, the share of car trips has been substantially reduced while simultaneously increasing the percentage of people using alternative transport modes. Construction of the NoMa Metro station included development of the new Metropolitan Branch Trail for hiking and biking. NoMa is now home to nearly 15,000 new residents, and 84% of them commute to work by walking, cycling, or public transportation. According to walkscore.com, NoMa has a very high Walk Score of 98, Transit Score of 100, and Bike Score of 92, indicating a significant level of modal shift. According to 2024 data, the district had over 14,000 permanent residents, 70% of whom were aged 18–37. As much as 96% of local residents had a college degree or higher, and 57% of property owners earned over $100,000 annually. The district boasted 6,400 apartments and six mixed-use buildings. There has been more than $9 billion total private investment in NoMa since the Metro station opened in 2004, and NoMa now includes more than 52,000 jobs, together with 30 new buildings receiving LEED Green Building certifications, including 19 Platinum and Gold certifications. NoMa's successful development is due to an integrated approach to development and transportation systems, as well as the collaboration of private and public entities and broad public participation (nomabid.org, accessed: 2.11.2025).

3. THE IMPORTANCE OF TOD STRATEGY AND ITS IMPACT ON PHYSIOGNOMIC ORDER

Over the last twenty years TOD has become a leading planning doctrine aimed at curbing suburban sprawl and closely connected with the idea of *Smart Growth*[4] and the approach promoted by New Urbanism (PUBLIC SQUARE A CNU Journal) (Dittmar and Ohland, 2004). P. Calthorpe[5] (1993) put forward a conceptof*Transit Oriented Development* formulating its main principles, while R. Cervero (Cervero and Kockelman, 1997; Cervero, 2004) defined its basic components, the so-called 3D — *Density, Diversity, Design*. Those components define the major postulates of the strategy: ensuring high density of development, multifunctional offer and pedestrian-friendly public spaces. In the following years of TOD research, two more components were added: D — *Distance to transit*and D — *Destination accessibility*. This resulted from the observation that implementation of the TOD strategy is impossible without accessibility of public transport (Cervero and Murakami, 2009; Ewing and Cervero, 2010). Finally, the last D — *Demand management* — completed the presentation of TOD philosophy, covering the aspect of the management of transport demand (Transit Authority, 2011).That component occurred in response to criticism (Handy, 1993) emphasizing that it is not possible to meet all the needs of modern cities by simply abandoning car transport. The elements of the 6Ds are indicators identified by experts that are related to various aspects of spatial planning (Abutaleb et al., 2019). However, research shows that not all elements of the 6D assessment are always taken into account at the same time, due to the difficulty of obtaining certain data (Jamaleddin et al., 2022).

Accessibility planning has a huge impact on the creation of rational spatial structures that function in harmony with the environment and users' needs. From the point of view of achieving specific goals related to sustainable development implementation through TOD, the following lines of research can be identified:

- shaping a healthy natural environment by reducing the number of journeys and promoting public transport that lowers pollution (Dou et al., 2016),
- increase in economic efficiency related to the reduction of travel time in the context of growing transport costs (Li et al., 2013),
- increasing the efficiency of the transport system and reducing traffic jams due to a shift in transport preferences — from individual car transport to public transport (Boschmann and Brady, 2013),
- promoting the rational use of land and limiting urban sprawl (Ratner, Goetz, 2013).

Accessibility planning is also an important component of sustainable spatial policy, the indicator of which is spatial order (Lin and Jen, 2009; Curtis and Scheurer, 2010). Sustainable transport based on the principle of accessibility and using the TOD strategy plays an important role in achieving the goals of sustainable urban and regional development and promotes the creation of compact and complete urban structures (Taki et al., 2017). TOD implementation contributes to both a reduction in urban sprawl and an increase in the number of people who use public transport, as well as pedestrians and cyclists, thus

[4] This notion corresponds to the idea of *compact city* and its presence in literature was established thanks to the movement of *New Urbanism* (por.) Growing Smart Legislative Guidebook, 2002.

[5] P. Calthorpe is one of the founders and the first board president of the Congress of New Urbanism — CNU. Source: https://www.cnu.org/publicsquare/2023/07/20/cnuers-rank-among-most-influential-urbanists-past-and-present

limiting the share of private cars in daily traffic (Curtis and Scheurer, 2010; Duany and Plater-Zyberk, 2014). R. Cervero (1993) emphasizes this by noting that the mere fact of living near a railway station is a sufficient incentive to use public transport.

4. FACTORS THAT DETERMINE TOD IMPLEMENTATION POTENTIAL

Grasping the relationships between the countless factors that influence the assessment of the studied area in terms of accessibility is possible by comparing observations and measurements. In their report, J.L. Renne and J.S. Wells (2005) drew attention to the lack of comprehensive measurement tools to objectively compare different areas. Like a number of other researchers (Evans et al., 2007), they pointed out the need to express the existing development potential of an area by developing a set of characteristics that describe the degree to which a given urban structure is oriented towards ensuring convenient accessibility. In the literature, despite some differences in research approaches to the analysis of the weight and significance of individual parameters that determine proper spatial development, two are most frequently mentioned: high density and multifunctionality of development.

