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RESEARCH ARTICLE

SPATIAL ANALYSIS OF THE L.N. GUMILYOV EURASIAN NATIONAL UNIVERSITY CAMPUS USING SPACE SYNTAX

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Abstract. *University campuses are complex spatial systems comprising educational buildings, public spaces, and pedestrian networks. Their spatial configuration influences movement and accessibility, yet its relationship with actual pedestrian movement remains insufficiently explored in Kazakhstan. This study analyzes the spatial structure of the L.N. Gumilyov Eurasian National University campus using Space Syntax and compares configurational measures with observed pedestrian movement. The methodology combines axial analysis and field observations. An axial map of 24 lines was constructed in DepthmapX. Four indicators were analyzed: Connectivity (mean 2.58; maximum 7), global Integration (Rn) (0.733; 1.102), local Integration (R3) (1.244; 2.636), and normalized Choice (0.301; 1.016). Pedestrian movement was recorded along all 24 lines during three observation periods, resulting in 72 five-minute observations. Results show that central routes with higher integration and connectivity form the structural backbone of the campus, although their correspondence with observed movement varies between routes. Spearman's rank correlation analysis revealed weak and statistically non-significant associations between mean pedestrian flow and Connectivity ($\rho = 0.225$, $p = 0.291$), global Integration (Rn) ($\rho = 0.080$, $p = 0.711$), local Integration (R3) ($\rho = 0.072$, $p = 0.739$), and normalized Choice ($\rho = 0.065$, $p = 0.762$). These findings indicate that configurational properties alone do not explain variations in pedestrian movement and should be interpreted together with functional and contextual conditions. The combined approach can support campus planning and provide a basis for future research involving longer observation periods and additional university campuses.*

Keywords: *Space Syntax; university campus; axial analysis; integration; connectivity; choice; pedestrian movement.*

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SPACE SYNTAX ӘДІСІН ҚОЛДАНУ АРҚЫЛЫ Л.Н. ГУМИЛЕВ АТЫНДАҒЫ ЕУРАЗИЯ ҰЛТТЫҚ УНИВЕРСИТЕТІ КАМПУСЫНЫҢ КЕҢІСТІКТІК ТАЛДАУЫ

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Аңдатпа. *Университет кампустары оқу ғимараттарын, қоғамдық кеңістіктерді және жаяу жүргіншілер желілерін қамтитын күрделі кеңістіктік жүйелер болып табылады. Олардың кеңістіктік конфигурациясы қозғалыс пен қолжетімділікке әсер етеді, алайда конфигурациялық сипаттамалар мен нақты жаяу жүргіншілер қозғалысы арасындағы байланыс Қазақстан жағдайында жеткілікті зерттелмеген. Зерттеудің мақсаты - Space Syntax әдісі арқылы Л.Н. Гумилев атындағы Еуразия ұлттық университеті кампусының кеңістіктік құрылымын талдау және конфигурациялық көрсеткіштерді бақыланған жаяу жүргіншілер қозғалысымен салыстыру. Әдістеме осьтік талдау мен далалық бақылауларды біріктіреді. DepthmapX бағдарламасында 24 осьтік сызықтан тұратын карта құрылды. Төрт көрсеткіш талданды: Connectivity (орташа мәні 2,58; максимумы 7), жаһандық Integration (Rn) (0,733; 1,102), жергілікті Integration (R3) (1,244; 2,636) және нормаланған Choice (0,301; 1,016). Жаяу жүргіншілер қозғалысы барлық 24 сызық бойында үш кезеңде тіркеліп, 72 бес минуттық бақылау жүргізілді. Нәтижелер интеграция және байланыстылық көрсеткіштері жоғары орталық бағыттардың кампустың құрылымдық негізін қалыптастыратынын көрсетті, алайда олардың бақыланған қозғалыспен сәйкестігі бағыттар бойынша әртүрлі болды. Спирменнің рангтік корреляциялық талдауы орташа жаяу жүргіншілер ағыны мен Connectivity (ρ = 0,225; p = 0,291), жаһандық Integration (Rn) (ρ = 0,080; p = 0,711), жергілікті Integration (R3) (ρ = 0,072; p = 0,739) және нормаланған Choice (ρ = 0,065; p = 0,762) арасында әлсіз әрі статистикалық мәнді емес байланыстарды анықтады. Нәтижелер конфигурациялық сипаттамалардың өздігінен жаяу жүргіншілер қозғалысының өзгермелілігін түсіндіре алмайтынын және оларды функционалдық әрі контекстік жағдайлармен бірге қарастыру қажеттігін көрсетеді. Біріктірілген тәсіл кампустарды жоспарлауда қолданылып, ұзақ мерзімді бақылаулар мен басқа университет кампустарын қамтитын болашақ зерттеулерге негіз бола алады.*

Түйінді сөздер: *Space Syntax; университет кампусы; осьтік талдау; интеграция; байланыстылық; таңдау; жаяу жүргіншілер қозғалысы.*

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НАУЧНАЯ СТАТЬЯ

ПРОСТРАНСТВЕННЫЙ АНАЛИЗ КАМПУСА ЕВРАЗИЙСКОГО НАЦИОНАЛЬНОГО УНИВЕРСИТЕТА ИМЕНИ Л.Н. ГУМИЛЕВА С ИСПОЛЬЗОВАНИЕМ МЕТОДА SPACE SYNTAX