Y.J. Singh and colleagues(Singh et al., 2014) proposed a multi-criteria analysis serving such research that takes into account various densities, land use and development structure, as well as parameters of economic development. He lists the following factors for evaluation of whether a given area is suitable for the implementation of TOD:

1. high density of residential and commercial buildings that favour greater efficiency of public transport, defined by:
   - residential density: number of residential buildings per unit of area,
   - population density: number of inhabitants per unit of area,
   - commercial density: number of commercial buildings per unit of area,
2. high diversity of land use, understood as an appropriate functional diversity in land use that reduces the number of car journeys and increases the vitality and safety of social integration sites,
3. proper arrangement of public spaces and urban design that encourages walking and cycling,
4. high level of economic development expressed by the number of businesses operating in a given area.

M. Beim and B. Modrzewski (2013), in an attempt to determine the minimum building density within walking distance of a transport node, cite calculations made by A. Duany and E. Plater-Zyberk (2014). Those calculations indicate a figure of at least 35 households per hectare, which corresponds to a building pattern based on terraced housing or small multi-family developments and may refer to American conditions due to building standards that differ from e.g.,European ones. D. Apel et al.(2001) determined a figure of 40–50 households per hectare based on European standards. Within a 500 m radius of a suburban railway station, the minimum number of residents should be 4,000. One of very few examples of research on transport accessibility in rural areas is Swiss research (Guzik, 2016; Jurkowski, 2017). S.R. MacCormac and J. Prichard (2005) also proposed a settlement unit model that corresponds to the requirements of development based on transport accessibility. In their research, they defined the minimum area for 5,000 inhabitants for which the profitability of public transport allows it to be operated effectively. This was an innovative proposal for shaping *sustainable suburbia*, consisting in the distribution of single- and multi-family housing on a circular plan with a local centre in the middle, ensuring the aforementioned number of residents in an area of approximately 113 ha. This assumption is close to the idea of a compact city, where it would take about 10 minutes to walk to the centre on foot (Wiśniewski, 2021).

Contemporary researchers are trying to identify comparable parameters describing *Transit Oriented Development* in order to better plan the development of buildings and transport networks, as well as to quantify transport nodes (Zemp et al., 2011; Papagiannakis, Vitopoulou and Yiannakou, 2021; Qiang, Zhang and Huang, 2022). One of the widely used TOD typologies is the NP (Node-Place) model proposed by L. Bertolini (1996, 1999, 2008) (Ill. 5). It is a universal tool that simultaneously takes into account the characteristics of a transport node and a place — understood as an area within walking distance of the node. The basic assumption is to improve the transport of a given location by improving accessibility, while creating favourable conditions for further land development. In turn, the development of a multifunctional building structure, due to the growing demand for transport, creates conditions conducive to the further development of the transport system (Yang et al., 2020; Yang et al., 2020).

Both the quality of the node (Bertolini and Chorus, 2011) and that of the place are described using accepted parameters, the values of which are shown in the diagram. The middle part is a field that defines the balance between the potential of the node and the potential of the area within walking distance.

A balance between the node and the place exists when both elements are equally strong. Technical and transport infrastructure and the functional and spatial profile of the buildings structure mutually support each other's development without the need to strengthen any of the elements through further expansion. The upper part of the diagram indicates stress, which is the state when the intensity and diversity of development and investment activity comes close to the maximum level. In such a situation, land use reaches maximum efficiency, ensuring high profitability of the transport offered at the transport node, which in turn allows the full potential of the site to be utilized. However, this state is associated with high competitiveness in the race for the most valuable land and, in the case of excessive land values, can cause difficulties in acquiring new land for the further development of the necessary infrastructure, as well as causing a tendency towards excessive building intensification. The opposite of this state is dependence, shown in the diagram as located below the balance area.It denotes a situation in which the transport supply and the degree of proper land development are low, and the competition for investment sites relatively small. When this is the case, an unjustified desire to stimulate development and artificial increase of property values through public investment in transport infrastructure may be a threat. In this situation, further infrastructure development does not fundamentally translate into system efficiency, as with low levels of traffic flow associated with low socio-economic potential, maintaining the node may require external assistance, resulting in an imbalance. Two types of unbalanced categories can be distinguished: the first is anunbalanced node, where traffic capacity is significantly higher than land use, and the second is an *unbalanced place*, where the situation is reversed. Interestingly, in the long term, most unbalanced nodes tend to approach a balanced state (Reusser et al., 2008). It follows that it is easier to achieve a balance by planning the development of buildings around an existing node than to introduce the necessary transport infrastructure in the case of an unbalancedplace.

Although the NP (Node-Place) model is widely used as a quantitative method to assess the coordination of transport and land use (Ma et al., 2022), some researchers extend this model to three- or multi-criteria dependency (Yang, Zhong and Gao, 2022; Vale, 2015). This is due to the fact that, despite the universality of the method, it ignores issues related to different local conditions, such as building development patterns (Kumar, Sekhar and Parida, 2020). An extended NP (Node-Place) model is proposed by E. Papa and L. Bertolini (2015) and L. Bertolini, F.D. Moccia and A. Nigro (2019) in their approach to TOD research. That is why Y. Yang, C. Zhong and Q.L. Gao (2022) give the specific parameters of the TOD Index in their research using the NP method as the basis, but additionally enriching the analysis with two criteria: quality of development (design) and temporal activity of the node users (vibrancy). This is important because the basic model lacks a perspective that presents the morphological and formal characteristics of built environments, despite the fact that the quality of public spaces is crucial for TOD areas (Renne, 2009).

5. FROM THE NODE TO THE PLACE — FROM THE TOD INDEXTO PHYSIOGNOMIC ORDER ASSESSMENT

From among many characteristics of spatial order identified through literature research, the author selected those that align with the necessary conditions for guiding spatial development in accordance with the principles of TOD. These conditions stem from the research methodology for assessing the TOD Index, which focuses on the characteristics of the transport node (Node) and the settlement centre located within the node and that constitutes its catchment area (Place). The following parameters were considered for assessing the TOD Index on a local scale: the number of possible modes of transport available at the train station and the number of services available at the station — which determine the potential of the node (Node); and the length of sidewalks and bicycle paths connecting the station to the city centre — reflecting the potential of the place (Place) (Tab.2). This research was conducted for three similar centres located within the functional area of Poznań: Gniezno, Września, and Środa Wielkopolska.

The final TOD Index rating for the potential of the hub was average for Września and Środa Wielkopolska. The lack of an integrated transfer system, the lack of additional functions at the station, and the long distance from the station to the city centre are factors that weaken the hub. The assessment of the component related to the location — the catchment area — is slightly better. A large proportion of tall greenery, relatively comfortable sidewalks and bike paths, and a moderately rich range of services on the ground floors — especially in the Old Town area — led to a slightly higher rating. In summary, the potential of the location is greater than the hub in Września and ŚrodaWielkopolska. Gniezno, a significant railway hub, has a relatively well-developed passenger service infrastructure. The lack of bicycle paths is a problem that reduces the potential of the location.

Tab. 2. Calculations of the metrics needed to assess the TOD Index parameters.

Detailing	**Number of possible means of transport available at the train station**	**Number of services available at the station**	**TOD Index node evaluation**	**Facilities for pedestrians and cyclists: a. total length of sidewalks, b. bicycle paths (in relation to the distance of the station from the centrality or centre of the unit)**	**TOD Index rating**
	amount	amount	point	%	point
WRZEŚNIA municipal commune				**pedestrians** / **cyclists**	
				path a: 987 path b: 1014 / patha: 530 path b: 530 path a: 53.7% path b: 52.3%	
Września station	3	2		**100** / **53,1**	
total		5	**2**	4 / **3**	**3,5**
ŚRODA WLKP				**pedestrians** / **cyclists**	
				path a: 2103 path b: 1914 / path a: 1440 path b: 1036 path a: 68.5% path b: 54.1%	
Środa Wielkopolska station	**3**	**2**		**100** / **61,3**	
total		5	**2**	4 / 3	**3,5**
GNIEZNO municipal commune				**pedestrians** / **cyclists**	
				path a: 1010 path b: 972 path c: 945 / path a: 94 path b: 94 path c: 94 path a: 9.3% path b: 9.7% path c: 9.9%	
Gniezno station	**7**	**4**		**100** / **9,6**	
total		11	**4**	4 / 1	**2,5**
		0–2 / 1 pt		0–25 / 1 pt / 0–25 / 1 pt	
		3–5 / 2 pts		26–50 / 2 pts / 26–50 / 2 pts	
		6–8 / 3 pts		51–75 / 3 pts / 51–75 / 3 pts	
		9–11 / 4 pts		76–100 / 4 pts / 76–100 / 4 pts	

Source: original work.

The next step was to examine the physiognomic order, for which the author considered legibility, articulation, and continuity[6] as the essential evaluation parameters. The distance between the train station and the Old Market Square in a straight line is just over 1,200 m, but the location of both locations and the existing urban layout increase the actual distance to be covered to 1,914 m. The designated sequence consists of 54 sequences divided by 55 measurement points (Ill. 7). The following illustrations (Ill. 8) depict photographic material used to analyse the Sky View Factor (SVF).

The visibility measurement results were summed, and then the average value was calculated. In the next step, the sections between the points with a score below the average were measured, assuming that sections containing a maximum of one point with a value above the average were considered as a whole. Based on this, it is possible to determine the proportion of the lengths of the sections with LEGIBILITY above and below the average. The second parameter examined in the assessment of physiognomic order is ARTICULATION. Using previous calculations (regarding individual sections of the sequences examined in terms of their legibility), the author performed a comparative analysis to determine the number of points located on sections with high legibility, as well as those located on sections of the sequence characterized by low legibility. The grouping results were converted into percentages and then averaged when multiple sequences were present in the analysed example.

The points of the assessment were awarded according to the principle: the greater the number of points characteristic for individual sequences located on sections with high legibility, the greater the articulation of the space. Low articulation levels range from 1 to 2 points, while high articulation levels range from 3 to 4 points. The final parameter defining physiognomic order is CONTINUITY, for which the metrics influencing the assessment are the percentage of services and the percentage of greenery in relation to the total length of the analysed routes that connected the railway station with the main public space defined as the centre of the settlement unit. The metrics were analysed as follows:

– Identifying the presence of tall vegetation along the designated road using data obtained from LIDAR scanning, which was then verified during a site inspection,
– Determining the location of service uses on the ground floors of buildings that constitute the urban walls of the studied routes based on a site inspection, taking into account premises with operating services, as well as those that were physically separated but where no business is conducted.