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Аннотация. *Университетские кампусы представляют собой сложные пространственные системы, включающие учебные здания, общественные пространства и пешеходные сети. Их пространственная конфигурация влияет на характер движения и доступность, однако взаимосвязь между конфигурационными характеристиками и фактическим пешеходным движением остаётся недостаточно изученной, особенно в Казахстане. Цель исследования - проанализировать пространственную структуру кампуса Евразийского национального университета имени Л.Н. Гумилева методом Space Syntax и сопоставить конфигурационные показатели с наблюдаемым пешеходным движением. Методология сочетает аксиальный анализ и полевые наблюдения. В программе DepthmapX построена карта из 24 аксиальных линий. Проанализированы четыре показателя: Connectivity (среднее 2,58; максимум 7), глобальная Integration (Rn) (0,733; 1,102), локальная Integration (R3) (1,244; 2,636) и нормализованный Choice (0,301; 1,016). Пешеходное движение фиксировалось вдоль всех 24 линий в течение трёх периодов, в результате чего проведено 72 пятиминутных наблюдения. Результаты показали, что центральные маршруты с более высокими значениями интеграции и связности формируют структурную основу кампуса, однако их соответствие наблюдаемому движению различается между маршрутами. Корреляционный анализ Спирмена выявил слабые и статистически незначимые связи между средним пешеходным потоком и Connectivity (ρ = 0,225; p = 0,291), глобальной Integration (Rn) (ρ = 0,080; p = 0,711), локальной Integration (R3) (ρ = 0,072; p = 0,739) и нормализованным Choice (ρ = 0,065; p = 0,762). Полученные результаты показывают, что конфигурационные характеристики сами по себе не объясняют вариативность пешеходного движения и должны рассматриваться совместно с функциональными и контекстуальными условиями. Комбинированный подход может применяться при планировании кампусов и служить основой для дальнейших исследований с более продолжительными наблюдениями и включением других университетских кампусов.*

Ключевые слова: *Space Syntax; университетский кампус; аксиальный анализ; интеграция; связность; выбор; пешеходное движение.*

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1 INTRODUCTION

Modern university campuses represent complex spatial systems that include academic buildings, public spaces, pedestrian networks, recreational areas, and infrastructure elements. The spatial organization of a campus plays a crucial role in shaping a comfortable educational environment, ensuring accessibility of functional zones, and supporting social interaction among users. Therefore, the planning structure of a campus directly influences movement patterns, the formation of pedestrian flows, and the degree of integration between different components of the educational environment.

In the context of the rapid development of higher education systems in Kazakhstan and globally, as well as the increasing number of newly constructed university campuses, the issue of effective spatial organization has become particularly relevant. Contemporary campus design requires a deeper understanding of how spatial configuration affects accessibility, movement efficiency, and user behavior. Traditional approaches to analyzing architectural and urban environments are typically based on functional planning or morphological analysis and often rely on qualitative or expert-based assessments [1,2]. However, such approaches do not fully reveal the underlying spatial structure or quantitatively explain its influence on movement patterns. In recent decades, the Space Syntax method, developed by Hillier and Hanson (1984) [3] and further elaborated by Hillier (1996) [4], has emerged as a powerful analytical tool for studying spatial configuration. The method represents space as a network of axial lines and allows the calculation of key spatial measures such as connectivity, integration, and choice, which reflect accessibility and potential movement patterns [5,6]. Numerous international studies have demonstrated a strong relationship between spatial configuration and pedestrian movement in urban environments and university campuses [7-9].

However, despite the wide application of Space Syntax in international research, its use in the analysis of university campuses in Kazakhstan remains limited. Existing studies in the region primarily focus on architectural, compositional, and functional aspects of spatial organization, without applying quantitative configurational methods. As a result, the relationship between spatial configuration, pedestrian movement patterns, and functional organization of campus environments in Kazakhstan remains insufficiently explored. This highlights a research gap regarding the lack of studies that combine configurational analysis with empirical observations of user behavior in university campuses within the Kazakhstani context.

This study examines the relationship between configurational properties and observed pedestrian movement within the campus of L.N. Gumilyov Eurasian National University in Kazakhstan. By combining Space Syntax analysis with empirical pedestrian observations, the study evaluates the extent to which configurational measures correspond to actual movement patterns and identifies cases of convergence and divergence between spatial configuration and observed campus use.

The aim of this study is to analyze the spatial structure of the campus of L.N. Gumilyov Eurasian National University using the Space Syntax method and to compare the results of configurational analysis with observed pedestrian movement patterns.

The findings contribute to a better understanding of the relationship between spatial configuration and user behavior on university campuses and may support future spatial planning and design decisions in Kazakhstan.

Over the past decades, the Space Syntax approach has become one of the leading methods for studying the relationship between spatial structure and user behavior in architecture and urban planning. The theory of Space Syntax was introduced by Hillier and Hanson [3], where space is understood as a configurational system that influences movement patterns, accessibility of functions, and the formation of social interactions. Hillier later developed these ideas in Space is the Machine [4], establishing the mathematical foundations of configurational analysis and demonstrating the relationship between spatial structure and the “economy of movement” in cities.

A comprehensive overview of the theoretical foundations of the method is presented by Yamu et al. [6], who systematize key concepts and metrics of Space Syntax, including axial lines, isovists,

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and centrality measures, and demonstrate their application at different urban scales. The authors emphasize that the method allows for a quantitative description of spatial relationships and helps reveal links between street network configuration and socio-economic processes, making it an effective tool for analyzing sustainable urban environments and educational campuses.

However, despite its strong analytical capabilities, this approach primarily focuses on configurational properties of space and may not fully account for contextual and behavioral factors influencing real user movement, such as functional zoning, entrance locations, and informal pathways.

The basic principles of axial analysis applied in the Space Syntax method are illustrated in Figure 1.