The final stage of the study was to collect and collate the calculation results to verify the degree of saturation of the analysed routes with elements considered as indicators. After performing calculations based on the prepared maps and determining proportions, the results were summed (in the case of multiple routes) and averaged. Points on a scale of 1–4 were awarded according to the principle: the higher the saturation with services and tall vegetation, the higher the number of points. After collating the obtained test results for the parameters: legibility, articulation, and continuity, a final assessment of the physiognomic order was possible. The highest score was obtained by the cities of Gniezno, then Środa Wielkopolska, and the lowest by Września (Tab.3).

The city of Września has a connection between the railway station and the city centre, which largely runs through open, undeveloped areas with little greenery or services. In this regard, the final score for physical order is relatively low. A slightly higher final score was achieved by the city of Środa Wielkopolska, where the analysed route is characterized by significantly better legibility and articulation. This is due to the fact that a large portion of the road runs along tree lines or is bounded by the urban walls of dense development. The biggest drawback in this research example is the very short section containing ground-floor services. This metric determined the lowest continuity parameter compared to the other studied examples. The highest-rated city, Gniezno, is characterized by very good legibility and articulation, as the route is predominantly covered by dense frontage development. Furthermore, the surrounding greenery enhances the impression of visual closure and, together with the large number of ground-floor services, contributes to the high continuity score.

[6] LEGIBILITY is a parameter that utilizes the challenges of the view sequence system, measured by the ratio of view obstructions to open space at designated observation points. Using the SVF (Sky View Factor) method, we determined the fields of view and the degree of obscuration of views from characteristic viewpoints representing identified sequences. ARTICULATION is a parameter measured by the number of viewpoints per section of the route with high and low legibility. The greater the number of points — representing individual sequences in sections of the route with high legibility — the higher the level of articulation. CONTINUITY is a parameter measured by the ratio of the length of the route connecting the railway junction with the main public space designated as the centre to the lengths of the route equipped with development elements, such as greenery and ground-floor services.

Tab. 3. Classification of centres in terms of physiognomic order.

Detailing	Legibility	Articulation	Continuity	Physiognomic order
Gniezno urban municipality	4 **(H+)**	**3 (H+)**	3 **(H+)**	**3,3**
ŚrodaWielkopolska	3 **(H+)**	**3 (H+)**	1,5 **(H-)**	**2,5**
Września urban municipality	2**(H-)**	**2 (H-)**	2 **(H-)**	**2**

Source: author's own elaboration.

6. RESULTS

The TOD Index and spatial order scores obtained allow for forecasting and, subsequently, for programming changes. The TOD Index classification provides the basis for adopting the appropriate compensatory-cumulative model and a starting point for defining desirable actions for the development of rational and harmonious spatial structures and transportation infrastructure. Compensatory-cumulative models were derived based on the observation of the relationships between node and place potential values, assessed according to three levels: low, medium, and high, which directly relate to the Node-Place (NP) model developed by L. Bertolini (tab.4).

The TOD Index result for the Gniezno urban commune is unbalanced, as it falls within the high node potential and medium site potential ranges, and therefore corresponds to Model 2 (hN/mP). The TOD Index results for the Września urban municipality and the ŚrodaWielkopolskamunicipalitywere balanced, as they fell within the medium node potential and medium site potential ranges, and therefore corresponded to Model 5 (mN/mP). The next step was a diagnosis of spatial order, which allows for the identification of factors that negatively affect its assessment. Spatial order assessment results for individual parameters were also subject to the compensation principle — assuming that a score between 1 and 2.5 points is treated as a lack of harmoniousness (H-) for the analysed structure. Such a result indicates the need for changes to improve the physiognomic order and achieve a state in which the analysed structure achieves parameter scores above 2.5 points, which will thus lead to the creation of harmonious functional and spatial structures (H+).

The final stage is the transition from the diagnostic phase to programming changes based on the development models proposed in this work. These models represent a differentiated approach to improving spatial

Tab.4. Types of compensatory-cumulative models.

Detailing	Place potential (P)	High	Mid	Low
node potential(N)				
high		**model 1 hN/hP**	**model 2 hN/mP**	**model 3 hN/lP**
mid		**model 4 mN/hP**	**model 5 mN/mP**	**model 6 mN/lP**
low		**model 7 lN/hP**	**model 8 lN/mP**	**model 9 lN/lP**
balanced potential				
unbalanced potential				

Source: original work.

Tab.5. Linking development models with spatial order parameters, taking into account their measures.

Detailing				Models								
Parameter	**Meter**	**Reference to a place (P)**	**Reference to a node (N)**	**hN/hP**	**hN/mP**	**hN/lP**	**mN/hP**	**mN/mP**	**mN/lP**	**lN/hP**	**lN/mP**	**lN/lP**
Legibility	percentage of view obscuration	X		X	X	X		X	X			X
	length of the pedestrian route	X	X	X	X	X	X	X	X	X	X	X
Articulation	number of points in a readable viewing sequence	X		X	X	X		X	X			X
	number of viewpoints of the analysed route	X		X	X	X		X	X			X
Continuity	length of the pedestrian route	X	X	X	X	X	X	X	X	X	X	X
	length of areas with tall greenery	X		X	X	X		X	X			X
	length of facades with services on the ground floor	X		X	X	X		X	X			X

Source: author's own elaboration.

order, taking into account the spatial order parameters defined in the work, in particular the specific metrics that influence the calculation of individual parameters. In detail, development programming aimed at compensating for negative phenomena leading to the creation of irrational and disharmonious spatial structures involves actions that are opposite to the processes observed and measured during the diagnostic phase of the research. These actions will involve applying the following principles (Tab. 5):

- in terms of legibility: planning compact development on both sides of the route leading from the station to the centre of the settlement, and if this is not possible, filling gaps in the development with tall greenery.
- in terms of articulation: creating development blocks according to the principle that the closer to the centre, the shorter the urban walls that delimited the blocks, thus increasing the number of visual sequences.
- in terms of continuity: locating functionally diverse development and tall greenery along the route connecting the station with the centre of the settlement, and — where possible — shortening walks to train stations and bus stops.

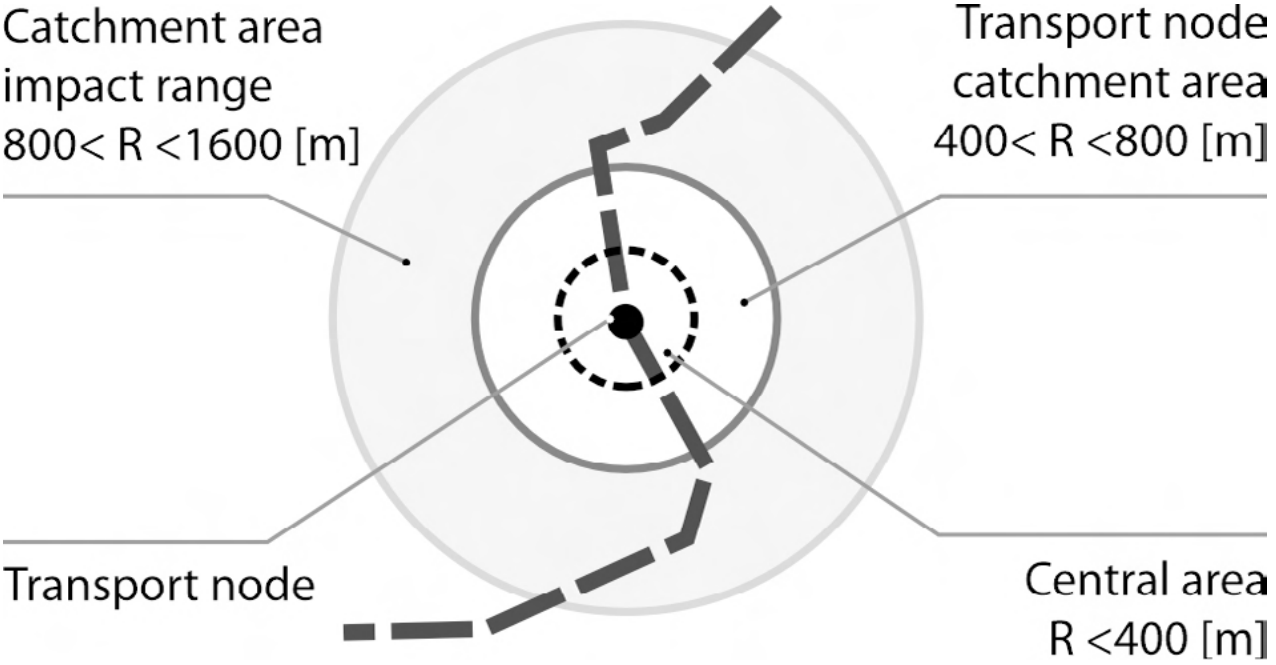
7. CONCLUSIONS

The TOD strategy may prove to be an efficient tool for reviving space in the social aspect and contributing to the creation of successful places.[7] The evaluation of transport efficiency therefore requires a broad approach that takes into account non-transport aspects of development, such as social, economic and environmental impacts. The success of TOD depends not only on the type of transport available, but also on the proper coordination of spatial planning with the development of the transport system.

Literature research on TOD planning presents many interesting proposals on how to describe this complex process with the use of comparable parameters. Interestingly, TOD is still being developed and along with advances in digital technology, many new possibilities are emerging for making accurate measurements in various subject areas and spatial scales. The accumulated knowledge allows us to assume that TOD can be an effective tool to support managing and balancing development. The universality of the approach is reflected in the possibility of applying this method in areas with different functional and spatial structures and different economic and socio-cultural conditions.

Despite the fact that the instruments enabling continuous monitoring of TOD indicators are still imperfect, researchers unanimously confirm the effectiveness of this strategy. Their claim is based on many years of observation of the development of settlement units that have already had some success implementing this doctrine. However, it is worth emphasizing that when one identifies ‘TOD implementation’, it is more about TOD ‘being implemented’, i.e., continuous efforts being made in the field of implementing the strategy than about using the perfective mode to state that it has been fully completed. There are several reasons for this. Firstly, the socio-economic processes involved in transforming space are highly complex, and the connections between the various aspects are not always clear or easy to identify. This makes it difficult to evaluate the measures taken as part of the implementation of the Transit Oriented Development strategy. Secondly, the scale of the area covered by TOD is significant. If TOD transformations take place in a small area around a single transport node, it is much easier to assess the effects of these transformations than in the complex systems of the settlement network, which is the case in metropolitan areas. Thirdly, the development of science constantly expands the scope of research fields, as each new discovery not only provides new answers but also raises new questions for researchers. In this context, any attempt to describe and evaluate TOD runs the risk of overlooking some aspect that has not yet been sufficiently diagnosed in the literature.