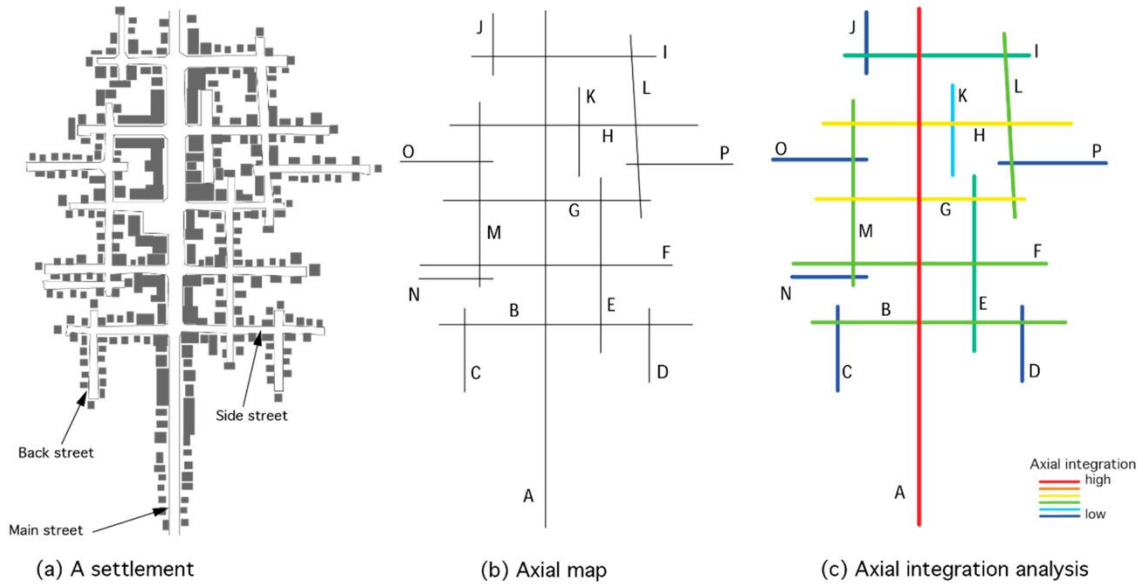

Figure 1 - Principle of axial analysis in the Space Syntax method: (a) settlement layout; (b) corresponding axial map; (c) axial integration analysis showing the relative integration values of axial lines (adapted from Yamu et al. [6] under the CC BY 4.0 license).

Previous research has demonstrated a relationship between Space Syntax measures and pedestrian movement across different urban contexts. Sharmin and Kamruzzaman [7], through a meta-analysis of previous studies, identified consistent associations between configurational measures and pedestrian movement. Koohsari et al. [8] further discussed the relationship between spatial configuration, urban form, and walking behavior. These findings provide a broader theoretical and empirical basis for examining whether configurational properties are also associated with observed pedestrian movement within university campus environments.

Recent research by Khorsheed and Goriel [10] and Hammadamin et al. [9] further develops the configurational approach as a basis for evaluating campus planning strategies. Using indicators such as connectivity, integration, choice, and intelligibility, these studies propose criteria for comparing different layouts of academic buildings, public spaces, and service areas. While they provide valuable analytical frameworks, they tend to assume a relatively linear relationship between spatial configuration and movement patterns, without sufficiently addressing discrepancies between modeled predictions and actual behavior.

Comparative studies by Zencirkiran and Suta [11] demonstrate that differences in the configuration of campus open spaces directly affect accessibility, travel distances, and the formation of activity nodes. At the same time, these studies mainly focus on spatial efficiency and give limited attention to the influence of local context and user-specific behavioral factors, which can significantly modify movement patterns.

In the context of Kazakhstan, existing studies primarily focus on architectural and functional aspects of spatial organization [12-14]. These works contribute to understanding typological and

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compositional characteristics of educational environments. However, they do not apply quantitative configurational methods such as Space Syntax and therefore do not provide measurable insights into spatial accessibility and movement dynamics.

Thus, while international research demonstrates the effectiveness of Space Syntax in identifying spatial structure and predicting movement potential, and local studies provide valuable architectural perspectives, there remains a lack of integrated approaches that combine configurational analysis with empirical observation of actual pedestrian movement, particularly in the context of university campuses in Kazakhstan.

To address this research gap, the present study combines Space Syntax analysis with quantitative pedestrian counts and qualitative contextual observations. Unlike many previous studies, this research focuses not only on identifying spatial potential but also on revealing discrepancies between predicted and observed movement patterns, thereby providing a more comprehensive understanding of campus spatial systems.

The scientific novelty of this study lies in the combined assessment of configurational properties and empirically observed pedestrian movement within a university campus in Kazakhstan. Unlike previous campus studies that have primarily used Space Syntax to evaluate spatial accessibility, connectivity, or movement potential, this study directly compares four configurational measures - Connectivity, global Integration (Rn), local Integration (R3), and normalized Choice - with systematic pedestrian counts collected along all axial lines of the analyzed network. This approach makes it possible to identify not only correspondence but also discrepancies between configurational potential and actual pedestrian movement. The study therefore provides empirical evidence that campus movement patterns cannot be explained by spatial configuration alone and should be interpreted together with functional and contextual conditions.

2 MATERIALS AND METHODS

In this study, the Space Syntax method is employed as a tool for configurational spatial analysis, allowing the investigation of relationships between spatial structure and patterns of space use. The method is based on representing space as a system of axial lines, which reflect the longest and fewest lines of sight and movement within the built environment [3,4].

The case study is the campus of L.N. Gumilyov Eurasian National University, located in Astana, Republic of Kazakhstan (Figure 2). The campus includes academic buildings, public spaces, and pedestrian routes forming an integrated spatial system. The analysis focuses on the pedestrian network and its configurational properties.