[7] In English-language literature, the notion of ‘successful places’ in the context of creating high quality public spaces is often found in, among others, (Gehl, 2017; Carmona, 2021 or https://www.pps.org/).



Ill. 1. Catchment area is defined by transport specialists as an area which provides a transport node with potential commuters. The designated radius of the catchment area is conventional and represents more less a 15-minute walking distance. Source: original work based on Jamaleddin et al., 2022.

Il. 1.Specjaliści do spraw transportu definiują obszar zasięgu jako taki, który stanowi węzeł transportowy z potencjalnymi dojeżdżającymi do pracy. Wyznaczony promień obszaru zasięgu jest umowny i odpowiada odległości mniej więcej 15 minut pieszo. Źródło: opracowanie własne na podstawie Jamaleddina et al., 2022.

Ill. 2. An example of a railway transport hub located in a TAD area. Even though medium distance between the railway station, uniform patterns of land use,and the transport node, lack of clearly defined spatial interiors as well as the lack of commercial services located along the pedestrian path are the factors that do not foster utilizing the potential associated with the availability of transport in this area. Example of the Poznań-Junikowo train station. Source: original work based on: https://www.google.com/maps/.

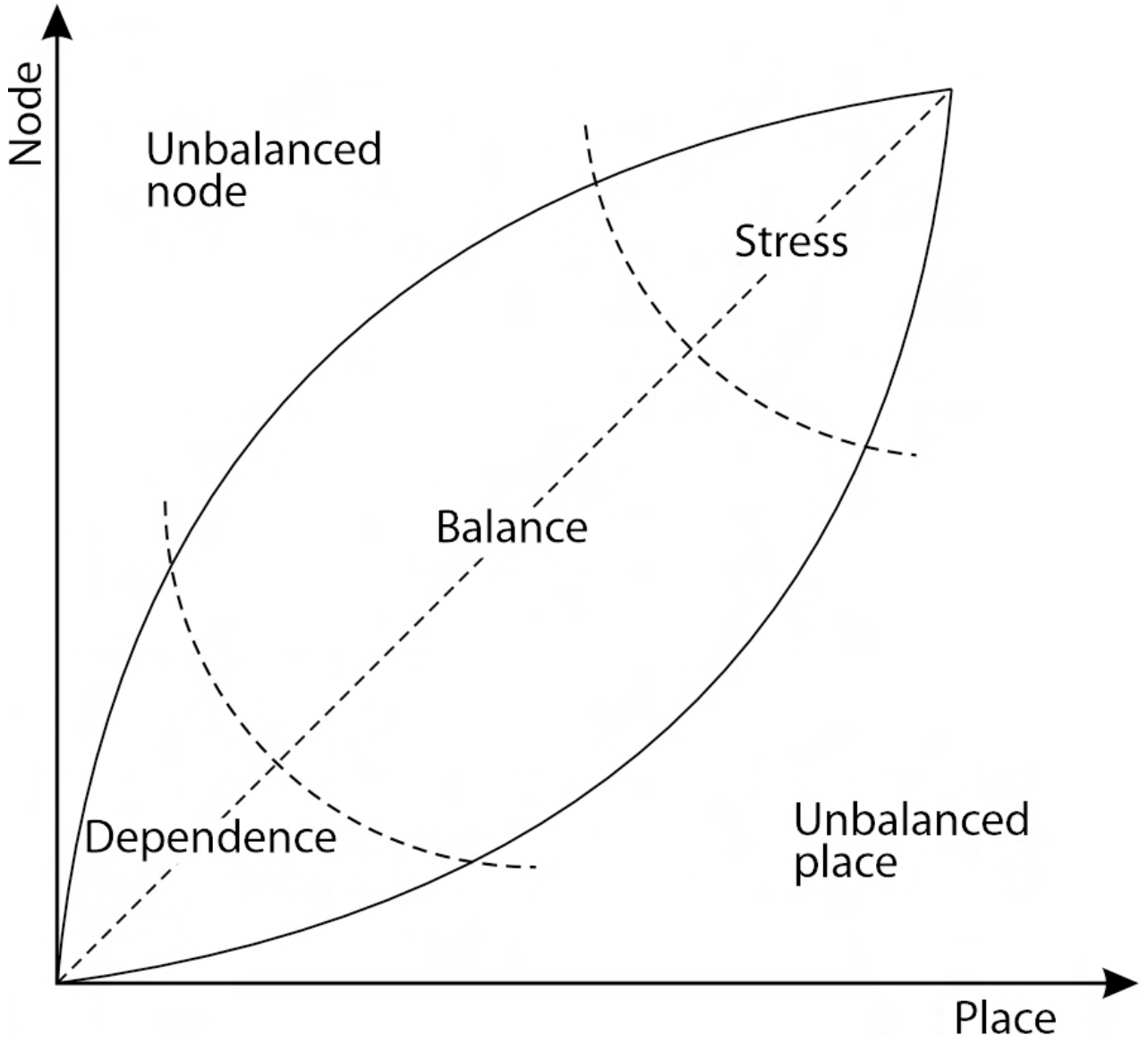
Il. 2. Przykład węzła kolejowego zlokalizowanego na obszarze TAD. Pomimo średniej odległości między dworcem kolejowym, jednorodnego zagospodarowania terenu a węzłem komunikacyjnym, brak wyraźnie zdefiniowanych wnętrz przestrzennych oraz brak usług komercyjnych, zlokalizowanych wzdłuż ciągu pieszego to czynniki, które nie sprzyjają wykorzystaniu potencjału związanego z dostępnością transportową na tym obszarze. Przykład dworca kolejowego Poznań-Junikowo. Źródło: opracowanie własne na podstawie: https://www.google.com/maps/.

Ill.3. Construction commenced; bottom image: picture taken in 2024 with the metro station. The building in red is the Federal Bureau of Alcohol, Tobacco, Firearms and Explosives; the condition for its construction was the accessibility of public transport. Source: https://www.google.com/maps/).

Il. 3. Rozpoczęta budowa: dolne zdjęcie zrobione w 2024 roku, przedstawiające stację metra. Budynek w czerwonej ramce to Federalne Biuro do spraw Alkoholu, Tytoniu, Broni Palnej i Materiałów Wybuchowych. Warunkiem jego budowy była dostępność transportu publicznego. Źródło: https://www.google.com/maps/.

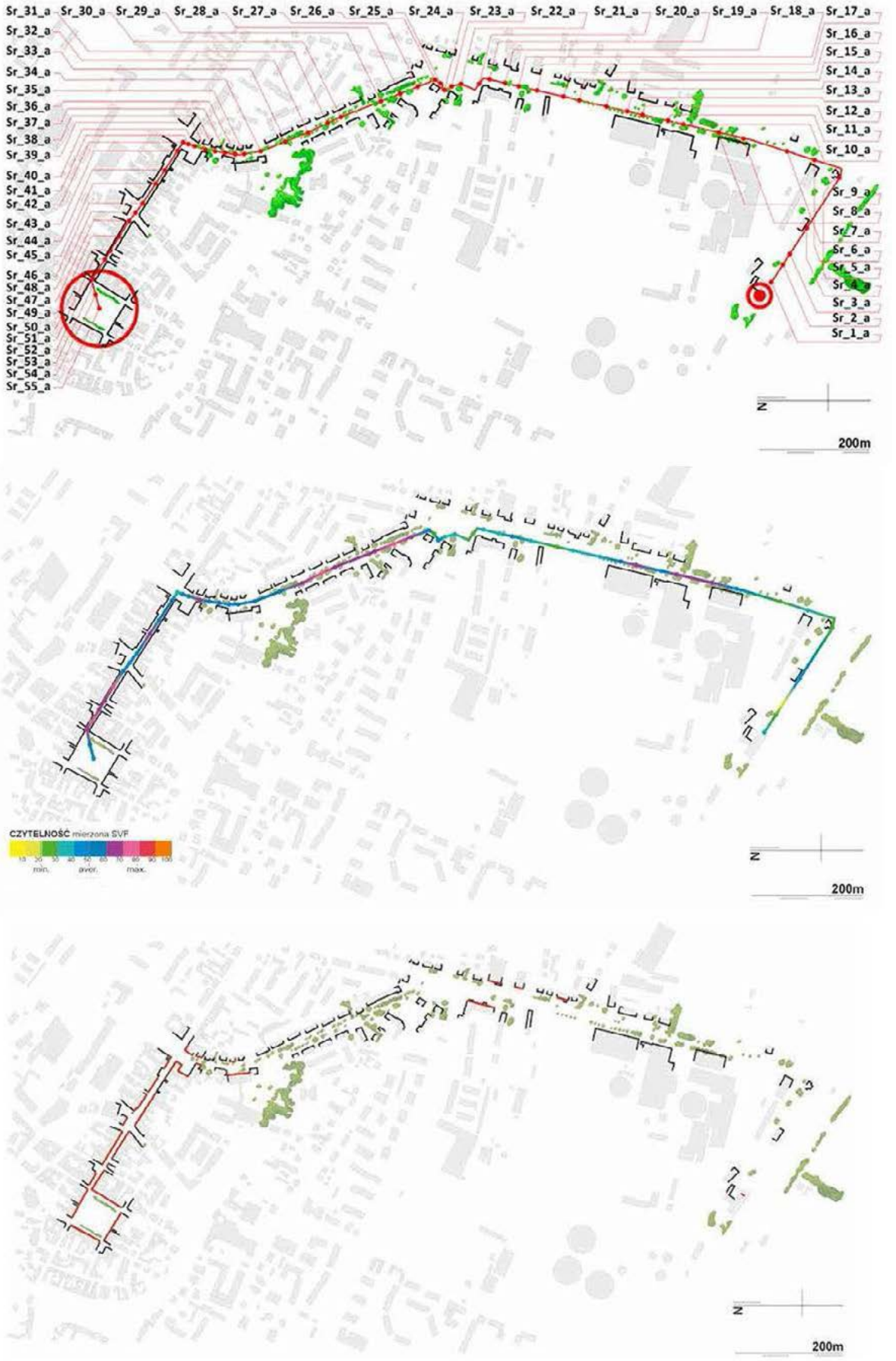
Ill. 4. NoMa district in Washington, DC — 198 L St NE. The top picture was taken in 2009; the bottom picture — in 2023. Development of the administrative use stimulated the creation of a mixed-use local centre with residential buildings, hotels, offices, shops and restaurants. Source: https://www.google.com/maps/.