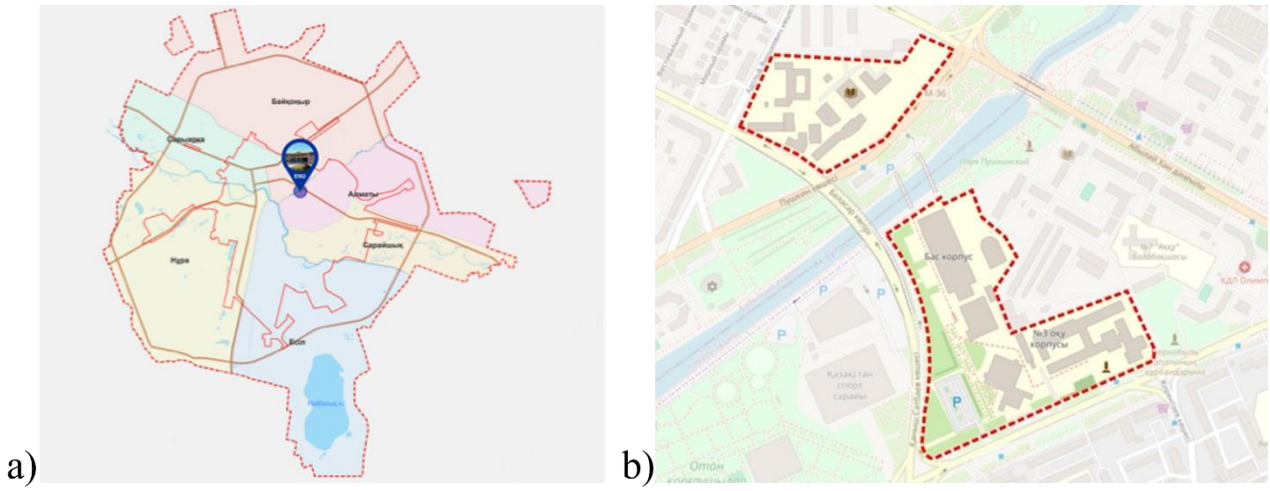

Figure 2 - Location of the ENU campus in Astana, Kazakhstan: (a) location of the ENU campus within Astana; (b) ENU campus area and its boundaries (base maps: OpenStreetMap, modified by the author)

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At the first stage, a cartographic base of the campus was prepared using open-source mapping data and master plan materials. Based on this, an axial map was constructed, representing the campus as a system of the longest and fewest straight lines capturing potential directions of movement. Axial analysis was selected because the objective of the study was to examine the topological structure of the campus pedestrian network and the relative position of its principal movement axes. Unlike segment analysis, which allows angular or metric analysis of individual street segments, the axial representation was considered appropriate for the present study because the analysis focused on the overall configuration of continuous pedestrian routes and their topological relationships.

The analytical network was defined functionally rather than strictly according to the formal campus boundary shown in Figure 2(b). While the model primarily represents pedestrian routes within the campus, several routes located outside the formal boundary were intentionally included because they provide direct connections between spatially separated parts of the university campus and form part of the everyday movement network used by students and university staff. These routes include connecting streets, pedestrian approaches, and bridges across the Ishim River. Excluding these links would artificially fragment the campus network and would not adequately represent the actual spatial system through which movement between university facilities occurs. Consequently, the reported global Integration (Rn) values should be interpreted in relation to this functionally defined campus network rather than the wider urban system.

At the second stage, the axial map was analyzed using depthmapX version 0.8.0. Axial analysis was performed based on topological relationships between axial lines. The analysis included Connectivity, global Integration [HH] (Rn), local Integration [HH] at radius 3 (R3), and normalized Choice (Choice [Norm]). Global Integration (Rn) was calculated for the entire axial system, whereas local Integration (R3) was calculated within a topological radius of three steps.

The following spatial measures were applied:

Connectivity reflects the number of directly connected axial lines and represents the local accessibility of each element within the spatial system.

Integration represents the degree of spatial accessibility of each axial line relative to the entire system. It is calculated based on the mean depth of each element and reflects how easily a space can be reached from all other spaces. In this study, both global integration (Rn) and local integration (R3) were analyzed. Global integration (Rn) evaluates accessibility at the scale of the entire system, while local integration (R3) captures accessibility within a limited radius and reflects short-range movement patterns typical for everyday use.

Choice represents the potential for through-movement and is analogous to betweenness centrality. It indicates how often an axial line lies on the shortest paths between all pairs of elements in the system. In this study, normalized Choice (Choice [Norm]), as calculated in depthmapX, was used for the analysis. Choice [Norm] represents the normalized form of the Choice measure provided by depthmapX and was used rather than the raw Choice value in the subsequent analysis.

The calculation of integration is based on the concept of mean depth, which can be expressed as:

$$MD = \frac{\sum d_i}{n-1} \tag{1}$$

where: MD - mean depth of an element;

d_i - topological depth from the considered axial line to another line in the system;

n - total number of axial lines considered within the specified radius.

$$RA = \frac{2(\mathrm{MD}-1)}{n-2} \tag{2}$$

where: RA - relative asymmetry;

$$D_n = \frac{2[\mathrm{n}\left(log_2\left(\frac{n+2}{3}\right)-1\right)+1]}{(n-1)(n-2)} \tag{3}$$

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where D_n is the normalization factor accounting for the size of the spatial system;

$$RRA = \frac{\mathrm{RA}}{D_n} \tag{4}$$

$$Integration[HH] = \frac{1}{RRA} \tag{5}$$

where RRA is real relative asymmetry. Integration [HH] is calculated as the inverse of RRA. Thus, lower mean depth corresponds to higher Integration [HH], indicating greater configurational accessibility. In this study, global Integration (Rn) was calculated considering the entire axial system, whereas local Integration (R3) was calculated within a topological radius of three steps [4,6].

In addition to the configurational analysis, systematic pedestrian counts were conducted to examine observed movement within the campus. All 24 axial lines included in the spatial model were observed using a standardized field protocol. For each axial line, pedestrian movement was recorded during three observation periods on weekdays in September 2025: morning (08:30-10:30), midday (12:00-14:00), and afternoon (16:00-18:00). Each observation lasted 5 minutes, resulting in three valid counts for each axial line and 72 observations in total. Pedestrians passing through the corresponding axial line in either direction during the observation interval were counted manually. All observations included in the analysis were completed without interruption and were considered valid for analysis. For each axial line, the mean pedestrian count across the three observation periods was calculated and used as the indicator of observed pedestrian flow. Field observations were conducted by two observers. Counts were performed continuously within the predefined morning, midday, and afternoon observation periods, irrespective of the class schedule. Each axial line was observed for a 5-minute interval, after which the observers proceeded to the next observation location. This procedure ensured a consistent observation protocol across all 24 axial lines while capturing pedestrian movement during the predefined observation periods.

To quantitatively assess the relationship between spatial configuration and observed pedestrian movement, Spearman's rank correlation coefficient (ρ) was calculated between the mean pedestrian count for each axial line and four configurational measures: Connectivity, global Integration [HH] (Rn), local Integration [HH] (R3), and normalized Choice (Choice [Norm]). Spearman's correlation was selected because it evaluates monotonic relationships based on ranks and does not require the assumption of normally distributed variables. Statistical significance was assessed at $p < 0.05$.

3 RESULTS AND DISCUSSION

This section presents the results of the spatial analysis of the campus of L.N. Gumilyov Eurasian National University using the Space Syntax method. The results include the construction of the axial map, as well as the analysis of key spatial measures: connectivity, integration, and choice.

3.1 Axial map of the campus

Based on the cartographic data and the functionally defined campus pedestrian network described in Section 2, an axial map comprising 24 axial lines was constructed (Figure 3). The model represents the principal pedestrian routes connecting the main university facilities and adjacent connecting routes.

The campus exhibits a relatively compact spatial structure with a dominant central axis and several secondary connections linking peripheral areas.

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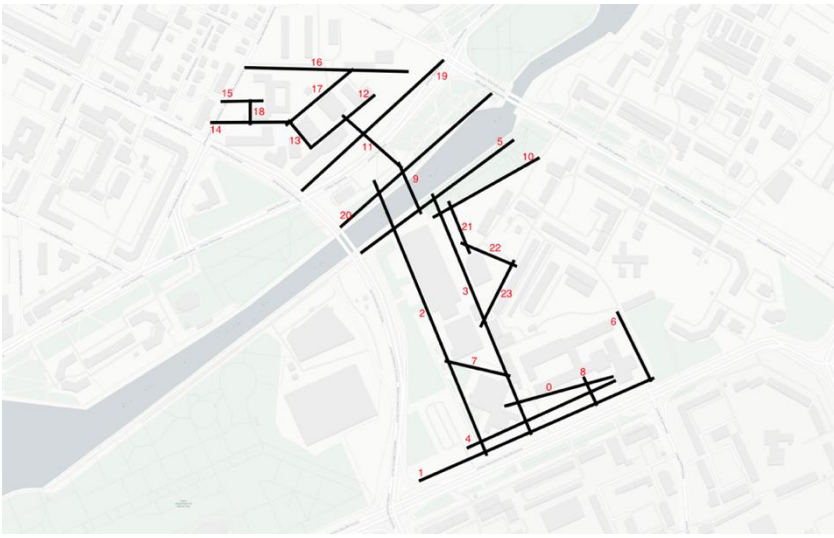

Figure 3 - Axial map of the ENU campus (base map: OpenStreetMap, axial analysis by the author)

3.2 Connectivity analysis

The connectivity analysis (Figure 4) shows that the highest values are concentrated in the central part of the campus, where multiple pedestrian routes intersect.

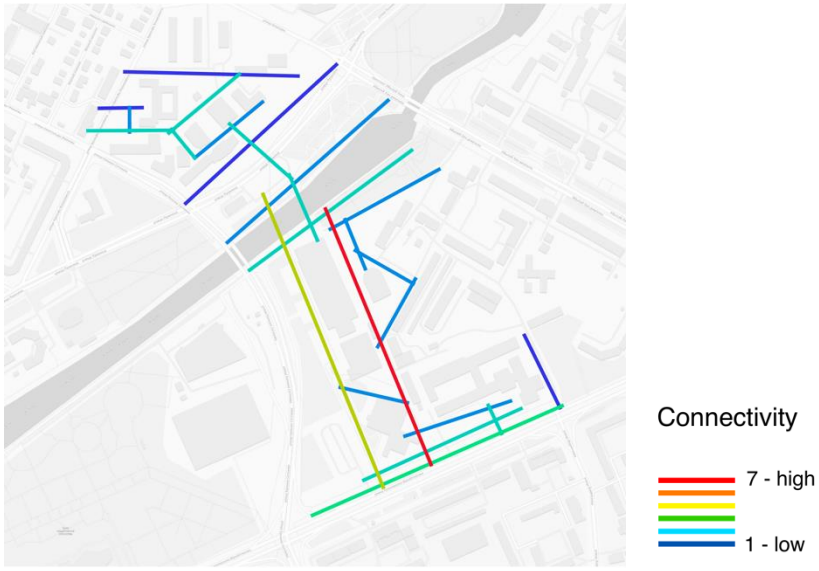

Figure 4 - Connectivity analysis of the ENU campus (generated in DepthmapX, base map: OpenStreetMap)

The average connectivity value is 2.58, while the maximum value reaches 7 (Table 1), indicating the presence of highly connected nodes forming key intersections within the network.

In contrast, peripheral areas demonstrate connectivity values close to 1-2, reflecting limited alternative routes and reduced local accessibility.

These findings reveal a clear spatial hierarchy, with central nodes serving as the primary connectors within the campus network.

Table 1 - Main spatial indicators of the ENU campus

Indicator	Value
Number of axial lines	24
Average connectivity	2.58
Maximum connectivity	7

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Average integration (Rn)	0.733
Maximum integration (Rn)	1.102
Average integration (R3)	1.244
Maximum integration (R3)	2.636
Average normalized Choice	0.301
Maximum normalized Choice	1.016

3.3 Integration analysis

The analysis of integration (Figure 5) reveals the distribution of spatial accessibility across the campus. The average global Integration (Rn) is 0.733, with a maximum value of 1.102. Higher Rn values are concentrated along the main pedestrian spine, indicating its relatively central position within the overall axial system.

At the local scale, Integration (R3) identifies routes with greater accessibility within a topological radius of three steps. The average local Integration (R3) value is 1.244, with a maximum value of 2.636.