Il. 4. Dzielnica NoMa w Waszyngtonie — 198 L St NE. Zdjęcie u góry wykonano w 2009 roku, zdjęcie u dołu — w 2023. Rozwój funkcji administracyjnej stymulował powstanie wielofunkcyjnego centrum lokalnego z budynkami mieszkalnymi, hotelami, biurami, sklepami i restauracjami. Źródło: https://www.google.com/maps/.

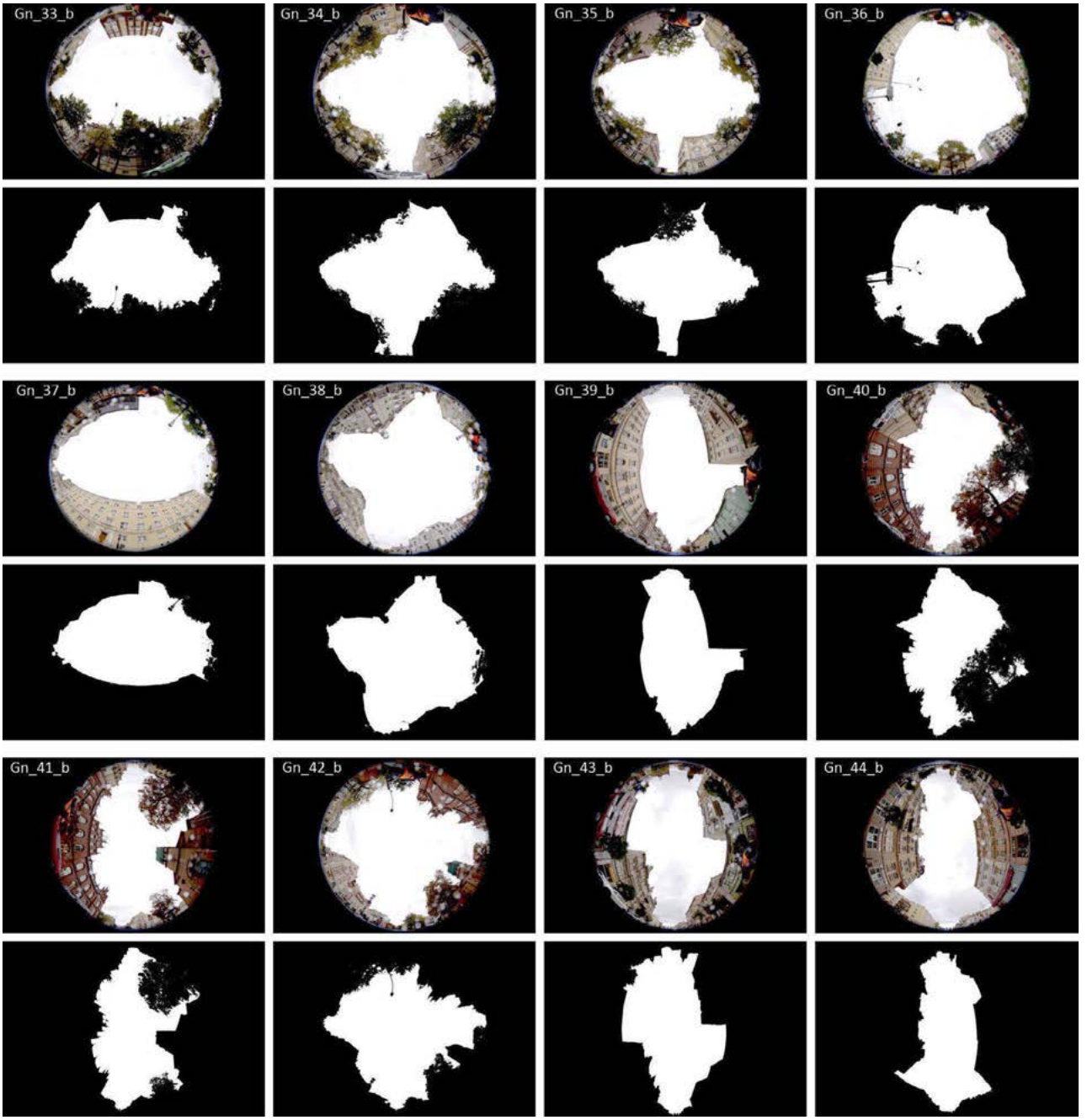


Ill.5. Diagram of the Node-Placemodel developed by Bertolini. Source: original work based on Bertolini, 1999.

Il. 5. Diagram modelu węzeł-miejsce opracowanego przez Bertoliniego. Źródło: opracowanie własne na podstawie: Bertolini, 1999.



Ill.6. Continuity, readability and articulation in graphic terms on the example of the study of Środa Wielkopolska. Source: original work.
Il. 6.Ciągłość, czytelność i artykulacja w ujęciu graficznym na przykładzie badań Środy Wielkopolskiej. Źródło: opracowanie własne.



Ill.7. Fragment of measurement documentation for SVF calculations. Source: original work.

Il. 7. Fragment dokumentacji pomiarowej do obliczeń SVF. Źródło: opracowanie własne.

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