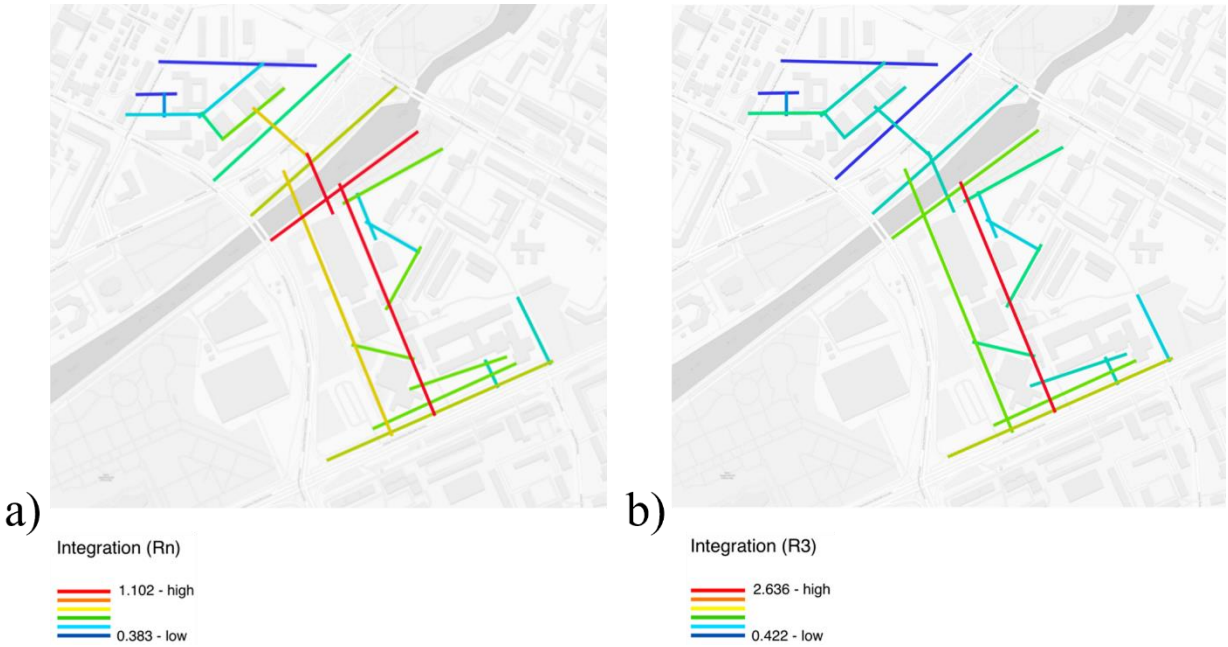

Figure 5 - Integration analysis of the ENU campus: (a) global integration (Rn); (b) local integration (R3) (generated in DepthmapX, base map: OpenStreetMap)

The comparison between Rn and R3 indicates that some axial lines occupy a more central position within the overall campus network, whereas others are more strongly integrated at the local scale, reflecting the multi-scale organization of the campus.

3.4 Choice analysis

The choice analysis (Figure 6) demonstrates the distribution of potential through-movement across the campus.

The average normalized Choice value is 0.301, with a maximum value of 1.016, indicating that only a limited number of axial lines serve as primary transit routes.

The highest normalized Choice values are concentrated along the main north–south axis, indicating its configurational potential as a key through-movement corridor connecting major functional zones.

Peripheral routes show near-zero values, indicating their limited role in through-movement and their primarily local function.

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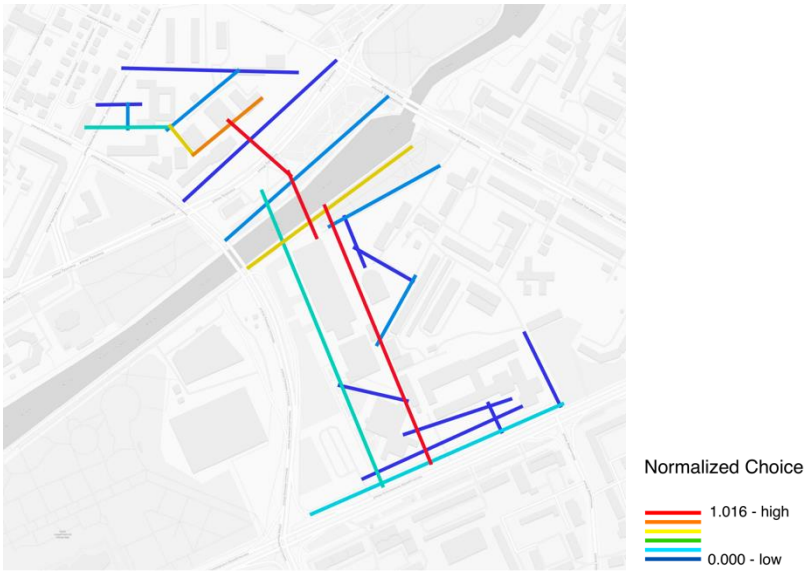

Figure 6 – Normalized Choice analysis of the ENU campus (generated in depthmapX, base map: OpenStreetMap)

3.5 Comparison with observed pedestrian movement

Pedestrian movement was systematically recorded along all 24 axial lines during three observation periods, as described in Section 2. For each axial line, the mean pedestrian count across the three 5-minute observation intervals was calculated and compared with the corresponding configurational measures. The observed mean pedestrian counts varied considerably across the campus, ranging from 4.3 to 112.3 pedestrians per 5-minute interval, indicating substantial differences in movement intensity between individual routes.

Examples of the pedestrian environments documented during the field observations are presented in Figure 7.

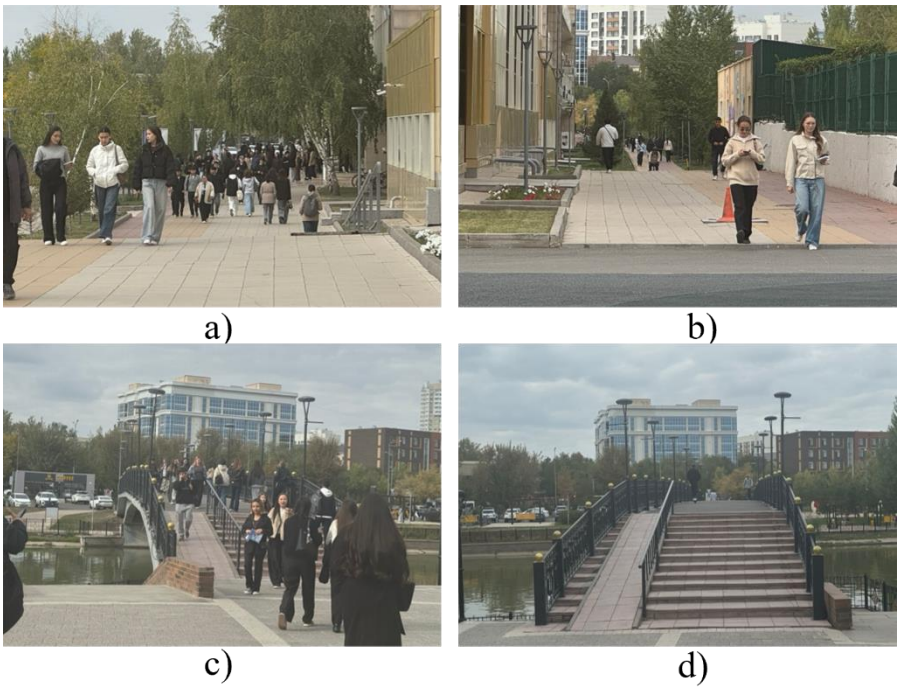

Figure 7 - Examples of pedestrian environments observed during field surveys at the ENU campus: (a) pedestrian route along the left side of the Rectorate Building; (b) pedestrian route along the right side of the Rectorate Building; (c) left pedestrian bridge; (d) right pedestrian bridge (author's photographs).

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These field observations illustrate the variation in pedestrian activity across different parts of the campus, including routes adjacent to the Rectorate Building and pedestrian bridges connecting campus areas. To quantitatively examine whether these observed movement patterns correspond to the spatial configuration of the campus, the mean pedestrian counts for each axial line were compared with Connectivity, global Integration (Rn), local Integration (R3), and normalized Choice. The resulting relationships are presented in Figure 8.

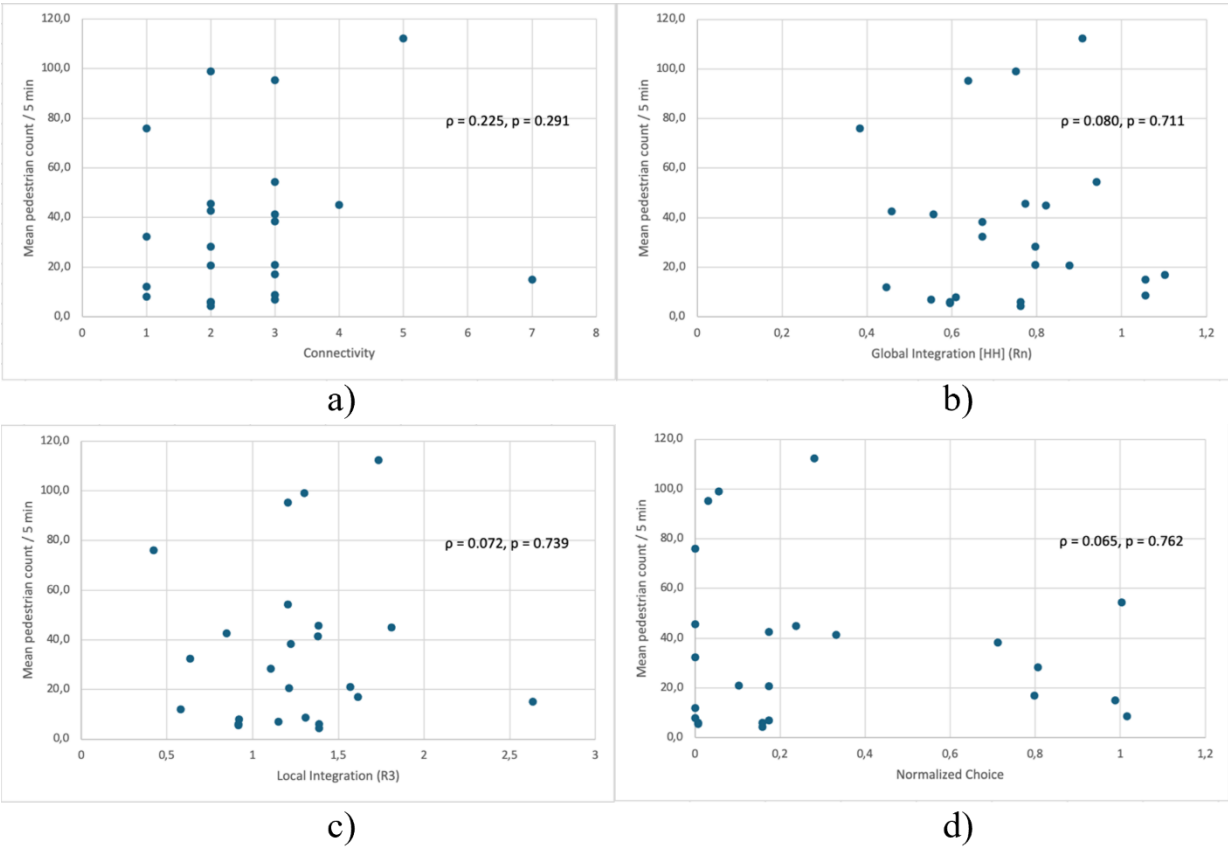

Figure 8 - Relationships between spatial configuration measures and observed pedestrian movement: (a) Connectivity; (b) Global Integration (Rn); (c) Local Integration (R3); (d) Normalized Choice. (Author's calculations)

The corresponding Spearman's rank correlation coefficients and p-values are summarized in Table 2.

Table 2 - Spearman's rank correlations between spatial configuration and observed pedestrian movement

Spatial measure	Spearman's ρ	p-value
Connectivity	0.225	0.291
Global Integration [HH] (Rn)	0.080	0.711
Local Integration [HH] (R3)	0.072	0.739
Normalized Choice (Choice [Norm])	0.065	0.762

Spearman's rank correlation analysis revealed weak positive associations between observed pedestrian movement and all four configurational measures (Table 2). The strongest association was found for Connectivity ($\rho = 0.225$, $p = 0.291$), followed by global Integration (Rn) ($\rho = 0.080$, $p = 0.711$), local Integration (R3) ($\rho = 0.072$, $p = 0.739$), and normalized Choice ($\rho = 0.065$, $p = 0.762$). None of these relationships reached statistical significance at the $p < 0.05$ level. Therefore, within the observed ENU campus network, the configurational measures did not independently provide a statistically significant explanation of variation in pedestrian movement.

The weak correlations do not imply that spatial configuration is irrelevant to campus movement. Rather, they indicate that configurational accessibility represents only one component of pedestrian

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route use. Individual axial lines with relatively low configurational values nevertheless recorded high pedestrian counts, while some highly integrated or high-choice lines exhibited comparatively low movement. These discrepancies suggest that pedestrian movement within the ENU campus is also shaped by contextual and functional conditions not represented directly in the axial model, including the location of building entrances, distribution of academic and administrative functions, route directness, connections between spatially separated university facilities, and temporal patterns of campus activity. These factors are interpreted here as possible explanations rather than independently measured determinants

3.6 Discussion

The results indicate that the spatial configuration of the ENU campus is associated with the organization of pedestrian movement and the distribution of accessibility across the campus. Axes with higher integration, connectivity, and choice values are concentrated within the central spatial structure and generally correspond to the principal pedestrian routes. This pattern is consistent with the configurational understanding of movement developed in Space Syntax research [1,4] and with empirical studies reporting relationships between syntactic measures and pedestrian activity [7,15].

Similar relationships have been reported in studies of university environments. Khorsheed and Goriel [10] used Space Syntax measures to assess campus walkability, while Hammadamin et al. [9] examined configurational properties in relation to the functional efficiency of higher-education environments. The ENU results are broadly consistent with the relevance of integration, connectivity, and choice for identifying potentially important movement routes. However, the correspondence between configurational values and observed pedestrian activity was not consistent across all analyzed axes.

This distinction is particularly important when the results are considered alongside the broader evidence on Space Syntax and pedestrian movement. Sharmin and Kamruzzaman [7] identified an overall relationship between syntactic measures and pedestrian movement across previous studies, while Hacar et al. [15] demonstrated that configurational measures can contribute to the explanation of pedestrian density. At ENU, however, several highly integrated or high-choice axes showed comparatively low pedestrian activity, whereas some less integrated routes were used intensively. The findings therefore indicate that configurational measures provide useful information on the spatial structure of the campus, while their correspondence with observed pedestrian movement varies between individual routes.

The observed mismatches may be interpreted in relation to the specific functional organization of a university campus. Factors such as the location of academic buildings and entrances, the directness of routes to particular destinations, and everyday patterns of campus use may contribute to the observed discrepancies; however, these factors were not directly measured in the present study. This interpretation can be considered alongside recent campus research emphasizing the relationship between spatial organization and user experience [11]. In the ENU case, secondary routes with relatively low configurational values may nevertheless attract substantial pedestrian movement when they provide a more direct connection to frequently used destinations. Conversely, a spatially prominent axis does not necessarily generate high pedestrian activity if it does not correspond to a major functional destination.

These results refine, rather than contradict, the configurational interpretation of pedestrian movement. Space Syntax measures identify the structural potential of particular routes within the overall network, whereas observed movement reflects the interaction between this potential and the functional and behavioral conditions of the campus. The main contribution of the ENU case is therefore the identification of both convergence and divergence between configurational potential and observed use. Rather than treating integration, connectivity, or choice as direct proxies for pedestrian volume, the findings suggest that these measures are more informative when interpreted together with empirical observations of actual campus use.

Methodologically, the study therefore supports the combination of configurational analysis and field observation. Space Syntax provides comparable quantitative measures of the spatial network,

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while observations help identify locations where actual behavior differs from configurational expectations. For campus research, this combined approach can distinguish routes whose use is largely consistent with their spatial position from routes where functional or contextual conditions appear to have a stronger influence.

From a planning perspective, these discrepancies are themselves informative. Highly integrated routes can be considered important elements of the campus spatial structure, but planning decisions should not be based on configurational values alone. Routes with lower syntactic values but consistently high observed use may also require attention in decisions concerning pedestrian infrastructure, entrances, functional zoning, and connections between campus destinations.

The study has several limitations. Pedestrian observations were conducted during a limited period and may not represent seasonal variations in campus use. Movement counts were based on short observation intervals, and the analysis was limited to a single university campus. Consequently, the observed relationships should not be interpreted as statistically validated causal relationships. Future research should extend the observation periods, include additional campuses, and quantitatively test the associations between configurational measures, functional characteristics, and pedestrian movement.

4 CONCLUSIONS

1. The Space Syntax analysis of the L.N. Gumilyov Eurasian National University campus identified a hierarchical spatial organization in which central axes with high values of integration, connectivity, and choice form the structural backbone of the campus and provide access between its key functional zones.
2. Comparison of configurational measures with observed pedestrian movement revealed only weak positive associations, none of which reached statistical significance ($p > 0.05$). The strongest association was observed for Connectivity ($\rho = 0.225$), while Global Integration (Rn), Local Integration (R3), and normalized Choice showed weaker associations. These results indicate that spatial configuration alone does not sufficiently explain the observed variation in pedestrian movement across the analyzed campus routes.
3. The findings demonstrate that the relationship between spatial configuration and pedestrian movement within the studied campus may be influenced not only by configurational properties but also by functional and behavioral factors. Combining Space Syntax analysis with empirical observation therefore provides a more comprehensive basis for interpreting campus spatial dynamics than configurational analysis alone.
4. From a practical perspective, the results can support campus planning and design decisions related to pedestrian circulation, the location of entrances and functional zones, and spatial accessibility. Configurational analysis may help identify structurally important routes within the campus network; however, planning interventions should also consider observed pedestrian use and functional characteristics.
5. Future research should extend the analysis to other university campuses in Kazakhstan and include longer observation periods and more systematic quantitative validation of pedestrian movement. This would allow the relationships between spatial configuration, campus functions, and actual movement patterns identified in this study to be tested under different spatial and institutional conditions.

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G.D. Maulenova – Supervision, Validation, Writing – Review & Editing.
K.R. Sultanova – Writing – Review & Editing.
B. Kambarova – Investigation, Data Collection.
A. Abdullah– Conceptualization, Supervision, Writing – Review & Editing.

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